World Journal of Agricultural Sciences 14 (6): 214-226, 2018
ISSN 1817-3047

DOI: 10.5829/idosi.wjas.2018.214.226

Effect of Irrigation Water Management and Zinc Nanoparticles on Growth, Productivity and Fruit Quality of Pomegranate (*Punica granatum* L., "Wonderful") Trees

I. Samah Nasr

Higher Institute for Agriculture Co-Operation, Cairo, Egypt

Abstract: The present study was carried out during two successive seasons, (2017and 2018) on Wonderful pomegranate trees to evaluate the effect of three irrigation water management (3500 m^3 of irrigation water were divided on the four physiological stages of tree growth as 40 & 30& 20 & 10 %, 30 & 40 & 25& 5 % and 35 & 35 & 20& 10 % m3 / fed./ year) as well as three concentrations (0.0, 50 and 100 ppm) of Zinc oxidase (ZnO) nanoparticles. Vegetative growth, leaf minerals content, fruit set, yield attributes, physical and chemical fruit characteristics were studied during both seasons of study. Applied of the second irrigation program with amendment percentages (30 & 40 & 25 and 5 %) plus spraying 100 ppm zinc nanoparticles, recorded the highest values of vegetative growth in terms of shoot length, shoot number /tree, leaves number / shoot and leaf area. However, total chlorophyll, total Carbohydrates, N % and C/N ratio were greatly improved with the used treatments than control. Final fruit set % and total yield related trait included (Marketable fruits, fruit number /tree and Fruit weight (g). clearly improved. Macro and Micronutrients levels in the Pomegranate leaves greatly increased with zinc nanoparticles spraying with all irrigation water managements. The trees which applied second irrigation water management and 100 ppm zinc nanoparticles spraying achieved highest significant of fruit qualities as firmness and Arils & Juice %, whilst peel thickness recorded the lowest values. Likewise, stimulating chemical characteristics fruits in terms of increasing TSS %, ascorbic acid and anthocyanins also reduced titratable acidity and total tannins. It could be recommended from the obtained data that irrigation water management at the four physiological stages (30, 40, 25 and 5) of Wonderful pomegranate trees and spraying with 100 ppm zinc oxidase nanoparticles is considered a good treatment in giving the highest growth, productivity and fruit quality.

Key words: Pomegranate (*Punica granatum* L. "Wonderful") · Irrigation water management · Zinc oxidase nanoparticles · Vegetative growth · Minerals content · Fruit set · Yield · Physico and chemical properties

INTRODUCTION

Pomegranate (*Punica granatum* L.) belongs to family Punicaceae, it is considered of the oldest trees grown in the world cultivated about 5000 years ago. Although it is one of the oldest edible fruits it is also eligible for growth in various agricultural conditions ranging from the tropical to subtropical. It is very appropriate for growing under arid and semiarid regions due to its versatile adaptability, hard nature, low cost maintenance and high returns [1-3].

It is traditionally known that pomegranate fruit contains a high level of nutrients and many health benefits. Recent scientific results confirm that the traditional use of pomegranate for medicinal purposes [4]. Reported that the tissues of pomegranate fruit, flowers, bark and leaves contain vital antimicrobial phytochemicals that reduce blood pressure and work against dangerous diseases such as cancer. It is also a good source of antioxidants, three times more than wine or green tea. It contains vitamin A, C and E and is a good source of potassium, calcium, magnesium, iron and zinc [5]. The consumable portion is about 55 - 60% of the total fruit weight and consists of about 75 - 85% juice and 15-25% seeds returns [5].

Corresponding Author: I. Samah Nasr, Higher Institute for Agriculture Co-Operation, Cairo, Egypt.

Fruit sunburn, cracking and pomegranate fruit moth infestation are amongst the major constraints for pomegranate production which highly decrease quality and marketability of this fruit [6, 3]. Fruit cracking or splitting is one of the principal disorders that influences pomegranate quality and quantity. Fruit cracking not only weaken marketability and consumer acceptance, but also provides pores of entry for insects and fungi and renders fruits greater prone to the environmental stresses, subsequently inflicting a serious commercial loss to farmers [7, 8]. Water deficiency, soil texture and structure, mineral deficiency as well as air humidity are amongst the factors that have a profound influence on pomegranate fruit cracking [9]. Sun burning is another restricting factor give rise to, serious economic losses to the pomegranate producers whole around the world [10]. Controlling irrigation reduced the percentage of fruit cracking, sunburn [11, 7]. The climate change by weather warming and drying possibly be another significant reason for the disorders [12].

The amount of irrigation water used depends on many factors such as the efficiency of the potential irrigation system, the uniformity of the system design, the relative coverage area, crop factors include crop type, plant size, plant density and other production system and climatic factors include solar radiation, temperature, humidity and wind speed. In addition to management factors, including irrigation scheduling decisions that affect irrigation frequencies and durations [13, 14]. In general, the differences between the yield of poor and medium crops can be attributed to the quantity and timing of soil water supplies. Improving water management is an extremely important means of increasing crop yields [15, 16]. Soil moisture and compaction can have a major impact on the temperature around the soil surface. The compact wet soil will store more space [17, 18].

The water level in pomegranate cultivation count on environmental factors that drive demand evaporation and transpiration, salinity and electrolyte composition in the soil solution, resistance of the soil, root penetration and moisture transfer, soil aeration, hydraulic engineering of trees and crop loading. However, the water indirectly interacts with the susceptibility of plants to diseases. Irrigation affects the performance of trees through the main mechanisms, such as: stomatal conductance, assimilation rate, turgor and expansive growth. This emphasizes the important role of the tree-water relation [19]. Regular irrigation is essential during the reproductive stage as irregular moisture reasons dropping of flowers and small fruits to senesce. A sudden change in soil moisture causes soil stress, which influences fruit development adversely and leads to fruit cracking [20]. Control of irrigation timing and seasonal application are essential not only for better growth and yield of pomegranate trees but are also used to control ripening time. For instance in India, timing of irrigation is used to control and optimize the harvesting season of evergreen pomegranate [21].

Zinc is a major component of some enzymes such as dehydrogenase, proteinase and peptidase. In this regard, zinc can influence electron transfer reactions such as the Krebs cycle and plant energy production. It also participates in other reactions such as protein building and analysis and carbohydrate metabolism [22, 23]. However Zinc is a prerequisite for making tryptophan and tryptophan is the raw material for making auxin and auxin plays an essential role in increasing leaf area and tree canopy. Foliar application of 0.25% of zinc significantly increased the yield vitamin C, TSS, total acid and juice % of pomegranate [24]. Zinc deficiency is one of the important soil constraints to crop growth, which may reduce crops and nutritional crop quality [25]. Zinc has promising impact on plant metabolism, accountable for producing the natural hormones IAA, activating some enzymes biosynthesis of chlorophylls, enhancing germination of pollens and regulating water uptake by way of plants [26]. Foliar application of nutrients, particular zinc was once necessary for producing healthy fruit trees as well as producing productive trees. In addition, they are responsible for improving physical and chemical parameters of fruits [27]. The positive effect of foliar application of zinc in increasing the productivity and improving the fruit quality in terms of TSS and total sugars [28-30].

Nanotechnology can be defined as new installation of material in new shapes within Nano scale from 1-100 nanometers linked to superior and effective properties (physical, chemical, biological, mechanical, magnetic, optical, electrical...etc.) [31]. It has high stability, tunable compositions, a high surface area, particular biological behaviors and a wide range of numerous physical functions [32, 33]. More recently, nanotechnology has been used in many agricultural fields such as production, processing, storing, packaging and transportation of agricultural products [34]. Fertilizers derived from nanotechnology began to attract the attention of those interested in agriculture. In addition, nanotechnology can have a profound impact on energy, the economy and environment, by improving fertilizer products [35]. Nanofertilizers (NFs) are widely applied in fruit crop nutrition such as soil based and spray based [36]. As they providenutrients with high efficiency and low waste because they move faster and higher to different parts of plants [37]. NMs are much smaller than conventional materials and due to a greater surface area to weight ratio, different shapes and higher penetrability, they may have more significant effects on growth and developmental processes and can directly enter leaf tissues through stomata [38, 39]. The concentration and consumption time of NMs can impact their effects on plants and different plant processes. Due to their tiny scale, NPs have high penetrability into plant tissues and high concentrations of NPs can also negatively affect growth and development. To prevent these negative effects, they are usually applied in very low concentrations at the mg L^{-1} level [38, 40]. Nano- substances can be used for designing new Zn fertilizers, with the solubility, diffusion and availability of Zn to plants being affected by using the nano-particulate Zn characteristics (size, specific surface area and reactivity) [41, 42]. For instance, high-quality of the application of nano-ZnO have been mentioned on seed germination, seedling vigour, leaf chlorophyll content, stem and root growth in peanut [33].

Therefore, the main goal of the present study was to test the impact of amendment of irrigation water management and spraying zinc nanoparticles on fruit productivity, quality and chemical composition of “Wonderful” pomegranates pomegranate trees.

MATERIALS AND METHODS

This study was carried out during 2017and 2018 seasons in a private orchard located at Giza governorate, Egypt. Thirty sex uniform healthy Wonderful pomegranate trees five years old were chosen for this study. Trees grown on sandy soil, under drip irrigation system planted. at 3.0 x 4.0 m^2 apart (350 trees/ fed). All horticultural practices including, pest management fertilization with macro and micro elements were done. A split plot design in 4 replicates was followed as experimental design where irrigation levels put in main plot and zinc nanoparticles spraying arranged in sub – main plot. The selected trees were divided to nine treatments.

Regarding irrigation water management it is regular with pomegranate trees producers to apply irrigate water at rate of 3500 m^3 of water/fed/year. Scheduling this amount on four physiological stages of the pomegranate tree as follows:

- The first phase (Mar. - May.), the period of flowering and fruit set
- The second phase (June - Aug.) the period of fruit development and fruit ripening
- The third phase (Sept. - Nov.) trees ready to enter into dormancy
- The final phase (Dec. - Jan.) trees in the rest phase

In this research it will be distributed the amount of irrigation water (3500 m^3 / fed/ year.) on the above mentioned physiological four stages as follows:

- 40 % & 30 % & 20 % & 10 % (Control-regular irrigation program)
- 30 % & 40 % & 25 % & 5 % (Second program)
- 35 % & 35 % & 20 % & 10 % (Third program)

Regarding spraying of Zinc oxidase (ZnO) nanoparticles 0.0, 50 and 100 ppm concentrations in combination with the three irrigation programs were used. The trees were sprayed twice, firstly in the beginning of bud bulge and secondly after one month of first spraying.

The treatments were arranged as follows:

- First irrigation program (Control-regular)
- First irrigation program plus spraying of zinc oxidase nanoparticles at 50 ppm
- First irrigation program plus spraying of zinc oxidase nanoparticles at 100 ppm
- Second irrigation program (Second program)
- Second irrigation program plus spraying of zinc oxidase nanoparticles at 50 ppm
- Second irrigation program plus spraying of zinc oxidase nanoparticles at 100 ppm
- Third irrigation program (Second program)
- Third irrigation program plus spraying of zinc oxidase nanoparticles at 50 ppm
- Third irrigation program plus spraying of zinc oxidase nanoparticles at 100 ppm

Thus 3 irrigation programs x 3 zinc nanoparticle concentrations x 4 replicates = 36 trees for each season. The following measurements were recorded:

Vegetative growth characters: Four main branches which were nearly uniform in growth, diameter and foliage density and distribution around the periphery of each tree were chosen and labeled in February the following vegetative characters were measured in first of August for each season. Shoot length (cm), number of shoot/tree, number of leaves / shoot and leaf area (cm^2).

Chemical Constituents: Total chlorophyll (mg/g fresh weight) was determined according to Moran and Porath [43]. Total carbohydrates content was determined in dried shoot powder as percentage according to Smith *et al*. [44]. Total nitrogen was determined as percentage using the micro-Kjeldahl method as described by Wilde *et al.* [45]. And C/N ratio was calculated by dividing total carbohydrates by total N.

Leaf Mineral Contents: Leaves were collected from the sixth node from the base of shoots at the second week of August in both seasons. The samples were washed, dried, grounded and digested according to Nijjar [26].

P, K and Mg%:

- Potassium content was determined by Flame photometer as percentage according to method of Jackson [46].
- Phosphorus: was estimated as the method described by Bringham [47].
- Magnesium (Mg): was determined using an atomicabsorption spectrophotometer Chapman and Pratt [48].

Fe, Zn and Mn (ppm): Were determined in digested solutions and measured using an absorption spectrophotometer according to Chapman and Pratt [48].

Fruit Set (%) and Yield Attributes: Fruit set (%) were calculated at the end of May, however fruits were harvested at mature stage in the two seasons at mid-September and the number of fruits per tree was counted, average fruit weight (g), average yield per tree was determined (Kg/tree) and marketable fruits percentage (number of healthy fruits without any cracked and sunburned or even diseases injury) were counted and their percentages to No. of total fruits per tree were calculated.

Fruit Physical Properties: Firmness (Kg/force), peel thickness (cm) percentage of arils and Juice.

Fruit Chemical Properties: Total acidity (expressed as gm malic acid per 100 ml juice) total soluble solids was measured by hand refractometer. However and, L- ascorbic acid content (mg/100 ml juice) were evaluated according to A.O.A.C. [49]. In addition the Pigment anthocyanins content as mg/100 ml juice according to Markham [50]. Finally, total tannins (mg/100 ml juice) were determined according to Swain and Hillis [51].

Statistical Analysis: Data were then analyzed for statistical significant differences using Duncan's multiple range tests. The standardized least significant range (L.S.R) at 5% level was used to compare the effect of various treatments according to Snedecor and Cochran [52].

RESULTS AND DISCUSSION

Vegetative Growth Characters: Data presented in Tables (1) showed the effect of irrigation water management and zinc nanoparticles on vegetative growth characters of "Wonderful" pomegranates during 2017 and 2018 seasons.

A great effect on average shoot length was recorded due to use of the second irrigation program with amendment percentages to 30 % & 40 % & 25 % and 5 % plus spraying 100 ppm zinc nanoparticles where it recorded the highest values of shoot length (69.58 and 72.04 cm) followed by the same irrigation program with spraying 50 ppm zinc nanoparticles (67.25 and 68.77 cm). However, the lowest values of the shoot length (53.90 and 52.93 cm) were recorded with the regular irrigation program without nano- zinc spraying.

Increasing shoot number per tree was clearly noticed with irrigation program No. 2 (30 & 40 & 25 and 5 %) followed by irrigation No 3 (35 & 35 & 20 & 10 %). Spraying of zinc nanoparticles significantly increased number of shoot /tree than unsprayed trees with all irrigation programs. The highest values were obtained with second irrigation and spraying zinc at 100 ppm (66.75 shoot /tree) in first season and (63.75 shoot /tree) in the second one.

Leaves number per shoot values were increased with amendment irrigation water managements and zinc nanoparticles spraying than control, but superior effect was recorded by second program of irrigation water management plus zinc nanoparticles spraying at 100 ppm. Meanwhile, the control irrigation program without zinc spraying recorded the lowest number of leaves per shoot.

Regulation of irrigation water management recorded highest significant values in their effect on leaf area whereas control irrigation program recorded the least values of leaf area in both studied seasons. Spraying 100 ppm of nano-zinc was effective than 50 ppm concentration or unsprayed. It is well known that zinc spray on pomegranate trees increase cell division and consequently increase leaf area which considered a good vegetables growth parameter .Unsprayed trees recorded the least values of leaf area in both studied seasons.

Table 1: Effect of irrigation water management and zinc nanoparticles on vegetative growth characters of "Wonderful" pomegranate fruit during 2017 and 2018 seasons

	Shoot length (cm)		N. of shoot/ tree		N. of leaves/ shoot		Leaf area (cm^2)	
Treatments	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Irrigation 1 (control)	53.90 f	52.93 f	42.25 f	41.00 g	61.11e	59.84 f	4.92 f	5.14 f
Irri. 1 + 50 ppm Zn	55.11 ef	56.27 e	45.00 f	46.75 f	60.78 e	62.89 e	5.60 cd	5.96 bc
Irri. 1 + 100 ppm Zn	57.28 e	59.23 d	53.75 e	48.25 ef	63.25 de	65.17de	5.54 de	5.49 e
Irrigation 2	61.37 d	60.18 d	58.50 cd	53.50 cd	64.19 d	67.08 d	5.49 de	5.89 cd
Irri. 2 + 50 ppm Zn	67.25 ab	68.77 b	63.00 ab	60.50 ab	81.23 a	79.52 as	6.23 b	6.37 a
Irri. 2 + 100 ppm Zn	69.58 a	72.04 a	66.75 a	63.75a	83.89 a	80.20 a	6.68 a	6.21 ab
Irrigation 3	56.47 e	58.12de	50.25 e	51.25 de	62.14 de	63.25 e	5.37 e	5.64 de
Irri. 3 + 50 ppm Zn	62.94 cd	64.17 c	54.50 de	56.75 bc	76.12 c	71.12 c	5.89 c	6.03 bc
Irri. 3 + 100 ppm Zn	65.11 bc	64.82 c	60.25 bc	58.00 b	78.15 b	75.10 b	5.71 cd	5.64 de

Irrigation 1 = 3500 m3 of irrigation water were applied as 40 & 30& 20 & 10 %
Irrigation 2 = 3500 m3 of irrigation water were applied as 30 & 40& 25 & 5 %
Irrigation 3 = 3500 m3 of irrigation water were applied as 35& 35 & 20 & 10 %
Values followed by the same letter (s) are not significantly different at 5% level

In this respect, Tarafdar *et al*. [53] and Liu *et al.* [54] reported that foliar application of nano Zn increased the growth parameters. On the other hand, it was reported that the increase in Zn concentrations in plants due to nanoparticles application might be due to higher penetration of nanoparticles into plant cells [55].

Fruit tree production plays an important role and the efficient use of water resources is mandatory, cell enlargement and division need adequate water during fruit growth and development period [54]. It is evident that irrigation management was the main factor affecting the pomegranate production during the season [56]. However, Intrigliolo *et al.* [57] suggested that mild water deficit during flowering-fruit set period, saving a 9-14% of irrigation water, was the best strategy for pomegranate trees because minimal negative effects on fruit yield take place. The obtained results confirmed that flowering-fruit set period is a non-critical period for pomegranate culture. However, irrigation water restrictions and plant water stress levels were far more important than those reported previously by Intrigliolo *et al*. [57].

Chemical Constituents: As is evident in Table (2) total chlorophyll, total carbohydrates, nitrogen content and C/N ratio values were greatly affected with irrigation water management and zinc nanoparticles spraying on "Wonderful" pomegranates tree .

Values of total chlorophyll were superior from all used treatments than the control and the greatest effect was recorded were obtained by second irrigation program plus spraying of zinc oxidase nanoparticles at 50 ppm and 100 ppm in both seasons. While the lowest values of total chlorophyll were observed with the regular irrigation program either separate, or plus 50 ppm zinc nanoparticles spraying without significant differences between them.

The total carbohydrates of pomegranate shoots increased as a result of irrigation amendment and spraying zinc nanoparticles from 25.6 % in regular irrigation program) control (to 40.4 % in irrigation program No 2 (30 & 40 & 25 & 5 %) plus 100 ppm zinc spraying. No significant differences were recorded between the second irrigation program plus spraying zinc at 50 ppm and the third irrigation program with spraying zinc at 100 ppm, this indicates that the water irrigation amendment, according to physiological stages have a greater effect on total carbohydrates, especially with spraying anao-zinc.

Slight effect was observed in nitrogen values with all irrigation systems used. Significantly, nitrogen values were affected by zinc nanoparticles spraying. The highest values of leaf N % (2.27 and 2.35 %) were obtained with second program irrigation and amendment percentage (30 & 40 & 25 and 5 %) plus spraying 100 ppm zinc nanoparticles in both seasons. On the contrary, the lowest values of nitrogen content were recorded with all irrigation programs without spraying zinc nanoparticles.

It is clear from data in Table (2) that C/N ratio greatly increased with the second irrigation program and third irrigation program with significant differences between them. While, control irrigation program recorded the lowest values of C/N ratio in both seasons. Spraying the zinc nanoparticles with both concentrations greatly increased C/N ratio than unsprayed trees, regardless of the used irrigation program, however, the great effect was more pronounced with 100 ppm of zinc spraying.

Table 2: Effect of irrigation water management and zinc nanoparticles on Chemical constituents of "Wonderful" pomegranate fruit during 2017 and 2018 seasons

	Total chlorophyll (mg/g fresh weight)		Total Carbohydrates (%)		N (%)		C/N ratio	
Treatments	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Irrigation 1 (control)	1.02 f	0.987 f	25.6 f	27.0 f	1.90 d	1.97 cd	13.48 e	13.71d
Irri. 1 + 50 ppm Zn	1.11 f	1.07 f	28.3 e	29.7 e	2.00 cd	2.07 b-d	14.15 de	14.35 d
Irri. 1 + 100 ppm Zn	1.23 e	1.30 de	30.7 de	32.6 d	2.06 bc	2.15 a-c	14.91 c-e	15.17cd
Irrigation 2	1.31 de	1.25 e	32.9 cd	33.1 cd	2.13 a-c	2.01 cd	15.45 cd	16.47bc
Irri. 2 + 50 ppm Zn	1.48 bc	1.51 ab	37.5 ab	38.1 b	2.20 ab	2.17 a-c	17.05 ab	17.56ab
Irri. 2 + 100 ppm Zn	1.63 a	1.55 a	40.4 a	43.7 a	2.27 a	2.35 a	17.80 a	18.60 a
Irrigation 3	1.38 cd	1.43 bc	30.5 de	34.3 cd	1.98 cd	1.94 d	15.41 cd	17.33ab
Irri. 3 + 50 ppm Zn	1.40 cd	1.36 cd	33.7 c	35.2 c	2.11 a-c	2.07 b-d	15.98 bc	17.01 b
Irri. 3 + 100 ppm Zn	1.56 ab	1.39 cd	36.3 b	39.8 b	2.25 ab	2.24 ab	16.14 bc	17.77 ab

Irrigation 1= 3500 m3 of irrigation water were applied as 40 & 30& 20 & 10 %

Irrigation 2= 3500 m3 of irrigation water were applied as 30 & 40& 25 & 5 %

Irrigation 3= 3500 m3 of irrigation water were applied as 35& 35 & 20 & 10 %

Values followed by the same letter (s) are not significantly different at 5% level

Increase water availability significantly increases flowering [58]. This might be due to the increase carbohydrates content during flower differentiation as a result of the irrigation treatments. Irrigation water management efficiency is an important indicator for measuring the relationship between crop yield and water use efficiency [59].

Use of nano-zinc as a foliar spray was found beneficial in improving plant growth, chlorophyll, carotenoid contents and NR activity in both pathogen-inoculated and un- inoculated plants. The increase in vegetative growth, chlorophyll, carotenoids and NR activity of lentil might be due to fundamental role of Zn in protection and maintenance of structural stability of cell membranes [60]. And also its use in protein synthesis, membrane function, cell elongation and tolerance [61]. ZnO NPs are also known to increase the shoot dry matter and leaf area [62].

Leaf Mineral Contents

P, K and Mg%: Data in Table (3) showed that second and third programs irrigation management were similar in their effect on leaf P content in both studied seasons. The two zinc spraying concentration increased leaf P content but the great effect was recorded by 200 ppm. Control irrigation unsprayed trees exhibited least values of leaf P content.

The highest values of K% (1.65 and 1.67 %) in first and second seasons were detected by second irrigation program plus 100 ppm nano-zinc spraying. However, third irrigation program and regular irrigation program plus 100 ppm zinc spraying recorded similar lower values of leaf K content than the second irrigation program. In the contrast, the lowest values of leaf K content were shown with irrigation regular and the third irrigation management without zinc nanoparticles spraying.

Mg content positively increased with spraying 100 ppm zinc nanoparticles with the three programs of irrigation water managements. The highest percentage of Mg (0.66 and 0.68 %) achieved by the second irrigation program plus 100 ppm nano-Zn spraying, while the lowest values (0.34 and 0.36%) recorded by the regular irrigation program (control) during the first and the second seasons respectively.

Fe, Zn and Mn (ppm): As it is evident in Table (4), Fe, Zn and Mn levels in the Pomegranate leaves greatly increased with zinc nanoparticles spraying with all irrigation water managements in both studied seasons. Concerning water irrigation management the positive significant effects were obtained with second program followed by third program of irrigation water management and lastly regular irrigation program (control).

The highest levels of Fe (229.12 and 240.53 ppm), Zn (41.56 and 39.07ppm) and Mn (92.00 and 66.59 ppm) were obtained with 100 pm zinc nanoparticles spraying plus irrigation management (30 & 40 & 25 and 5 %) during growth physiological stages in first and second season. On the other side of view, the lowest values of Fe (153.61 and 160.67 ppm), Zn (19.73 and 19.67 ppm) and Mn (66.59 and 67.59 ppm) were declared with traditional irrigation without nano-zinc spraying in the two studied seasons.

Table 3: Effect of irrigation water management and zinc nanoparticles macronutrients levels N, P, K and Mg content (%) of "Wonderful" pomegranate fruit during 2017 and 2018 seasons

	P %		K %		Mg	
Treatments	1st season	2nd season	1st season	2nd season	1st season	2nd season
Irrigation 1 (control)	0.23 e	0.26 d	1.20 d	1.16 e	0.34 e	0.36 d
Irri. 1 + 50 ppm Zn	0.26 de	0.27 d	1.32 cd	1.39 cd	0.51 c	0.58 b
Irri. 1 + 100 ppm Zn	0.32 bc	0.34 ab	1.54 ab	1.59 ab	0.60 ab	0.63 ab
Irrigation 2	0.26 de	0.29 cd	1.25 d	1.28 de	0.43 d	0.47 c
Irri. 2 + 50 ppm Zn	0.30 bc	0.32 bc	1.43 bc	1.42 cd	0.57 bc	0.60 ab
Irri. 2 + 100 ppm Zn	0.37 a	0.36 a	1.65 a	1.67 a	0.66 a	0.68 a
Irrigation 3	0.25 de	0.27 d	1. 17 d	1.23 e	0.38 de	0.42 cd
Irri. 3 + 50 ppm Zn	0.29 cd	0.28 cd	1.47 bc	1.48 bc	0.53 c	0.57 b
Irri. 3 + 100 ppm Zn	0.34 ab	0.35 ab	1.57 ab	1.58 ab	0.61 ab	0.64 ab

Irrigation 1= 3500 m3 of irrigation water were applied as 40 & 30& 20 & 10 %
Irrigation 2= 3500 m3 of irrigation water were applied as 30 & 40& 25 & 5 %
Irrigation 3= 3500 m3 of irrigation water were applied as 35& 35 & 20 & 10 %
Values followed by the same letter (s) are not significantly different at 5% level

Table 4: Effect of irrigation water management and zinc nanoparticles on micronutrient levels (ppm) Fe, Zn and Mn of "Wonderful" pomegranate fruit during 2017 and 2018 seasons

	Fe ppm		Zn ppm		Mn ppm	
Treatments	1st season	2nd season	1st season	2nd season	1st season	2nd season
Irrigation 1 (control)	153.61 e	160.67 f	19.73 e	19.67 d	66.59 d	67.59 d
Irri. 1 + 50 ppm Zn	185.56 cd	194.34 de	29.74 d	30.54 c	77.47 c	70.26 d
Irri. 1 + 100 ppm Zn	201.05 bc	217.20 bc	35.94 bc	36.12 ab	84.25 b	82.84 bc
Irrigation 2	171.20 de	177.84 ef	24.17 e	23.57 d	69.35 d	77.32 c
Irri. 2 + 50 ppm Zn	191.43 cd	204.41 cd	35.79 bc	33.91 bc	83.17 b	85.11 ab
Irri. 2 + 100 ppm Zn	229.12 a	240.53 a	41.56 a	39.07 a	92.00 a	89.26 a
Irrigation 3	153.70 e	169.74 f	21.43 e	24.69 d	67.21 d	65.26 d
Irri. 3 + 50 ppm Zn	205.94 b	202.43 cd	31.56 cd	29.75 c	80.20 bc	78.57 c
Irri. 3 + 100 ppm Zn	224.22 a	228.50 ab	38.23 ab	37.53 ab	90.51 a	84.12 ab

Irrigation 1= 3500 m3 of irrigation water were applied as 40 & 30& 20 & 10 %
Irrigation 2= 3500 m3 of irrigation water were applied as 30 & 40& 25 & 5 %
Irrigation 3= 3500 m3 of irrigation water were applied as 35& 35 & 20 & 10 %
Values followed by the same letter (s) are not significantly different at 5% level

Water management is implemented to avoid a deficit or an increase in the amount of water may be negative effects. Overwatering may lead to nutrient leaching which may affect environmental quality and increase production costs, while water deficit can deleteriously affect potential growth and cause death of plants [63, 64]. Thus it , is necessary to define water management to suit environmental laws and improve the quality. The main factors that affect the development and quality of the trees are the quality of its genetic materials, water management, nutrition, the type of container and the substrates used [65]. Water management is defined as the process of determining how much to apply (irrigation volume) and timing (when to apply) [66].

Faizan *et al.* [67] concluded that presence of zinc nanoparticles stimulated the antioxidant systems and increased proline accumulation that could provide stability to plants and improved photosynthetic efficiency. Foliar spray of zinc nanoparticles resulted in increased permeability of lipophilic organic molecules through the cuticle [68]. Hence, nano-Zn have more chances to penetrate the leaf surface and release ions across the cuticle compared to water soluble ions [69].

Prasad *et al*. [33] observed that nano size and lower water solubility of ZnO NPs resulted in higher bioavailability of these NPs, which may be responsible for higher yields.

Fruit Set (%) and Yield Attributes: Data presented in Table (5) showed that irrigation water management and zinc nanoparticles spraying improved fruit set (%) and yield attributes of "Wonderful" pomegranate fruits during 2017 and 2018 seasons.

Table 5: Effect of irrigation water management and zinc nanoparticles on fruit set (%) and yield attributes of "Wonderful" pomegranate fruit during 2017 and 2018 seasons

	Final fruit set %		No of fruit/tree		Fruit weight (g)		Yield/tree (Kg)		Marketable fruits %	
Treatments	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Irrigation 1 (control)	38.88 f	40.11 f	54.75 g	57.75 e	385.5e	391.8 e	21.11 f	22.63 f	69.60 g	71.03 e
Irri. 1 + 50 ppm Zn	42.02 e	41.32 f	59.25 f	59.50 e	401.7 e	405.5 de	23.80 e	24.13 ef	75.10 f	76.47d
Irri. 1 + 100 ppm Zn	43.26 e	42.88 ef	60.00 ef	61.75 e	412.5 de	421.3 cd	25.16de	26.00de	78.69 e	78.14 d
Irrigation 2	47.87 cd	47.22 cd	67.50 cd	68.00 d	438.7 bc	443.8 ab	29.61 c	30.18 c	82.96cd	84.56 c
Irri. 2 + 50 ppm Zn	56.56 ab	56.77 b	79.75 ab	81.75 b	461.4 ab	465.2 a	36.80ab	8.03ab	89.34 b	88.69 b
Irri. 2 + 100 ppm Zn	59.04 a	60.94 a	83.25 a	87.75 a	470.2 a	461.5 a	39.14 a	40.50 a	94.29 a	93.16 a
Irrigation 3	45.04 de	45.83 de	63.25 de	66.00 d	417.3 cd	411.4 de	26.50 d	27.13 d	77.95 ef	78.79 d
Irri. 3 + 50 ppm Zn	50.53 c	51.22 c	71.25 c	73.75 c	425.2 cd	438.0 bc	30.30 c	32.30 c	81.05de	84.41 c
Irri. 3 + 100 ppm Zn	54.61 b	55.03 b	77.00 b	79.25 b	446.5 b	451.3 ab	34.38 b	35.77 b	86.04bc	85.80bc

Irrigation 1 = 3500 m3 of irrigation water were applied as 40 & 30& 20 & 10 %
Irrigation 2 = 3500 m3 of irrigation water were applied as 30 & 40& 25 & 5 %
Irrigation 3 = 3500 m3 of irrigation water were applied as 35& 35 & 20 & 10 %
Values followed by the same letter (s) are not significantly different at 5% level

The second irrigation programs was effective than third one or regular irrigation (control) in increasing fruit set % and producing highest fruit number / tree in both studied seasons. However, spraying zinc nanoparticles at 100 or 100 ppm were effective in hastening fruit set as well as fruit number /tree than unsprayed one. High value of fruit set (59.04 and 60.94 %) and fruit number /tree (83.25 and 87.75 fruit /tree) were obtained in first and second seasons by second irrigation program in combination with 100 ppm zinc nanoparticles spraying.

In addition, the greatest fruit weight values (470.2 and 461.5 g) in 1st and 2nd seasons respectively resulted from sprayed fruits with zinc nanoparticles at 100 ppm through irrigation No. 2 management. On the other hand, the lowest values of these qualities (385.5 & 391.8 g) were recorded with treated unsprayed fruits and irrigated with irrigation program No. 1.

Regarding total yield/tree and marketable fruits it is evident that, both concentrations of nano-zinc and irrigation water management significantly increased the total Yield / Tree (Kg) than the control in the two seasons. The effective treatment in producing the highest yield and highest marketable fruits were those trees irrigated with the second program and sprayed with 100 ppm nano Zn. However, spraying zinc nanoparticles at 50 ppm with any irrigation programs gave a mediate value. Regular irrigation (control) unsprayed trees showed the worst treatments where the unmarketable fruits % reached nearly a quarter of total yield/tree.

Regulated irrigation is probably the most useful deficit irrigation strategy to improve water saving and even harvest quality, inducing minimum impacts in marketable yield. Regulated irrigation is based in reducing irrigation or non-irrigating during the water stress-tolerant phenological periods (non-critical periods) and supplying full irrigation during the water stress-sensitive phenological periods (critical periods) [70, 71]. It is known that irrigation can modify processes related to fruit trees floral biology such as the duration of phenological stages, flowering intensity and fruit set [72]. Considering that in pomegranate trees spring vegetative growth and flowering-fruit happen simultaneously, the reduction in total shoot growth values by water stress could decrease the competition between both processes favouring flowering. Total shoot growth decrease can be considered as an advantageous result because a compensatory young fruit growth could be favoured when irrigation was resumed due to a shift in the carbon allocation pattern, [73]. Zinc is an essential component of some enzymes such as dehydrogenase, proteinase and peptidases. In this regard, zinc can affect electron transfer reactions such as the Krebs cycle and energy production of the plant. Zinc is also involved in other reactions such as protein construction and analysis [22]. So, promote growth by increasing plasticity of the cell wall followed by the hydrolysis of starch into sugars which reduces the cell water potential, resulting in the entry of water into the cell and causing elongation [74].

Physical Fruit Properties: It is clear from data in Tables (6) that Physical fruit properties of "Wonderful" pomegranate were greatly affected with irrigation water managements and zinc nanoparticles in both seasons of this study.

The values of fruit firmness of "Wonderful" pomegranate fruits produced from regulated irrigation water program were superior than the control due to effect of water management and zinc nanoparticles.

Table 6: Effect of irrigation water management and zinc nanoparticles on some Physical fruit properties of "Wonderful" pomegranate fruit during 2017 and 2018 seasons

Treatments	Firmness Kg. force		Peel thickness (cm)		Arils %		Juice %	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Irrigation 1 (control)	9.2 e	9.7 d	0.66 a	0.67 a	43.82 g	44.76 f	35.70 f	36.43 f
Irri. 1 + 50 ppm Zn	10.0 de	10.4 cd	0.65 ab	0.66 ab	47.65 f	49.12 e	40.54 e	41.58 e
Irri. 1 + 100 ppm Zn	10.4 d	10.8 c	0.63 bc	0.64 bc	51.27 e	53.13 d	44.56 d	46.31 d
Irrigation 2	11.0 cd	11.2 bc	0.61cd	0.60 e	56.18 cd	58.58 bc	49.74 c	51.96 c
Irri. 2 + 50 ppm Zn	12.6 ab	12.0 ab	0.57 e	0.57 f	60.90 b	60.88 b	58.17 b	56.08 b
Irri. 2 + 100 ppm Zn	13.2 a	12.8 a	0.57 e	0.56 f	67.34 a	66.17 a	61.81 a	60.45 a
Irrigation 3	10.4 d	10.6 cd	0.64 ab	0.63 cd	53.25 de	52.14 de	46.71 d	45.55 d
Irri. 3 + 50 ppm Zn	11.6 bc	11.0 bc	0.60 d	0.61 de	56.91 c	57.84 c	50.59 c	51.37 c
Irri. 3 + 100 ppm Zn	11.8 bc	12.0 ab	0.59 de	0.60 e	58.44 bc	59.38 bc	52.33 c	53.15bc

Irrigation 1 = 3500 m3 of irrigation water were applied as 40 & 30& 20 & 10 %
Irrigation 2 = 3500 m3 of irrigation water were applied as 30 & 40& 25 & 5 %
Irrigation 3 = 3500 m3 of irrigation water were applied as 35& 35 & 20 & 10 %
Values followed by the same letter (s) are not significantly different at 5% level

Second irrigation program (30 & 40 & 25 and 5 %) and zinc nanoparticles at 100 ppm exhibited the highest values of fruit firmness. However, third irrigation program (35& 35 & 20 and 10) with 100 or 50 ppm zinc nanoparticles or alone recorded intermediate values. Irrigation control (40 & 30 & 20 and 10%) either alone or 50 &100 ppm nano-Zn spraying or recorded least values of the firmness.

A slight different due to the both studied factors for peel thickness effect were obtained. However, slight decrease were observed with all the fruits that applied second water management regardless of zinc nanoparticles spraying where the values ranged from (0.56 to 0.60 cm) during both seasons. Meanwhile slight increase (from 0.63 to 0.67 cm) was observed with irrigation regular water either alone or with nano-zinc sprays.

On the general side there was a positive relationship between the arils and Juice % with the fruit weight (Table 5). The trees which applied second water irrigation management and 100 ppm zinc nanoparticles spraying achieved highest significant values of both qualities (arils and Juice %) and this finding was parallel to the highest. No significant differences between the second irrigation water management plus 50 ppm nano-Zn and irrigation water management No.3 plus 100 ppm nano-Zn both characters mentioned in concentrations, which gave intermediate values but higher than irrigation control.

Fruit trees require frequent irrigation during fruit development and mismanagement of water supply to trees at critical stages leads to fruit drop, reduced fruit size and quality. So, proper irrigation is essential in maintaining a healthy and productive fruit orchard. Whereas over irrigation slow root growth, increases the potential for iron chlorosis in alkaline soils and leaches nitrogen, sulfur and boron out of the root zone leading to nutrient deficiencies. It can also induce excessive vegetative vigor. Excessive soil moisture also provides an ideal environment for crown and collar rots in plant .On the other hands applying insufficient irrigation water results in drought stress and reduced fruit size and quality [75, 65]. water restriction do not effect morphological and physiological processes of tree. In fact, enhance the bearing, maturation and fruit tree features [76].

Chemical Fruit Properties: Results in Table (7) show that supplying pomegranates trees with (30 & 40 & 25 and 5 %) management irrigation and 50 or 100 ppm zinc nanoparticles were significantly effective in stimulating chemical characteristics of the fruits in terms of increasing total soluble solids percentage, also the same treatments significantly reduced titratable acidity. While pomegranates trees exposed to control irrigation led to reduction the values of TSS % and increased acidity.

However, ascorbic acid contents showed that pomegranates trees irrigated with (30 & 40 & 25 and 5 %) management irrigation plus 50 & 100 ppm zinc nanoparticles gave the highest significant values of L-ascorbic acid in both seasons. On the other hand, ascorbic acid content in control irrigation fruits significantly decreased.

Table 7: Effect of irrigation water management and zinc nanoparticles on Some chemical fruit constitutes of "Wonderful" pomegranate fruit during 2017 and 2018 seasons

Treatments	Total Acidity %		TSS %		Ascorbic Acid mg/100 ml juice		Tannins mg/100 ml juice		Anthocyanin mg/100 ml juice	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Irrigation 1 (control)	1.17 a	1.25 a	13.28 e	14.00 e	25.79 f	27.26 e	2.37 a	2.44 a	3.52 f	3.59 f
Irri. 1 + 50 ppm Zn	1.14 ab	1.21 ab	13.76 de	14.12 e	28.14 e	29.78 d	2.23ab	2.29ab	4.07 e	3.91 e
Irri. 1 + 100 ppm Zn	1.12 ab	1.14 cd	15.10 c	15.26 cd	32.65 c	32.14 c	2.06 bc	2.07 c	4.91 d	4.69 e
Irrigation 2	1.07 cd	1.12 d	15.60 bc	16.00 bc	33.75bc	34.11 b	1.89 de	1.95 c	5.53bc	5.11 d
Irri. 2 + 50 ppm Zn	1.03 d	1.05 e	15.76 a	17.20 a	36.02 a	36.54 a	1.86 de	1.81 d	6.05 a	5.89 ab
Irri. 2 + 100 ppm Zn	0.96 e	1.01 e	17.04 a	17.46 a	36.64 a	37.12 a	1.74 e	1.85 d	6.19 a	6.26 a
Irrigation 3	1.10 bc	1.17 bc	14.72 cd	14.88 de	30.21 d	32.07 c	2.15 bc	2.11bc	4.47 e	4.33 e
Irri. 3 + 50 ppm Zn	1.11 bc	1.14 cd	15.30 bc	15.60 bc	34.26 b	33.12bc	1.97 cd	2.03 c	5.14cd	5.25 cd
Irri. 3 + 100 ppm Zn	1.07 cd	1.10 d	16.30ab	16.60 ab	35.18ab	34.45 b	1.96 cd	1.98 c	5.86ab	5.63 bc

Irrigation 1 = 3500 m3 of irrigation water were applied as 40 & 30& 20 & 10 %
Irrigation 2 = 3500 m3 of irrigation water were applied as 30 & 40& 25 & 5 %
Irrigation 3 = 3500 m3 of irrigation water were applied as 35& 35 & 20 & 10 %
Values followed by the same letter (s) are not significantly different at 5% level

Total tannins greatly affected with all applied treatments, generally total tannins of wonderful juice fruit ranged from (1.74 to 2.37 mg/100 ml juice) in first season and (1.81 to 2.44 mg/100 ml juice) in the second season. Spraying both concentrations of zinc nanoparticles reduces tannin values with all irrigation water management. On the other hand, high tannin values were recorded with all irrigation management without nano-zinc spraying especially traditional irrigation program.

Control fruit recorded the least values of anthocyanins pigment (3.52 & 3.59 mg/100 ml juice), in both seasons. In the contrast irrigation 2 + 100 ppm Zn gave the highest values of anthocyanins pigment content (6.19 and 6.26 mg/100 ml juice) in 2017 and 2018 seasons. It is well known that the increase in the anthocyanin content which was due to greater accumulation of carbohydrates.

The positive significant effect of Zn on the quality aspects of fruits in comparison with the other treatments may be attributed to the significant absorption of macro and micronutrient. In addition, plays an important role in water status of plant, promoting the translocation of newly synthesized photosynthetics and mobilization of metabolites as well as promoting the synthesis of sugars and polysaccharides and improving the fruit quality in terms of TSS and total sugars [28-30]. Zn, play an important role in achieving satisfactory fruit set [77, 78].

Appropriate irrigation can provide plants with the water needed for growth in a timely, effectively improve the soil environment and achieve the purpose of improving production, quality and water use efficiency [79]. Water consumption during the growth period is greatly affected by soil moisture. Irrigation management can effectively replenish the soil water deficit caused by plant growth. It is greater of irrigation amount and the moister the soil; and the water [80].

Generally, it could be concluded that amendment of irrigation water management by decreasing the amount of irrigation water in first phase (Mar. May), the period of flowering and fruit set and increase it in the second phase (June – August) the period of fruit development and fruit ripening was effector in increasing fruit quality and decreasing the percent of discarded fruits. However, nano-zinc spraying was promoting factor in increase the efficiency of irrigation water amendments in pomegranate.

REFERENCES

1. Al-Maiman, S.A. and D. Ahmad, 2002. Changes in physical and chemical properties during pomegranate (*Punica granatum* L.) fruit maturation. Food Chem. 76: 437-441.
2. Sarkhosh, A., Z. Zamani, R. Fatahi and M. Sayyari, 2009. Antioxidant activity, total phenols, anthocyanin, ascorbic acid content and woody portion index (wpi) in Iranian soft-seed pomegranate fruits, Food., 3(1): 68-72.
3. Bakeer, S., 2016. Effect of ammonium nitrate fertilizer and calcium chloride foliar spray on fruit cracking and sunburn of Manfalouty pomegranate trees. Scientia Horticulturae, 209: 300-308.
4. Jurenka, J.M., 2008. Therapeutic Applications of Pomegranate (*Punica granatum* L.): A Review. Alternative Medicine Review, 13(2): 128-144.

5. Haidari, M.M., S.W. Casscells and M. Madjid, 2009. Pomegranate (*Punica granatum*) purified polyphenol extract inhibits influenza virus and has a synergistic effect with oseltamivir. Phytomedicine, 16(12).
6. Gharesheikhbayat, R., 2006. Anatomical study of fruit cracking in pomegranate cv. Malas-e Torsh. Pajouhesh & Sazandegi, 68: 10-14.
7. El-Rhman, I., 2010. Physiological studies on cracking phenomena of pomegranates. Journaln of Applied Sciences Research, 6: 696-703.
8. Abubakar, A.R., N. Ashraf and M. Ashraf, 2013. Effect of plant biostimulants on fruit cracking and quality attributes of pomegranate cv. Kandhari kabuli . Academic Journals, 8(44): 2171-2175.
9. Jalili, M.Z., 2016. A Complete Guide of Pomegranate Growing. Education and Promoting Agriculture Publication.
10. Melgarejo, P., J. Martınez, F. Hernández, R. Martınez-Font, P. Barrows and A. Erez, 2004. Kaolin treatment to reduce pomegranate sunburn. Scientia Horticulturae, 100: 349-353.
11. Talaat, K.R., A.K. Mohamed and N.I. Mohamed, 2009. Effect of flower thinning and spraying with gibberellic acid and ethephon on yield and fruit quality of Manfaloty pomegranate cultivar. Assuit J. Agric. Sci., 40: 69-91.
12. Olyaie, T.A., S.H. Goldansaz., M.A. Asgari and A.K. Zarei, 2017. Effect of organic and biological fertilizers on pomegranate trees: yield, cracking, sunburning and infestation to pomegranate fruit moth Ectomyelois ceratoniae (Lepidoptera: Pyralidae) J. Crop Prot., 6(3): 327-340.
13. El-Qousy, D.A., M.A. Mohamed, M.A. Aboamera and A.A. AbouKheira, 2006. On-Farm energy requirements for localized irrigation systems of citrus in old lands. Misr J. Ag. Eng., 23(1): 70-83.
14. Khattab, M.M., A.N. Shaban, E.F. El-Shrief and A.H. Mohamed, 2011. Growth and productivity of pomegranate trees under different irrigation levels. II: Fruit quality. J. Hortic. Sci. Ornament. Plants, 3(3): 259-264.
15. Brouwer, C., A. Goffeau and M. Heibloem, 1985. Irrigation Water Management: Training Manual No. 1-Introduction to Irrigation; Food and Agriculture Organization of the United Nations: Rome, Italy.
16. Davies, W.J., M.A. Bacon, D.S. Thompson, W. Sobeih and L.G. Rodriguez, 2000. Regulation of leaf and fruit growth in plants growing in drying soil: exploitation of the plants' chemical signalling system and hydraulic architecture to increase the efficiency of water use in agriculture. J. Exp. Bot., 51: 1617-1626.
17. Hilhorst, M.A., C. Dirksen, F.W. Kampers and R.A. Feddes, 2001. Dielect ric relaxation of bound water versus soil matric pressure. Soil Science Society of America Journal, 65: 311-314.
18. Kato, Y., M. Okami and K. Katsura, 2009. Yield potential and water use efficiency of aerobic rice (*Oryzasativa* L.) in Japan. Field Crops Research, 113(3): 328-334.
19. Jones, H.G., A.N. Lakso and J.P. Syvertsen, 1985. Physiological control of water status in temperate and subtropical fruit trees. Journal of Horticultural Science and Biotechnology, 66: 311-34.
20. Patil, A.V., A.R. Karale and T.K. Bose, 2002. Pomegranate. In: Bose TK, Some MG (Eds) Fruits: Tropical and Subtropical, Naya Prakash, Kolkata, India, pp: 225-262
21. Sonawane, P.C. and U.T. Desai, 1989, Performance of staggered cropping in pomegranate J. Maharashtra Agric. Univ., 14: 341-342.
22. Bose, T.K., S.K. Mitra and M.K. Sadju, 1988. Citrus. In: The mineral nutrition of fruit crop. Ed. Naya, Prokash, Calcutta. India, pp: 70-90.
23. Yamaguchi, M., Y.H. Gao and Z.J. Ma, 2000. Synergistic effect of genistein and zinc on bone components in femoral-metaphyseal tissues of female rats. J. Bone Miner Metab., 18(2): 77-83.
24. Balakrishnan, K., K. Vekatesan and S. Sambandamurthis, 1996. Effect of foliar application of Zn, Fe, Mn and B on yieldquantity of pomegranate, cv. Ganesh. Orissa J. Hortic., 24(1-2): 33-35.
25. Hasani, M., Z. Zamani, G. Savaghebi and R. Fatahi, 2012. Effects of zinc and manganese as foliar spray on pomegranate yield, fruit quality and leaf minerals Journal of Soil Science and Plant Nutrition, 12(3): 471-480.
26. Nijjar, G.S., 1985. Nutrition of fruit trees. Mrs Usha Raj Kumar, Kalyani, New Delhi, India, pp: 306-308.
27. Banik, B.C., S.K. Sen and T.K. Bose, 1997. Effect of zinc, iron and boron in combination with urea on growth, flowering, fruiting and fruit quality of mango cv. Fazli. Environment and Ecology, 15(1): 122-125.
28. Singh, G. and A.N. Maurya, 2004. Effect of, micronutrients on bearing of mango cv. Mallika. Progressive Agriculture, 4: 47-50.
29. Ranjit, K., P. Kumar and U.P. Singh, 2008. Effect of foliar application of nitrogen, zinc and boron on flowering and fruiting of mango cv Amrapali. Environ. Ecol., 26: 1965-1967.
30. Rashmi, P., R. Sing and C.P. Pantnagar, 2007. Effect of preharvest foliar spray of micronutrients on chemical properties of mango fruit cv. Langra. J. Res., 5: 56-61.

31. Yogesh, B., K. Gangadhara, C. Rabinal, G. Chaudhari and P. Ugale, 2015. Nanotechnology in Agriculture: A Review. Journal of Pure and Applied Microbiology, 9(1): 1-11.
32. Ali, M.A., I. Rehman, A. Iqbal, S. Din, A.Q. Rao, A. Latif, T.R. Samiullah and T. Husnain, 2014. Nanotechnology, a new frontier in Agriculture. Adv. Life Sci., 1(3): 129-138.
33. Prasad, R., A. Bhattacharyya and Q.D. Nguyen, 2017. Nanotechnology in Sustainable Agriculture: Recent Developments, Challenges and Perspectives. Front Microbial., 8: 1014.
34. Ditta, A., M. Arshad and M. Ibrahim, 2015. Nanoparticles in Sustainable Agricultural Crop Production: Applications and Perspectives., Nanotechnology and Plant Sciences, pp: 55-75.
35. DeRosa, M.C., C. Monreal, M. Schnitzer, R. Walsh and Y. Sultan, 2010. Nanotechnology in fertilizers. Nat. Nanotechnol., 5(2): 91.
36. Dehghanipoodeh, S., C. Ghobadi, B. Baninasab, M. Gheysari and S.S. Bidabadi, 2016. Effects of potassium silicate and nanosilica on quantitative and qualitative characteristics of a commercial strawberry (Fragaria × ananassa cv. 'Camarosa'). J. Plant Nutr., 39: 502-507.
37. Davarpanah, S., A. Tehranifar, G. Davarynejad, J. Abadía and R. Khorassani, 2016. Effects of foliar applications of zinc and boron nano-fertilizers on pomegranate (*Punica granatum* cv. Ardestani) fruit yield and quality. Sci. Hortic., 210: 57-64.
38. Sabir, A., K. Yazar, F. Sabir, Z. Kara, M.A. Yazsci and N. Goksu, 2014. Vine growth, yield, berry quality attributes and leaf nutrient content of grapevines as influenced by seaweed extract (*Ascophyllum nodosum*) and nanosize fertilizer pulverizations. Sci Hort., 175: 1-8.
39. Barrios, A.C., C.M. Rico, J. Trujillo Reyes, I.A. Medina Velo, J.R. Peralta Videa and J.L. Gardea Torresdey, 2016. Effects of uncoated and citric acid coated cerium oxide nanoparticles, bulk cerium oxide, cerium acetate and citric acid on tomato plants. Sci. Total Environ., 1: 563-564.
40. Rai, M., C. Ribeiro, L. Mattoso and N. Duran, 2015. Nanotechnologies in Food and Agriculture. Springer International Publishing, pp: 347.
41. Subramanian, K.S. and C. Sharmila Rahale, 2012. Ball milled nanosized zeolite loaded with Zinc sulfate: a putative slow release Zn fertilizer. Int. J. Innov. Hortic., 1: 33-40.
42. Mosanna, R. and B.E. Khalilvand, 2015. Morpho-physiological response of maize (*Zea mays* L.) to zinc nano-chelate foliar and soil application at different growth stages. J. New Biol., 46-50.
43. Maranto, J. and K.A. Hake, 1985. Summer lemons, a new option for California growers Cal. Agric., 39: 4
44. Smith, M.W., A.L. Kenworthy and O.L. Bedford, 1979. The response of fruit trees to injection of nitrogen through a trickle irrigation system. J. Amer. Soc. Hort. Sci., 104: 311-313
45. Wilde, S.A., R.B. Cory, J.G. Lyer and G.K. Voigt, 1985. Soils and Plants Analysis for Tree cultures. OxforIBH, New Delhi, India, pp: 94-105.
46. Jackson, M.L., 197. Soil Chemical Analysis Prentice Hall of India Private, LTD, New Delhi.
47. Bringham, F.T., 1982. Methods of Soil Analysis, (Ed), Part 2., Agronomy, 9: 431-447.
48. Chapman, H.D. and P.R. Pratt, 1982. Analysis for Soils, Plants and Waters." Pub- Search, 69: 237-277.
49. A.O.A.C., 2000. Official Methods of analysis 15th Edition. Association of Official Anal Chem., 2: 918 (942015), Washington, D.C., USA
50. Markham, K.R., 1982. Techniques of flavonoid identification. London: Academic Press, pp: 15-51.
51. Swain, J. and W.E. Hillis, 1959. The Phenolic Constitutents of Prunus domestica. I. The Quantitative Analysis of Phenolic Constituents. Journal of the Science of Food and Agriculture, 10: 63-68.
52. Snedecor, C.W. and W.G. Cochran, 1982. Statistical Methods. 7th Ed. The Iowa State Univ. Press. Amesth Iowa, USA.
53. Tarafdar, J.C., R. Raliya, H. Mahawar and I. Rathore, 2014. Development of zinc nanofertilizer to enhance crop production in pearl millet (*Pennisetum americanum*). Agric. Res. J., 3(3): 257-262.
54. Liu, R., H. Zhang and R. Lal, 2016. Effects of stabilized nanoparticles of copper, zinc, manganese and iron oxides in low concentrations on lettuce (*Lactuca sativa*) seed germination: nanotoxicants or nanonutrients. Water, Air and Soil Pollution., 227: 42.49.
55. Moghaddasi, S., A. Fotovat, A.H. Khoshgoftarmanesh, F. Karimzadeh, H.R. Khazaei and R. Khorassani, 2017. Bioavailability of coated and uncoated ZnO nanoparticles to cucumber in soil with or without organic matter Ecotoxicology and Environmental Safety, 144: 543-551.

56. Rodriguez, P., C.D. Mellisho, W. Conejero, Z.N. Cruz, M.F. Ortuno, A. Galindo and A. Torrecillas, 2012. Plant water relations of leaves of pomegranate trees under different irrigation conditions. Environ. Exp. Bot., 77(19): 24.
57. Intrigliolo, D.S., L. Bonet, P.A. Nortes, H. Puerto, E. Nicolas and J. Bartual, 2013. Pomegranate trees performance under sustained and regulated deficit irrigation. Irrigation Sci., 31: 959-970.
58. Grattan, S.R., M.J. Berenguer, J.H. Connell, V.S. Polito and P.M. Vossen, 2006. Olive oil production as influenced by different quantities of applied water. Agricultural Water Management, 85: 133-140.
59. Jasechko, S., Z.D. Sharp, J.J. Gibson, S.J. Birks, Y. Yi and P.J. Fawcett, 2013. Terrestrial water fluxes dominated by transpiration. Nature, pp: 496.
60. Welch, R.M., M.J. Webb and J.F. Loneragan, 1982. Zinc in membrane function and its role in phosphorus toxicity. In: A. Scaife (ed.): Proc. of the Ninth Plant Nutrition Colloquium. Warwick, UK. Wallingford, UK, CAB International, pp: 710-715.
61. Cakmak, I., 2000. Possible roles of zinc in protecting plant cells from damage by reactive oxygen species. New Phytol., 146: 185-205.
62. Taheri, M., H.A. Qarache, A.A. Qarache and M. Yoosefi, 2015. The effects of zinc-oxide nanoparticles on growth parameters of corn (SC704). STEM Fellowship J., 1: 17-19.
63. Bauerle, W.L., C.J. Post, M.F. McLeod, J.B. Dudley and J.E. Toler, 2002. Measurement and modeling of the transpiration of a temperate red maple container nursery. Agric. For. Meteorol., 114(1-2): 45-57.
64. Montague, T. and R. Kjelgren, 2006. Use of thermal dissipation probes to estimate water loss of containerized landscape trees. J. Environ. Hort., 24(2): 95-104.
65. Qi, J.X., X. Liu, X.B. Zhao, G.D. Ma and X.Y. Zhang, 2017. Effects of different irrigation frequency on the growth, photosynthesis and fluorescence characteristics of tomato. Water-saving Irrigation, 4: 50-56.
66. Warren, S.L. and T.E. Bilderback, 2005. More plant per gallon: getting more out of your water. Hortic. Technol., 15(1): 14-18.
67. Faizan, M., A. Faraz, M. Yusuf, S.T. Khan and S. Hayat, 2017. Zinc oxide nanoparticle-mediated changes in photosynthetic efficiency and antioxidant system of tomato plants. Photosynthetica, 56(2): 678-686.
68. Laware, S.L. and S. Raskar, 2014. Influence of Zinc Oxide nanoparticles on growth, flowering and seed productivity in onion .International Journal of Current Microbiology Science, 3(7): 874-881.
69. Da Silva, L.C., M A. Oliva, A.A. Azevedo and M.J. Araujo, 2006. Response of resting plant species to pollution from an iron pelletization factory. Water, Air and Soil Pollution, 175: 241-256.
70. Chalmers, D.J., P.D. Mitchell, L. Van Heek, 1981. Control of peach tree growth and productivity by regulated water supply, tree density and summer pruning J. Am. Soc. Hortic. Sci., 106: 307-312.
71. Galindo, A., P. Rodríguez, C.D. Mellisho, E. Torrecillas, A. Moriana, Z.N. Cruz, W. Conejero, F. Moreno and A. Torrecillas, 2013. Assessment of discretely measured indicators and maximum daily trunk shrinkage for detecting water stress in pomegranate trees Agric. For. Meteorol., 180: 58-65.
72. Ruiz-Sánchez, M., A. León and F. Del, 1988. Amor Floral biology of the almond tree under drip irrigation Adv. Hortic. Sci., 2: 96-98.
73. Abrisqueta, J.M., O. Mounzer, S. Alvarez, W. Conejero, Y. García-Orellana, L.M. Tapia, J. Vera, I. Abrisqueta and M.C. Ruiz-Sánchez, 2008. Root dynamics of peach trees submitted to partial rootzone drying and continuous deficit irrigation Agr. Water Manage., 89: 959-996.
74. Richard, M., 2006. How to grow big peaches. Department of Horticulture, Virginia Tech. Blacksburg, VA 24061. Internet, www. Rce. Rutgers. edu. pp: 8, August.
75. Menzel, C.M., T. Olesen and C.A. McConchie, 2000. Lychee, Longan and Rambutan. Optimizing Canopy Management. Final Report to the Rural Industries Research and Development Corporation, Canberra, pp: 92.
76. Cui, H.Y., F.L. Hu, Z.S. Fang and J.Y. Niu, 2015. Effects of irrigation amount and irrigation period on water requirement and yield of flax. Journal of Nuclear Agricultural Sciences, 29: 812-819.
77. Baldi, E., M. Toselli, D. Deudellar, M. Taglivini and B. Maringoni, 2004. Foliar feeding of stone fruit trees. Informatore-Agrorio, 60(21): 43-46.
78. Abd El-Fatah, D.M., S.A. Mohamed and O.M. Ismail, 2008. Effect of biostimulants, ethrel, boron and potassium nutrient on fruit quality of "Cos-tata" persimmon. Aust. J. Basic Appl. Sci., 2(4): 1432-1437.
79. Jasechko, S., Z.D. Sharp, J.J. Gibson, S.J. Birks, Y. Yi and P.J. Fawcett, 2013. Terrestrial water fluxes dominated by transpiration. Nature, pp: 496.
80. Zhang, Y.H., Q. Zhang, X.X. Xu, J.P. Li and B. Wang, 2016. Optimal irrigation frequency and nitrogen application rate improving yield formation and water utilization in winter wheat under micro-sprinking condition. Transactions of the CSAE., 32: 88-95.