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Assessment of the impact of treated and untreated Sewage water on growth and productivity of Okra (*Abelmoschus esculentus* L. Moench)

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Abstract

During the summer of 2018, an experiment was done at the Agronomy Field Unit, College of Agriculture, Navile, Shivamogga, and Karnataka. Okra (cv. Arka Anamika) is primarily grown for its fruits and used as a vegetable because its fruits and leaves contain calcium, iron, proteins, and vitamins, all of which are dietary supplements required for a basic diet. Vegetable demand is higher in urban areas even though they are grown in sewage water and are better for human consumption. As a result, okra was chosen as the test crop, and it was watered with Normal Water (NW), Treated Sewage Water (TSW), and Untreated Sewage Water (UTSW) separately and in conjunctive mode, resulting in nine treatments reproduced three times using the RCBD design. The treated and untreated sewage water obtained from college where it is created in huge amounts and on a continual basis. To grow the crops, the recommended package was followed. In comparison to the application of NW, TSW and UTSW irrigation changed the soil's chemical properties. The results indicated that TSW application resulted in a larger height (168.50), number of leaves (33.00), and number of branches (4.47). However, sewage-irrigated soils were much below the salinity threshold, resulting in improved crop growth components and yield. TSW application resulted in a higher fruit production of 32.35 t ha^{-1} compared to NW (25.20 t ha^{-1}) and UTSW applications (21.61 t ha^{-1}). It's also worth noting that in the conjunctive mode of application, one or two times of NW application fb TSW in cyclic mode resulted in yields of 28.12 and 29.22 t ha^{-1}, respectively, putting them closer to those of plots getting TSW. It also opens the way to the conclusion that sewage water derived from campus has the fewest influencing factors, affecting crop growth insignificantly, and indicating its prospective usage.

Keywords irrigation conjunctive mode, okra production, water quality

Introduction

Water is essential to all living things, accounting for 50 to 97 percent of plant and animal weight and roughly 70 percent of the typical human body weight, but it is also the world's most poorly managed resource [1]. Due to a scarcity of water, non-traditional water sources have been investigated. Concurrently, increasing urbanization has resulted in the development of the preferred minor wastewater source, because to its consistent and consistent supply throughout the year, as well as the abundance of nutrients embedded in it [2]. In recent years, it has become more important to reduce the misuse of water sources through conservation, recycling, and pollution management. According to estimates, wastewater accounts for 75 to 85 percent of all water utilized [3] and [4]. The rise in capacity of municipal wastewater due to increased metropolitan populace and improved coverage of home and sewage water systems needs to be predisposed cautiously sans pollution. Such marginal cost-effective source of water could be crucial in agriculture allowing growers to use the nutrients present in it to grow their preferred crops. The irrigation system will be supplemented by the repurposed processed wastewater or the conjunctive mode of residential wastewater with better grade water, diminishing pressure over sparse portable water supply. It also leads to improved agronomic water quality for crop production this in turn improves the agronomic water quality required in the production of crops [5]. Crop selection, irrigation systems, and appropriate tactics targeted at amending agricultural produce and quality, maintaining soil fertility, and protecting the nature will all play a successful role in using processed wastewater for crop productivity.

Okra, *Abelmoschus esculentus* L. (Moench), belonging to the Malvaceae family is an economically vital vegetable crop. It is known as Lady's finger or Bhindi as well. It comes from Ethiopia and is found all over the globe. This crop can be grown both as a garden or commercial farm crop [6]. It is a good source of protein, carbs, vitamins, calcium, potassium, enzymes, and total minerals, all of which are frequently inadequate in the diets of impoverished countries, tropical, subtropical as well as warm temperate parts [7]. Water plays a vital input in a reliable vegetable production system, especially in locations where vegetable production is hampered by water scarcity or variable rainfall distribution, particularly from mid-March to the end of June [8]. Due to the high demand for this crop, it is grown all year near urban or peri-urban regions, using either natural or municipal sewage water. The major source of concern is that much of the sewage discharged from metropolitan areas is unprocessed to be used as raw sewage to grow various vegetables to suit the demands of the urban population. The aim of the present study is to determine the effect of sewage water on the growth and productivity of Okra.

Methodology

Experimental site description

The field experiment was conducted at the College of Agriculture, University of Agricultural and Horticultural Sciences, Shivamogga, which is located in Karnataka's Southern Transition Zone (Zone-7) on a sandy loam soil. The location of the experimental site was between 13° 58' and 14° 1' north latitude and 75° 34' and 75° 42' east longitude, at 650 m above average sea level. The average maximum temperature ranged from 29.2 °C to 36.7 °C, while the minimum temperature ranged from 15.3 °C to 22.7 °C monthly during the crop growing season. During this time, humidity levels ranged from 61 to 89 percent. Soil pH is 6.21, electrical conductivity is 0.187 dS m^{-1}, soil organic carbon is 3.10 g kg^{-1}, available N is 250.80 kg ha^{-1}, available P is 28.43 kg ha^{-1}, available K is 171.40 kg ha^{-1}, and sodium is 14.10 mg $100g^{-1}$.

Experimental design, management and treatment details

The experiment was conducted during the summer of 2018 using three different water sources: Normal water was collected from an open storage tank which was gorged using a canal for irrigation purposes on-site collection of untreated water from college's laboratories and student and staff housing and the treatment unit was used for treated water. This treatment plant, a Sequencing Batch Reactor (SBR), is located on campus and is used to divert all untreated water from the above-mentioned sources. The system, which has a capacity of 25 kiloliters per day (KLD), is made up of a screen chamber, an equalization tank, an SBR unit, a sludge holding tank, a filter press, as well as a pre-filtration tank, a pressure sand filter, an activated carbon filter, and a chlorination tank. To obtain treated water, untreated sewage is subjected to solid collection, pH rectification, and settling before being passed through a sand and activated carbon filter. This aids in the removal of principle non-compliances including excess suspended particles and bacteriological pollutants. Influencing variables for the removal or monitoring of microorganisms, as well as the removal of pollutants, are influent pressure, residual pressure in the influent to the membranes, and the mean flow consistent to definite flux of the membranes with chlorination step. For this experiment, randomized full block design was used which included nine treatment combinations, three replications each. Normal water, treated and untreated sewage water were used individually as well as in a conjunctive fashion in a cyclic pattern from one time to the next. Normal water application (T_1), treated sewage water application (T_2), untreated sewage water application (T_3), normal and treated sewage water alternate application (T_4), normal and untreated sewage water alternate application (T_5), twice normal water application fb once treated sewage water (T_6), twice normal water application fb once untreated sewage water (T_7), once normal water application fb twice treated sewage water (T_8), once normal (T_9). As depicted in Figure 1 it shows a general perspective of the experimental plot and the diverse sources of water employed for the study exhibited heterogeneity in chemical characteristics. Chemical characteristics differed amongst the different sources. The pH readings for normal water, treated sewage water, and untreated sewage water were 6.8, 7.72, and 8.18, respectively, indicating neutral to slightly alkaline. For various sources, the electrical conductivity (EC) ranged from 0.49 dSm^{-1} (normal water) to 1.67 dSm^{-1} (untreated water). Because of the salt load applied in different contributing parts, untreated sewage water had greater values.

Table 1. Treatment details of irrigation water applied

Treatments	**First cycle**		**Second cycle**		**Third cycle**		**Fourth cycle**		
	1st irrigation (20 DAS)	**2nd irrigation (30 DAS)**	**3rd irrigation (40 DAS)**	**4th irrigation (50 DAS)**	**5th irrigation (60 DAS)**	**6th irrigation (70 DAS)**	**7th irrigation (80 DAS)**	**8th irrigation (90 DAS)**	**9th irrigation (100 DAS)**
T_1	NW	NW	NW	NW	NW	NW	NW	NW	-
T_2	TSW	TSW	TSW	TSW	TSW	TSW	TSW	TSW	-
T_3	UTSW	UTSW	UTSW	UTSW	UTSW	UTSW	UTSW	UTSW	-
T_4	NW	TSW	NW	TSW	NW	TSW	NW	TSW	-
T_5	NW	UTSW	NW	UTSW	NW	UTSW	NW	UTSW	-
T_6	NW	NW	TSW	NW	NW	TSW	NW	NW	TSW
T_7	NW	NW	UTSW	NW	NW	UTSW	NW	NW	UTSW
T_8	NW	TSW	TSW	NW	TSW	TSW	NW	TSW	TSW
T_9	NW	UTSW	UTSW	NW	UTSW	UTSW	NW	UTSW	UTSW

Note: NW: normal water, TSW: treated sewage water, UTSW: untreated sewage water

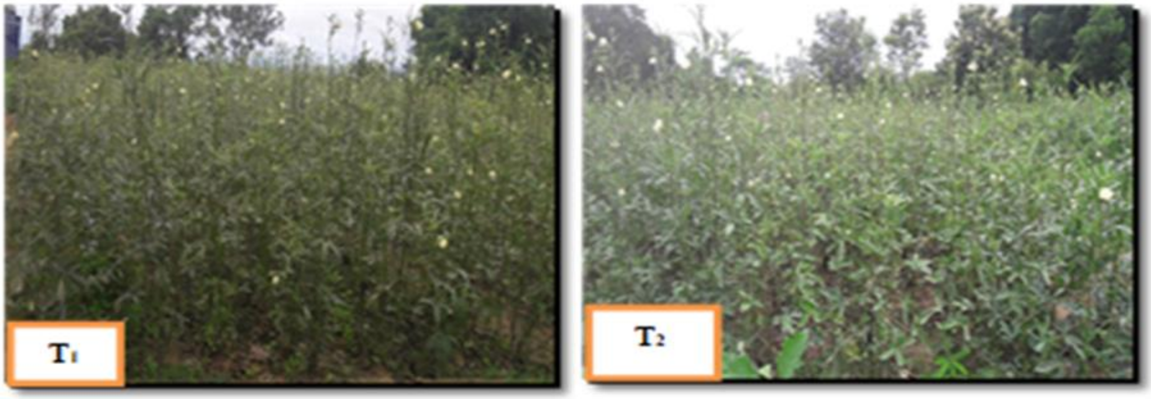

Figure 1. General view of the treatment T_1 and T_2 at experimental site experimental plot

Untreated sewage water had a BOD value of 70.50 mg L^{-1}, which was greater than both treated (27.20 mg L^{-1}) and normal (28.40 mg L^{-1}) water sources. In the current investigation, treated water had higher nitrogen level (15.50 ppm) than untreated water (8.05 ppm) (7.90 ppm). Based on the diverse profiles of the constituents and the ratios observed in this study, to alleviate stress over freshwater and surface and groundwater contamination, the recycled treated sewage water irrigation is an influential mode for water conservation and nutrient reuse. The trial field was ploughed in depth once, applied 25 t ha^{-1} of farm yard manure then passed cultivators in cross directions, and levelled for ease during the sow process. Ridges were built to provide space between treatments with the aim that the water doesn't infiltrate. Arka Anamika was the variety utilized in the experiment, which was sowed on February 28th, 2018 with the spacing of 60 x 30 cm. Each treatment had a plot size of 4.2 × 4.8 m, accommodating 112 plants. A base application of 125 kg N ha^{-1}, 75 kg P_2O_5 ha^{-1}, and 63 kg K_2O ha^{-1} in the form of urea, super phosphate and potassium chloride, respectively was executed in all experimental plots. The first 20 days after sowing were set aside for good crop establishment. Soil pH is 6.21; electrical conductivity is 0.187 dS m^{-1}; soil organic carbon is 3.10g kg^{-1}; available N is 250.80 kg ha^{-1}; available P is 28.43 kg ha^{-1}; available K is 171.40 kg ha^{-1}; sodium is 14.10 mg $100g^{-1}$. The university's campus housed the College of Agriculture, as well as student, staff, and labor residences. A significant amount of sewage is produced by the colleges various laboratories and homes. A connecting pipe collects all of the sewage water and transports it to a sewage water treatment plant. It implemented a sequencing batch reactor technology with a capacity of 25 kL per day. Screen chamber, equalization tank, SBR unit, sludge holding tank and filter press, pre-filtration tank, pressure sand filter, activated carbon filter, chlorination tank, and final tank are among the components of the system. After the first irrigation cycle (Table 1), water was applied in the amount of 120 litres per treatment and was applied equally for the combination, and the second irrigation cycle (Table 2) was irrigated in the amount of 170 liters per treatment, and the third and fourth irrigation cycles were applied in the amount of 150 liters of water used. The treatment plan began twenty days after seeding, with ten-day intervals at a depth of five centimeters. Other cultural behaviors remained consistent throughout all plots and were implemented in accordance with the package of practices. Water was used in T4 through T5 in a combination of normal and treated/untreated sewage water. As a result, four complete cycles were seen in two irrigation sets of 20 and 30, 40 and 50, 60 and 70, 80 and 90 days during the course of the crop's life. Similarly, three irrigations of 20, 30 and 40 days (T_6), 50, 60 & 70 days (T_7), and 80, 90 and

Table 2. Nutrient profiling of various water sources applied for irrigation

Parameters	NW	TSW	UTSW	Standards of FAO (1985)
pH	6.800	7.720	8.180	6.5-8.4
EC (dS m^{-1})	0.480	1.020	1.670	0-3
N (parts per million)	5.520	15.500	7.900	0-10
P (parts per million)	7.600	18.400	16.800	0-2
K (parts per million)	7.100	20.800	18.200	0-2
Na (meq L^{-1})	6.560	5.430	8.700	0-40
BOD (mg L^{-1})	28.40	27.20	70.50	10-80
COD (mg L^{-1})	133.50	100.20	151.30	30-160
Carbonates (mg L^{-1})	2.900	1.240	7.800	0-10
Bicarbonates (mg L^{-1})	21.400	18.400	28.70	0-150
SAR (mg L^{-1})	3.290	2.610	4.580	0-15
RSC (mg L^{-1})	16.39	11.04	29.30	-
TDS (mg L^{-1})	-	447.70	760.40	0-2000

100 days (T_9) constituted three complete cycles, because water is applied in 1:2 or 2:1 proportion using the aforesaid sources in these treatments. Treatments T_1, T_2, and T_3, which employed only normal water, treated and untreated sewage water, were evaluated in line with the above-mentioned cycles (Table 1).

Results and Discussion

As tabulated in Table 3 okra plant height, leaves' numbers, and number of branches are affected by the source of water used (Table 2) and its conjunctive irrigation mode at various growth phases. Compared to treated (1.02 dS m^{-1}) and untreated (1.67 dS m^{-1}) sewage water, the electrical conductivity for normal water was significantly lower (0.48 dSm^{-1}) [9], with fluctuations falling within the permissible limit (3.00 dS m^{-1}). The BOD level for both the treated (27.20 mg L^{-1}) as well as untreated (70.50 mg L^{-1}) sewage water was below the suggested maximum concentration (80 mg L^{-1}) accredited to organic colloids suspensions [9]. The COD values of the various water sources examined ranged from 100.20 to 151.30 mg L^{-1}, lesser than 160 mg L^{-1} which is the standard limit set by FAO. As observed, the untreated sewage water had higher sodium levels, allowing an increase in pH as well as in electrical conductivity. For the different water sources examined, the bicarbonate content ranged from 18.40 to 28.70 mg L^{-1} which was below the detectable limit of 150 mg L^{-1} and therefore, being unharmful [9]. The total nitrogen content for normal water (5.52 ppm) and untreated sewage water (7.90 ppm) was below the recommended maximum limit of 10 ppm. However, for the treated sewage water, it was found to be 15.50 ppm [9]. The difference could be related to bio-organisms' need for energy and decreased retentively when organic suspended particles degrade. Phosphorus (7.60 to 18.40 ppm) and potassium (7.10 to 20.80 ppm) concentrations in different water sources were well above the threshold limit of 2 ppm. This takes into account the abundance of important macronutrients in water sources as well (Table 2). The results of the growth and yield attributing traits at 90 days after sowing revealed that plots receiving treated sewage water maintained significantly

Table 3. Physicochemical parameters

Treatments	Growth parameters and yield			
	Plant height (cm)	Number of leaves	Number of branches	Yield (t ha^{-1})
T_1- Normal water (NW)	153.57	30.20	3.76	25.20
T_2- Treated sewage water (TSW)	168.50	33.00	4.47	32.35
T_3 -Untreated sewage water (UTSW)	140.54	23.07	3.11	21.61
T_4- NW and TSW applied alternatively	157.99	30.40	3.88	28.12
T_5- NW and UTSW applied alternatively	144.49	27.60	3.40	23.32
T_6- Two times NW fb one-time TSW	143.02	26.53	3.18	26.02
T_7- Two times NW fb one-time UTSW	145.26	28.60	3.42	23.60
T_8- One time NW fb two times TSW	162.14	30.87	4.12	29.24
T_9- One time NW fb two times UTSW	142.58	26.60	3.12	21.92
S.Em. ±	**3.29**	**0.82**	**0.19**	**1.25**
CD (P=0.05)	**9.77**	**2.43**	**0.56**	**3.71**

higher plant height (168.50 cm), followed by application in 1:2 mode for normal water and treated sewage water (162.14 cm) and normal and sewage water applied alternately (157.99 cm), which were found to be comparable. However, the treatment using untreated sewage water resulted in the shortest plant height (140.54 cm) (Figure 2). Based on the leaves' numbers per plant, the results depicted that plots with treated sewage water application had a significantly higher number of leaves per plant (33.00), followed by plots treated with once normal water fb twice treated sewage water (30.87) and normal and sewage water applied alternately (30.40). During harvest, the treatment with untreated sewage water application produced the fewest leaves per plant (23.07). This could be attributed to the application of N fertilizers as well as the contents of untreated sewage water had little effect on soil retention but on contrary crop plants were able to absorb more efficiently. The availability of nutrients affects the synthesis of food through photosynthesis and the subsequent partitioning of biomass into leaves. The treatment using treated sewage water (4.47) had the maximum primary branches per plant of all the treatments, followed by once normal water fb twice treated sewage water (4.12) and normal water fb treated sewage water applied alternately (4.12). (3.88). All of these therapies were discovered to be on par with one another. The plots receiving untreated sewage water had the minimum number of primary branches per plant (3.11) and, during harvest; there was a substantial difference in total dry matter accumulation per plant attributable to treatment effects. This could be owing to the fact that higher growth means higher yields. Three significant primary visible growth parameters are plant height, leaves' numbers, and number of branches. As evident based on statistics, different treatments and time both affected the plant height. Due to applied treatments, statistical discrepancies are observed from the beginning to the end of maturity; however, differences are more obvious at later stages of growth. The use of treated sewage water alone resulted in tall plants, reaching a maximum height of 168.5 cm at harvest. Progression of tallness in the treatment is aided by increased partial nutrient supply from the water, which can be used as a substitute for freshwater irrigation, as well as improved physiological processes including cell division and cell elongation, as well as timely metabolic activities. The findings are consistent with Yaser et al., [10]. Any crop's transition from heterotrophic to autotrophic requires the development of leaves. Plants are autotrophic because their green leaves serve as a main photosynthetic surface. Another criterion for determining how well provided nutrients are utilized by a crop is its ability to produce a large number of leaves. During harvest, usage of treated sewage water produced a greater number of leaves (up to 33) and branches (4.47). A well-fed crop has a strong root system, resulting in higher plants with more functional leaves. The findings of Arunachalam et al., [11] and

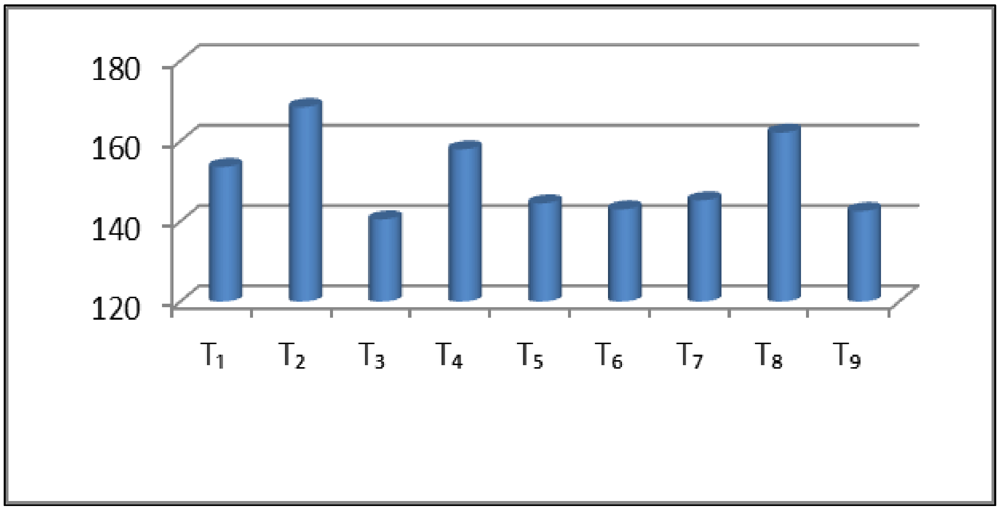

Figure 2. Influence of various water sources used and its combination of irrigation effect on plant height

Purushotham et al., [12] are supported by the findings of this study. For all of these criteria, twice regular water fb once treated water performed similarly to treated water alone, suggesting effective partial replacement. Treatments had a considerable impact on fruit yield. The application of treated sewage water yielded the most fruit (32.35 t ha^{-1}), followed by plots treated with the combination of once normal water and twice treated sewage water (29.24 t ha^{-1}), and alternative application of normal water and treated sewage water (28.12 t ha^{-1}). Applying wastewater at rates that maintain a balance between nutrient input and plant uptake will enhance optimal plant development and output thus, reducing pollution hazards [13]. With the use of treated sewage water, there was increased availability of N in soil leading to increase in N concentration in leaves which in turn resulted in effective use of solar radiation [14]. However, the least fruit yield (21.61 t ha^{-1}) was obtained using untreated sewage water. The treatment using untreated sewage water, on the other hand, had the lowest fruit yield (21.61 t ha^{-1}). It is re-iterated that normal water yielded 25.20 t ha^{-1} and that replacing treated sewage water as an alternate or after two irrigations in a cyclic way for greater yields is clearly envisaged. The percent increase in yield from the treatment receiving treated sewage water and normal water was (28%); from normal water and untreated sewage (16%); and plot treated with treated sewage water and untreated sewage water was (49%) indicating a probable beneficial trend by treated sewage water.

Conclusion and recommendations

If there is no practical application for a true innovation, it is rendered useless. With adoption of new technology as the primary goal, the farming community must be convinced of its benefits. Both treated and untreated sewage water as well as conjunctive mode is a beneficial method for production of crops like Okra. This helps with the conservation of invaluable natural source of water, freshwater and can aid in extension of the production area. The impact of heavy metal accumulation in the health chain must be taken into account when using untreated sewage water or nutrient-rich effluent on various soils and crops. Construction or expansion of sewerage and wastewater treatment infrastructure in peri-urban areas will assist wastewater re-use in meaningful ways, such as agriculture.

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