Journal of Waste Water Treatment & Analysis - Open Access

Research Article
OPEN ACCESS Freely available online
doi:10.4172/2157-7587.1000104

Assessing the Yields and Nutrient Uptake of Okra *Abelmoschus Esculentu* Using Diluted Stabilized Wastewater for Irrigation in South -Western Nigeria

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Abstract

Growth, crop yields and nutrient uptake of Okra [*Abelmoschus esculentus* (L.) Moench] irrigated with different mix proportions of stream water to partially treated sewage effluent (0:100; 25:75; 50:50; 75:25; 100:0) under furrow system were determined. There were four replicates of each treatment and the 100% stream water served as the control, the stream water has little effluent discharges along the downstream. The 75% treated sewage effluent gave the highest fruit yield of 10.5 t/ha while the 100% stream water gave the lowest fruit yield of 5.40 t/ha. The highest dry matter yield of 9.8 t/ha was obtained with 100% partially treated sewage. There was no significant difference among the treatments in the number of leaves and plant heights. The 100% partially treated sewage effluent however gave significantly ($P<0.05$) higher leaf area index and plant girth than other treatments while the 50% partially treated sewage had significantly ($P<0.05$) higher fruit moisture content at harvest. Analysis of the plant indicated that maximum nutrient uptake occurred in 25:75% stream water: sewage effluent treatment and the nutrient content of the crop in all the treatments compared with acceptable limits in common crops. There was little or no trace of odour on the water or trace of bacteria in the harvested crop since the water has been treated through waste water stabilization ponds. The sewage resulted in higher P, K, and Cu content of the soil. This study shows that okra can safely be grown in the study area with partially treated sewage effluent but would be best when mixed in 25:75% of stream water to partially treated sewage and the soil leached intermittent to prevent Cu and macro-nutrient build-up.

Keywords: Yield; Nutrient uptake; Sewage effluent; Fruit yield; Leaf area index

Introduction

Land application of partially treated sewage effluent from Waste water stabilization ponds is increasing in many parts of the world, for agricultural use [1-3]. The safe disposal of partially treated sewage effluent has been a major environmental concern in Nigeria in recent time. Wastewater irrigation or the use of sewage water for irrigation purposes is widely gaining acceptance because it is a major source of plants' needed nutrients. The sewage water also serves as a source of organic fertilizer and water which are becoming scarce and expensive.

Many works [4-8] abound in the developed countries on the use of partially treated sewage effluent for irrigation of crops like corn, turf grass, sugarcane using pot experiments, sprinklers or basin irrigation systems. Not much work has been done on vegetable/horticultural crops and on border/furrow irrigation system. Also studies on the use of partially treated sewage effluent for irrigation are still limited in Africa in general and Nigeria in particular. In Nigeria, a partially treated of waste water is usually ignored. This study is based on proportional mix of partially treated waste water and stream water. Waste water stabilization is always in four phases: Aerobic, Anaerobic, Facultative and later discharge to Maturation ponds for re – use. This study take care of the salt accumulation in the process of waste water stabilization by mixing the waste effluent with stream water.

Small scale surface irrigation is becoming increasingly popular among the rural farmers in Nigeria because of the management problem of large scale-irrigation systems. The farmers grow mainly leafy vegetable crops using border or furrow irrigation system [9]. This study therefore aimed at studying the effects, on both the crops and the soils, of the usage of different rates of diluted partially treated sewage effluent on irrigated okra under furrow system of irrigation.

Methodology

A field experiment was conducted on a gentle sloping land near the Obafemi Awolowo University's oxidation pond during the dry season between November, 2003 and February, 2004. The soil was a sandy clay loam soil classified as '*Alfisol*' [10]. It has a water holding capacity of 90 mm per meter depth of soil. The land was cleared and harrowed before the treatments were imposed. The experiment was a randomized block design consisting of five treatments (100:0; 75:25; 50:50; 25:75; 0:100) of mix proportions of partially treated sewage effluent and fresh water. The 100% stream water served as the control. There were four replicates of each treatment. Each subplot measured 6m x 4m and consisted of 4 furrows channels. Five tanks of 500 Litres each were used to mix the stream water and partially treated sewage effluent, one for each mix proportion. Each tank was used for each replicate at 250 Litres in the Morning and Evening respectively at 3 days irrigation intervals. Soil and Water samples were taken before, during and after the irrigation for laboratory analysis. A small pump was used to supply the mixture to the head ditch of the sub plots in turn. The initial physico-chemical and biological properties of the sewage, stream water and soil (Table 1 and Table 2) were determined before the experiment.

Okra seed was planted on the furrow ridge at the recommended spacing of 30cm. Weeds and insects were controlled using

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Received October 14, 2010; **Accepted** November 13, 2010; **Published** November 15, 2010

Citation: Adewoye AO, Okunade DA, Adekalu KO (2010) Assessing the Yields and Nutrient Uptake of Okra *Abelmoschus Esculentu* Using Diluted Stabilized Wastewater for Irrigation in South -Western Nigeria. J Waste Water Treatment Analysis 1:104. doi:10.4172/2157-7587.1000104

recommend procedures. The height, stem girth and leaf area index were measured fortnightly. At the end of the season, a central 2 x 3 m of each subplot was harvested for both dry matter and fruit yield. Samples of the harvested crop were also analysed for nutrient composition and moisture content. Also samples of the soil were analysed for the macro and micro nutrient content.

Soil moisture content was monitored before and after irrigation using the gravimetric method. Neutron probes (Model EA514-054) manufactured by ELE were installed at 15, 30, 45, and 60 cm depth in the center of each sub-plot also for soil-water content measurements.

The land was smoothened to a design slope of 3% which is within the safe limit for the soil type. The furrow stream size used was 2L/s, which represents about the maximum non-erosive stream for the soil type. An irrigation frequency of 3days with a net depth of 40 mm of water per irrigation based on Penman-Monteith equation [11] was used.

Total nitrogen and organic carbon were determined with the Carlo-Erba automatic micro-analyser. Total organic matter was calculated using 1.72 as a conversion factor. Available phosphorus was measured by spectrophotometry after extraction in 0.5 m sodium bicarbonate. Total coliform count was determined using methylene blue as a medium and the methods of pour-plate with plate streaking under asepsis. Cation exchange capacity was determined with barium chloride and tri-ethanolamine and exchangeable potassium was measured in the same extract by flame photometry. Available micro nutrients (Fe, Mn, Zn and Cu) were determined by atomic absorption spectrometry in a 1:2 diethylene-triaminepentacelate extract. The pH was measured in soil saturated with water and 1M potassium chloride solution and electrical conductivity in 1:10 water extracts. Water holding capacity at 1/3 atmospheric pressure was determined by a pressure plate. Calcium carbonate was determined with a calcimeter. Particles size distribution was assessed by sieving and sedimentation.

Results and Discussion

Effect of sewage treatments on plant growth

The 100% partially treated sewage effluent gave the highest leaf area index and stem girth. However there was no significant

Characteristics	partially treated Sewage water	Stream water
pH	7.40	7.10
Salinity, %	0.70 (7.0 ppt)	0.20(2.0 ppt)
Electrical conductivity, µmho	1.96×10^{-4}	0.085×10^{-4}
Total dissolved solids, mg/L	192.0	109.4
Dissolved cations, mg/L		
Calcium	1.24	0.92
Magnesium	0.17	0.23
Sodium	0.84	.32
Potassium	13.0	2.0
Soluble anions, mg/l		
Nitrate	32	13.
Phosphate	29	5
Sulphate	11.8	0.29
Carbonate	0.61	0.21
Bicarbonate	1.35	0.55
Chloride	2.82	0.22
Trace Elements, mg/l		
Boron	0.49	0.16
Zinc	0.24	0.16
Iron	2.5	0.52
Copper	2.5	0.10
Mangnesse	1.5	0.33
BOD mg/L	3.80	0.21
Total Coliform Count/100L	2.9×10^{5}	N.D*

*N.D-Not Detected
Note: Salinity % =salt mass / Total mass x 100
% salinity x10 = (ppt) parts per thousand

Table 1: The initial physico-chemical and biological properties of partially treated sewage water and stream water.

Characteristics	Value
pH	6.8
Electrical Conductivity, ds/m	6.5×10^{-3}
Organic matter, %	3.6
Total N, %	0.12
Total P, %	0.18
Cation exchange capacity, cmol/kg	18.3
Exchangeable k, %	0.12
Clay, %	30.6
Silt, %	13.3
Sand, %	56.1
Water holding capacity, mm/m	90

Table 2: Characteristics of the soil at the experimented site before the experiment.

Treatments	Growth parameters			
Stream:pts effluent	Plant height, cm	Leaf area index	Stem girth, cm	Number of leaves per plant
0:100	4.33_d	0.19	2.2_b	4
25:75	5.69_c	0.29	2.6_b	5
50:50	5.98_c	0.34	3.3_a	5
72:25	6.30_b	0.35	3.5_a	5
100:0	6.40_a	0.35	3.5_a	5

$^{a, b, c, d}$ - *Values followed by dissimilar letter are significantly different at 0.05 using Duncan multiple-range test*

Table 3a: Effect of sewage on crop growth parameters at four (4) weeks after planting.

difference ($P<0.05$) among the treatments in number of leaves per crop and plant height (Table 3a and Table 3b). However the 25% partially treated sewage effluent gave the highest number of fruits per crop ($P<0.05$) and there was a decrease in number of fruits per crop with increasing percentage of sewage effluent. The synthesis of food through the process of photosynthesis and its subsequent partitioning of the biomass into leaves, stem and fruits depends on nutrients [12, 13] and water availability. Thus the crop must have been able to absorb more nutrients in the treatments with higher sewage content.

Effect of sewage treatments on yields

The 25:75 percent stream water: partially treated sewage treatment had the highest fruit yield of 10.5t/ha (Table 4). There was a significant difference ($P<0.05$) among the treatments in fruit yields. All the treatments with partially treated sewage effluent had higher yields reflected in the number of fruits produced per crop, than the control except the treatment with 100% partially treated sewage effluent. Fasciolo et al. [7] obtained similar higher yield of onion and garlic with sewage effluent.

The results of the dry matter follows the same trend as the leaf area index with the 100% partially treated sewage effluent having the highest dry matter yield of 9.8t/ha and the control the lowest yield. This is consistent with the finding of Hanway and Weber [14] that vegetative tissue serves as a reservoir of minerals and minerals are translocated out of the vegetative tissue to seeds during pod filling.

Effect of sewage treatments on nutrient composition of plant and soil

Sewage significantly increased the electrical conductivity and organic matter of the soil. There was no significant difference ($P<0.05$) among the treatments in the pH and cation exchange capacity of the soil (Table 5). Similar increase in organic carbon with sewage irrigation was obtained by Fine et al. [15] and Yadav et al. [6]. Sewage also significantly increased ($P<0.05$) the phosphorus, nitrogen, copper and manganese content of the soil. The potassium content increased slightly but the increase is not significant ($P<0.05$). There was no significant difference among the treatments in level of iron and zinc. Yadav et al. [6] obtained similar increase in macro nutrients of the soil after irrigating with sewage effluent. Though the levels of these elements are still within acceptable limits for the soil, the continuous use of sewage may result in copper toxicity especially when the sewage is used raw.

The level of nutrient uptake by the crop is shown in (Table 6). The use of sewage effluent significantly ($P<0.05$) increased the macro nutrient content of the crop. There was no significant difference in the level of the micro nutrient (Cu, Zn, Mn, and Fe) content of the crop. The level of coliforms counts were within the permissible limit in partially treated sewage water. This may be because the sewage was treated (biologically in an oxidation pond) before use and the furrow system which further exposed the irrigated water to further sunlight.

Fasciolo et al. [7] found onion and garlic grown under furrow system with treated sewage effluent to reach sanitary acceptability some days after harvest, while Jordan et al. [8] observed foliar damage of ornamental trees sprinkler-irrigated with wastewater. The levels of

Treatments	Growth parameters			
Stream:pts effluent	**Plant height, cm**	**Leaf area index**	**Stem girth, cm**	**Number of leaves per plant**
0:100	19.0_{a}	0.75_{d}	4.1_{b}	7
25:75	19.5_{a}	1.34_{c}	4.3_{b}	7
50:50	20.0_{a}	1.40_{c}	5.3_{b}	8
72:25	21.3_{a}	1.80_{b}	5.8_{a}	8
100:0	20.7_{a}	2.20_{a}	6.2_{a}	8

a, b, c, d - *Values followed by dissimilar letter are significantly different at 0.05 using Duncan multiple-range test*
pts-partially treated sewage

Table 3b: Effect of partially treated sewage on crop growth parameters at six (6) weeks after planting.

Treatment	**Growth parameters**			
Fresh water: sewage effluent	**Number of fruit per plant**	**Fruit yield t/ha**	**Dry matter t/ha**	**Fruit moisture content %**
0:100	11_{c}	7.2_{d}	5.1_{c}	45.2_{b}
25:75	15_{a}	10.5_{a}	6.7_{b}	50.6_{a}
50:50	14_{b}	9.2_{b}	7.2_{b}	50.7_{a}
72:25	14_{b}	8.6_{c}	9.4_{a}	42.4_{b}
100:0	12_{c}	8.4_{c}	9.8_{a}	42.6_{b}

a, b, c, d - *Values followed by dissimilar letter are significantly different at 0.05 using Duncan multiple-range test*

Table 4: Effects of partially treated sewage treatments on number of fruits per plant, fruit yield, dry matter and fruit moisture content.

Properties	**Treatment** **Stream water:** partially treated **sewage effluent**				
	0:100	**25:75**	**50:50**	**75:25**	**100:0**
pH	$6.85_{(\pm 0.31)}$	$6.82_{(\pm 0.25)}$	$6.76_{(\pm 0.35)}$	$6.63_{(\pm 0.29)}$	$6.61_{(\pm 0.38)}$
Electrical conductivity, um	$0.13_{(\pm 0.15)}$	$0.15_{(\pm 0.12)}$	$0.15_{(\pm 0.10)}$	$0.18_{(\pm 0.14)}$	$0.35_{(\pm 0.30)}$
Organic matter %	$3.84_{(\pm 0.21)}$	$3.84_{(\pm 0.23)}$	$3.71_{(\pm 0.20)}$	$3.65_{(\pm 0.21)}$	$3.63_{(\pm 0.19)}$
Cation exchange capacity, cmol/kg	$19.50_{(\pm 2.16)}$	$21.75_{(\pm 2.24)}$	$22.50_{(\pm 2.30)}$	$24.25_{(\pm 2.21)}$	$24.75_{(\pm 2.31)}$
Total P, %	$0.30_{(\pm 0.06)}$	$1.01_{(\pm 1.00)}$	$1.74_{(\pm 1.61)}$	$2.00_{(\pm 1.96)}$	$2.89_{(\pm 2.56)}$
Total N, %	$0.92_{(\pm 0.56)}$	$2.09_{(\pm 2.01)}$	$2.35_{(\pm 2.21)}$	$2.44_{(\pm 2.38)}$	$2.53_{(\pm 2.43)}$
Exchangeable K, %	$0.92_{(\pm 0.58)}$	$0.10_{(\pm 0.09)}$	$1.05_{(\pm 0.98)}$	$0.13_{(\pm 0.82)}$	$1.33_{(\pm 1.28)}$
Zn, mg/kg	$0.00_{(\pm 0.00)}$	$0.18_{(\pm 0.14)}$	$0.21_{(\pm 0.99)}$	$0.26_{(\pm 0.21)}$	$0.32_{(\pm 0.29)}$
Mn, mg/kg	$1.56_{(\pm 1.36)}$	$1.79_{(\pm 1.68)}$	$1.90_{(\pm 1.63)}$	$2.04_{(\pm 1.96)}$	$2.18_{(\pm 2.08)}$
Fe, mg/kg	$1.32_{(\pm 0.28)}$	$2.12_{(\pm 0.06)}$	$3.80_{(\pm 0.58)}$	$4.08_{(\pm 0.38)}$	$4.26_{(\pm 0.35)}$
Cu, mg/kg	$0.55_{(\pm 0.39)}$	$0.62_{(\pm 0.42)}$	$0.95_{(\pm 0.31)}$	$1.42_{(\pm 0.23)}$	$1.65_{(\pm 0.34)}$
% Sand	$56.6_{(\pm 3.23)}$	$56.7_{(\pm 3.13)}$	$56.8_{(\pm 2.86)}$	$57.2_{(\pm 2.68)}$	$57.7_{(\pm 2.73)}$
% Silt	$13.3_{(\pm 1.34)}$	$13.5_{(\pm 1.34)}$	$14.2_{(\pm 1.42)}$	$14.2_{(\pm 1.40)}$	$14.1_{(\pm 1.41)}$
% Clay	$30.6_{(\pm 2.32)}$	$30.5_{(\pm 2.32)}$	$30.0_{(\pm 2.23)}$	$30.2_{(\pm 2.24)}$	$30.4_{(\pm 2.32)}$

Table 5: Some physico-chemical properties of the soil after the experiment.

Properties	**Treatment Stream water: partially treated sewage effluent**				
	0:100	25:75	50:50	75:25	100:0
Nitrogen	3.8 (±0.32)	4.9 (±0.34)	6.9 (±0.28)	7.1 (±1.23)	7.8 (±0.86)
Phosphorus	1.7 (±0.62)	3.9 (±0.82)	4.1 (±0.72)	4.2 (±0.56)	4.7 (±0.58)
Potassium	5.1 (±0.62)	5.8 (±0.70)	6.0 (±0.53)	6.3 (±0.38)	7.6 (±0.72)
Zinc	0.16 (±0.12)	0.19 (±0.12)	0.22 (±0.14)	0.29 (±0.18)	0.37 (±0.25)
Manganese	0.12 (±0.13)	0.21 (±0.18)	0.22 (±0.16)	0.33 (±0.28)	0.40 (±0.32)
Iron	0.12 (±0.14)	0.25 (±0.18)	0.35 (±0.25)	0.46 (±0.23)	0.47 (±0.32)
Copper	0.12 (±0.15)	0.16 (±0.08)	0.21 (±0.18)	0.27 (±0.16)	0.38 (±0.21)

Table 6: Macro and micro nutrients (mg/g) uptake of the crop after the experiment.

Element	**Levels (mg/g)**			
	Milk	Egg	Potato	Cabbage
Calcium	220.0	52.0	8.0	57.0
Sodium	50.0	137.0	7.0	-
Iron	0.1	2.0	0.5	0.5
Magnesium	12.0	25.0	24.0	17.0
Potassium	140.0	136.0	56.8	-
Phosphorus	95.0	220.0	40.0	54.0

Source: MAFF (1981)

Table 7: Levels of major elements in some common foods.

Trace/heavy elements	Maximum permissible levels
Chromium	0.10
Lead	0.10
Mercury	0.005
Zinc	15.00
Copper	1.50
Manganese	0.50

Source: WHO (1989) and Holfkes *(1988)*

Table 8: Maximum permissible levels of trace elements (heavy metals in drinking water (g/l).

the nutrients in the crop are below the level in some common crops and permissible level in drinking water (Table 7 and Table 8) [17-18].

Conclusion

Growth and yield of Okra furrow-irrigated with different mix-proportion of partially treated sewage effluent and stream were evaluated on the field.

Results showed that partially treated sewage irrigation gave higher fruit yield of 10.5, 9.2, and 8.6 t/ha in the stream water to partially treated sewage effluent ratios of 25:75; 50:50; and 75:25, respectively. Dry matter increased in the order of 6.7, 7.2, 9.4 and 9.8 t/ha for the same ratios respectively. The 25% partially treated sewage effluent gave the highest fruit yield while 100% sewage gave the highest dry matter yield. Although the sewage resulted in higher macro and micro nutrients in the soil and plant, the levels are within acceptable limits and the crop was found safe for consumption. The study showed that okra can safely be grown with partially treated sewage effluent using furrow system but it would be best when mixed with 50-75% of good quality stream water.

Acknowledgements

This research was funded by a grant from the International Foundation of Science, Stockholm Sweden. The authors would also like to thank Josiane Lindberg and Michael Ståhl for the support provided.

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