Effect of Organic and Inorganic Fertilization with Spraying of Fulvic Acid on Nutrients Uptake, Quality and Yield of Roselle (*Hibiscus sabdariffa* L.) Plant Grown in Sandy Soil at Siwa Oasis, Egypt

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ABSTRACT

During two successive seasons (2016 and 2017) at Khimisah experimental farm which is located at the latitude of 29°12' 34.5 N'', and the longitude of 25° 24' 2.56'' E., Siwa Research Station, (Matrouh Governorate), Desert Research Center, Egypt, a field experiment was executed under irrigation with saline water (4.2dSm^{-1}) to investigate the effect of five fertilizer combinations (FC) of both organic and inorganic fertilization as follows; 100%NPK recommended dose i.e. 180kgN, 31kgP and 100kgK ha^{-1} (FC1), 50%NPK+6MT compost ha^{-1} (FC2), 75%NPK+ 6MTha^{-1} compost (FC3), 50%NPK + 12MTcompost ha^{-1} (FC4) and 75%NPK + 12 MTcompost ha^{-1} (FC5) and foliar application of fulvic acid at four levels i.e. 0.0, 250, 500 and 750mgL^{-1} on the vegetative growth parameters, leaf nutrient uptake, yield and quality of roselle (*Hibiscus sabdariffa* L.) plants in arandomized complete block design with split plot technique in three replications where the main factor was five fertilizer combinations (FC) while the sub main factor was the foliar application of fulvic acid treatments (FA).

Results indicated that the single application of FC5 or FA (at 750mgL^{-1}) showed the highest significant values for plant height (cm), leaves number/plant, leaves dry weight g/plant, branches number/plant, branches fresh weight g/plant and branches dry weight /plant, leaf N, P, K, Fe, Zn and Mn uptake, sepals yield MTha^{-1}, seed yield MTha^{-1}, seed fixed oil yield Lha^{-1}, sepals anthocyanin, vitamin C and acidity in both study seasons. The dual application of FC5 with FA at 750mgL^{-1} resulted in increasing in all studied parameters except sepals acidity which are reduced in both study seasons. It can be concluded that the dual application of FC5 with FA at 750mgL^{-1} is considered as a recommended treatment in the cultivation of roselle plants at Siwa Oasis due to it resulted in high yield and quality and the highest net profit (40.450×10^{3}ha^{-1}) and the highest net return (29.336×10^{3}ha^{-1}) and reducing theenvironmental pollution because of it had partial replacement of mineral fertilizer with organic one (compost and fulvic), especially under the conditions of Siwa Oasis as a natural reserve.

Keywords: Roselle, inorganic & organic fertilization, leaf nutrients uptake, yield and quality.

INTRODUCTION

Roselle (*Hibiscus sabdariffa*, L.) is one of the most important plants of the Malvaceae Family, which produce a fleshly red calyxes and epicalyxes (sepals). Roselle sepals are used for the preparation of hot and cold red drinks and obtaining the natural food coloring pigments such as anthocyanin compounds (Diab, 1968). Moreover, it is used as hypotensive agent since it lowers blood pressure without producing side effect (Sharaf, 1962). In addition, Roselle seeds contain about 17-30% fixed oil which is similar in its properties to cotton seed oil (Hussin *et al.*, 1991). It has antimicrobial activities due to its phenolic compounds. It contains protein, fibers, calcium, iron, carotene, and ascorbic acid (Fasoyiro *et al*. 2005).

The NPK requirements of medicinal and aromatic plants were recorded by many authors. In this respect, Ashorabadi, *et al*. (2003) on Foeniculum vulgare, Niakan *et al*. (2004) on Mentha piperita, Lee *et al*. (2005) on Chrysanthemum boreale and Gomaa and Youssef (2007) on fennel plant, Amran (2013) on Pelargonium graveolens plants and El-Khyat (2013) on Rosmarinus officinalis. They concluded that NPK fertilizers had an important physiological and biochemical functions on structure of photosynthetic pigments, metabolism of carbohydrates and protein and these effects were observed with significant increase in growth, yield and essential oil content of the different plant species.

Organic fertilizers increase soil organic matter, particularly for the sandy soils in Egypt, which record less than 1% and hence improve the physical, chemical and biological properties. Consequently, the availability of nutrients for plants as well as soil characteristics should be improved (FAO, 1977). Compost application to sandy soil significantly increased both dry matter production of sepals and number of roselle plant fruits. It is used to increase anthocyanin and ascorbic acid contents in addition to a reduction of the acidity and glucose in sepals (Kandeel, 2004).

Balanced plant nutrition has an important role in increasing the quality and color of flowers. Hilbert *et al.* (2003) reported that high intake of potassium can increase the amount of anthocyanins, but it will be reduced by high amounts of nitrogen fertiliser. Research has shown that organic fertilizers or hormones can increase product quality and quantity. Shehata, *et al*

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(2011) reported that, by using compost the amounts of total soluble salt and anthocyanin levels in strawberry fruit have increased in greater extent with respect to chemical fertilizer. El-Shrief and Sarwat (2007) reported that the amount of anthocyanins, iron, zinc and manganese in Roselle flowers have increased by application of poultry manure.

Many beneficial effects are attributed to foliar application of fulvic acid (FA), including stimulation of plant metabolism, increased enzyme activity (transaminase, invertase), increased bioavailability and uptake of nutrients and increased crop growth and yield (Jifon and Lester, 2009). Fulvic acid has maximum influence on chemical reactions because of the presence of more electronegative oxygen atoms than any other humate molecules, which enhances membrane permeability (Priya *et al*., 2014). Application of fluvic acid positively affected plant growth under saline soil conditions, but higher doses of FA inhibited plant growth (Türkmen *et al*., 2004). Fluvic materials can affect physiological processes of plant growth directly or indirectly (Yang *et al*., 2013). Fluvic substances might show anti-stress effects under abiotic stress conditions such as, unfavorable temperature, pH, salinity etc. Fluvic substances could improve plant growth under soil condition with enhancing the uptake of nutrients and reducing the uptake of some toxic elements (Kulikova *et al*., 2005). Fulvic acid easily binds or chelate minerals such as iron, calcium, copper, zinc and magnesium, as it can deliver this elements to plant directly (Yamauchi *et al*., 1984). Fulvic acid application enhanced root activity, increase in ion uptake, high rate of transport of phosphorus to the grains (Xudan, 1987), increasing the number and length of root hairs of Arabidopsis plants (Schmidt *et al*., 2005), promote plant growth and increase marketable yield in tomato production (Suh *et al*., 2014), improved plant growth and yield quantity and quality of cucumber plants and enhanced the activity of soil microorganism (Kamel *et al*., 2014), enhanced effectively the physiological activities and yield production of tomato plants, as antitranspirants via conserving soil water and thereby reduce the applied water by 25% of irrigation water (Aggag *et al*., 2015), improve the quality of berry fruit and more absorption of calcium by grape (Huanpu *et al*., 2004), enhanced potassium levels in leaves of tobacco acts in a manner similar to the plant hormone auxin (Priya *et al*., 2014).

Anjum *et al*. (2011) reported that fulvic acid increased chlorophyll and water content of leaves. It also increased photosynthesis, reduced stomata opening status and transpirations, thus led to growth stimulation and water loss reduction.

Aminifard *et al*. (2012) reported that fulvic acid enhanced multiple parameters of fruit quality, including total soluble solids, antioxidant activity, total phenolics, carbohydrates, capsaicin, and carotenoids of pepper. Bocanegra *et al*. (2006) concluded that "the combined capacity of fulvic acids both to chelate nutrients and move through membranes has suggested the fulvic acids may play similar roles as natural chelators in the mobilization and transport micronutrients". Moreover, Yang *et al*. (2013) have demonstrated that fulvic acid is optimum choice for the improvement of nutrients availability and soil physicochemical conditions. Anjum *et al*. (2011) reported that fulvic acid increased chlorophyll and water content of leaves. It also increased photosynthesis, reduced stomata opening status and transpirations, thus led to growth stimulation and water loss reduction (Li *et al*., 2005). Also they have found that fulvic acid and humic acid have been used to regulate the plant growth under well watered and drought conditions. Furthermore, fulvic acid as metabolic antitranspirations is an organic acid, nontoxic, not expensive and did not cause pollution problems as a result of extensive use (Nardi *et al*., 2002). Silva *et al*., (2016) observed that fulvic acid easily binds or chelate minerals such as iron, calcium, copper, zinc and magnesium, as it can deliver this elements to plant directly. Kamel *et al*. (2014) revealed that the foliar application of fulvic acid improved plant growth and yield quantity and quality of cucumber plants.

Li *et al*. (2005) indicated that falvic acid foliar spraying resulted to 7.2% increase of grain yield at the optimal concentration of fulvia acid ($1.5mlL^{-1}$). Aggag *et al*. (2015) were studied the kaolin and fulvic acid as antitranspirants on tomato plants under three water regimes in the two seasons and revealed that both kaolin and fulvic acid enhanced effectively the physiological activities and yield production of tomato plants, These led to conserving soil water and thereby reduce the applied water by 25% of irrigation water. Anjum *et al*. (2011) reported that fulvic acid increased chlorophyll and water content of leaves. Fulvic acid also increased photosynthesis, reduced stomata opening status and transpiration, thus led to growth stimulation and water loss reduction. Zancani *et al*. (2011) suggested that fulvic acid applied to cell cultures of Greek fir interacted with the signaling pathway for plant hormones and increased intercellular levels of ATP and glucose-6-phosphate, physiological effects that were related to growth promotion.

Yazdani *et al*. (2014) found higher nutrient uptake and accumulation of N, P, K, Ca, Fe and Zn in leaves of gerbera by fulvic acid. Hendawy *et al*. (2015) suggested that foliar application of humic acid had a significant effect on essential oil percentage and oil constituents of Mint plant. They concluded that increasing nutrient absorption can induce enzyme activity and metabolism of essential oil production. They also were stated that phosphorous can activate coenzymes for amino acid production, photosynthesis, glycolysis, respiration and fatty acid synthesis. On the other hands, increasing potassium absorption by fulvic acid may affect the metabolism of N and carbohydrates and the synthesis of lipid, starch and protein as reported by Zahra *et al*. (1984).

The cultivated area of roselle plant (*Hibiscus sabdariffa* L.) in Egypt is increasing gradually for local utilization and export. Using Egyptian desert soils in cultivating medical and aromatic plants such as roselle plant is considered as one of the most important targets especially in Siwa Oasis as a Protected Area where it is favourable to reduce application of chemical fertilizer and pesticides to prevent environmental pollution as possible. It is well known that most of irrigation water in Siwa Oasis is saline either agricultural drainage or well water. So this investigation aims to overcome these adverse conditions by cultivating economical and salinity tolerant plant such as roselle plant and trying to improve its leaf nutrients uptake, yield and quality by doing the integration between inorganic fertilizer and organic one such as compost and fulvic acid foliar spray.

MATERIALS AND METHODS

This study was performed at the Experimental Khamisa Farm (25º 24' 2.56" E, 29º 12' 34.5" N), Siwa Research Station, Desert Research Center during 2016 and 2017 seasons to study the effect of five fertilizer combinations (FC) of both organic and inorganic fertilization as follows; 100%NPK of recommended dose (FC1) i.e. 180kgN, 31kgP and 100kgKha^{-1} in the form of ammonium sulfate, superphosphate and potassium sulfate, respectively), 50%NPK+6MT compostha^{-1} (FC2), 75%NPK+ 6MT compostha^{-1} (FC3), 50%NPK + 12MTcompostha^{-1} (FC4) and 75%NPK + 12MTcompostha^{-1} (FC5) with foliar application of fulvic acid (FA) at four levels i.e. 0.0, 250, 500 and 750mgL^{-1} on vegetative growth, leaf nutrient uptake, yield and quality of roselle (*Hibiscus sabdariffa* L.) plants. This experiment was conducted in a split plot design with three replicates where the five combinations of both organic and inorganic fertilizers were assigned in the main plot, while the foliar application treatments of fulvic acid were assigned in the sub main plot.

Some physical and chemical properties of the experimental soil were determined according to Jackson (1973) and Black *et al.* (1982). The obtained results of soil analyses are presented in Table 1. The chemical properties of applied compost, which are producing from plant wastes and animal manure, and irrigation water, are also shown in Table 1.

Roselle seeds were sown in sandy soil on 15 March of each season in plots (1.5x6 m) containing three rows (50cm width) every row had 12 hills (50cm apart) and at three seeds per hill, and one month later, the plants were thinned, leaving only one seedling/hill.

The amount of N and K fertilizers were divided into three equal portions as side dressing and added at three dates: on 15 June, on 15 July and on 15 August, respectively of both study seasons. However, the amount of P-fertilizer and compost were added to the soil before seed sowing during soil preparation. Fulvic acid treatments were applied as foliar spray at 30, 60 and 90 days after planting, respectively.

Table 1. Some physical and chemical properties of the experimental soil, applied compost and irrigation water at Khamisa farm

Soil depths (cm)	Coarse sand%	Fine sand%	Silt%	Clay%	Texture
0-30	67.15	24.94	6.05	0.86	Sand
30-60	67.20	26.30	6.67	0.83	Sand

Soil depths (cm)	EC dSm^{-1}	Ph	Organic Matter (OM) %	Available nutrients (N) %	(P) mgL^{-1}	(K) mgL^{-1}
	Soil extraction 1:2.5					
0-30	0.833	8.14	0.21	0.21	2.50	22.3
30-60	0.698	8.03	0.24	0.23	2.38	20.4

The applied compost	EC dS.m^{-1} (1:10)	pH (1:10)	Total C %	Total N %	Total P %	Total K %	Total Fe mgL^{-1}	Total Zn mgL^{-1}	C:N ratio
	3.32	7.52	23.56	1.24	0.43	1.51	1297	224	19:1

Irrigation water	pH	EC dSm^{-1}	Na^+	K^+	Ca^{++}	Mg^{++}	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	SAR
			Soluble Cations in mmolcL^{-1}				Soluble Anions in mmolcL^{-1}				
	7.79	4.20	30.20	1.40	4.40	6.10	…	4.00	25.60	12.50	13.18

Vegetative growth parameters such as plant height (cm.), number and dry weight of leaves (g)/plant, number, fresh and dry weight of branches (g)/plant were taken at the beginning of flowering stage; on 30 August, 2016 and 2017 seasons.

Data of yield parameters as sepals yield (MTha^{-1}), seed yield in (MTha^{-1}) and seed fixed oil yield (MTha^{-1}) were recorded at harvesting time i.e. 15 October, 2016 and 2017 seasons (i.e. growth season duration was about 7 months).

The determinations of chemical constituents were determined as follows; at harvesting time (on 15 October) anthocyanin content was determined in air-dried roselle sepals according to the method described by Du and Francis (1973), the percentage of fixed oil in seeds was determined according to the method mentioned by A.O.A.C (1980), ascorbic acid was determined in sepals as described in A.O.A.C. (1980), sepals acidity (pH value) was determined according to Diab (1968), while during flowering stage (on 30 August), the percentage of N, P, K and total carbohydrates% were determined in the dry leaves, where total nitrogen was determined using Micro-Kieldahl method according to A.O.A.C. (1980), phosphorus was determined colourimetrically in spectrophotometer using the method described by Trouge and Meyer (1939), whereas, K content was determined by flame photometer according to Brown and Lilleland (1946), Fe, Zn, and Mn were determined in the wet digested samples by atomic absorption as described by Chapman and Paratt (1961). Total carbohydrates (mg/g D.W), total sugars (mg/g F.W), total free amino acids (mg/g F.W), chlorophyll a & b and carotenoids (mg/g F.W), were determined in the roselle leaves at the beginning of flowering stage according to Herbert *et al*. 1971, Thomas and Dutcher, 1924, Rosed,1957 and A.O.A.C, 1980, respectively.

All data obtained in both seasons of study were subjected to statistical analysis of variance as factorial experiments in split plot design. L.S.D. method was used to differentiate means according to Snedecor and Cochran (1989).

RESULTS AND DISCUSSION

The highest plant height (147.1 and 151.4cm), branches fresh weight (1125.5 and 1216.1g/plant) and branches dry weight (201.4 and 208.6g/plant) were recorded with the treatment of the full dose of mineral fertilizers (FC1), the second highest plant (143.4 and 174.5cm) was noticed at FC3 treatment whereas no significant differences were observed between FC1, FC3 and FC5 regarding their effect on both fresh and dry weight of branches, combination of inorganic and organic fertilizers at 75% + 12MT compostha^{-1} (FC5) achieved the highest leaves number (140.1 and 147.5), branches number (20.95 and 22.11) and leaves dry weight (24.23 and 26.37), there were no significant differences were noticed among the effects of FC1, FC3 and FC5 concerning their effect on leaves number in the 1st and 2nd seasons, respectively. On the other hand application of 50% inorganic fertilizers + 6MT compostha^{-1} (FC2) scored the lowest values of all studied vegetative growth parameters in both study seasons.

With respect to the effect of foliar application of fulvic acid levels, Tables 2 and 3 reveal that most of all the studied vegetative growth parameters were gradually increased with increasing of fulvic acid (FA) concentrations over the control with superiority of 750mg/L level, there were significant differences between all FA levels regarding their effect on plant height, leaves number and branches fresh weight. No significant differences between 500 and 750mg/L of FA levels concerning their effect on leaves dry weight, branches dry weight and branches number in the two study seasons.

As shown in Tables 2 and 3, the interaction effect between the inorganic and organic fertilizer combinations (FC) and the levels of fulvic acid (FA) increased all the studied vegetative growth parameters of Roselle plant in both seasons. However, the highest significant interaction treatment was the foliar application of FA at 750mg/L with FC5 (70% mineral + 5.0MT compost ha^{-1}) regarding leaves number (146.0 and 156.1), leaves dry weight (27.08 and 29.72g/plant) and branches number (23.97 and 25.19) and with FC1 (100% mineral) concerning plant height (153.2 and 156.1cm), branches fresh weight (1190.9 and 1365.1g/plant) and branches dry weight (209.4 and 232.9g/plant) in the 1st and 2nd seasons, respectively.

These results are in accordance with those obtained by El-khayat (2001) on roselle plants, Niakan *et al.* (2004) on *Mentha piperita*, El-Maadawy and Moursy (2007) on jojoba, El-Shora (2009) on *Mentha piperita*, Khalil *et al.* (2010) on basil plants, Majeed and Ali (2011) on roselle plant, Gendy *et al.* (2012) on roselle plants, Gendy *et al.* (2013) on guar plants, Priya *et al*. (2014) on tobacco plant, Paramasivan *et al*. (2015) on *Solanum melongena* L., Khatab (2016) on roselle plant and Moradi *et al* (2017) on safflower plant.

Table 2.Effect of fulvic acid (FA) and Fertilizer combinations (FC) on plant height (cm), leaves number and leaves dry weights of roselle plants during 2016 and 2017 seasons

Parameters	Plant height (cm)				Mean	Leaves number/plant				Mean	Leaves dry weight g/plant				Mean
FC	Fulvic Acid (FA) in mgL^{-1}					Fulvic Acid (FA) in mgL^{-1}					Fulvic Acid (FA) in mgL^{-1}				
treatments*	0	250	500	750		0	250	500	750		0	250	500	750	
First Season (2016)															
FC1	139.2	146.2	149.9	153.2	147.1	134.6	140.3	139.6	145.9	140.1	21.45	23.53	22.90	25.61	23.37
FC2	131.7	134.9	135.7	138.0	135.1	100.8	103.3	109.8	105.7	104.9	15.35	17.72	17.12	20.09	17.57
FC3	137.5	142.8	145.1	148.1	143.4	134.2	140.1	140.3	145.9	140.1	21.26	23.80	23.79	26.35	23.80
FC4	132.9	136.2	137.4	139.5	136.5	110.3	115.3	124.6	120.4	117.7	17.54	20.35	22.28	23.17	20.83
FC5	135.7	139.4	140.3	143.1	139.6	133.7	139.9	140.9	146.0	140.1	21.08	24.08	24.68	27.08	24.23
Mean	135.4	139.9	141.7	144.4		122.7	127.8	131.0	132.8		19.33	21.90	22.15	24.46	
LSD0.05	**FC=1.0208 FA= 0.913 FC×FA= 0.189**					**FC= 1.758 FA= 1.572 FC×FA=0.518**					**FC= 0.424 FA= 0.380 FC×FA= 0.104**				
Second Season (2017)															
FC1	146.0	151.1	152.3	156.1	151.4	139.7	144.4	146.9	149.1	145.0	21.30	24.06	24.49	27.68	24.38
FC2	134.6	138.4	139.7	142.2	138.8	99.4	118.2	103.4	137.0	114.5	15.41	18.64	20.52	25.64	20.05
FC3	142.8	147.3	148.3	151.8	147.5	138.5	145.5	149.2	152.6	146.5	21.91	25.59	25.30	28.70	25.38
FC4	137.5	140.7	140.7	143.8	140.7	112.9	123.8	131.9	134.7	125.8	19.43	22.81	22.41	25.38	22.51
FC5	139.7	143.5	144.2	147.4	143.7	137.3	146.7	151.6	156.1	147.9	22.53	27.13	26.12	29.72	26.37
Mean	140.1	144.2	145.1	148.3		125.5	135.7	136.6	145.9		20.12	23.65	23.77	27.42	
LSD0.05	**FC=0.459 FA=0.410 FC×FA=0.189**					**FC=4.38 FA=3.92 FC×FA=0.542**					**FC=0.620 FA=0.554 FC×FA=0.118**				

*FC1; Mineral 100% (180N as ammonium sulphate, 31P as ordinary super phosphate & 10K as potassium sulphate $kgha^{-1}$) FC2; Mineral 50% + 6MT $compostha^{-1}$, FC3; Mineral 75%+ 6MT $compostha^{-1}$, FC4; Mineral 50% + 12MT $compostha^{-1}$, FC5; Mineral 75%+ 12MT $compostha^{-1}$.

Table 3.Effect of fulvic acid (FA) and Fertilizer combinations (FC) on number, fresh weight (F.W.) and dry weight (D.W.) of branches of roselle plants during 2016 and 2017 seasons

Parameters	Branches number/plant				Mean	Branches fresh weight g/plant				Mean	Branches dry weight /plant				Mean
FC treatments*	Fulvic Acid (FA) in mgL^{-1}					Fulvic Acid (FA) in mgL^{-1}					Fulvic Acid (FA) in mgL^{-1}				
	0	250	500	750		0	250	500	750		0	250	500	750	
First Season (2016)															
FC1	17.12	19.24	22.87	19.99	19.80	1033.6	1112.2	1165.4	1190.9	1125.5	190.2	199.8	206.4	209.4	201.4
FC2	14.96	16.26	17.20	16.08	16.12	782.9	845.8	799.0	908.7	834.1	139.3	151.9	145.3	164.4	150.2
FC3	17.58	20.00	23.42	20.50	20.38	1040.4	1109.7	1155.6	1179.0	1121.2	191.5	199.8	205.6	208.2	201.3
FC4	16.25	18.07	19.66	17.96	17.98	820.3	923.5	941.8	1026.8	928.1	148.4	167.4	171.3	186.3	168.3
FC5	18.05	20.77	23.97	21.01	20.95	1047.2	1107.1	1145.8	1167.1	1116.8	192.7	199.9	204.8	207.1	201.1
Mean	16.79	18.87	21.42	19.11		944.9	1019.7	1041.5	1094.5		172.4	183.7	186.7	195.1	
LSD0.05	**FC= 0.505 FA=0.452 FC×FA=0.084**					**FC= 17.34 FA=15.51 FC×FA=4.55**					**FC=3.28 FA=2.94 FC×FA=0.774**				
Second Season (2017)															
FC1	18.48	21.04	21.42	23.60	21.13	1059.1	1228.3	1212.1	1365.1	1216.1	182.2	212.0	207.5	232.9	208.6
FC2	15.95	17.08	20.66	18.22	17.97	847.5	856.8	974.5	1101.6	945.1	145.7	143.4	169.1	192.4	162.6
FC3	18.65	21.52	21.91	24.39	21.62	1075.3	1205.3	1193.0	1310.7	1196.1	187.6	210.8	207.0	226.4	208.0
FC4	16.86	19.13	19.66	21.39	19.26	865.3	998.8	960.5	1055.7	970.1	154.0	175.4	169.8	185.6	171.2
FC5	18.83	22.01	22.41	25.19	22.11	1091.4	1182.4	1173.9	1256.3	1176.0	193.0	209.6	206.5	220.0	207.3
Mean	17.75	20.15	21.21	22.55		987.7	1094.3	1102.8	1217.9		172.5	190.2	192.0	211.5	
LSD0.05	**FC=0.664 FA=0.594 FC×FA=0.085**					**FC=26.80 FA=23.97 FC×FA=4.96**					**FC=5.47 FA=4.89 FC×FA=0.856**				

*FC1; Mineral 100% (180N as ammonium sulphate, 31P as ordinary super phosphate & 10K as potassium sulphate $kgha^{-1}$) FC2; Mineral 50% + 6MT $compostha^{-1}$, FC3; Mineral 75%+ 6MT $compostha^{-1}$, FC4; Mineral 50% + 12MT $compostha^{-1}$, FC5; Mineral 75%+ 12MT $compostha^{-1}$.

2. Leaf nutrients uptake:

2.1. Leaf macronutrients uptake:

As presented in Table 4, although FC1 gave the highest roselle leaf macronutrients uptake (16.80 and 18.19, 3.739 and 3.722, and 29.28 and 29.74kgha^{-1}) for N, P and K in the 1st and 2nd season, respectively, there were no significant differences between FC1, FC3 and FC5 (Table, 4).

The highest significant FA foliar application treatment was FA4 which achieved the highest roselle leaf macronutrients uptake (17.47 and 19.70, 3.758 and 4.020, and 29.38 and 32.04kgha^{-1}) for N, P and K in the 1st and 2nd season, respectively.

Concerning the interaction effect of FC with FA treatments data in Table 4 reveal that the highest values for N, P and K uptake by roselle plant leaves were due to the interactions of FC1, FC3 and FC5 with FA at 750mgL^{-1}, respectively and there were no significant differences among all those three interaction treatments in both study seasons.

2.2. Leaf micronutrients uptake:

Table 5 indicated that there are significant differences among all fertilizer combinations (FC) treatments regarding Fe and Mn uptake of leaf roselle plant while no significant differences among FC1, FC3 and FC5 were observed for Zn uptake. The highest values were achieved by FC5 for Fe and Mn uptake and by FC1 for Zn uptake. On contrary the lowest significant treatment was FC2.

Foliar application of fulvic acid (FA) at 750mgL^{-1} was the highest significant treatment which gave the highest leaf micronutrients uptake values i.e. 847.9 and 937.7gha^{-1} for Fe, 439.4 and 523.4gha^{-1} for Zn and 214.4 and 218.5gha^{-1} for Mn in the 1st and 2nd seasons, respectively, while the lowest significant treatment was observed at without FA foliar application treatment in both study seasons (Table, 5).

With respect to the interaction between FC and FA treatments (Table, 5), the highest significant interaction treatment was the foliar application of FA at 750mgL^{-1} with FC5 (70% mineral + 12MT compostha^{-1}) for both Fe (971.8 and 1042.6gha^{-1}) and Mn (251.5 and 262.2gha^{-1}) and with FC1 for Zn (505.9 and 580.1gha^{-1}) in the 1st and 2nd seasons, respectively.

The previous results of fertilization regarding leaf nutrients uptake are in agreement with those obtained by El-khayat (2001) on roselle plants, Niakan *et al.* (2004) on *Mentha piperita*, El-Maadawy and Moursy (2007) on jojoba, El-Shora (2009) on *Mentha piperita*, Khalil *et al.* (2010) on basil plants, Majeed and Ali (2011) on roselle plant, Gendy *et al.* (2012) on roselle plants, Gendy *et al.* (2013) on guar plants, Priya *et a.l* (2014) on tobacco plant, Paramasivan *et al*. (2015) on *Solanum melongena* L., Khatab (2016) on roselle plant and Moradi *et al* (2017) on safflower plant.

3. Yields of roselle plant:

3.1. Dry sepals yield:

It is clear from data in Table 6 that there are significant differences between all inorganic and organic fertilizers combinations (FC) regarding their effect on dry sepals yield in MT ha^{-1}. The highest dry sepals yield (1.075 and 1.217MTha^{-1}) was achieved at FC5 followed by FC3 treatments, whereas, the lowest dry sepals yield (0.840 and0.965MTha^{-1}) was noticed at FC2 treatment in the 1st and 2nd seasons, respectively.

Data in Table 6 indicate that all levels of fulvic acid (FA) resulted in significant increases in dry sepals yield especially that received the high level (750mgL^{-1}) as compared with no FA application in the two study seasons. In general, all resulted interactions between FC and FA treatments statistically affected the sepals dry yield (MTha^{-1}) in both seasons. However, the highest sepals dry yield (1.212 and 1.294MTha^{-1}) was earned by using the combined treatments between FC5 and FA at 750mgL^{-1} when compared with other combinations in the 1st and 2nd seasons, respectively.

3.2. Seed yield:

Although, FC1 treatment gave the highest seed yield (1.622 and 1.745MTha^{-1}), it didn't significantly differ with FC3 and FC5 (Table, 6), whereas the lowest seed yield (1.315 and 1.452MTha^{-1}) was observed at FC2 treatment in the 1st and 2nd season, respectively. Foliar application of FA at 750mgL^{-1} gave the highest significant seed yield (1.750 and 1.726MTha^{-1}) and the lowest one (1.325 and 1.548MTha^{-1}) was observed at no FA foliar application in the 1st and 2nd season, respectively. The interaction treatments between FC and FA treatments affected significantly on seed yield where the highest seed yield was gained at FC1 with FA at 750mgL^{-1} treatment followed by FC3 with FA at 750mgL^{-1} and FC5 with FA at 750mgL^{-1} in both study seasons.

3.3. Seed fixed oil yield:

As presented in Table 6, significant differences were observed between all organic and inorganic fertilizer combinations (FC). FC5 had the highest seed fixed oil yield (236.9 and 260.01Lha^{-1}) followed by FC3 and FC1, whereas FC2 treatment gave the lowest seed fixed oil yield in the 1st and 2nd season, respectively. Foliar application of FA on roselle plant significantly increased seed fixed oil yield per ha, especially with high level (750mgL^{-1}) in both study seasons. The interaction treatment of FC5 with FA at 750mgL^{-1} gave the highes.

Table 4.Effect of fulvic acid (FA) and Fertilizer combinations (FC) on N, P and K uptake of leaves of ofroselle plants during 2016 and 2017 seasons

Parameters	N uptake (kgha^{-1})					P uptake (kgha^{-1})					K uptake (kgha^{-1})				
FC treatments*	Fulvic Acid (FA) in mgL^{-1}				Mean	Fulvic Acid (FA) in mgL^{-1}				Mean	Fulvic Acid (FA) in mgL^{-1}				Mean
	0	250	500	750		0	250	500	750		0	250	500	750	
First Season (2016)															
FC1	14.62	15.98	17.06	19.51	16.80	2.959	3.816	3.713	4.469	3.739	25.42	29.09	29.90	32.74	29.28
FC2	9.34	10.56	11.18	13.03	11.04	1.898	2.162	2.225	2.551	2.208	16.22	18.12	17.26	20.02	17.90
FC3	13.51	16.80	16.68	19.87	16.73	2.674	3.223	3.449	4.224	3.391	23.18	28.42	28.15	33.65	28.34
FC4	10.90	14.21	13.06	15.22	13.34	2.244	2.856	2.724	3.204	2.758	19.15	23.21	24.60	27.26	23.57
FC5	14.06	16.39	16.87	19.70	16.75	2.815	3.518	3.581	4.346	3.564	24.31	28.75	29.04	33.19	28.82
Mean	12.48	14.78	14.98	17.47		2.518	3.115	3.137	3.758		21.65	25.51	25.80	29.38	
LSD0.05	FC=0.425 FA=0.382 FC×FA=0.101					FC=0.127 FA=0.115 FC×FA=0.026					FC=0.773 FA=0.691 FC×FA=0.180				
Second Season (2017)															
FC1	14.18	18.00	18.82	21.82	18.19	2.774	3.754	3.713	4.651	3.722	24.05	29.66	29.98	35.28	29.74
FC2	8.83	12.53	11.11	16.25	12.19	1.877	2.285	2.633	3.386	2.544	15.02	20.81	18.94	26.57	20.33
FC3	13.92	17.78	18.14	21.65	17.86	2.878	3.754	3.550	4.224	3.600	23.06	29.09	31.08	35.11	29.59
FC4	12.46	14.78	14.81	17.09	14.78	2.407	2.878	2.906	3.408	2.899	20.06	24.05	24.19	28.06	24.10
FC5	14.04	17.88	18.48	21.72	18.02	2.825	3.754	3.631	4.438	3.662	23.57	29.38	30.53	35.18	29.66
Mean	12.70	16.20	16.27	19.70		2.551	3.286	3.286	4.020		21.14	26.59	26.93	32.04	
LSD0.05	FC=0.592 FA=0.439 FC×FA=0.120					FC=0.118 FA=0.106 FC×FA=0.024					FC=0.689 FA=0.617 FC×FA=0.185				

*FC1; Mineral 100% (180N as ammonium sulphate, 31P as ordinary super phosphate & 10K as potassium sulphate kgha^{-1}) FC2; Mineral 50% + 6MT compostha^{-1}, FC3; Mineral 75%+ 6MT compostha^{-1}, FC4; Mineral 50% + 12MT compostha^{-1}, FC5; Mineral 75%+ 12MT compostha^{-1}.

Table 5. Effect of fulvic acid (FA) and Fertilizer combinations (FC) on Fe, Zn and Mn uptake of leaves of ofroselle plants during 2016 and 2017 seasons

Parameters	Fe uptake (gha^{-1})					Zn uptake (gha^{-1}.)					Mn uptake (gha^{-1})				
FC treatments*	Fulvic Acid (FA) in mgL^{-1}				Mean	Fulvic Acid (FA) in mgL^{-1}				Mean	Fulvic Acid (FA) in mgL^{-1}				Mean
	0	250	500	750		0	250	500	750		0	250	500	750	
First Season (2016)															
FC1	657.1	777.8	757.0	898.3	772.6	354.5	430.3	415.4	505.9	426.5	146.1	184.6	184.2	223.2	184.5
FC2	421.0	530.4	490.1	639.8	520.3	198.0	248.9	269.3	299.8	253.9	74.7	125.2	120.2	175.7	123.9
FC3	660.0	797.5	796.3	935.0	797.3	343.0	421.0	421.7	498.7	421.0	154.7	196.1	196.1	237.4	196.1
FC4	509.0	651.6	700.8	794.2	663.8	254.6	328.1	368.2	401.8	338.2	117.5	150.9	174.8	184.2	156.8
FC5	663.1	817.4	835.7	971.8	822.0	331.4	411.4	427.7	491.5	415.4	163.4	207.5	207.9	251.5	207.6
Mean	582.0	715.0	715.9	847.9		296.4	367.9	380.4	439.4		131.3	172.8	176.6	214.4	
LSD0.05	**FC=15.89 FA=14.23 FC×FA=4.92**					**FC=9.94 FA=8.88 FC×FA=2.88**					**FC=6.77 FA=6.05 FC×FA=1.56**				
Second Season (2017)															
FC1	678.5	785.5	835.7	993.1	823.2	395.0	487.7	475.4	580.1	484.6	155.7	196.6	193.8	237.5	195.9
FC2	447.4	593.8	621.6	796.1	614.6	192.5	287.5	270.5	382.6	283.2	86.7	112.2	131.2	137.7	117.0
FC3	707.0	846.7	862.3	1017.8	858.5	388.3	482.9	489.4	577.7	484.6	158.6	204.2	206.4	249.8	204.7
FC4	611.3	708.2	725.3	839.3	721.0	305.5	403.4	423.1	501.4	408.5	120.2	162.9	188.7	205.6	169.3
FC5	735.6	907.9	889.0	1042.6	893.8	381.6	478.3	503.3	575.0	484.6	161.6	211.8	218.9	262.2	213.6
Mean	636.0	768.5	786.7	937.7		332.6	427.9	432.2	523.4		136.5	177.6	187.8	218.5	
LSD0.05	**FC=15.50 FA=13.87 FC×FA=5.04**					**FC=6.77 FA=6.05 FC×FA=3.54**					**FC=5.42 FA=4.85 FC×FA=1.46**				

*FC1; Mineral 100% (180N as ammonium sulphate, 31P as ordinary super phosphate & 10K as potassium sulphate $kgha^{-1}$) FC2; Mineral 50% + 6MT $compostha^{-1}$, FC3; Mineral 75%+ 6MT $compostha^{-1}$, FC4; Mineral 50% + 12MT $compostha^{-1}$, FC5; Mineral 75%+ 12MT $compostha^{-1}$.

Table 6. Effect of fulvic acid (FA) and Fertilizer combinations (FC) on Yield of dry sepals, seed and seed fixed oil of roselle plants during 2016 and 2017 seasons

Parameters	Dry sepals yield ($MTha^{-1}$)				Mean	Seed yield ($MTha^{-1}$)				Mean	Seed fixed oil yield (Lha^{-1})				Mean
FC	Fulvic Acid (FA) in mgL^{-1}					Fulvic Acid (FA) in mgL^{-1}					Fulvic Acid (FA) in mgL^{-1}				
treatments*	0	250	500	750		0	250	500	750		0	250	500	750	
First Season (2016)															
FC1	0.900	1.003	1.044	1.190	1.034	1.406	1.613	1.625	1.843	1.622	189.5	219.0	220.9	252.2	220.4
FC2	0.732	0.804	0.852	0.972	0.840	1.135	1.265	1.332	1.529	1.315	163.8	184.1	195.7	227.6	192.8
FC3	0.919	1.042	1.061	1.200	1.056	1.394	1.625	1.606	1.814	1.610	196.5	229.6	228.3	260.1	228.6
FC4	0.835	0.962	0.979	1.126	0.977	1.313	1.507	1.541	1.769	1.531	182.3	221.4	221.2	260.1	221.3
FC5	0.938	1.080	1.075	1.212	1.075	1.380	1.639	1.584	1.788	1.598	203.6	240.2	235.8	268.0	236.9
Mean	0.864	0.979	1.003	1.140		1.325	1.529	1.538	1.750		187.2	218.9	220.4	253.6	
LSD0.05	FC= 0.010 FA= 0.009 FC×FA=0.005					FC= 0.018 FA= 0.016 FC×FA=0.007					FC=2.820 FA=2.522 FC×FA=0.950				
Second Season (2017)															
FC1	1.109	1.169	1.186	1.262	1.181	1.601	1.723	1.805	1.848	1.745	211.5	231.9	240.6	252.2	234.0
FC2	0.965	0.962	0.967	0.967	0.965	1.450	1.433	1.507	1.418	1.452	204.3	210.1	218.6	215.9	212.2
FC3	1.111	1.210	1.195	1.279	1.198	1.613	1.721	1.778	1.831	1.735	226.5	244.5	254.5	262.5	247.0
FC4	0.941	0.994	1.104	1.265	1.075	1.452	1.586	1.555	1.723	1.579	216.3	233.6	238.9	250.9	234.9
FC5	1.114	1.253	1.205	1.294	1.217	1.625	1.718	1.752	1.812	1.728	241.6	257.2	268.3	272.8	260.0
Mean	1.049	1.118	1.130	1.214		1.548	1.637	1.680	1.726		220.0	235.5	244.2	250.9	
LSD0.05	FC=0.0386 FA=0.0336 FC×FA=0.0043					FC=0.0379 FA=0.0341 FC×FA=0.0050					FC=3.288 FA=2.942 FC×FA=0.660				

*FC1; Mineral 100% (180N as ammonium sulphate, 31P as ordinary super phosphate & 10K as potassium sulphate $kgha^{-1}$) FC2; Mineral 50% + 6MT $compostha^{-1}$, FC3; Mineral 75%+ 6MT $compostha^{-1}$, FC4; Mineral 50% + 12MT $compostha^{-1}$, FC5; Mineral 75%+ 12MT $compostha^{-1}$.

.

Table 7. Effect of fulvic acid (FA) and Fertilizer combinations (FC) on Antocyanin, Vitamin-C and Acidity of dry sepals of roselle plants during 2016 and 2017 seasons

Parameters	Sepals Anthocyanin (mg/100g DW)				Mean	Sepals Vitamin-C (mg/100g DW)				Mean	Sepals acidity (pH value)				Mean
FC	Fulvic Acid (FA) in mgL^{-1}					Fulvic Acid (FA) in mgL^{-1}					Fulvic Acid (FA) in mgL^{-1}				
treatments*	0	250	500	750		0	250	500	750		0	250	500	750	
First Season (2016)															
FC1	143.1	146.5	151.6	149.9	147.7	34.63	39.13	40.34	43.63	39.43	1.989	2.015	1.938	1.862	1.951
FC2	140.4	142.2	153.7	144.1	145.1	35.63	35.35	37.60	35.07	35.91	1.981	1.976	1.936	1.896	1.947
FC3	144.8	148.6	150.0	152.4	149.0	35.56	40.66	39.44	45.76	40.35	1.972	1.938	1.934	1.930	1.943
FC4	146.6	150.8	148.4	155.0	150.2	37.09	36.98	45.25	36.86	39.04	1.853	2.032	1.955	1.879	1.930
FC5	144.6	151.9	147.9	159.2	150.9	36.48	42.18	38.53	47.88	41.27	2.049	1.802	1.823	1.845	1.880
Mean	143.9	148.0	150.3	152.1		35.88	38.86	40.23	41.84		1.969	1.952	1.917	1.882	
LSD0.05	FC= 3.191 FA= 2.854 FC×FA=0.185					FC= 2.757 FA= 2.466 FC×FA=0.149					FC=0.0504 FA= 0.0424 FC×FA=0.0023				
Second Season (2017)															
FC1	147.2	150.7	156.5	154.2	152.2	36.18	40.32	39.27	44.46	40.05	2.066	2.049	1.968	1.887	1.992
FC2	144.0	146.1	158.4	148.2	149.2	35.11	35.32	36.72	35.53	35.67	2.006	1.989	1.934	1.879	1.952
FC3	147.8	152.7	154.1	157.7	153.1	36.07	41.59	39.25	47.10	41.00	2.019	1.955	1.921	1.887	1.945
FC4	146.5	155.0	145.8	163.5	152.7	37.24	36.70	47.71	36.16	39.45	1.964	1.853	1.845	1.836	1.874
FC5	148.3	154.7	151.6	161.1	153.9	35.97	42.86	39.24	49.75	41.95	2.032	1.921	1.908	1.896	1.939
Mean	146.8	151.8	153.3	156.9		36.11	39.36	40.44	42.60		2.017	1.953	1.915	1.877	
LSD0.05	FC=2.44 FA=2.182 FC×FA=0.169					FC=2.28 FA=2.042 FC×FA=0.130					FC=0.0186 FA=0.0167 FC×FA=0.0024				

*FC1; Mineral 100% (180N as ammonium sulphate, 31P as ordinary super phosphate & 10K as potassium sulphate $kgha^{-1}$) FC2; Mineral 50% + 6MT $compostha^{-1}$, FC3; Mineral 75%+ 6MT $compostha^{-1}$, FC4; Mineral 50% + 12MT $compostha^{-1}$, FC5; Mineral 75%+ 12MT $compostha^{-1}$

seed fixed oil (268.0 and 272.8Lha^{-1}) in the 1st and 2nd season, respectively.

The previous results of fertilization with respect to yield parameters are in parallel with those obtained by El-khayat (2001) on roselle plants, Niakan *et al.* (2004) on *Mentha piperita*, El-Maadawy and Moursy (2007) on jojoba, El-Shora (2009) on *Mentha piperita*, Khalil *et al.* (2010) on basil plants, Majeed and Ali (2011) on roselle plant, Gendy *et al.* (2012) on roselle plants, Gendy *et al.* (2013) on guar plants, Priya *et al* (2014) on tobacco plant, Paramasivan *et al*. (2015) on *Solanum melongena* L., Khatab (2016) on roselle plant and Moradi *et al* (2017) on safflower plant.

4. Sepals quality parameters:

4.1. Sepals anthocyanin content:

Table 7 showed that the highest anthocyanin content (180.79 mg/100g DW) was accumulated in sepals as a result of using FC5 treatment (150.9 and 153.9mg/100g DW) in the 1st and 2nd seasons, respectively. No significant differences were observed between FC5, FC1, FC3 and FC4 in both seasons. In addition, FA foliar application at 750mg/L was the highest significant (152.1 and 156.9mg/100g DW) and no significant differences between this treatment and FA at 500mg/L one treatment in the 1st and 2nd season, respectively. In general, the interaction effect of FC5 and FC4 with foliar application of fulvic acid at 750 resulted in the highest anthocyanin content of roselle sepals i.e. 159.2 and 163.5 mg /100g DW in the 1st and 2nd seasons, respectively.

4.2. Sepals vitamin C content:

Data in Table 7 indicate that the highest content of vitamin C (41.27 and 41.95mg/100g DW) was noticed at FC5 in the 1st and 2nd seasons, respectively, and no significant differences was observed among FC1, FC3, FC4 and FC5 in both study seasons. Moreover, foliar application of fulvic acid (FA) significantly increased sepals content of vitamin C compared to no FA application in both study seasons. On the other hand, the interaction of FC5 with FA at 750mg/L showed to be the most effective one for enhancing the highest sepals vitamin-C content (47.88 and 49.75mg/100g DW, in the 1st and 2nd seasons, respectively).

4.3. Sepals acidity value:

Data in Table 7 show that the highest significant sepals acidity value was noticed at FC1 treatment (1.951 and 1.992) in the 1st and 2nd seasons, respectively, while the lowest sepals acidity value was due to FC5 treatment whish had no significant differences with FC1, FC3 and FC4 treatments in both study seasons. Regarding the effect of fulvic acid treatments, no application of FA treatment achieved the highest acidity values (1.969 and 2.017) in the 1st and 2nd seasons, respectively, whereas FA at 750 showed the lowest sepals acidty value and no significant differences among FA application treatments i.e. FA at 750, 500 and 250mg/L in both study seasons. Generally, slightly reducing in sepals acidity values were scored due to the interaction between FC5 with all FA foliar application treatments i.e. FA at 750, 500 and 250mg/L in both study seasons.

The previous data of sepals quality parameters (i.e. sepals anthocyanin, vitamin C and acidity) in close conformity with the findings of El-khayat (2001) on roselle plants, Niakan *et al.* (2004) on *Mentha piperita*, El-Maadawy and Moursy (2007) on jojoba, El-Shora (2009) on *Mentha piperita*, Khalil *et al.* (2010) on basil plants, Majeed and Ali (2011) on roselle plant, Gendy *et al.* (2012) on roselle plants, Gendy *et al.* (2013) on guar plants, Priya *et al*. (2014) on tobacco plant, Paramasivan *et al*. (2015) on *Solanum melongena* L., Khatab (2016) on roselle plant and Moradi *et al* (2017) on safflower plant.

5. Net profit and net return:

To recognize the net profit and net return of the different studied treatments, the average increase of dry sepals yield (MTha^{-1}) as a main yield of roselle plant, were calculated during both study seasons by comparing the lowest sepals dry yield at FC2+FA0 treatment with the that at the other treatments (Table, 8).

Results indicated that the highest net profit (40.450×10^3LEha^{-1}) and the highest net return (29.336×10^3LEha^{-1}) were achieved due to the dual application of FC5 with FA at 750mgL^{-1}.

CONCLUSION

Fulvic acids (FAs) are a mixture of weak aliphatic and aromatic organic acids which are soluble in water at all pH conditions (acidic, neutral and alkaline). Their composition and shape is quite variable. The size of fulvic acids (HFs) are smaller than humic adds (HAs), with molecular weights which range from approximately 1,000 to 10,000. Fulvic acids (FAs) have an oxygen content twice that of humic acids (HAs). They have many carboxyl (COOH) and hydroxyl (COH) groups, thus fulvic acids (FAs) are much more chemically reactive. The exchange capacity of fulvic acids (FAs) is more than double that of humic acids (HAs). This high exchange capacity is due to the total number of carboxyl (COOH) groups present. The number of carboxyl groups present in fulvic acids (FAs) ranges from 520 to 1120cmol (H+)/kg. Fulvic acids collected from many different sources and analyzed, show no evidence of methoxy groups (CH_3) groups, they are low in phenols, and are less aromatic compared to humic acids from the same sources. Because of the relatively small size of

Table 8. Net profit and net return for the average increase in dry sepals yield for both study seasons

Treatments	Average yield MT/fed	Average Increase in yield $MTha^{-1}$	Cost LE $\times 10^3$ ha^{-1}	Net profit LE $\times 10^3$ ha^{-1}	Net return LE $\times 10^3$ ha^{-1}
FC1+FA0	1.005	0.156	6.419	15.600	9.181
FC2+FA0	0.849	0.000	5.010	0.000	-5.010
FC3+FA0	1.015	0.167	6.614	16.650	10.036
FC4+FA0	0.888	0.039	6.810	3.950	-2.860
FC5+FA0	1.026	0.178	8.414	17.750	9.336
FC1+FA250	1.086	0.238	7.319	23.750	16.431
FC2+FA250	0.883	0.035	5.910	3.450	-2.460
FC3+FA250	1.126	0.278	7.514	27.750	20.236
FC4+FA250	0.978	0.130	7.710	12.950	5.241
FC5+FA250	1.167	0.318	9.314	31.800	22.486
FC1+FA500	1.115	0.267	8.219	26.650	18.431
FC2+FA500	0.910	0.061	6.810	6.100	-0.710
FC3+FA500	1.128	0.280	8.414	27.950	19.536
FC4+FA500	1.042	0.193	8.610	19.300	10.691
FC5+FA500	1.140	0.292	10.214	29.150	18.936
FC1+FA750	1.226	0.378	9.119	37.750	28.631
FC2+FA750	0.970	0.121	7.710	12.100	4.391
FC3+FA750	1.240	0.391	9.784	39.100	29.316
FC4+FA750	1.196	0.347	9.510	34.700	25.191
FC5+FA750	1.253	0.405	11.114	40.450	29.336

FC1; Mineral 100% (180N as ammonium sulphate, 31P as ordinary super phosphate & 10K as potassium sulphate $kgha^{-1}$) FC2; Mineral 50% + 6MT $compostha^{-1}$, FC3; Mineral 75%+ 6MT $compostha^{-1}$, FC4; Mineral 50% + 12MT $compostha^{-1}$, FC5; Mineral 75%+ 12MT $compostha^{-1}$.

fulvic acid (FA) molecules they can readily enter plant roots, stems, and leaves. As they enter these plant parts they carry nutrients from plant surfaces into plant tissues. Foliar spray applications containing fulvic acid (FA) mineral chelates, at specific plant growth stages, can be used as a primary production technique for maximizing the plants productive capacity. Fulvic acids (FAs) are the most effective carbon containing chelating compounds known. They are plant compatible, thus non-toxic, when applied at relatively low concentrations (Majeed and Ali (2011); Priya *et al.*, 2014; Paramasivan *et al.*, 2015; Khatab (2016) and Moradi *et al.*, 2017).

To interpret and evaluate the effect of nitrogen, phosphorus and potassium concerned in this study, on augmenting the different tested vegetative growth parameters, yield component leaf nutrients content and sepals quality parameters of roselle plants, it is important to refer to the physiological roles of nitrogen, phosphorus and potassium in plant growth and development. Such three macronutrient elements are the common elements usually included in fertilizers (Cooke, 1982). Plant supplement with these macronutrients in form of fertilizers is necessary because the soil is usually in deficient of them due to plant removal leaching or they are not readily available for plants. Therefore, such addition of well balanced NPK fertilization quantities insured production of high productivity and chemical constituents of roselle plants.

Nitrogen is essential for plant growth and development as a constituent of many amino acids, enzymes and energy transfer materials such as chlorophyll, ADP and ATP. Growing plants must have nitrogen to form new cells and the rate of growth then becomes very nearly proportional to the rate at which nitrogen is supplied (Bidwell, 1974). Besides, supplying the plants with adequate quantities of N at right time tends to increase cell number and cell size with an overall increase in the vegetative growth production (Thompsond and Troch, 1975).

Phosphorus is essential for cell division and for development of meristematic tissues and it is very important for carbohydrate transformation due to multitude of phosphorylation reaction and to energy rich phosphate bond (Lambers *et al.*, 2000). Phosphorus compounds are also essential for photosynthesis, the inter conversion of carbohydrates and related glycolysis, amino acid metabolism, fat metabolism and biological oxidation. Lack of phosphorus, therefore hampers metabolic processes, such as the conversion of sugars into starch and cellulose (Devlin, 1972).

Potassium is important for growth and elongation probably due to its function as an osmotic and may react synergistically with IAA. Moreover, it promotes CO_2 assimilation and translocation of carbohydrates from the leaves to storage tissues (Mengel and Kirkby, 1987).

When organic manures added as fertilizer, it led to decrease soil pH which in turn increasing solubility of nutrients for plant uptake, in some cases organic materials may act as low release fertilizer. Recently, on the way of sustainable agriculture with minimum effects, the use of organic manures as natural soil amendments is recommended to replace the soluble chemical fertilizers. They improve the structure of weak-structured sandy soils and increase their water holding capacity. Also, they improve soil fertility, and stimulate root development, induce active biological conditions and enhancing activities of micro-organisms especially those involved in mineralization (Zheljazkov and Warman, 2004).

The present study, therefore, indicated that the using the integration between mineral (NPK) and organic fertilizers (compost and fulvic acid) has become an urgent necessity to provide maximum net return and high exportation characteristics for medicinal plants such as roselle plant due to its important roles in reducing soil and water pollution consequently playing a safety role on human health especially under Siwa Oasis conditions as a natural reserve.

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الملخص العربي

تأثير التسميد العضوى والمعدنى مع الرش بحامض الفالفيك على إمتصاص المغذيات وجودة وإنتاجية نبات الكركدية النامى فى واحة سيوة، مصر

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أجريت تجربة حقلية خلال موسمين متعاقبين (٢٠١٦ ، ٢٠١٧) بمزرعة خميسة التجريبية التي تقع على خط عرض 29°12' 34.5" شمالاً وخط طول 25° 24' 2.56" شرقاً بمحطة بحوث سيوة ، محافظة مطروح ، مركز بحوث الصحراء ، القاهرة ، مصر ، تحت ظروف الري بالمياه المالحة (٤,٢ ديسيسيمنز/م) لدراسة تأثير خمس توليفات من الأسمدة المعدنية والعضوية (FC) وهى على النحو التالي: ١٠٠٪ من الجرعة الموصى بها من عناصر NPK (FC1) (١٨٠كجم نيتروجين ، ٣١كجم فوسفور ، ١٠٠كجم بوتاسيوم/هكتار) ، ٥٠% من الجرعة الموصى من عناصر NPK + ٦طن كمبوست/هكتار (FC2) ، ٧٥% من الجرعة الموصى من عناصر NPK + ٦طن كمبوست/هكتار (FC3) ، ، ٥٠% من الجرعة الموصى من عناصر NPK + ١٢طن كمبوست/هكتار (FC4) ، ٧٥% من الجرعة الموصى من عناصر NPK + ١٢طن كمبوست/هكتار (FC5) ، وتأثير أربعة مستويات من الرش الورقى لحامض الفولفيك (FA) هى كما يلى: ٠,٠ ، ٢٥٠ ، ٥٠٠ و ٧٥٠ جزء في المليون على كل من مقاييس النمو الخضري ، امتصاص المغذيات الورقية ، وجودة وإنتاجية محصول نبات الكركديه ، وقد نفذت التجربة فى قطاعات كاملة العشوائية بنظام القطع المنشقة مرة واحدة فى ثلاث مكررات حيث كان العامل الرئيسى هو الخمس توليفات من الأسمدة المعدنية والعضوية بينما كان العامل تحت الرئيسى هو مستويات الرش الورقى حامض الفولفيك.

أشارت النتائج إلى أن المعاملة FC5 منفردة والمعاملة FA عند ٧٥٠ جزء في المليون منفردة أظهرت أعلى قيم معنوية لارتفاع النبات (سم) ، عدد الأوراق / النبات ، الوزن الجاف للأوراق (جم/نبات) ، عدد الأفرع/لنبات ، الوزن الطازج للأفرع جم/نبات والوزن الجاف للأفرع (جم/نبات) ، الممتص من العناصر الكبرى والصغرى فى الأوراق ، ومحصول كل من السبلات والبذور (طن/هكتار) ومحصول الزيت الثابت (لتر/هكتار) ومحتوى السبلات من صبغة الأنثوسيانين ، وفيتامين سى ، وأقل قيم معنوية لدرجة الحموضة بالسبلات فى كلا موسمى الدراسة

وقد أدت الإضافة المزدوجة للمعاملة FC5 مع المعاملة FA عند ٧٥٠ جزء في المليون إلى الزيادة في جميع المقاييس تحت الدراسة باستثناء الحموضة التى إنخفضت إلى أقل درجاتها فى كلا موسمى الدراسة. فعلى ذلك يوصى باستخدام الإضافة المزدوجة للمعاملة FC5 ، المعاملة FA عند ٧٥٠ جزء في المليون لزراعات الكركدية في واحة سيوة لأنها تحقق إنتاجية وجودة عالية مع أعلى صافى ربح (٤٠,٤٥٠×١٠^{٣} جنيه /هكتار) وأعلى صافى عائد (٢٩,٣٣٦×١٠^{٣} جنيه /هكتار)ولأن بها إستبدال جزئى للأسمدة المعدنية بالأسمدة العضوية (الكمبوست والفولفيك) فإنها تساهم بدور كبير في الحد من تلوث التربة ومياه الرى خاصة تحت ظروف واحة سيوة كمحمية طبيعية.