Morphological Responses of *Moringa* (*Moringa stenopetala* L.) Accessions Seedlings to Irrigation interval under Greenhouse Conditions

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Abstract
Moringa (*Moringa stenopetala* L.) has a wide range of adaptability and various uses for human life. However, the plant is not well researched under Ethiopian conditions to maximize its benefit and exploit its potential. Therefore, a pot experiment was conducted to investigate the morphological responses of *M. stenopetala* accessions seedlings to irrigation intervals under greenhouse conditions at Hawassa, Ethiopia. The experiment was conducted using three accessions (Konso, Arbaminch Zuria, and Humbo) and four irrigation intervals (daily, 5 days interval, 10 days interval, and 15 days interval watering) assigned in a completely randomized design with three replications. The accessions significantly differed for most of the morphological traits studied in this experiment. The accession Arbaminch Zuria was higher in seedling height, stem diameter, leaf area, root length, root fresh weight, root dry weight, total seedling fresh weight, and total seedling dry weight than the other accessions. There were no significant differences between Arbaminch Zuria and Konso accessions in leaf number and root diameter. Regarding the irrigation interval, the highest seedling height, stem diameter, leaf area, leaf number, root length, root diameter, root fresh weight, root dry weight, total seedling fresh weight and total seedling dry weight were obtained from the daily watering interval. In contrast, the lowest growth parameters were from the 15 days interval watering. The 10 and 15 days interval watering were statistically similar for seedling height and leaf number. Additionally, fresh and dry leaf weights were significantly influenced by the interaction effect of accession and irrigation interval. The Arbaminch Zuria accession grown under daily watering had the highest fresh and dry leaf weights compared to the other accessions. Shorter interval of irrigation, if possible daily, is recommended to produce quality Moringa seedlings in a shorter period.

Keywords: Drought, Plant height.

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INTRODUCTION
The high demand for food, nutrition and medicine is putting intense deficit in the world (Jane, 2015; FAO, 2018). Therefore, focusing on nutritious, medicinal, multi-purpose and drought tolerant plants is necessary. *Moringa (Moringa stenopetala)* is one of the world's most valuable plants. Indeed, it is considered as a super food and storehouse of nutrition in addition to being remedy for more than 300 diseases (Daba, 2016; Mall and Tripathi, 2017). It is also used for water purification material, and oil and biogas source. Besides, *Moringa* is fast growing plant under wide range of agro-ecologies (Badran *et al*., 2016; Daba and Adisu, 2017).

Moringa stenopetala is domesticated in the east African lowlands and is native to southern Ethiopia (Eyassu, 2014). Several ecotypes and accessions of *M. stenopetala* exist in Ethiopia. *Moringa stenopetala* is often called "cabbage tree" and is an important indigenous vegetable in south western Ethiopia, where it is cultivated as food crop (Eyassu, 2014). It has been adapted in southern Ethiopia, particularly around Konso, Gamo, Goffa, Burji, and South Omo areas for a century (Yohannes and Teshale, 2016). Nowadays, it is hardly possible to find a household without a *Moringa* tree in Konso, Gamo and Goffa homesteads. Hence, *M. stenopetala* is a favorite and main component of the daily meal of the people at the area (Personal observation). *Moringa stenopetala* is particularly important as human food because the leaves have high nutritional value, appear towards the end of the dry season when other sources of green vegetables are limited (Abuye *et al*., 2003).

Nevertheless, biotic and abiotic factors such as pests, soil, temperature, and water deficit can affect and reduce its potential growth, development and functions (Palada and Chang, 2003). Among numerous factors, water deficit is a significant factor in dryland areas and it is critical to seedling growth and development (Awodol and Nwoboshi, 1993). *Moringa* does not have a preference towards a specific habitat but it performs better in hot and humid environments, and thus found throughout a range of eco-zones from dry savanna to rainforests (ref???). It generally prefers altitudes below 600 meter above sea level, although it can grow at elevations of up to 2000 meters in protected tropical zones (Anonymous, 2006). Because of the tuberous taproot, *Moringa* trees are capable of enduring anything between as little as 250 mm to 1500 mm of annual rainfall. Even though *Moringa* is drought tolerant, longer irrigation intervals reduce cell expansion, enlargement, growth and development of plants, especially during early stages (Kamara *et al.*, 2003; Shao *et al*., 2008; Jaleel *et al.*, 2009; Badran, 2016).

Moringa is highly heterozygous because it is highly cross pollinated in nature and has a wide variability in morphological traits (Amoatey *et al*., 2012). Several studies revealed that morphological traits of *Moringa* (seedling height, stem collar girth, root length and diameter, leaf number and area, fresh and dry weights) varied under different irrigation intervals (Wafa, 2006; Kenneth, 2012; Baiyeri *et al*., 2015; Jane *et al.* 2015; Sale *et al.*, 2015; Jacob, 2016). However, in Ethiopia, research on seedling performance of *M. stenepetala* accessions under different water management schemes has not been conducted and documented (Eyassu, 2014; Ashenafi, 2014; Sreepada and Vijayalaxmi, 2013). Instead, previous researches have focused mainly on field surveys to assess the traditional uses of *M. stenopetala* based on information from *Moringa* growers. Furthermore, research has been focused on its potential values for human nutrition, water purification, livestock feed, dyes, herbal medicine, oil production, and climate mitigation (Mall and Tripathi, 2017). Therefore, this study investigated morphological responses of *M. stenopetala* accessions seedlings to irrigation intervals.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted under greenhouse condition during October 2018 – January 2018 at Hawassa, Ethiopia. The site is located at 7°05′55" N latitude and 38°47'45" E longitudes, and at an altitudinal of 1689 m.a.s.l. According to 11 years (2007-2018) data, the average annual rainfall and temperature (maximum and minimum) of the area is 971.9 mm, and 27.9 °c and 13.8 °c, respectively, (NMA, 2019).

Description of the greenhouse and its condition

The greenhouse used for the experiment was metal framed protected with metal wire from all sides. The top of the greenhouse was covered by polyacrylic. The daily minimum and maximum air temperatures in the greenhouse were recorded on randomly selected locations for 45 days using mini data logger during the experimental period from October to January 2018. Data logger was placed inside an open bucket to avoid direct sunlight and hanged close to the seedling canopy. The data logger recorded the climate data every hour for 45 days. The average value of 45 days measurements is presented in Fig 1.

Mean minimum and maximum air temperature in the greenhouse were 12.6 ^{0}C and 28.9 ºC, respectively (Fig. 1). Therefore, the greenhouse condition was in the range of optimum temperature (20 to 35 ºC) for raising *Moringa* seedling as described by Alatar, (2011) and Muhl *et al.* (2011).

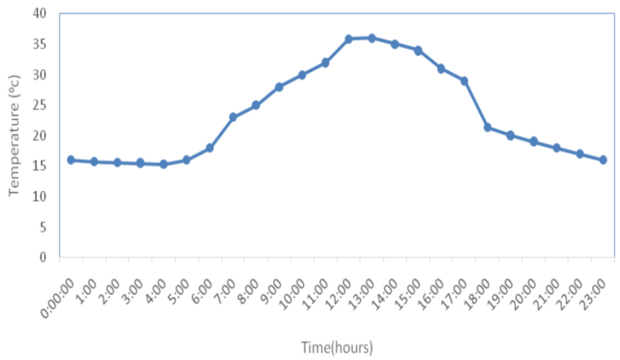

Figure 1. Average daily greenhouse temperature during experimental period (October to January 2018).

Experimental Materials and Procedures

Three *M. stenopetala* accessions seeds were obtained from Arbaminch Agricultural Research Center (AARC), Ethiopia (Table 1). Seeds were planted in perforated black polyethylene tube with 22 cm length and 16 cm wide filled with a soils mixture of top soils, compost and river sand at a ratio of 3:2:1 following the recommendation by Ede *et al*. (2015).

Soil particle size distribution was determined by the Boycouos hydrometric method (Van Reeuwijk, 1992) after destroying OM using hydrogen peroxide (H_2O_2) and dispersing the soils with sodium hexameta phosphate ($NaPO_3$).

Table 1. Description of *Moringa stenopetala* accessions used for the experiment.

Accession code	Origin of accession	Growing altitude	Source

Arbaminch Zuria	Arbaminch Zuria	1222 masl	AARC
Humbo	Humbo	1432masl	AARC
Konso	Konso	1320 masl	AARC

Source: Arbaminch Agricultural Research Center (Personal Communication)

Soil bulk density was determined after drying the soil samples in an oven at 105 ºC to constant weights, while particle density was measured by the pycnometer method (Black, 1965). The pH of the soils was measured in water and potassium chloride (1M KCl) suspension in a 1:2.5 (soil: liquid ratio) potentiometrically using a glass-calomel combination electrode (Van Reeuwijk, 1992). The electrical conductivity (EC) of soils was measured from a soil water ratio of 1:2.5 socked for one hour by electrical conductivity method as described by Sahlemdhin and Taye (2000). The Walkley and Black (1934) wet digestion method was used to determine soil carbon content and percent soil organic matter. Total N was analyzed using the Kjeldahl digestion, distillation and titration method as described by Black (1965) by oxidizing the OM in a concentrated sulfuric acid solution (0.1N H_2SO_4). The soil moisture content at field capacity was determined using pressure plate apparatus (FAO, 2006) (Table 2). Then, the perforated black polyethylene tubes filled with media were arranged under a greenhouse in a factorial scheme of 4 x 3, that was, four irrigation intervals [daily (Control), five day interval, ten days interval and fifteen days interval] and three *M. stenopetala* accessions (Konso, Arbaminch Zuria and Humbo). The 12 treatment combinations were arranged in completely randomized design with three replications. The amount of water required to apply in the perforated black polythene tubes to field capacity was calculated by the formula recommended by FAO (2006) as follows:

$$\text{Amount of water to be applied} = (FC - AMC) x\ D\ x\ A$$

Where, FC = Volumetric moisture content at FC and AMC = Actual volumetric moisture content determined by moisture tester, D = Depth of the perforated black polythene tubes (cm), A= Perforated black polythene tubes area (cm^2).

Table 2. Physical and chemical properties of the experimental media

Properties	Determined values
Soil textural class	Sandy loam
Sand (%)	84.68
Silt (%)	8
Clay (%)	7.32
Total nitrogen (%)	0.4538
Organic matter (%)	9.076
Organic carbon (%)	5.265
pH of media	7.3
Electro conductivity(ms cm^{-1})	0.52
Bulk density(g/cm^2)	1.02
Moisture content at FC (v/v %)	31.9

Two seeds of each *M. stenopetala* accessions were sown on 09 October 2018 at depth of 2 cm and then thinned after germination. All Experimental units were watered to field capacity until the commencements of the treatments (up to 13 days after emergence of seedlings). Then the treatments were applied until the seedlings reached first transplantation. Thereafter, the seedlings were subjected to watering interval treatments, and the seedlings were maintained in those irrigation intervals for two months while subsequent measurement and observations were made on their morphological attributes.

Data Collection

Seedling height and stem diameter (cm) were measured using the method by Ede *et al*. (2015). Seedling height was measured from the surface of the seedling above the media up to tip of the seedling. Seedling stem diameter was measured with digital caliper on the collar of the seedling.

Root length and root diameter (cm) were measured using the method by Jane *et al*. (2015). Three seedlings were randomly selected, and the perforated polyethylene tube was removed with sharp scissors, thereafter, to protect breaking of roots to adhered soil, exactly blow stem- root junction of the seedling was inserted in to the large pot water until the soil adhered with root has been washed. Then, it was measured using a 30 - centimeter ruler placed along-side from underground surface to the root tip of the seedling root. Root diameter was measured using a digital caliper (precision in mm).

Leaf area was measured using the method by Jane *et al*. (2015). The equipment used was LI- 3100C Area meter (precision Square cm), LI-COR. Bio science area meter, Australia.

Total Seedling fresh weight (g) and Leaf fresh weight **(g)** were measured using the method by Ede *et al*.

(2015). After destructive sampling (two months after emergence), seedling fresh weight was recorded by placing whole seedling on sensitive balance. Thereafter, leaves were removed (separated) from selected seedlings. Finally, leaf fresh weight was recorded separately.

Total seedling dry weight (g) and Leaf dry weight **(g)** were measured using the method by Badran *et al*. (2016). After fresh weights of the samples were recorded (at two month), samples were placed in paper bags and then oven dried for 48 hours at 70 ^oC temperature. Whole seedling and leaf dry weights were measured by electronic sensitive balance.
Fresh and dry weights (g) of root were measured using the method by Wafa and Adam (2006). Three seedlings were selected randomly (at two month). In order to protect breakage of roots in to the adhered soil, part of the seedling exactly below the stem- root junction was inserted in to large pot water until the soil adhered with root was washed. Afterward, the above ground part of the seedlings were separated by using sharp scissor, and then the below ground part sample was rolled by plastic and brought to laboratory. Fresh weight was recorded immediately after harvest using electronic sensitive balance. Finally, roots were placed in paper bag and oven dried with adjusted temperature at 70 ^oC for 48 hours and then the root dry weight was recorded.

Data Analysis
All data collected were subjected to analysis of variance (ANOVA) using proc GLM procedure of SAS version 9.3 (SAS Institute, 2009). Tukey's HSD test was used to separate means at the 5% level of significance.

RESULTS AND DISCUSSION

Morphological Response of *Moringa stenopetala* Accessions Seedlings to irrigation interval

Seedling stem and leaf traits
The seedling height, stem diameter, leaf number and leaf area of *Moringa* were significantly (P<0.001) influenced by accession and irrigation interval (Table 3). The interaction effect of accession and irrigation interval significantly affected leaf fresh and dry weights. However, all other morphological parameters mentioned above were not significantly (P>0.05) influenced by the interaction of the accessions and irrigation interval (Table 3).

Current results indicated that Arbaminch Zuria accession had the tallest seedlings, the largest stem diameter and wider leaf area compared to the other accessions. On the other hand, accession Humbo was the shortest seedling and had the smallest stem diameter, the least number of leaves and the smallest leaf area than the remaining accessions (Table 4). Accessions Arbaminch Zuria and Konso were not significantly different (P>0.05) in the number of leaves produced. These results are in agreement with Baiyeri *et al.* (2015), who reported significant variations among the accessions of *M. oleifera* seedlings in height, stem diameter, leaf number and area. This might be due to the genetic variability and differences in growth environment of the accessions.

Table 3. Mean square values of seedling height (SH), stem Diameter (SD), leaf number (LN), leaf area (LA), root fresh weight (RFW), leaf fresh weight (LFW) and leaf dry weight (LDW) of *Moringa stenopetala* accessions under different irrigation interval.

Source of variation	Df	Mean squares SH	SD	LN	LA	RFW	LFW	LDW
Accession(A)	2	30.749***	0.042***	137.00***	8091.27***	78.55***	0.45***	0.680***
Irrigation Interval(II)	3	152.945***	0.407***	805.18***	41837.94***	3743.64***	21.31***	7.309***
A* II	6	0.464^{ns}	0.0018^{ns}	13.46^{ns}	417.22^{ns}	1.057^{ns}	0.070**	0.105***
Error	24	0.432	0.0013	7.851	179.71	3.614	0.020	0.0026
CV (%)		**4.25**	**5.21**	**12.64**	**10.84**	**8.2**	**5.43**	**3.92**

*Where, ns=indicates non-significant difference at P≤5%,**significant difference at P<0.01% and ***significant difference at P<0.001% probability levels, respectively. df = degree of freedom*

Moreover, seedling height had strong positive association (r=0.94***) with leaf number (Table 5). Furthermore, the largest leaf area produced might be due to the wider leaves produced by accession Arbaminch Zuria. Regarding irrigation interval, the tallest seedling, the largest stem diameter, higher number of leaves and wider leaf area were produced on seedlings grown under daily watering condition. Whereas, seedlings grown under 15 days interval watering produced the smallest stem diameter, and narrow leaf area. Seedling height and leaf number of the seedlings grown under 10 and 15 days interval were not significantly different (P>0.05). Thus, this study confirmed that the seedling height, stem collar girth, leaf number and area of the *M. stenopetala* accessions decreased as watering interval increased. Similar results have been reported by Sale *et al.* (2015), who reported significant decrease in seedling height, stem diameter, leaf number and leaf area of *Moringa* as watering interval increased. Likewise, Daba and Adisu (2017) also reported that plant height significantly increased as watering interval decreased. At the third month after treatment application, Baiyeri *et al.* (2015) also reported significant difference among watering interval in seedling height and stem collar girth of *Moringa*. In other plants like citrus seedlings (Wue *et al*., 2008), and *Abelmoschus esculentus* (Sankar*et al.*, 2008) studies also indicated that increased water stress reduced seedling height and girth of the different cultivars. In general, the inhibition of cell expansion and cell growth is mainly due to low turgor pressure under water deficit conditions, which leads to reduced seedling girth (Shao *et al.*, 2008). Increased irrigation interval was also found to lead to inhibition of cell expansion, cell growth, and developmental process of the plant depending on the accession (Majiken, 2005).

Table 4. Responses of seedling height (cm), stem diameter (cm), leaf number (count) and leaf area of three *Moringa stenopetala* accessions seedling to irrigation interval under greenhouse condition at Hawassa.

Treatments	Parameters			
Accessions	Seedling height (cm)	Stem diameter (cm)	Leaf number	Leaf area (cm^2/plant)
Konso	15.41± 0.26^b	0.69±0.01^b	22.88±1.14^a	123.81 ±5.47^b
Arbaminch Zuria	17.07±0.26^a	0.75±0.01^a	25.11±1.14^a	149.50±5.47^a
Humbo	13.87±0.26^c	0.63±0.01^c	18.47±1.14^b	97.56±5.47^c
Tukey/HSD	0.67	0.03	2.85	13.66
Irrigation Interval				
Daily (control)	20.39±0.30^a	0.98±0.01^a	35.37 ±1.32^a	215.13 ±6.31^a
5 days interval	17.29±0.30^b	0.70±0.01^b	21.96±1.32^b	134.95±6.31^b
10 days interval	12.34± 0.30^c	0.56±0.01^c	17.77± 1.32^c	81.06±6.31^c
15 days interval	11.78±0.30^c	0.51±0.01^d	13.52± 1.32^c	63.35±6.31^d
Tukey/HSD	0.85	0.04	3.64	
CV (%)	4.25	5.21	12.64	

Where, HSD= honestly significant difference, CV= Coefficient of variation, means with different letter in each column of each factor are statistically significant at P≤ 0.05%.

M. stenopetala accessions responded differently when they were exposed to different irrigation intervals (Table 5). The highest leaf fresh and dry weights were measured on accession from Arbaminch Zuria under daily watering conditions. The results further revealed decline in leaf fresh and dry weight variation among the accessions as the stress was intensified. Generally, the Konso accession performed better under 15 days irrigation interval for leaf fresh and dry weights.

The accession Arbaminch Zuria under daily watered conditions significantly differed from others, which indicated that, availability of water is an important factor to express the genetic potential of leaf growth. This indicates that irrigation interval limited the growth potential and narrows down the difference in growth of *Moringa* accessions. The study showed that evaluations of plants under more stressed conditions cannot reflect the true potential of a particular plant or accession. However, the present study indicated that increasing irrigation interval significantly reduced leaf fresh and dry weight of *M. stenopetala* accessions. In line with our study Majken*et al. (*2005) revealed that as plants subjected to different level of irrigation interval, the reduction of leaf fresh and dry weight might be due to the reason that, leaf production and leaf expansion growth are very sensitive to water availability. Furthermore, the leaf production and leaf expansion growth were gradually reduced when plants are subjected to prolonged irrigation interval (Jaleel *et al.*, 2009).The result was also in agreement with works reported by Wafa (2006), Jacob (2013) and Badran *et al*. (2016) who indicated that, leaf fresh and dry weight of *Moringa* are reduced with respect to increased irrigation interval.

Table 5. Interaction effect of accessions and irrigation interval on leaf fresh and dry weight of *Moringa stenpetala* seedlings under greenhouse condition at Hawassa.

	Irrigation interval			
Accessions	Daily	5 Days interval	10 Days interval	15 Days interval
	Leaf fresh weight (gram per plant)			
Konso	4.88±0.11[b]	2.25±0.11[cd]	1.93±0.11[defg]	1.52±0.11[g]
Arbaminch Zuria	5.33±0.11[a]	2.48±0.11[c]	1.96±0.11[def]	1.63±0.11[efg]
Humbo	4.56±0.11[b]	2.03±0.11[d]	1.70±0.11[efg]	1.58±0.11[fg]
	Tukey/HSD = 0.42		CV (%) = 5.43	
	Leaf dry weight (gram per plant)			
Konso	2.56±0.04[b]	1.84±0.04[cd]	0.75±0.04[g]	0.50±0.04[h]
Arbaminch Zuria	2.80±0.04[a]	1.70 ±0.04[d]	0.97±0.04[f]	0.43±0.04[hi]
Humbo	1.88±0.04[c]	1.39± 0.04[e]	0.55±0.04[h]	0.32±0.04[i]
	Tukey/HSD = 0.15……………………CV (%) =3.92			

Where, HSD= honestly significant difference, CV= coefficient of variation, means wit hdifferent letters in the same parameter are statistically significant at P ≤ 0.05.

Root traits

Root length (cm), collar diameter (cm), fresh and dry weight (gram per seedling)

The longest root length, the highest root diameter, fresh and dry weight was recorded from Arbaminch Zuria accession (Table 6). In contrast, the shortest root length, the thinnest diameter and the smallest root fresh and dry weight was observed in accession Humbo. However, there was no significant (P>0.05) difference in root length among accessions Konso and Humbo. Whereas, there was no significant (P>0.05) difference between Arbaminch Zuria and Konso accessions in root diameter. The variability shown in the present study might be due to the existing genetic variability of the accessions for root related traits. Moreover, the difference among the accessions observed in root biomass could be attributed to longer root length and wider girth of the seedlings.

With regard to irrigation interval, the longest root length, the highest root girth, the largest fresh and dry weight of *M. stenopetala* were recorded from seedlings grown under daily watering. On the other hand, the shortest root length, the lowest root girth, fresh and dry weights were recorded on the seedlings watered in fifteen days interval watering. The present study results also indicated that irrigation intervals significantly influenced all root traits (Table 6). The reduction in root length observed in this study was in agreement with the findings of Badran *et al.* (2016), who observed that the growth declined as watering interval increased. The present result was also confirmed with the study conducted by Daba and Adisu (2017), who reported that root diameter of *M. oleifera* decreased as watering interval increased.

Similarly, root fresh and dry weight of *M. stenopetala* in the present study has been related with patterns reported by Wafa, (2006) and Badran *et al.* (2016), who indicated that, prolonging irrigation interval reduced root fresh weight of *M. oleifera* and *M. peregriana*. Dunford and Vazquez (2005) reported also that, decreased moisture in the soil had a significant reduction in root fresh weight. Additionally, as described above, the reduction of root dry weight might be associated with root length and fresh weight influenced by irrigation interval.

Table 6. Impact of irrigation interval on root length, root diameter, root fresh weight and root dry weight of three *Moringa stenopetala* accessions seedling under greenhouse condition at Hawassa.

Treatments	**Parameters**			
Accessions	**Root length (cm)**	**Root diameter (cm)**	**Root fresh weight (g plant^{-1})**	**Root dry weight (gram plant^{-1})**
Konso	14.23±0.47^{b}	1.71±0.05^{a}	21.41±0.72^{b}	10.29±0.56^{b}
Arbaminch Zuria	16.18±0.47^{a}	1.72±0.05^{a}	24.33±0.72^{a}	13.64±0.56^{a}
Humbo	13.08±0.47^{b}	1.50±0.05^{b}	19.23± 0.72^{c}	7.90±0.56^{c}
Tukey/HSD	**1.19**	**0.12**	**1.81**	**1.41**
Irrigation Interval				
Daily (control)	18.296±0.55^{a}	2.38±0.05^{a}	51.60±0.83^{a}	19.39±0.65^{a}
5 days interval	14.96±0.55^{b}	1.68±0.05^{b}	17.34±0.83^{b}	12.53±0.65^{b}
10 days interval	13.35±0.55^{c}	1.41±0.05^{c}	10.26±0.83^{c}	6.92±0.65^{c}
15 days interval	11.39±0.55^{d}	1.24±0.05^{d}	7.40±0.83^{d}	3.61±0.65^{d}
Tukey/HSD	1.52	0.16	2.31	1.80
CV (%)	8.06	7.45	8.2	13.07

Means with different letter in each column of each factor are statistically significant at P≤0.05.

Total seedling fresh and dry weight

Total seedling fresh weight of the *M. stenopetala* seedling was significantly (P<0.001) influenced by accessions and irrigation interval (Table 7). Also, total seedling dry weight of the *M. stenopetala* seedling was significantly (P<0.001) influenced by both accessions and irrigation interval. However, there was no significant (P>0.05) interaction effect of accessions and irrigation interval on both total seedling fresh and dry weight of the *M. stenopetala* seedlings.

Table 7. Mean square values of total fresh weight (TFW) and total dry weight (TDW) of *Moringa stenopetala* accessions under different irrigation intervals

		Mean squares	
Source of variation	DF	TFW	TDW
Accession(A)	2	175.8***	1046.47***
Irrigation Interval (II)	3	4917.46**	324.47***
A* II	6	7.03^{ns}	6.90^{ns}
Error	24	3.614	2.925
CV (%)		**6.76**	**9.91**

*Where, ns, ** and *** indicates non-significant difference at P≤5%, significant difference at P≤1% and P≤ 0.1% probability levels, respectively. df = degree of freedom*

Maximum total seedling fresh and dry weight of the *M. stenopetala* seedling was recorded from the accession Arbaminch Zuria followed by accession Konso and the minimum total seedling fresh weight was recorded from accession Humbo (Table 8). The Maximum seedling fresh and dry weight of the accession Arbaminch Zuria might be associated with its greater production of leaf and root biomass.

With regard to irrigation interval, the highest total seedling fresh and dry weight was recorded on the seedlings grown under daily watering, followed by five days, ten days interval, and the seedlings watered with fifteen days intervals (Table 8). The present experiment revealed that, increased irrigation interval caused in decreased total seedling dry weight of *M. stenopetala* accessions. Similar pattern on *M. oleifera* and *M. peregrine* was reported that increased watering interval (increased drought stress) reduced total seedling fresh and dry weight (Wafa, 2006; Badran *et al*, 2016). Comparable results were also reported by several scholars on many other plants (Anyia and Herzog, 2004; Liuand Stutzel, 2004; Majken *et al.*, 2005; Jacob, 2013). This is because water deficit reduces cell expansion, enlargement, growth and development of plants, especially during early stage. Additionally, the reduction of the total seedling weight with increment of irrigation interval was as a result of a decrease in the correlated parameters such as seedling height, leaf number, leaf area, and root growth

Table 8. Impact of irrigation interval on total seedling fresh weight and total dry weight of three *Moringa stenopetala* accessions seedling under greenhouse condition at Hawassa.

Accessions	**Total fresh weight (gram plant^{-1})**	**Total dry weight (gram plant^{-1})**
Konso	27.80±0.77^{b}	15.61±0.69^{b}
Arbaminch Zuria	32.09±0.77^{a}	23.08±0.69^{a}
Humbo	24.45±0.77^{c}	13.07±0.69^{c}
Turkey/HSD	1.93	1.74
Irrigation Interval		
Daily (control)	61.80 ±0.89^{a}	31.05±0.80^{a}
5 days interval	25.63±0.89^{b}	20.00± 0.80^{b}
10 days interval	14.92±0.89^{c}	11.62±0.80^{c}
15 days interval	10.11±0.89^{d}	6.34± 0.80^{d}
Tukey/HSD	2.47	2.22
CV (%)	6.76	9.91

Means with different letter in each column of each factor are statistically significant at P-values ≤ 5%.

CONCLUSION AND RECOMMENDATION

Moringa accessions significantly differed for most of the morphological traits studied in this experiment. The accession Arbaminch Zuria was higher in seedling height, stem diameter, root length, leaf area, root fresh weight, total seedling fresh weight, root dry weight and total seedling dry weight than other accessions. On the other hand, accession Humbo was the lowest in seedling height, stem diameter, root length, leaf number, root diameter, leaf area, root fresh weight, total seedling fresh weight, root dry weight and total seedling dry weight than other accessions.

The experiment showed that *M. stenopetala* had the highest seedling height, stem diameter, root length, root diameter, leaf number, leaf area, root fresh weight, total seedling fresh weight, root dry weight and total seedling dry weight when daily watered, while, watering at 10 and 15 days intervals were statistically similar for seedling height and leaf number. However, the lowest stem diameter, root length, root diameter, leaf area, root fresh weight, total seedling fresh weight, root dry weight and total seedling dry weight were recorded from 15 days interval watering. Additionally, fresh and dry leaf weights were significantly influenced due to the interaction effect of accession and irrigation interval. Therefore, seedling growers can use Arbaminch Zuria accession and can water daily to produce quality *Moringa* seedlings.

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