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Growth Performance and Mineral Composition of *Moringa oleifera* Seedlings as Affected by Soil Depth under Water Stress Conditions

Oshunsanya, S.O[1,*], Fagbenro, J.A[2] and Oyewo, T.O[1]

[1]Department of Agronomy, University of Ibadan, Ibadan, Nigeria.

[2]Department of Crop Production, Soil and Environmental Management, Bowen University, Iwo, Nigeria.

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ABSTRACT

Different parts of Moringa oleifera shoot are reportedly useful for nutrition, medicine, water purification and as raw material for the industry. It is however hypothesized that the growth and mineral composition of Moringa could be affected by the medium in which it is growing. Consequently, a factorial experiment involving three pre-determined soil depths of 0-15, 15-30 and 30-45 cm at four soil water levels: 100, 75, 50 and 25% Field Moisture Capacity (FMC) was conducted in Ibadan, South western Nigeria, to investigate the effect of soil depth and water stress on the growth and mineral composition of Moringa shoot. The total N, C, P, K, Mg and Ca contained in the soil samples collected from the three soil depths were in the order of 0-15>15-30>30-45 cm. As a result, Moringa plants produced in the surface soil (0-15 cm) was superior in height; stem girth, number of leaves and dry matter yield irrespective of water- stress condition. Reduction in FMC from 100 to 50% did not significantly affect growth performance. Surface soil produced stems and leaves richer in mineral composition (Ca, Mg, K, Fe, Cu and Zn) than subsoil. Therefore, growing moringa on a fertile-soil is better for animal health.

Introduction

Moringa oleifera is the most widely known and utilized species of the family Moringaceae. *Moringa* is one of the world's most nutritious crops [1]. This fast-growing tree is grown throughout the tropics and it is considered as one of the World's most useful trees, as all parts of the moringa shoot are used for human food, livestock forage, medication and industrial purposes [2]. It grows well in the humid tropics or hot dry lands. It survives in less fertile soils and rarely affected by drought [3]. It is advisable not to consume the root since researchers have discovered that the root is toxic and contains chemicals that can paralyze nerves [4]. With the leaves being rich in nutrients, pregnant women and lactating mothers use the powdered leaves to enhance their child's or children's nourishment, especially in under developed countries suffering from malnutrition [5][6]. The leaves can be used in the same way as spinach. The pods can be eaten from when they first appear to when they become too woody to snap easily (up to 30cm long). They are cooked like other green beans (National Research [7], and have a similar flavour to asparagus. Cattle, sheep, pigs, goats and poultry browse the bark, leaves and young shoots of Moringa. The best diet for pigs is 70% Moringa, 10% Leucaena and 20% other leaves [4].

Seed powder can be used as a quick and simple method for cleaning dirty river water. This treatment removes 90-99% of bacteria and replaces Aluminium sulphate, which are dangerous to people and the environment [4].

Moringa is extensively promoted worldwide for nutrition supplementation as it is rich in protein (5-10%), in minerals (Iron and Calcium) and in vitamins such as vitamins c and carotene [8]. In view of its high nutritional value, it becomes very important as a human food as it can supplement a number of food crops. In comparison, gram for gram, moringa has more beta-carotene than carrots (*Daucus carota*), more protein than peas (*Pisum sativa*), more vitamin than oranges (*Citrus citrii*), more calcium than milk, more potassium than bananas (*Musa spp*) and more iron than spinach (*Spinocea oleracea*) [1]. In the fresh leaves analysis, the highest was in Ca followed by Potassium, Magnesium, phosphorus, Iron and the lowest in Zinc which also followed the same trend in the mineral composition of dried leaves of the plant. [9] reported that among the macronutrients in M. oleifera leaves, the highest quantity was in N, followed by Ca, K, Mg, P, Cl and Na, while in the case of micronutrients, the highest was in Fe, followed by B, Mn, Zn and Cu. [10] also reported similar case of *M. oleifera* leaves having Ca as the most abundant macro nutrient followed by K, Mg, S, P, Na and in the case of micro nutrients, Fe having the highest value followed by Se, Mn, B, Zn and the least was found in Cu.

Soil water is one of the most important factors that influence agricultural crop yield [11]. Water stress develops when the water efflux from the plant is greater than the water influx into the plant. Although plant growth rates are generally reduced when the soil water supply is limited, the shoot growth is often more inhibited than the root growth [12]. It is a well known fact that crop growth is frequently subjected to water stress during the course of its lifetime. However, certain growth stages, such as germination, seedling, and flowing, are the most critical for water-stress damage stress imposed during these periods drastically affects crop growth, ultimately leading to a massive loss in yield and quality [13]. Water deficit also inhibited nitrogen, phosphorus and potassium uptake. For example, N, P and K were reduced by (29 – 43) %, (50 – 77) % and (32-48) % respectively under water stressed conditions of (40-60) % field capacity. The root to shoot ratio was 2.1 times higher in water-stressed plants, indicating that plant roots thrived better under

Tele:
E-mail addresses: soshunsanya@yahoo.com

water stress conditions [14]. Moringa still remains unpopular in South Western Nigeria despite its acclaimed economic values and importance [15]. Little or no reports have been made on water use efficiency of *Moringa oleifera* as influenced by soil properties. Thus, a screen house experiment was conducted to examine *Moringa oleifera* mineral composition as influenced by soil depths under water stressed conditions in Southwest Nigeria.

Materials And Methods

The pot experiment was conducted at the screen house of the Department of Agronomy, University of Ibadan. A factorial experiment involving three pre-determined soil depths of 0-15, 15-30 and 30-45 cm at four soil water levels, namely 100, 75, 50 and 25% Field Moisture Capacity (FMC) were setup. The pots were filled with 1kg of the soil. Two seeds of *M. oleifera* was sown into each of the pots and later thinned down to one at 2 weeks after sowing (WAS) as presented in Fig.1. The physical and chemical properties of soil at different levels were determined. The texture of soils was determined using Bouyoucos hydrometer method [16]. In order to ascertain bulk densities at different depths, the core method was employed. Saturated hydraulic conductivity was determined using the constant head permeameter. Soil water retention was determined using the tension table followed by pressure plate (0 – 15 bars). The soil pH was determined with the pH meter using glass electrode in a 1:1 soil: water. The organic carbon, total N, available P, Na, Mg, K and Ca were determined. Fe, Mn, Cu and Zn were determined with atomic absorption spectrometer.

Fig. 1: *Moringa oleifera* seedlings in a screen house at 3 weeks after sowing

Data Collection

Plant parameters determined were plant height, number of leaves, and stems girth. These parameters were determined at weekly intervals starting from 3WAS to 8WAS. The experiment was terminated at 8 WAS by uprooting the whole plant in order to determine the fresh weight of shoot (g) and root (g) of the samples, and the root length (cm). Harvested leaves and stems were weighed fresh and dried at 65°C for 24 hours. The dried samples were weighed, and milled to powder using mortar and pestle and bagged.

Determination of Nutrients in Moringa Leaves and Stems, and Seeds used for Planting

The mineral composition of some moringa seeds used to establish nursery was determined to ascertain the base-line nutrients status of plant. The total nitrogen of moringa seed was determined using the micro Kjeldahl method. The available phosphorus read with the spectrophotometer, Na was read on the flame photometer, K, Ca, Mg and Fe was read on atomic adsorption spectrophotometer. The mineral composition of harvested stems and leaves (total N, P, K, Ca, Mg, Na and Fe) were also determined.

Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) and the means compared and separated by Duncan Multiple Range Test (DMRT) at 5% level of probability.

Results And Discussion

Physical and Chemical Status of Soils used for the Experiment

Analysis of soil at different depths revealed that surface soil (0 -15cm), sub - soil A (15 – 30cm), and sub - soil B(30 – 45cm) are loamy sand, sandy loam and sandy clay loam, respectively indicating that ability of soils to hold water for plant use varies down the profile (Table 1). Higher content of finer soil particles in lower depths might be due to the translocation of finer particles from the surface horizons and subsequent illuviate in sub surface horizons [17]. Saturated hydraulic conductivity (Ksat.) values were in the order of soil surface > sub - soil A > sub - soil B suggesting that it is easier for water to flow (circulate) in surface soil when irrigated than sub - soil A and B. Sub–soil B pH was more acidic than surface soil and sub–soil A which could have been responsible for low nutrients status in sub–soil B than other soil depths. Soil organic matter, Total N, available P and exchangeable acidity were in the order of surface > sub–soil A > sub–soil B pointing to their potential nutrients capacity to sustain crops. The same trend was maintained by Ca, Mg, K, and Zn as presented in Table 1. Similar observations were made by [18] where K (sat) - Saturated hydraulic conductivity.the author observed that organic content in all the land use systems decreased with increase in soil depth. The author attributed the higher organic carbon content in the soil surface to accumulation of organic matter due to leaf falls. Soil aggregation index, Ca/Mg ratio, was higher in surface soil followed by sub–soil A (15 – 30 cm) and least by sub – soil B (30 – 45 cm) indicating that surface soil is more structured and less collapse under the impact of rain drops than sub–soils. Ability of soil to retain water for crop use reduces down the profile as presented in Table 2. Soil available water (SAW) at 0 – 15cm depth was higher than 15 – 30cm depths by 43.1 and 55.7%, respectively. In addition, soil moisture characteristics curve revealed that at every suction from saturation to permanent wilting point, surface soil holds more water followed by sub soil A and least by sub – soil B as presented in Fig. 2.

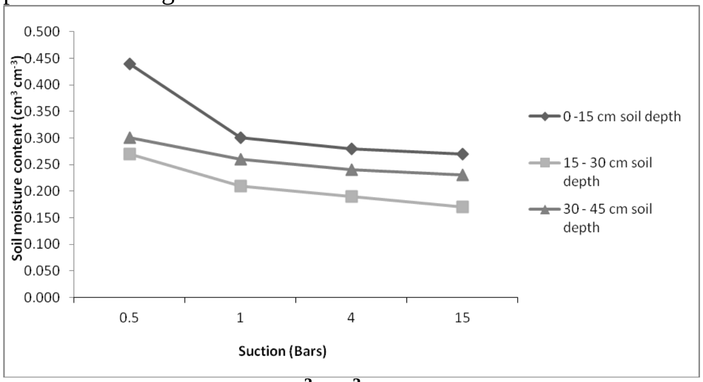
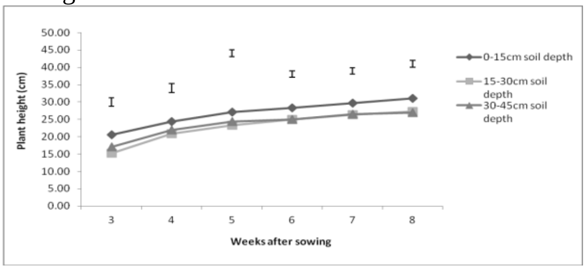


Fig. 2: Soil moisture (cm^3cm^{-3}) retention curves of soils of different depths

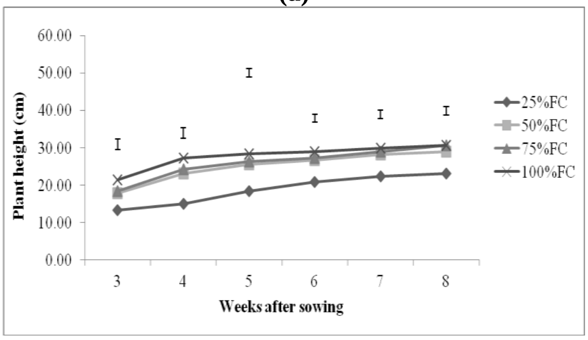
This could be as a result of decreasing organic matter down the soil profile. [19] reported that increase in organic matter results in increase in SAW. It is important to note that the total amount of water used to irrigate moringa for 8 weeks was in order of subsoil B > surface soil> subsoil A suggesting that it is better and economical to raise moringa with surface soil that requires less water for optimum crop performance (Table 2).

Moringa Seedlings Performance as Affected by Soil Depth and Water Stress

Germination percentage of *M. oleifera* was in the order of surface soil > subsoil A > subsoil B as presented in Table 2. The fineness of soil increases down the profile which could result to reduction in soil aeration. Poorly aerated soils could affect germination, roots establishment and proliferation [20]. The effects of soil depth and water stress on moringa plant height are presented Fig. 3. Moringa plant height was significantly (P=0.05) higher in surface soil (0-15)cm than sub–soil (30-45)cm throughout the study period but there was no significant between 15 – 30 cm and 30 – 45 cm soil depths. Higher Moringa plant height in surface soil could be attributed to higher nutrient status of surface soil than sub-soil. [21] reported higher stem height values on compost treated plot and they attributed this in part to the fact that compost treated plot contained an appreciable amount of N which is responsible for promoting vegetative growth.



(a)

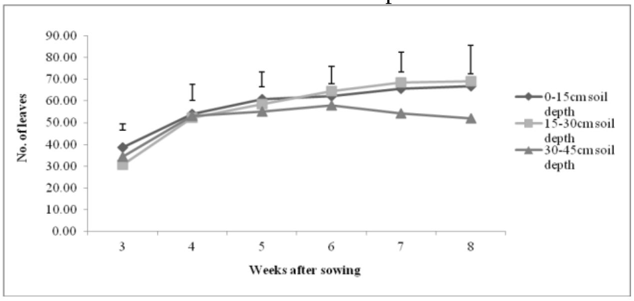


(b)

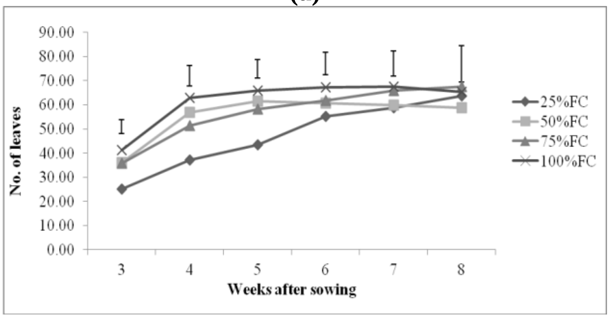
Fig. 3: Soil depth (a) and water stress (b) effects on *Moringa oleifera* plant height

Water stress significantly (P=0.05) influenced Moringa plant heights throughout the nursery stage (Fig. 3). Moringa plant height was not significantly difference among 100% FC, 75%FC and 50% FC suggesting that reducing field capacity to 50% on surface soil could be more economical especially during the dry season when water limits the growth of crops. Moring plant from 25%FC was drastically reduced in height indicating that the potential capacity of moringa roots to absorb water and nutrients generally declines in a water-stressed condition owing to a substantial decrease in transpiration rates and impaired active transport and membrane permeability, resulting in a reduced root-absorbing power of crop plants [22].

At early growth stage of Moringa, soil depth did not significantly influence the number of leaves up to 6 weeks after sowing (WAS) (Fig. 4). Thereafter, soil depth significantly influenced the number of leaves at 7 and 8 WAS. This shows that at higher stage of growth, more nutrients are needed for physiological development which could not be met by sub–soil B. Consequently, surface soil and sub-soil A produced significantly higher number of leaves at 7 and 8 WAS than sub soil B. However, water stress had significant initial influence on number of moringa leaves as presented in Fig.5. From 3 WAS to 5WAS, (100 – 50) % FC had significant higher number of leaves than 25% FC at different soil depths.



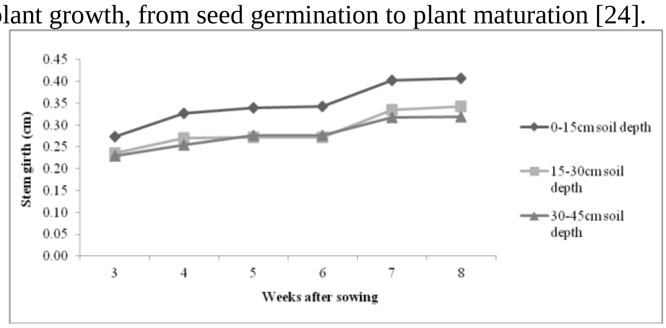
(a)



(b)

Fig. 4: Soil depth (a) and water stress (b) effects on *Moringa oleifera* number of leaves

This could partly be due to water that is needed for germination and also a medium of nutrients availability. [23] reported that nutrient availability and uptake by crop plants are generally decreased under water-stress conditions as a result of decrease in root transpiration rates. Soil depth significantly influenced stem girth throughout the study period (Fig. 5). Stem girth from surface soil was significantly higher than sub soil A and sub soil B starting from 3WAS to 8WAS. The higher stem girth value obtained from surface soil could be attributed to higher nutrient contents available to the seedlings at surface soil than sub soil. Fig. 5 indicated that 100 to 50% FC significantly provided higher stem girth than 25% FC. This shows that water stress could be a major factor limiting moringa production. For optimum crop performance, water is essential at every stage of plant growth, from seed germination to plant maturation [24].



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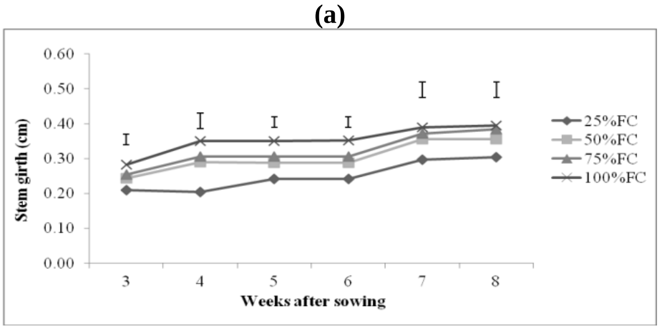

(b)

Fig. 5: Soil depth (a) and water stress (b) effects on *Moringa oleifera* stem girth

Table 1: Physico-chemical properties of soils at different depths used in filling the pots for sowing *Moringa oleifera* seeds in a screen house

Soil characteristics		Soil depth	
	0 - 15 cm	15 - 30 cm	30 – 45 cm
Physical properties			
Sand (g kg^{-1})	847.3	813.0	764.7
Silt (g kg^{-1})	64	43	33.3
Clay (g kg^{-1})	88.7	144.0	202.0
Textural class	Loamy sand	Sandy loam	Sand clay loam
Bulk density (Mg m^{-3})	1.16	1.52	1.6
Total porosity (g cm^{-3})	0.51	0.51	0.37
K_{sat} (cm/hr)	19.88	9.54	3.75
FC @0.5 bar (cm^3 cm^{-3})	0.437	0.269	0.303
PWP@15 bars (cm^3 cm^{-3})	0.269	0.174	0.230
SAW (cm^3 cm^{-3})	0.167	0.095	0.073
Chemical properties			
pH (H_2O) (1: 1)	6.5	6.37	5.5
N (g kg^{-1})	1.9	1.8	1.5
OM (g kg^{-1})	15.5	9.6	8.8
P (mg kg^{-1})	28.4	20.5	12.8
Exchangeable acidity	0.29	0.23	0.22
Exchangeable bases (cmol kg^{-1})			
Ca	1.17	0.55	0.21
Mg	0.48	0.38	0.44
K	0.22	0.20	0.18
Na	0.38	0.73	0.71
Micro- elements (mg kg^{-1})			
Mn	149.67	168.33	173.00
Fe	71.20	77.53	81.10
Cu	1.06	1.51	2.17
Zn	4.40	2.91	2.40
Ca/Mg	1.65	1.45	0.48
Al/Fe	0.92	0.70	0.81

Table 2: Total amount of water (cm^3) used to irrigation *M. oleifera* up to the point of transplanting (8 weeks after sowing)

Soil depth	100%FC	75%FC	50%FC	25%FC	Germination
	litres				%
0-15cm	2.175	1.671	1.153	0.645	21.67
15-30cm	1.815	1.395	0.961	0.541	18.33
30-45cm	2.310	1.764	1.232	0.686	17.50

Table 3: Soil depth and water stress effects on *M. oleifera* yield parameters

Treatments	FWS	FWR	FBW	FWS:FWR	RL	DWS
Soil depth						
0-15	3.80	6.00	9.80	0.70	10.52	1.06
15-30	2.64	4.71	7.35	1.10	10.05	0.74
30-45	1.98	5.20	7.18	0.41	10.38	0.60
$LSD_{(0.05)}$	0.72*	1.04*	1.45*	0.44*	1.94	0.17*
FC (Field Capacity)						
25%FC	1.70	1.80	3.50	1.57	8.54	0.42
50%FC	2.79	5.40	8.19	0.54	10.58	0.74
75%FC	3.57	6.50	10.07	0.59	10.52	0.97
100%FC	3.34	6.81	10.15	0.50	11.21	1.07
$LSD_{(0.05)}$	0.83*	1.20*	1.67*	0.50*	2.23	1.98*
S*F	Ns	Ns	Ns	*	ns	ns

Table 4: Mineral composition of *M. oleifera* seed planted

Mineral	Composition
N (g kg^{-1})	45.0
P (mg kg^{-1})	276.9
Ca(mg kg^{-1})	1056.0
Mg(mg kg^{-1})	1505.0
K(mg kg^{-1})	7525.0
Na(mg kg^{-1})	1110.0
Mn(mg kg^{-1})	10.5
Cu(mg kg^{-1})	24.7
Zn(mg kg^{-1})	16.0
Fe(mg kg^{-1})	885.0

Table 5: Soil depth and water stress effects on mineral composition of dry *M. oleifera* stem

Treatments	Ca	Mg	K	Fe	P	Na	N
	g kg^{-1}			mg kg^{-1}	g kg^{-1}		
Soil depth							
0-15	11.8	2.2	23.1	21	0.2	0.3	12.3
15-30	10.9	1.4	17.2	15	0.6	0.2	8.8
30-45	10.0	1.9	8.7	12	0.3	0.3	7.3
LSD $_{(0.05)}$	3.5	0.6	3.9*	7	0.1*	0.1	4.1
FC (Field Capacity)							
25%FC	7.0	0.6	14.2	14	0.7	0.2	1.1
50%FC	11.9	1.6	17.0	27	0.2	0.2	10.4
75%FC	10.9	1.6	17.0	20	0.3	0.3	10.7
100%FC	11.9	2.0	17.8	22	0.3	0.3	11.4
LSD $_{(0.05)}$	4.0	0.7*	4.5	8*	0.1*	0.1	4.7
S*F	Ns	*	*	Ns	*	Ns	*

Table 6: Soil depth and water stress effects on mineral composition of dry *M. oleifera* leaves

Treatments	Ca	Mg	K	Fe	P	Na	N
	g kg^{-1}			mg kg^{-1}		g kg^{-1}	
Soil depth							
0-15	21.4	4.5	24.0	43	0.7	0.3	18.6
15-30	9.8	1.3	14.3	20	0.3	0.3	15.3
30-45	8.0	0.9	22.4	16	0.2	0.8	12.8
LSD $_{(0.05)}$	2.7*	0.4*	3.6*	6*	0.1*	0.1*	2.0*
FC (Field Capacity)							
100%FC	25.5	4.7	36.0	51	0.7	0.8	7.7
75%FC	11.2	1.5	15.1	22	0.3	0.3	8.4
50%FC	8.2	1.6	17.2	17	0.3	0.3	5.3
25%FC	9.6	1.5	16.3	19	0.4	0.4	5.9
LSD $_{(0.05)}$	3.2*	0.4*	4.2*	0.6*	0.1*	0.2*	3.0
S x F	Ns	*	*	Ns	*	ns	*

Fresh and Dry Weight of *M. oleifera* Seedlings as Affected by Soil Depth and Water Stress

Table 3 presents effects of soil depth and water stress on fresh and dry weight of *M. oleifera* seedlings. Soil depth significantly influenced fresh total biomass of moringa in the order of 0 – 15cm > 15 – 30cm > 30 – 45cm soil depth. Fresh shoot weight followed the same trend in the ratio of 2: 1.3:1. This could be attributed to the potential nutrients capacity to sustain crops (Organic carbon, Total Nitrogen, P, K, Ca and Mg) which is in the order of surface soil > sub soil A > sub soil B. [25] reported that increased soil nutrient status favoured the growth performance of *M. oleifera* seedlings. The ratio of fresh shoot weight to fresh root weight was significantly higher in 15 – 30cm followed by 0 – 15 cm and least by 30 – 45 cm (Table 3) suggesting that it is better to grow moringa in a sub soil A (15 – 30 cm soil depth) with a medium soil nutrients concentrations. Higher nutrient could favour moringa root elongation and development at the expense of vegetative growth (shoot). This conforms to the report of [25] that stated that organic manure generally increased root

FWS- fresh weight of shoot, FWR- fresh weight of root, FBW- fresh biomass weight, RL- root length, DWS- dry weight of root, ns- not significant, * significant difference at P=0.05 S x F = Interaction between soil depth and field capacity length and root girth of moringa seedlings as compared to the control. Water stress significantly influenced both fresh and dry weight of *M. oleifera* seedlings (Table 3). The fresh weight of total biomass of moringa seedling was reduced by 0.8, 19.3 and 65.5% respectively when field capacity was reduced to 75%, 50% and 25% FC. Fresh weight of moringa shoot was in the ratio of 1: 1.6:2:2 for 25%FC, 50 %FC, 75% FC and 100%FC, respectively (Table 3). This implies that reducing field capacity beyond 50% could have adverse effect on growth performance. As reported by [14], most plant species experience a decline in their tissue relative water content due to water stress, leading finally to a decline in net photosynthesis and ultimate yield. Root fresh weight to root fresh weight was nearly the same from 100%FC to 50%FC but it was three times higher

at 25% FC than 100 – 50% FC. Higher root weight observed at 100 to 50% FC could serve as water storage to meet up evapo-transpirational demand of atmosphere and physiological need of the plant. This is contrary to[14] that recorded the root to shoot ratio of 2.1 times higher in water stressed plants indicating that plant roots thrived under water stress conditions.

Mineral Composition of *M. oleifera* Dry Stems and Leaves as Affected by Soil Depth and Water Stress

Mineral composition status of moringa seeds used for planting is presented in Table 4. The sown seeds contained N (45.0 g kg^{-1}), P (276.9 mg kg^{-1}), Ca (1056 mg kg^{-1}), Cu (24.7 mg kg^{-1}), Zn (16.0 mg kg^{-1}) and Fe (885 mg kg^{-1}) at the point of sowing. Analysis of dry harvested stems at 8 WAS revealed that soil depth significantly (P=0.05) influenced mineral composition of moringa stem (Table 5). Moringa stems obtained from surface soil (0 – 15cm) were significantly higher in macro- and micro-nutrients than subsoil A and B. This shows that the nutrient status of soil could influence the mineral composition of *M. oleifera* seedlings. Surface soil which had higher nutrient concentration produced stems and leaves richer in nutrients than subsoil A and B (Table 6). It is also interesting that the dried moringa leaves have high deposit of mineral elements. Calcium was higher in moringa from surface soil than subsoil. Calcium is required for formation and maintenance of bones and teeth thus, preventing osteoporosis. It is also needed for normal blood clothing and nervous function. Moringa seedling from surface soil contained higher Fe contents in both stems and leaves than subsoil (Tables 5 and 6). Iron is a component of haemoglobin and myoglobin for oxygen transport and cellular processes of growth and division [26]. In term of energy metabolism, Fe facilitates transfer of electrons in the electron transport chain for the formation of ATP [26]. Higher Fe contents suggest that moringa leaves could be added to animal feed to maintain a healthy livestock [27]. This is because Fe is an essential trace element for normal functioning of the central nervous system and in the oxidation of carbohydrates, proteins and fats [28]. Therefore, moringa leaves could be included in feed formulation for healthy livestock production.

* = significant difference at P=0.05; ns = no significant difference at p = 0.05; S x F = Interaction between soil depth and field capacity

* = significant difference at P=0.05; ns = no significant difference at p = 0.05; S x F = Interaction between soil depth and field capacity

Conclusion

The potential soil nutrient capacity determines to a very large extent the mineral composition of M. Oleifera stems and leaves for human and livestock consumption. Surface soil with higher macro and micro nutrients produced a remarkable plant height, number of leaves and stem girths. For optimum growth performance, moringa seedlings must not be stressed beyond 50% field capacity irrespective of soil depth. This implies that water stress could be a major factor limiting moringa cultivation. The results also demonstrated that the total amount of water needed to grow moringa depends on the soil texture and nutrients which vary down the profile. In addition, the mineral composition of moringa are clear indications that the plant stems and leaves are rich in nutrients and has potential to be used as a feed additive with multiple purposes. Growing moringa on a fertile soil could produce stems and leaves that are rich in mineral composition which can serve as nutritional, medicinal and thera-peutic for animal and human feed formulations. Therefore, dried moringa leaves can be used to improve animal health and nutrition in Africa.

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