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Irrigation and fertilization practices for Moringa plant growth under Upper Egypt conditions

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A field trial was conducted at The Experimental Farm, Fac. of Agric., Al-Azhar Univ., Assuit on a clay loam soil cultivated by Moringa plants on May 20th, 2015. The study aims to examine the effect of irrigation methods (drip and flooding) at different soil moisture depletion (50 and 75% SMD) with various fertilizer sources (chemical, compost and compost plus rock phosphate) on water consumptive use, water use efficiency, growth traits, yield, yield quality and physiological plants of *Moringa oleifera* Lam.

The applied amount of irrigation water and water consumptive use decreased as the percentage of soil moisture depletion (SMD) increased. the highest value of both field water use efficiency (FWUE = 0.53 kg/m^3) and crop water use efficiency (CWUE =0.58 kg/m^3) were recorded in the treatment of drip irrigation at 75% SMD with compost (CO), while the lowest values of FWUE (0.22 and 0.24 kg/m^3) and CWUE (0.32 and 0.34 kg/m^3) were recorded under flood irrigation at 50% SMD with chemical fertilization in the 1st cut and flood irrigation at 75% SMD with compost plus rock phosphate application (CO+RP) in 2nd cut, respectively. The drip irrigation method realized the highest yield and its components compared to that of flood irrigation method. As well as organic fertilization enhanced plant resistance for water stress compared to chemical fertilization.

The nutrient contents (N, P, K and Ca) in dry leaves were higher under drip irrigation at 50% SMD with CO+RP application (2.96, 0.008, 3.9 and 1.2 %, respectively). The highest value of Chlorophyll a (152.1 mg/ g FWt), chlorophyll b (32.6 mg/ g FWt) and Carotenoids (59.62 mg/ g FWt), soluble proteins (158.50 mg/ g FWt) and total antioxidants (62.61 mg/ g FWt) were recorded under drip irrigation at 50% SMD with CO+RP application. Drip irrigation at 75% SMD with CO+RP application showed the highest value of prolin (1.61 mg/ g DWt), falvonoids (2.31 mg/ g FWt), vitamin C (2.30 mg/ g FWt) and reducing power (0.307 mg/ g FWt) compared to other treatments. As well as Drip irrigation at 75% SMD with CO application showed the highest value of phenolics (8.34 mg/ g FWt) compared to other treatments.

Key words: Drip irrigation, soil moisture depletion, flood irrigation, compost, rock phosphate, Moringa plants, physiological component

Introduction

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 drip irrigation system, it is important to consider water use efficiency, humidity, temperature, ground water. Irrigation at 60 % water holding capacity and applying mineral nitrogen 60 kg/fed., with presence of the chicken manure as an organic fertilizer produced the highest wheat yield through two growth seasons (Yassen *et al*., 2006; Eddahhak *et al*., 2007 and El-Sayed, 2007).

Superphosphates are commonly recommended to correct phosphorus (P) deficiencies, but most developing countries import these fertilizers, which are often in limited supply and represent a major outlay for resource-poor farmers. In addition, intensification of agricultural production in these countries necessitates the addition of P not only to increase crop production but also to improve soil P status in order to avoid further soil degradation. Hence, it is imperative to explore alternative P sources. Direct application of rock phosphate (RP) especially where locally available has proven to be agronomically and economically sound alternative to the more expensive superphosphates. Rock phosphate is usually applied to replenish the soil P status, but upon dissolution it also provides other nutrients present in the rock phosphate (Chien, 2003). The EU-regulation 834/2009 only allows the

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application of rock phosphate as mineral phosphorus fertilizer in organic farming (Walker *et al.* 2006).

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). Shivakumar *et al*. (2004) found that application of rock phosphate in considerable amount under low moisture condition is necessary for getting high yields of chick pea. Jalil *et al*. (2014) reported that compost with rock phosphate increased dissolution of rocks. The physical and chemical condition of soil improved through usage of organic fertilizers. Combined compost with rock phosphate realized significant impact regarding nutrient uptake resulting an enhancement in yield (Muhammad *et al*., 2014).

Moringa plants 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 resolves 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).

Photosynthesis is particularly sensitive to abiotic stresses, with implications at chloroplast structure. A primary cell target of most abiotic stresses is the increase of reactive oxygen species and therefore, the antioxidant system is in general also affected. This was well shown for plants under water deficit (Dias *et al.,* 2014 and Xu *et al*., 2015). Drought affects plant water potential and turgor, possibly leading to changes in physiological and morphological traits of plants (Vurukonda *et al.,* 2016).

Therefore, this study was conducted to evaluate the effect of in organic, organic fertilizer and rock phosphate on Moringa plant growth under soil moisture deficit using different irrigation systems.

Materials and Methods

This study was conducted at The Experimental Farm, Fac. of Agric., Al-Azhar Univ., Assuit, Egypt (27° 12ˉ 16.67˭ N latitude, 31° 09ˉ 36.86˭ E longitude and at 51 m altitude) during summer growing season of 2015. The relevant chemical and physical properties of the investigated area were determined according to Page (1982) & Klute (1986) and they are shown in Table (1a &b).

Table (1a): Some chemical properties of the investigated soil.

Soil depth (cm)	OM (%)	$CaCO_3$ (%)	pH (1: 2.5)	SP	ECe (dS/m)	SAR	Available nutrients (ppm) N	P	K
0-30	**1.4**	**3.5**	**7.85**	**79**	**1.15**	**4.05**	**70**	**10**	**325**
30-60	**1.19**	**3.18**	**7.88**	**78**	**1.2**	**4.06**	**66**	**9.8**	**310**

OM = organic matter SP = saturation % SAR = sodium adsorption ratio

Table (1b): Some physical properties of the investigated soil.

Soil depth (cm)	Percentage Sand	Silt	Clay	Texture class	Moisture content (v% / v%) FC	WP	AW (%)	Bd (g/cm^3)	IR (cm/ h)	HC (m/ day)
0-30	**21**	**43**	**36**	**Clay Loam**	**38**	**20**	**18**	**1.31**	**0.3**	
30-60	**22**	**41**	**37**	**Clay Loam**	**39**	**21**	**18**	**1.38**	**----**	**0.07**

FC = field capacity WP = welting point AW = available water Bd = bulk desity
IR = infiltration rate HC = hydraulic conductivity

The experiment was laid out in split split plots design with three replicates. The study included two irrigation methods (flood and drip) with two soil moisture depletion levels (50 and 75%

SMD) and three fertilizer sources (chemical, compost and rock phosphate plus compost). The main plots were assigned for irrigation methods that bounded with buffer zone (5 m width) to avoid the horizontal seepage. The water stresses were devoted to the spilt plots while fertilizer sources were assigned in spilt spilt plots. The plot area was 20 m^2 (5 X 4 m). The rock phosphate in powder texture obtained from Mangabad Superphosphate Factory, Assiut Governorate was mixture with soil surface (2.4 ton/ ha.) before cultivation. While the compost stuff obtained from Agricultural Waste Compost Factory, El-Minya Governorate was mixture with soil surface (12 ton/ ha.) before cultivation. Some chemical properties of the rock phosphate and the compost stuff were analyzed according to Black (1981) and they are presented in Table (2). The field layout of tested treatments is shown in Fig. (1).

Table 2: Some chemical properties of used rock phosphate and compost stuff.

Material	Total macro elements (%)			Total micro elements (mg kg^{-1})				OM	EC (dSm^{-1})	pH Susp.
	N	P	K	Fe	Cu	Zn	Mn	(%)	(1:5)	(1:2.5)
Rock phosphate	---	24.82	0.01	2144	342	152	387	---	2.92	6.36
Compost	1.89	0.83	1.06	1300	165	58	128	38.11	3.47	7.7

		Replicate I	Replicate II	Replicate III
Flood irrigation	50% soil moisture depletion	Chemical fertilization	Compost stuff	Rock phosphate plus compost stuff
		Compost stuff	Rock phosphate plus compost stuff	Chemical fertilization
		Rock phosphate plus compost stuff	Chemical fertilization	Compost stuff
	75% soil moisture depletion	Chemical fertilization	Compost stuff	Rock phosphate plus compost stuff
		Compost stuff	Rock phosphate plus compost stuff	Chemical fertilization
		Rock phosphate plus compost stuff	Chemical fertilization	Compost stuff
Buffer zone				
Drip irrigation	50% soil moisture depletion	Chemical fertilization	Compost stuff	Rock phosphate plus compost stuff
		Compost stuff	Rock phosphate plus compost stuff	Chemical fertilization
		Rock phosphate plus compost stuff	Chemical fertilization	Compost stuff
	75% soil moisture depletion	Chemical fertilization	Compost stuff	Rock phosphate plus compost stuff
		Compost stuff	Rock phosphate plus compost stuff	Chemical fertilization
		Rock phosphate plus compost stuff	Chemical fertilization	Compost stuff

Fig. 1: Drawing sketch for field layout of tested treatments.

The amount of water consumed from the root zone between two successive irrigations as a water depth in cm, was calculated according to the equation of Israelsen and Hansen (1962) as follows:

$$WCU = D \times Pb \times (Q_2 - Q_1)/100$$

Where: WCU = water consumptive use.

D = the irrigation soil depth (cm).

*P*b = bulk density of soil (gm/cm^3).

Q_1 = the percentage of soil moisture before irrigation.

Q_2 = the percentage of soil moisture at field capacity.

Field water use efficiency (FWUE) defined as the weight of crop production per the volume unit of applied irrigation water. Crop water use efficiency (CWUE) expressed as Kg produced/ m^3 of water consumed to evaluate the efficiency of different irrigation methods in producing maximum yield per water unit consumed according to Vites (1965).

FWUE = leaves yield (Kg ha^{-1}) / Seasonal applied irrigation water (m^3 ha^{-1}).

CWUE = leaves yield (Kg ha^{-1}) / Seasonal crop consumptive use (m^3 ha^{-1}).

Moringa seeds were obtained from Field Crop Rec. Inst., Agricultural Res. Center, Giza. Initially, Moringa seeds were de-hulled, soaked overnight and planted in seedling trays in a greenhouse and nursed till they were 50 – 150 mm tall. Then, they transplanting into the field on 20th of May 2015with mineral fertilization according to the recommended doses of Ministry of Agriculture. Planting holes (30 cm among hills and 50 cm among rows) were prepared and watered a night before transplanting which was carried out during the late afternoon to reduce the damage effect of direct sunlight on the seedling. Nitrogen fertilizer (238 kg N/ ha/ cut) was applied as ammonium nitrate (33.5 % N) and it divided into three equal doses; the first one side dress three weeks after transplanting. Two other applications were carried at monthly intervals. Phosphorus fertilizer (90 kg P_2O_5/ ha/ cut) was applied as superphosphate (15.5 % P_2O_5) before cultivation. The amount of potassium sulphate (60 kg K_2O/ ha/ cut) was divided into three equal doses and it added at the same time of nitrogen fertilization.

Four plants were sampled randomly from each plot by cutting the plants 10-cm above the soil surface after 90 days from transplanting as a first cut to determine some morphological data (plant height, stem diameter, plant dry weight, leaves dry weight/ plant and / plot and dry leave yield/ ha. Leaves samples from all treatments were freshly weighed cleaned with distilled water and then air dried until constant dry weight. Then, they ground and wet digested with sulfuric acid and perchloric acid (3:1), for chemical analysis. The nitrogen, phosphorus, potassium and calcium in dry leaves were determined according to the method described by Helrich (2000). The same proceeds were done three months later at the second cut.

Soluble proteins and proline were determined according to the method described by Lowry *et al.* (1951) and Bates *et al*. (1973), respectively. Vitamin C and photosynthetic pigments were determined according to the method described by Jagota & Dani (1982) and Lichtenthaler (1987), respectively. The total antioxidant contents were estimated by following the method of Prieto *et al.* (1999). Total phenolic contents were assessed using the Folin-Ciocalteau reagent method according to Singleton and Rossi (1965). The reducing power of the samples was determined according to the procedure described by Oyaizu (1986). Total flavonoid content was measured based on the method described by Moreno *et al*. (2000).

The obtained data of the two cutting were subjected to statistical analysis using variance analysis according to Snedecor and Cochran (1990). Duncan's multiple range tests at the 5% level of probability was used to compare means of treatments by SPSS 16 software.

Results and Discussion

Moringa traits and its yield

In general, the plant height, the dry weight/ plant and leaves weight/ hectare in the 2nd cut were better than that in the 1st cut while the opposite was true for stem diameter. The plant height under drip irrigation at 50% SMD with chemical fertilizer realized the tallest one in both cuts (Table 3). The plant height reached 136 and 160 cm in the 1st and 2nd cut, respectively. On the other side, flood irrigation at 50% SMD with compost application produced the shorter plant height (84 and 91cm in the 1st and 2nd cut, respectively). Also, data in table (3) showed that the stem diameter under drip irrigation at 50% SMD with compost + Rock phosphate application (CO+ RP) was the maximum one in both cuts (1.83 and 1.57 cm in the1st and 2nd cut, respectively). Flood irrigation at 50% SMD with chemical fertilizer (CF) produced the minimum stem diameter (0.9 and 0.86 cm in the 1st and 2nd cut, respectively). Also, data in table (3) showed that the dry leaves weight/ plant under drip irrigation at 50% SMD with compost application realized the maximum dry leaves weight/ plant in the 2nd cut (145.3 g). Flood irrigation at 50% SMD with chemical fertilizer produced the lowest dry leaves weight/ plant in the 1st cut (78.33g). The leaves weight/ ha under drip irrigation at 75% SMD with compost application were the maximum one in both cuts (table 3). The leaves weight reached 2464 and 2430 kg/ ha in the 1st and 2nd cut, respectively. On the other side, flood irrigation at 50% SMD with chemical fertilizer produced the lowest leaves weight (1406 kg/ ha). The data presented in table (3) indicated that the application of chemical and organic fertilizers significantly improved the Moringa plant components and their yield as well as mitigated the adverse effect of water stress. In general, the drip irrigation method achieved the highest Moringa yield and its components compared to the flood irrigation method. In the same context applying organic fertilizers improved Moringa plant growth by increasing plant resistance to water stress compared to chemical fertilization.

Table 3: Moringa plant growth and its yield in relation to soil moisture depletion and fertilizer types under deferent irrigation methods.

Treatment			Plant height (cm)		Stem diameter (cm)		Dry weight (g)/ plant		Leaves yield (kg/ ha)	
			1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
Flood irrigation	SMD 50 %	CF	135^{a}	139^{bc}	0.9^{h}	1.37^{ab}	78.33^{l}	103^{de}	2213^{abc}	2204^{abc}
		CO	84^{f}	91^{g}	1.03^{fgh}	1.0^{cd}	103.33^{k}	135^{ab}	1632^{fgh}	2052^{abc}
		CO+RP	90^{f}	129^{cd}	1.4^{bcd}	1.37^{ab}	113.33^{hi}	125^{ab}	2117^{bcd}	2383^{ab}
	SMD 75 %	CF	129^{b}	90^{g}	0.9^{h}	0.86^{d}	120.67^{f}	125.3^{ab}	2464^{a}	2430^{a}
		CO	101^{de}	119^{de}	1.47^{bc}	1.37^{ab}	106.67^{k}	135.3^{ab}	1919^{cdef}	2262^{abc}
		CO+RP	97^{ef}	103^{f}	1.2^{defg}	1.0^{cd}	110.00^{j}	90^{f}	1773^{efg}	1957^{abcd}
Drip irrigation	SMD 50 %	CF	136^{a}	160^{a}	1.53^{b}	1.2^{abcd}	138.33^{a}	145^{a}	1406^{h}	1730^{cd}
		CO	$105d^{e}$	136^{bc}	1.47^{bc}	1.2^{abcd}	122.33^{ef}	145.3^{a}	1534^{gh}	1870^{bcd}
		CO+RP	135^{a}	141^{b}	1.83^{a}	1.57^{a}	132.33^{bc}	134.7^{ab}	1963^{bcde}	2268^{abc}
	SMD 75 %	CF	134^{a}	120^{de}	1.2^{defg}	1.1^{bcd}	119.67^{fg}	135^{ab}	2225^{ab}	2274^{ab}
		CO	100^{ef}	139^{bc}	1.23^{def}	1.13^{bcd}	116.67^{h}	144.7^{a}	1920^{cdef}	1900^{abcd}
		CO+RP	112^{cd}	103^{f}	1.2^{defg}	1.07^{bcd}	129.00^{cd}	122.3^{ab}	1674^{efgh}	1440^{d}

SMD = soil moisture depletion CF = chemical fertilization CO = compost RF = rock phosphate

Irrigation scheduling for Moringa production.

The seasonal amount of irrigation water applied or consumptive use under flood or drip irrigation at different soil moisture depilation with various fertilizer sources are shown in table (4). In general, the applied amount of irrigation water decreased as the percentage of soil moisture depletion (SMD) increased. This was true for both cuts. The results of 1st and 2nd cut indicated that the highest amount of seasonal water consumptive use (WCU) was recorded under flood irrigation at 50% SMD with chemical fertilizer (CF) treatment, while the lowest one was recorded under drip irrigation at 75% SMD with compost plus rock phosphate (CO+RP) treatment. It is clear that increasing the available soil moisture in root zone caused a significant increase in the seasonal water consumptive use. These results may be attributed to the high availability of water at low moisture depletion which in turn increases transpiration from vigor vegetative growth of existed plants and evaporation from soil surface by capillary rise force.

The obtained results indicated that field water use efficiency (FWUE) and crop water use efficiency (CWUE) were higher under drip irrigation than those under flood irrigation in both cuts. It might be stated that drip irrigation method had an advantage of water distribution uniformity, less percolated water and less amount of applied water during the growing season. The results of 1st and 2nd cut indicated that the highest value of both FWUE (0.53 kg/m^3) and CWUE (0.58 kg/m^3) were recorded in the treatment of drip irrigation at 75% SMD with compost (CO), while the lowest values of FWUE (0.22 and 0.24 kg/m^3) and CWUE (0.32 and 0.34 kg/m^3) were recorded under flood irrigation at 50% SMD with CH in the 1st cut and flood irrigation at 75% SMD with CO+RP in 2nd cut respectively. These results agreed with those obtained by Abdou and Mahmoud (2003); El-Sayed (2007); El-Sayed (2012) and Youssef *et al*. (2013).

The above mentioned results indicated that application of compost or compost + rock phosphate to Moringa plant could be considered beneficial materials to produce high yield of Moringa and its components. The obtained results are agreed with those mentioned by Beaulah (2001), El-Ghadban *et al*. (2002), Ghallab and El–Gahdban (2004), Khalil *et al*. (2004), Abo Elazm (2008), Gharib *et al*. (2008), Dash and Gupta (2009), Al-Fraihat *et al*.(2011) and Youssef *et al*. (2013).

Table 4: Effect soil moisture depletion and fertilizers types on applied irrigation water, water consumptive use, leaves yield and water use efficiency of Moringa plants grown under deferent irrigation methods.

Treatment			Applied irrigation water (m^3/ ha)		water consumptive use (m^3/ ha)		Leaves yield (kg/ ha)		FWUE (kg/m^3)		CWUE (kg/m^3)	
			1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
Flood irrigation	SMD 50 %	CF	6249	6057	4374	4240	1406	1730	0.22	0.29	0.32	0.41
		CO	6236	6046	4365	4232	1963	2268	0.31	0.38	0.45	0.54
		CO+RP	6231	6043	4362	4230	1920	1900	0.31	0.31	0.44	0.45
	SMD 75 %	CF	6136	5986	4295	4190	1534	1870	0.25	0.31	0.36	0.45
		CO	6124	5974	4287	4182	2225	2274	0.36	0.38	0.52	0.54
		CO+RP	6120	5970	4284	4179	1674	1440	0.27	0.24	0.39	0.34
Drip irrigation	SMD 50 %	CF	4838	4694	4354	4225	2213	2204	0.46	0.47	0.51	0.52
		CO	4839	4687	4355	4218	2117	2383	0.44	0.51	0.49	0.56
		CO+RP	4832	4684	4349	4216	1919	2262	0.40	0.48	0.44	0.54
	SMD 75 %	CF	4744	4628	4270	4165	1632	2052	0.34	0.44	0.38	0.49
		CO	4740	4620	4266	4158	2464	2430	0.52	0.53	0.58	0.58
		CO+RP	4736	4617	4262	4155	1773	1957	0.37	0.42	0.42	0.47
	SMD = soil moisture depletion				CF = chemical fertilizer					CO = compost stuff		
	RF = rock phosphate											

Nutrients content in Moringa dry leaves

In general, the drip irrigation method realized the highest value of nutrient contents (N, P, K and Ca) compared to that of flood irrigation method. The same trend was true under 50% SMD compared to that of 75% SMD. On the average basis of both cuts, the nutrients content (N, P, K and Ca) in the dry leaves were the highest under drip irrigation at 50% SMD with compost plus rock phosphate application. The nutrients content values in the dry leaves were 2.96, 0.008, 3.9 and 1.2 % for N, P, K and Ca, respectively (table 5). The lowest nutrients content of N and P (2.1 and 0.004 %, respectively) were recorded in plants irrigated by flood irrigation at 50% SMD with chemical fertilization. The lowest potassium and calcium content (2 and 0.7%) in the dry leaves was recorded in plants irrigated by flood irrigation at 75% SMD with chemical fertilization and compost plus rock phosphate, respectively (table 5). The obtained results are in accordance with those reported by Kandeel and Sharaf (2003); Ali (2009); Dash and Gupta (2009) and Al-Fraihat *et al*. (2011).

Table 5: Nutrients content in Moringa dry leaves in relation to soil moisture depletion and fertilizer types under deferent irrigation methods.

Treatment			(g/ 100g)	(mg/ 100g)		
			N	P	K	Ca
Flood irrigation	SMD 50 %	CF	2.12[g]	3.85[h]	2298[k]	753[g]
		CO	2.60[bc]	5.80[e]	3109[d]	774[fg]
		CO+RP	2.93[a]	7.33[b]	2717[g]	1091[b]
	SMD 75 %	CF	2.15[g]	5.23[f]	2005[p]	773[fg]
		CO	2.55[bcd]	5.9[e]	2665[h]	762[fg]
		CO+RP	2.45[def]	6.5[d]	2498[j]	655[h]
Drip irrigation	SMD 50 %	CF	2.50[cde]	4.55[g]	2952[e]	802[ef]
		CO	2.35[f]	6.75[c]	2769[f]	842d[e]
		CO+RP	2.96[a]	7.86[a]	3918[a]	1197[a]
	SMD 75 %	CF	2.48[cde]	5.80[e]	2467[i]	834d[e]
		CO	2.52[bcde]	5.80[e]	3352[c]	883[c]
		CO+RP	2.63[b]	6.70[cd]	3443[b]	1128[b]
	SMD = soil moisture depletion			CF = chemical fertilization		
	CO = compost			RF = rock phosphate		

Chemical constituent of Moringa plants

On the average basis of both cuts, Moringa plants grown in soil treated by compost plus rock phosphate and irrigated by drip irrigation at 50% SMD had the highest value of chlorophyll a (152.1 mg/ g), chlorophyll b (32.6 mg/ g) and carotenoids (59.62 mg/ g) compared to other treatments (Fig. 2). Compost as an organic fertilizer tended to increases the content of total chlorophyll a & b as reported by El-Sayed *et al*. (2002) and Abo Elazm (2008). Drought stress caused obvious changes in the ratio of chlorophyll a & b and carotenoids (Anjum *et al*. 2003 and Farooq *et al*. 2009). A decrease of total chlorophyll with drought stress implies a lowered capacity for light harvesting. Since the production of reactive oxygen species is mainly driven by excess energy absorption in the photosynthetic apparatus, this might be avoided by degrading the absorbing pigments (Herbinger *et al*., 2002).

Highly significant differences in the total antioxidant were observed under irrigation methods at both water levels with various fertilizers (Fig.3). There was significant interaction between water levels and fertilizer types. The highest value of total antioxidants (62.61 mg/g FWt) was recorded under drip irrigation at 50% SMD by compost plus rock phosphate application. The lowest one (31.51 mg/g FWt) was recorded under flood irrigation at 75% SMD by compost application. The obtained results agreed with those found by Ogbunugafor *et al*. (2011) and Attia *et al*. (2014). In general, data presented in figure (3) showed that water stress level at 75% SMD reduced soluble proteins content under almost all fertilizer types compared to that of water stress level at 50% SMD. The highest value of soluble proteins (158.50 mg/g FWt) was recorded under drip irrigation at 50% SMD with compost plus rock phosphate application and the lowest one (60.89 mg/g FWt) was recorded under flood irrigation at 75% SMD with chemical fertilization.

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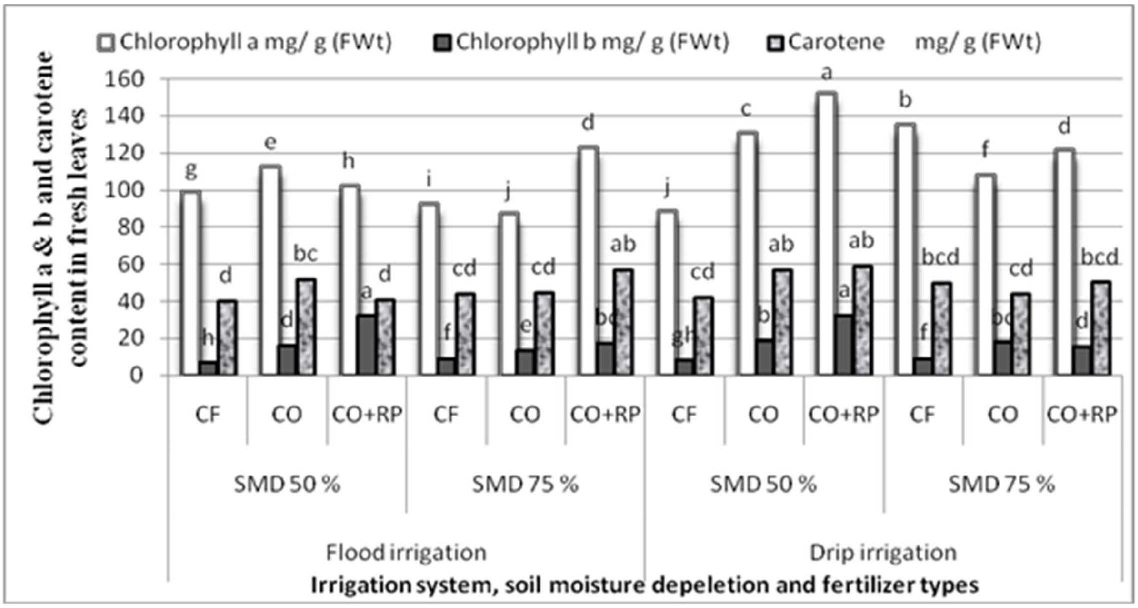

Fig. 2: Chlorophyll and carotene content in fresh leaves of Moringa plants in relation to soil moisture depletion and fertilizer types under deferent irrigation methods.

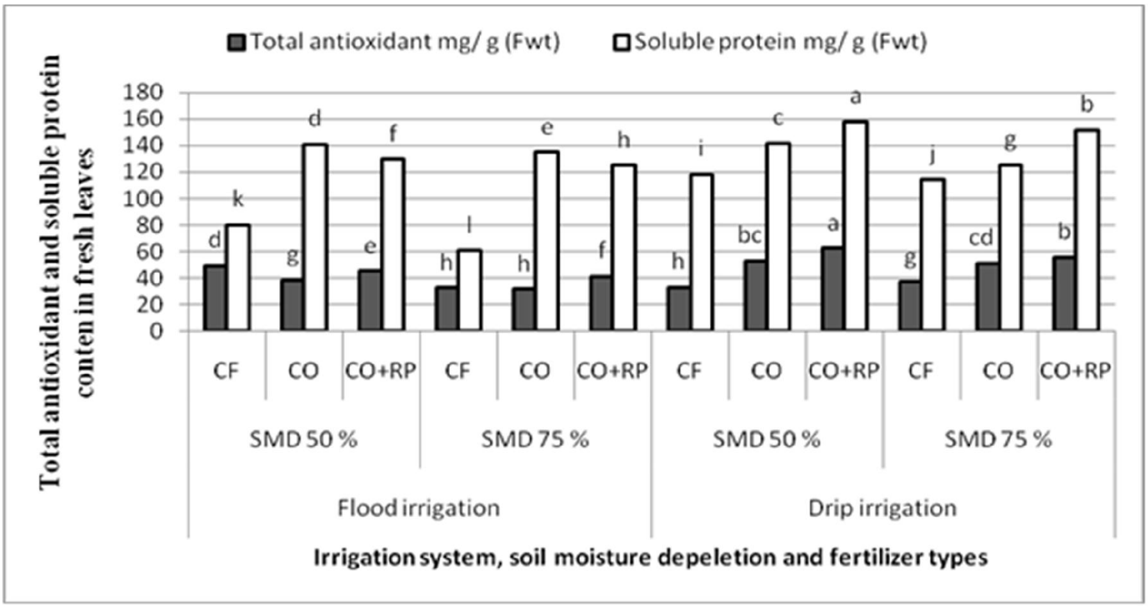

Fig. 3: Total antioxidant and soluble protein content in fresh leaves of Moringa plants in relation to soil moisture depletion and fertilizer types under deferent irrigation methods.

On the average basis of both cuts, data presented in figures 4 and 5 showed that irrigation systems, water stress and fertilizer types resulted in significant changes in proline, phenolics, falvonoids and vitamin C content in Moringa leaves. Drip irrigation at 75% SMD and compost plus rock phosphate application showed the highest value of prolin (1.61 mg/g DWt), falvonoids (2.31 mg/g FWt), vitamin C (2.30 mg/g FWt) and reducing power (0.307 mg/g FWt) of Moringa plants compared to those in other treatments (Fig. 4 & 5). Prolin accumulation is believed to play adaptive roles in plant stress tolerance. Accumulation of proline has been advocated as a parameter of selection for stress tolerance (Jaleel *et al*., 2007 and Verbruggen & Hermans, 2008). Drip irrigation at 75% SMD with compost application enhanced phenolics content compared to other treatments since its value reached 8.34 mg/g FWt (Fig. 4 & 5). The above results agreed with those obtained by Jaleel *et al*. (2008) and Ogbunugafor *et al*. (2011).

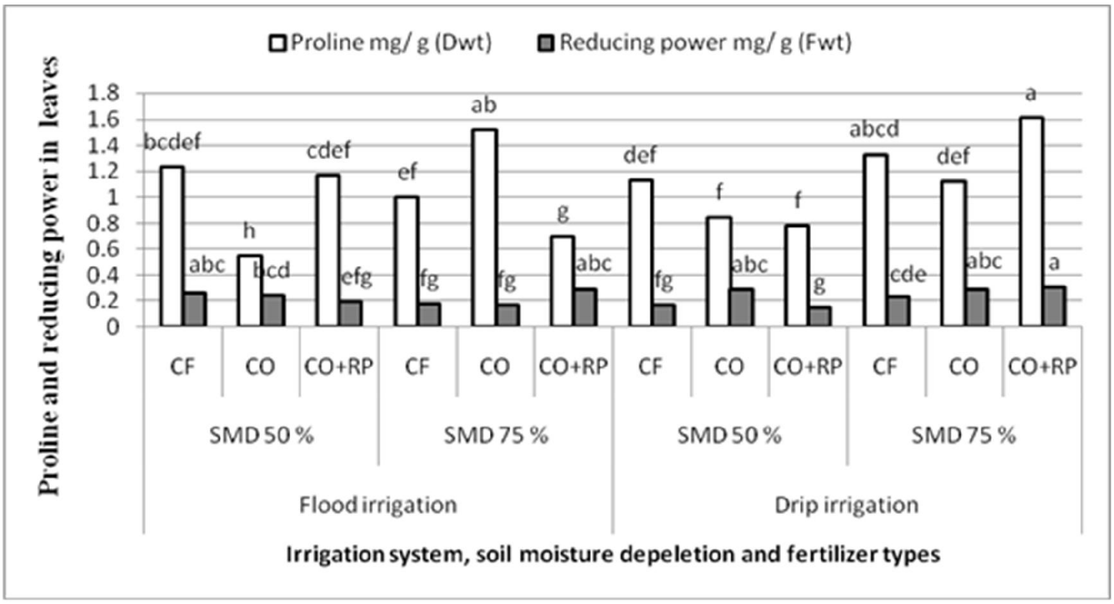

Fig. 4: Proline and reducing power content of Moringa plants in relation to soil moisture depletion and fertilizer types under deferent irrigation methods.

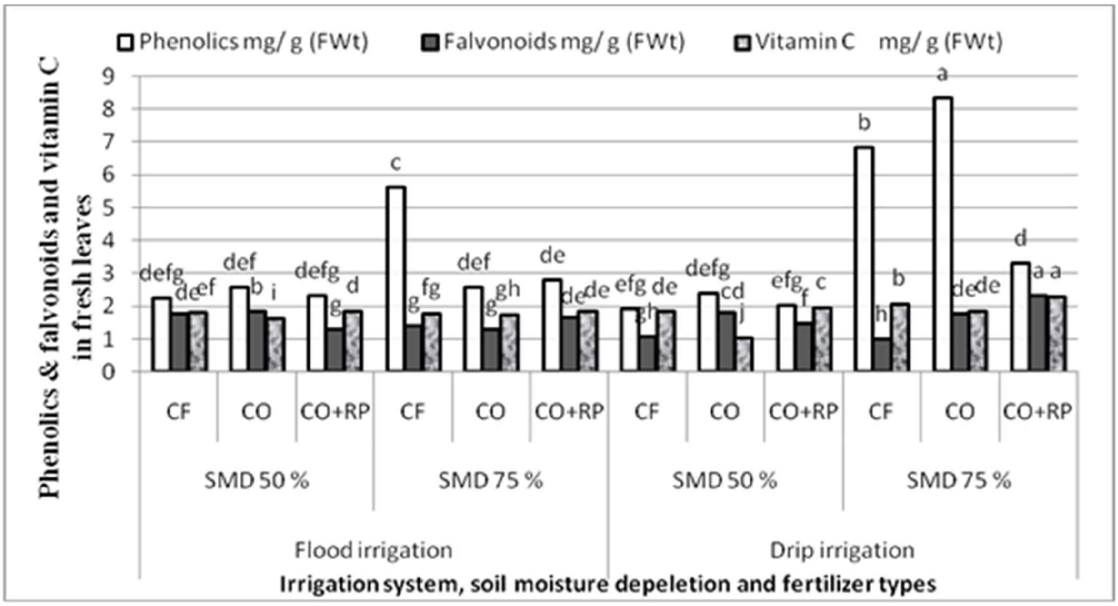

Fig. 5: Phenolics, falvonoids and vitamin C content of Moringa plants in relation to soil moisture depletion and fertilizer types under deferent irrigation methods**.**

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