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Impacts of liquid organic fertilizer on characterization of sunflower under irrigationwater levels

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***Abstract*---**Liquid organic fertilizer (LOF) research has revealed its obvious benefits to plant productivity and soil fertility. These benefits are noticeable in the form of increased soil water holding capacity and plant nutrient availability. These alterations may also boost a plant's ability to withstand drought stress. The results indicated that foliar application of LOF at 1.50 L/fed was higher effective regarding the studied parameters under application of 100% water requirement (WR).The recorded sunflower yield parameters were significantly increased by application of LOF compared with the control. The foliar application of LOF increased water use efficiency for sunflower at the applied irrigation treatments. Under water stress, the application of LOF at 1.50 L/fed produced better agronomic performance of yield components, carbohydrates, protein, oil, flavonoids and antioxidant activity (DPPH radical scavenging) of sunflower seeds over remaining treatments. This dosage could be used for optimum sunflower production.

***Keywords*---**sunflower, irrigation regime, liquid organic fertilizer,antioxidants, seed quality.

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Introduction

Sunflower (*Helianthus annuus,* L.) is an annual oilseed crop globally cultivated on 24.77 million hectares with a production of 44.31 million metric tons and it has 8% share in the world oilseed market (USDA, 2016). Sunflower contains 40–50% oil and 17–20% protein, thus have a fair potential to narrow the gap between production and consumption of edible oil and animal feed in the world. Actually, it is a crop of tropical and subtropical regions with semi-arid to arid climate, and frequently grown in dry lands or on supplementary irrigation. Therefore, the crop is affected by ambient environmental conditions like heat and drought (Robert *et al.*, 2016). Several reports indicated that drought stress significantly reduces sunflower achene yield, oil yield and oil quality globally (Ibrahim *et al*., 2016). In addition to the hiking problem of water stress, the area devoted to irrigated food production systems is expected to decrease resulting in lesser food production (Farooq *et al*., 2012).

An alternative source of nutrients for plants is the use of organic fertilizers. Organic fertilizers can improve the physical, chemical and biological properties of the soil and also help reduce the use of inorganic fertilizer so that it is more environmentally friendly. Liquid organic fertilizer contains (LOF) various macro and micro nutrients and the amino acids that is needed by plants. In addition, LOF contain microorganisms that will improve soil fertility so that it can support plant growth and development. Microbes are added to organic fertilizers in addition to increasing nutrient availability, also able to increase the efficiency of nutrients uptake by plants, so that fertilization efficiency increases (Pangaribuan *et al.*, 2017).

The application of LOF is thought to accelerate the synthesis of amino acids and proteins, thereby accelerating plant growth. This is in accordance with the opinion of Hadi (2005) that LOF contain potassium which plays an important role in every plant metabolic process, namely in the synthesis of amino acids and proteins from ammonium ions. The element potassium also plays a role in maintaining good turgor pressure so as to allow the smooth running of metabolic processes and ensure the continuous elongation of cells.

According to Taufika (2011), LOF are fertilizers with low chemical content of a maximum of 5%, can provide nutrients in accordance with the needs of plants in the soil, because of its liquid form. The LOF in fertilization are clearly more evenly distributed and there will be no accumulation of fertilizer concentrations in one place, this is because LOF is 100% soluble. The LOF have the advantage of being able to increase nutrient uptake and quickly overcome nutrient deficiencies because the nutrients in it have broken down so that they became more easily to absorb. Studies have shown that the use of organic fertilizers in either solid or liquid form can also provide good plant growth and yield. Research results by Pangaribuan *et al.* (2017) showed that a combination of LOF and inorganic fertilizers (Urea, SP-36 and KCl) of 20% recommendation can be an alternative fertilizer for sweet corn that is more economical because its growth and production are the same as recommended inorganic fertilizers. The purpose of this paper is to study the effect of LOF on the growth and yield of sunflower under different irrigation regimes. The use of LOF is expected to reduce the use of inorganic fertilizers in order to achieve environmentally friendly and sustainable agriculture.

Materials and Methods

Experimental procedures

Field experiment were carried out at the Research and Production Station of the National Research Centre, Nubaria region (30 30.054' N - 30 19.421' E), Beheira Governorate, Egypt during 2019 and 2020 seasons. Seeds of Sunflower *(Helianthus annuus*, L) cv. Giza 53 were sown on November. The experimental design was a split plot with four replications.

The initial soil analysis for theexperimental area was: sandy loam in texture (74.2% sand, 6.52% silt, 18.33% clay), OM (0.68%), $CaCO_3$ (1.54%), pH (7.69); EC (1.17 dS m^{-1}) and available N, P and K were 34.3, 6.88 and 15.6 mg/Kg soil, respectively. Soil analysis executed according to technique of Rebecca (2004).

The experimental treatments included: A) Water supply treatments (100, 80 and 60% of water requirement (WR), B) Foliar fertilization with LOF at 0.0, 0.50, 1.0 and 1.5 liter per feddan (L/fed). The tested LOF contains 4.21% N, 3.04% K, 38% OM, 6.5 pH, 4.62% Fe, 2.52% Mn, 2.8% Zn, 0.7% Cu, 12.11% Humic acid, 16.05% Fulvic acid, 3.27% Citric acid, 2.30% Malic acid and 2.16% Lactic acid. Before planting, the experimental soil received the recommended fertilizer dose according to the Ministry of Agriculture recommendations (50 $Kg.fed^{-1}$ Ammonium sulphate "20% N", 100 $Kg.fed^{-1}$ Super phosphate "15.50% P_2O_5" and 50 $Kg.fed^{-1}$ Potassium sulphate "48% K_2O").

Chemical analysis

Leaf greenness present in a plant was determined with the Minolta-SPAD Chlorophyll Meter (Minolta Camera Co., Osaka, Japan). The SPAD-502 chlorophyll meter measures the chlorophyll absorbance in the red and near- infrared regions and calculates a numeric SPAD value which is proportional to the amount of chlorophyll in the leaf Minolta (1989). For mineral ions content estimation, a known weight (0.5 g) of the dry seeds of sunflower was digested andthe obtained extract was used for the estimation of some macronutrient content according to Rebecca (2004).

Some biochemical aspects were determined including Phenolic content was measured as described by Danil and George (1972). Total soluble sugars (TSS) extracted according to Homme *et al.* (1992) and assayed according to Yemm and Willis (1954). The antioxidant activity was determined using the method of Liyana-Pathiranan and Shahidi (2005). Total flavinoids were determined using themethod reported by Chang *et al*. (2002).

Dry samples of seeds were used to determine total carbohydrate using thecolorimetric method described Dubois *et al.* (1956). Crude protein percentage was extracted and determined by Micro-Kjeldahl method as described by A.O.A.C(1990). The value of total crude protein was calculated by multiplying total valuesof total-N by factor 6.25. Water use efficiency (WUE) was calculated for each treatment using the following formula, WUE = Grains yield (Kg/fed)/total water applied (m^3/fed) = $Kg/m^{3.}$

Yield and its components

Samples were harvest from random selected plants in each experiment unit to estimate the average Plant height, capitulum values such as; diameter, fresh and dry weight) and seed values, like fresh weight, 1000-seed weight as well as seed yield.

Statistical analysis

A combined analysis of data for the two seasons were statistically analyzed according to the technique of analysis of variance (ANOVA) for the split plotdesign. Least Significant Difference (LSD) method was used to test the differences among treatment means at 5% level of probability as described by Snedecor and Cochran (1990).

Results

Plant height

The present study revealed that irrigation WR, it had a significant gradual increase on plant height (119.2 Cm) by increasing the rates of applied water up to 100% of WR and (117.8 Cm) at 80% of WR. With regard to foliar fertilization with LOF, a significant (P<0.05) increase in sunflower plant height was recordedcompared with the control treatment (Fig. 1) in both seasons 2019 and 2020. Meanwhile, the plants received 1.5 L/fed of LOF recorded the highest plant height, while the plants in the control which were grown without LOF application had the lowest values at all growth occasions under water stress treatments

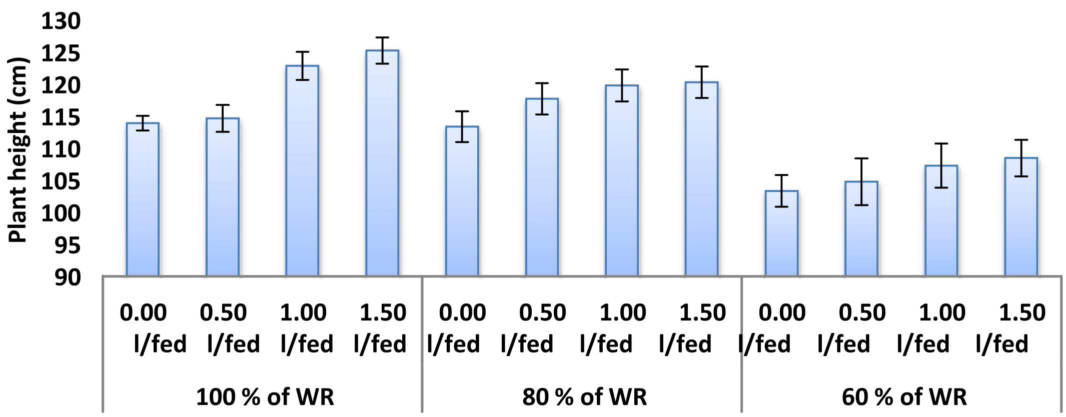

Figure (1): Effect of liquid organic fertilizer on plant height of sunflower plant under different water levels.

The highest values of plant height produced with application of 1.5 L/fed LOF compared to control treatment (being 118.03 Cm *Vs.* 110.22 Cm). The interaction among WR, LOF had a significant effect in the growing seasons. The highest plant height (125.3 Cm) were recorded by increasing rate of LOF up to (1.5 L/fed) at 100% WR and the lowest one (103.3 Cm) at 60% WR without application of LOF.

Chlorophyll contents

The Results revealed that foliar application of LOF significantly (P<0.05) increased chlorophyll content of sunflower compared with control treatment (Fig. 2) in both studied seasons. Foliar application of 1.5 L/fed LOF produced the highest chlorophyll contents followed by 1.0 L/fed LOF, while the lowest values observed in the control treatment which were grown without LOF application at all growth occasions under water stress treatments. The highest values of chlorophyll content (37.8 and 42.0) compared to control treatment (32.9 and 33.8) producedat 45 and 60 days after sowing (DAS), respectively. With regard to irrigation WR, it had a significant gradual increase on chlorophyll content (37.4 and 40.5) by increasing the rates of applied water up to 100% of WR and (33.9, 36.3) at 60% of WR at 45 and 60 day after sowing (DAS), respectively.

The interaction between WR and LOF had a significant (P<0.05) effect in the two growing seasons. The highest chlorophyll content (39.4 and 44.9) were recorded by increasing rate of LOF up to 1.5 L/fed at 100% WR and the lowest one (30.3and 30.5) at 60% WR without application of LOF at 45 and 60 DAS, respectively.

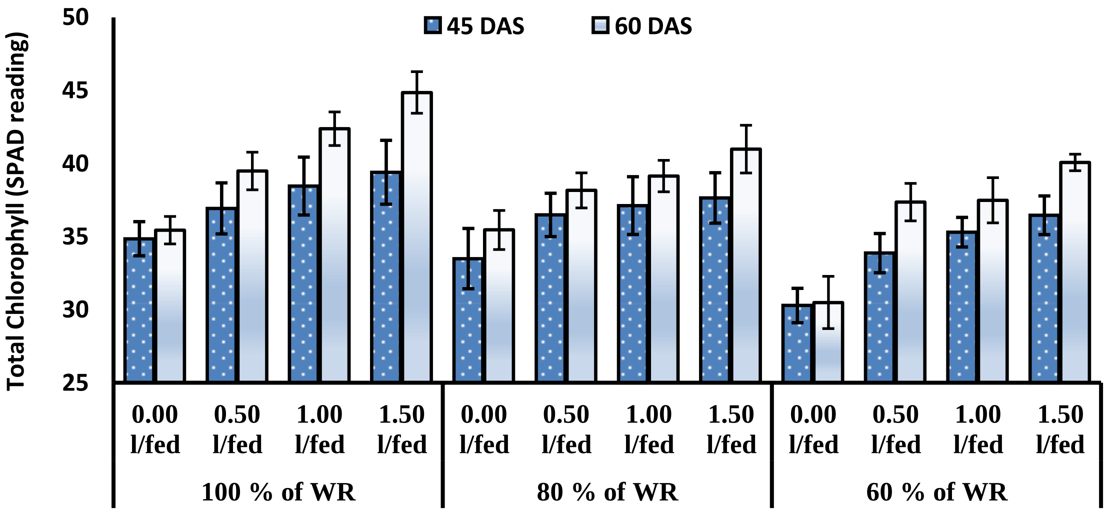

Figure (2): Effect of liquid organic fertilizer on chlorophyll contents of sunflowerplant under different water levels.

Compatible solutes in Sunflower leaves

Data in Table (1) indicated that water stress significantly (P<0.05) reduced antioxidant activity (DPPH radical scavenging), total phenols and indole acetic acid (IAA) concentrations in sunflower leaves. While, this stress led to increase total soluble sugars (TSS) and proline contents in leaves. The effect of LOF on antioxidant activity values was significant in both seasons. Depending on the mean values, the highest values of TSS (22.59), total phenol (12.83) with application of 1.5 L/fed LOF compared to control TSS (19.25), total phenol (7.99), respectively.

With regard to mean values irrigation WR, it had a significant (P<0.05) gradual decrease in TSS (from 22.45 to 17.9) and phenol (from 12.21 to 8.47) contents in leaves from with 100% and 60% WR, respectively. The interaction between WR and LOF had a significant (P<0.05) effect on the phytochemical composition of sunflower in the two growing seasons. The highest TSS (23.2) and phenol (16.5) values were recorded by increasing rate of LOF up to (1.5 L/fed) at 100% WR, while the lowest ones (16.8 TSS) and (6.40 phenol) were obtained at 60% WR without application of LOF.

Foliar fertilization with LOF at the rates of 0.5, 1.0 and 1.5 L/fed significantly (P<0.05) increased all tested parameters, except proline and IAA content in sunflower leaves. The effect of LOF on proline content was significant (P<0.05) in both seasons. The highest value of proline content (5.37 mg/g dry weight) produced with zero application of LOF (control treatment) compared to 1.5 L/fedLOF, which gave 3.16 mg/g dry weight of proline content, respectively. With regard to irrigation WR, water stress had a significant (P<0.05) gradual increase in proline content (5.11 and 4.44) at 60% and 80% of WR and the lowest value (3.09) registered at 100% of WR. The interaction between WR and LOF had a significant (P<0.05) effect in the two growing seasons. The highest proline content (6.54) was recorded at control treatment without LOF at 60 % of WR and the lowest one (2.22) reported with LOF (1.5 L/fed) at 100% WR.

Table (1): Effect of liquid organic fertilizer on Chemical composition of sunflower plant under different water levels.

Treatment		DPPH	TSS	Total Phenol	IAA	Proline
WR	LOF (L/fed)	%	(mg/g dry wt.)			
100 %	0.00	46.88	21.55	9.14	11.58	4.13
	0.50	47.69	22.22	10.97	10.96	3.35
	1.00	53.76	22.85	12.21	9.84	2.66
	1.50	67.07	23.17	16.54	9.15	2.22
80 %	0.00	41.26	19.39	8.42	14.92	5.43
	0.50	45.02	19.97	8.93	13.62	4.72
	1.00	52.81	22.56	10.45	12.74	4.21
	1.50	56.61	25.70	11.32	12.05	3.39
60 %	0.00	38.09	16.80	6.40	17.58	6.54
	0.50	38.83	17.70	7.34	16.25	5.51
	1.00	41.26	18.04	9.52	15.06	4.53
	1.50	42.03	18.91	10.65	14.35	3.86
Mean of WR	100%	53.85	22.45	12.21	10.38	3.09
	80%	48.93	21.91	9.78	13.33	4.44
	60%	40.05	17.86	8.47	15.81	5.11
Mean of LOF	0.00	42.08	19.25	7.99	14.69	5.37
	0.50	43.85	19.96	9.08	13.61	4.53
	1.00	49.28	21.15	10.72	12.55	3.80
	1.50	55.24	22.59	12.83	11.85	3.16
LSD 0.05	WR	1.56	1.32	1.32	0.675	0.19
	LOF	1.80	1.23	1.58	0.778	0.22
	WR x LOF	3.12	2.25	2.75	1.340	0.37

WR: Water requirement, **LOF:** Liquid organic fertilizer

Yield components

Capitulum values

Capitulum values (diameter, fresh and dry weight) per plant were significantly (P<0.05) different across all treatments (Table 2). The highest capitulum value was obtained with 100% WR and 1.5 L/fed LOF at both seasons 2019 and 2020. This could be attributed to the fact that application of 1.5 L/fed LOF was compatible with the WR and growing characteristics of sunflower plants for growth and yield enhancement. Capitulum diameter decreased significantly (P<0.05) with each decrease in the level of water applied. The lowest value of capitulum diameter and its fresh weight was obtained from sunflower plants which did not receive LOF and received the lowest level of WR.

Table (2): Sunflower yield as affected by liquid organic fertilizer under different water levels

Treatment		Capitulum values			Seed values			WUE (kg/m)
WR*	LOF (L/fed)	Diameter (cm)	Fresh wt. (g/plant)	Dry wt. (g/plant)	Fresh wt. (g/plant)	1000-Seed weight (g)	Seed yield (ton/fed)	
100 %	0.00	14.26	131.00	18.55	72.68	39.58	2.13	2.48
	0.50	15.21	143.31	19.03	81.43	38.52	2.16	2.51
	1.00	16.99	147.59	21.23	85.17	41.36	2.23	2.59
	1.50	17.77	153.31	23.29	91.14	45.41	2.76	3.21
80 %	0.00	12.17	110.83	15.21	43.00	30.64	1.45	2.11
	0.50	13.99	116.22	17.80	58.25	34.62	1.94	2.82
	1.00	14.84	129.72	21.93	63.60	33.54	2.06	3.00
	1.50	15.97	132.20	22.16	68.76	38.27	2.16	3.13
60 %	0.00	9.54	77.90	10.23	32.22	23.75	1.17	2.26
	0.50	11.45	89.80	12.89	34.20	24.35	1.28	2.48
	1.00	12.82	93.50	14.85	42.63	26.26	1.62	3.14
	1.50	13.07	105.87	16.86	47.84	26.50	1.66	3.22
Mean of WR	100%	16.06	143.80	20.52	82.60	41.22	2.32	2.70
	80%	14.24	122.24	19.28	58.40	34.27	1.90	2.76
	60%	11.72	91.77	13.71	39.22	25.21	1.43	2.77
Mean of LOF	0.00	11.99	106.58	14.66	49.30	31.32	1.58	2.28
	0.50	13.55	116.44	16.57	57.96	32.50	1.79	2.60
	1.00	14.88	123.60	19.34	63.80	33.72	1.97	2.91
	1.50	15.60	130.46	20.77	69.25	36.72	2.19	3.19
LSD (0.05)	WR	1.34	3.67	0.62	1.51	0.89	0.14	0.23
	LOF	1.55	4.24	0.72	1.75	0.65	0.16	0.29
	WR x LOF	NS	7.44	1.22	3.04	1.36	NS	0.51

WR: water requirement, **LOF**: liquid organic fertilizer, **WUE** : Water use efficiency

Seed values

The response of grain values to rates of LOF in 2019 and 2020 is shown in Table (2). Irrigation treatments had a considerable effect on seed values and the treatment of 100% WR was the best. The enhanced seed yield with 100% WR may be interpreted by the more efficiency of nutrients in soil treated with 100% WR compared with other regimens. In the meantime, there were significant differencesin seed values of the plants in both years of evaluation due to the application of LOF. The highest values of 1000-seed weight (36.72 g) and seed yield (2.19 ton/fed) produced with application of 1.5 L/fed LOF compared to control (31.32 g and 1.58 ton/fed), respectively. Also, the application rate of LOF at 1.5 L/fed increased seed values more than the other application rates possibly because an increase in LOF with the optimum WR was suitable for increasing nutrientcontent, water holding capacity, aggregation of soil and decrease of bulk density,all of which interplay to increase grain yield of sunflower plants. With regard to irrigation WR, it had a significant ($P<0.05$) gradual increase in 1000-seed weight and seed yield (41.22 g and 2.32 ton fed^{-1}) by increasing the rates of applied waterup to 100% of WR and (25.21 g and 1.43 ton fed^{-1}) at 60% of WR.

Respecting the interaction between WR and LOF, it had a significant ($P<0.05$) effect in both growing seasons. The highest 1000-seed weight and seed yield(45.41 g and 2.76 ton fed^{-1}) were recorded by increasing rate of LOF up to 1.5 L/fed at 100% WR, while the lowest one (23.75 g and 1.17 ton fed^{-1}) was recordedwhen 60% of WR was applied without LOF application. Data in Table (2) also presents for the WUE of sunflower yields as affected by irrigation and fertilization treatments. It is interesting to note that, rational irrigation and fertilization management are among the most important measures to improve seed yield and WUE toward better land use, minimize of production input costs and improve the agricultural economy. In general, WUE defined as biomass accumulation over water consumed, it is considered one of the parameters used to evaluate the performance of agricultural production systems. The WUE of sunflower increased gradually with increasing irrigation levels and fertilizer application. These results emphasized that low yields due to water stress didn't concomitant to low WUE values and the increase in WUE didn't refer to high amount of water. This may be due to mathematically, WUE calculated as [yield (Kg/fed)/total water applied (m^3/fed)], hence increasing water amount tend to raise the denominator of equation subsequently decrease the net result. It has been predicted that plants generally have the capability to optimize their water use in short term and maximize their chance of survival during drought in the long term. The highest value of WUE (3.19) produced with zero application of LOF (control treatment) ascompared to those treated with 1.5 L/fed (2.28). The interaction among WR and LOF had a significant effect in both growing seasons. The highest WUE (3.21) was recorded by increasing rate of LOF up to 1.5 L/fed at 100% WR and the lowest one (2.26) recorded at 60% WR without application of LOF.

Nutrient composition of sunflower seeds

The nutrient content of sunflower seeds increased significantly ($P<0.05$) with increasing irrigation rate (Table 3). This may be attributed to the role of water in improving plant cells development. Irrespective of irrigation rates, fertilization treatments (LOF) affected significantly ($P<0.05$) N, P and K content in sunflower seeds.

The LOF treatment (1.50 L/fed) at 100% WR is considered the best followed by application of 80% WR, while the lowest value was obtained with the control. This could be due to, under control and mineral fertilizers, the plant is suffering from water and nutrient stress, so it must be expanding to gain it is requiring of them. The interaction effect of irrigation and fertilization was significant for increase the nutrient content of sunflower seeds. Under water stress (60% WR), the treatments with LOF at 1.50 and 1.0 L/fed were higher than other treatments.

With regard to irrigation WR, it caused a significant ($P<0.05$) gradual increase in N, P and K by increasing the rates of applied water from 60 to 100% of WR, being 2.67, 0.503 and 0.678 *Vs.* 1.20, 0.197 and 0.328, respectively. The effect of LOF on nutrient values was significant. Depending on the mean valued, the highest values of N (2.16), P (0.417) and K (0.601) produced with application of 1.5 L/fed LOF compared to the control (1.89, 0.313 and 0.411, respectively). The interaction between WR and LOF had a significant ($P<0.05$) effect in the two growing seasons. The highest N (2.85), P (0.560) and K (0.783) were recorded by increasing the rate of LOF up to 1.5 L/fed at 100% WR and the lowest N (1.06), P (0.156) and K (0.269) obtained at 60% WR without LOF application.

Table (3): Nutrient in seeds as affected by liquid organic fertilizer under different water levels

Treatment		**Macronutrient contents**			**Micronutrient contents**			
WR	**LOF (L/fed)**	**N (%)**	**P (%)**	**K (%)**	**Fe (ppm)**	**Zn (ppm)**	**Mn (ppm)**	**Cu (ppm)**
100 %	0.00	2.54	0.457	0.513	161.2	66.9	36.2	8.32
	0.50	2.61	0.482	0.644	168.3	78.6	37.4	9.16
	1.00	2.69	0.514	0.770	182.4	82.4	39.7	9.72
	1.50	2.85	0.560	0.783	193.6	87.3	42.5	9.83
80 %	0.00	2.06	0.327	0.450	138.2	46.2	32.1	6.14
	0.50	2.12	0.386	0.591	139.6	48.1	33.6	6.28
	1.00	2.22	0.429	0.610	146.5	51.2	35.8	6.41
	1.50	2.31	0.456	0.648	148.8	54.3	37.6	6.53
60 %	0.00	1.06	0.156	0.269	91.5	27.9	21.2	3.35
	0.50	1.17	0.187	0.318	93.1	28.5	22.3	3.70
	1.00	1.26	0.212	0.350	94.8	30.0	23.4	3.94
	1.50	1.32	0.235	0.373	96.4	32.2	23.9	4.14
Mean of WR	100%	2.67	0.503	0.678	137.9	52.8	32.1	6.46
	80%	2.18	0.399	0.575	143.3	50.0	34.8	6.34
	60%	1.20	0.197	0.328	94.0	29.6	22.7	3.78
Mean of LOF	0.00	1.89	0.313	0.411	130.3	47.0	29.8	5.94
	0.50	1.97	0.352	0.517	133.7	51.7	31.1	6.38
	1.00	2.05	0.385	0.577	141.2	54.5	33.0	6.69
	1.50	2.16	0.417	0.601	146.3	57.9	34.7	6.83
LSD (0.05)	WR	0.0089	0.0046	0.0379	1.40	1.00	1.09	0.14
	LOF	0.0083	0.0029	0.0427	1.61	1.15	1.25	0.16
	WR x LOF	0.0130	0.0075	0.0730	2.77	1.98	2.16	0.27

WR: Water requirement, **LOF:** Liquid organic fertilizer

Iron (Fe), Manganese (Mn), Zinc (Zn) and Cupper (Cu) content of sunflower seeds (Table 3) were affected significantly (P<0.05) with irrigation treatments. It increased by the order 100%WR>80%WR>60%WR, whereas it decreased with decreasing irrigation rate. As for the effect of LOF fertilization treatments on nutrient content, values showed that Fe, Mn, Zn and Cu of seeds increased significantly (P<0.05) with increasing the application levels. The interaction effect of irrigation-fertilization treatments tended to increase nutrients uptake by seeds as compared to untreated plots. Under water stress, the application effect of 1.5L/fed LOF fertilizer produced more remarkably micronutrients content of sunflower seeds than adding 1.0 and 0.5 L/fed LOF + 60% WR and control.

Chemical constituents of the yielded seeds

Data in Table (4) illustrate the effect water stress (80% and 60%) and/or foliar application of LOF on some chemical constituents, *i.e.* carbohydrates, oil, protein, flavinoids and antioxidant activity (DPPH radical scavenging), of sunflower seed. All the previous parameters showed significant (P<0.05) decreases in the yielded seeds in comparison with their corresponding control as the result of increasingwater stress. With regard to irrigation WR, it had a significant (P<0.05) gradual increase on carbohydrates (21.4), oil (30.7), protein (16.7), flavinoids (12.6) and DPPH (24.4) produced by application 100% of WR and the lowest values of carbohydrates (16.6), oil (25.9), protein (7.5), flavinoids (10.3) and DPPH (20.8) recorded at water stress treatment (60% of WR).

Table (4): Chemical constituents of the yielded seeds of sunflower as affected by Liquid organic fertilizer under different water levels

Treatment		Carbohydrate	Oil	Protein	Flavinoids	DPPH
WR	**LOF (L/fed)**	**Content (%)**				
100 %	0.00	18.10	27.43	15.88	9.71	22.12
	0.50	20.74	29.80	16.31	11.96	23.99
	1.00	22.61	31.80	16.81	12.89	25.24
	1.50	24.08	33.57	17.81	15.81	26.35
80 %	0.00	17.33	22.68	12.88	9.23	21.19
	0.50	17.58	27.93	13.25	11.51	23.69
	1.00	20.66	29.95	13.85	12.74	25.09
	1.50	21.28	30.01	14.42	14.70	25.79
60 %	0.00	15.69	20.85	6.65	8.74	20.06
	0.50	15.93	26.93	7.32	9.54	20.46
	1.00	17.31	27.45	7.86	11.39	21.31
	1.50	17.53	28.49	8.26	11.57	21.51
Mean of WR	100%	21.38	30.65	16.70	12.59	24.43
	80%	19.21	27.64	13.60	12.05	23.94
	60%	16.62	25.93	7.52	10.31	20.84
Mean of LOF	0.00	17.04	23.65	11.80	9.23	21.12
	0.50	18.08	28.22	12.29	11.00	22.71
	1.00	20.19	29.73	12.84	12.34	23.88
	1.50	20.96	30.69	13.50	14.03	24.55
LSD 5%	WR	0.64	0.59	0.132	0.48	1.23
	LOF	0.73	0.68	0.086	0.55	1.42
	WR x LOF	1.27	1.17	0.126	0.95	2.46

WR: Water requirement, **LOF**: Liquid organic fertilizer

Foliar fertilization with LOF treatments at the rates of 0.5, 1.0 and 1.5 L/fed under the different levels of WR caused an increment in the flavinoids and total antioxidant contents in comparison with their corresponding control. It is obvious that the magnitude of increase in these tested chemical constituents in the yielded seeds was most pronounced with the highest concentration of LOF (1.5 L/fed). The effect of LOF on antioxidant activity values was significant and the highest values of carbohydrates (21.0), oil (30.7), protein (13.5), flavinoids (14.0) and DPPH (24.6) registered with application of 1.5 L/fed LOF compared to the control, respectively.

Correlation coefficients.

Values of simple correlation coefficient (r) for the inter relationships of seed yield, N, P, K, carbohydrate, oil, protein and flavinoids are given in Table (5). Positive and significant ($P<0.05$) correlation coefficients (r) among seed yield and all studied characters. Also, positive and significant ($P<0.05$) relationship was found between seed yield and nutrient content (0.891, 0.938 and 0.923 for N, P and K, respectively). Also, positive and significant ($P<0.05$) relationship between seed yield and carbohydrate, oil and protein contents (0.915, 0.869 and 0.890, respectively).

Positive and significant ($P<0.05$) relationship between seed yield and the phytochemical components in terms of flavinoids and DPPH (0.754 and 0.906, respectively) was recorded. Moreover, positive and significant ($P<0.05$) correlation was found between Nitrogen content and carbohydrate (0.834) and protein content (0.981). Also, positive and significant ($P<0.05$) relationship was found between P content and oil (0.743) and flavinoids (0.633) and DPPH (0.889). It could be notice that the rest of characters correlated positively with each other indicating that these characters should be considered when the agronomist selects the optimum N, P and K fertilizers for obtaining higher seed yield.

Table (5): Simple correlation coefficients among seed yield and its related characters in sunflower plants

	Seed yield	N	P	K	Carboh--ydrate	Oil	Protein	Flavinoids
Nitrogen	0.891							
Phosphorus	0.938	0.989						
Potassium	0.923	0.933	0.965					
Carbohydrate	0.915	0.834	0.889	0.935				
Oil content	0.869	0.656	0.743	0.804	0.849			
Protein	0.890	0.981	0.989	0.933	0.833	0.655		
Flavinoids	0.754	0.525	0.633	0.742	0.817	0.833	0.523	
DPPH	0.906	0.821	0.889	0.950	0.939	0.841	0.820	0.888

Discussion

Data of plant height showed their reduction under water deficit conditions (Fig. 1). Low water intake, photosynthetic disturbances, reduced endogenous hormone production and decreased activity of various enzymes that may be the most relevant reasons for this decline (Sadak andRamadan, 2021). According to Gholami *et al.* (2010), water deficit is one of the environmental stresses that negatively affect plant development, organs and activities by accumulating reactive oxygen species (ROS), which is then eliminated by the antioxidant defense system by reducing the damaging effects of stress.

Reducing water application rate from 100% WR to 60% WR reduced seed weight and seed yield compared with control, while the reverse was true since it significantly ($P<0.05$) increased 1000-seed weight and seed yield of sunflower, respectively (Table 2). This indicates that under dry conditions the reduction effect of irrigation water is higher than the side effects refer to increasing irrigation rate. This is in agreement with those of Eghball *et al*. (2004) who showed that lower grain yield under less irrigation water was found. El-Sayed *et al.* (2020) on peanut plants, Bakry *et al.* (2016) on Quinoa plants and Abdallah *et al.* (2019) on wheat plants found that plants grown under water deficit (by skipping irrigation) led to lowered nutritive values (oil, protein and carbohydrates) of the yielded seeds in comparison with corresponding control. It was reported that the enough amount of water is more suitable to export the dry matter content to grains resulting in more grain filling and improving soil chemical and biological properties, decreasing nutrient losses by leaching and introduce good aeration associated with the relatively low application of irrigation water (Abou- Baker 2008).

The differentiation between WUE (Table 2) of studied sunflower and its reference range, can be ascribed to nutrient management application treatments. These results are in close association with Fan *et al.* (2005) who hypothesized that perhaps the WUE of manure + NP treatment could increase with time as soil organic matter increased. They also added that organic materials could increase water-holding capacity that, in turn, improves water availability to plants and arrests grain yield declines and sustains productivity. These results are on line with results of Bakry *et al.* (2012), on linseed plants, who reported that TSS played an essential role in carbon storage and osmotic adjustment as well as radical scavenging which increased in a company to water stress. Moreover, Ezzo*et al.* (2018) on Moringa plants and Hellal *et al*. (2019) on barley plants showed that free amino acids, e.g., Proline and TSS were increased in water stressed and non-stressed plants. This revealed that these components improved cells adaptation capability to different stress conditions, since it raised osmotic pressure in cytoplasm, stabilized proteins and membranes resulting in maintaining the relatively higher water content necessary for plant growth and its cell functions.

In addition, Anjum *et al.* (2011) indicated that proline as a nitrogen and carbon source for recovery from stress, acting as stabilizer for membranes and some macromolecules and free radical scavenger as well. Various abiotic stress caused motivation in proline synthesis in plant tissues accompanied to the decrease in proline oxidase activity which might play a vital role against oxidative damages resulted from reactive oxygen spices "ROS" (Bakry *et al.* (2012). Recently, Abdallah *et al.* (2019) on wheat plants and El-Sayed *et al.* (2020) on peanut plants observed that there was significant accumulation for large amount of some compatible solute (Proline, free amino acids and total soluble sugar) under water stress, while DPPH%, phenolic compounds and IAA were decreased.

The interaction between WR and LOF had a significant ($P<0.05$) effect on the studied parameters during the two growing seasons. Foliar fertilization with LOF caused significant ($P<0.05$) increases in plant height and chlorophyll contents (Figs. 1 and 2) at 45 and 60 DAS under different irrigation requirements (normal and water deficit conditions). The LOF contained many nutrients and organic acids, Humic acid, Fulvic acid and Citric acid which have an motivation effect on plants growth. In these respect, Rongting *et al*. (2017) found that LOF significantly improved root and aboveground growth by 10.2–77.8 % and 10.7– 33.3% of Chrysanthemum plants. Also, Shaik *et al.* (2022) showed that the chlorophyll content of lettuce plants fertilized with LOF was greater in all sampling dates compared with the control treatment and explained these increments due to the presence of macro- and micronutrients (Treadwell *et. al.,* 2007). Also, the findings of Haggag *et al.* (2016) on Apricot trees and Zandvakili *et al*. (2019) on lettuce came on line with the present results.

The highest seed quality (Carbohydrates, Oil, protein, Flavinoids and DPPH) as well as mineral contents (N, P, K, Fe, Zn, Mn and Cu) were recorded in the yielded seeds by increasing rate of LOF (Tables 3 & 4). The increase in chemical constituents maybe due to the increments in total chlorophylls (Fig. 2), antioxidant compounds (Total phenol and DPPH), osmoprotectants (TSS and proline) and IAA content (Table 1). These results are in agreement with those obtained by Haggag *et al.* (2016) who discovered that applying LOF to apricot trees at concentrations of 0.5, 1.0 and 1.5 Cm/L improved leaf mineral content (N, P, K, Fe, Zn and Mn), leaf area, and leaf pigments content (chlorophyll a, b and carotenoids) and accordingly fruit quality and yield.

They also stated that all treatments were effective in improving TSS percentage, TSS/acid and total sugar percentage compared to the control group. Yadegari (2016) found that the applications of micronutrients and bio fertilizer had significant effects of essential oils of Lemon balm. Data postulated in Table (5) showed that there is a positive strong correlation between the seed yield and the content of chemical components (Carbohydrate, oil, protein, flavinoids and NPK) in seeds as a result of foliar spraying with LOF.

Conclusions

The application of LOF (1.5 L/fed) under water stress can be the recommended dosage for optimum sunflower production due to the improvement of plant growth parameters and seed yield and the studied chemical and biochemical parameters. The use of LOF is expected to reduce the use of inorganic fertilizers in order to achieve environmentally friendly and sustainable agriculture.

Conflicts of Interest

Regarding the publication of this manuscript, the authors declare no conflicts of interest.

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