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Mineral Composition of Maize (*Zea mays* L) Plant Irrigated with Wastewater and *Moringa oleifera* Leaf Extract

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Authors' contributions

This work was carried out in collaboration between both authors. Author HES designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author VA managed the analyses and literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

A study was conducted in the screen house at the FAO/TCP teaching and research farm of Adamawa state University, Mubi to assess the effect of wastewater from fish pond and *Moringa oleifera* leaf extract on the mineral composition of maize plant. Results showed that the concentration of minerals in maize plant were in deficient range for P (0.11-0.12%), Ca (0.12 – 0.22%), Cu (1.65 – 2.55 mg/kg), and Mn (17.5 – 19.0 mg/kg) in all irrigations except K (2.05 – 3.02%) that was in sufficient range. Wastewater irrigation had Mg (0.70%) and Zn (31.93 mg/kg) composition in sufficient range and Fe (45 mg/kg) in deficient range. *Moringa* leaf extract irrigation had maize plant composition of Fe (66.7 mg/kg) in sufficient range while combined wastewater and *Moringa* leaf extract irrigation had Mg (0.31%), Fe (51.67 mg/kg) and Zn (33.60 mg/kg) in sufficient range. Irrigating maize plant with wastewater + *Moringa* leaf extract improved P, K and Zn composition by 9.1, 43.8 and 5.2%, respectively. Regression and correlations analyses indicate that Na concentration in the soil is the element affecting greater number of elements composition in the plant and subsequently the growth characters. Therefore, wastewater from fish pond and *Moringa* leaf extract irrigation either in combination or separately did not increase the nutrient elements and heavy metals to toxic limits and therefore can be used for irrigation purposes especially maize crop.

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1. INTRODUCTION

With the increasing global population, the gap between supply and demand for water is widening and has reached an alarming level such that in some part of the world especially in the arid and semiarid regions, it is posing a threat to human existence. In these regions, waste water is considered a valuable source of irrigation water and a fertilizing material [1]. However, there is an increasing awareness on the need to dispose waste water safely and beneficially which is of paramount importance bearing in mind environmental health and water pollution issues.

Most sewage wastes contain valuable nutrients that improve soil fertility and crop production [2]. Therefore, the benefits of wastewater use in irrigation are numerous but precautions must be taken to avoid short and long-term environmental risks. So, inappropriate handling and management of wastewater reuse for irrigation can create serious environmental and health hazards [3]. Such a proper use can relatively minimize pollution of the ecosystem which otherwise would be contaminated by direct disposal of wastewater into surface or ground water [4]. Wastewater contains essential nutrients for plant growth like N, P, K, iron (Fe), zinc (Zn), manganese (Mn), and copper (Cu) and a considerable amount of organic matter [4,5].

However, improper management of wastewater irrigation may provide the crops with nutrients beyond their specific requirement and subsequently accumulate them at undesirable high levels in the crop. This would lead to reduction in the yield and its quality [5,6].

The concentration of macro and micro nutrients in corn plants were affected by chelate fertilizers [7]. It was reported by Lockman [8] that there were sufficient range for different element in leaf and whole corn and sorghum at various stages.

One of the sources of foliar fertilizer that is attracting attention is *Moringa oleifera* plant which is termed as 'tree for life' due to its importance. The efficacy of *Moringa* as organic fertilizer has already proved by a number of field trials conducted in Nigeria. Application of processed *M. oleifera* fresh leaves and seed cake as organic fertilizer improved the yields of maize and sorghum yield [9]. Maize has been reported [10] as one of the most intensively cultivated cereals worldwide and it is known to be the main energy source in human food, mainly in developing countries. In addition, maize is used in animal feeds as a feedstock in agricultural complexes [11].

The importance of waste water and *Moringa leaf extract* irrigation on the mineral composition of maize 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 waste water from fish pond and *Moringa* leaf extract on mineral composition of maize plant.

2. 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.

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 leave of *Moringa oleifera* are presented in the Table 2.

Eight 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 maize were planted in each pot on 3rd of March 2014. A total of 1.59 lt of water and the treatments were applied per pot per irrigation. The crops were irrigated 3 times a week. The plant population was thinned to four plants per pot two weeks after crop germination and was 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 [12] was followed.

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

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

Soil organic carbon was determined by wet oxidation method as described by Walkley and Black [13]. The Titrimetric method for the determination of Calcium and Magnesium in the soil as described by Black, [14] was followed. Soil pH was determined as described by Bates, [15]. Hydrometer method of Soil Mechanical Analysis was followed as described by Bouyoucos, [16]. Available P in soil was determined as described by Bray and Kurtz, [17] at the wavelength of 660 nm. Potassium and sodium was determined in 1 M neutral NH_4Ac soil extract using flame photometry and exchangeable acidity as described by Mclean, [18]. The Di-ethylene triaminepenta acetic acid (0.005M DTPA) [19] and 0.1 N HCl [20] method of extracting available Zn and Mn in the soil was adopted. The determination of total iron in soil by atomic absorption spectrophotometry, after digestion with strong oxidizing acids and treatment with hydrofluoric acid to eliminate silica as described by Jackson [21] was maintained.

Waste water used for irrigation was analyzed as described in the Standard Methods for the Examination of Water and Waste water [22]. Fresh leaves of *Moringa oleifera* were prepared at the ratio of 1:36 as described by Mathur, [23]. The results of the concentration of different minerals in maize plant were compared with the data reported by Lockman [8] on corn.

The data was subjected to analysis of variance using SAS [24]. The significant difference among the mean was compared using Duncan Multiple Range Test.

3. RESULTS AND DISCUSSION

3.1 Response of Some Growth Characters of Maize

The effect of wastewater and *Moringa* leaf extract irrigation on the growth of maize plant is presented in Table 3. Plant height at *Moringa* leaf extract irrigation was superior to plant height recorded at wastewater + *Moringa* leaf extract and *Moringa* leaf extract. The result obtained agreed with Emmanuel et al. [9] and Mvumi et al. [25] who reported that organic manure from *Moringa* leaf extract increased plant height in maize. There were no significant (P=.01) differences between wastewater and *Moringa leaf* extract application on number of leaves. However, combination of wastewater and *Moringa* leaf extract had number of leaves advantage of 5.3 and 8.6% over wastewater and *Moringa* leaf extract, respectively. Increase in the number of leaves of maize plant from irrigation with Moringa leaf extract has been reported by Emmanuel et al. [9] while that of wastewater has been reported by [26]. Thus, the combined effect of wastewater and *Moringa* leaf extract gave the number of leaf advantage over wastewater and *Moringa* leaf extract irrigated separately. Leave length shows that application of the treatment did

Table 3. Effect of wastewater and *Moringa* leaf extract on growth parameter of maize

Treatment	Plant height (cm)	Number of leave	Leave length (cm)	Width of leave (cm)
WW	71.51±3.34b	11.67±0.58a	83.17±3.26a	4.38±0.13a
MLE	86.53±4.19a	12.00±1.00a	83.05±4.59a	4.63±0.39a
WW+MLE	69.60±7.28b	12.67±0.58a	87.18±1.72a	4.78±0.20a
LSD	10.70	1.49	6.79	0.53
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 $LSD_{0.05}$
*P – Level of significance, *- significant at 5% level of probability, NS – Not significant, CV-Coefficient of variation*

not indicate any significant difference. This differs with the findings of Ramana et al. [27] who observed that influence of distillery wastewater on the physiology of maize increased leave length. Same response was recorded with the width of leaf. However, there were no significant differences between the treatments.

3.2 Mineral Composition of Maize Plants

The effect of wastewater and Moringa leaf extract on mineral composition of maize plant is presented in Tables 4 and 5. Phosphorus concentration was highest at wastewater + *Moringa* leaf extract with corresponding value of 0.12% while wastewater and *Moringa* leaf extract had lower values of 0.11% phosphorus each. Similar results were reported by Sadiq and Hussain [7] Who found varying concentrations and responses by maize for the uptake of different element receiving fertilizer. Similarly, wastewater + *Moringa* leaf extract application had the highest K concentration of 2.20% significantly (*P*=.01) higher than K concentration from *Moringa* leaf extract (2.10% and wastewater (2.05%). Therefore, the combination of wastewater and *Moringa* leaf extract produced higher concentration of K than irrigating them separately. Calcium concentration decreased from the application of *Moringa* leaf extract (0.22%) to wastewater and wastewater + *Moringa* leaf extract with corresponding composition of 0.14 and 0.12%, respectively.

Magnesium concentration at wastewater irrigation was 2.3 and 5.4 folds that of wastewater + *Moringa* leaf extract and *Moringa* leaf extract irrigation, respectively. This was significant at *P*=.01. Sodium concentration was not significantly (*P*=0.05) different between the treatments as it ranged between 0.10 and 0.13%. Iron and Copper concentrations of 67 and 25 mg/kg at *Moringa* leaf extract were significantly (*P*=0.05) higher with 28.8 and 25% over wastewater + *Moringa* leaf extract and 48.8 and 47.1% over wastewater. The concentrations of the two elements decreased with the application of the treatment and their concentrations were deficient according to Lockman [8]. Zinc, Manganese and Nickel were highest at wastewater + *Moringa* leaf extract irrigation with the corresponding values of 34, 19 and 3 mg/kg, respectively. The result agreed with the finding of Al-Jaloud et al. [28] who revealed increase in concentration of zinc with application of sewage. Manganese and Ni showed no significant difference due to combined effects of the treatment. Reports by [6] indicated that accumulation of heavy metals such as cadmium and lead in Maize shows a little variation in concentration of the elements. Zinc concentration increased with increases in the concentration of respective elements in the treatment. There was no significant difference in the concentration of Pb, however it was highest (0.42 mg/kg) at wastewater application. The difference in mean concentration of each element between different treatments was significant (*P*=.05) for K, Mg (Table 4), Fe, Cu, Zn and Mn (Table 5) while P, Ca, Na (Table 4) Ni and Pb (Table 5) were not. The coefficient of determination (R^2) show that 70-99% variability in the concentration of Ca, Na, Zn, Mn, Cu, Ni and Pb in maize plants was affected receiving wastewater, wastewater + *Moringa* leaf extract and *Moringa* leaf extract irrigation. However, P, K, Mg, and Fe correlation matrix (r) was poor and ranged from 0.02 – 0.59. The concentration of P, K, Ca, Fe and Cu were in deficient range in all treatments except for Zn and Mg at wastewater and wastewater + *Moringa* leaf extract. The variation in the concentration of minerals agrees with the report of Sadiq and Hussain [7] who found varying concentrations and responses by maize for the uptake of different elements receiving fertilizers.

Table 4. Effect of wastewater and *Moringa* leaf extract on the composition of macro nutrient in maize plant

Treatment	P	K	Ca	Mg	Na
	←		%		→
WW	0.11±0.02a	2.45±0.13b	0.14±0.18a	0.70±0.02a	0.131±0.004a
MLE	0.11±0.01a	2.10±0.10b	0.22±0.11a	0.13±0.01b	0.131±0.004a
WW+MLE	0.12±01a	3.02±0.08a	0.12±0.17a	0.31±0.17b	0.126±0.005a
LSD	0.02	0.21	0.32	0.20	0.009
P	NS	**	NS	*	NS
R^2	0.20	0.90	0.11	0.89	0.29

Means in the same column followed by the same letter are not significantly different by $LSD_{0.05}$
P – Level of significance,-significant at P=0.05, **- significant at P=.01, NS-not significant, R^2 – Coefficient of determination*

Table 5. Effect of wastewater and *Moringa* leaf extract on the composition heavy metals in maize plant

Treatment	Fe	Cu	Zn	Mn	Ni	Pb
	←		mg/ kg			→
WW	45.00±15.00b	1.65±0.11b	31.93±1.75a	17.50±0.87b	2.33±1.15a	4.18±0.07a
MLE	66.67±5.77a	2.55±0.29a	24.93±3.02b	17.83a±0.29b	3.33±0.58a	3.61±0.07a
WW+MLE	51.67±7.64b	2.00±0.58b	33.60±2.39a	19.00±0.87a	3.33±2.08a	3.61±0.03a
LSD	20.50	0.59	0.78	0.54	0.14	0.25
P	*	**	*	*	NS	NS
R^2	0.54	0.59	0.78	0.54	0.14	0.25

Means in the same column followed by the same letter are not significantly different by $LSD_{0.05}$
*P – Level of significance, *-significant at P=0.05, **- significant at P=.01, NS-not significant, R^2 – Coefficient of determination*

3.3 Mineral Concentration in Soil

The effect of wastewater and *Moringa* leaf extract irrigation on mineral concentration in soil under maize plant is presented in Tables 6 and 7. Phosphorus concentration was highest (5.34 mg/kg) in soils irrigated with wastewater + *Moringa* leaf extract, which are 1.2 and 3.3 folds of that accumulated by *Moringa* leaf extract and wastewater. There was no significant difference in the residual soil concentration of P irrigated with wastewater + *Moringa* leaf extract and *Moringa* leaf extract. This was in agreement with the observation of Dastorani et al. [29] who reported that, application of wastewater increased P content in the soil as well as K (Table 6), where K concentration at wastewater irrigation was 0.07 cmol/kg while wastewater + *Moringa* leaf extract and *Moringa* leaf extract had the least value with significant difference at *P*=.01. Calcium content, at wastewater + *Moringa* leaf extract was highest (0.16 cmol/kg) and was significantly different at *P*=.05 while Magnesium content was significantly (*P*=.01) high (0.05 cmol/kg) at *Moringa* leaf extract. This shows that Mg present in *Moringa* leaf extract increased the Mg content of the soil. The result of Schipper et al. [30] revealed that wastewater application increased contents of Mg and Ca in the soil. Sodium concentration was significantly (*P*=.01), highest at waste water (3.19) application followed by wastewater + *Moringa* leaf extract (3.10). According to Al-Jaloud et al. [28] macro- and micronutrients in the effluent neutralize the undesirable effect of high Na concentrations in waste water. Moreover, antagonistic effect between Na and K was more pronounced under low K concentrations in soil [31]. Application of the treatment did not significantly influence the mineral composition of soil Fe (Table 7). A similar result was reported by Lindsay and Norvell [19]. Analysis of variance shows that application of the treatment was significant (*P*=.01) in Cu concentration with highest value of 0.62 mg/kg at wastewater application. The DTPA-extractable Zn did not show any significant difference. In a similar work, some wastewater used for irrigation increased trace metals in soils and plants, especially Zn levels in soils [32]. Manganese, Ni, and Pb did not show any significant difference between the treatment and the concentration were highest (13.76, 0.04 and 0.38 mg/kg) at wastewater + *Moringa* leaf extract irrigation, respectively. This agrees with Dastorani et al. [29] who reported that the use of some wastewater for irrigation increased trace metals in soils and plants, most importantly Mn, Ni, and Pb levels in soils.

Table 6. Effect of wastewater and *Moringa* leaf extract on mineral composition of soil under irrigated maize plants

Treatment	P	K	Ca	Mg	Na	OC	OM
	← mg/kg →	←		cmol/kg	→	← %	→
WW	1.61±0.06b	0.07±0.004a	0.09±0.003b	0.03±0.001b	3.19±0.07a	6.61±0.41a	11.40±0.70a
MLE	4.55±1.04a	0.06±0.003b	0.08±0.015b	0.05±0.013a	1.87±0.04b	2.70±0.15b	4.67±0.27b
WW+MLE	5.39±0.19a	0.06±0.002b	0.16±0.044a	0.04±0.003ab	3.10±0.07a	6.95±0.15a	11.98±0.25a
LSD	1.23	0.006	0.05	0.02	0.12	0.53	0.91
P	*	*	*	*	*	**	**
R^2	0.91	0.84	0.75	0.53	0.99	0.99	0.99

Figures in a column above followed by the same letter are not significantly (P=.05) different.
*P – Level of significance, *-significant at 5% level of probability, **- significant at 1% level of probability, R^2 – Coefficient of determination*

Table 7. Effect of wastewater and moringa leaf extract on composition of heavy metals in soil under irrigated maize plants

Treatment	Fe	Cu	Zn	Mn	Ni	Pb
		←	mg/kg	→		
WW	1.38±0.10a	0.62±0.11a	2.96±0.01a	13.43±0.35a	0.03±0.001a	0.32±0.09a
MLE	1.15±0.23a	0.44±0.08b	2.86±0.16a	13.40±0.60a	0.03±0.006a	0.38±0.03a
WW+MLE	1.48±0.25a	0.43±0.05b	2.84±0.27a	13.76±0.62a	0.04±0.012a	0.36±0.09a
LSD	0.41	0.16	0.36	1.08	0.02	0.15
P	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.
*P – Level of significance, *-significant at 5% level of probability, NS-not significant, R^2 – Coefficient of determination*

Table 8. Regression analyses of significant correlation coefficient among soil and plant minerals

Mineral in soil	Mineral in plant	Regression equation	R^2
P	K	y = 1.1427x + 2.2260	0.520*
P	Mg	y = -0.1156x + 0.8269	0.614*
K	Mg	y = 38.508x – 1.966	0.808**
K	Cu	y = -52.059x + 5.4505	0.444*
Ca	K	y = 4.4715x + 2.1662	0.513*
Na	Mg	y = 0.2985x – 0.4295	0.518*
Na	Fe	y = -14.431x + 93.68	0.497*
Na	Cu	y = -0.5842x + 3.6549	0.538*
Na	Zn	y = 5.9708x + 13.922	0.717**
Cu	K	y = -1.5814x + 3.4515	0.436*

**= P=.05, **= P=.01, R^2 = Coefficient of determination*

Regression and correlation analyses (Table 8) indicate that Na concentration in the soil affected Fe and Cu composition in maize plant which differs with the findings of Crammer and Spur [33] who reported that Ca concentration in the soil as the element affecting Ca and Mg concentrations in lettuce plants. However, Na was positively correlated with Mg (r = 0.720) and Zn (r = 0.847) while the relationship between K and Mg was the strongest (R^2 = 0.808) as the remaining R^2 ranged between 0.436 and 0.614. The negative correlation between K and Cu (r = -0.666) is similar to the finding of Smith [34] who reported that K top dressing reduced Cu levels in Alfalfa plants.

4. CONCLUSION

The result from the present study shows that wastewater from fish pond and *Moringa* leaf extract irrigation either in combination or separately did not increase the concentration of nutrient elements and heavy metals to toxic limits in both maize plant and soil. Therefore, they can be used for irrigation purposes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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