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Integrated system for maximizing water unit productivity of Moringa vegetative yield under Shalatien conditions

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This study deals with using Modern irrigation system such as drip irrigation system, (Surface, SD and Subsurface, SSD) and mini-sprinkler, MS, as well for irrigating a magic crop like Morenga (*Morenga oleifera*) plants. Also, this work includes different irrigation water requirements which represent two deficits (ETc, 20%, T_2 and ETc, 40%, T_3) in addition to the control, (without any stresses, T_1). The experiment was carried out in an Abo Sfera area which belongs to Shalatien where it lies in the east-west of the Red sea in Egypt. Surface evaporation in this area has a paramount importance because of its aridity hot climate under the circumstances of saline irrigation water usage. The objective of the present work is to implement some of water deficits in computing water consumptive use of Morenga, to maximize the yield production under different irrigation systems, to save and conserve more water quantities, finally to keep the soil sustainable against degradation by using different kinds of natural soil conditioners such as compost, C, farm yard manure, FYM and filter-mud, FM. Results revealed that Evapotranspiration could be reduced 20% when sub-surface drip irrigation system was used comparing with surface or mini-sprinkler system. The most typical soil moisture patterns and homogeneous on the effective root zone of Moringa oleifera in sandy soil are SSD compared with both SD and MS irrigation systems. For the vegetative yield, such as WUE, plant height (cm), stem diameter (mm), number of leaves per plant, leaf area (cm^2), plant weight (kg/m^2), stems fresh weight (g/plant), leaves fresh weight (g/plant), stems dry weight (g/plant) and leaves dry weight (g/plant) of Moringa oleifera plants, in two studied seasons. (2017/18-18/19). The highest significant values are obtained positively by SSD, T_3, T_2 and C, so it can saved about 20% of ETc for Moringa oliefra under shalateen conditions or any other region characterized by arid, hot and desert climate, provided that using the highest significant value treatments without any reduction of vegetative yield.

Keywords: Moringa Water Drip Mini-Sprinkler Soil-Moister Evaporation Compost WUE and Shalateen

INTRODUCTION

Moringa (Moringa *oleifera*) is a tropical plant and exhibits certain degree of xerophytic behavior. Botanically the perennial Moringa types are featured with large size water storage cells in limbs and low transpiration rate to tolerate against drought and also have the adaptation of shedding all its leaves to reduce transpiration loss. Moreover the developing fruits are autotrophic since they also contain high chlorophyll content and also draw water from the storage cells for photosynthesis. This mechanism was helpful in the retention and development of fruit. Moringa can be successfully grown in soils with good drainage viz., red loam, red sandy loam, clay loam and sandy loam soils. Moringa roots are highly sensitive to water logging. Annual Moringa types raised through seeds requires frequent and regular irrigation compared to perennial or country types. In annual Moringa types the roots are highly succulent and fast spreading and draw more water from the subsoil region, hence it needs frequent and regular irrigation Agronomic practices viz., Summer ploughing, broad bed and furrow system, adoption of drip irrigation system, mulching with crop residues, use of organic manures and humic substances can be integrated for successful soil moisture management of Moringa for high flowering and fruit yield. (Armelle de Saint Sauveur and Mélanie Broin 2002. And Rajangam et al. 2010)

A drip irrigation system has been demonstrated to improve crop productivity, reduce energy costs, improve irrigation efficiency and reduce water loss by deep percolation. When implementing a drip irrigation system. (Yassen et al., 2006; Eddahhak et al., 2007 and El-Sayed, 2007). Drip irrigation systems are having an important priority in the new reclaimed area. Drip irrigation systems were found to result in 30 to 70% water savings in various orchard crops with 10 to 60% increase in yield as compared to conventional methods of irrigation. Surface and subsurface drip irrigation methods can play a significant role in overcoming the scarcity of water mostly in water shortage areas (Talat F. A.et al. 2012). Surface drip irrigation systems and subsurface drip irrigation have been part of the new agriculture. Current commercial and grower interest levels indicate that future use of subsurface drip irrigation systems will continue to increase. Subsurface drip irrigation applies water below the soil surface, using buried drip tapes (ASAE). (2001). Subsurface drip irrigation uses buried lateral pipelines and emitters to apply water directly to the plant root zone. Subsurface drip irrigation requires the highest level of management of all micro irrigation systems. The performance of the drip irrigation should be tested under adverse conditions of shallow water table and heavy soils. In addition, irrigation management is a tool whereby timely application of water can improve irrigation efficiencies and ultimately yields, (Baille A. 1997). Studies on the effects of furrow, micro-jet, surface drip, and sub-surface drip irrigation on vegetative growth and early production of crimson Lady' peach [Prunus persica (L.)] trees indicated that subsurface drip irrigation improves vegetative growth. (Bryla, D. R(2003). The highest yields (190 kg/tree) are coupled with the largest increase in average fruit size with irrigation at a crop factor of 0.9 on a 3 day cycle. With this consumption micro-jet irrigation gave better results than drip irrigation, (Plessis. 1985). The arid environments (high air temperature, low humidity and wind) causes of water losses in sprinkler irrigation systems, reached to30% of total applied water. (Spurgeon et al. 1983). The water losses during sprinkler irrigation process may be reaching to 45% under the hard conditions of high sun radiation and low air humidity. (Frost and Schwalen, 1955).

The sugarcane press-mud increased nutrients in the soil and affected the agronomical attributes of S. melongena in both the growing seasons. The maximum agronomical performance of S. melongena was observed with 40 % treatment of the sugarcane press-mud. Thus, sugarcane press-mud can be used as a bio-fertilizer in lower proportion (up to 40 %) to improve yield of this crop. Further studies on the agronomic growth and changes in biochemical composition of S. melongena after sugarcane press-mud treatments are required to use different field conditions. (Vinod K. and A. K. Chopra, 2016). Sugarcane press-mud is the solid residue produced after filtration of sugarcane juice. The purification process separates the juice into a clear juice that rises to the top and goes for the manufacture of sugar, and a mud that collects at the bottom (Gaikwad et al. 1996; Bokhtiar et al. 2001; Sharma et al. 2002). The mud is then filtered to separate the suspended matter, which includes insoluble salts and fine bagasse (Partha and Sivasubramanian 2006; ; Jamil et al. 2008).

In intensive cropping systems, the need to start with a very fertile soil is crucial. Large amounts of compost, well decomposed manure or mineral fertilizers will still be needed to maintain productivity at an appreciably high level (Akinbamijo et al. 2004). Moringa plant can survive in harsh climatic condition, including barren soil without being much affected by drought. It is a plant with exceptional medicinal properties which can resolve the health care needs in several situations. Moringa is an outstanding source for nutritional component necessity. Its leaves contain calcium 4 times that of milk, vitamin C 7 times that of oranges, potassium 3 times that of bananas, iron 3 times that of spinach, vitamin A 4 times that of carrots, and protein 2 times that of milk. Hence, it is considered as a powerhouse of nutritional value. Easy cultivation of Moringa within adverse environmental circumstance attracts attention for economic and health related potential in resource limited developing countries (Aslam et al., 2005; Kamal, 2008; Anjorin et al., 2010 and Raja et al. 2013). Drought affects plant water potential and turgor, possibly leading to changes in physiological and morphological traits of plants (Vurukonda et al., 2016).

List of acronyms and nomenclature		
SD	:	Surface drip irrigation systems,
SSD	:	Subsurface drip irrigation systems,
MS	:	Mini-sprinkler irrigation system,
T_1	:	00% of ETc,
T_2	:	20% of ETc,
T_3	:	40% of ETc,
C	:	Compost,
FYM	:	Farm Yard Manure, and
FM	:	Filter Mud

The main objective of the present work was to study integrated system for maximizing water unite productivity of *Morenga oleifera* vegetative yield under arid areas conditions.

MATERIALS AND METHODS

Morenga seedlings (15 cm height) are transplanted manually in successful two seasons 2017/2018 and 2018/2019; the space of plants is 2 m and 2.5 m of the plant row.

A field experiment was carried in an Abo Sfera area which belongs to Shalatien where it situates in the east-west of the Red sea in Egypt (elevation 12.75 m, Latitude 31° 22' 55' N and 29° 27' 15' E.). Soil samples have variable origins and CaCO3 content were collected from the studied area, namely, Typic Torripsamments, Mixed, Hyperthermic and Typic Calciorthents, loamy mixed, Thermic, respectively according to Soil Taxonomy as described by Soil Survey Staff (1975). The study is conducted to evaluate the interaction effect of some soil organic fertilization, (i.e., Compost, Farm Yard Manure and Filter Mud), in addition to the suitable irrigation water scheduling by (20% and 40% as soil moisture depletion treatments) in addition to 0.00% (as a control) treatment quantities calculated from Penman – Monteith equation under the modern irrigation system, (i.e. surface and sub-surface drip irrigation systems besides mini sprinkler) on maximizing Morenga production. All treatments repeated three times under statistical design as Split - Split plot design.

The studied area is characterized as a desert region and the soil of the experimental site was deep, well- drained sandy composing of 78.95% sand, 16.95% silt and 4.44% clay, with an alkaline pH 7.9, EC 0.54 dS/m, CaCO3 15.55 %, O.M 0.44% as an average shown in table (1_a&$_b$).

An irrigation water sample was taken and the chemical properties were determined according to (Black, 1983). Of the studied area. The data in table (2) shows the value of electrical conductivity of irrigation water, which reached 4.23 dS/m and pH 7.65. The highest value of cations was for Na, (18.34 me/l) and the highest value of anions was for Cl-, (35.67 me/l). This means that the dominant salt is NaCl, which need to spotlighted in this trial.

Soil measurements:

Soil samples were taken under three used irrigation systems, by a screw auger at three spaces from beginning of the drip main line, the space between samples were 20 cm, and at three depths (20,40, and 60cm) at two direct X and Y where the horizontal and vertical space of the sample was 20 cm. Samples were analyzed for determining both soil moisture and salt accumulation. The results were drawn by SURFER, ve. 11 under on a color scale for soil moisture 1-50 and for soil salt distribution from1-100, under windows program, and the "Kriging" regression method as the base model for analysis and contour map development.

The experiment was arranged in Split – split plot design consisting of combinations of irrigation methods (surface and sub-surface drip irrigation systems) in addition to the mini-sprinkler and was replicated three times in 2.5 m X 3 m apart of trees. The compost consisted of a mixture of various organic residues (plant and animal residues). Table (3) shows Chemical properties of this product. Values of moisture content reached 23%, 18% and 7% for compost, farmyard manure and Filter mud, respectively, while C/N ratios were 12.42, 19.52 and 10.5, EC values were 1.04, 5.29 and 1.01dS. M-1 (determination in extraction by 1: 10) according (Klute, 1986) with the same mentioned order as well.

Average meteorological data of the experimental Field study, (Averages of 30 years 1985-2015) according to Climatic Atlas of Egypt (2015) is shown in table (4) while data in table (5) was collected through the work season indicates that the maximum air temperature ranges between 18.90° C and 31.20° C while the minimum temperature values ranges between 8.50° C in February and 23.60° C which reaches its maximum value in August month.

Table 1a: Soil physical properties of the studied area.

Depth, cm	Particle size distribution%				Textural Class	Bd ($Mg.m^{-3}$)	Moisture content,102KPa	
	Coarse Sand	Fine Sand	Silt	Clay			0.06	15
0-20	12.91	61.97	20.21	4.91	L.S	1.66	14.55	5.89
20-40	15.22	63.58	18.21	4.99	L.S	1.69	13.96	5.56
40-60	17.11	61.44	17.31	4.14	L.S	1.68	13.58	5.45
60-80	14.19	66.04	15.22	4.55	L.S	1.67	14.02	5.70
80-100	20.15	61.55	14.11	4.19	L.S	1.66	13.88	4.88
>100	23.22	56.34	16.61	3.83	L.S	1.65	13.33	4.87
Average	17.13	61.82	16.95	4.44		1.67	13.89	5.39

L.S = Loamy Sand

Table 1b: Soil chemical properties of the studied area.

Depth, Cm	CaCO3, %.	EC, dS/m	PH	% O.M	Cations me/l				Anions me/l			
					Na+	K+	Ca++	Mg++	CO_3=	HCO_3-	Cl -	SO_4=
0-20	17.25	0.76	7.9	0.32	0.72	0.31	2.81	3.76	0.0	0.30	3.22	4.08
20-40	14.52	0.67	7.9	0.34	0.73	0.30	2.82	2.85	0.0	0.32	3.09	3.29
40-60	15.58	0.49	7.8	0.65	0.65	0.29	1.89	2.06	0.0	0.28	2.81	1.81
60-80	15.08	0.50	7.8	0.54	0.61	0.32	2.71	1.36	0.0	0.28	2.85	1.87
80-100	16.39	0.36	8.0	0.48	0.50	0.28	1.92	0.90	0.0	0.26	1.82	1.85
>100	14.50	0.43	8.0	0.33	0.42	0.28	1.89	1.71	0.0	0.28	1.89	2.13
Average	15.55	0.54	7.90	0.44	0.61	0.30	2.34	2.11	0.00	0.29	2.61	2.51

Table 2: Chemical analysis of irrigation water.

EC, dS/m	PH	Cations me/l				Anions me/l				SAR
		Ca++	Mg++	K+	Na+	CO_3=	HCO_3-	Cl-	SO_4=	
4.23	7.65	11.70	8.19	4.05	18.34	0.0	6.00	35.67	0.61	5.56

Table 3: Chemical analysis of Compost, farmyard manure and Filter mud added to the experimental field.

Organic Matter Source	Moisture content %	pH (1:10)	EC (1:10) dS.m-1	N. ppm	C. ppm	C/N Ratio	P. %	K. %	OM %
Compost, C	% 23	7.04	1.04	0.69	17.98	12.42	0.16	0.59	51.8
farmyard manure, FYM	%18	7.84	5.29	1.82	10.73	19.52	0.49	0.58	34.3
Filter mud, FM	%7	7.02	1.01	0.54	19.44	10.5	0.11	0.48	24.16

Table 4: Average meteorological data of the experimental Field study, (Averages of 30 years) 1985-2015

Months	Max Temp. C°	Min. Temp. C°	Avg. Temp. C°	Relative Hum. %	Sunshine Hr. hr	Wind Speed Km/h	Total Rain mm.	Effective Rain mm.	Solar Radiation ($MJ/m^2/day$)	Evapotranspiration (mm/day)
Jan.	17.50	7.50	12.50	70.00	7.20	18.67	15.0	12.00	12.30	2.90
Feb.	17.50	10.00	13.75	65.00	8.20	15.08	10.0	8.00	15.70	3.15
Mar.	22.50	12.50	17.50	60.00	8.70	20.88	10.0	8.00	19.40	4.99
April	25.00	15.00	20.00	60.00	9.40	18.38	7.00	5.60	22.70	5.75
May	27.50	17.00	22.50	60.00	10.80	17.29	1.00	0.80	25.90	6.56
June	27.50	20.00	23.75	60.00	12.30	17.33	0.00	0.00	28.40	6.94
July	30.00	22.50	26.25	70.00	12.00	8.33	0.00	0.00	27.80	5.96
Aug	32.50	22.50	27.50	70.00	11.70	8.50	0.00	0.00	26.30	6.04
Sep.	30.00	22.50	26.25	70.00	10.60	9.00	1.00	0.80	22.60	5.14
Oct.	27.50	20.00	23.75	65.00	9.40	8.21	5.00	4.00	18.10	4.07
Nov.	22.50	15.00	18.75	70.00	7.90	11.92	10.0	8.00	13.60	3.11
Dec.	20.00	12.50	16.25	65.00	6.60	14.75	15.0	12.00	11.10	2.99
Avg.	25.00	16.46	20.73	65.42	9.57	14.03	6.17	4.93	20.33	4.80
Ann.	325	213.5	269.5	850.42	124.4	182.4	74	59.2	264.23	1752

Table 5: Meteorological data of the studied area as average of 2017

Element	Months of the year												Year
	Jan	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	
Max.T	25.5	26.5	28.3	31.7	34.7	36.5	37.4	37.4	36.1	33.9	30.4	26.8	32.1
Min.T	14	14.3	16.1	18.9	22.4	23.6	25.3	25.6	24.2	22.3	19.1	15.8	20.1
Avg.T	26.1	19.75	20.4	22.2	25.3	28.55	30.05	31.35	31.5	30.15	28.1	24.75	21.3
Mean RH	69.00	68.00	66.00	63.00	65.00	63.00	72.00	70.00	71.00	72.00	76.0	71.00	68.83
Wind Speed (m/sec)	2.86	2.70	3.88	3.85	3.82	4.06	3.88	3.96	3.25	2.91	3.00	3.80	3.50
Sunshine hours	10	11	12	12.7	13.3	13.5	13.5	12.9	12.3	12.6	11.6	10.7	12.2
Rs (MJ/m2/d)	11.70	15.20	18.90	22.60	25.40	28.10	27.90	25.90	22.40	17.80	13.00	11.10	20.00
G (MJ/m2/d)	-0.14	-0.01	0.59	0.20	0.40	0.30	0.22	0.08	-0.24	-0.52	-0.42	-0.55	0.00
Ra-G	4.58	6.70	9.20	12.27	14.47	16.19	17.03	15.53	12.97	9.32	6.00	4.54	10.73
Total Rain (mm)	0	0	0	1	0	0	0	0	0	2	9	2	1.2
S = Kpa/oC	0.104	0.104	0.132	0.147	0.171	0.191	0.207	0.214	.196	0.161	0.137	0.110	0.151

Table 6: Irrigation schedule for Moringa plantations in the studied area

Growth Stages	Early spring	Spring	Late spring	Early summer	Summer	Late summer	Early fall	Fall
Phenological stage	Flower bud development - bloom	Pod-set	Pod growth stages: cell division -pit hardening		Pod growth stages: cell enlargement			Harvest and fall growth
Evaporation (mm/day)	5.6	7.3	8.7	8.7	8.0	6.9	5.4	3.5
No. of days/ stage	15	31	30	31	30	31	30	31
Crop coefficient	0.40	0.40	0.50	0.50	0.55	0.55	0.55	0.4
(liters/tree)	30	40	50	60	60	60	50	30
m^3/ha.	338.7	912.0	1315.4	1359.8	1330.6	1186.4	898.1	437.5
m^3/ha/day	22.56	29.424	104.4	43.872	44.352	38.28	29.9376	14.112
* Moringa – annual water consumption rate: 7778.4 m^3/ha								

The relative humidity is nearly high and reaches its maximum mean value in November month. The sunshine hours vary from 7.20 in January to 12.30 in June. The wind velocity ranges between 8.33 in July and 20.88 in March. The total rainfall occurs through December, January, February and March months' are15. 00, 15.00, 10.00 and 10.00 mm, respectively. Evapotranspiration (mm/day), which calculated according Penman-Monteith equation, (Allan et al., 1998), is ranged from 2.90 in January to 6.94 in June and reached to be 1752 mm for the annual average value of 30 years.

Irrigation systems and control head:

The drip irrigation system was used to irrigate Moringa trees. The system consists of a diesel pump (18m^3/h, flow rate) which takes water from open sub-surface tank (75m^3 capacity) through two filter units, the first one is screen (130 mesh) and the other is gravel filter.

Climatic Atlas of Egypt (2015)

The filtration system is controlled by safety valve, relief valve, four control valves, pressure regulator unit, flow meter unit, air tank (balloon) unit, 6.4 mm pressure meter. The manifold is 50 mm PVC pipeline with 50 mm end plug for flushing. The drippers flow rate of 4 L/h (GR), the space of two drippers is 50cm. They were installed in 16 mm Polyethylene laterals, surface and subsurface systems. Mini sprinklers were installed with each 10 meters apart.

Phenological stages and irrigation schedule for Moringa plantations in the studied area are shown in table (6) which cleared how much irrigation water need, (m^3/ha/day) for every growth stage and when they added besides to the crop coefficient which ranged from 0.4 for the early spring and harvest stages to 0.5 for the other most Moringa growth stages . Also, the table shows that the annual irrigation rate was 7714 m^3/ha.

Daily rate (liters/tree) as water amounts for Moringa trees is shown in Table (6) which ranged from 30 in the early spring and fall growth stages to 60 in the summer season besides the irrigation interval (days) which ranged from 3 to 7 days.

The Evapotranspiration process combined of two processes whereby water is lost from the soil surface by evaporation and on the other hand from the crop by transpiration. (Allen et al., 1998) selected the FAO Penman–Monteith method to estimate ETo as follows:

Penman – Monteith equation

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

Where:

ETo	Reference Evapotranspiration (mm day^{-1}),
Rn	Net radiation at the crop surface (MJm^{-2} day^{-1}),
G	Soil heat flux density (MJ m^{-2} day^{-1}),
T	Mean daily air temperature at 2 m height (ºC),
U_2	Wind speed at 2 m height (m s $^{-1}$),
e_s	]Saturation vapor pressure (Kp_a),
e_a	Actual vapor pressure (Kp_a),
e_s-e_a	Saturation vapor pressure deficit (Kp_a),
Δ	Slope vapor pressure curve (Kpa ºC^{-1}), and
γ	Psychometric constant (Kpa ºC^{-1}).

Actual water consumption (ETa) for each treatment was determined according to the following equation:

ETa = (F.C. % - M %) X Bd X D X 1000 mm.

Where:

ETa Actual Evapotranspiration, mm/period.
F.C. Field capacity of soil.
Bd Bulk density of soil, g/cm^3.
D Soil depth, 3 depths on 20 cm.

The irrigation rate of olive orchards (the most similar tree of Moringa) was calculated based on the Penman - Monteith equation, multiplied by the season-specific crop coefficient (KC) Table (6). Seasonal crop water requirement: 7714 m^3/ha/ year; under drip irrigation system as mentioned above. ETcrop can be found by the equation that aforementioned that Allen et al. (1998) reported that crop coefficient is "The ratio of the actual Evapotranspiration (ETa) occurring with a specific crop at a specific stage of growth to potential Evapotranspiration at the same time, i.e.

KC = ETa / ETo

Where:

KC crop coefficient.
ETa actual Evapotranspiration, mm/day.
ETo potential Evapotranspiration, mm/day.

Vegetative system yield measurements:

All the plants of each plot were harvested and have measured fresh and dry during left to air dry the next vegetative system measurements are taken as follows: Plant height (cm), stem diameter (mm), number of leaves per plant, leaf area (cm^2), plant weight (kg/m^2), stem fresh weight (g/plant), leaves fresh weight (g/plant), stems dry weight (g/plant) and leaves dry weight (g/plant) of Moringa oleifera plants, in two studied seasons. (2017/18-18/19).

Water use efficiency (kg/m^3):

It is expressed as the weight of yield (kg/ha). Computed for the different treatment by using the formula of El-Boraie (2006) and Viets (1965), as follow:

WUE=Biological yield (kg/ha) / Applied water amounts (m^3/ha), according to Vietes (1965).

Statistical analysis

All the obtained data during the two seasons of study were subjected to analysis of variance method according to (Snedecor and Cochran, 1990). Meanwhile, differences among means were compared using Duncan's multiple range tested at a probability of 5 % level (Duncan, 1955)

RESULTS AND DISCUSSION

Soil moisture patterns under irrigation systems:

Surface drip irrigation systems:

The soil moisture patterns SD irrigation system in sandy soil cleared, that the water distribution and concentration of the maximizing value in the deep layers of soil (40 to 60 cm soil depth). Which is about 11.5% in addition to the non-uniformity of soil moisture distribution on vertical direction where the volume metric of soil moisture in layers (0 to 30 cm) is about 5.5%. The crystal variation of soil moisture distribution under surface irrigation between the surface and depth layers is due to the water losses by soil evaporation from the soil surface, According the experiment site is located in very hot arid area (shalteen) and the sunshine hours increasing, temperature degree increasing which reach to 45 in some days. In general the climate in Shalateen is a desert climate. For this reason, the water losses by evaporation must be considered as an important source of water losses which must considered by water conserved., The root system of plants is adapted and mitigated according to the availability of water in soil layers, but in limit zone. In general, most of plants take the water from the soil as graduated behaviors. According to the root depth, where the most plant water requirements are adsorbed by the root zone. In maximizing adsorbed water begging of surface layers, and decrease gradually where the root zone go into the depths soil. By other means trees root systems are important for tree anchorage and support. They also provide a mean of collection and transport of water and nutrients essential for tree growth and production. Studies of the citrus root distribution in Florida have shown the potential for citrus to very deeply root and extensively under favorable environmental conditions. These studies showed that the depth of rooting was influenced by tree age, rootstock, soil type, and drainage characteristics. Irrigation practices also affect citrus root system development and distribution. Soil water status is a major component of the root environment, affecting the growth and health of roots (Boman et al., 2002). For example, the highest concentration of fibrous roots develops under the drip-irrigated systems within the volume of wetted soil around the emitters. Research conducted in Florida shows that soil water depletion is directly related to water availability and fibrous root abundance. The general pattern of water absorption of citrus trees suggests that water is depleted first in surface roots experiencing high soil water content. As the available water supply decreases the surface soil there is an increase in absorption from roots at successively greater depths in advance of the drying front (Noling, 2003) and (Boman et al., 2002).

The last scenario is affected by the root system health, according to the root zone environment, by the same token, the plant growth and health are negatively affected by the water stress, which happened as a result to the non-uniform water distribute in soil depths. According to the water losses, which are happening by evaporation, which is happening from the soil surface and directly from a water drop during the irrigation time, It's important to mention that in aired area the water losses by evaporation reach to Bonachela et al. (2001). Figure: (1)

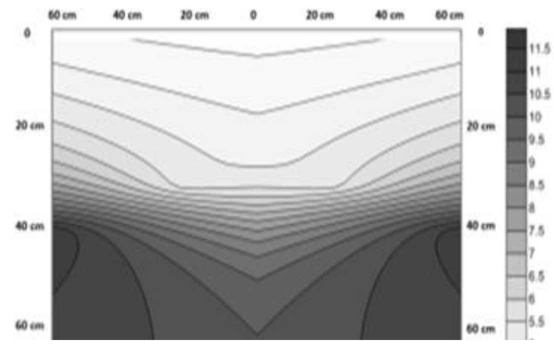

Figure 1: Soil moisture patterns under SD

Subsurface drip irrigation systems:

Regarding to soil moisture patterns under sub-surface drip irrigation systems, SSD, It's clear that the homogenous of water distribution in the soil profile in the radial direction and vertical direction. The results are due to the irrigation hose is buried at 20 cm below the soil surface. For this, the water losses by soil surface evaporation are reduction and water conserved by sub-surface drip technique, especially in this arid area. It is can note that the maximize soil moisture value is about 15% and ranged to 11% vertically and radially in the soil profile. It's a typical soil moisture distribution in sandy soil under the desert climate conditions. As a consequence, the root system is very healthy and has a typical environmental growth reasons, and the plant also does not suffer from any water stress according to save about 35% of applied water.

(Dukes and Scholberg, 2005) show that subsurface drip irrigation systems may increase water use efficiency due to reduced soil and plant surface evaporation and because only the root zone or the partial root zone is irrigated as opposed to sprinkler irrigation where the entire field area is wetted.

(Lamm and Trooien, 2002) mention that, 10 years of SDI research on corn in the Great Plains and reported that water savings of 35% to 55% were possible compared to traditional forms of irrigation such as sprinkler and furrow. Automation of SDI systems based on soil moisture sensors may further improve water use efficiency.

In this investigation, the most of high significant positive values of vegetative yield and physical characterizes of Moringa oleifera plants are under sub-surface drip irrigation according to the saving of water losses by conserved during the burial of the water emission point (Gr hose) under soil surface. Figure (2).

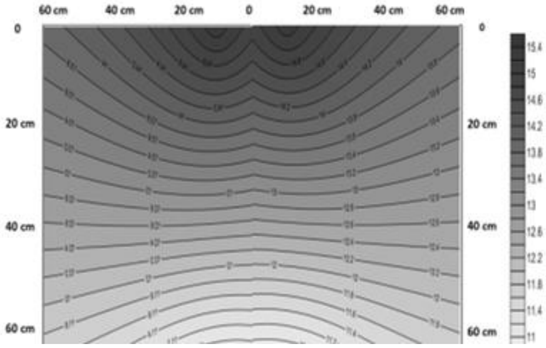

Figure 2: Soil moisture patterns under SSD

Mini-sprinkler irrigation systems:

No one can deny the advances of mini-sprinkler irrigation systems. Especially in sandy soil where the wetted volume is very narrow. In addition to the water distribution is radially poor. But mini-sprinkler support a full wetted zone in circle circumference, according to the jet radius of water, where the operating pressure works to emit the water droplet for one meter of the mini-sprinkler location center. In other means, the horizontal direction of soil moisture contents is very narrow comparing vertical direction. As a result, to reduction of water hold capacity of sandy soil. The last water movement type encourages the water movement to soil lower layers in deep depths. And then, water losses by deep-percolation of the underground water. For these challenges, mini sprinkler is considered the typical irrigation system in sandy soil (in general in light soil). Despite the last features of mini-sprinkler, but in this investigation. Mini-sprinkler systems have the lower significant values positively, for the vegetative system, physical characterizes and water use efficiency. During this investigation, by having considered area zone and environmental conditions, it is also reasonable to look at the reasons of mini-sprinkler efficiency reductions. That is due to the hot, sunrise hours, wind and dry climate which is going to extremes in trail site, so the water losses under mini-sprinkler by evaporation according to the water droplets of MS jet. Which eases the water evaporates, in addition to the wind erosion. Moreover the high ratio of water application in mini-sprinkler systems, as shown in mini-sprinkler soil moisture the maximum soil moisture values are about 21% and concentrate in the surface layers which make water is more available to evaporate and increase the water losses, from both of soil surface, plant surface and water droplet in air during the irrigation process time.

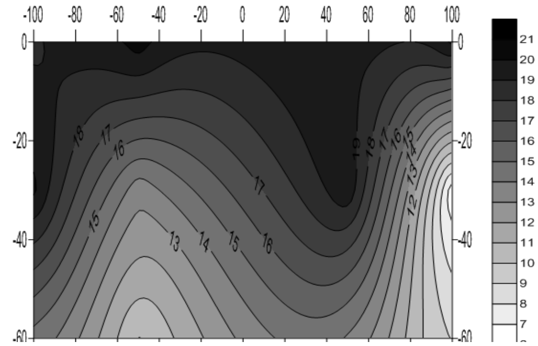

Figure 3: Soil moisture patterns under MS

Yazar (1984). mention that, the water losses have ranged from 1.5 to 16.8% of full sprinkled water, the wind speed and humidity, pressure are the most important factors which increase the water losses.

Frost and Schwalen (1955) reported the water losses during sprinkler irrigation process may be reaching to 45% under the hard conditions of high sun radiation and low air humidity.

Water use efficiency of Moringa oleifera:

The water use efficiency is expressed in the ratio between the marketable yield of plant (kg) and the field consumption water (m^3). But it is important to mention that, the marketable yield is variable from plant to another. According to what is the usage parts of the plant and the economic feasibility of these parts, so the yield may be a bulb, leaf, seed, oil, straw… etc.. In this study, the yield is all of the plant, according the magic tree (*Moringa oleifera*) has the economic features of all of plant parts. The data illustrated in table (7) showed the high significant values of WUE are positive (SSD + T_2 + C) and (SSD + T_3 + C), on the other side, the lowest significant values of WUE is (MS + T_3 + Filter-mud). And these results agree with the last soil moisture description under three irrigation systems. It is important to note that, the WUE values may be a trick, according it depends on the ratio of yield and water. economic. In general, the highest significant values are obtained by SSD, T_2 and C treatments, under Shalteen environmental conditions. And this So where the applied water value is decreasing the WUE is increasing. So it must be in the economic yield per area unit. For this reason, the WUE value (SSD + T_2 + C) is acceptable, but the WUE is not acceptable according the last one is not result is agreed with (Vasconcelos et al. 2019 and EL-Sayed M.M. and A. W. M. Mahmoud, 2018). Figure (4).

Table 7: Effect of Irrigation system and Irrigation water deficit on WUE (kg/m^3) of *Moringa oleifera* plants, in two studied seasons. (2017/18-18/19).

Irrigation system	Irrigation water deficit as a depletion	Soil conditioners		
		Compost, C	Farm Yard Manure, FYM	Filter Mud, FM
Surface Drip, SD	0%, T_1	18.54^{D}	8.09^{K}	5.58^{R}
	20%, T_2	16.77^{E}	7.22^{M}	5.96^{PQ}
	40%, T_3	20.97^{C}	7.36^{M}	6.27^{O}
Sub-Surface Drip, SSD	0%, T_1	23.49^{B}	9.49^{J}	8.09^{K}
	20%, T_2	26.57^{A}	9.68^{L}	7.22^{M}
	40%, T_3	26.55^{A}	10.89^{I}	7.36^{M}
Mini-Sprinkler, MS	0%, T_1	11.98^{H}	5.61^{R}	5.27^{S}
	20%, T_2	13.09^{G}	6.08^{OP}	5.57^{R}
	40%, T_3	16.23^{F}	6.58^{N}	5.76^{GR}

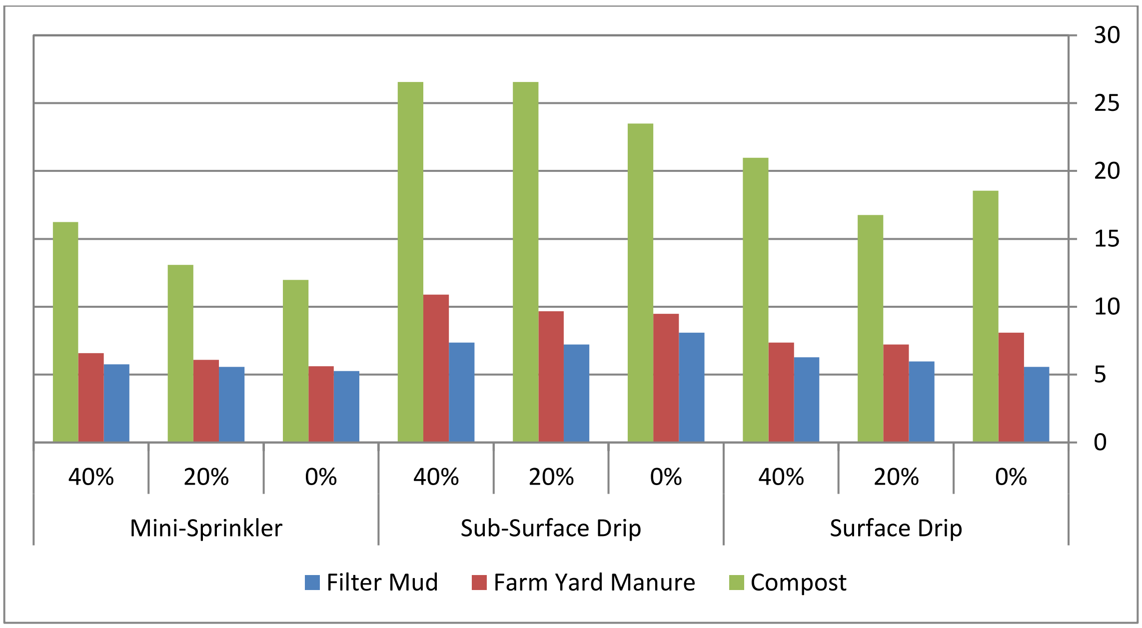

Figure 4: The means of water use efficiency of *Moringa oleifera* plants under variable treatments

Table 8: Effect of Irrigation system and Irrigation water deficit on plant height (cm) of *Moringa oleifera* plants, in two studied seasons. (2017/18-18/19)

Irrigation system	Irrigation water deficit as a depletion	Soil conditioners		
		Compost, C	Farm Yard Manure, FYM	Filter Mud, FM
Surface Drip, SD	0%, T_1	103.33^{B}	77.67^{CDE}	76.44^{CDE}
	20%, T_2	76.78^{E}	74.44^{DE}	71.78^{E}
	40%, T_3	70.78^{A}	66.00^{G}	58.22^{H}
Sub-Surface Drip, SSD	0%, T_1	115.33^{A}	90.78^{B}	88.78^{BC}
	20%, T_2	94.44^{A}	87.67^{C}	84.67^{D}
	40%, T_3	72.89^{A}	83.56^{C}	81.22^{CD}
Mini-Sprinkler, MS	0%, T_1	79.78^{CD}	62.33^{B}	47.00^{E}
	20%, T_2	72.78^{F}	59.67^{C}	56.22^{D}
	40%, T_3	58.66^{C}	59.22^{C}	46.67^{E}

Irrigation is an important limiting factor of crop yield, because it is associated with many factors of plant environment, which influence growth and development. Availability of adequate amount of moisture at critical stages of plant growth not only optimizes the metabolic process in plant cells but also increases the effectiveness of the mineral nutrients applied to the crop. Consequently, any degree of water stress may produce deleterious effects on growth and yield of the crop (Saif et al., 2003). Surface irrigation method is the most widely used all over the world (Mustafa et al., 2003).

Moringa physical characterizes yield:

Plant height (cm) of Moringa oleifera:

It is obvious from the data presented in table (8) that Compost recorded the highest significant value, concerning water treatments, where the mini-sprinkler recorded the lowest significant value of plant height (cm) of Moringa oleifera plants, in two studied seasons. (2017/18-18/19). For more clearing, the highest mean value of plant height (cm) is (SSD + T1 + C), (115.3 cm) where the lowest value is (MS + T_3+ FM), (46.7 cm). It's important to mention that the last results are agreed with Maria et al., (2010), Ranbir Singh et al. (2002) and (Vasconcelos *et al.* 2019).

Stem diameter (mm) of Moringa oleifera:

The data in table (9) showed that, concerning the stem diameter (mm) of Moringa oleifera plants,

In two studied seasons. (interactions and the all of interaction of the rest data, in addition to by saving about 20% of Etc under SSD and c 2017/18-18/19) that there is no significant deference between the interaction of next factors (SD + C + T_1), (SSD + C + T_1) and (SSD + C + T_2) by notice that there are significant differences between the last treatment there is no significant which means it can saved about 20 % of Etc without any decrease in stem diameter (mm) of *Moringa oleifera* plants. According to (Vasconcelos et al. 2019).

Number of leaves per Plant of Moringa oleifera:

It's crystal clear in the table (10) regarding the water deficit, the (T_1, T_2 and T_3) it is can note that there is insignificant difference between them according to the limit response of leafs number to water stress, in the same time the © treatment with (SD + T_3), (SSD + T_1), (SSD + T_2) and (SSD + T_3) had the highest significant values. The leave of number is an important indicator of plant healthy and typical environmental conditions, these results are agreed with (Vasconcelos *et al.* 2019).

Leaf area (cm^2) of Moringa oleifera:

The date in Table (11) clear that under compost treatment, the SD and SSD irrigation systems significantly affected plant leaf area by having the highest significant differences on the leaf area (cm^2) of Moringa oleifera plants, in addition to (SD + T_1 + FYM), (SSD + T_2 + FYM), (SSD + T_3 + FYM) and (SSD + T_1 + FM), on the other hand the interaction of both of actors (MS + T3 + FM) affected negatively on the leaf area (cm^2) of Moringa oleifera plants, where it had the lowest significant deference. And these data are agreed with (Mohy, 2011) and Khattab et al. (2011).

Plant weight (kg/m^2) and yield of Moringa oleifera:

The data in table (12) showed that, concerning the two studied seasons, the compost additions affected positively on the plant weight where it include the highest value significant differences regarding the water deficit and irrigation systems, In contrast, FM had the lowest value significant differences of plant weight which means that, the FM doesn't affected significantly on the weight of plants. (SD + T_1 + C), (SSD + T_1 + C), (SSD + T_2 + C), affected positively on the yield of Moringa and had the highest significant values according to the compost increases the water hold capacity of soil in additional to subsurface drip irrigation save about 30% of water losses by evapotranspiration where study area is located in aired and hot zone. So it can save about 20% of Etc under shalateen condition using subsurface irrigation drip and compost additions, on the other hand, It is obvious from the table data that the lowest significant value are obtained by both of FM and FYM treatments, which mean both of FYM and FM treatment regarding the interaction with both of irrigation systems and water deficit affected negatively on Moringa yield according the water losses by evaporation and water deficit under FYM and FM treatments.

Table 9: Effect of Irrigation system and Irrigation water deficit on stem diameter (mm) of *Moringa oleifera* plants, in two studied seasons. (2017/18-18/19)

Irrigation system	Irrigation water deficit as a depletion	Soil conditioners		
		Compost, C	Farm Yard Manure, FYM	Filter Mud, FM
Surface Drip, SD	0%, T_1	9.45^{A}	7.89^{BC}	7.67^{BCD}
	20%, T_2	8.78^{CD}	7.33^{CD}	7.34^{BCD}
	40%, T_3	8.56^{AB}	7.22^{CD}	7.00^{CD}
Sub-Surface Drip, SSD	0%, T_1	14.00^{A}	9.78^{ABC}	10.34^{AB}
	20%, T_2	11.00^{A}	9.56^{BCD}	9.45^{BCD}
	40%, T_3	9.56^{B}	8.11^{BCD}	8.56^{BC}
Mini-Sprinkler, MS	0%, T_1	8.34^{D}	7.22^{BCD}	6.67^{E}
	20%, T_2	8.11^{BCD}	6.89^{E}	6.67^{D}
	40%, T_3	6.89^{CD}	6.33^{D}	6.22^{D}

Table 10: Effect of Irrigation system and Irrigation water deficit on number of leaves per Plant of *Moringa oleifera* plants, in two studied seasons. (2017/18-18/19)

Irrigation system	Irrigation water deficit as a depletion	Soil conditioners		
		Compost, C	Farm Yard Manure, FYM	Filter Mud, FM
Surface Drip, SD	0%, T_1	14.11^{A}	12.33^{AB}	10.89^{ABC}
	20%, T_2	12.22^{BC}	11.22^{ABC}	10.45^{CDE}
	40%, T_3	11.44^{ABC}	10.78^{CDE}	10.44^{B}
Sub-Surface Drip, SSD	0%, T_1	15.78^{A}	12.78^{AB}	13.00^{AB}
	20%, T_2	13.22^{A}	12.68^{BC}	11.33^{CD}
	40%, T_3	12.00^{A}	12.44^{B}	11.11^{BCD}
Mini-Sprinkler, MS	0%, T_1	12.78^{AB}	10.78^{AB}	10.33^{BC}
	20%, T_2	12.22^{A}	10.56^{D}	10.11^{ABC}
	40%, T_3	11.22^{ABC}	10.44^{ABC}	10.00^{B}

Table 11: Effect of Irrigation system and Irrigation water deficit on leaf area (cm^2) *of Moringa oleifera* plants, in two studied seasons. (2017/18-18/19)

Irrigation system	Irrigation water deficit as a depletion	Soil conditioners		
		Compost, C	Farm Yard Manure, FYM	Filter Mud, FM
Surface Drip, SD	0%, T_1	420.00^{A}	418.00^{A}	370.67^{BC}
	20%, T_2	418.33^{A}	384.00^{B}	360.67^{C}
	40%, T_3	396.00^{A}	377.67^{B}	350.67^{C}
Sub-Surface Drip, SSD	0%, T_1	496.67^{A}	475.33^{B}	418.00^{A}
	20%, T_2	444.33^{A}	431.00^{A}	389.00^{B}
	40%, T_3	421.67^{A}	418.33^{A}	372.33^{B}
Mini-Sprinkler, MS	0%, T_1	386.33^{B}	369.33^{c}	354.00^{C}
	20%, T_2	361.67^{C}	369.33^{C}	345.00^{C}
	40%, T_3	351.33^{C}	356.33^{C}	341.67^{D}

Table 12: Effect of irrigation system and irrigation water deficit plant weight (kg/m²) and yield of *Moringa oleifera* plants, in two studied seasons. (2017/18-18/19)

Irrigation system	Irrigation water deficit as a depletion	Soil conditioners					
		Compost, C		Farm Yard Manure, FYM		Filter Mud, FM	
		Plant weight (kg /m²)	Yield T/ha*	Plant weight (kg /m²)	Yield T/ha*	Plant weight (kg /m²)	Yield T/ha*
Surface Drip, SD	0%, T_1	6.512^{A}	144.2^{A}	3.996^{B}	62.9^{DE}	3.033^{C}	43.4^{DE}
	20%, T_2	6.398^{C}	104.3^{B}	3.788^{AB}	44.9^{EF}	2.606^{F}	37.1^{DE}
	40%, T_3	4.454^{A}	97.9^{B}	3.449^{AB}	34.4^{F}	2.513^{B}	39.3^{E}
Sub-Surface Drip, SSD	0%, T_1	9.152^{A}	182.7^{A}	4.553^{D}	73.8^{C}	3.202^{F}	62.9^{DE}
	20%, T_2	7.578^{B}	165.4^{A}	4.410^{D}	60.2^{CD}	3.163^{C}	44.9^{EF}
	40%, T_3	6.595^{A}	123.9^{B}	4.142^{DF}	50.8^{DE}	3.135^{A}	34.4^{F}
Mini-Sprinkler, MS	0%, T_1	5.489^{A}	93.2^{C}	3.345^{B}	43.6^{DE}	2.457^{C}	41DE
	20%, T_2	5.079^{A}	81.4^{CD}	3.285^{A}	37.8^{DE}	2.409^{C}	34.7^{DE}
	40%, T_3	4.074A^{B}	75.7^{CD}	3.244^{B}	30.7^{E}	2.386^{C}	26.9^{E}

*T/ha= Tons per hectar

Table 13: Effect of irrigation system and irrigation water deficit on stem fresh weight (g/plant) of *Moringa oleifera* plants, in two studied seasons. (2017/18-18/19)

Irrigation system	Irrigation water deficit as a depletion	Soil conditioners		
		Compost	Farm Yard Manure	Filter Mud
Surface Drip, SD	0%, T_1	53.73^{B}	37.98^{B}	30.21^{C}
	20%, T_2	48.89^{A}	36.33^{D}	30.00^{F}
	40%, T_3	45.33^{B}	33.95^{C}	29.53^{E}
Sub-Surface Drip, SSD	0%, T_1	99.58^{A}	42.22^{C}	33.12^{C}
	20%, T_2	80.70^{A}	41.99^{C}	32.22^{E}
	40%, T_3	57.92^{A}	38.89^{D}	32.17^{B}
Mini-Sprinkler, MS	0%, T_1	52.16^{B}	34.80^{D}	28.92^{D}
	20%, T_2	44.49^{A}	33.79^{C}	28.89F^{G}
	40%, T_3	42.64^{C}	33.14^{C}	28.56^{D}

Table 14: Effect of Irrigation system and Irrigation water deficit on stems dry weight (g/plant) of *Moringa oleifera* plants, in two studied seasons. (2017/18-18/19)

Irrigation system	Irrigation water deficit as a depletion	Soil conditioners		
		Compost, C	Farm Yard Manure, FYM	Filter Mud, FM
Surface Drip, SD	0%, T_1	20.097^{AB}	10.97^{A}	7.51 ^{BC}
	20%, T_2	19.247^{C}	10.930^{E}	7.46 ^{BC}
	40%, T_3	18.543^{BC}	10.423^{E}	7.43^{A}
Sub-Surface Drip, SSD	0%, T_1	49.520^{A}	12.420^{D}	8.12^{A}
	20%, T_2	27.443^{B}	11.137^{DE}	8.01^{A}
	40%, T_3	21.717^{A}	11.060^{E}	7.86^{AB}
Mini-Sprinkler, MS	0%, T_1	17.777^{C}	9.140^{EF}	7.360^{F}
	20%, T_2	14.173^{D}	8.30 ^{B}	7.42A^{BC}
	40%, T_3	12.733^{D}	8.127^{F}	7.17A^{BCD}

Table 15: Effect of Irrigation system and Irrigation water deficit on leaves fresh weight (g/plant) of *Moringa oleifera* plants, in two studied seasons. (2017/18-18/19)

Irrigation system	Irrigation water deficit as a depletion	Soil conditioners		
		Compost, C	Farm Yard Manure, FYM	Filter Mud, FM
Surface Drip, SD	0%, T_1	78.530^B	55.59^B	47.50^B
	20%, T_2	77.78^A	54.44^F	47.44^B
	40%, T_3	75.56^B	53.88^A	46.613^F
Sub-Surface Drip, SSD	0%, T_1	86.21^A	64.807^C	50.583^E
	20%, T_2	84.273^A	64.44^E	47.96^B
	40%, T_3	80.67^A	61.853^D	47.78^G
Mini-Sprinkler, MS	0%, T_1	71.11^C	52.48^C	45.56^H
	20%, T_2	68.89^D	52.05^C	44.05^B
	40%, T_3	67.78^D	51.997^E	43.98^D

Table 16: Effect of Irrigation system and Irrigation water deficit on leaves dry weight (g/plant) of *Moringa oleifera* plants, in two studied seasons. (2017/18-18/19)

Irrigation system	Irrigation water deficit as a depletion	Soil conditioners		
		Compost, C	Farm Yard Manure, FYM	Filter Mud, FM
Surface Drip, SD	0%, T_1	33.847^B	22.89^B	16.95^B
	20%, T_2	32.917^{BC}	22.593^C	16.42^E
	40%, T_3	30.853^C	22.033^E	16.170^E
Sub-Surface Drip, SSD	0%, T_1	61.520^A	25.45^A	18.47^D
	20%, T_2	42.153^A	24.94^A	18.287^D
	40%, T_3	35.177^B	23.93^{AB}	17.72^A
Mini-Sprinkler, MS	0%, T_1	29.533^B	21.13^C	16.09^A
	20%, T_2	28.120^D	20.28^C	16.01^E
	40%, T_3	26.990^D	19.10^A	15.870^F

Stem fresh/ dry weight (g/plant) of *Moringa oleifera*:

Data in table (13) and (14) showed that the same behaviors of data of biometric and physiological characterizes of Moringa, by other mean the highest values significant are obtained by SSD and C treatment regarding the water deficit, In contrast, the lowest significant values are obtained by MS, FM and 40% water deficit treatment, according to the water and heat stress which plant expose to them under both of the last treatments. It's important to mention that these data is agreement with (Vasconcelos et al. 2019).

Leaves fresh/ dry weight (g/plant) of *oringa oleifera*:

Regarding data in both of table (15) and (16), it's crystal clear SSD under C in addition to water deficit treatments had the highest significant values, correspondingly, the lowest significant values are obtained by MS, three soil conditioner with the water deficit 40%, T_3. Data is agreement with (Silva et al., 2008).

In general, water deficit (20% and 40% Etc) decreases the Moringa plant growth rate, by the same toked reduce the yield production, according to the biomass is related to the stomata closure mechanism and leaf area reduction which reduce in CO2 fixation and light interception, according to (Dresch et al. 2016) and (Silveira et al., 2016).

The Moringa biometric parameters remained stable during the water deficit process. This is due to many physiological processes of plants are affected by water deficit. Which make plant adaptation as follow: plant growth is controlled during cell division, and then by cell expansion; insufficient water maintains a cell that is growing zones under conditions. Thereby, it is reducing cell division coefficient and all cell expansion, thus preventing plants vegetative growth. According to (Taiz & Zeiger, 2009)

CONCLUSION

According to the previous results discussion of the investigation, it was clarified that the most acceptable irrigation system under arid zone conditions is subsurface drip irrigation. As a result to the water is saved by evaporation, compared with both of drip irrigation and mini sprinkler irrigation. The water deficit in variable system irrigation is significant under subsurface drip, drip and compost treatments, especially 20% of ETc, which can be saved, without any stress on vegetative yield. The most significant positively values of soil conditioners are obtained by compost compared with both of farm yard manure and filtermud. The most significant positive values vegetative yield and physical characterizes of Moringa oliefera are obtained by subsurface drip irrigation and compost under water deficit 0, and 20 % of Etc. the highest significant value of water use efficiency is for subsurface drip irrigation and compost under water deficit 20% of Etco. Moringa oliefera can adaptation and mitigation under arid condition by using subsurface drip irrigation, compost and save about 20% of water consumption.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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