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Influence of sewage water on soil chemical properties and yield of Okra

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Abstract

Field experiment was conducted with an objective of utilizing sewage water as a source of irrigation on Okra and to know its effect on soil properties. Sewage water of both treated and untreated are obtained from the university campus. The crop was irrigated using Normal Water (NW), Treated Sewage Water (TSW) and Untreated Sewage Water (UTSW) alone and in conjunctive mode constituting nine treatments replicated thrice using RCBD design. Major nutrient constituents in treated and untreated sewage water were higher compared to the normal water. Electrical conductivity and sodium content of UTSW was high (1.67 dS m⁻¹ and 8.70 meq L⁻¹ respectively) compared to TSW (1.67 dS m⁻¹ and 8.70 meq L⁻¹ respectively) and NW (1.67 dS m⁻¹ and 8.70 meq L⁻¹ respectively) but found below the threshold level. Carbonates, bicarbonates, BOD, COD, SAR, RSC and TDS (7.80 mg L⁻¹, 28.70 mg L⁻¹, 70.50 mg L⁻¹, 151.30 mg L⁻¹, 4.58 mg L⁻¹, 29.30 mg L⁻¹ and 760.40 mg L⁻¹) was high in UTSW compare to the TSW and NW but did not qualify to cause salt hazards. The results showed that the soil irrigated with TSW and its conjunctive mode led to a significant increase of available nitrogen (270.89, 270.14, 269.47 kg ha⁻¹), available phosphorous (50.76, 48.12, 42.87 kg ha⁻¹) and available potassium (180.42, 178.82, 176.58 kg ha⁻¹) in comparison with NW with decrement in pH values. Treatment receiving only UTSW significantly increased the electrical conductivity (0.19 dS m⁻¹) and sodium content (16.66 mg 100⁻¹) in soil as compared to TSW and NW. Application of treated sewage water registered significantly highest fruit yield (32.35 t ha⁻¹) followed by application of one time normal water *fb* two times treated sewage water (29.24 t ha⁻¹) and normal water *fb* treated sewage water applied alternatively (28.12 t ha⁻¹).

Keywords: Normal water, okra, salinity, sewage water, treated water

Introduction

Water is considered as an elixir to life and predictions suggest that many Asian countries will have severe water problems by 2025 (Tuong and Bouman 2003) [19]. Limited water resources have probed into the use of non-conventional water sources. Growing urbanization has led to the generation of wastewater which is a preferred marginal water source on account of reliable and uniform supply around the year with copious nutrients embedded in it (Haruvy 1997) [6]. Estimates indicate 75 to 85 per cent of the water consumed is generated as wastewater (Manjunatha *et al.* 2017) [12]. Expansion of urban populations and increased coverage of domestic water supply and sewerage give rise to greater quantities of municipal wastewater that needs to be disposed of safely without pollution problems. Use of such water in agriculture could be an important consideration as marginal quality water with cost-effectiveness taking advantage of nutrients contained in it to grow the choice of crops by the growers. Even though domestic wastewater available throughout the year provides farmers an opportunity to grow crops consistency but heavy metals are the causes of concern that may be toxic if their concentration exceeds than the permissible limit. Hence, treating this useful resource in an appropriate method paves way for its value and hence fit for reuse. Increasing reuse of treated wastewater promotes sustainable agriculture, preserves the scarce water resource and environmental quality (Haruvy 1997) [6]. Treated wastewater can be used as an alternative for irrigation of the crop which is eaten after cooking and also can serve as an alternative source to chemical fertilizers which are expensive.

Okra, *Abelmoschus esculentus* L. (Moench) is an economically important vegetable crop belongs to the family *Malvaceae* and widely spread all over tropical, subtropical and warm temperate regions of the world. The crop is suitable for cultivation as a garden crop as well on large commercial farms.

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As water scarcity mounts, farmers in the semi-urban areas are increasingly using sewage to grow variety of vegetables including okra. The big concern is a large part of the sewage discharge from the urban centers is untreated and used directly as raw sewage to grow different vegetables in order to meet the demand of the urban people. Present study is an effort to know the effect of sewage water on soil properties and yield of Okra.

Material and Methods

Field experiment was conducted during summer 2018 on a sandy loam soil at College of Agriculture, University of Agricultural and Horticultural Sciences, Shivamogga, coming under Southern Transition Zone (Zone-7) of Karnataka. The geographical reference of the experimental site was 13° 58' to 14° 1' North latitude and 75° 34' to 75° 42' East longitude with an altitude of 650 m above the mean sea level. The chemical properties of the top soil (0-20) include: soil pH, 6.21; Electrical conductivity, 0.187 dS m⁻¹; soil organic carbon, 3.10g kg⁻¹; available N, 250.80 kg ha⁻¹; available P, 28.43kg ha⁻¹; available K, 171.40 kg ha⁻¹; sodium, 14.10 mg 100g⁻¹.

Three different water sources are used for the study. Normal water was obtained from the open storage tank built for the irrigation purpose, which receives the water from canal. Untreated water is collected from the campus which includes laboratories, staying facility as hostel for both students and staff. Treated water was obtained from treatment unit. This treatment unit is of Sequencing Batch Reactor (SBR) type installed in the campus, wherein, all the untreated water from the above said sources is being diverted. Both for untreated and treated water, quality was tested for different parameters by following standard procedures.

The experiment was laid out in randomized complete block design with three replications involving nine treatment combinations. Treatments comprised of three different water sources as above and also in conjunctive mode applied in the cyclic form of one time to after. Treatments consist of application of normal water (T₁), Treated sewage water (T₂), Untreated sewage water (T₃), Normal water and treated sewage water applied alternatively (T₄), Normal water and untreated sewage water applied alternatively (T₅), Two times normal water application *fb* one time treated sewage water (T₆), Two times normal water application *fb* one time untreated sewage water (T₇), One time normal water application *fb* two times treated sewage water (T₈) and One time normal water application *fb* two times untreated sewage water (T₉).

The experimental area was deep ploughed once followed by application of farm yard manure @25 tha⁻¹, passed cultivators in cross directions and then leveled to facilitate sowing. The variety used in the experiment was Arka Anamika at a spacing of 60 x 30 cm sown on 28th February, 2018. The gross plot size was 4.2 x 4.8 m, accommodating 112 plants in a treatment. All the experimental plots received a basal application of 125 kg N ha⁻¹, 75 kg P₂O₅ ha⁻¹ and 63 kg K₂O ha⁻¹. After sowing, first 20 days was reserved for good establishment of the crop. Treatment schedule began from twenty days after sowing, at ten days interval with 5 cm depth. In T₄ and T₅, water was applied alternatively using normal with treated/untreated sewage water. Hence two irrigations set of 20 and 30, 40 and 50, 60 and 70, 80 and 90 days forms four complete cycles during the crop duration. Similarly for T₆ to T₉, three irrigations on 20, 30and 40 days makes a set likewise, 50, 60 & 70 and 80, 90 & 100 days

formed three complete cycles, since in these treatments water was applied either in 1:2 or 2:1 proportion. Treatments T₁, T₂ and T₃ was sole application considered in accordance with the respective cycles of the above. These cycles were considered for monitoring water and soil quality parameters.

Results and Discussion

Characteristics of Sewage water

The different sources of water used for the study showed variability in possessing chemical properties (Table 1). The three different sources of water used recorded neutral to slightly alkaline pH. Normal water a source from canal stored in the open tanks recorded the average pH value of 6.8. Compared to this, both treated and untreated water recorded high pH value (upto 8.18) due to more cationic load from different households and laboratories. Ayres and Westcot (1991) [1] also recommend a pH between 6.5 and 8.4 for water used in irrigation. The electrical conductivity of normal water (0.48 dS m⁻¹) was found much lower than that of both treated and untreated sewage water (1.02 to 1.67 dS m⁻¹) and variations were found within the safe limit (3.00 dSm⁻¹) as suggested by FAO (1985) [5]. The BOD values of treated (27.20 mg L⁻¹) and untreated (70.50 mg L⁻¹) sewage water though differed due to suspended organic colloids but found lower than the recommended maximum concentration of 80 mg L⁻¹ (FAO 1985) [5]. The BOD value of untreated sewage water was found higher indicating more bio-organisms activity due to suspended organic colloids. However, upon treatment values reduced greatly indicating the roles of pressure sand filter and activated carbon in the processing step thereby reduced suspended particles and its activity. The COD values of different sources of water used varied from 100.20 to 151.30 mg L⁻¹ was also found below the FAO standard limit of 160 mg L⁻¹. The COD focuses the relationship between bio-organisms and oxygen consumption pattern by them for degrading the nonessential organic substances. However, upon treatment, it substantially reduced indicating its readiness to use in agricultural crops.

The total dissolved solids in treated (447 mg L⁻¹) and untreated (760.40 mg L⁻¹) sewage water though varied but did not cross the recommended maximum concentration of 2000 mg L⁻¹ for irrigation water as per the criteria of FAO (1985) [5]. Among the basic cations, Na⁺ was dominant in sewage water (5.43 to 8.70 meq L⁻¹) compared to other water sources, which was lower than 40 meq L⁻¹ a critical value above which water is not safe to use (FAO 1985) [5]. Sodium in particular as seen from the results was higher in untreated source paving way for not only enhancing pH value but also effected electrical conductivity. The bicarbonate content was also quite low in the different sources of water tested (18.40 to 28.70 mg L⁻¹) suggesting that these levels are not toxic since they are well within the perceptible limits of 150 mg L⁻¹ (FAO 1985) [5]. On the similar lines, the residual sodium carbonate of treated and untreated sewage water (11.04 to 29.30 mg L⁻¹) and sodium absorption ratio of treated and untreated sewage water (2.61 and 4.58 mg L⁻¹), were also within the perceptible limits (FAO 1985 and Eaton 1950) [5], indicates its total usability. According to Ayers and Westcot (1985) [2], considering EC and Na⁺ values observed in the study, their reuse for irrigation can be considered, also, if the values of SAR are related to the values of EC it follow that their application would not cause a reduction of the infiltration rate into the soil. On the other hand, carbonates and bicarbonate was also quite lower along with total dissolved salts. The trend remained the same for samples at different time

intervals. The tendency of higher bicarbonates, sodium, chlorides and sulphates was observed in Calcutta city sewage effluents (Maiti *et al.*, 1992) [9].

Normal water poses total nitrogen to the extent of 5.52 ppm while that of untreated was 7.90 ppm. But the total nitrogen in treated (15.50 ppm) sewage water was found higher and also exceeded the recommended maximum concentration of 10 ppm (FAO 1985) [5]. The variation may be due to essential use by bio-organisms as a energy source and less retentivity due to degrading organic suspended particles. The phosphorus content in different sources of water used ranged from 7.60 to 18.40 ppm indicating above the critical concentration of 2 ppm. Likewise, the concentration of potassium content (7.10 to 20.80 ppm) in various sources of water was also higher than the critical value (2 ppm). This also envisages the richness of essential macronutrients in water sources. The major attributable reason for such high values may be due to organic and inorganic form of phosphorus present in different daily usage materials, retention ability by organic compounds, highly active ionic reaction behavior, polyphosphate degradation and by the circulation of waste streams within the plant.

Chemical Properties of Soils

The pH of soils irrigated with treated, untreated sewage water, normal water and its conjunctive mode of irrigation is presented in fig. 1. The pH of soils was 6.21 in the begging. After completion of first cycle of irrigation, two alternative irrigations (T4 and T5) showed values ranging from 6.53 to 7.44 as against 7.15 to 7.53 for three irrigations (T6 to T9). Slightly enhanced soil reaction is due to residues from fertilizer application apart from sources of water having a pH range from 6.87 to 7.21. Similarly for second cycle, values ranged from 6.87 to 7.55 and 7.12 to 7.52 respectively for two and three irrigation cycles. At the end of all irrigation cycles, soil irrigated with treated and untreated sewage water recorded pH of 7.20 and 7.21 respectively while the plots receiving one time normal water *fb* two times untreated sewage water, recorded highest pH of 7.52. Hence, irrigation with different sources was not much influenced on soil reaction as the values were within the range of neutrality. Slightly higher pH is related to effluent alkalinity, addition of exchangeable cations and anions to soil and changes in the N cycling production of OH⁻ ions due to enhanced denitrification or nitrate reduction. Mancino and Pepper (1992) also found that irrigation with treated wastewater raised the soil pH by 0.1 to 0.2 units when compared with irrigation with drinking water.

The salt load left on the soils after treatments was found highest (EC of 0.189 dS m⁻¹) in untreated sewage water plots followed by the plots receiving one time normal water *fb* two times untreated sewage water (0.184 dS m⁻¹) but below the threshold limit to cause salinity hazard to the soil. Salt content of sewage water is a major criteria for enhancement. The precipitation that occurred during the soil reaction might have influenced the dissolution of effluent salts, causing the evenness in the EC of the soil solution. Khai *et al.* (2008) [8] and Mojiri (2011) [14] stated that the increase of EC in soils irrigated with wastewater was mainly due to the original higher concentration of cations such as Na and K. Nevertheless, EC values observed in soil remained below the indicative threshold value (4.00 dS m⁻¹) beyond which a soil is defined as saline. The organic carbon (OC) content varied slightly due to application of water treatments. One time normal water *fb* two times untreated sewage water irrigated

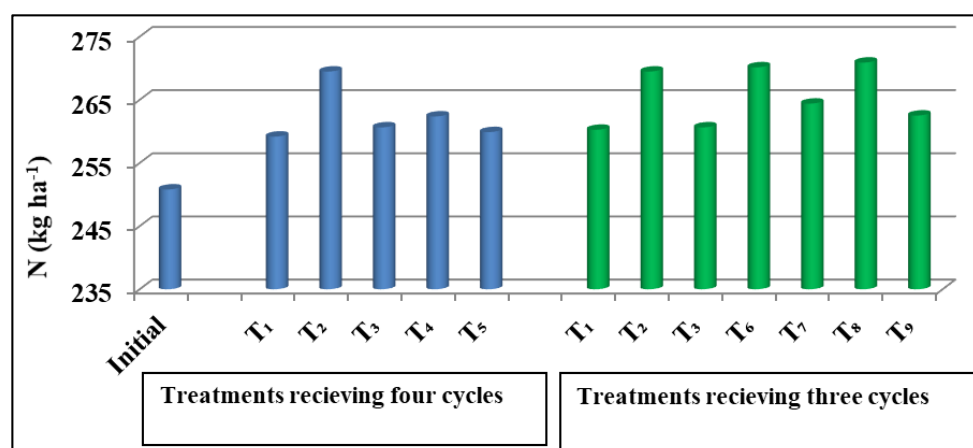
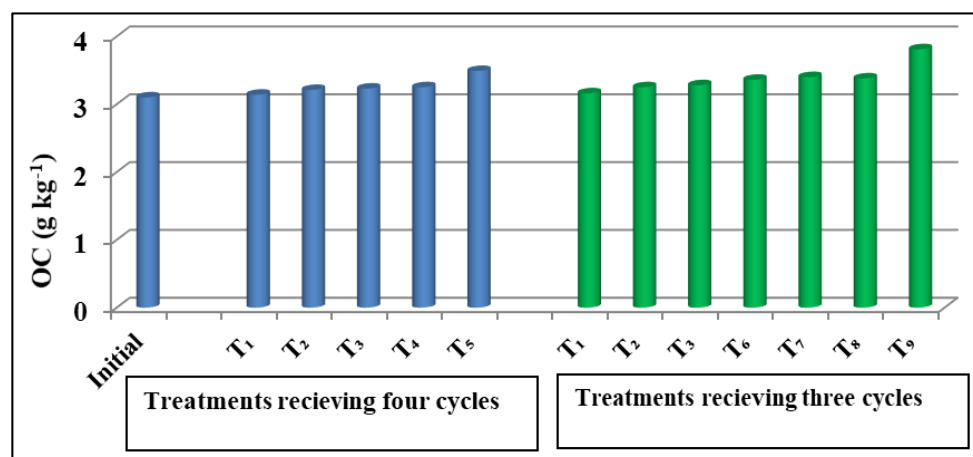
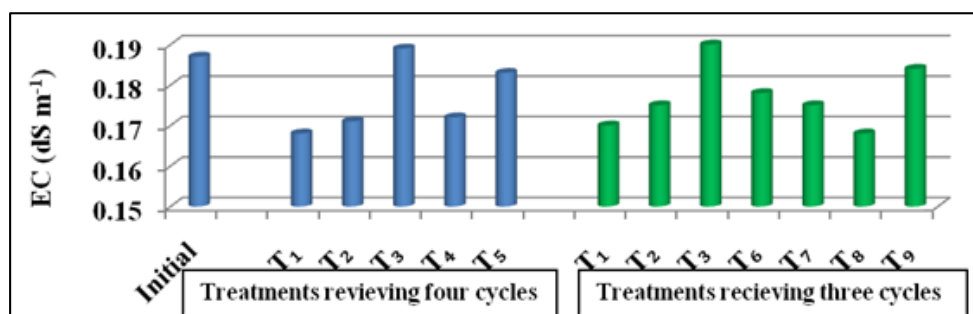
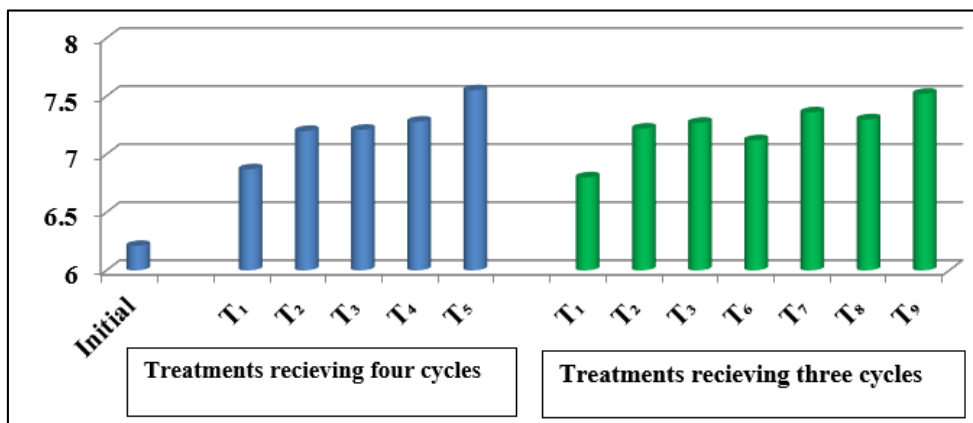
soils was recorded slightly higher (3.81 g kg⁻¹) followed by alternative application of normal water *fb* untreated sewage water (3.49 g kg⁻¹) as against initial value of 3.10g kg⁻¹. Although wastewater is said to be a source of organic compounds, but only after several years of continuous application it has been observed its increase, without changing in the short-term application (Silva *et al.* 2015) [17]. The Treatments in test enhanced the exchangeable sodium content in the soil as compared to initial value of 14.10mg 100 g⁻¹. One time normal water *fb* two times untreated sewage water irrigated plots possessed higher exchangeable sodium (17.54 mg 100 g⁻¹) followed by two times normal water *fb* one time untreated sewage water (17.01 mg 100 g⁻¹). On the other hand, treatment receiving treated sewage water recorded lowest sodium content (14.63 mg 100 g⁻¹).

The treated sewage water and its conjunctive mode of irrigation recorded higher available N, P and K compared to the initial status. Plots receiving one time normal water *fb* two times treated sewage water recorded highest available N in soil (270.89 kg ha⁻¹) closely followed by two times normal water *fb* one time treated sewage water irrigated soil (270.14 kg ha⁻¹) and treated sewage water (269.47 kg ha⁻¹). It leads to infer that the applied source of N fertilizers and the contents in water hardly influenced on retention in soils rather given a good platform for the crop plants to absorb with. Morishita (1985) [15] reported that irrigation with nitrogen enriched polluted water can supply a considerable excess of nutrient nitrogen to growing rice plants. Discrepancies between measured and effective quantities may have important effect in terms of crop response obtained at a given location for that particular soil conditions. However, the higher NH₄-N concentration in water results in a higher NH₄-N concentration in the corresponding irrigated plots only if samples derived immediately, otherwise subjected for losses. The NH₄-N supplied through irrigation water was readily available for plants growth, most of it was adsorbed to the negatively charged clay particle surface of irrigated soil (Duan, *et al.*, 2010) [4].

On the similar lines, available phosphorous and potassium was highest in the treatment receiving one time normal water *fb* two times treated sewage water (50.76 and 180.42 kg ha⁻¹ respectively) followed by treatment receiving treated sewage water (48.12 and 178.82 kg ha⁻¹ respectively) as against plot receiving normal water (30.47 and 173.36 respectively). This was probably due to basal application of P (75 kg ha⁻¹) along with addition of P rich water. Compared to nitrogen, phosphorus content in water sources used is relatively higher and after completion of all the cycles of irrigation about 28.73 to 82.46 kg ha⁻¹ available phosphorous (Figure 2) have been added to the soil through different sources and its conjunctive mode of application. It is learnt that phosphorus being very reactive, gets fixed to functional sites, however, the soils being rich in sandy nature, losses were also expected due to leaching apart from readily availability form. Potassium regarded as third major nutrient also more prone to leaching losses in sandy soils and for fixation. Compared to initial values (171.40 kg ha⁻¹), across different treatments, values varied from 173.36 to 180.42 kg ha⁻¹ indicating least influence, despite additions of potassium was to the tune of 19.21 to 68.19 kg ha⁻¹ (Figure 2) by different water resources. Increase or decrease observed in the top layer was probably because the biodynamic processes that are restricted to the surface soil layers, where the irrigation effect is more apparent. Authors such as Silva and Borges (2008) [16] stated that K concentration in the soil is quite variable and might be

associated with the dynamics of K in the soil-plant-effluent system. Depending on the textural classes, there might be decrease in K due to its leaching and plant absorption. Fruit yield differed significantly due to treatments. Application of treated sewage water registered significantly highest fruit yield (32.35 t ha⁻¹) followed by application of

one time normal water *fb* two times treated sewage water (29.24 t ha⁻¹) and normal water *fb* treated sewage water applied alternatively (28.12 t ha⁻¹) due to favorable nutrient dynamics and impact on soils as explained. However, significantly lowest fruit yield (21.61 t ha⁻¹) was recorded in the treatment applied with untreated sewage water.



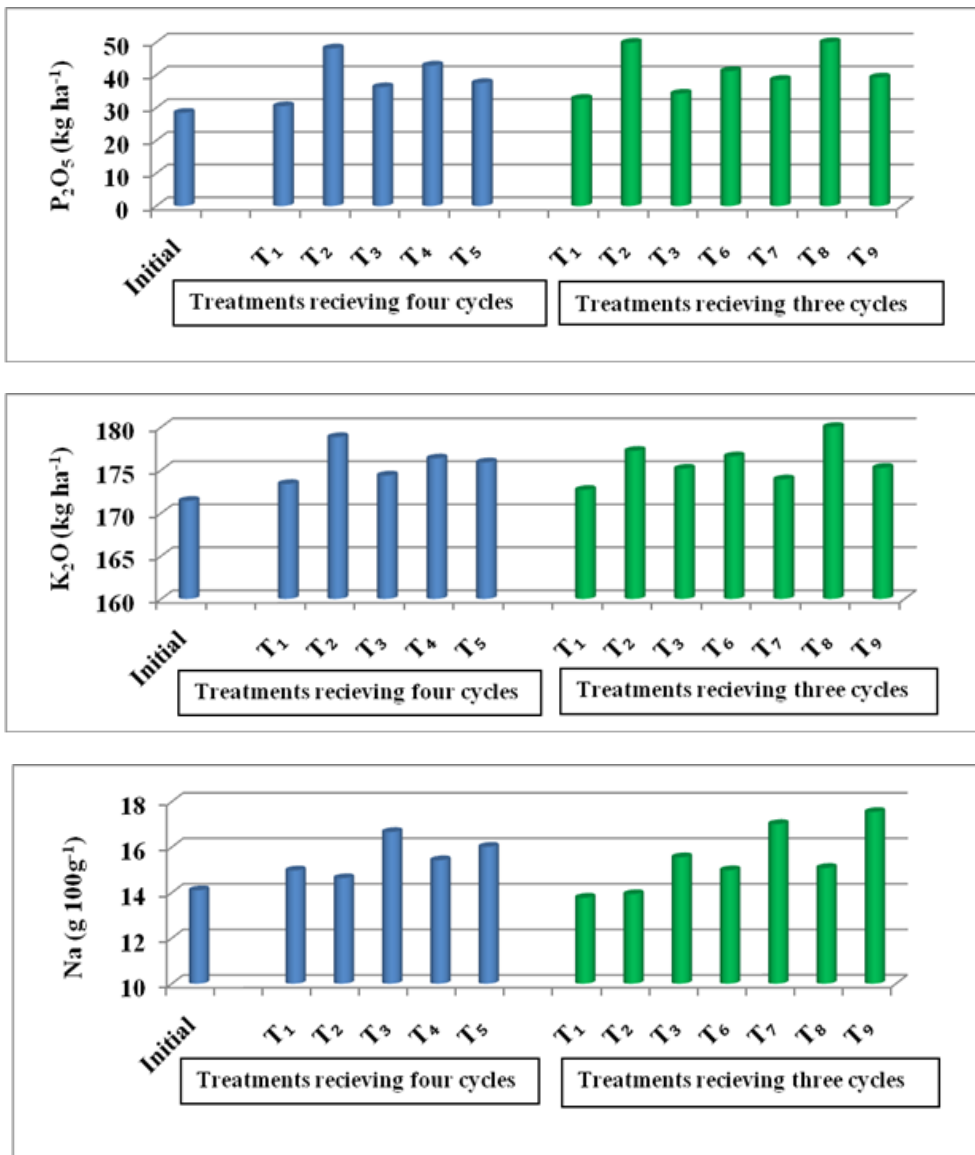


Fig 1: Nutrient profiling of soil as influenced by sewage water and its conjunctive mode of irrigation.

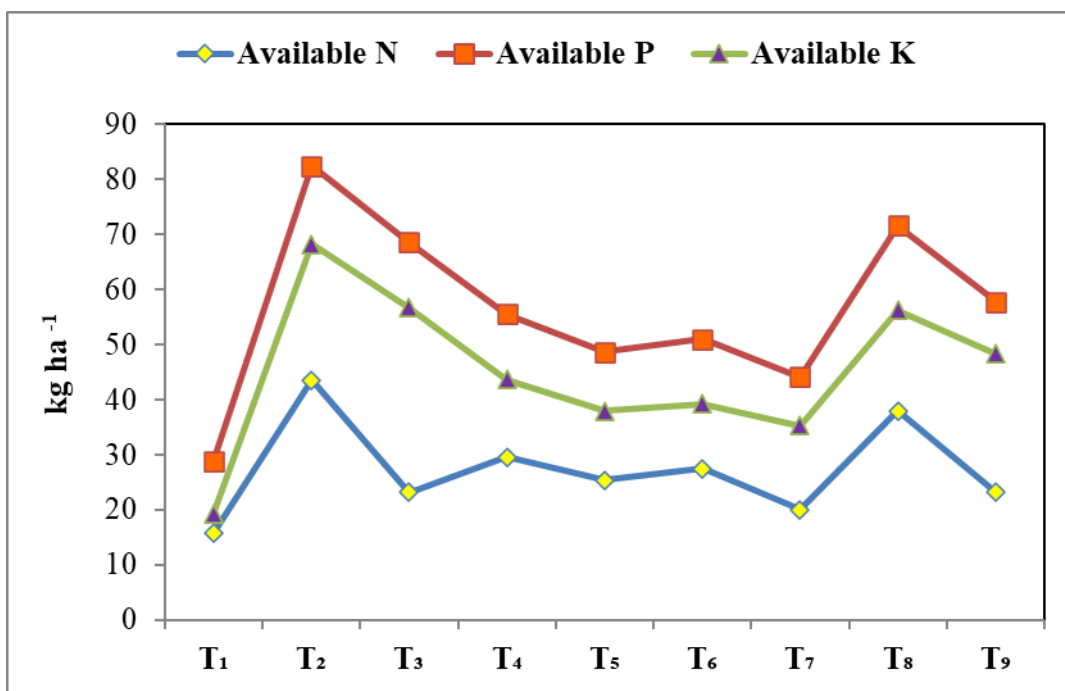


Fig 2: Total amount of available N P K added to the soil after completion of all the cycle of irrigation through different sources of water used and its conjunctive mode of application

Table 1: Chemical characterization of different sources of water used in the study

| Sl. No | Parameters | Normal water | Treated sewage water | Untreated sewage water | FAO Standards(1985) |
|--------|------------------------------------|--------------|----------------------|------------------------|---------------------|
| 1. | pH | 6.80 | 7.72 | 8.18 | 6.5-8.4 |
| 2. | EC (dS m ⁻¹) | 0.48 | 1.02 | 1.67 | 0-3 |
| 3. | N (ppm) | 5.52 | 15.50 | 7.90 | 0-10 |
| 4. | P (ppm) | 7.60 | 18.40 | 16.80 | 0-2 |
| 5. | K (ppm) | 7.10 | 20.80 | 18.20 | 0-2 |
| 6. | Na (meq L ⁻¹) | 6.56 | 5.43 | 8.70 | 0-40 |
| 7. | BOD (mg L ⁻¹) | 28.40 | 27.20 | 70.50 | 10-80 |
| 8. | COD (mg L ⁻¹) | 133.50 | 100.20 | 151.30 | 30-160 |
| 9. | Carbonates (mg L ⁻¹) | 2.90 | 1.24 | 7.80 | 0-10 |
| 10. | Bicarbonates (mg L ⁻¹) | 21.40 | 18.40 | 28.70 | 0-150 |
| 11. | SAR (mg L ⁻¹) | 3.29 | 2.61 | 4.58 | 0-15 |
| 12. | RSC (mg L ⁻¹) | 16.39 | 11.04 | 29.30 | - |
| 13. | TDS (mg L ⁻¹) | - | 447.70 | 760.40 | 0-2000 |

Conclusion

The nutrient profiling of untreated and treated sewage water from university campus was found safe to use in agriculture since most of the quality parameters determined were well within the acceptable standards and its impact on soil (sandy loam) is also at negligible proportion. The treatments involved with untreated sewage water irrigation observed slightly higher electrical conductivity, organic carbon and sodium in soils but within the tolerance limit to cause any soil salinity hazard. Untreated or treated sewage water although possess a little higher available N, P and K status, its impact on soil properties were at minimal envisaging its immediate utilization in crops. Crops like Okra can be grown with treated sewage water or else untreated sewage water and its conjunctive mode, thereby it saves precious resource of nature *i.e.*, fresh water giving scope for extension of production area.

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