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Foliar spray with potassium nitrate and salicylic acid for improving growth, yield and nutrients uptake by olive trees under salinity stress conditions

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Abstract : A field experiment was conducted at Ras – Sudr, South Sinai Governorate, Egypt located at 29º 32'28" N and 32º 39'25 " E during two successive seasons, 2015 and 2016 on 96 Manzanillo olive tree, of about 8 years old grown on sandy loam soil to study the effect of foliar spray with potassium nitrate (KN) and salicylic acid (SA) on improving growth, yield and nutrients uptake by olive trees under salinity stress conditions . The soil was irrigated with water of 7.85dSm^{-1} and with soil paste extract of 8.56dSm^{-1}. The experiment was carried out using spilt plot randomized complete blocks design with the main plots being salicylic acid (SA) at 0, 250, 500 and 1000 mg SA L^{-1}, and sub –plots potassium nitrate (KN) at 0, 10, 20 and 30 g KN L^{-1} with three replicates and two trees per each replicate. The trees were sprayed 3 times; at vegetative stage, beginning of flowering and after fruit setting. All growth, yield and fruits physical and chemical properties, , total chlorophyll and proline contents in leaf and leaf nutrients uptake increased by increasing application of SA and KN either separately or in combinations. The most effective treatments were 1000 mg SAL^{-1} and 30gKNL^{-1}. Combination of the two treatments was the most effective.

Keywords: Foliar spray, potassium nitrate, salicylic acid, olive trees, salinity stress conditions.

Introduction

Olive (*Olea europaea* L.) is a long-lived evergreen tree, one of the most widely cultivated and economically important fruit crop for several countries, olive native to the Mediterranean basin that accounts for about 90% of the world's olive cultivation and production. In Egypt the total harvested area is 64835 ha with a production of 1320800 Mg (megagrams) [1].The use of saline water for irrigation requires an adequate understanding of how salts affected soil characteristics and plant performance [2]. The relationship between saline water and olive cultivation has been intensively studied [3,4]. Saline conditions limit the vegetative and reproductive development of olives mainly as a result of interference with the osmotic balance in the root system zone and detrimental effects caused by specific toxic accumulation of chloride and sodium ions in the leaves [5]. Salinity is one of the main factors limiting crop productivity [6]. Salinity stress is always accompanied by changes in plant metabolism, which in turn affects plant constituents. The most harmful effect is the reduction of water availability to plants. Salinity accumulates Cl^- and Na^+ ions in toxic contents in plant and minimizes foliar pigments [7]. High irrigation water salinity of up 8000 mg soluble salts L^{-1} was reported to increase leaf osmotic potential and decrease leaf contents of [8].

Salicylic acid (SA) could induce the alternative oxidase enzyme activity in mitochondria which is involved in stress alleviation and enhances specific secondary metabolites of plants [9]. Spraying SA at 300 mgL^{-1} increased orange growth, fruit setting and yield [10]. SA is most readily accessible as plant growth regulator compared with acetyl salicylic acid and methyl salicylate [11], and it is safe to human and environment

and plays an important role in protecting plant cells from senescence. It minimizes the effects of stresses conditions and enhances natural hormones regulate plant growth and development [12]. It enhances yield and fruit quality of different fruit crops [13, 14,15] and acts as hormone-like substance, which plays important roles in regulating and resisting abiotic stresses [16,17]. Spraying SA on pistachio nut trees increased nut fresh weight and decreased blank nut percentage [18].

Potassium is an essential plant nutrient and under salinity stress, metabolic toxicity of Na is largely due to its ability to compete with K for binding site essential for cellular function [19]. Foliar K application of as potassium nitrate at 40g potassium nitrate L^{-1} after final fruit setting or pit hardening improved the vegetative growth [20]. Potassium alleviates the adverse effects of salinity on plant growth by regulating the desirable K/Na ratio [21]. Its foliar application improved nutrient status and increased salt tolerance [22] and plays an important role in the synthesis of amino acids and proteins as well as translocation of sugars and assimilates within the plant and accumulating carbohydrates [23]. It controls cell water content and carbohydrate biosynthesis in plant tissues [24, 25,26], and in N uptake and translocation from roots to vegetative growth [27]. Toleration of salinity by plant depends on its status in leaves [28]. Potassium by date palm seedling increased with the increase in salinity [29]. Application 4.5kg potassium nitrate per tree of date palm in March, June and September caused highest fruit quality and leaf mineral [30]. Potassium nitrate alleviated salinity stress of Valencia orange [31]. When potassium was applied in combination with biofertilizers to date palm it increased fruit yield , enhanced leaf chlorophyll content, fruit setting percentage, , fruit quality and leaf minerals content of "Hayany" date palm [32].

Potassium activates the enzymes involved in sugar biosynthesis and helps in translocation of sugars and affects the quantity and quality of dates [33]. It has a positive role in plant growth under saline conditions [34], and is required for physiological processes such as activation of enzymes, regulation of osmotic pressure and stomata movement [35]. It reduces excess uptake of ions such as sodium and iron under saline conditions and plays an important role in alleviating stress conditions [36 ,37].

The aim of the present investigation was to study the effect of foliar spray with potassium nitrate and salicylic acid on growth, yield and nutrient uptake by olive trees under salinity stress conditions.

Material and Methods

This study was conducted at Ras – Sudr, South Sinai Governorate, Egypt for two successive seasons, 2015 and 2016 on a number of 96 trees of10-year old Manzanillo olive , grown on a loamy sand soil. The trees were healthy, uniform in growth, vigor and fruiting and received regularly the same cultural practices. Soil and irrigation water analyzed according to Chapman and Pratt [38] and the data are presented in **Table 1**.

Table 1 : Physical and chemical analysis of the soil and irrigation water ofn the experiment

Soil depth (cm)	Soil particles distribution (%)			Texture	$CaCO_3$ gkg^{-1}	EC dSm^{-1}	pH
	sand	silt	clay				
0-30	81.2	8.57	10.23	Sandy loam	269.9	8.56	7.7
30-60	80.08	10.59	9.33	Sandy loam	224.8	7.35	7.9

	Soluble ions (mmolc L^{-1}) in soil past extract							
	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	SO_4^{-}	Cl^{-}	HCO_3	CO_3
0-30	24.5	5.2	57.2	8.8	26.2	61.5	8.0	0.0
30-60	16.8	3.8	42.5	12.9	23.5	49.0	3.5	0.0

EC, pH and Soluble cations and anions in water of irrigation ($mmol_c$ L^{-1})								
EC dSm^{-1}	pH	Soluble Cations				Soluble Anions		
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	SO_4^{-2}	Cl	HCO_3^{-}	CO_3^{-2}
7.85	7.7	20.5	8.5	52.95	0.35	19.8	57.5	5	nd

The experiment was carried out using spilt plot randomized complete blocks design with the main plots being salicylic acid (SA) at 0, 250, 500 and 1000 mg SA L^{-1}, and sub –plots potassium nitrate (KN) at 0, 10, 20 and 30 g KN L^{-1} with three replicates and two trees per each replicate. Trees were labeled and treatments were undertaken. The trees were sprayed three times; at the vegetative growth stage, at beginning of flowering

and after fruit setting. On early March of each season, twenty healthy one-year old shoots well distributed around the canopy of one-year old shoots were randomly selected and labeled (5 shoots of each direction) for carrying out the following measurements: vegetative characteristics such as number of new shoots, shoot length number of leaves per shoot, leaf area [39], and leaf total chlorophyll contents by using Minolta chlorophyll meter SPAD- 502. At full bloom (mid. April) flowering behaviors were recorded i.e. flowering percent , flowering density, sex ratio, inflorescence length and fruit set [40] .At maturity (mid- October), fruits of were harvested and yield was measured. Thirty fruit per each tree were randomly selected for carrying out the fruit quality i.e. fruit dimensions fruit volume , average weight per fruit and fruit moisture content [41] .Fresh oil content [42] ,leaf proline content [43], total soluble solids, leaf mineral content and total acidity of fruit were determined [42].

All the obtained data during both 2015 and 2016 experimental seasons were subjected to analysis of variances (ANOVA) according to [44].

3. Results and Discussion

3.1. Vegetative growth characteristics:

Data in **Table 2** indicate that under salt stress conditions application of SA and KN separate or combined gave positive effects. The highest rate of SA caused average increases (for both seasons) of 61.3, 45.3, 55.5 and 22.1% for No. of new shoots, shoot length, No of leaves /shoot and leaf area, respectively. The highest rate of KN gave average increase of 32.5, 18.2, 24.6 and 12.5% for No. of new shoots, shoot length (cm), No of leaves /shoot and leaf area (cm^2), respectively.

Combination of 1000 mg KNL^{-1} with 30g SAL^{-1} gave an average increase in the number of new shoots, shoot length , No of leaves /shoot and leaf area of ; 101.7, 78.9, 92.5 and 30.3%, respectively for both seasons.

Table (2): Effect of salicylic acid and potassium nitrate foliar application on some growth parameters of Manzanillo Olives.

Salicylic Acid (SA)	KNO_3 (KN) " g L^{-1} "									
	None	10	20	30	Mean	None	10	20	30	Mean
	Season 1					Season 2				
	No of new shoots									
None	5.33	6.67	6.33	7.33	6.42	6.33	6.00	7.33	8.00	6.92
250 mg L^{-1}	6.00	7.67	8.67	9.00	7.83	8.00	9.33	9.33	10.00	9.17
500 mg L^{-1}	7.33	9.33	8.67	9.67	8.75	9.33	10.67	10.67	11.33	10.50
1000 mg L^{-1}	8.33	10.33	11.67	11.67	10.50	9.00	11.67	11.67	11.67	11.00
Mean	6.75	8.50	8.83	9.42		8.17	9.42	9.75	10.25	
LSD0.05	SA=0.05, KN=0.05, SA× KN =1.01					SA=0.06, KN =0.06, SA× KN =1.02				
	Shoot length (cm)									
None	14.7	17.5	18.0	18.1	17.1	15.1	16.7	20.0	21.0	18.2
250 mg L^{-1}	19.0	23.2	24.2	24.9	22.8	20.7	22.0	23.5	25.0	22.8
500 mg L^{-1}	25.6	24.2	24.3	24.7	24.7	21.8	25.3	25.1	26.0	24.5
1000 mg L^{-1}	24.1	26.2	27.0	26.8	26.0	22.4	26.2	26.3	26.2	25.2
Mean	20.8	22.8	23.4	23.6		20.0	22.6	23.7	24.6	
LSD0.05	SA= 0.04, KN =0.04, SA× KN =0.08					SA=1.01, KN =1.01, SA× KN =2.02				
	No of leaves/shoot ratio									
None	18.3	21.7	22.7	24.3	21.8	19.3	21.0	23.7	25.0	22.3
250 mg L^{-1}	20.0	25.0	26.7	28.0	24.9	27.3	27.7	30.3	32.7	29.5
500 mg L^{-1}	24.7	27.7	29.7	31.3	28.3	33.0	35.3	36.0	37.7	35.5
1000 mg L^{-1}	27.3	32.3	34.7	34.7	32.3	32.7	37.3	37.7	37.3	36.3
Mean	22.6	26.7	28.4	29.6		28.1	30.4	31.8	33.2	
LSD0.05	SA=0.82, KN =0.82, SA× KN =1.63					SA=1.42, KN =1.42, SA× KN =2.84				
	Leaf area (cm^2)									
None	3.23	3.28	3.29	3.25	3.26	3.27	3.44	3.52	3.64	3.47
250 mg L^{-1}	3.29	3.53	3.55	3.56	3.48	3.21	3.86	3.92	4.10	3.77
500 mg L^{-1}	3.55	3.90	3.90	3.90	3.81	3.43	4.23	4.15	4.21	4.00
1000 mg L^{-1}	3.84	4.16	4.22	4.15	4.09	3.79	4.21	4.25	4.22	4.12
Mean	3.48	3.72	3.74	3.72		3.42	3.94	3.96	4.04	
LSD0.05	SA=0.041, KN =0.041, SA× KN =0.083					SA=0.097, KN =0.097, SA× KN =0.195				

Therefore foliar application treatments positive effect can be arranged as follows Salicylic acid + potassium nitrate > Salicylic acid > potassium nitrate, (Fig. 1).

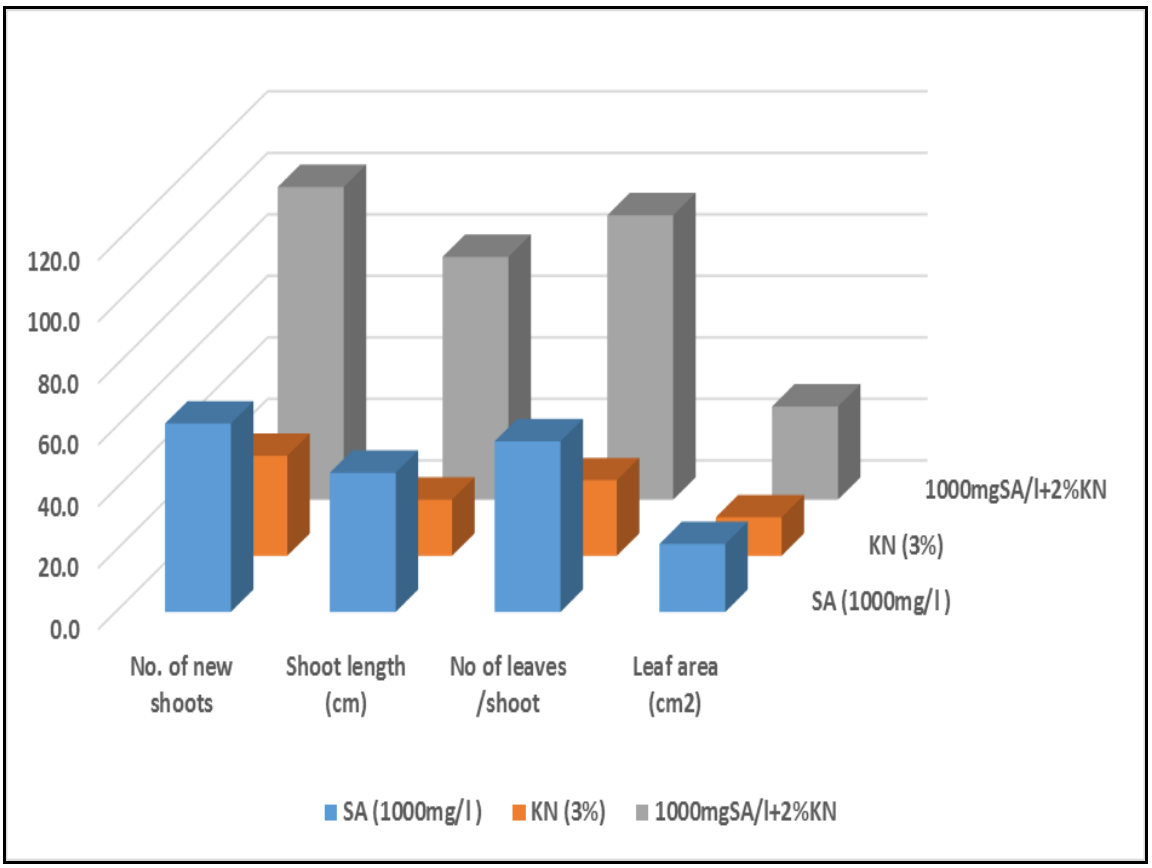

Fig.1: Average increase percentages for vegetative characteristcs of Manzanillo olives in both studied seasons (the highest significant treatment compared with the none treated)

In addition, as shown in Fig.1 it can be concluded that all the studied vegetative growth characteristics can be arranged according their affecting by the foliar sprays of SA, KN and their interaction as follows: No. of new shoots > No of leaves/shoot > shoot length > leaf area.

These results are in agreement with those obtained by [9, 31,10] on Orange trees. Also, these results are in accordance with[45] who demonstrated that adding potassium, increased leaf surface, vegetative growth, net photosynthetic rate and chlorophyll content of plants. In this respect, in addition [20] stated that, foliar application of potassium nitrate at 4% after final fruit set or pit hardening improved the vegetative growth. On the other hand, the effect of K on increasing olive trees growth was confirmed by [46,47].

The beneficial effect of SA application on mitigated effect of salinity on all growth tree parameters may be attributed to the important role of Salicylic acid that is involved in minimizing of the stresses through enhancing antioxidant system. It is responsible for enhancing natural hormones that play a key part in regulating plant growth and development [13]. In this respect, Salicylic acid is the most readily accessible plant growth regulators which are effective in other forms of acetyl salicylic acid and methyl salicylate in plant as well [12]. Salicylic acid (SA) is considered as a hormone-like substance, which plays an important role in the regulation of plant growth and development, seed germination, fruit yield, rooting of cuttings and resistance to abiotic stresses [16,17].

Regarding the effect of K on increasing olive trees growth was confirmed by[46,47]. This result was in agreement with [45] who demonstrated that adding potassium, increased leaf surface, vegetative growth, net photosynthetic rate and chlorophyll content of plants. Generally the essential element potassium has a great regulatory role within plant cells and organs such as activating more than 50 enzymes, osmosis regulation and photosynthesis and loading and unloading of sugars in phloem[48].

The enhancement effect of potassium nitrate application on mitigated effect of salinity on all growth tree parameters may be attributed to the important role of potassium in nutrient and sugar translocation in plant and turgor pressure of plant cells. Also potassium active numerous enzyme systems involved in the formation of organic substances and in the buildup of compounds such as starch or protein. Potassium is involved in cell enlargement and in triggering the young tissues or be due to that potassium is involved in plant mersitematic growth [49,34,35].

3.2. Flowering characteristics:

Results in **Table 3** indicate that under salt stress conditions application of SA and KN separate or combined gave positive effects. The highest rate of SA caused average increases (for both seasons) of 25.6, 38.1, 26.1 and 46.6% for flowering%, flowering density, sex ratio, and inflorescence length (cm), respectively. The highest rate of KN gave average increase of 12.0, 13.7, 9.5 and 13.5% for flowering%, flowering density, sex ratio, and inflorescence length (cm), respectively.

Combination of 1000 mg KNL^{-1} with 30g SAL^{-1} gave an average increase in the flowering%, flowering density, sex ratio and inflorescence length (cm) of 6.0, 63.8, 33.0, and 54.7%, respectively for both seasons.

Table3: Effect of salicylic acid and potassium nitrate foliar application on flowering characteristics of Manzanillo olives

Salicylic Acid (SA)	KNO_3 (KN) " g L^{-1} "									
	None	10	20	30	Mean	None	10	20	30	Mean
	Season 1					Season 1				
	Flowering %									
None	2.41	2.53	2.52	2.53	2.50	2.40	2.50	2.53	2.57	2.50
250mg/l	2.59	2.75	2.79	2.89	2.75	2.50	2.66	2.69	2.79	2.66
500mg/l	2.65	2.95	3.06	3.15	2.95	2.65	3.00	2.97	3.02	2.91
1000mg/l	2.83	3.23	3.25	3.30	3.15	2.87	3.19	3.22	3.24	3.13
Mean	2.62	2.86	2.91	2.97		2.61	2.85	2.85	2.89	
LSD0.05	SA=0.05, KN =0.05, SA× KN =0.09					SA=0.09, KN =0.09, SA× KN =0.18				
	Flowering density									
None	44.6	47.0	46.9	48.2	46.7	44.1	57.2	61.1	61.8	56.1
250mg/l	50.4	53.7	55.1	57.8	54.3	58.1	65.6	67.0	68.0	64.7
500mg/l	61.3	63.0	64.1	67.2	63.9	63.6	71.3	71.2	71.4	69.4
1000mg/l	66.1	68.9	69.3	72.1	69.1	68.7	72.4	73.1	73.2	71.9
Mean	55.6	58.2	58.9	61.3		58.6	66.6	68.1	68.6	
LSD0.05	SA= 1.20, KN =1.20, SA× KN =2.39					SA=1.74, KN =1.74, SA× KN =3.48				
	Sex ratio									
None	55.7	57.2	56.7	57.9	56.9	55.3	55.8	58.9	59.6	57.4
250mg/l	58.1	62.1	62.9	64.2	61.8	58.5	63.8	67.6	68.1	64.5
500mg/l	66.5	69.5	69.8	68.9	68.7	63.8	71.6	71.8	74.0	70.3
1000mg/l	70.3	71.5	71.8	72.5	71.5	66.0	74.5	74.6	75.1	72.6
Mean	62.6	65.1	65.3	65.9		60.9	66.4	68.2	69.2	
LSD0.05	SA=0.91, KN =0.91, SA× KN =1.82					SA=1.45, KN =1.45, SA× KN =2.90				
	Length of inflorescence.									
None	1.94	2.05	2.01	2.02	2.00	1.85	1.88	1.91	1.91	1.89
250mg/l	2.10	2.34	2.37	2.38	2.30	1.80	1.98	2.11	2.14	2.01
500mg/l	2.48	2.64	2.71	2.67	2.63	2.00	2.55	2.67	2.79	2.51
1000mg/l	2.85	2.90	2.91	2.94	2.90	2.46	2.87	2.92	2.92	2.80
Mean	2.34	2.48	2.50	2.50		2.03	2.32	2.40	2.44	
LSD0.05	SA=0.049, KN =0.049, SA× KN =0.097					SA=0.126, KN =0.126, SA× KN =0.252				

From the aforementioned results it can be concluded that the different foliar application treatments significantly improved the studied flowering characteristics of Manzinello olive trees that are cultivated under salinity stress conditions in the following arrange, interaction of Salicylic acid + potassium nitrate > Salicylic acid > potassium nitrate, (Fig. 2).

In addition, as illustrated in Fig. 2, it can be concluded that all the studied flowering characteristics can be arranged according their affecting by the foliar sprays of SA, KN and their interaction as follows: flowering density > inflorescence length (cm) > flowering% > sex ratio.

Flowering is the main processes influencing the productivity of fruit trees and is particularly important for olive, where biannual bearing is acutely experienced and where there is an apparently delicate relationship between vegetative and reproductive stages of growth[50].

SA applied in the appropriate time lead to an increase in length of flowering period. While, the enhancement effect of SA had increased effects flowering parameters, this could be attributed to the role of these materials as thermo genesis in plant [51]. Improving flowering percentage and density could be also interpreted to salicylic acid as endogenous growth regulator which plays an important role in increasing antioxidants [52]. This interpretation confirmed by [53] who noticed that salicylic acid treatment decreased catalase and peroxidase with concomitant increase in glutathione reductase which play a role in antioxidant action. The mechanism of salicylic acid was reported by [54,55] who concluded that salicylic acid induced flowering by acting as a chelating agent. This view was supported by[11] who confirmed that salicylic acid functioned as endogenous growth regulators of flowering effects.

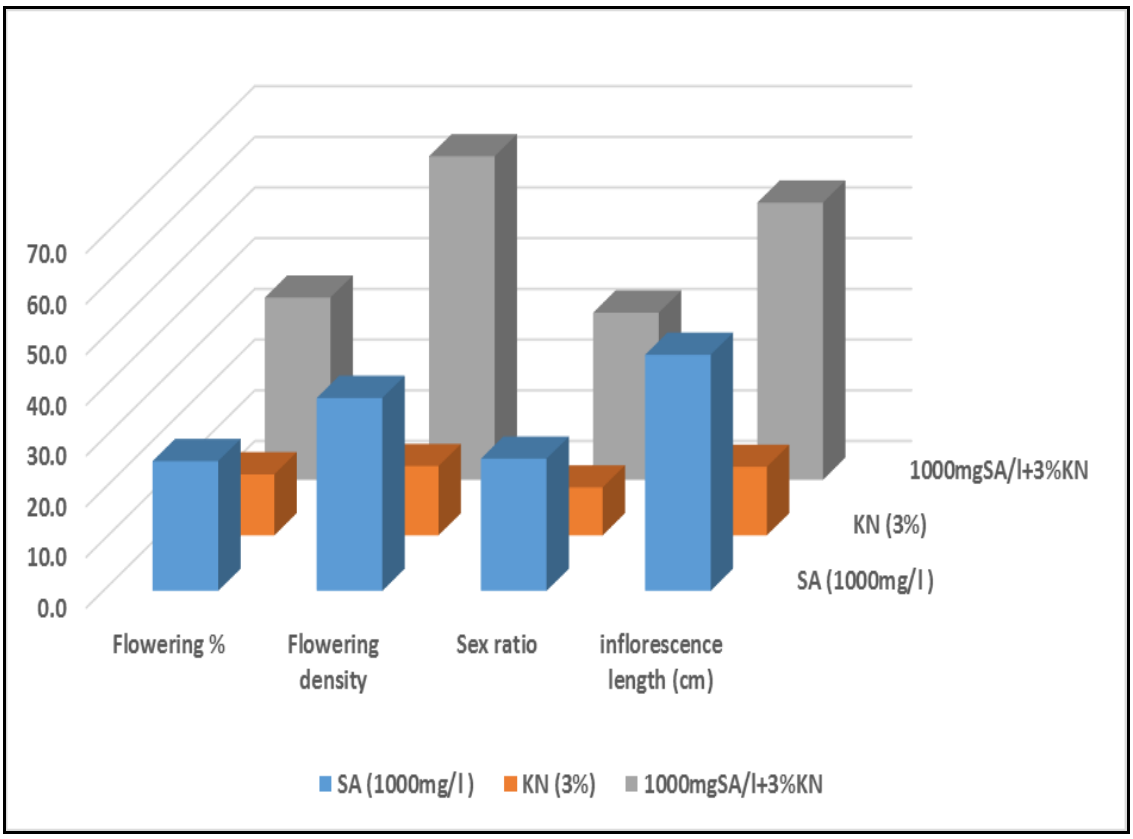

Fig.2: Average increase percentages for flowering and setting characteristcs of Manzanillo olives in both studied seasons (the highest significant treatment compared with the none treated)

The enhancement effect of potassium nitrate may be attributed to the role of potassium e in photosynthesis and osmotic regulation [34], and to its essentiality for physiological processes such as activation of enzymes, regulation of osmotic pressure and stomata movement[35]. It reduces excess uptake of ions such as sodium under saline stress. Combining salicylic acid and potassium nitrate had increasing effects on length of flowering period, weight of primary and secondary fruit, and secondary fruits of date palm trees [56].

3.2. Yield parameters:

As shown in **Table4** it can be noticed that under salt stress conditions application of SA and KN separate or combined gave positive effects. The highest rate of SA caused average increases (for both seasons) of 24.6, 26.8 and 22.5% for fruit set%, fruit weight (g) and fruit yield (kg/tree), respectively. The highest rate of KN gave average increase of 15.1, 9.4 and 11.9% for fruit set%, fruit weight (g) and fruit yield (kg/tree), respectively.

Combination of 1000 mg KNL^{-1} with 30g SAL^{-1} gave an average increase in fruit set%, fruit weight (g) and fruit yield (kg/tree) of 41.1, 34.0 and 37.6% respectively, for both seasons.

Data tabulated in **Table4** indicated that the different foliar application treatments significantly improved the studied yield parameters i.e. fruit set%, fruit weight (g) and fruit yield (kg/tree) of Manzinello olive trees that are cultivated under salinity stress conditions in the following arrange, interaction of Salicylic acid + potassium nitrate > Salicylic acid > potassium nitrate, (Fig. 3).

Table 4: Effect of salicylic acid and potassium nitrate foliar application on some yield parameters of Manzanillo olives.

Salicylic Acid (SA)	KNO_3 (KN) " g L^{-1} "									
	None	10	20	30	Mean	None	10	20	30	Mean
	Season1					Season2				
	Fruit set %									
None	25.7	28.0	27.6	28.6	27.5	25.6	27.7	29.1	30.3	28.2
250mg/l	29.3	31.0	33.6	32.3	31.6	26.0	31.3	32.3	32.0	30.4
500mg/l	29.3	33.2	33.6	33.9	32.5	29.7	33.5	34.1	32.8	32.5
1000mg/l	30.9	36.7	36.2	37.2	35.3	31.3	34.7	35.1	35.2	34.1
Mean	28.8	32.2	32.8	33.0		28.1	31.9	32.7	32.5	
LSD0.05	S=0.98, KN =0.98, S× KN =1.96					S=0.79, KN =0.79, S× KN =1.57				
	Fruit weight(g)									
None	2.98	3.23	3.21	3.19	3.15	2.88	2.88	2.99	2.96	2.93
250mg/l	3.10	3.21	3.40	3.49	3.30	3.10	3.55	3.65	3.77	3.52
500mg/l	3.50	3.69	3.79	3.72	3.68	3.52	3.89	3.86	3.95	3.80
1000mg/l	3.70	3.82	3.92	3.93	3.84	3.64	3.95	3.93	3.92	3.86
Mean	3.32	3.49	3.58	3.58		3.29	3.57	3.61	3.65	
LSD0.05	S=0.076, KN =0.076, S× KN =0.151					S=0.116, KN =0.116, S× KN =0.232				
	yield/tree (kg)									
None	8.90	9.43	9.87	10.23	9.61	9.06	9.77	10.52	10.47	9.96
250mg/l	9.46	10.34	10.99	11.32	10.53	9.66	10.99	11.32	11.17	10.78
500mg/l	9.73	11.47	11.34	11.57	11.03	10.22	11.96	11.53	11.77	11.37
1000mg/l	11.41	12.27	12.46	12.41	12.14	10.77	11.92	12.27	12.30	11.82
Mean	9.88	10.88	11.17	11.38		9.93	11.16	11.41	11.43	
LSD0.05	S=0.294, KN =0.294, S× KN =0.589					S=0.208, KN =0.208, S× KN =0.416				

In addition, as shown in **Table 4** and Fig.3, it can be concluded that all the studied yield parameters can be arranged according their affecting by the foliar sprays of SA, KN and their interaction as follows: fruit set% > fruit yield (kg/tree) > fruit weight

These results are in agreement with these obtained by [16,17,12,13,15,10].

The obtained results recorded the effect of potassium nitrate application on fruit set and yield are in harmony with the findings of [24]on date palm cultivar "Zaghloul", [26] on date palm cultivar "Khalas", [30]on date palm cultivar " Bartamoda" and [57] on date palm cultivar "Khalas".

The enhancement effect of SA on mitigated effect of salinity on fruit yield/tree of Manzanillo olive tree may be attributed to the increase of vegetative growth parameters especially total chlorophyll content which leads to more carbohydrates production through photosynthesis process and increasing vegetative growth and finally improved fruit yield. Also, SA have beneficial effect on enhancing organic matter, lowering soil pH as well as increased the uptake of water and nutrients [58,59] and enhanced soil fertility [60, 61].

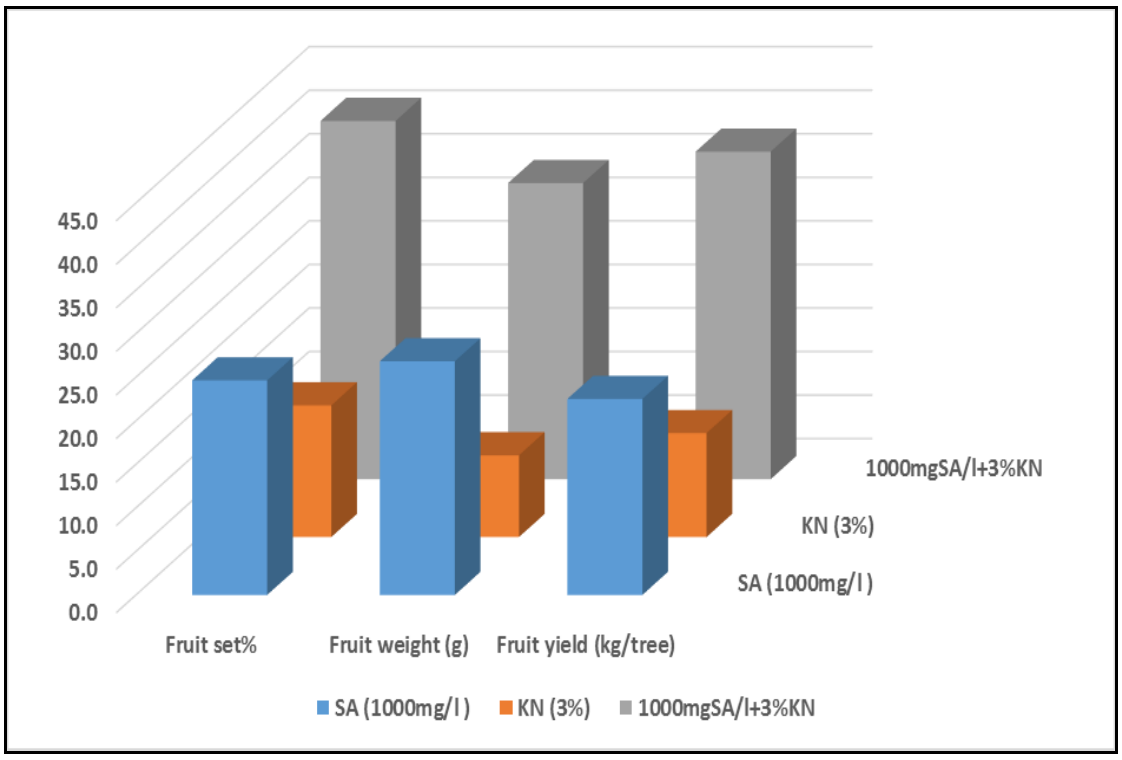

Fig.3: Average increase percentages for some yield parameters of Manzanillo olives in both studied seasons (the highest significant treatment compared with the none treated)

The enhancement effect of potassium nitrate on mitigated effect of salinity on fruit yield may be attributed to that potassium reduces the excess uptake of ions such as sodium under saline stress. Generally, potassium plays an important role in controlling cell water content and carbohydrates biosynthesis and mobilization in plant tissues, consequently carbohydrates play a serious role in fruit set.

3.3. Fruit physical and chemical properties:-

a. Fruit physical properties

Results in **Table 5** indicate that under salt stress conditions application of SA and KN separate or combined gave positive effects. The highest rate of SA caused average increases (for both seasons) of 28.9, 27.5 and 15.4% for fruit length (cm), fruit width (cm) and fruit volume (cm^3), respectively. The highest rate of KN gave average increase of 14.1, 13.4 and 11.3% for fruit length (cm), fruit width (cm) and fruit volume (cm^3), respectively.

Combination of 1000 mg KNL^{-1} with 30g SAL^{-1} gave an average increase in fruit length (cm), fruit width (cm) and fruit volume (cm^3) of 44.1, 37.6, and 21.6%, respectively, for both seasons.

Data presented in **Table 5** indicated that the different foliar application treatments significantly improved the studied fruit physical parameters i.e. fruit length (cm), fruit width (cm) and fruit volume (cm^3) of Manzinello olive trees that are cultivated under salinity stress conditions in the following arrange, interaction of Salicylic acid + potassium nitrate > Salicylic acid > potassium nitrate, (Fig. 4).

Moreover, as shown in **Table 5** and **Fig 4**, it can be concluded that all the studied fruit physical parameters can be arranged according their affecting by the foliar sprays of SA, KN and their interaction as follows: fruit width (cm) > fruit length (cm) > fruit volume (cm^3)

Table5: Effect of salicylic acid and potassium nitrate foliar application on some fruit physical properties Manzanillo olives.

Salicylic Acid (SA)	KNO_3 (KN) " g L^{-1} "									
	None	10	20	30	Mean	None	10	20	30	Mean
	Season1					Season2				
	Fruit length(cm)									
None	1.790	1.850	1.833	1.903	1.844	1.693	1.780	1.737	1.680	1.723
250mg/l	1.803	1.943	2.023	2.070	1.960	1.647	1.820	1.883	1.997	1.837
500mg/l	1.977	1.983	1.960	2.067	1.997	1.723	2.280	2.273	2.353	2.158
1000mg/l	1.990	2.08	2.193	2.310	2.143	2.343	2.363	2.363	2.693	2.441
Mean	1.890	1.964	2.003	2.088		1.852	2.061	2.064	2.181	
LSD0.05	SA=0.041, KN =0.041, SA× KN =0.082					SA=0.127, KN =0.127, SA× KN =0.254				
	Fruit width(cm)									
None	1.313	1.370	1.347	1.427	1.364	1.267	1.300	1.333	1.300	1.300
250mg/l	1.320	1.527	1.500	1.577	1.481	1.333	1.467	1.500	1.500	1.450
500mg/l	1.420	1.613	1.620	1.693	1.587	1.467	1.567	1.633	1.700	1.592
1000mg/l	1.620	1.753	1.797	1.817	1.747	1.500	1.667	1.700	1.733	1.650
Mean	1.418	1.566	1.566	1.628		1.392	1.500	1.542	1.558	
LSD0.05	SA=0.015, KN =0.015, SA× KN =0.030					SA=0.082, KN =0.082, SA× KN =0.164				
	Fruit volume									
None	3.50	3.50	3.52	3.51	3.51	3.40	3.60	3.78	3.73	3.63
250mg/l	3.19	3.52	3.60	3.71	3.51	3.40	3.89	4.00	4.21	3.88
500mg/l	3.25	3.90	3.90	4.20	3.81	4.24	3.90	4.12	4.18	4.11
1000mg/l	3.77	4.24	4.16	4.20	4.09	3.96	4.22	4.24	4.19	4.15
Mean	3.43	3.79	3.80	3.90		3.75	3.90	4.04	4.08	
LSD0.05	SA=0.08, K=0.08, SA×K=0.15					SA=0.08, KN =0.08, SA× KN =0.15				

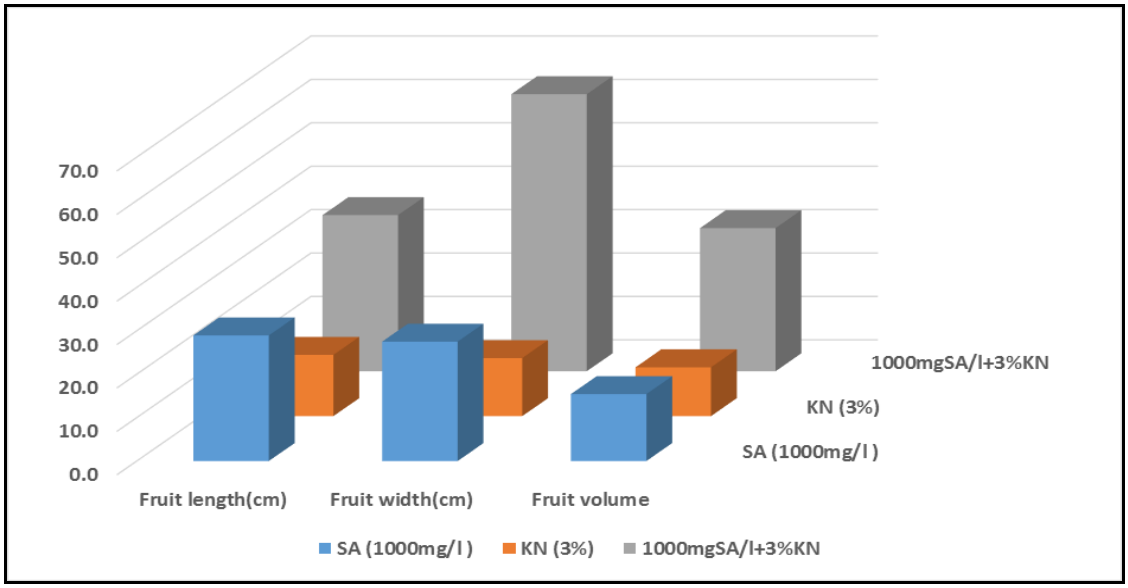

Fig.4: Average increase percentages for some physical properties of fruit Manzanillo olives in both studied seasons (the highest significant treatment compared with the none treated)

b. Fruit chemical properties

The obtained data in **Table 6** indicate that under salt stress conditions application of SA and KN separate or combined gave positive effects. The highest rate of SA caused average increases (for both seasons) of 6.7 and 27.5% for TSS (%) and flesh oil content (%), respectively. It caused average decreases of -35.2% for total acidity (%). The highest rate of KN gave average increase of 5.4 and 13.6% for TSS (%) and flesh oil content (%), respectively. It caused average decreases of -6.8% for total acidity (%).

Combination of 1000 mg KNL^{-1} with 30g SAL^{-1} gave an average increase in TSS (%) and flesh oil content (%) of 10.9 and 44.5%, respectively, for both seasons. It caused average decreases of -35.2% for total acidity (%).

Table 6: Effect of salicylic acid and potassium nitrate foliar application on some fruit chemical properties of Manzanillo olives.

Salicylic Acid (SA)	KNO_3 (KN) " g L^{-1} "									
	None	10	20	30	Mean	None	10	20	30	Mean
	Season1					Season2				
	T.S.S. (%)									
None	10.78	10.86	10.78	10.75	10.80	10.72	10.80	10.54	10.77	10.71
250mg/l	10.93	10.83	11.04	11.02	10.96	10.38	10.89	11.08	10.90	10.81
500mg/l	10.69	11.49	11.57	11.51	11.32	10.66	11.53	11.57	11.51	11.32
1000mg/l	10.79	11.48	11.81	11.92	11.50	10.70	11.48	11.74	11.92	11.46
Mean	10.80	11.17	11.30	11.30		10.62	11.18	11.23	11.27	
LSD0.05	SA=0.160, K=0.160, SA×K=0.321					SA=0.197, K=0.197, SA× KN =0.393				
	Flesh oil content (%)									
None	12.90	12.66	12.96	14.27	13.20	12.80	14.24	14.27	15.50	14.20
250mg/l	14.80	14.53	15.20	15.41	14.99	14.86	15.26	15.96	16.57	15.66
500mg/l	15.83	16.26	15.84	16.47	16.10	15.13	17.31	17.98	18.23	17.16
1000mg/l	15.74	17.02	17.16	18.17	17.02	15.70	18.42	18.50	18.96	17.90
Mean	14.82	15.12	15.29	16.08		14.62	16.31	16.68	17.32	
LSD0.05	SA=0.67, KN =0.67, SA× KN =1.33					SA=0.45, KN =0.45, SA× KN =0.90				
	Total acidity (%)									
None	0.467	0.463	0.557	0.453	0.485	0.463	0.463	0.460	0.453	0.460
250mg/l	0.443	0.430	0.433	0.417	0.431	0.457	0.427	0.430	0.410	0.431
500mg/l	0.377	0.367	0.337	0.330	0.353	0.387	0.357	0.327	0.330	0.350
1000mg/l	0.313	0.310	0.300	0.303	0.307	0.310	0.310	0.300	0.300	0.305
Mean	0.400	0.393	0.407	0.376		0.404	0.389	0.379	0.373	
LSD0.05	SA=0.036, KN =0.036, SA× KN =0.072					SA=0.014, KN =0.014, SA× KN =0.027				

The obtained results of SA application regarding their positive effect on fruit physical and chemical properties are in harmony with the findings of [13,14,15]. Using salicylic acid was very effective in enhancing yield and fruit quality of different fruit crops**.** Salicylic acid (SA) is considered as a hormone-like substance, which plays an important role in the regulation of plant growth and development, seed germination, fruit yield, rooting of cuttings and resistance to abiotic stresses [16,17,62] on "Bartamuda" date palm [63]on date palm cultivars "Sewy", "Zaghloul" and "Hayany" and [10] on Valencia orange.

The enhancement effect of SA application on alleviating the detrimental effect of salinity stress on fruit physical and chemical properties may be due to increasing vegetative growth parameters especially total chlorophyll content which leads to more carbohydrates production through photosynthesis process and increasing vegetative growth and consequently improved flowering characteristics, fruit set percentage, fruit set and yield and finally improved fruit physical and chemical properties.

The enhancement effect of potassium nitrate application on alleviating the negative effect of salinity on fruit physical and chemical properties may be due to that potassium has an essential role in photosynthesis and osmo regulatory[34], and it is required for physiological processes such as activation of enzymes, regulation of osmotic pressure and stomata movement[35]. As well as, it activates the enzymes involved in sugar biosynthesis and helps in translocation of sugars[23]. Moreover, potassium shows an important role in controlling cell water content and carbohydrates biosynthesis and mobilization in plant tissues.

The obtained results regarding the effect of potassium nitrate application on fruit physical and chemical properties go in line with the findings of [24]on date palm cultivar "Zaghloul"; [25] on date palm cultivar "Khalas"; [26] on date palm cultivar "Khalas"; [30]on date palm cultivar " Bartamoda"; [57] on date palm cultivar "Khalas"; [31] on "Valencia" orange and [32] on "Hayany" date palm and [10] on Valencia orange.

3.4. Leaf nutrients uptake

Data presented in **Table 7** indicated that all nutrients uptake in leaf of Manzanello olives that cultivated under salt stress conditions were significantly increased with the increasing of foliar application rates of SA and KN when they were sprayed either single or in a combinations. Results in **Table 7** show that all tested foliar sprays of salicylic acid (SA) were significantly increased the understudied leaf nutrients uptake with superiority for sprayed olive trees by 1000mgSA/l as compared with the other sprayed treatments in both seasons.

Table 7: Effect of salicylic acid and potassium nitrate foliar application on nutrients uptake by leaf of Manzanillo olives.

Salicylic Acid (SA)	KNO_3 (KN) " g L^{-1} "									
	None	10	20	30	Mean	None	10	20	30	Mean
	Season1					Season2				
	N (mg/leaf)									
None	6.23	6.38	6.35	6.44	6.35	6.29	6.62	6.92	7.05	6.72
250mg/l	6.47	6.71	6.95	6.95	6.77	6.70	7.42	7.67	7.78	7.39
500mg/l	6.61	7.22	7.56	7.82	7.30	7.27	7.97	8.03	8.22	7.87
1000mg/l	7.80	7.95	8.63	9.73	8.53	7.56	8.32	8.78	10.07	8.68
Mean	6.78	7.07	7.37	7.73		6.96	7.58	7.85	8.28	
LSD0.05	SA=0.261, K=0.261 , SA×K=0.017					SA=0.252, K=0.252 , SA×K=0.016				
	P (mg/leaf)									
None	0.86	1.00	0.99	1.02	0.97	0.89	0.96	1.02	1.06	0.98
250mg/l	1.04	1.06	1.13	1.16	1.10	1.03	1.12	1.19	1.25	1.15
500mg/l	1.01	1.22	1.25	1.33	1.20	1.22	1.38	1.44	1.46	1.38
1000mg/l	1.34	1.40	1.58	1.80	1.53	1.26	1.47	1.56	1.83	1.53
Mean	1.06	1.17	1.24	1.33		1.10	1.23	1.30	1.40	
LSD0.05	SA= 0.056, K=0.056 , SA×K=0.006					SA=0.053, K=0.053 , SA×K=0.007				
	K (mg/leaf)									
None	2.52	2.46	2.60	2.79	2.60	2.67	2.89	3.01	3.13	2.93
250mg/l	2.63	3.18	3.27	3.45	3.13	2.76	3.27	3.39	3.52	3.24
500mg/l	2.97	3.69	3.72	3.79	3.54	3.36	3.47	3.82	3.97	3.66
1000mg/l	3.46	4.03	4.39	4.81	4.17	3.49	4.00	4.22	4.93	4.16
Mean	2.90	3.34	3.49	3.71		3.07	3.41	3.61	3.89	
LSD0.05	SA=0.151, K=0.151 , SA×K= 0.014					SA=0.134, K=0.134 , SA×K= 0.011				
	Fe µg/leaf									
None	72.3	72.7	72.6	74.4	73.0	70.5	73.0	76.1	77.1	74.2
250mg/l	74.4	76.3	79.4	80.0	77.5	73.8	76.6	79.0	80.9	77.6
500mg/l	78.1	80.4	82.2	84.3	81.3	75.9	80.7	82.8	83.6	80.8
1000mg/l	77.3	84.0	91.6	100.7	88.4	77.5	84.5	89.3	102.5	88.4
Mean	75.5	78.3	81.3	84.7		74.4	78.7	81.7	85.8	
LSD0.05	SA=2.86, K=2.86 , SA×K=0.131					SA=2.68, K=2.68 , SA×K=0.13				
	Mn µg/leaf									
None	14.1	14.3	14.5	14.8	14.4	14.6	15.4	15.6	16.1	15.4
250mg/l	14.3	15.8	16.4	17.0	15.9	15.6	16.0	17.2	17.7	16.6
500mg/l	15.7	17.2	17.7	18.2	17.2	17.2	17.7	18.3	18.9	18.0
1000mg/l	16.7	18.7	20.5	22.4	19.6	17.2	19.1	20.5	23.4	20.1
Mean	15.2	16.5	17.2	18.0		16.2	17.0	17.9	19.0	
LSD0.05	SA=0.632, K=0.632 , SA×K=0.075					SA=0.658, K= 0.658 , SA×K=0.063				
	Zn µg/leaf									
None	22.4	23.2	23.2	23.3	23.0	22.6	23.2	25.9	25.7	24.3
250mg/l	23.1	26.1	26.9	27.2	25.8	26.1	27.4	27.6	28.1	27.3
500mg/l	26.0	26.1	27.1	28.1	26.8	27.5	28.5	29.4	29.1	28.6
1000mg/l	25.5	29.0	31.8	34.9	30.3	27.5	29.8	31.9	37.5	31.7
Mean	24.2	26.1	27.2	28.2		25.9	27.2	28.6	29.9	
LSD0.05	SA=1.14, K=1.14 , SA×K=0.08					SA=1.22, K= 1.22 , SA×K=0.082				

Data presented in **Table7** indicate that under salt stress conditions application of SA and KN separate or combined gave positive effects. The highest rate of SA caused average increases (for both seasons) of 31.7, 56.9, 51.2, 20.1, 33.3 and 31.3% for N (mg/leaf), P (mg/leaf), K (mg/leaf), Fe (µg/leaf), Mn (µg/leaf) and Zn (µg/leaf), respectively. The highest rate of KN gave average increase of 16.5, 26.4, 27.3, 13.8, 17.9 and 16.0% for N (mg/leaf), P (mg/leaf), K (mg/leaf), Fe (µg/leaf), Mn (µg/leaf) and Zn (µg/leaf), respectively.

Combination of 1000 mg KNL^{-1} with 30g SAL^{-1} gave an average increase in N (mg/leaf), P (mg/leaf), K (mg/leaf), Fe (µg/leaf), Mn (µg/leaf) and Zn (µg/leaf),of 58.1, 107.5, 87.8, 42.3, 59.6 and 60.9%, respectively, for both seasons.

From the aforementioned results it can be concluded that the different foliar application treatments significantly improved the studied nutrients uptake by leaf of Manzinello olive trees that are cultivated under salinity stress conditions in the following arrange, interaction of Salicylic acid + potassium nitrate > Salicylic acid > potassium nitrate, (Fig. 5).

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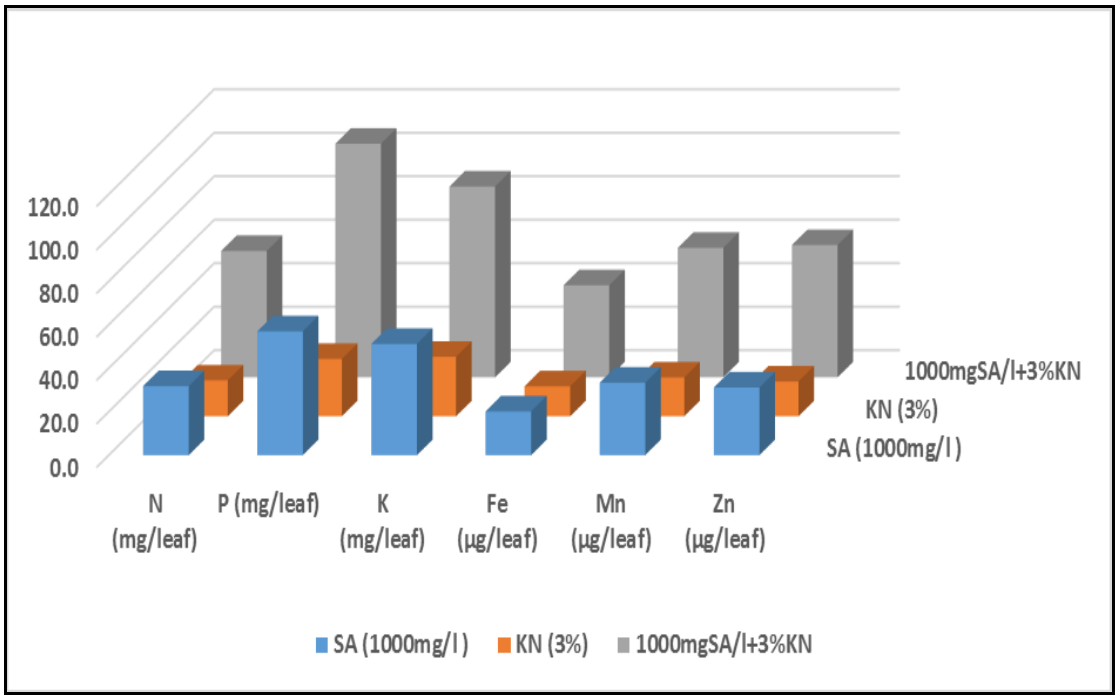

Fig.5: Average increase percentages for nutrients uptake in leaf of Manzanillo olives in both studied seasons (the highest significant treatment compared with the none treated)

In addition, as illustrated in Fig.5, it can be concluded that all the studied nutrients uptake by leaf of Manzanillo olives can be arranged according their affecting by the foliar sprays of SA, KN and their interaction as follows: P (mg/leaf) > K (mg/leaf) > Zn (µg/leaf) > Mn (µg/leaf) > N (mg/leaf) > Fe (µg/leaf). This ascending order mean that the effect of foliar application of salicylic acid and KNO_3 was more pronounced on the nutrients uptake by leaf of Manzanillo olives especially that are concerned with photosynthesis (e.g. P, K, Zn and Mn) and that represent an important role in formation of fruit biochemical contents. So this is reflected on the fruit quality and productivity of Manzanillo olives that grown under salt stress conditions. These results are accordance with those obtained by [27,31, 9]

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