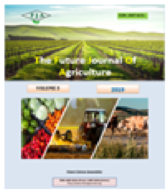
Available online free at www.futurejournals.org

The Future Journal of Agriculture

Print ISSN: 2687-8151 Online ISSN: 2687-8216

Future Science Association



Future J. Agric., 1 (2020) **27-43** **OPEN ACCES**

DOI: 10.37229/fsa.fja.2020.02.10

IMPACT OF REGULATED DEFICIT IRRIGATION AND FOLIAR ZINC NANOPARTICLES APPLICATION ON PRODUCTIVITY OF MANGO TREES

El-Alakmy, H.A.[1*] and M.S. El-Kassas[2]

[1]Plant Production Dept., Fac. Environ. Agric. Sci., Arish Univ., North Sinai, **Egypt.**
[2]Soil and Water Dept., Fac. Environ. Agric. Sci., Arish Univ., North Sinai, **Egypt.**

[*]**Corresponding author:** Hando_100@hotmail.com **Received:** 10 Jan. 2020 **; Accepted:** 10 Feb. 2020

ABSTRACT: what is impact of regulated deficit irrigation and foliar Zn nanoparticles application on productivity of mango trees? the answer to this question represents the main objective of this study. To verify this, an experiment was performed during the 2016/2017 on the mango trees mango (*Mangifera indica* L.) cvs." Nawomy" and "Sokary" which have about 16 years old in sandy soil under drip irrigation system. 100, 50, 75% of the crop evapotranspiration "ETc" were used, in parallel with three levels of concentrations of NPs-Zn micronutrient (0, 50, and 100 ppm) were applied three times; i.e., before flowering, 10 days after full bloom and after fruit set stages in both seasons. The highest yield and water-use efficiency were obtained with applying the RDI-75% of ETc treatment without significant difference that 100% of ETc treatment. The average fruit weight and size, length and width were larger for mango fruits from the 100% of ETc and 75% of ETc, with TSS%, total reducing sugars and ascorbic acid content being significantly greater than fruits of other irrigation treatments. Therefore, using the nano zinc as foliar sprays on mango trees at a concentration of 100 ppm improved fruit set percentage, total yield fruit quality (physical and chemical properties), also increased water use efficiency. It could be concluded that irrigated trees with 75% of ETc plus foliar spraying of nano zinc (NPs-$ZnSO_4$) at 100 ppm was the most effective treatment for increasing fruit set, total yield and quality as well as water use efficiency of Nawomy and Sokary mango trees.

Key words: Mango, regulated deficit irrigation (RDI), Zn nano-particles, fruit quality and water use efficiency.

INTRODUCTION

Mango (*Mangifera indica* L.) belonging to family Anacardiaceae is one of most important strategic fruit crops and is a source of hard currency in Egypt. Egypt ranks the seventh after India, China, Thailand, Indonesia, Mexico and Pakistan in the world production of mango, which is estimated at 47.13 million tons according to the Food and Agriculture Organization (FAO) of the United Nations **(FAOSTAT, 2017)**. FAO report also showed that average growth rate of mango production in the country had been 3.76 per cent until 2007 from its production at 2016.

Cultivation of mango trees face factors that limit production in the newly reclaimed soils in the Mediterranean basin of Egypt, especially in North Sinai region. The major problem is the scarcity of rainfall or it irregularity **(IPCC, 2000)** and deficit of fresh water availability for agricultural is the most pervasive impact environmental stress on mango productivity which limits the sustainable development under climatic changes with population growth **(Shangguan *et al.*, 2000; Kang *et al.*, 2002; Jury and Vaux, 2005; Junya *et al.*, 2017).** This scenario leads to an increasing demand for irrigation water and may cause many serious problems, reducing mango crop yield, intensified pressure on water availability making it to an increasingly scarce resource and increasing the cost of irrigation water **(Kirnak *et al.*, 2005; Tognetti *et al.*, 2005; Durán-Zuazo *et al.*, 2011).** Water stress decreases plant growth by reducing cell division and root enlargement; leads to lowering ion adsorption on the root surface. Also, deficit of water had adversely effect on different physiological process such as photosynthesis, translocation of sugars and phytohormones, ion uptake transport and assimilation, nitrogen fixation, cell turgidity and dark respiration, consequently, yield of different crops was injured. **(Fageria *et al.*, 2006).** Therefore, irrigation with precision and high water use efficiency (WUE) is essential, requiring deficit irrigation strategies in order to not compromise production **(Spreer *et al.*, 2009; Dos-Santos *et al.*, 2016).**

The development of different water-saving irrigation strategies such as regulated deficit irrigation (RDI) in order to save water and increase water use efficiency (WUE) in fruit crops under semiarid conditions were studied by **Romero *et al.* (2004) and Khan *et al.* (2009).** Regulated deficit irrigation (RDI) is the strategy of irrigation with deficits in developmental stages of the culture whose growth and fruit quality have low sensitivity to water stress, and normal irrigation in the other stages **(Grant *et al.*, 2004; Nakajima *et al.*, 2004; Wakrim *et al.*, 2005; Wahbi *et al.*, 2005; Carlos *et al.*, 2011)**. Regulated deficit irrigation management for the mango crop must follow technical criteria, so that water is applied at the right time and the right amount **(Phene, 1991; Phene *et al.*, 1992).** Most studies have shown that deficit water applied during the slow fruit growth period could control excessive vegetative growth, while maintaining or even increasing crop yield. These included studies on mango cv. "Tommy Atkins" **(Dos-Santos *et al.*, 2016)**, cv. "Keitt" **(Levin *et al.*, 2017)** and cv. "Banganpalli" **(Subbaiah *et al.*, 2017)**. Irrigation requirement and its effect on micro-nutrition in mango are still not well investigated, especially under the Mediterranean climate **(Lechaudel *et al.*, 2005).**

Micronutrient deficiencies is one of the most important problems in the Mediterranean region, where the soils are characterized by high pH content, low carbon content, high salinity level, and low organic matter as well as have free calcium carbonate. Micronutrients are essential for different biological functions that might be attributed to tree yield and fruit quality **(Shoeib and El-Sayed 2003; Prasad *et al.*, 2012).** In these soils, deficiencies of Zn can become severe **(Tavallali and Rahemi, 2007)** which lead to deficiency of synthesis of many enzymes needed for nitrogen metabolism, energy transfer, and protein synthesis **(Beede *et al.*, 2005),** retards growth and yield of trees **(Rosati *et al.*, 2010; Hafeez *et al.*, 2013),** low fruit setting in many fruit crops **(Mozafari, 2005; Gursoz *et al.*, 2010)** and limiting factors to fruit quality **(Prasad *et al.*, 2012).** Also, Zn is required for the synthesis of tryptophan which is a precursor of IAA, it also has an active role in the production of an essential growth hormone auxin **(Alloway, 2004; Brennan, 2005; Zagzog and Gad 2017).**

Nanotechnology has provided the feasibility of exploiting nanostructred materials as fertilizers carries or controlled – release vectors for building of so- called smart fertilizer as new facilities to enhance nutrient use efficiency **(Al-Amin and Jayasuriya, 2007).** Utilization of foliar nanofertilizers is a new strategy has started to attract attention in agriculture currently increasingly growing in popularity day by day. The foliar sprays with nanofertilizers have been shown to be convenient for field use under high soil salinity, have a good effectiveness and very rapid trees response **(Erdal *et al.*, 2004; Fernández *et al.*, 2013).** They are also considered the most important promising approaches for sustainable agriculture with high production, low deterioration and feed the world grown rapidly **(Sekhon 2014).** The application of nanoparticles is an easy way to fertilizing plants, as they can increase transfer into the plant cell. On the basis of nanotechnology, some metals such as zinc oxide-based nanoparticles increase the permeability and create new holes in the cell wall. **(Sondi and Salopek, 2004; Brayner *et al.*, 2006)**. Substitution of nano-fertilizer with traditional fertilizers is approach to reduce nutrient losses, improve soil fertility and increase orchard profitability **(Naderi and Abedi 2012; Mishra *et al.*, 2016).**

Therefore, this research aimed to study the effect of under regulated deficit irrigation (RDI) strategies and foliar spray of nano-zinc micronutrient (Zn NPs) on mango (*Mangifera indica* L.) *cvs.* "Nawomy" and "Sokary" yield and its components in El-Skiekh Zwaid region, North Sinai Governorate, Egypt.

MATERIALS AND METHODS

Location of the study area and Climatic conditions

The experiment was carried out on Mango trees (*Mangifera indica* L.) *cvs.* "Nawomy" and "Sokary" of about 16 years age at a commercial orchard in El-Skiekh Zwaid region, North Sinai Governorate, Egypt, in two successive seasons of 2016 and 2017. The study area is bounded by longitudes 33° 54' 45.2" E and latitudes 30° 57' 22" N. The maximum temperature of 30.1 and 30.6 °C in July meanwhile the lower one was 12.3 and 11.6°C in January in both seasons with the average annual mean temperature 21.3 °C. The all climatic data were collected from meteorological station of the Faculty of Environmental Agricultural Sciences at El-Arish, Arish University.

Study treatments

The study included three levels of irrigation water and three $ZnSO_4$ NPs concentrations and their interaction. The three levels of irrigation water were 100 (as a control treatment), 75 and 50% of crop evapotranspiration (ETc). Trees were sprayed with different concentrations of nanoparticles of zinc micronutrient treatments (ZnSO4 NPs) at 0, 50, and 100 ppm. Trees were applied three times before flowering, 10 days after full bloom and after fruit set in both seasons. Spraying was done with a hand sprayer; the two mango varieties received uniform management practices including pruning, fertilizer, insecticide and pesticide applications.

The distances between the mango trees were 4*6 and 3*5 meter for Nawomy and Sokary mango cultivars, respectively and it's were grown in sandy soil under drip irrigation system. Soil and water characteristics of the Mango orchard are presented in **Tables (1 and 2)** according to **Van Reeuwijk (2002)**. The selected trees received the same horticultural practices.

Table 1. Initial soil physical and chemical characteristics of the investigated orchard at El-Skiekh Zwaid region

Parameter		Soil depth (cm) 0-30	30-60	0-30	30-60
		Season 2016		*Season 2017*	
Physical characteristics					
Sand gkg^{-1}		967	933.9	961	930.1
Silt gkg^{-1}		14.1	25.1	13.3	24.9
Clay gkg^{-1}		18.9	41.0	24.7	45.0
Soil texture		Sandy	Sandy	Sandy	Sandy
Bulk density Mg.m^{-3}		1.57	1.59	1.58	1.61
Chemical characteristics					
pH		8.34	8.40	8.21	8.35
EC (dS.m^{-1})		0.46	0.50	0.48	0.52
Cations (mmolc.l^{-1})	**Ca^{2+}**	2.22	2.50	2.60	2.49
	Mg^{2+}	1.38	1.60	1.33	1.72
	Na^{+}	0.86	0.82	0.80	0.85
	K^{+}	0.14	0.08	0.07	0.14
Anions (mmolc.l^{-1})	**CO_3^{2-}**	-	-	-	-
	HCO_3^{-}	2.60	1.30	2.50	1.40
	Cl^{-}	1.62	3.01	1.70	3.22
	SO_4^{2-}	0.38	0.69	0.60	0.58

Table 2. Some water chemical analysis of the investigated artesian well at El-Skiekh Zwaid region

pH	EC (dS.m^{-1})	EC (ppm)	Cations (mq.l^{-1}) Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Anions (mq.l^{-1}) CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
Season 2016										
7.80	0.83	531.20	2.89	2.00	3.22	0.19	-	4.25	2.40	1.65
Season 2017										
7.85	0.84	537.60	2.98	2.20	3.03	0.21	-	4.35	2.61	1.44

Reference evapotranspiration (ETo)

The ETc is the irrigation volume required to meet the crops evapotranspiration demand for the irrigation period. The Modified Blaney-Criddle method was used to determine reference evapotranspiration (ET_o) recommended by **Doorenbos and Pruitt (1977) and Allen *et al.* (1998),** the equation was given as:

$$ET_o = C\,[p(0.46\,T + 8.13)]\quad (mm.day^{-1})$$

Where:

ET_o= Reference crop evapotranspiration mm.day^{-1} for the month considered.

C = Adjustment factor which depends on minimum relative humidity (RH min), ratio of actual to maximum possible (tabulated) sunshine hours (n/N) and daytime wind speed at 2 meters from the soil surface in m/sec (U2).

p = Mean daily percentage of total annual day time hours for given month and latitude.

T = Mean daily temperature in C° over the month considered.

Crop evapotranspiration (ETc)

Crop evapotranspiration (ETc) was calculated according to **Doorenbos and Pruitt, (1977) and Allen *et al.* (1998)** with the following formula**:**

$$ET_{crop} = Kc.ET_o \quad (mm.day^{-1})$$

Where:

Kc = Crop coefficient.

ET_o = Reference crop evapotranspiration (mm.day^{-1}).

Crop coefficients (Kc) with the adjustment of tree size were estimated from drainage lysimeters located in the same orchard. The Kc values estimated for mango trees during the irrigation period were about 0.66, 0.79, 0.91 and 0.88 at flowering, fruit set, fruit growth and fruit maturation, respectively according to **Durán-Zuazo *et al.* (2011)**. "Nawomy" and "Sokary" mango were irrigated using a drip irrigation system, with two on-line drippers with emitters discharge of 4 L.h^{-1} per tree, each was placed 50 cm from the tree-trunk base. Irrigation treatments were applied from March and continued until February of next year and were programmed weekly during the afternoon based on calculation crop evapotranspiration **(Table 3)**.

Table 3. Amount of irrigation water (m^3.ha^{-1}) for Nawomy and Sokary mango cultivars during 2016 and 2017 seasons.

Parameter / Month	Amount of irrigation water (m^3.ha^{-1})					
	100%	RDI-75%	RDI-50%	100%	RDI-75%	RDI-50%
	"Nawomy" *cv.*			"Sokary" cv.		
March	731.18	548.38	365.59	1169.89	877.41	584.93
April	794.30	595.74	397.15	1270.90	953.17	635.44
May	930.98	698.24	465.48	1489.57	1117.17	744.80
June	1068.38	801.30	534.19	1709.41	1282.06	854.71
July	1188.24	891.19	594.12	1901.19	1425.91	950.60
August	1017.16	762.89	508.58	1627.47	1220.61	813.75
September	920.94	690.70	460.48	1473.51	1105.13	736.75
October	866.56	649.91	433.28	1386.49	1039.87	693.25
November	761.89	571.41	380.94	1219.01	914.25	609.52
December	760.10	570.08	380.06	1216.16	912.11	608.09
January	118.98	89.23	59.50	190.38	142.78	95.18
February	118.71	89.04	59.36	189.95	142.47	94.99
Total	9277.43	6958.10	4638.74	14843.92	11132.93	7421.98

Note: RDI refers to regulated deficit irrigation

Data recorded and measurements:

Water relationships

Consumptive use of water (CU): It was calculated using the equation given by **Israelson and Hansen (1962)** as follows:

$$CU = D \times AD \times [(e_z - e_i) \times 100]$$

Where:

CU = Consumptive use of water in cm,

D = Irrigated soil depth in cm,

AD = Bulk density, gm cm^{-3}, of the chosen irrigated soil depth,

ez = Soil moisture percent after irrigation, and

ei = Soil moisture percent before the next irrigation.

Water use efficiency (WUE): The consumed water by mango trees was calculated according to **Yaron *et al.*, (1973)** as follows:

$$WUE = Y / ETa$$

Where:

WUE = Water use efficiency

Y = Crop yield (kg.ha^{-1}.), and

ETa = Evapotranspiration (m^3.ha^{-1}.)

The actual evapotranspiration, ETa, is assumed to be synonymous to the calculated consumptive use of water (CU). Consequently, daily and monthly consumptive use of water were calculated for specified soil depths for all treatments.

The yield reduction and water saving: They were calculated from the following equations according to **Ismail, (2010)** as follows:

$$YR = 100 - \left[\left(\frac{Y\ of\ RDI - 75\ or\ 50\%\ of\ WR}{Y\ of 100\%\ of\ WR}\right) \times 100\right]$$

$$\mathbf{IWS} = \mathbf{100} - \left[\left(\frac{\boldsymbol{CU\ of\ RDI - 75\ or\ 50\%\ of\ WR}}{\boldsymbol{CU\ of 100\%\ of\ WR}}\right) \times \mathbf{100}\right]$$

Where:

Y = Yield

WR = Water requirements

CU = Water consumption

YR = Yield reduction

IWS = Irrigation water saver

Plant measurements

At maturity stage of "Nawomy" and "Sokary" mango fruits, the yield (kg.tree^{-1}) was estimated by multiplying fruits number per tree. In addition, mean fruit weight (g), fruit length (cm), fruit width (cm), fruit size (cm^3), fruit TSS (%), fruit acidity (%) and fruit total sugars (TSS %) according to the methods in association of official analytical chemists (**A.O.A.C., 1999)** were determining.

Experiment design and statistical analysis

The treatments were arranged in different experimental plots using a randomized complete blocks design (as a factorial experiment). Each treatment was replicated thrice and each replicate was consisted of two trees. All measured variables occurred under the influence of two factors as follows: the 1st factor was concentrations of NPs-Zn which have three levels (0, 50, and 100 ppm of ZnSO4 NPs, whilst, the 2nd factor one was irrigation treatments which have three levels (100, 75 and 50% of ETc). Data were statistically analyzed using MSTATC computer program **(Russell, 1986)**. The two-way ANOVA test was performed to determine the effect of studied factors (i.e. NPs-Zn concentration and irrigation treatments) on the measured variables. If the p-value is less than 0.05, we reject the null hypothesis that there's no difference between the means and conclude that a significant difference does exist. If the p-value is larger than 0.05, we cannot conclude that a significant difference exists (**Steel and Toorrie, 1980)**. The ANOVA test was followed by post hoc test using Duncan multiple range (DMR) test for comparisons between means of differences treatments (**Duncan, 1955)**. The means followed by the same letter in each column are not significantly different from each other at the 5-percent probability level.

RESULTS AND DISCUSSION

1. Water relationships

1.1. Actual evapotranspiration (ETa)

Water consumptions were computed from the data of soil moisture depletions; i.e., the differences between soil moisture contents before and after irrigations. Results in **Table (4)** show that, the ETa (m^3.ha.$^{-1}$), for mango "Nawomy" and "Sokary" during the two investigated seasons were affected by regulated deficit irrigation. They obviously decreased with increasing deficit irrigation. Their highest total monthly values were 8689.81 and 8187.59 m^3.ha.$^{-1}$, for "Nawomy", and 13903.69 and 13100.14 m^3.ha.$^{-1}$ for "Sokary" obtained with 100% irrigation treatment, in the first and second growth seasons, respectively. The lowest ones were 4103.52 and 3826.80 m^3.ha.$^{-1}$ for "Nawomy", and 6797.36 and 6051.70 m^3.ha.$^{-1}$ for "Sokary" with 50% irrigation treatment in the first and second growth seasons, respectively. Consequently, the average total consumed water for both seasons were 8442.07, 6301.00 and 3966.76 m^3.ha^{-1}. for Nawomy and 13507.31, 9912.29 and 6427.10 m^3. ha^{-1}. for Sokary plants irrigated with 100, 75% and 50% of ETc, respectively.

It could notice that, the value of the wet surface area per hectare that used for the calculation of total volumes of water was 10000 m^2, due to the fact that all experimental plots surface areas were moistened during irrigation. Also, the total applied volumes of irrigation water for "Naomy" or "Sokary" plants, in both seasons were 9281.17, 6960.88 and 4640.57 m^3. ha^{-1}; and 14849.86, 11137.40 and 7424.93 m^3. ha^{-1} for 100, 75 and 50% of ETc in first and second seasons, respectively. Hence, as the total applied irrigation water increases the total consumed water also increases. Apparently, there is a critical limit for the ratio of the depth of consumed water to the depth of applied water. In respect to the variations in daily ETa values, it generally increased from February till July.

Table (4): Actual evapotranspiration ($m^3.ha.^{-1}$) for "Nawomy" and "Sokary" mango cultivars during 2016 and 2017 seasons.

Parameter / Month	Actual evapotranspiration ($m^3.ha^{-1}$)					
	100%	RDI-75%	RDI-50%	100%	RDI-75%	RDI-50%
	"Nawomy" *cv.*			"Sokary" *cv.*		
	First season (2016)					
March	706.63	535.86	333.69	1130.61	838.54	552.75
April	772.45	585.78	364.77	1235.92	916.65	604.23
May	877.80	665.67	414.52	1404.48	1041.66	686.63
June	1041.56	789.85	491.85	1666.49	1235.98	814.73
July	1142.16	866.14	539.36	1827.46	1355.37	893.43
August	908.94	689.28	429.22	1454.31	1078.61	711.00
September	850.16	644.70	401.47	1360.26	1008.86	665.01
October	798.09	605.21	376.87	1276.94	947.06	624.28
November	702.51	532.73	331.74	1124.01	833.64	549.52
December	698.62	529.78	329.90	1117.78	829.02	546.47
January	96.22	72.96	45.44	153.95	114.18	75.26
February	94.67	71.79	44.71	151.48	112.34	74.05
Total	8689.81	6589.77	4103.52	13903.69	10311.90	6797.36
	Second season (2017)					
March	623.03	457.11	291.20	996.85	723.26	460.50
April	671.91	492.97	314.04	1075.05	780.00	496.63
May	815.70	598.48	381.25	1305.12	946.92	602.91
June	901.13	661.15	421.18	1441.80	1046.09	666.05
July	1018.83	747.51	476.19	1630.12	1182.72	753.05
August	942.45	691.47	440.49	1507.92	1094.06	696.59
September	825.48	605.66	385.82	1320.78	958.28	610.14
October	778.64	571.29	363.93	1245.83	903.90	575.52
November	683.75	501.66	319.58	1093.99	793.74	505.38
December	684.44	502.17	319.90	1095.11	794.55	505.89
January	120.57	88.46	56.35	192.91	139.96	89.11
February	121.67	89.27	56.87	194.67	141.24	89.93
Total	8187.59	6007.20	3826.80	13100.14	9504.72	6051.70

Note: RDI refers to regulated deficit irrigation

1.2. Water use efficiency (WUE)

The water use efficiency for full and deficit irrigation treatments are presented in **Tables (5 and 6).** Increasing the irrigation deficit gained a high increase in the WUE. The highest value of WUE was obtained with 50% of IWR treatment, while the lowest one was recorded with 100%of IWR treatment. The difference in WUE between 100% of IWR and 75% of IWR was slight compared to that between 75% of IWR and 50% of IWR treatments; however, these differences were significant in the two tested seasons.

A sharp increase in WUE was obtained by deficit irrigation. This indicates that water movement into fruits may be decreased with the progressive in water deficit without any effect on the translocation of dry matter into the seed and this effect resulted in an increase in mass production per unit of water, which in turn increased water use efficiency.

The water use efficiency for addition of $ZnSO_4$ NPs fertilization treatments are presented in **Tables (5 and 6).** Increasing the addition of nano Zn fertilization gained a high increase in the WUE. The highest value of WUE was obtained with addition of 100 ppm of nano Zn fertilization treatment, while the lowest one was recorded with no addition of nano Zn fertilization treatment. The difference in WUE between addition of 100 ppm of nano Zn fertilization and addition of 50 ppm of nano Zn fertilization was slight compared to that between addition of 100 ppm of nano Zn fertilization and no addition of nano Zn fertilization treatments.

Data in T**ables (5 and 6)** show the effect of interaction between regulated deficit irrigation and $ZnSO_4$ NPs fertilization on water use efficiency for "Nawomy" and "Sokary" mango cultivars during 2016 and 2017 seasons. The highest values were recorded with the interaction between 50% irrigation treatment with 100 ppm nano Zn fertilization treatment (1.259, 1.01 and 1.491, 1.28 with Nawomy and Sokary mango plant in the first and second season, respectively). However, the lowest values were recorded with the interaction between 100% irrigation treatment and no nano Zn fertilization treatment (0.827, 0.650 and 0.931, 0.72 in the first and second season, respectively). Similarly, the results of this study are in agreement with **Spreer *et al.* (2009)** who concluded that a potential to increase water-use efficiency (WUE) of "Chok Anan" mango was obtained by deficit irrigation. Also, **Junya *et al.* (2017)** concluded that comprehensive evaluation of the effect of indexes of correlation on irrigation treatment by subordinate function showed that when the soil moisture content were controlled at about 65–70% of the field water moisture capacity, water demand in the growth and development of mango could be ensured, and maximum production efficiency of irrigation and the best quality of fruit could be achieved.

1.3. Yield reduction (YR) and irrigation water saving (IWS)

Obviously, deficit irrigation saves water but reduces the yield **(Tables 5 and 6)**. Irrigating Nawomy trees with 75% of irrigation water requirements increased the total yield by (6.35% and 5.01%) and saved about (24.16% and 26.63%) of (IWR) in the 1st and 2nd seasons, respectively. Increasing the deficit irrigation to 50% of IWR resulted in a severe yield reduction (32.95 % and 28.31%), but increased the water saving to about 52.77% and 53.26% of IWR in the 1st and 2nd seasons, respectively. However, irrigating Sokary plants with 75% of irrigation water requirements (IWR) increased the total yield by 10.72% and 13.43% and saved about 25.83% and 27.44% of (IWR) in the 1st and 2nd seasons, respectively. Increasing the deficit irrigation to 50% of IWR resulted in a severe yield reduction (29.20 % and 24.30%), but increased the water saving to about 51.11% and 53.80% of IWR in the 1st and 2nd seasons, respectively. From the present study, it could observe that the highest fruit yield was obtained from plants grown with no-stress (100% of IWR), while, deficit irrigation decreased fruit yield. The amount of saved water increased sharply by deficit irrigation treatments. In conclusion, deficit irrigation could be considered as a suitable irrigation technique for mango production, where the benefit from saving large amounts of water outweighs the decrease in total yield.

Date in **Tables (5 and 6)** show the effect of $ZnSO_4$ NPs fertilization on reduction of yield. Addition of 100 ppm of nano Zn fertilization to Nawomy plants increased the total yield by 5.83% and 5.44% in the first and second seasons, respectively, while the low concentration (50 ppm) resulted in a severe yield increasing (0.62% and 2.88%) in the first and second seasons, respectively. On the other hand, addition of 100 ppm of nano Zn fertilization to Sokary plants increased the total yield by 7.67% and 11.02% in the 1st and 2nd seasons, respectively, while, the low concentration (50 ppm) resulted in yield reduce of 2.78% and increased 0.82% in the first and second seasons, respectively. It could conclude that the highest fruit yield was obtained from plants grown with addition of 100 ppm of nano Zn fertilization.

Data in **Tables (5 and 6)** show the effect of interaction between regulated deficit irrigation and $ZnSO_4$ NPs fertilization on irrigation water saving (%), reduction in yield (%) for "Nawomy" and "Sokary" mango cultivars during 2016 and 2017 seasons. The results show that the best treatments were the interaction between 75% irrigation treatment with addition of 100 ppm nano Zn treatment, where this interaction saved water of about 24.17, 25.83 and 26.63, 27.45% with Nawomy and Sokary plants which was reflected on increased yield of about 13.62, 23.10 and 14.10, 22.91% in the first and second season, respectively. The data show that the highest increase in yield was with the interaction between 100% irrigation treatment with 100 ppm nano Zn treatment, while the highest reduction was recorded with the interaction between 50% irrigation treatment with no addition of nano Zn fertilization.

Table 5. Effect of interaction between regulated deficit irrigation and $ZnSO_4$ NPs fertilization on irrigation water saving (%), reduction in yield (%) and water use efficiency ($kg.m^{-3}$) of "Nawomy" mango cultivar during 2016 and 2017 seasons

Parameter / Zn T. (ppm)	WUE ($kg.m^{-3}$)				IWS (%)				YR (%)			
	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean of Zn	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean of Zn	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean of Zn
First season (2016)												
0	0.827	1.076	1.061	**0.988**					0.00	1.39	39.46	**13.617**
50	0.884	1.165	1.205	**1.085**	0.00	24.167	52.778	**25.65**	-6.89	-6.84	31.23	**-5.83**
100	0.963	1.239	1.259	**1.154**					-16.40	-13.62	28.16	**-0.62**
Mean of RDI	**0.891**	**1.160**	**1.175**						**-7.76**	**-6.357**	**32.950**	
Second season (2017)												
0	0.931	1.238	1.169	**1.113**					0.00	2.40	37.78	**13.393**
50	0.995	1.311	1.38	**1.229**	0.00	26.63	53.261	**26.63**	-6.89	-3.33	26.54	**-5.44**
100	1.072	1.448	1.491	**1.337**					-15.19	-14.1	20.63	**-2.88**
Mean of RDI	**0.999**	**1.332**	**1.347**						**-7.36**	**-5.010**	**28.317**	

Notes: RDI, WUE, IWS, YR refers to regulated deficit irrigation, Water use efficiency, Irrigation water Save and Reduction in yield and the negative sign in the tables indicates an increase in the crop, respectively.

Table 6. Effect of interaction between regulated deficit irrigation and $ZnSO_4$ NPs fertilization on irrigation water saving (%), reduction in yield (%) and water use efficiency ($kg.m^{-3}$) of "Sokary" mango cultivar during 2016 and 2017 seasons

Parameter / Zn T. (ppm)	WUE ($kg.m^{-3}$)				IWS (%)				YR (%)			
	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean of Zn	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean of Zn	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean of Zn
First season (2016)												
0	0.65	0.87	0.85	**0.790**					0.00	0.52	35.94	**12.153**
50	0.72	0.96	0.96	**0.880**	0.00	25.833	51.111	**25.65**	-10.11	-9.59	28.04	**2.78**
100	0.80	1.08	1.01	**0.963**					-23.54	-23.1	23.62	**-7.67**
Mean of RDI	**0.723**	**0.970**	**0.940**						**-11.21**	**-10.723**	**29.200**	
Second season (2017)												
0	0.72	1.03	1.03	**0.927**					0.00	-3.75	30.92	**9.057**
50	0.84	1.13	1.08	**1.017**	0.00	27.446	53.804	**27.08**	-16.34	-13.65	27.53	**-0.82**
100	0.90	1.22	1.28	**1.133**					-24.61	-22.91	14.46	**-11.02**
Mean of RDI	**0.820**	**1.127**	**1.130**						**-13.65**	**-13.437**	**24.303**	

Notes: RDI, WUE, IWS, YR refers to regulated deficit irrigation, Water use efficiency, Irrigation water Save and Reduction in yield and the negative sign in the tables indicates an increase in the crop, respectively.

2. Fruit set percentage

As shown in **Table (7)**, fruit set percentage was significantly improved in response to spraying nanoparticles of Zn micronutrient at 100 ppm on both mango cultivars during both seasons as compared to the control treatment (without Zn spray). The increasing in number of set fruits was associated with increasing concentrations of nano Zn micronutrient. The highest values of fruit set were detected on the Nawomy and Sokary mango trees that sprayed with NPs-$ZnSO_4$ at 100 ppm (13.09 and 13.50 %) and (12.17 and 12.55 %) during both seasons. The untreated trees produced the lowest values (10.82 and 10.96 %) and (10.41 and 10.65%) during both seasons.

Data in **Table (7)** show the effect of RDI treatments on fruit set % of Nawomy and Sokary mango trees, it could be noticed that trees irrigated with 100 and 75 % of ETc gave the highest values of fruit set percentage in both seasons, respectively compared to 50% of ETc treatment which recorded the lowest values in this respect. Concerning the interaction between the two factors under study, the highest values were recorded with application of 100% or 75% of ETc +100 ppm nano Zn treatments without significant differences between them in both seasons, while, the 50% of ETc + no nano Zn had the most depressive effect in this respect. These results are matched with those of **Kamiab and Zamanibahramabadi (2016)** who found that the highest percentages of initial and final fruit set and yield per shoot were observed in "Shokufeh Almond" cultivar with nano-chelate super plus ZFM 2g/l (Zinc, Iron and Manganese), fertilizer spraying in two stages and the lowest percentage of initial and final fruit set was observed in control treatment in all tested cultivars.

3. Total yield and number of fruits per tree

Data in **Table (7)** show the effect of nanoparticles of Zn micronutrient, regulated deficit irrigation and their interaction treatments on yield (Kg.tree^{-1}) of "Nawomy" and "Sokary" mango cvs. during 2016 and 2017 seasons. Concerning, the nanoparticles effect, NPs-$ZnSO_4$ at 100 ppm treatment gave the highest significant values (17.37 and 18.56 kg.tree^{-1}) on Nawomy and Sokary mango cvs. (14.59 and 15.53 kg.tree^{-1}) in both seasons, respectively. Regarding to RDI treatments effect, 100 % and 75 % of ETc treatments showed a higher significant values (18.60 and 19.65 kg. tree^{-1}); (18.36 and 19.22 kg. tree^{-1}) on Nawomy cv. and (15.07 and 16.07 kg. tree^{-1}); (15.00 and 16.04 kg. tree^{-1}) on Sokary mango cvs. compared to 50% of ETc treatment in both seasons, respectively. **Subbaiah *et al.* (2017)** found that the maximum fruit number, yield per tree, fruit weight and total sugars were observed in RDI at 100 % Ep, followed by PRD at 75% Ep on Banganpalli mango trees during two seasons. The interaction between the two studied factors, 100 and RDI-75 % of ETc with NPs-$ZnSO_4$ at 100 ppm treatments gave the highest values (20.09 and 21.08 kg.tree^{-1}); (19.61 and 20.88 kg.tree^{-1}) for "Nawomy" cv. and (16.74 and 17.62 kg.tree^{-1}); (16.68 and 17.38 kg.tree^{-1}) for "Sokary" cv. in both seasons, respectively. However, 50 % of ETc without NPs-$ZnSO_4$ treatment gave the lowest values (10.45 and 10.74 kg.tree^{-1}) for "Nawomy" cv. and (8.68 and 9.36 kg.tree^{-1}) for "Sokary" in both seasons, respectively. These results are in harmony with those obtained by **Zagzog and Gad (2017)** on mango trees and **El-Said *et al.* (2019)** who worked on Flame Seedless Grape using five levels of of nano-zinc (0, Zinc sulphat at 565 ppm, Zinc EDTA at 140 ppm, nano zinc at 0.4 ppm, nano zinc at 0.8 ppm and nano zinc at 1.2 ppm). They showed that 0.4, 0.8 and 1.2 ppm of nano-zinc had a significant increase in yield compared with the conventional fertilizer.

As for the nanoparticles effect on number of fruits per tree, data in **Table (8)** revealed that number of fruits per tree was significantly improved owing to spraying Nawomy and Sokary mango trees with NPs-$ZnSO_4$ fertilization compared to the control. Spraying NPs-$ZnSO_4$ at 100 ppm was significantly superior than using NPs-$ZnSO_4$ at 0.00 or 50 ppm in improving the number of fruits per tree in both seasons. Concerning, the effect of RDI treatments, data in the same table clearly show that increasing amount of irrigation water from 50 to 100% ETc had no significant promotion on number of fruits per tree for "Nawomy" and "Sokary" mango cvs. in the first season, while trees irrigated with 100 and RDI-75 % of ETc gave the highest values of number of fruits per tree (47.42 and 46.42) and (34.67 and 35.66) for "Nawomy" and "Sokary" mango *cvs.* in the second season, respectively. Regarding the interaction between nanoparticles and regulated deficit irrigation treatments, the irrigation treatments with NPs-$ZnSO_4$ were significantly interactive for number of fruits per tree. The highest number of fruits per tree was given by 100% of ETc + NPs-$ZnSO_4$ at 100 ppm for "Nawomy" cv. and 100 or 75% of ETc + NPs-$ZnSO_4$ at 100 ppm for "Sokary" cv. in both seasons. However, RDI-50% of ETc without NPs-$ZnSO_4$ treatment had the lowest number of fruits per tree for the two cultivars in the both seasons. These observations are supported by the previous findings of **Davarpanah *et al.* (2016)** who reported that the foliar sprays of nano-fertilizers of zinc (636 mg Zn tree^{-1}) increased pomegranate fruit yield, and this was mainly due to increases in the number of fruits per tree.

Table 7. Effect of regulated deficit irrigation (RDI) and $ZnSO_4$ NPs fertilization treatments on fruit set and total yield per tree of "Nawomy" and "Sokary" mango cultivars during 2016 and 2017 seasons

Zn T. (ppm)	Fruit set (%)								Total yield (kg.tree^{-1})							
	"Nawomy" *cv.*				"Sokary" *cv.*				"Nawomy" *cv.*				"Sokary" *cv.*			
	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean
								First season (2016)								
0	11.75 c	10.62 d	10.09 e	**10.82C**	10.94c	10.72cd	9.56e	**10.41C**	17.26 c	17.02 c	10.45 f	**14.91 C**	13.55 c	13.48 c	8.68 f	**11.90 C**
50	12.28 b	11.75 c	11.33 cd	**11.79B**	11.83ab	11.66b	10.08d	**11.19B**	18.45 b	18.44 b	11.87 e	**16.25 B**	14.92 b	14.85 b	9.75 e	**13.17 B**
100	13.70 a	13.65 a	11.91 bc	**13.09A**	12.92a	12.81a	10.77cd	**12.17A**	20.09a	19.61a	12.40 d	**17.37 A**	16.74 a	16.68 a	10.35 d	**14.59 A**
Mean	**12.58 A**	**12.01 A**	**11.11 B**		**11.90A**	**11.73A**	**10.14B**		**18.60 A**	**18.36 A**	**11.57 B**		**15.07 A**	**15.00 A**	**9.59 B**	
								Second season (2017)								
0	12.46c	11.15e	9.28g	**10.96C**	11.89bcd	11.26cd	8.80f	**10.65C**	18.30 bc	17.86 c	10.74 f	**15.63 C**	14.14 c	14.67 c	9.36 e	**12.72 C**
50	13.02b	12.34c	10.42f	**11.93B**	12.62b	12.24bc	9.48e	**11.45B**	19.56 ab	18.91 b	12.68 e	**17.05 B**	16.45 ab	16.07 b	9.82 e	**14.11 B**
100	14.52a	14.54a	11.43d	**13.50A**	13.61a	13.58a	10.45d	**12.55A**	21.08 a	20.88 a	13.70 d	**18.56 A**	17.62 a	17.38 a	11.59 d	**15.53 A**
Mean	**13.33A**	**12.68B**	**10.38C**		**12.71A**	**12.36A**	**9.57B**		**19.65 A**	**19.22 A**	**12.37 B**		**16.07 A**	**16.04 A**	**10.26 B**	

Means having the same alphabetical litter (s) are not significantly differ at 0.05 level according to Duncan's multiple range test.

Table 8. Effect of regulated deficit irrigation (RDI) and $ZnSO_4$ NPs fertilization treatments on number of fruits per tree of "Nawomy" and "Sokary" mango cultivars during 2016 and 2017 seasons

Zn T. (ppm)	Number of fruits.tree^{-1}							
	"Nawomy" *cv.*				"Sokary" *cv.*			
	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean
				First season (2016)				
0	63.50d	62.83e	60.31g	**62.21C**	51.74c	51.83c	49.41e	**50.99C**
50	65.46b	64.24c	61.43f	**63.71B**	54.99b	54.46b	50.65d	**53.37B**
100	66.26a	65.89ab	63.27de	**65.14A**	56.39a	56.24a	54.97b	**55.87A**
Mean	**65.07A**	**64.32B**	**61.67C**		**54.37A**	**54.18A**	**51.68B**	
				Second season (2017)				
0	66.11c	65.40d	59.84g	**63.78B**	52.52c	52.47c	48.90e	**51.30C**
50	67.12b	64.97e	59.03h	**63.71B**	53.91b	54.09b	50.69d	**52.90B**
100	69.03a	68.87a	63.46f	**67.12A**	58.57a	58.41a	53.92b	**56.97A**
Mean	**67.42A**	**66.41A**	**60.78B**		**55.00A**	**54.99A**	**51.17B**	

Means having the same alphabetical litter (s) are not significantly differ at 0.05 level according to Duncan's multiple range test.

4. Fruit physical characteristics

4.1. Fruit weight and size

Data presented in **Table (9)** reveal that fruit weight and volume were affected significantly by different concentration of NPs-$ZnSO_4$ fertilization treatments in both seasons. The highest fruit weight and volume values were recorded by NPs-$ZnSO_4$ at 100 ppm, followed by NPs-$ZnSO_4$ at 50 ppm in the both seasons. On the contrary, the lowest values were detected in NPs-$ZnSO_4$ at 0 ppm (control) treatment. The enhancement in fruit weight and size may be due to the catalytic action of micronutrients particularly at higher concentration (NPs-$ZnSO_4$ at 100 ppm). Hence, the foliar application of nano zinc quickly increased the uptake of macronutrients in the tissues and organs of the mango plants, decreased the nutritional deficiencies and improved fruit quality. These results are in harmony with those obtained by **Al-Amin and Jayasuriya (2007)**. As for the effect of regulated deficit irrigation (RDI) treatments on fruit weight and volume, data in the same table show that the irrigating mango trees with 100% of ETc and RDI-75 % of ETc showed the most effective effect on fruit weight and volume as compared with irrigating trees with RDI-50 % of ETc in both seasons. Regarding the interaction effect, data in the same table indicate that the highest fruit weight and volume were observed in RDI-100 % or RDI-75 % of ETc + NPs-$ZnSO_4$ at 100 ppm, while, the lowest ones were obtained with irrigating trees with RDI-50 % of ETc without applying NPs-$ZnSO_4$ in both seasons.

4.2. Fruit length and width

The obtained results from **(Table 10)** show that fruit length and width of "Nawomy" mango cultivar was affected by foliar application of NPs-$ZnSO_4$ fertilization and the highest values of fruit length and width were recorded with NPs-$ZnSO_4$ at 100 ppm, followed by NPs-$ZnSO_4$ at 50 ppm in comparison to NPs-$ZnSO_4$ at control (without Zn applications) in both seasons. However, there were no significant differences among NPs-$ZnSO_4$ treatments on "Sokary" cv. in both seasons. As for regulated deficit irrigation (RDI) effect, the highest values of fruit length and width were found with applying RI-100 % followed by RDI-75% of ETc without significant differences compared to RDI-50 % of ETc treatment. Concerning, the interaction effect between regulated deficit irrigation (RDI) and application of NPs-$ZnSO_4$ treatments, data in the same table show that irrigating trees with RDI-100 % and RDI-75 % of ETc + spraying NPs-$ZnSO_4$ at 100 ppm gave the highest fruit length and width, while RDI-50 % of ETc without NPs-$ZnSO_4$ treatment had the lowest fruit length and fruit width in both seasons. These results are in harmony with those obtained by **Zagzog and Gad (2017),** who found that nano-zinc treatments recorded the highest values of fruit length and width as well as increased yield as number of fruit or weight per tree of mango trees. Also, **Razzaq *et al.* (2013)** reported that trees sprayed with 0.6% zinc sulfate exhibited highest increase in fruit diameter and fruit weight compared to control treatment with better fruit quality in 'Kinnow' mandarin.

5. Fruit chemical characteristics of the fruit

5.1. Total soluble solids (TSS %) and total reducing sugars

Data in **Table (11)** show that foliar application of NPs-$ZnSO_4$ positively improved total soluble solids percentage (TSS %) and total sugar in juice of "Nawomy" and "Sokary" mango cultivars. The statistical analysis show that the highest values of total soluble solids in juice (TSS %) and total sugar were recorded with spraying 100 ppm NPs-$ZnSO_4$ treatment, followed by 50 ppm NPs-$ZnSO_4$ in both seasons. Data also reveal that in both study seasons, total soluble solids percentage in fruit juice (TSS %) and total sugar percentages were increased linearly with increasing the amount of irrigation water. The irrigating trees with RDI 100 % ETc gave the highest TSS % and total sugar values, followed by RDI-75 % of ETc in 2016 and 2017 seasons. On the other hand, irrigating trees with RDI- 50% of ETc had the most depressive effect on total soluble solids (TSS %) and total sugar values in both seasons. These results are matched with those of **Gugulethu (2006)** who reported that the RDI treatment (75 % of the amount of irrigation water applied) improved the total soluble solids concentration (TSS %) of "Kent" mango fruits.

Data presented in **Table (11)** indicate that total soluble solids (TSS%) and total reducing sugar were significantly influenced by the interaction between different irrigation levels and NPs-$ZnSO_4$ treatments. The highest TSS % and total reducing sugar were noticed with applying irrigation water at 100 % of ETc with spraying NPs-$ZnSO_4$ at 100 ppm treatment which did not differ statistically than RDI-75% of ETc with spraying NPs-$ZnSO_4$ at 100 ppm treatment in 2016 and 2017seasons. However, the lowest TSS % and total reducing sugar values were recorded with applying RDI-50% of ETc without spraying NPs-$ZnSO_4$ in both seasons. These results are matched with those of **Davarpanah *et al.* (2016)** who found that foliar sprays of nano-fertilizers of zinc increased total soluble solids (TSS %) and decreased total acidity (TA) of pomegranate fruits cv. "Ardestani". Also, **Razzaq *et al.* (2013)** found that foliar application of zinc sulfate up to 0.6% improved ascorbic acid content with better fruit quality in 'Kinnow' mandarin.

5.2. Total acidity and ascorbic acid content

Concerning total acidity percentage, data in **Table (12)** show that there were no significant differences among regulated deficit irrigation treatments and spraying mango with nano-zinc in both seasons. Total acidity percentage showed close values (1.31 and 1.44 %); (1.32 and 1.48 %) for "Nawomy" and (1.16 and 1.31%); (1.21 and 1.33%) for "Sokary" mango cultivars in first and second seasons, respectively. As, regard to the specific effect of foliar application of NPs-$ZnSO_4$ on ascorbic acid content (mg/ 100 g of pulp), data in **Table (13)** show that nano-zinc application caused the highest significant increase in ascorbic acid values. The highest values were obtained with NPs-$ZnSO_4$ at 100 ppm treatment (34.78 and 35.81 mg/ 100 g of pulp) for Nawomy and (25.50 and 26.31 mg/ 100 g of pulp) for Sokary mango trees, followed by NPs-$ZnSO_4$ at 50 ppm treatment (34.24 and 34.64 mg/ 100 g of pulp) for Nawomy and (25.12 and 25.58 mg/100 g of pulp) for Sokary mango trees during first and second seasons, respectively. However, the lowest values of ascorbic acid were noticed with non-sprayed trees in both seasons. **Table (12)** reveal that irrigating trees with 100 % and RDI-75 % of ETc gave the highest ascorbic acid values as compared to RDI- 50 % of ETc which had the most depressive effect of ascorbic acid values in both seasons. Regarding, the interaction effect between regulated deficit irrigation (RDI) and nano-zinc applications, the results in the same table indicate that ascorbic acid content of both mango cultivars was increased due to regulated deficit irrigation + nano- zinc treatments. Furthermore, the irrigating trees with RDI-100 or RDI-75 % of ETc + NPs-$ZnSO_4$ at 100 ppm treatments proved to be the superior interaction treatment in increasing ascorbic acid values in both seasons, However, irrigating trees with 50% of ETc + without NPs-$ZnSO_4$ treatment gave the lowest ascorbic acid values. These observations are supported by the previous findings by various workers (**Anees *et al.*, 2011; Kumar and Singh, 2018)** on mango trees who revealed that the application of foliar spray of $ZnSO_4$ at 0.4 % + Boric acid at 0.2 % + $CuSO_4$ at 0.2 % significantly increased the chemical properties of fruits than the control. Whereas, trees sprayed with $ZnSO_4$ showed the maximum total soluble solids, ascorbic acid and non-reducing sugars with low acidity in comparison to rest of control.

Table 9. Effect of regulated deficit irrigation (RDI) and $ZnSO_4$ NPs fertilization treatments on fruit weight and size of "Nawomy" and "Sokary" mango cultivars during 2016 and 2017 seasons

Zn T. (ppm)	Fruit weight (g)								Fruit size (ml)							
	"Nawomy" *cv.*				"Sokary" *cv.*				"Nawomy" *cv.*				"Sokary" *cv.*			
	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean
	First season (2016)															
0	271.81b	270.89b	173.27d	**238.66B**	261.89c	260.08c	175.67f	**232.55C**	333.69b	328.18bc	248.71d	**303.53C**	326.60ab	315.21b	243.88d	**295.23B**
50	281.85ab	287.05ab	193.23c	**254.04AB**	271.32b	272.68b	192.50d	**245.50B**	349.52ab	339.31b	262.58cd	**317.14B**	348.07a	319.71b	245.87d	**304.55A**
100	303.20a	297.62a	195.99c	**265.60A**	296.86a	296.59a	188.28 e	**260.58A**	361.33a	358.34a	300.92c	**340.20A**	351.90a	322.02ab	252.90c	**308.94A**
Mean	**285.62A**	**285.19A**	**187.49B**		**276.69A**	**276.45A**	**185.48B**		**348.18A**	**341.94A**	**270.74B**		**342.19A**	**318.98B**	**247.55C**	
	Second season (2017)															
0	276.74b	273.03b	179.46d	**243.08B**	269.17b	279.50b	191.41d	**246.70B**	353.71b	344.59c	228.81e	**309.04C**	346.20a	330.97a	224.37b	**300.51B**
50	291.37ab	291.09ab	214.81c	**265.76AB**	305.16a	297.10a	193.79d	**265.35AB**	370.49ab	356.28b	241.57de	**322.78B**	368.95a	335.70a	231.12b	**311.92AB**
100	305.42a	303.25a	215.95c	**274.87A**	300.91a	297.55a	214.98c	**271.15A**	383.01a	381.63a	288.88d	**351.17A**	373.01a	341.34a	245.31b	**319.89A**
Mean	**291.18A**	**289.12A**	**203.41B**		**291.75A**	**291.38A**	**200.06B**		**369.07A**	**360.83A**	**253.09B**		**362.72A**	**336.00A**	**233.60B**	

Means having the same alphabetical litter (s) are not significantly differ at 0.05 level according to Duncan's multiple range test.

Table 10. Effect of regulated deficit irrigation (RDI) and $ZnSO_4$ NPs fertilization treatments on fruit length and width of "Nawomy" and "Sokary" mango cultivars during 2016 and 2017 seasons

Zn T. (ppm)	Fruit length (cm)								Fruit width (cm)							
	"Nawomy" *cv.*				"Sokary" *cv.*				"Nawomy" *cv.*				"Sokary" *cv.*			
	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean
	First season (2016)															
0	10.19b	9.00c	8.93c	**9.37C**	9.65abc	9.93ab	8.85c	**9.48A**	7.65b	7.27c	7.05d	**7.32B**	7.60a	7.50ab	7.00b	**7.37A**
50	10.89ab	10.83ab	9.00c	**10.24B**	10.32a	10.00ab	9.03bc	**9.78A**	8.17a	7.93ab	7.33bc	**7.81AB**	7.80a	7.60a	7.00b	**7.47A**
100	11.63a	11.45a	9.95bc	**11.01A**	10.50a	10.27a	9.07bc	**9.95A**	8.56a	8.23a	7.74b	**8.18A**	8.00a	7.85a	7.03b	**7.63A**
Mean	**10.90A**	**10.43A**	**9.29B**		**10.16A**	**10.07A**	**8.98 B**		**8.13 A**	**7.81AB**	**7.37B**		**7.80A**	**7.65A**	**7.01B**	
	Second season (2017)															
0	10.80c	9.45d	8.22e	**9.49C**	10.23a	10.43a	8.14b	**9.60 A**	8.11ab	7.63b	6.49c	**7.41B**	8.06a	7.88ab	6.44b	**7.46A**
50	11.54b	11.37b	8.28e	**10.40B**	10.94a	10.50a	8.49b	**9.98 A**	8.66a	8.33a	6.75c	**7.91AB**	8.27a	7.98a	6.58b	**7.61A**
100	12.33a	12.19a	9.55d	**11.36A**	11.13a	10.89a	8.80b	**10.27A**	9.07a	8.76a	7.43b	**8.42A**	8.48a	8.32a	6.82b	**7.87A**
Mean	**11.56A**	**11.01A**	**8.68B**		**10.77A**	**10.61A**	**8.48 B**		**8.61A**	**8.24A**	**6.89B**		**8.27A**	**8.06A**	**6.61B**	

Means having the same alphabetical litter (s) are not significantly differ at 0.05 level according to Duncan's multiple range test.

Table 11. Effect of regulated deficit irrigation (RDI) and $ZnSO_4$ NPs fertilization treatments on TSS and total sugar of "Nawomy" and "Sokary" mango cultivars fruits during 2016 and 2017 seasons

Zn T. (ppm)	TSS (%)								Total sugars (%)							
	"Nawomy" *cv.*				"Sokary" *cv.*				"Nawomy" *cv.*				"Sokary" *cv.*			
	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean
First season (2016)																
0	21.56bc	21.33cd	20.76e	**21.22B**	14.38bc	14.11c	12.41e	**13.63C**	10.11b	9.73bcd	8.85d	**9.56 C**	11.82d	11.69de	11.27e	**11.59C**
50	21.94ab	21.85abc	21.22d	**21.67AB**	15.25ab	14.78b	12.93de	**14.32B**	10.47ab	9.95bc	9.33cd	**9.92 B**	12.94abc	13.02ab	12.41c	**12.79B**
100	22.56a	22.51a	21.47bcd	**22.18A**	15.81a	15.55a	13.39d	**14.92A**	10.84a	10.41ab	9.97bc	**10.41A**	13.64a	13.32a	12.72bc	**13.23A**
Mean	**22.02A**	**21.90A**	**21.15B**		**15.15A**	**14.81AB**	**12.91B**		**10.47A**	**10.03AB**	**9.38B**		**12.80A**	**12.68A**	**12.13B**	
Second season (2017)																
0	22.85abc	22.40bc	19.10e	**21.45B**	15.24cd	14.82d	11.42f	**13.83C**	10.72b	10.22c	8.14e	**9.69 C**	12.53b	12.27c	10.37d	**11.72B**
50	23.26c	22.94ab	19.52e	**21.91AB**	16.17b	15.52c	12.15ef	**14.61B**	11.10ab	10.45bc	8.58e	**10.04B**	13.72ab	13.67ab	11.67cd	**13.02A**
100	23.91a	23.97a	20.61d	**22.83A**	16.76a	16.48ab	12.99e	**15.41A**	11.49a	11.09ab	9.57d	**10.72A**	14.46a	14.12a	12.34bc	**13.64A**
Mean	**23.34A**	**23.10A**	**19.74B**		**16.06A**	**15.61B**	**12.19C**		**11.10A**	**10.58AB**	**8.77B**		**13.57A**	**13.35A**	**11.46B**	

Means having the same alphabetical litter (s) are not significantly differ at 0.05 level according to Duncan's multiple range test.

Table 12. Effect of regulated deficit irrigation (RDI) and $ZnSO_4$ NPs fertilization treatments on acidity and ascorbic acid of "Nawomy" and "Sokary" mango cultivars fruits during 2016 and 2017 seasons

Zn T. (ppm)	Acidity (%)								Ascorbic acid (mg/100 g of fresh pulp)							
	"Nawomy" *cv.*				"Sokary" *cv.*				"Nawomy" *cv.*				"Sokary" *cv.*			
	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean	100% of ETc	RDI-75% of ETc	RDI-50% of ETc	Mean
First season (2016)																
0	1.38a	1.41a	1.44a	**1.41A**	1.22a	1.25a	1.31a	**1.26A**	33.39bc	32.95cd	32.45d	**32.93B**	24.28b	24.32b	23.61c	**24.07B**
50	1.35a	1.38a	1.43a	**1.39A**	1.24a	1.27a	1.29a	**1.27A**	34.82ab	34.80ab	33.11bcd	**34.24A**	25.71ab	25.54ab	24.12bc	**25.12A**
100	1.31a	1.34a	1.37a	**1.34 A**	1.16a	1.24a	1.27a	**1.22A**	35.45a	35.41a	33.47b	**34.78A**	26.45a	25.95a	24.11bc	**25.50A**
Mean	**1.35A**	**1.38A**	**1.41A**		**1.21A**	**1.25A**	**1.29A**		**34.55A**	**34.39A**	**33.01B**		**25.48A**	**25.27A**	**23.95B**	
Second season (2017)																
0	1.32a	1.42a	1.48a	**1.41 A**	1.21a	1.31a	1.33a	**1.29A**	35.39c	34.60d	29.85g	**33.28B**	25.74bc	25.54bc	21.72d	**24.33C**
50	1.32a	1.42a	1.45a	**1.39A**	1.21a	1.29a	1.31a	**1.27A**	36.91b	36.54bc	30.46f	**34.64AB**	27.25ab	26.82abc	22.67cd	**25.58B**
100	1.32a	1.39a	1.43a	**1.38A**	1.23a	1.23a	1.31a	**1.26A**	37.58a	37.71a	32.13e	**35.81A**	28.04a	27.51a	23.39c	**26.31A**
Mean	**1.32B**	**1.41A**	**1.45A**		**1.22A**	**1.28A**	**1.32A**		**36.63A**	**36.28A**	**30.82B**		**27.01A**	**26.62A**	**22.59B**	

Means having the same alphabetical litter (s) are not significantly differ at 0.05 level according to Duncan's multiple range test.

Conclusions

The amount of mango irrigation is important to improve the water-saving strategies for sustainable subtropical agriculture in orchard mango trees. In the Nawomy and Sokary mango trees studied, the highest yield and water-use efficiency were obtained with RDI-100% of ETc or RDI-75% of ETc treatment, and thus the RI-75% of ETc is a recommended irrigation treatment that save 25% of irrigation water. In addition, the average fruits weight and size, length and width were larger for mango from the 100% of ETc and RDI-75% of ETc, with TSS %, total reducing sugars and ascorbic acid content being significantly greater than fruit of other irrigation treatments. Also, the results of this research are due to the beneficial effects of nano zinc foliar spray treatments that enhanced the fruiting of Nawomy and Sokary mango trees and this may be reflect on enhancing nutrient use efficiency. It could be concluded that irrigated trees at RDI- 75% of ETc with foliar spraying of nano zinc (NPs-$ZnSO_4$ at 100 ppm) was the most effective treatment for increasing fruit set, total yield and physical and chemical characteristics of fruit as well as water use efficiency of Nawomy and Sokary mango trees.

REFERENCES

A.O.A.C. (1999). Official Methods of Analysis of the Association of Official Agricultural Chemists. Washington D.C., 12 Ed.,USA.

Al-Amin, M. D. and Jayasuriya, H. P. (2007). Nanotechnology Prospects in Agricultural Context: An overview. In Processing of the International Agricultural Engineering Conference, 3-6 December, Banghok, p. 548.

Allen, R.G.; Pereira, L.S.; Raes, D. and Smith, M. (1998). Crop evapotranspiration (guidelines for computing crop water requirements), FAO Irrigation and Drainage, No. 56, FAO, Rome, Italy.

Alloway, B. J. (2004). Zinc in Soil and Crop Nutrition. International Zinc Association. Brussels, Belgium.

Anees, M.; Tahir, F. M.; Shahzad, J. and Mahmood, N. (2011). Effect of foliar application of micronutrients on the quality of mango (*Mangifera indica* L.) *cv*. "Dusehri" fruit. Mycopath., 9(1): 25-28.

Arafa, M. A. (2006). Effect of paclobutrazol and potassium nitrate on flowering and fruiting of Ewais and sedik mango trees. M.Sc. Thesis, Fac. Agric., Hort. Dept., Cairo Univ., Egypt, pp: 144.

Beede, R. H.; Brown, P. H.; Kallsen, C. and Weinbaum, S. A. (2005). Diagnosing and correcting nutrient deficiencies. In: L. Ferguson (ed), Pistachio production manual. 4th edition. Division of Agric. and Natural Resources. Univ. of California: Oakland. Pp: 147-157.

Brayner, R.; Ferrari-Iliou, N.; Brivois, S.; Djediat, M.F. and Benedetti, F. (2006). Toxicological impact studies based on *Escherichia coli* bacteria in ultrafine ZnO nanoparticles colloidal medium. Nano Letter 6: 866 – 870, http://dx.doi.org/10.1021/ n l052326h.

Brennan, R. F. (2005). Zinc Application and Its Availability to Plants. Ph. D. dissertation, School of Environmental Science, Division of Science and Engineering, Murdoch University.

Carlos, E. C.; Maurício, A. C.; Eugenio, F. C.; Marcio, M. R. and Paulo, R. C. (2011). Regulated deficit irrigation and Tommy Atkins mango orchard productivity under micro sprinkling in Brazilian semi-arid. Engenharia Agrícola, 31 (6): http://dx.doi.org/10.1590/S0100-69162011000600003.

Davarpanah, S.; Tehranifar, A.; Davarynejad, G.; Abadía, J. and Khorasani, R. (2016). Effects of foliar applications of zinc and boron nano-fertilizers on pomegranate (*Punica granatum* cv. Ardestani) fruit yield and quality. Scientia Horticulturae, 210: 57–64.

Doorenbos J. and Kassam, A. H. (1979). Yield Response to Water Food and Agricultural Organization of the United Nations (FAO) Rome. Italy, Irrigation and Drainage Paper No. 24.

Doorenbos, J. and Pruitt, W. O. (1977). Crop Water Requirements. FAO, Irrigation and Drainage, Paper No.24. Rome.

Dos-Santos, M. R.; Donato, S. L.; Coelho, E. F.; Junior, P. R. and De Castro, I. N. (2016). Irrigation deficit strategies on physiological and productive parameters of 'Tommy Atkins' mango. Caatinga, Mossoró, 29 (1): 173 – 182.

Duncan, D.B. (1955). Multiple Range and Multiple F test. Biometrics, 11: 1-24.

Durán-Zuazo, V. H.; Pleguezuelo, C. R. and Tarifa, D. F. (2011). Impact of sustained-deficit irrigation on tree growth, mineral nutrition, fruit yield and quality of mango in Spain. EDP Sciences, www.Fruits-Journal.Org, 66: 257–268.

El-Said, R. A.; El-Shazly, S. A.; El-Gazzar, A. A.; El-Azeez, E. A. and Saleh, M. S. (2019). Efficiency of nano-Zinc foliar spray on growth, yield and fruit quality of Flame seedless grape. J. Appl. Sci., 19: 612-617.

Erdal, Ü.; Kepenek, K. and Kizilgoz, Ü. (2004). Effect of foliar iron applications at different growth stages on iron and some nutrient concentrations in strawberry cultivars. Turk. J. Agric. © T.BÜTAK, 28: 421-427.

Fageria, N. K.; Baligar, V. C. and Clark, R. B. (2006). Physiology of Crop Production. New York: The Haworth Press, pp: 34-318.

FAOSTAT (2017). The Food and Agriculture Organization (FAO) of the United Nations. The statistics of food and agriculture organization of the United Nations. Mango production sees drop. FE Online Report, Cited in http://www.fao.org.

Fernández, V.; Sotiropoulos, T. and Brown, P.H. (2013). Foliar fertilization. In: Scientific Principles and Field Practices. International Fertilizer Industry Association, Paris.

Grant, O. M.; Stoll M. and Jones, H. G. (2004). Partial rootzone drying does not affect fruit yield of raspberries. J. Hort. Sci. & Biot., 79 (1): 125-130.

Gugulethu, M. J. (2006). Effects of irrigation and shading on fruit yield and quality in mango. Univ. Pretoria, http://hdl.handle.net/2263/29373.

Gursoz, S.; Gokoglu, S. and Ak, B. N. (2010). Determination of mineral nutrition contents of grape and pistachio cultivars grown as inter planted orchard. Options Mediterraneennes, 94: 25-30.

Hafeez, B.; Khanlf, Y. M. and Saleem, M. (2013). Role of Zinc in plant nutrition- A review. role of zinc in Plant Nutrition- A Review.

IPCC, Intergovernmental Panel on Climate Change (2000). Disponível em: <http://www.ipcc.ch/pdf/special-reports/spm/sres-sp.pdf>. Acesso em: 22 set. 2014.

Ismail, S. M. (2010). Influence of deficit irrigation on water use efficiency and bird pepper production (Capsicum annuum L.), JKAU: Met., Enviro. and Arid Land Agric. Sci., 21 (2): 29-43.

Israelson, O. W. and Hansen, V. C. (1962). Irrigation Principles and Practices 3rd ed. John Wiley & Sons Inc. New York, pp. 240-253.

Junya, W. I.; Guoyin, L.; Debing, L. and Yeyuan, C. (2017). Influence of irrigation during the growth stage on yield and quality in mango (*Mangifera indica L*). PLoS One, 12(4): e0174498.

Jury, W.A. and Vaux Jr, H. (2005). The role of science in solving the world's emerging water problems. Proceedings of the National Academy of Sci., USA, 102: 15715-15720.

Kamiab, F. and Zamanibahramabadi, E. (2016). The effect of foliar application of nano-chelate super plus ZFM on fruit set and some quantitative and qualitative traits of almond commercial cultivars. J. Nuts, 7(1): 9-20.

Kang, S. Z; Zhang, L.; Liang, Y. L. and Cai, H. J. (2002). Effects of limited irrigation on yield and water use efficiency of winter wheat in the Loess Plateau of China. J. Agric. Water Manage., 55:203–216.

Khan, S.; Khan, M.A.; Hanjra, M.A. and Mu, J. (2009). Pathways to reduce the environmental footprints of water and energy inputs in food production. Food Policy, 34(2): 141-149.

Kirnak, H.; Higgs, D.; Kaya, C. and Tas, I. (2005). Effects of irrigation and nitrogen rates on growth, yield, and quality of muskmelon in semiarid regions. J. Plant Nutr., 28 (4): 621-638.

Kumar, P. and Singh, A. K. (2018). Effect of soil and foliar application of macro and micronutrients on nutrient concentration in soil and leaves of mango (*Mangifera indica*) cv. "Dashehari". Inter. J. Chemical Studies, 6(2): 3446-3451.

Lechaudel, M.; Joas, J.; Caro, Y.; Genard, M. and Jannoyer, M. (2005). Leaf : fruit ratio and irrigation supply affect seasonal changes in minerals, organic acids and sugars of mango fruit, J. Sci. Food Agric., 85: 251–260.

Levin, A. G.; Peres, M.; Noy, M.; Love, C.; Gal, Y. and Naor, A. (2017). The response of field-grown mango (*cv.* "Keitt") trees to regulated deficit irrigation at three phenological stages. Irrig. Sci., Springer-Verlag GmbH Germany, DOI 10.1007/s00271-017-0557-5.

Mishra, S.; Keswani, C.; Singh, A.; Singh, B.R.; Singh, S. P. and Singh, H. B. (2016). Microbial nanoformulation: Exploring potential for coherent nanofarming. In the Handbook of Microbial Resources:107-120. https://www.cabi.org/animalscience/eb-ook/20163199950.

Mozafari, V. (2005). The Role of Potassium, Calcium and Zinc in Controlling Pistachio Die-Back. Ph.D. Thesis, Tarbiat Modarres University, Tehran, Iran. (in Persian).

Naderi, M. R. and Abedi, A. (2012). Application of nanotechnology in agriculture and refinement of environment pollutants. In Journal of Nanotechnology, 11 (1): 18–26.

Nakajima, H.; Behboudian, M. H.; Greven, M. and Zegbe-Dominguez, J. A. (2004). J. Plant Nutri. and Soil Sci., 167 (1): 91-92.

Phene, C. J. (1991). Advances in Irrigation Under Water Shortage Condition. Proc. Conferences on Collaborative Research and Development Application in Arid Lands. 93-110.

Phene, C. J.; Hutmacher, R. B.; Ayars, J. E.; Davis, K. R.; Mead, R. M. and Schoneman, R. A. (1992). Maximizing Water Use Efficiency with Subsurface Drip Irrigation. International Summer Meeting, Charlotte 20p.

Prasad, T. N.; Sudhakar, P.; Sreenivasulu, Y.; Latha, P.; Munaswamy, V.; Reddy, K.; Sreeprasad, T.S.; Sajanlal, P.R. and Pradeep, T. (2012). Effect of nanoscale zinc oxide particles on the germination, growth and yield of peanut. In J. of Plant Nutri., *35* (6): 905–927. DOI:10.1080/01904167.2012.663443.

Razzaq, K.; Khan, A. S.; Malik, A. U.; Shahid, M. and Ullah, S. (2013). Foliar application of zinc influences the leaf mineral status, vegetative and reproductive growth, yield and fruit quality of 'Kinnow' mandarin. J. Plant Nutri., 36:1479–1495.

Romero, P.; Navarro, J. M.; García, F. and Botía, P. (2004). Effects of regulated deficit irrigation during the pre-harvest period on gas exchange, leaf development and crop yield on mature almond trees. Tree Physiol., 24: 303–312.

Rosati, A.; Zipancic, M.; Caporali, S. and Paoletti, A. (2010). Fruit set is inversely related to flower and fruit weight in olive (*Olea europaea* L.). Scientia. Hortic., 126: 200-204.

Russell, D. F. (1986). MSTATC Director, Crop and Soil Sciences Department, Michigan State University, Computer Program Package Version 2.10.

Sekhon, B. S. (2014). Nanotechnology in agri-food production: an overview. In Nanotechnology, Science and Applications, vol. 7, no. 1, pp. 31–53. DOI: 10.2147/NSA. S39406.

Shangguan, Z.; Shao, M. and Dyckmans, J. (2000). Effects of nitrogen nutrition and water deficit on net photosynthetic rate and chlorophyll fluorescence in winter wheat. J. Plant Physiol., 156: 46-51.

Shoeib, M. M. and El-Sayed, A. (2003). Response of "Thompson Seedless" grape vines to the spray of some nutrients and citric acid. Minia J. Agric. Res. Dev., 23(4): 681–698.

Sondi, I. and Salopek, B. S. (2004). Silver nanoparticles as antimicrobial agent: a case study on *E. coli* as a model for Gram-negative bacteria. J. Colloid and Interface Sci., 275: 177–182. DOI: http://dx.doi.org/10.1016/j.jcis.2004.02.012.

Spreer, W.; Müller, J.; Hegele, M. and Ongprasert, S. (2009). Effect of deficit irrigation on fruit growth and yield of mango (*Mangifera indica*, L.) in Northern Thailand. Acta Horti., 820: 357-364.

Steel, R.C.D. and Torrie, J.H. (1980). Reproduced from Principles and Procedures of Statistics. C. I. Bliss, pp: 448-449.

Subbaiah, K. V.; Reddy, N. N.; Reddy, M. L. N.; Dorajeerao, A.V. D. and Reddy, A. G. K. (2017). Effect of different irrigation levels on yield and physiological-biochemical characteristics of mango *cv.* "Banganpalli". Int. J. Pure Appl. Biosci., 5 (6): 177-182.

Tavallali, V. and Rahemi, M. (2007). Effect of rootstock on nutrient acquisition by leaf, kernel and quality of pistachio (*Pistacia vera* L.). American-Eurasian J. Agric. Environ. Sci., 2(3): 240-246.

Tognetti, R.; d'Andria, R.; Morelli, G. and Alvino, A. (2005). The effect of deficit irrigation on seasonal variations of plant water use in *Olea europaea* L. Plant and Soil, 273 (1-2): 139-155.

Van Reeuwijk, L. (2002). Procedures for Soil Analysis. 6th Edition, ISRIC, FAO, Wageningen.

Wahbi, S.; Wakrim, R.; Aganchich, B.; Tahi, H. and. Serraj, R. (2005). Effects of partial root zone drying (PRD) on adult olive tree (*Olea europea*) in field conditions under arid climate - I. Physiological and agronomic responses. Agri., Ecosystems and Environ., 106: 289-301.

Wakrim, R.; Wahbi, S.; Tahi, H.; Aganchich, B. and Serraj, R. (2005). Comparative effects of partial root drying (PRD) and regulated deficit irrigation (RDI) on water relations and water use efficiency in common bean (*Phaseolus vulgaris* L.). Agric., Ecosystems & Environ., 106 (2-3): 275-287.

Yaron, B.; Danfors, E. and Vaddia, Y. (1973). Arid Zone Irrigation. Springer-Verlag Berlin, Heidelberg, New York.

Zagzog, O. A. and Gad, M. M. (2017). Improving Growth, Flowering, Fruiting and Resistance of Malformation of Mango Trees using Nano-Zinc. Middle East J. Agric., 6(3): 673-681.