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Effects of grey water irrigation on the cultivation of African spinach (*Amaranthus hybridus*)

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ABSTRACT

Water is a limited resource, hence there is a need for its judicious use. This study was designed to investigate the utilization and the effects of grey water irrigation on the growth parameters of African spinach (*Amaranthus hybridus*) and its soil properties when planted in a green house. The irrigation treatment consisted of Tap water (TW) and grey water (GW) collected from Akindeko Hostel in Federal University of Technology, Akure. The vegetables were planted in five bucket samples for each irrigation treatment. The water samples were assessed to determine chemical properties, while soil samples were collected and analysed before irrigation application and after harvest. Crop morphology that includes the plant height, number of leaves and stem girth parameters were recorded weekly after emergence. Our results indicate that the grey water type has the highest chemical parameters. These included TSS, SAR, pH, HCO_3^-, Ca^{2+}, Mg^{2+}, and Na^+. What is more, soil pH decreased in all the soil samples after the different water applications, the lowest pH being from grey water. The sodium adsorption ratio (SAR) also decreased in all the irrigation treatments. In addition, the plant height, number of leaves and stem girth of the crop were affected by the water type used. Herein, the crop irrigated with grey water had the highest morphology parameters. Furthermore, soil chemical properties were significantly affected by the use of grey water, hence, appropriate wastewater treatment and water management practices have to be followed to remove the toxic elements that could be hazardous to human health when crops produced on them are consumed.

***Keyword*:** Irrigation, Grey water, African spinach, Agronomic and Growth parameters, *Amaranthus hybridus*

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1. INTRODUCTION

In arid and semi-arid regions, there's increase in the demand for making use of wastewater for agriculture because of the shortage of fresh water (El Youssfi et al., 2012). This is because there is a serious struggle to balance water use among domestic, industrial and agricultural users (Darvishi et al., 2010). Rapid increase in population has not only caused an increase in the demand for the limited available freshwater but has also caused an increase in the volume of wastewater generated yearly (Thapliyal et al., 2011). The untreated water generated can find its way into water systems such as rivers, lakes, groundwater and coastal waters with the potential to cause serious pollution. Wastewater may contain undesirable chemical constituents and pathogens that pose negative environmental and health impacts (Rana et al, 2010). Likewise, Wastewater has a potential to supply carbon nutrients (NPK) and micro nutrients to support crop/plant growth (Singh et al., 2011). It serves as a valuable source of plant nutrients and organic matter needed for maintaining fertility and productivity levels of the soil (Rusan et al., 2007). Wastewater can have a positive effect on soil and eventually plant growth, due to its being rich in organic matter and nutrients (Mohammad and Ayadi, 2004; Ghanbari et al., 2007). If the wastewater can be used as an alternative water source for irrigation, the dual problems of negative environmental effects and huge water demand for agricultural irrigation would be solved (Darvishi et al., 2010). The usage of treated wastewater in agriculture is seriously enhancing because of the wide range of its benefits. (Heidarpour et al., 2007). These benefits are conservation of fresh water, high level of organic matter and recycling of nutrients, thereby minimizing the need to invest on chemical fertilizers (Mojiri et al, 2013). An economical study of the reuse of sewage water in irrigation, Al-Abdulqader and Al-Jaloud (2003) stated that it saved up to 45% in fertilizers cost for wheat crop and 94% for alfalfa crop compared to irrigation with well water due to the fact that sewage water contains the essential elements needed by such crops. They also indicated that the usage of treated sewage water in irrigating of wheat and alfalfa crops increased their yield by 11 and 23%, respectively, and consequently increasing the profit by 14 and 28%, respectively as compared to irrigation with well water.

Using wastewater in crop production sometimes decrease the quantity and quality of the yield however, it is possible to achieve high yields of crops without deterioration of their quality by using treated wastewater for the irrigation of crops under controlled conditions. This is evident was from large number of the previous researches as in (Najafi et al., 2003, Jimenez, 2005, Munir and Ayadi 2005, Esmailiyan et al., 2008 and Zavadil, 2009).

In agricultural practices, irrigation water quality is believed to affect the soil characteristics, crops production and management of water (Mojiri, 2011). For instance, the application of saline/sodic water results in the reduction of crop yield and deterioration of the physical/chemical properties of soil (Singh et al, 2011). In this context, many studies have been conducted to evaluate the effects of treated and untreated wastewater irrigation on soil physical and chemical properties and crop performance and nutrient status across climates, soils and diverse crops, however results vary between different settings. Tabari et al. (2008) reported that wastewater irrigation could enrich soils with heavy metals to levels that may pose potential risk to the environment and human health while Tabatabaei (2007) observed that continuous wastewater application to the soil could alter soil infiltration characteristics. Mojiri et al. (2013) working on the impact of urban wastewater on soil properties and *Lepidium sativum* in an arid region found increased electrical conductivity (EC), organic matter (OM), total N, Na and heavy metals due to wastewater irrigation. However, they reported an increase in root and shoot length. In contrast, Singh et al. (2012) found that domestic wastewater irrigation had no significant effects on properties of a clay soil apart from slight changes in salt solubility and alkalinity. Therefore, the objective of this study was to investigate the effects of wastewater irrigation on soil properties and growth parameters of African spinach (*Amaranthus hybridus*). Despite this volume of studies, there is a dearth of information on the impact of household wastewater irrigation on soil properties and quality of irrigated vegetables applicable where there is an increased popularity in the application of domestic wastewater for irrigation. Thus, hypothesis was formulated that irrigation using kitchen wastewater will reduce soil quality and negatively impact African spinach growth and yield. The specific objectives this work is to determine the physio-chemical properties of the soil irrigated with grey water and the tap water and to determine the effect of grey water on the yield and growth of African spinach (Tiwari, 1998)

Efo tete as called in Yoruba language is a widely-grown vegetable which is consumed by a higher population in Nigeria. Though grown locally on a small scale basis by peasant farmers, it is also grown on a large scale for commercial agriculture. It can been grown on the soil and been maintained by irrigating with treated wastewater. Keeping in view the above facts, this study was carried out to analyse the comparison between irrigating with treated and untreated wastewater on vegetable, using African spinach (*Amaranthus hybridus*) as a case study.

2. MATERIALS AND METHODS

This explains the materials and methods used to determine the effects of wastewater irrigation on the growth of African spinach (Sengkhamparn, 2010; Siemonsma, 1982).

Study Area

Fig. 1. A fully constructed greenhouse

The studies reported here were undertaken in the greenhouse facility at Agricultural and Environmental Engineering, Federal Polytechnic, Auchi Edo State, Nigeria during the month of March to April, 2014.

Soil Sampling and Analyses

Deformed soil samples of the soil to be used were taken. Sampling and analysis are carried out before planting and after harvesting for each of the different water types used for irrigating the crops during the course of the experiment. The samples were analysed using standard procedure which are soil pH, Particle-size distribution, K^+, Na^+, Ca^{2+}, Mg^{2+}, Sodium adsorption ratio-SAR, soil moisture content.

Water Sampling and Analysis

The study was conducted with grey water released from Regal Rise Hostel kitchen at Federal Polytechnic. The treated water and the grey water were taken to the Chemical department laboratory of The Federal Polytechnic Auchi for water analysis. The following constituents were analysed in the Laboratory: TSS, Total suspended solids; SAR, Sodium adsorption ratio; HCO_3^-, hydrogen carbonate; Ca^{2+}, Calcium; Mg^{2+}, magnesium; Na^+, sodium concentration; and pH; of the two samples.

Experimental set up and raising of plants

Ten buckets were prepared and genetically uniform seeds of spinach were sown in each bucket. Uniform irrigation schedule was followed to maintain similar moisture condition throughout the growth of plants. Names of the two buckets were given as, TW A, B, C, D, E, (for tap water), and GW A, B, C, D, E (for grey water) bucket. When the plants were growing morphological characteristics (vegetative growth) like stem girth, plant height and number of leaves were recorded.

Crop plantation

Fig. 2. Crop plantation inside a bucket

Vegetable seeds were obtained from Vegetable market in Benin city, Edo state. The seedlings were mixed with the soil inside the bucket and watered manually.

Agronomic practices

Manual thinning that is, removal of excess vegetables were carried when the shoot starts coming out to avoid over crowding and competition for photosynthesis, water and nutrients. This helped the more viable plants to germinate perfectly.

BW A-E GW A-E

Fig. 3. Leaf Spinach after 2weeks in the buckets

Irrigation Method

Fig. 4. Grey water ready for irrigation use

Equal volume of water was applied manually to maintain the moisture needed for the plant. The grey water was ensured that it doesn't touch the root of the leaf while irrigating so that the plant won't take in harmful elements which may be harmful to human's health when consume.

Agronomic Parameters

The crop was monitored and the growth parameters (Plant height, stem girth and number of leaves) were measured and recorded under the different irrigation water type. Growth parameters were measured every week after planting. Plant length was determined by measuring the length of the plant from the ground level to the tip of top-most leaf using a flexible tape. The number of leaves per plant was made by a visual count of the green leaves while the stem girth was measured with the aid of a vernier caliper.

Data Analysis

Data was subjected to analysis using Excel to plot the graph of the number of leaves against week for each water irrigation type. Also, the height of the plant was plot against week for each water irrigation type. And comparison was done.

3. RESULTS AND DISCUSSION

Water quality

The results of the water (Tap water and grey water) analyses are shown in Table 1. Of the two water samples, tap water had the lowest values for all the parameters. Generally, the pH values of the two waters fall within the acidic range. The wastewater had the highest values of Na^+, Ca^{2+} and Mg^{2+}, TSS and SAR. It also had the highest HCO_3^- concentration. The soap chemicals used and suspended particles of food remnants from kitchen waste may have contributed to the highest values of TSS, SAR and HCO_3^-.

Table 1. Properties of the different water types before planting.

Parameter	Tap water	Grey water
HCO_3^- (mg/L)	30	70
Na^+ (mg/L)		
Ca^{2+} (mg/L)	1.44	27.36
Mg^{2+} (mg/L)	92.56	352.64
TSS (mg/L)	0	1960
SAR	-	-
pH	6.27	5.73

TSS, Total suspended solids; SAR, Sodium adsorption ratio; HCO_3^-, hydrogen carbonate, Ca^{2+}, Calcium, Mg^{2+}, magnesium and Na^+, sodium concentration;

Soil Properties

The physiochemical properties analysed from the soil before planting are stated in Table 2

Table 2. Soil physical and chemical properties before planting.

Soil properties	pH	Na^+ g/ml	Ca^{2+} g/ml	Mg^{2+} g/ml	K^+ g/ml	SAR	EC dS/cm	Sand	Silt %	Clay	Soil type
	5.65	6.34	10.02	0.87	4.48		0	52.80	19.28	27.92	L

SAR, Sodium adsorption ratio; HCO_3^-, hydrogen carbonate; Ca^{2+}, Calcium; Mg^{2+}, magnesium; Na^+, sodium concentration; EC, electrical conductivity; SL, sandy loam.

Agronomic Results

Plant height

The different height of the plants from the soil surface to the apex of the leaf is shown in Table 3 and Table 4.

Table 3. Plant height in cm per week when irrigated with tap water

Samples	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
A	1.68	3.22	6.97	7.89	8.52	8.66
B	1.01	2.14	4.12	4.92	7.89	8.52
C	1.51	3.01	6.77	7.91	8.51	8.66
D	1.42	3.01	6.77	7.65	8.60	8.66
E	1.21	2.76	5.32	7.21	7.98	8.52
Avg	1.37	2.83	5.99	7.12	8.30	8.60
SDT	0.26	0.42	1.24	1.26	0.34	0.08

Table 4. Plant height in cm per week when irrigated with grey water

Samples	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
A	1.98	6.11	10.01	12.72	14.88	16.02
B	1.51	5.32	9.52	11.74	13.38	15.01
C	1.61	5.41	9.76	12.99	15.35	16.50
D	1.53	5.38	9.61	12.52	15.11	15.71
E	1.58	5.40	9.60	12.41	14.11	15.65
Avg	1.64	5.52	9.70	12.48	14.57	15.78
SDT	0.19	0.33	0.19	0.47	0.81	0.55

Number of Leaves

Table 5. Number of leaves per week when irrigated with Treated water

Samples	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
A	2	3	5	5	7	9
B	2	3	3	4	5	7
C	2	4	5	7	9	9
D	2	4	5	5	7	9
E	2	3	4	5	7	7
Avg	2	3	4	5	7	8
STD	0.0	0.5	0.8	1.0	1.3	1.0

AVG, Average; STD, Standard deviation

Table 6. Number of leaves per week when irrigating with untreated grey water

Samples	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
A	2	3	5	7	9	12
B	2	3	5	7	9	10
C	2	2	4	5	7	9
D	2	2	4	5	5	8

E	2	3	5	7	9	10
Avg STD	2 0.0	3 0.5	5 0.5	6 1.0	8 1.6	10 1.3

The number of leaves on the plant are shown in Table 5 and Table 6 for each plants irrigated with different water type.

Plant stem girth

The plant stem girth of each plants are shown in Table 7 and Table 8

Table 7. Plant stem girth in cm per week when irrigated with Tap water

Samples	Week1	Week 2	Week 3	Week 4	Week 5	Week 6
A	0.16	0.24	0.30	0.33	0.37	0.40
B	0.13	0.23	0.28	0.31	0.35	0.38
C	0.17	0.25	0.30	0.34	0.40	0.40
D	0.17	0.25	0.30	0.34	0.37	0.40
E	0.17	0.25	0.28	0.32	0.37	0.40
Avg SDT	0.16 0.02	0.24 0.01	0.29 0.01	0.33 0.01	0.37 0.02	0.39 0.01

Table 8. Plant stem girth per week when irrigated with grey water

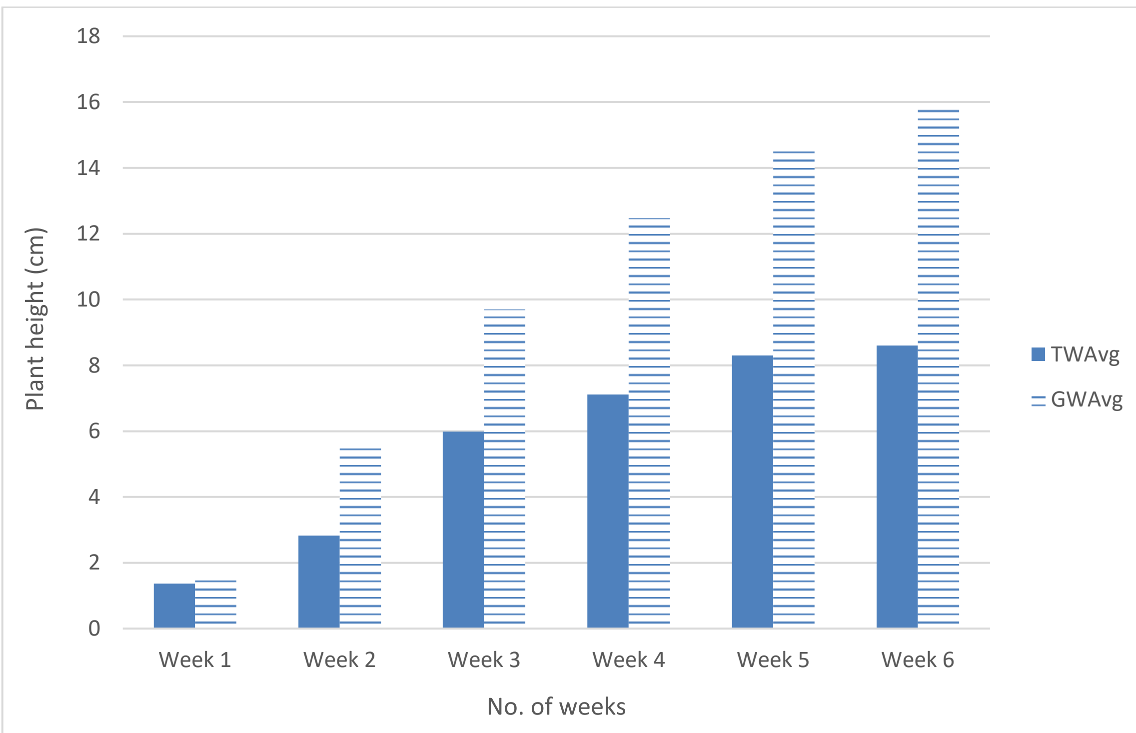
Samples	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
A	0.16	0.20	0.30	0.38	0.40	0.44
B	0.14	0.19	0.25	0.34	0.38	0.38
C	0.13	0.18	0.21	0.30	0.34	0.37
D	0.14	0.19	0.26	0.34	0.38	0.38
E	0.15	0.20	0.26	0.34	0.38	0.38
Avg SDT	0.14 0.01	0.19 0.01	0.26 0.03	0.34 0.03	0.37 0.02	0.39 0.03

Comparison of Result

The results discussed in Table 1 to Table 8 is analysed here using a bar chart. Each chart shows the comparison and difference in the plant height and number of leaves for both different water type irrigation.

Plant height

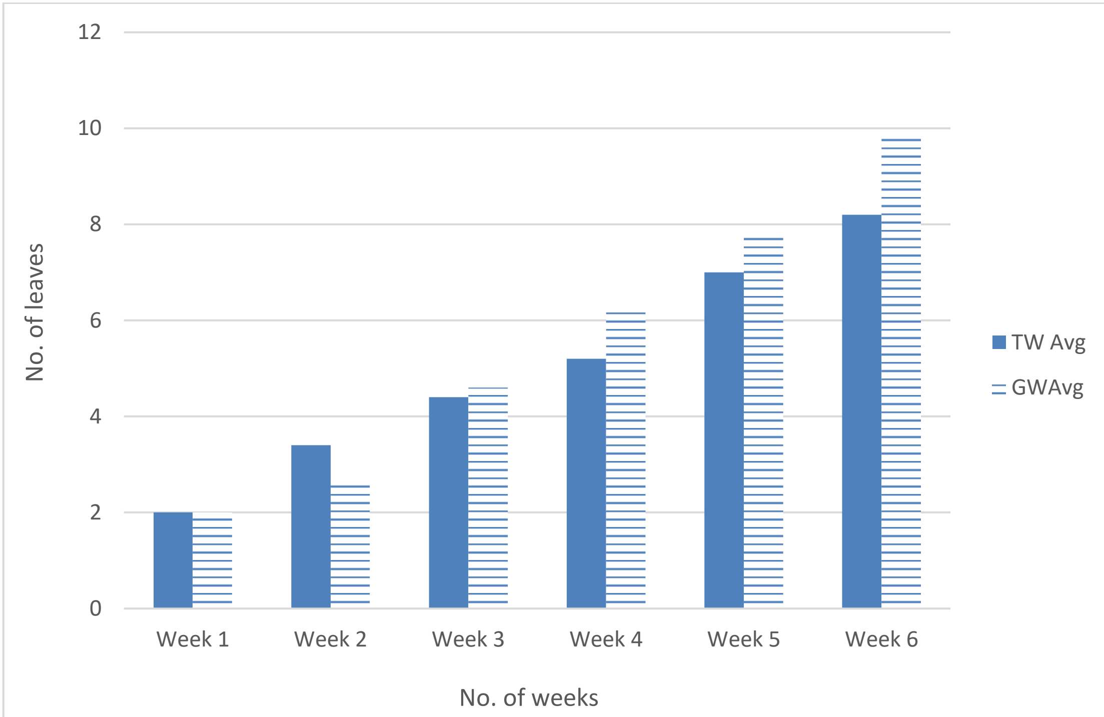
The response of the plant height to the irrigation of the water types can be seen in Graph 1 below. The height of the plant irrigated with Grey water (GWAvg) is more than that of the tap water (TWAvg).



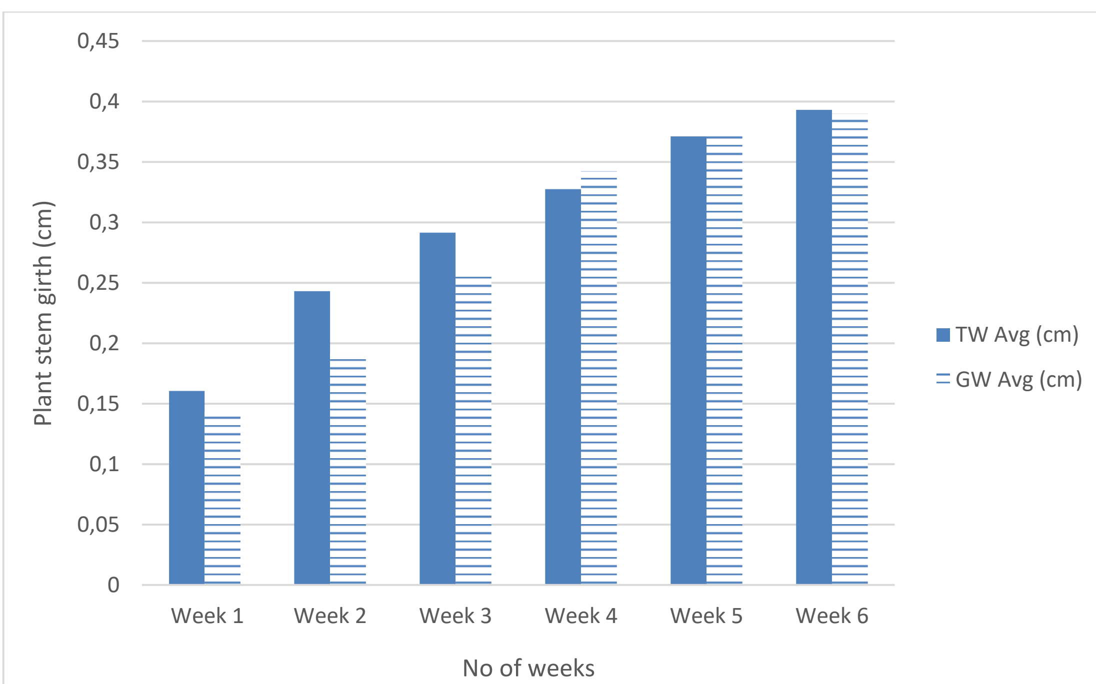
Graph 1. Variation in plant height per week

Number of leaves

Graph 2 below shows the comparison between the numbers of leaves of each plant irrigated with Tap water (TWAvg) and Grey water (GWAvg).



Graph 2. Variation in numbers of leaves per week



Graph 3. Plant stem girth

4. CONCLUSION AND RECOMMENDATION

Conclusion

From the experiment, it can be concluded that irrigating African spinach vegetable with grey water is economical and it's yielding well than irrigating with that of tap water. This was deduced as the number of leaves, plant height and the stem girth of the vegetable irrigated with grey water supersede that of the one irrigated by tap water. The quality of the Leaf spinach vegetable irrigated with grey water is higher than that irrigated with tap water due to high biomass the leaf has when irrigated with grey water compare to irrigation with tap water. It was also observed that the vegetable species ***Amaranthus hybridus***, which is also known as **African spinach** does not grow rapidly.

Recommendation

It is strongly recommended that grey water can be reused for irrigation for places like the arid or semi-arid-region that suffers for sufficient water to irrigate their plants and also during dry season when there is little or low rainfall. More so, due to the pose of risk on human health from crops irrigated with wastewater, it is recommended that grey water is treated to reduce heavy metals and toxic substances in the water.

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