Adamawa State University Journal of Scientific Research
ISSN: 2251-0702 (Paper)
Volume 5 Number 1, April, 2017
http//www.adsujsr.com

Irrigation Effect of Wastewater and *Moringa oleifera* Leaf Extract on Mineral Composition of Sorghum (*Sorghum bicolor* L. Moench) Plant.

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Abstract
A pot experiment was conducted in the screen house at the FAO/TCP Teaching and Research Farm of Adamawa State University, Mubi in 2014 to assess the effect of wastewater from fish pond and *Moringa oleifera* leaf extract on the mineral composition of sorghum plant. The treatments were wastewater, *Moringa* leaf extract and wastewater plus *Moringa* leaf extract laid out in complete randomized design replicated three times. Results showed that in all the treatments, the concentration of P (0.11-0.12%) was in deficient range. Potassium (2.43 – 2.55%), Ca (0.58 – 0.78%), Mg (0.16 - 0.0.25%), Fe (35 – 40 mg/kg), Cu (2.13 – 2.28 mg/kg), and Mn (16.5 – 19.5 mg/kg) were low while Zn (34.93 – 40.50 mg/kg) was normal. Combined wastewater and *Moringa* leaf extract irrigation improved P, Ca and Mg composition in sorghum plant by 9.1, 14.7 and 56.3%, respectively. Therefore, wastewater from fish pond and *Moringa oleifera* leaf extract irrigation either in combination or separately did not increase the nutrient elements and heavy metals concentration in both plant and soil beyond globally acceptable limits and therefore safe to be used for irrigation purposes especially sorghum crop.

Key words: Wastewater, *Moringa* leaf extract, mineral composition, sorghum, irrigation

Introduction

Water resources are constantly decreasing in both arid and semi-arid regions of the world. It has become a global challenge that in countries like Nigeria, interest and practices of reclamation and use of waste water which might be used economically and effectively in developing agricultural programs are promoted. Use of treated municipal wastewater in countries poor in water resources is less expensive and considered an alternative source of irrigation water and the interest in reusing wastewater for irrigation purposes in these countries is rapidly increasing (Arar, 1994). Yaryan (2000) studied the effects of irrigation with treated wastewater, well water and irrigation systems on the yield of sugarbeat, corn and sunflower and properties of soil. It was reported that the yield of sunflower and corn were higher under wastewater treatment. However the differences were not statistically significant. Wastewater treatment increased pH, available N, P, K, Mn, Pb, Ni and Co but EC decreased significantly. Kiziloglu *et al.* (2008) showed that wastewater irrigation affected significantly soil chemical characteristics and nutrient content of cauliflower and red cabbage.

Moringa oleifera is a multipurpose tree with fast growing perennial habit, has high biomass production and its leaf extracts are used as plant growth stimulant to improve crop productivity. *Moringa* leaf extract when obtained from fresh leaves are rich in antioxidants, some plant secondary metabolites and osmoprotectants making it natural stimulant for growth. The leaf extracts are also source of many plant growth regulators including zeatin, cytokinin, vitamins and several mineral elements

(Yasmeen *et al.,* 2014: Rady and Mohamed, 2015). Several studies has shown *Moringa* leaf extract to have the potential of improving crop resistance to drought (Yasmeen *et al.*, 2013a), salinity (Yasmeen *et al*., 2013b; Rady *et al.*, 2015) heavy metal stress, metal and/or salinity tolerance (Howladar, 2014) including crop productivity (Rehman *et al.,* 2014).

The importance of wastewater from fish pond and *Moringa oleifera* leaf extract irrigation on the mineral composition of sorghum plant needs to be assessed to give more understanding of the dynamics of nutrients in plant and soil. Therefore, this work was conducted to assess the effect of wastewater from fish pond and *Moringa* leaf extract on mineral composition of sorghum plant.

Materials and Methods

The experiment was conducted in the screen house at the Food Agricultural Organisation/Tree Crop Program (FAO/TCP) Teaching and Research Farm of Adamawa State University, Mubi, Nigeria in 2014.

The experiment was laid out in a complete randomized design comprising of three (3) treatments; wastewater from fish pond (WW), *Moringa* leaf extract (MLE) and wastewater + *Moringa* leaf extract (WW+MLE). This was replicated three times. The experiment was done in plastic pots measuring 25 cm diameter and 22 cm height. Top soil at 0-15 cm depth was collected at Shuware along river Yadzaram. It was air dried and sieved through 2 mm screen. The texture of the soil was sandy loam (54% sand, 28% silt and 18% clay), with pH of 7.3, electrical conductivity of 799 µS/cm while the water holding capacity was 28.8%, organic matter and organic carbon were 4.01% and 2.33%, respectively, while available phosphorus was 13.4 mg/kg. The amounts of exchangeable cations were 0.06, 1.0, 0.04 and 0.08 cmol/kg for K, Na, Mg and Ca, respectively (Table 1). The concentration of elements in wastewater and fresh leaves of *Moringa oleifera* are presented in Table 2.

Table 1: Some Chemical Properties of the Experimental Soil

Element	**Value**
P (mg/kg)	13.44
K (cmol/kg)	0.06
Ca (cmol/kg)	0.084
Mg (cmol/kg)	0.042
Na (cmol/kg)	1.00
Fe (mg/kg)	1.35
Cu (mg/kg)	0.46
Zn (mg/kg)	3.064
Mn (mg/kg)	13.55
Ni (mg/kg)	0.03
Pb (mg/kg)	0.29
OC (%)	2.33
OM (%)	4.01
EC (µS/cm)	799
pH	7.25
WHC (%)	28.8

Table 2: Chemical Composition of Irrigation Water and *Moringa oleifera* Leaf Extract

Element	Wastewater from fish pond	*Moringa oleifera* leaf extract
P (mg/l)	8.0	8.10
K (mg/l)	54	52
Ca (mg/l)	46.1	34.7
Mg (mg/l)	38.0	35.0
Na (mg/l)	192	223
Fe (mg/l)	Nd	0.75
Cu (mg/l)	Nd	0.25
Zn (mg/l)	0.04	0.05
Ni (mg/l)	Nd	0.03
Pb (mg/l)	Nd	0.42
EC (µS/cm)	81.3	37.5
pH	7.8	7.0

Heavy metals like Fe, Cu, M n, Ni, and Pb were beyond limit of detection

Eight kilogram (kg) of the soil was placed in the plastic pots. The pots were irrigated to field capacity and left over for three days to attain equilibrium. The experimental pots were kept in the screen house. Eight seeds of sorghum were planted in each pot on 3rd of March 2014. The crop was irrigated 3 times a week. Sorgum seedlings were thinned to four plants per pot two weeks after crop germination and were harvested after 52 days of planting.

The single acid digestion method for the analysis of plant tissues for P, K, Ca, Mg, Na, Fe, Cu, Mn and Zn as described by Marr and Cresser (1983) was followed. Soil organic carbon was determined by wet oxidation method as described by Walkley and Black (1934). The Titrimetric method for the determination of Calcium and Magnesium in the soil as described by Black, (1965) was followed. Soil pH was determined as described by Bates (1954). Hydrometer method for Soil Mechanical Analysis was followed as described by Bouyoucos (1951). Available phosphorus (P) in soil was determined as described by Bray and Kurtz(1945) at the wavelength of 660 nm. Potassium (K) and sodium (Na) was determined in 1M neutral NH_4Ac soil extract using flame photometry and exchangeable acidity as described by Mclean, (1965. The Di-ethylene triaminepenta acetic acid (0.005M DTPA) (Lindsay and Norvell, 1978) and 0.1N HCl (Nelson *et al.*, 1959) method of extracting available zinc (Zn) and manganese (Mn) in the soil was adopted. The determination of total iron in soil by atomic absorption spectrophotometry, after digestion with strong oxidizing acids and treated with hydrofluoric acid to eliminate silica as described by Jackson (1958) was used.

Wastewater used for irrigation was analyzed as described in the Standard Methods for the Examination of Water and Wastewater (APHA, 2012). Fresh leaves of *Moringa oleifera* were prepared at the ratio of 1:36 v/v as described by Mathur, (2006).The results of the concentration of different minerals in sorghum plant were compared with the data reported by Lockman (1972) on sorghum.

The data was subjected to analysis of variance using SAS (2010). The significant difference among the mean was compared using Duncan Multiple Range Test.

Results and Discussion

Response of growth characters of Sorghum plant

The effect of wastewater and *Moringa* leaf extract on the growth of sorghum is presented in Table 3. Plant height (60.63 cm) was significantly (P=0.05) higher for wastewater + *Moringa* leaf extract irrigation than for either *Moringa* leaf extract or wastewater application alone that had 51.45 and 47.87cm, respectively. This response agrees with the findings of Rehman *et al.* (2017) who reported superior shoot height response from *Moringa* leaf extract irrigation. This could be attributed to some plant secondary metabolic and osmoprotectants making it natural stimulant for growth containing many plant growth regulators including zeatin, cytokinin, vitamins and several mineral elements (Yasmeen *et al.,* 2014; Rady*et al.,* 2015). There was no significant (P=0.05) difference for wastewater application on number of leaves, however, wastewater irrigation had 6.7 and 10% number of leaves advantage over *Moringa* leaf extract and Wastewater + *Moringa* leaf extract irrigation, respectively. This result agrees with the findings of Harati (2003), who studied wastewater effects on sorghum and concluded that macro (N, P and K) and microelements in the wastewater improve number of leaves due to its gradual accumulation in soil. Leaf length was highest (86.70cm) for wastewater + *Moringa* leaf extract irrigation and did not show any significant difference between the treatments.The width of leaf was highest (3.93 cm) with wastewater irrigation which is 0.36 and 0.31 cm greater than that obtained from *Moringa* leaf extract and wastewater + *Moringa* leaf extract irrigation, respectively. This corroborates the finding of, Harati (2003), who reported that wastewater improves the width of leavesof sorghum.

Mineral composition in Sorghum plant

Phosphorus content was highest (0.12%) for *Moringa* leaf extract irrigation (Table 4). However, there was no significant (P=0.05) difference between the treatments, and the result agree with Sadiqu and Hussain (1993) who found varying concentrations and responses by maize and sorghum for the uptake of different element receiving fertilizer.

Potassium concentration in sorghum plants were not significantly (P=0.05) different as well as the concentrations of Ca and Mg. However, wastewater + *Moringa* leaf extract produced Ca concentration higher than wastewater and *Moringa* leaf extract irrigation by 25.6 and 12.8%, respectively. Wastewater + *Moringa* leaf extract and *Moringa* leaf extract each had 36% Mg concentration advantage over wastewater. This differs with the findings of Sinha *et al.* (1986) who reported an increase in Ca and decrease in Mg concentrations in sorghum plants due to the application of wastewater used for irrigation. This could be attributed to the source of the wastewater that contains varying concentrations of nutrient elements. Sodium content, of sorghum plants showed no significant (P=0.05) difference between the treatments. However, the concentration of Na in sorghum plant was lowest with the combined application of wastewater and *Moringa* leaf extract. The concentrations of Fe, Cu, Zn, Mn, Ni and Pb in sorghum plants were not significantly (P<0.05) different between the treatments. However, wastewater + *Moringa* leaf extract irrigation lowered the concentration of Fe by 12.5% compared to wastewater and *Moringa* leaf extract irrigated separately. Similarly, *Moringa* leaf extract irrigation had Zn concentration advantage of 13.6 and 11.3% over wastewater + *Moringa* leaf extract and wastewater, respectively while *Moringa* leaf extract irrigation had Mn concentration advantage of 15.4 and 5.1% over wastewater and wastewater +

Moringa leaf extract irrigation, respectively. This suggests that irrigation with wastewater from fish pond and combination of wastewater and *Moringa* leaf extracts produced similar concentrations of these elements in sorghum plants. The results therefore differs with the findings of Sinha *et al.* (1986) who reported both increase and decrease in the concentration of elements in sorghum plants due to the application of wastewater used for irrigation.

Table 3: Effect of Wastewater and *Moringa* Leaf Extract on Growth Characters of Sorghum

Treatment	**Plant height (cm)**	**Number of leave**	**Leave length (cm)**	**Width of leave (cm)**
WW	47.87±1.08b	11.00±1.00a	85.73±9.03a	3.93±0.38a
MLE	51.45±4.67b	10.33±1.53a	79.37±9.35a	3.57±0.32a
WW+MLE	60.63±0.96a	10.00±0.02a	86.70±11.19a	3.62±0.51a
LSD	5.64	2.11	19.79	0.82
P	*	NS	NS	NS
CV (%)	7.06	6.15	4.03	5.73

Figures in the same column followed by the same letter are not significantly different by $LSD_{0.05}$

NS – Not significant, *- significant at 5% level of probability, CV-Coefficient of variation

Table 4: Effect of Wastewater and *Moringa* Leaf Extract on the Mineral Composition of Sorghum Plant.

Treatment	P	K	Ca	Mg	Na
	%				
WW	0.11±0.01a	2.55±0.22a	0.68±0.12a	0.16±0.04a	0.131±0.02a
MLE	0.11±0.01a	2.53±0.23a	0.58±0.15a	0.25±0.08a	0.131±0.04a
WW+MLE	0.12±0.01a	2.43±0.21a	0.78±0.05a	0.25±0.08a	0.122±0.05a
LSD	0.02	0.44	0.23	0.14	0.08
P	NS	NS	NS	NS	NS
R^2	0.20	0.44	0.23	0.14	0.001

	Fe	Cu	Zn	Mn	Ni	Pb
	mg/ kg					
WW	40.0±10.00a	2.28±0.56a	35.93±2.18a	16.50±3.00a	2.00±1.15a	3.23±0.02a
MLE	40.0±8.60a	2.13±0.34a	40.50±6.06a	19.50±4.50a	3.00±0.58a	3.48±1.00a
WW+MLE	35.0±5.00a	2.24±0.61a	34.93±2.15a	18.50±3.12a	3.00±2.08a	3.61±0.02a
LSD	16.30	1.03	7.83	7.20	1.15	1.53
P	NS	NS	NS	NS	NS	NS
R^2	0.54	1.59	0.78	0.54	0.14	0.25

Means in the same column followed by the same letter are not significantly different by $LSD_{0.05}$

NS-not significant, R^2 – Coefficient of determination

Mineral concentration in soil

Table 5 presents post harvest concentration of minerals in the soil and shows that P content was highest (7.51 mg/kg) at wastewater + *Moringa* leaf extract with 0.70 and 0.27 mg/kg P higher than at wastewater and *Moringa* leaf extract irrigation, respectively. However, there was no significant (P=0.05) difference between the treatments. This shows that the P contents of *Moringa* leaf extract + wastewater increased P content of soil when compared to wastewater and *Moringa* leaf extract separately, whereas the difference in K, Ca, Mg, Na, Fe, Cu, , Mn, Ni And Pb were not significant at 5% level of probability. The result showed that the K content in wastewater increased the K concentration in soils greater than the one irrigated with *Moringa* leaf extract and wastewater + *Moringa* leaf extract. Calcium concentration in the soil increased by 19, 31 and 19% from wastewater, *Moringa* leaf extract and *Moringa* leaf extract irrigation, respectively while Mg content was highest (0.03 cmol/kg) at wastewater followed by wastewater + *Moringa* leaf extract and *Moringa* leaf extract indicating a corresponding decrease of 0.012, 0.022 and 0.022 mg/kg, respectively. This differs from the result of Schipper *et al*. (1996) who reported that wastewater application increased Mg concentration. Sodium was highest (2.88 cmol/kg) with *Moringa* leaf extract irrigation showing an increase in soil Na with 1.88 cmol/kg while soils irrigated with wastewater and wastewater + *Moringa* leaf extract increased Na concentration by 1.64 and 1.80 cmol/kg, respectively. Similar result was reported by Fonseca *et al*. (2005c) who found increasing Na concentrations in the soil and also in the plants (Fonseca *et al*., 2005b). The mean concentration of DTPA-extractable elements in soil (Fe, Cu, Mn, Ni, and Pb) did not show any significant difference between the treatments. Zn concentration was highest with wastewater irrigation (3.15 mg/kg) which is at par with that of *Moringa* leaf extract but significantly (P=0.05) higher than that recorded at wastewater + *Moringa* leaf extract irrigation. The higher concentration of Zn, Mn and Pb in wastewater corroborates the findings of Akbari *et al*. (1997) but differs in the concentrations of Fe and Cu where it was observed that higher concentrations of Cd, Cu, Fe, Mn, and Pb in soil (extracted with DTPA-TEA) was attributed to higher metal concentrations in the total sewage effluent.

Interaction studies of elements

The regression and correlation analysis (Table 6) indicate that there is no single most important element affecting sorghum plant growth. This differs with the findings of Al-Jaloud *et al*, (1995) where he reported Na as the most important element affecting Plant growth. The non dominance of Na could be attributed to the presence of other nutrient elements in wastewater and *Moringa* leaf extract that might have neutralized the adverse effect of Na in irrigation waters (Al-Jaloud *et al.*, 1995). The regression developed for mineral in soil and that of plant showed a weak relationship except for Ca and K (R^2 = 0.512) and Cu and Mn (R^2 = 0.558).

Conclusion

Results of this study showed that combined wastewater and *Moringa* leaf extract significantly increased shoot height compared to wastewater or *Moring* leaf extract separately. Other growth characters showed little or no change. The mineral concentrations in plants were within allowable threshold and showed no significant difference between the treatments indicating the low concentration of these elements in the irrigation water. The concentration of heavy metals in both plant tissues and soil falls within globally acceptable value. Therefore, wastewater and *Moringa* leaf extract either separately or in combination can be used for irrigation purposes especially sorghum crop.

Table 5: Effect of Wastewater and *Moringa* Leaf Extract on Mineral Composition of Soil Under Irrigated Sorghum Plants.

Treatment	P	K	Ca	Mg	Na	OC	OM
	mg/kg	cmol/kg				%	
WW	6.81±1.06a	0.08±0.04a	0.10±0.014a	0.03±0.003a	2.64±0.64a	3.30±0.55a	5.69±0.95a
MLE	7.24±2.36a	0.07±0.003a	0.11±0.011a	0.02±0.014a	2.82±0.72a	2.64±0.30b	4.55±0.52b
WW+MLE	7.51±1.67a	0.07±0.002a	0.10±0.009a	0.02±0.002a	2.80±0.66a	2.75±0.27a	4.74±0.47a
LSD	3.55	0.031	0.023	0.02	1.34	0.53	0.91
P	NS	NS	NS	NS	NS	*	*
R^2	0.91	0.84	0.75	0.53	0.99	0.99	0.99

	Fe	Cu	Zn	Mn	Ni	Pb
	mg/kg					
WW	9.67±4.31a	0.46±0.0e	3.15±0.11a	13.78±0.53a	0.01±0.006a	0.42±0.09a
MLE	11.83±5.06a	0.44±0.12a	3.02±0.04a	13.33±0.33a	0.02±0.012a	0.34±0.06a
WW+MLE	12.83±6.05a	0.53±0.10a	2.30±0.06a	13.57±1.15a	0.02±0.0ea	0.34±0.15a
LSD	10.37	0.18	0.15	1.51	0.01	0.21
P	NS	NS	NS	NS	NS	NS
R^2	0.41	0.64	0.12	0.12	0.17	0.13

Figures in a column above followed by the same letter are not significantly (*P*=.05) different.
*-significant at 5% level of probability, NS-Not significant, R^2 -Coefficient of determination

Table 6: Regression Analyses of Significant Correlation Coefficient Among Soil and Plant Minerals

Mineral in soil	**Mineral in Plant**	**Regression equation**	**R^2**
P	Mg	y = -1.466x + 0.548	0.003*
Ca	K	y = 4.471x +2.166	0.512*
Mg	Cu	y = 21.81x + 1.237	0.187*
Na	P	y = 0.0002x + 0.105	0.026*
Cu	Mg	y = 0.166x - 0.446	0.558*

*= *P*=0.05

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