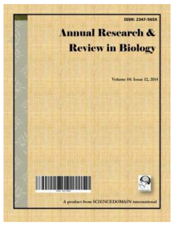

Annual Research & Review in Biology

18(3): 1-11, 2017; Article no.ARRB.36395
ISSN: 2347-565X, NLM ID: 101632869

Effect of Foliar Application of Biosimulated Nanomaterials (Calcium/Yeast Nanocomposite) on Yield and Fruit Quality of 'Ewais' Mango Trees

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Authors' contributions

This work was carried out in collaboration between all authors. Author EAER designed the study, managed the literature searches, applied the field works, collected samples with its physical measurements, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author OAA designed the part of yeast study, conducted the field works in the experimenal design, collected the field samples, prepared the samples for analysis and managed the analyses of the study. Author AMEN was responsible of nanomaterials preparation using the chemically modified nano-materials (CMNM) with sol-gels, provided the nanotechnology literature searches and supplied the Transmission Electron Microscope (TEM) images of the nanoparticles. Author NAH consulted the study design, statistical analysis, literature searches, protocol, treatments and analyses of this study. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARRB/2017/36395
Editor(s):
(1) George Perry, Dean and Professor of Biology, University of Texas at San Antonio, USA.
Reviewers:
(1) Raúl Leonel Grijalva Contreras, Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias, México.
(2) Adalberto Di Benedetto, Buenos Aires University, Argentina.
Complete Peer review History: http://www.sciencedomain.org/review-history/21404

Original Research Article

Received 27th August 2017
Accepted 4th October 2017
Published 14th October 2017

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ABSTRACT

Poor fruit set in mango is consider the main problem that reduces the production. This study aims to raise fruit set, minimize the percentage of fruit drop, increase tree yield and improve fruit quality by providing the trees with biosimulated nano materials (calcium/yeast nanocomposite) as foliar application. Nanotechnology is generally used when referring to materials with the size of 0.1 to 100 nanometres (nm= 10^{-9}). The chemically modified nano-materials (CMNM) such as Sol-gels was used in this study due to their unique stability in a pure form that characterize with strong position in nanotechnology. In this respect, 'Ewais' mango trees were treated with yeast and calcium / yeast nanoparticles as foliar application three times (at full bloom, two weeks after fruit set and one month after the second application). The treatments were as follows: (1) Yeast 1%. (2) Yeast 2%. (3) Yeast 3%. (4) Calcium / yeast nanoparticles 1%. (5) Calcium / yeast nanoparticles 2%. (6) Calcium / yeast nanoparticles 3%. (7) Control (spray water only). Where, the results of 2 on-year seasons were recorded. Results show that foliar application of calcium / yeast nanoparticles 1, 2 and 3% had a positive effect on growth, leaf mineral content, yield and fruit quality of 'Ewais' mango trees comparing with traditional yeast at the same concentration. The foliar application of calcium / yeast nanoparticles 3% three times is the promising treatment for increasing fruit set, reducing fruit drop, raising fruit retention, maximizing the yield and improving fruit physical properties (fruit weight, length, width, peel and pulp weight, and pulp/seed ratio) as well as chemical properties of mango fruits by increasing TSS. All of them achieve the highest marketing value.

Keywords: Foliar application; calcium/yeast nanocomposite; nanotechnology; fruit quality; yield; mango.

1. INTRODUCTION

Mango is one of the important fruit in the tropics and subtropics regions. In Egypt, mango considered the most popular fruit and occupies the third place in acreage after citrus and grapes. The area of mango orchards reached 77003 h. producing about 786528 tons of fruits annually [1]. However, poor fruit set in mango is consider the main problem that reduces the production especially under the new reclaimed soils condition. While, the trees give low yield and fruit quality due to lacking their mineral constituents. As a result, many investigations were done to raise fruit set, minimize the percentage of fruit drop, increase tree yield and improve fruit quality by providing the trees with some simulative materials to reach this goal [2-20].

In this respect, Nanotechnology provides opportunity to develop improved systems for delivering nutrients and thus potentially enhance yields or nutritional values [21]. Whereas, the definition of nanotechnology is based on the prefix “nano” which is from the Greek word meaning “dwarf”. Nanotechnology is generally used when referring to materials with the size of 0.1 to 100 nanometres (nm= 10^{-9}), however, it is also inherent that these materials should display different properties from bulk materials as a result of their size. These differences include physical strength, chemical reactivity, electrical conductance, magnetism, and optical effects [22].

In addition, sol-gels as a nano material are used today in many fields including sensors, coatings, optical, biological and separations due to their numerous advantages over other materials. Moreover, sol-gels can be formed into different forms as fertilizers, films, fibers, powders, and monoliths nanomaterials [23-26].

Also, the processing conditions of sol gels can be manipulated by changing the type and concentration of sol components allows for sol-gels to be used for different treated applications [27-29].

Furthermore, nano-materials have emerged as suitable alternatives to overcome limitations of micro-materials and monolithics, while posing preparation challenges related to the control of elemental composition and stoichiometry in the nanocluster phase [29].

Calcium is a key component of cells, maintaining the structure of cell walls and stabilizing cell membranes. It is also involved in cell wall division and elongation. Optimum fruit Ca concentration promotes fruit firmness, increases disease tolerance and reduces storage related disorders. In contrast, poor calcium nutrition results in a wide range of fruit quality problems, such as lack of firmness, many physiological disorders and susceptibility to pre- and post-harvest fungal decay [30,31].

The objectives of this study is using Ca / yeast nanoparticles to raise the fruit set, minimize the percentage of fruit drop, increase tree yield and improve fruit quality by spraying the trees with this biosimulated nano-materials in different growth stages i.e. full bloom and during fruit development (pea and egg stages). The chemically modified nano-materials (CMNM) such as sol-gels was used in this study due to their unique stability in a pure form that characterize with strong position in nanotechnology [23-29].

2. MATERIALS AND METHODS

'Ewais' is a polyembryonic mango cultivar of major commercial importance (it has a high price compare with the other mango cvs in Egypt). The tree is vigorous, the fruit small (about 275 g in average), yellow with no blush, with small, light-brown slightly corky dots, ovate-oblong in shape (11.7 cm long by 7.2 cm wide by 6.3 cm thick), with adherent skin of intermediate thickness, relatively free of disease; flesh orange, juicy but susceptible to jelly seed, with no objectionable fibre, sweet and agreeable in taste, of very good quality and the stone is large (38.5 g). Fruit ripens midseason during mid-June to August. In warm subtropics this cultivar has shown a tendency for flowering in the warm season, with fruit ripening during the cool winter. It has good anthracnose tolerance.

The experiment was carried out during three seasons from 2014 to 2016 (data of two on-year seasons were recorded in the results) in a private orchard located at El-Adlia agricultural society, Belbis city, El-Sharkia governorate, Egypt (Latitude: N 30° 21' 5.76", Longitude: E 31° 35' 6" and Altitude: 19.30 m). Ten-year-old 'Ewais' mango trees were the materials of this study that grown in sandy soil under drip irrigation system, spaced at 6 X 4 m apart and the selected trees were uniform in vigour and size. All trees received the standard orchard practices (fertilization routine, weeds and pest control, irrigation routine) and the experiment was designed in a complete randomized blocks with three replications (3 trees per plot).

In this research, nanomaterials were prepared according to El-Nahrawy and Ibrahim [26]. Where, low temperature sol-gel method was synthesized for the purpose of creating organic-inorganic nanocomposites material. In this respect, calcium nanoparticles prepared by the sol–gel method and the particle size for the prepared nanocomposites was confirmed by transmission electron microscopy (Fig.1) and mixed with yeast to apply calcium / yeast nanoparticles. The treatments were applied as follows:-

T1= Yeast 1%.
T2= Yeast 2%.
T3= Yeast 3%.
T4= calcium / yeast nanoparticles 1%.
T5= calcium / yeast nanoparticles 2%.
T6= calcium / yeast nanoparticles 3%.
T7= Control (spray water only).

The treatments were applied as foliar application three times, at full bloom, two weeks after fruit set (pea stage) and one month after the second application (egg stage). The foliar spray was prepared by dissolving brewer's yeast (*saccharomyces cerevisiae*) in the water at 1% or 2% or 3% followed by adding sugar at a ratio of 1:1 and kept 24 hours in a warm place for reproduction alone or in combination with calcium nanoparticles with the same concentration (1% or 2% or 3%) according to the methods of Morsi et al. [32]. Triton B at 0.1 % as a wetting agent was added to the procedures and all trees were sprayed until the run off point. The yeast was supplied by The Egyptian Starch, Yeast & Detergents Company in Cairo. Table (1) shows the chemical composition of bread yeast according to Nagodawithana [33].

The following parameters were measured for both seasons:

1) Fruit set/panicle was recorded.
2) Fruit drop % was calculated using the following equation: Fruit drop % = (Fruit set - Fruit retention)/ Fruit set x 100).
3) Fruit retention/panicle was recorded at mature stage (a week before harvest) in both seasons.
4) Tree yield was harvested on mid-June in each season, the number of fruits per tree was counted and tree yield was weighted as Kg/tree.
5) Fruit quality: A sample of 10 fruits of each tree was taken at the harvest time to determine the physical and chemical properties i.e., fruit weight (g), fruit length and circumference (cm) as well as fruit pell and pulp weight (g), seed weight (g), and pulp/seed ratio. The total soluble solids

percentage (T.S.S.%) was measured using a hand refractometer, while acidity % was determined as citric acid content using fresh juice with titration against 0.1 Na OH. Finally, pulp content of vitamin C was estimated according to A.O.A.C [34].

6) Leaf mineral content: Macro nutrients were determined in dry leaf samples which collected from each tree at the second week of July in both seasons. N% was measured by Micro-Kjeldahl according to Pregel [35]. Also, P% was determined as described by Champman and Parker [36], while K% was measured according to Brown and Lilleland [37].

2.1 Statistical Analysis

Data were analyzed by analysis of variance (ANOVA), and means were compared using Duncan's test at $p < 0.05$ to determine the significance of differences between the conducted treatments [38].

3. RESULTS

3.1 Transmission Electron Microscope (TEM) images of the Nanoparticles

In order to verify the formation of calcium nanoparticles and calcium/ yeast nanocomposite, the TEM was performed. Fig. 1(a, b) shows TEM images for the calcium nanoparticles and calcium/ yeast nanocomposite prepared by sol gel process. From Fig. 1(a), it can be seen clearly that the size of these calcium nanoparticles is around 7-11 nm and with nearly spherical shape. These can be contributed to the presence of calcium cluster in short range order due to the low viscosity calcium oxide gel, which improves balance between nucleation and growth stages. By incorporation the calcium oxide through the organic matrix contenting yeast. The TEM image indicates clear regular spherical particles with average diameter ranging from 9 nm to 19 nm embedded in organic matrix as in Fig. 1(b).

3.2 Leaf Area and Mineral Content of NPK

Table (2) shows that leaf area was significantly affected by yeast and nano yeast treatments. In this respect, T4, T5 and T6 recorded higher values comparing with T1, T2, T3 and T7 (the control) in both studied seasons. However, T1, T2 and T3 came in the second order, while, T7 was the lowest value of leaf area during the two seasons of this study.

3.3 Mineral Content of NPK

Concerning the leaf mineral content, Table (2) indicates that N content was significantly enhanced by all treatments especially T6 which had the highest values in the two studied seasons than T7. Furthermore, there was different variation between treatments, while, T5 and T6 took the second and the third place in the two studied years. Meanwhile, T3, T2 and T1 came in the fourth, fifth and sixth order during the two seasons, respectively. While, T7 had the lowest value of leaf N content during this study.

As for P% in the leaves, T6 recorded the highest value of P content followed by T5, while, calcium / yeast nanoparticles 1% came in the third place. However, T1, T2 and T3 occupied fourth, fifth and sixth order before T7 which had the lowest P content. The previous observation was detected in the first and second seasons.

Regarding K content in the leaves, T4, T5 and T6 gave higher values followed by T3 and T2, while, T1 came in the third order in the first season. However, in the second season T6 recorded the highest content of K followed by T5 and T4. While T3 occupied the third place followed by T2 and T1. T7 was the lowest content of K in the leaves during the two seasons.

Finally, from the previous results, it's clear that T6 was the best treatment that had the highest leaf content of NPK than the other treatments and the control.

3.4 Fruit Set, Drop, Retention and Number of Fruits per Tree

Regarding number of fruit set, drop, and retention per panicle as well as number of fruits per tree, it's clear from the results in Table (3) that all treatments significantly increased number of fruit set, retention and fruit per tree comparing with the untreated trees, however, they decreased significantly fruit drop percentage than the control. The obtained results took the same trend in both studied seasons. Concerning number of fruit set and fruit retention per panicle as well as number of fruits per tree, T6 achieved the highest number of them followed by T5, while, T4 occupied the third place followed by T1, T2 and T3 in the next orders, respectively.

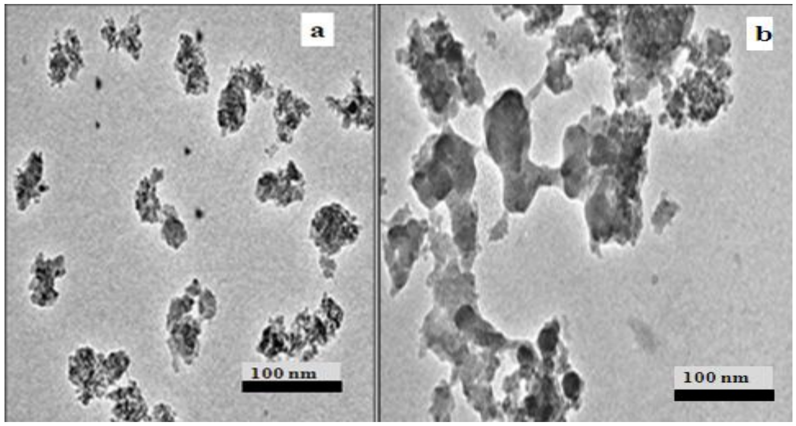

Fig. 1. TEM images for calcium nanoparticles (a) and calcium/yeast nanocomposite (b) prepared by sol gel method

Table 1. Chemical composition of brewer's yeast (Nagodawithana, 1991).

Protein	47%	Nucleic acids	8%
Carbohydrates	33%	Lipids	4%
Minerals	8%		
Approximate composition of vitamins (mg/g):			
Thiamine	6-100	Biotin	1.3
Riboflavin	35-50	Cholin	4000
Niacin	300-500	Folic acid	5-13
Pyridoxine HCl	28	Vit-B12	0.001
Pantothenate	70		
Approximate composition of minerals (mg/g):			
Na	0.12	Cu	8.00
Ca	0.75	Se	0.10
Fe	0.02	Mn	0.02
Mg	1.65	Cr	2.20
K	21.0	Ni	3.00
P	13.5	Va	0.04
S	3.90	Mo	0.40
Zn	0.17	Sn	3.00
Si	0.03	Li	0.17

Table 2. Effect of biosimulated nanomaterials as foliar application on growth (leaf area) and leaf mineral content (NPK) of 'Ewais' mango trees during two studied seasons.

Treatments	Leaf area $(cm)^2$		N (%)		P (%)		K (%)	
	First season	Second season	First season	Second season	First season	Second season	First season	Second Season
T1= Yeast (1%)	40.1 b	42.0 b	1.42 f	1.40 f	0.153 cd	0.176 c	0.83 c	0.88 d
T2= Yeast (2%)	40.7 b	42.8 b	1.45 e	1.43 e	0.156 cd	0.177 c	0.90 b	0.92 cd
T3= Yeast (3%)	43.6 b	45.7 b	1.49 d	1.47 d	0.168 c	0.185 c	0.91 b	0.95 c
T4= Ca/yeast nanoparticles (1%)	51.3 a	54.2 a	1.54 c	1.53 c	0.197 b	0.231 b	1.01 a	1.03 b
T5= Ca/yeast nanoparticles (2%)	55.4 a	57.5 a	1.58 b	1.57 b	0.223 ab	0.250 ab	1.03 a	1.07 ab
T6= Ca/yeast nanoparticles (3%)	59.2 a	61.5 a	1.62 a	1.60 a	0.234 a	0.267 a	1.06 a	1.10 a
T7= Control	30.1 c	32.6 c	1.30 g	1.28 g	0.130 d	0.142 d	0.71 d	0.75 e

Means within a column followed by different letter (s) are statistically different at 5 % level.

As for fruit drop percentage, T6 recorded the lowest percentage then came T5, whilst, T4 came in the third order followed by T1, T2 and T3. Therefore, T6 gave the best results for fruit yield production as fruit numbers.

3.5 Yield and Fruit Physical Properties

Results in Table (4) show that yield and fruit physical properties were affected significantly by all yeast treatments. Concerning yield (kg per tree), T6 and T5 recorded the maximum significant yield in compare with all other treatments including the control (T7) which had the lowest yield. T6 recorded 78.5 and 75.8 kg in the first and second seasons, respectively and T5 gave 71.3 and 72.2 kg in both seasons, respectively followed by T4 which recorded 65.6 and 58.7 kg in the two seasons, respectively. On the other side, T3 and T2 achieved the third and forth orders since T3 had 53.4 and 49.9 kg, while, T2 had 49.2 and 45.8 kg (in the first and second seasons, respectively). There was no significance between T1 and T7 that recorded the lowest yield (T1 recorded 44.1 and 39.6 kg and T7 reached 33.2 and 31.6 kg in the both studied seasons).

Regarding fruit physical properties, results in Table (4) reveal that fruit weight, fruit length and fruit width were significantly affected by all treatments especially T6 and T5 which gave the highest values for all the above mentioned parameters. While all treatments significantly increased these parameters than the control (T7).

Results in Table (5) present that peel weight, pulp weight, seed weight and pulp/seed ratio were affected by yeast treatments. Concerning peel weight, it was increased significantly by T6 and T4, since T6 gave 44.5 and 48.3 g as well as T4 recorded 39.3 and 36.1 g comparing with T7 which had the lightest pell weight (22.0 and 24.0 g) during the two studied seasons, respectively. As for pulp weight, all treatments except T1 achieved an increment (pulp weight ranged from 186.8 to 220.2 g in the first year and from 177.9 to 232.1 g in the second year). T1 and T7 which had the same significant value (T1 had 160.6 and 149.1 g as well as T7 had 138.8 and 131.0 g) during the two seasons, respectively. Concerning seed weight, results reveal that T6 increased seed weight and reached the maximize value (41.8 and 47.4 g) than T7 (19.8 and 25.5 g) in the first and second seasons, respectively. Regarding pulp/seed ratio, no significant differences were detected among all treatments during the two studied seasons.

3.6 Chemical Properties

Results in Table (6) indicat that TSS% was significantly increased by T1, T4 and T6 than T7 in both studied seasons, since they gave the highest TSS content (25.3, 25.4 and 25.7 % in the first season and 25.2, 25.1 and 24.9 % in second one, respectively) in compare with T7 (21.1 and 19.9% in both seasons, respectively). As for acidity percentage, TSS/acid ratio and vitamin C (ascorbic acid), no significant differences were detected among all treatments including the control.

Table 3. Effect of biosimulated nanomaterials as foliar application on fruit set, fruit drop, retention and No. fruit /tree of 'Ewais' mango trees during two studied seasons

Treatments	No. fruit set/ panicle		Fruit drop (%)		Fruit retention/ panicle		No. of fruits/tree	
	First season	Second season	First season	Second season	First season	Second season	First season	Second Season
T1= Yeast (1%)	13.5 d	12.4 d	26.8 b	26.4 b	9.9 d	9.1 d	206 c	190 b
T2= Yeast (2%)	14.5 cd	14.2 cd	25.9 b	25.5 b	10.7 cd	10.6 cd	209 c	197 b
T3= Yeast (3%)	16.1 c	15.5 c	24.5 b	25.6 b	12.1 c	11.5 c	212 c	204 b
T4= Ca/yeast nanoparticles (1%)	19.1 b	18.6 b	21.7 c	22.0 c	15.0 b	14.5 b	243 b	230 a
T5= Ca/yeast nanoparticles (2%)	20.5 b	19.5 ab	19.4 cd	20.2 cd	16.5 b	15.6 ab	260 ab	245 a
T6= Ca/yeast nanoparticles (3%)	22.4 a	21.1 a	19.1 d	19.4 d	18.2 a	17.0 a	274 a	252 a
T7= Control	10.2 e	9.9 e	30.9 a	29.0 a	7.0 e	6.8 e	184 c	178 b

Means within a column followed by different letter (s) are statistically different at 5 % level.

Table 4. Effect of biosimulated nanomaterials as foliar application on yield and some fruit physical properties of 'Ewais' mango trees during two studied seasons.

Treatments	Yield (kg/tree)		Fruit weight (gm)		Fruit length (cm)		Fruit width (cm)	
	First Season	Second season	First Season	Second Season	First Season	Second Season	First Season	Second Season
T1= Yeast (1%)	44.1 de	39.6 cd	215.4 d	209.4 c	10.8 a	9.4 bc	7.0 a	7.5 a
T2= Yeast (2%)	49.2 d	45.8 c	234.0 cd	232.6 bc	10.7 a	10.7 ab	7.0 a	7.6 a
T3= Yeast (3%)	53.4 cd	49.9 cb	252.7 bc	245.4 b	11.6 a	11.6 a	6.8 a	7.7 a
T4= Ca/yeast nanoparticles (1%)	65.6 bc	58.7 b	268.5 ab	254.5 b	11.2 a	11.2 a	7.3 a	8.2 a
T5= Ca/yeast nanoparticles (2%)	71.3 ab	72.2 a	273.9 ab	294.9 a	10.3 a	10.3 ab	6.9 a	7.5 a
T6= Ca/yeast nanoparticles (3%)	78.5 a	75.8 a	286.6 a	301.5 a	11.4 a	11.4 a	7.3 a	7.6 a
T7= Control	33.2 e	31.6 d	180.7 e	177.3 d	8.6 b	8.6 c	5.6 b	5.8 b

Means within a column followed by different letter (s) are statistically different at 5 % level

Table 5. Effect of biosimulated nanomaterials as foliar application on fruit physical properties of 'Ewais' mango trees during two studied seasons

Treatments	Pell weight (g)		Pulp weight (g)		Seed weight (g)		Pulp/seed ratio	
	First season	Second season	First season	Second season	First season	Second Season	First season	Second Season
T1= Yeast (1%)	30.3 abc	31.1 bc	160.6 bc	149.1 cd	24.5 b	29.3 bc	6.7 b	5.3 b
T2= Yeast (2%)	24.1 bc	26.5 bc	186.8 ab	177.9 bc	23.1 b	28.4 bc	8.0 ab	6.3 ab
T3= Yeast (3%)	30.0 abc	33.8 bc	192.2 ab	182.0 bc	30.5 ab	30.0 bc	6.3 b	6.3 ab
T4= Ca/yeast nanoparticles (1%)	39.3 ab	36.1 b	198.7 ab	186.2 bc	30.2 ab	32.2 bc	6.5 b	5.8 ab
T5= Ca/yeast nanoparticles (2%)	30.8 abc	32.8 bc	220.2 a	232.1 a	22.9 b	33.3 b	10.5 a	7.8 a
T6= Ca/yeast nanoparticles (3%)	44.5 a	48.3 a	200.4 ab	205.7 ab	41.8 a	47.4 a	5.8 b	4.4 b
T7= Control	22.0 c	24.0 c	138.8 c	131.0 d	19..8 b	25.5 c	7.0 ab	5.9 ab

Means within a column followed by different letter (s) are statistically different at 5 % level.

Table 6. Effect of biosimulated nanomaterials as foliar application on fruit chemical properties of 'Ewais' mango trees during two studied seasons.

Treatments	T.S.S (%)		Acidity (%)		T.S.S/acid ratio		Ascorbic acid (mg/ 100 ml juice)	
	First season	Second season	First season	Second season	First Season	Second Season	First season	Second Season
T1= Yeast (1%)	25.3.a	25.2 a	0.221 a	0.231 a	114.48 a	109.09 a	93.3 a	73.3 a
T2= Yeast (2%)	23.4 ab	22.9 ab	0.242 a	0.305 a	96.69 a	75.08 a	70.0 a	50.0 a
T3= Yeast (3%)	23.1 ab	23.2 ab	0.200 a	0.284 a	115.50 a	81.69 a	120.0 a	80.0 a
T4= Ca/yeast nanoparticles (1%)	25.4 a	25.1 a	0.189 a	0.294 a	134.39 a	85.37 a	116.7 a	100.0 a
T5= Ca/yeast nanoparticles (2%)	23.4 ab	22.8 ab	0.210 a	0.368 a	111.43 a	61.96 a	110.0 a	90.0 a
T6= Ca/yeast nanoparticles (3%)	25.7 a	24.9 a	0.305 a	0.263 a	84.26 a	94.67 a	103.3 a	63.3 a
T7= Control	21.1.b	19.9 b	0.284 a	0.293 a	74.30 a	67.91 a	90.0 a	40.0 a

Means within a column followed by different letter (s) are statistically different at 5 % level

4. DISCUSSION

From the above results, it's clear that growth (leaf area) and leaf mineral content of NPK were improved by calcium / yeast nanoparticles treatments (1, 2, 3%) with clear status compare with the other treatments. Leaf content of NPK were raised by increasing calcium / yeast nanoparticles concentration in foliar application. In this respect, calcium / yeast nanoparticles 3% recorded highest value of NPK between all treatments. However, yeast treatments without nano calcium (yeast 1, 2, 3%) came in the following orders for improving these parameters (growth as leaf area and nutrient status as NPK Leaf content). This can be attributed to the role of nanocomposite in improving the systems of delivering nutrients and raising the nutritional status that reflected on increasing yield and fruit quality as shown from the results. This explain is parallel with Zenu et al. [21], since they mentiond that nanotechnology provides opportunity to develop improved systems for delivering nutrients and thus potentially enhance yields or nutritional values.

Furtheremore, These results are in harmony with those of Ali [4] on 'Ewais' and Sedik mango, Abd-Elmotty and Fawzy [2] on Zebda and Langra mango as well as Abd-Elmotty *et al.* [3] on Keitte mango, Gharge et al. [5] on Alphonso mango, Darwesh [39] on Mejdol date palm, Stino et al. [40] on apricot young trees, Shaaban et al. [41] on Canino apricot, Kassem et al. [42] on Costata persimmon, Hikal et al. on navel orange [43] and Qin on Jincheng orange (*citrus sinensis*) [44], who applied mineral or bio-organic fertilizers mixed with yeast and found a useful impact on improving growth and leaf mineral content.

The improving in growth (Leaf area) and mineral nutrient statue can be attributed also to the increase efficiency of absorbation of calcium/yeast nanocomposite through the foliar application due to its size which was less than 100 nm (nm= 10^{-9}) as shown by Transmission Electron Microscope (TEM) images (Fig. 1), This explication is in agreement with Joseph and Morrison [22], since, they reported that nanotechnology is generally used when referring to materials with the size of 0.1 to 100 nanometres (nm= 10^{-9}), however, it is also inherent that these materials should display different properties from bulk materials as a result of their size. These differences include physical strength, chemical reactivity, electrical conductance, magnetism, and optical effects.

It's evident from the results that calcium / yeast nanoparticles (1, 2, 3%) had the highest no. of fruit set per panicle and fruit retention as a result to decreasing fruit drop percentage comparing with the other treatments. This explains the significant differences among treatments concerning the yield as number of fruits per tree and yield weight (kg / tree). In addtion, the yield was affected also with fruit weight, where the treatment of yeast 3% produced yield with the same significance of calcium / yeast nanoparticles 1% in both seasons as a result to improve fruit weight. Whereas, calcium / yeast nanoparticles 3% maximuized yield during the two seasons because it had a positive impact on increasing no. of fruits per tree as well as fruit weight and decreased also fruit drop percentage. Furthermore, the increase in fruit set and retention per panicle as well as the reduction in fruit drop percentage could be attributed to the efficient impact of calcium on preventing abscission layer formation [19,30,31,43]. This could be explain the former results.

Moreover, calcium / yeast nanoparticles treatments (1, 2, 3%) improved fruit physical properties (fruit weight, length, width, peel and pulp weight, seed weight and pulp/seed ratio) and chemical properties of fruit by increasing TSS especially at high concentration (calcium / yeast nanoparticles 3%) due to the role of Ca that promotes the earliness of fruit development, since calcium is a key component of cells, maintaining the structure of cell walls and stabilizing cell membranes. It is also involved in cell wall division and elongation. Optimum fruit Ca concentration promotes fruit firmness, increases disease tolerance and reduces storage related disorders. In contrast, poor calcium nutrition results in a wide range of fruit quality problems, such as lack of firmness, many physiological disorders and susceptibility to pre- and post-harvest fungal decay [19,30,31,43].

The previous results that reported by many researchers confirmed that spraying mango trees with some macro & micro elements and antioxidants alone or combined with yeast increased fruit set, fruit retention, reduced fruit drop, also maximized the productivity and improved the fruit quality [2-20]. The same findings were found on the other fruit trees [39-45].

In general, the increase in fruit set and fruit retention, decreasing fruit drop, as well as the increment of yield and improving fruit quality may be due to the positive effect of calcium / yeast nanoparticles treatments on improving growth and enhancing the nutritional status of trees (especially at high concentration (ca / yeast nanoparticles 3%). In this respect, calcium / yeast nanoparticles have positive action on biosynthesis of IAA and activation the enzymes, the biosynthesis of chlorophlls and carbohydrates [18,45]. Calcium is also used in activating certain enzymes and to send signals that coordinate certain cellular activities [19,30, 31,43].

Using Calcium/ yeast nanoparticles as nanotechnology in the foliar application provides opportunity to develop improved systems for delivering nutrients and thus potentially enhance nutritional values [4] that increase the yields and improve also the fruit quality of 'Ewais' mango trees.

5. CONCLUSION

Foliar application of calcium / yeast nanoparticles had a positive effect on growth, leaf mineral content, yield and fruit quality of 'Ewais' mango trees. The foliar application of calcium / yeast nanoparticles 3% three times: at full bloom, two weeks after fruit set and one month after the second application is the promising treatment for increasing fruit set, reducing fruit drop, raising fruit retention, maximizing the yield and improving fruit physical properties (fruit weight, length, width, peel and pulp weight, seed weight and pulp/seed ratio) as well as chemical properties of mango fruits by increasing TSS. All of them achieve the highest marketing value of 'Ewais' mango trees.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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