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Effect of foliar spray of ammonium nitrate and irrigation time on vegetative growth, fruit set, yield and fruit quality of “Ewais” mango trees

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Abstract

Background: The current experiment was done during the 2018 and 2019 seasons on ‘Ewais’ mango trees (*Mangifera indica*) grown in Research Station, El-Nubaria district, Egypt, to study the impact of spraying ammonium nitrate (NH_4NO_3) and irrigation time on vegetative growth, yield and fruit quality. All experimental plants have been received the same care, i.e. control of pests & weeds, fertilization, and irrigation until the 1st week of October. The irrigation was adapted to apply $5\text{m}^3/\text{feddan}$ (4200m^2)/week to control leaves damage due to low temperature after this period and the treatments included: (T1) Water spraying at 1st week of November + start normal irrigation program at the same time after four weeks of adapted irrigation as $5\text{m}^3/\text{feddan}$ (4200m^2)/week (Control). (T2) Spraying with NH_4NO_3 2% at 1st week of November + start normal irrigation program at the same time after four weeks of adapted irrigation as $5\text{m}^3/\text{feddan}$ /week. (T3) Spraying NH_4NO_3 2% at 1st week of November + start normal irrigation program at 1st week of December after eight weeks of adapted irrigation as $5\text{m}^3/\text{feddan}$ /week. (T4) Spraying NH_4NO_3 2% at 1st week of November + start normal irrigation program at 1st week of January after twelve weeks of adapted irrigation as $5\text{m}^3/\text{feddan}$ /week. All treatments received the same quantity of irrigation water, approximately $4000\text{m}^3/\text{feddan}/\text{year}$.

Results: All treatments (T2, T3 & T4) had a significant influence on vegetative growth, fruiting behavior (fruit set % & the yield), and the fruit quality compared with the control (T1). The significant was not only the fruit physical characteristics (weight, dimensions, volume, and specific gravity) but also the fruit chemical characteristics (total soluble solids % (T.S.S.), acidity %, T.S.S / acid ratio and vitamin C (L- ascorbic acid)).

Conclusion: Spraying NH_4NO_3 2% at 1st week of November plus start normal irrigation program at 1st week of November or December or January after 4 or 8 or 12 weeks of adapted irrigation as $5\text{m}^3/\text{feddan}$ (4200m^2)/week (T2, T3, and T4) increased the vegetative growth, i.e. length of terminal shoots, No. leaves / terminal shoots & leaf area as well as the fruiting behavior such as fruit set percentage, No. fruits per tree & the tree production (kg/tree) and improved the fruit characteristics not only the fruit physical parameters but also the chemical properties in comparing with the untreated trees. During the two seasons, spraying NH_4NO_3 2% at 1st week of November plus start normal irrigation program at 1st week of January after 12 weeks of adapted irrigation as $5\text{m}^3/\text{feddan}/\text{week}$ (T4) is recommended since; it is the only treatment with the superiority effect on studied parameters.

Keywords: Mango, Foliar spray, Irrigation, Fruit set, Yield, Fruit quality

Background

Mangoes are considered as one of the most important fruits in the tropics and subtropical regions. Its production occupies the third order in fruit production of Egypt after citrus and grapes, where the production area reached to 135,524 ha. with about 1,473,538 tons of fruits

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annually (FOSTAT 2019). In the tropics and subtropics, it is known that the flowering period of mango trees is affected by environmental conditions. The environmental signals for flowering are a limiting factor to get constant mangoes production (Sukhvibul et al. 1999). In addition, blooming delay for mango trees is very necessary to enhance the flowering in the optimum status which reflected on the better fruit set, fruit drop reduction, and higher yield (Singh et al. 2005). However, spraying ammonium nitrate could be more effective in promoting the flowering of mangos, but the harvest date may not be advanced significantly (Nunez-Elisea 1987). Moreover, spraying ammonium nitrate is considered the agricultural application conducted in the tropical and subtropical regions to enhance the flowering induction and obtain fruits out-of-season for some varieties, *i.e.* Tommy Atkins, to reach better sale prices (Morales-Martinez et al. 2020).

The foliar spray of ammonium nitrate (NH_4NO_3) has given excellent results as promoter of flowering in a wide range of mango cultivars (Salazar-Garcia et al. 2000). Foliar spray of NH_4NO_3 has been more effective when applied shortly before the normal start of the flowering period, although the response to these treatments has been strongly influenced by the dosage, cultivar and distance from the equator (Salazar-Garcia et al. 2000). Singh (2002) reported that mango leaf absorbs most nutrients 24–72 h after spraying. Afterwards, the leaves nutrient content depletion is occurred due to NPK translocating to the actively growing tissues through the plant system.

Many researchers studied spray application impact of different nitrogenous sources on behavior of flowering and fruiting as well as the productivity of some mangoes cultivar, and they found that spray ammonium nitrate NH_4NO_3 (1% or 2%) enhanced early flowering in 'Manila', 'Ataulfo' and 'Tommy Atkins' (Salazar-Garcia et al. 2000) as well as cv. Alphonso (Sudha et al. 2012).

However, the effect of the soil water deficit on flowering response is still a matter of controversy. Water deficits can be considered an inducer for flowering of mango for some countries like Egypt. Therefore, Spreer et al. (2009) mentioned that the strategic management of irrigation depends on the control of water deficit used experimentally, since it causes some troubles when it lacks of the control like the reduction of differentiation for vegetative buds of the inflorescence as well as physiology turbulences due to the water deficit. Also, Spreer et al. (2009) stated that "the proper management of water deficit could improve the efficiency of irrigation and increase the productivity with no passive long-range influences".

The mechanism of mango floral induction remains elusive under the tropics and subtropics environments conditions (Davenport and Nunez-Elisea 1997a). In this

respect, most of the mango trees flower only when their leaves are fully mature and it has been noticed that the floral stimulus originates from mature leaves in mango while, young leaves inhibit the floral initiation of buds (Kulkarni 1988). The water deficit limits the vegetative growth, increases the rate of mature inductive leaves, and makes the trees more receptive to the marginal induction temperatures in the warm subtropics (Nunez-Elisea and Davenport 1994). Moreover, the flowering response was related the intensity of the soil water deficit before flowering. Under the warm weather and non-limiting soil water conditions, the trees maintained high vegetative growth, while water stress adjusts the growth such as branch diameter and predisposes the tree to floral stimulus (Lu and Chacko 2000). In this regard, water deficit for mango trees at 0% or 25% ET_c in the stage of flowering, as well as regular irrigation at 100% ET_c in the fruiting phase, are considered important tools to increase the induction of inflorescence (Faria et al. 2016).

Hence, this investigation is considered an attempt to improve flowering, fruit set and fruit retention, as well as yield and fruit quality of mango trees using foliar spray of NH_4NO_3 , combined with the start time of irrigation after different water periods as the irrigation management strategies.

Methods

Tree materials

Our experiment was conducted in the 2018 & 2019 seasons on 'Ewais' mango trees grown in the Research Station of National Research Centre (NRC) located at latitude 30.8667 N & longitude 30.1667 E in El Nubaria district, Km 107 Cairo-Alex Desert Road, Egypt. The trees were 13 years old budded on Sukkary rootstocks, and the experimental trees were similar in vigor, size & shape, planted at 5 X 3 m apart, grown in sandy soil under a drip irrigation system. The experimental trees were received the same horticultural serving. The design of our experiment was complete randomized block with three replicates, where 3 plants were included for each plot. Tables 1 and 2 presented the analysis for soil in both physical & chemical properties. Table 3 illustrates the analysis of the chemical properties of water used in irrigation.

Soil properties and irrigation water analyses

Representative soil samples have been presented for 0–15, 15–30, 30–45, and 45–60 cm depths. The Nile is the source of irrigation water that goes throughout the channel to the experimental area. Soil physical and chemical properties and also chemical properties of the irrigation water were as follows:

Table 1 The physical properties of the soil during the two years*

Depth (cm)	Particle size distribution (%)					Soil physical parameters (% on weight basis)				
	C. sand	F. sand	Silt	Clay	Texture class	FC (%)	PWP (%)	AW (%)	BD (g/cm) ³	TP (%)
0–15	14.87	78.90	4.40	1.83	Sand	10.50	4.16	6.34	1.58	40.38
15–30	14.91	78.93	4.30	1.86	Sand	10.40	4.10	6.30	1.60	39.62
30–45	14.89	78.73	4.41	1.97	Sand	10.46	4.13	6.33	1.64	38.11
45–60	14.96	78.66	4.39	1.99	Sand	10.45	4.20	6.25	1.66	37.36

* There were no significant differences between the two years, the data presented the mean of the two years, and the soil samples were taken at the 1st week of October each year before treatments

Table 2 The chemical properties of the soil during the two years*

Depth, (cm)	pH 1:2.5	EC, dS/m	Soluble cations (mg/L)				Soluble anions (mg/L)			
			Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	CO ₃ ⁻	HCO ₃ ⁻	SO ₄ ⁻	Cl ⁻
0–15	8.30	0.35	0.50	0.42	1.05	0.23	0.00	0.11	0.82	1.27
15–30	8.20	0.36	0.51	0.43	1.04	0.24	0.00	0.13	0.86	1.23
30–45	8.30	0.34	0.55	0.41	1.05	0.23	0.00	0.12	0.85	1.27
45–60	8.40	0.73	0.57	0.43	1.06	0.25	0.00	0.17	0.86	1.28

* There were no significant differences between the two years, the data presented the mean of the two years, and the soil samples were taken at the 1st week of October each year before treatments

Table 3 The chemical properties of irrigation water during the two years*

pH	**EC (dS/m)	Soluble cations (mg/L)				Soluble anions (mg/L)				***SAR
		Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	CO ₃ ⁻	HCO ₃ ⁻	SO ₄ ⁻	Cl ⁻	
7.20	0.36	0.75	0.23	2.50	0.11	0.00	0.90	0.33	2.52	3.67

* There were no significant differences between the two years, the data presented the mean of the two years, and the water samples were taken at the 1st week of October each year before treatments

** EC Electrical conductive; ***SAR Sodium absorption ratio

Soil physical properties

Soil particle volume distribution was conducted according to Gee and Bauder (1986) that known as Pipette's Method. Also, according to Gardener (1986) method, the content of moisture in the soil in booth FC (field capacity) & PWP (permanent wilting point) were determined. The results of these analyses are presented in Table 1.

Soil chemical properties

Soil chemical properties were measured in the laboratory of Soil Dept. NRC as follows: Soil pH and EC were measured in 1:2.5 (soil: water suspension) and in soil paste extract, respectively. Results of these analyses are shown in Table 2.

Chemical properties of irrigation water

Chemical analysis of irrigation water was measured using the standard methods and shown in Table 3. All the measured chemical parameters describe the status of the irrigation water, and it can be used normally in irrigation. Data indicate that irrigation water was classified as no problem water according to FAO (1994).

Treatments

All experimental trees received the same farm serving such as the control of pests & weeds, the fertilization, the irrigation until the 1st week of October where, the irrigation was adapted to apply 5m³/feddan (4200 m²)/week to control leaves damage due to low temperature in this period and the treatments included:

- **(T1)** Water spraying at 1st week of November + start normal irrigation program at the same time after four weeks of adapted irrigation as 5m³/feddan /week (Control).
- **(T2)** Spraying with NH₄NO₃ 2% at 1st week of November + start normal irrigation program at the same time after four weeks of adapted irrigation as 5m³/feddan/week.
- **(T3)** Spraying NH₄NO₃ 2% at 1st week of November + start normal irrigation program at 1st week of December after eight weeks of adapted irrigation as 5m³/feddan/week.
- **(T4)** Spraying NH₄NO₃ 2% at 1st week of November + start normal irrigation program at 1st week of January after twelve weeks of adapted irrigation as 5 m³/feddan/week.

The spray materials included Triton B at 0.1%, which was used as an instrument for wetting, and the spraying was done until the run-off point. In addition, all treatments received the same quantity of irrigation water, approximately 4000 m³/feddan/year.

Fruiting and yield parameters

On each tree. 10 terminal shoots were tagged aspects (North, South, East, and west) at the beginning of flowering for determining the following parameters:

- **fruit set:** was determined as the number of setting fruits per panicle two weeks after petal fall for panicles on tagged shoots.
- **Fruit retention %:** was determined by counting the number of retained fruits per panicle at harvest (1st week of August).
- **Fruit drop %:** was determined at harvest by the following equation: (fruit set – fruit retention) / fruit set * 100.
- **No. fruits/tree:** was counted in maturity stage in the 1st week of August, when mango has green skin and is fully developed, firmness, wide shoulders at the stem end and a lack of blemishes or wounds.
- **Yield (kg) per tree:** was estimated by multiplying the number of fruits per tree X the average of fruit weight.

Fruit measurements

At the harvest time, ten fruits from each replicate as sample was presented to determine the physical & chemical fruit characteristics like weight (g), volume (cm³), dimensions: width & length (cm), specific gravity (g/cm³), according to Abd El-Razek et al. (2013). A hand refractometer was used to measure T.S.S.% (Total Soluble

Solids), while the acidity percentage in the samples as citric acid content was estimated using the titration of fresh juice against 0.1 Na OH (A.O.A.C 1990). Vitamin C (L-ascorbic acid) in pulp was determined as milligrams of ascorbic acid per 100 g Juice with using 2,6-dichloro phenol indophenol (A.O.A.C 1990).

The statistics: analysis of variance (ANOVA) was used for all data, and Duncan's test made the comparison between means at $p < 0.05$. According to Duncan (1955), the significance of differences among the treatments mean were recorded.

Results

Data in Table 4 show the influence of foliar spray of ammonium nitrate combined the date of start water irrigation on vegetative growth and panicle characteristics of mango trees cv. 'Ewais' during two years. The results showed that all treatments improved the vegetative growth (length of the terminal shoot, number of leaves per terminal shoot & leaf area) and panicle characteristics (panicle length and width & number of secondary branches per panicle) compared with the control. Concerning the length of terminal shoot, T4 recorded the tallest terminal shoot (16.7 and 18.1 cm) followed by T3 (15.4 & 16.3 cm), T2 (14.3 & 15.4 cm), and the control (13.3 & 13.4 cm) in decreasing order in the 1st & 2nd season, respectively. Regarding No. leaves per terminal shoot, T4 achieved the highest average in both seasons (20.9 & 21.3) followed by T3 (19.2 & 19.1), then T2 came in the third-order (17.8 & 18.2); however, the control had the lowest number (16.6 & 15.8). As for leave area, T4 had the highest values the two seasons (66.8 & 67.6 cm²), then T3 took second place (61.5 & 60.3 cm²), and T2 came in the third-order (57.1 & 59.0 cm²), while the control occupied the last order (53.1 & 50.0 cm²).

Concerning the length of the panicle as shown in Table 4, T4 achieved the tallest panicle during the two years of this study (23.9 & 25.7 cm), followed by T3 (20.8 & 22.2 cm), T2 (18.7 & 19.1 cm) and the control (15.2 & 15.6 cm) in a decreasing order for booth 1st & 2nd years, respectively. Nevertheless, a similar trend has been noticed regarding the panicle width, where T4 had the widest values (17.6 & 19.7 cm), T3 (14.3 & 16.8 cm), T2 (12.2 & 14.0 cm), while the control had the narrowest ones (9.8 & 10.3 cm). Regarding the number of secondary branches per panicle, T4 was recorded (31.7 & 33.8), followed by T3 (28.4 & 30.7), T2 (24.2 & 27.1), and the control (18.1 & 20.0) in descending order in both years, respectively. In general, all applications enhanced the vegetative growth, including the panicle characteristics compared with the control in both seasons of this study.

Table 5 shows the impact of foliar spray of ammonium nitrate combined with the date of start water irrigation

Table 4 Influence of foliar spray of ammonium nitrate combined with the date of start water irrigation on vegetative growth and panicle characteristics of mango trees cv. 'Ewais' during two years

Treatments	Length of terminal shoot (cm)		No. leaves per terminal shoot		Leaf area (cm ²)		Panicle length (cm)		Panicle width (cm)		No. secondary branches per panicle	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T1 = Untreat. trees	13.3 d	13.4 c	16.6 d	15.8 c	53.1 d	50.0 c	15.2 c	15.6 d	09.8 c	10.3 d	18.1 d	20.0 d
T2 = 1st week Nov	14.3 c	15.4 b	17.8 c	18.2 b	57.1 c	59.0 b	18.7 b	19.1 c	12.2 b	14.0 c	24.2 c	27.1 c
T3 = 1st week Dec	15.4 b	16.3 b	19.2 b	19.1 b	61.5 b	60.3 b	20.8 b	22.2 b	14.3 b	16.8 b	28.4 b	30.7 b
T4 = 1st week Jan	16.7 a	18.1 a	20.9 a	21.3 a	66.8 a	67.6 a	23.9 a	25.7 a	17.6 a	19.7 a	31.7 a	33.8 a

Means in a column have the same letter (s) are not statistically different at level of 5%

Table 5 Influence of foliar spray of ammonium nitrate combined with the date of start water irrigation on fruiting behavior of mango trees cv. 'Ewais' during two years

Treatment	Fruit set (%)		Fruit drop (%)		Fruit retention (%)	
	First year	Second year	First year	Second year	First year	Second year
T1 = Untreat. trees	2.04 b	2.00 b	89.71 a	81.50 a	0.21 b	0.37 c
T2 = 1st week Nov	4.13 a	4.07 a	91.53 a	82.80 a	0.35 a	0.64 b
T3 = 1st week Dec	4.33 a	3.80 a	91.45 a	83.95 a	0.37 a	0.61 b
T4 = 1st week Jan	4.60 a	4.47 a	90.87 a	80.31 a	0.42 a	0.88 a

Means in a column have the same letter (s) are not statistically different at level of 5%

on fruiting behavior (fruit set %, fruit drop %, and fruit retention %) of mango trees cv. 'Ewais' during two years. It is clear from Table 5 that all applications (T2, T3 & T4) increased the fruit set (%) than the untreated one (T1) in the two studied seasons. T2, T3 & T4 had similar effects of increasing the fruit set % with no significant differences between them (4.13, 4.33 & 4.60% and 4.07, 3.80, 4.47% in the 1st year & the 2nd year, respectively) compared with the untreated once (T1) which recorded the minimum percentage in fruit set, where it recorded 2.04 and 2.00%. As for fruit retention (%), results clear that T2, T3 & T4 followed the same trend as mentioned in the above-mentioned results of fruit set % in the first season, where, the values recorded 0.35, 0.37 & 0.42%, respectively) compared with the control, which recorded 0.21%. However, in the second season, T4 maximized the fruit retention percentage up to 0.88%, followed by T2 & T3, which recorded 0.61 & 0.64% in decreasing order, respectively, while the control showed the lowest percentage (0.37%). Regarding the fruit drop (%), all treatments had no effect.

Table 6 illustrates the influence of foliar spray of ammonium nitrate combined the date of start water irrigation on the number of fruit per tree, fruit weight, volume and specific gravity of 'mango trees cv. 'Ewais' during two years. The results in Table 6 show that (T4) had the highest number of fruits per tree in both seasons (130 & 180), followed by T1 & T2 (83 and 98 in the 1st season & 118

and 130 in the 2nd season, respectively) compared with the control (T1), which gave the minimum number (36 and 55).

Regarding the fruit weight, T2, T3, and T4 had a similar effect on enhancing the fruit weight (265, 286, and 290 g in 1st season, and 296, 303 and 314 g in 2nd season, respectively) compared with the control during the two years (235 and 240 g). Concerning the yield, T4 achieved the highest yield during the two studied seasons (37.7 and 56.5 kg per tree), followed by T2 & T3 (22.0 & 28.0 kg per tree for the first season and 35.0 and 39.4 for the second season, respectively); however, the untreated trees (T1) had the lowest yield (08.3 and 13.2 kg/tree).

Table 7 represents the impact of foliar spray of ammonium nitrate combined with the date of start water irrigation on physical characteristics for the fruit of 'mango trees cv. 'Ewais' during two years. It is clarifying from Table 7 that T2, T3 & T4 produced the largest fruit in length, width, volume and specific gravity and gave high values of fruit shape index than the control during the two years of this investigation. Both fruit length and fruit width followed the same trend, where T4 recorded the highest values than all other treatments included the control.

Regarding the fruit shape index, all treatments (T2, T3, and T4) gave a fruit shape index (1.50 ± 5) that is acceptable and preferred by the customers than the control, which gave narrower fruits (1.77, and 1.65) during the

Table 6 Influence of foliar spray of ammonium nitrate combined with the date of start water irrigation on number of fruit per tree, fruit weight, volume and specific gravity of 'mango trees cv. 'Ewais' during two years

Treat	No of fruit/plant		Fruit weight (g)		Yield (kg)	
	First year	Second year	First year	Second year	First year	Second year
T1 = Untreat. trees	36 c	55 c	235 b	240 b	08.3 c	13.2 c
T2 = 1st week Nov	83 b	118 b	265 a	296 a	22.0 b	35.0 b
T3 = 1st week Dec	98 b	130 b	286 a	303 a	28.0 b	39.4 b
T4 = 1st week Jan	130 a	180 a	290 a	314 a	37.7 a	65.5 a

Means in a column have the same letter (s) are not statistically different at level of 5%

Table 7 Influence of foliar spray of ammonium nitrate combined with the date of start water irrigation on physical characteristics of fruit in 'mango trees cv. 'Ewais' during two years

Treat	Length (cm)		Width (cm)		Shape index (length/width)*		Volume (cm ³)		Specific gravity (g/cm ³)	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T1 = Untreat. Trees	09.30 c	09.53 c	5.27 c	5.79 c	1.77 a	1.65 a	225 b	235 b	1.022 b	1.021 b
T2 = 1st week Nov	10.17 b	10.50 b	6.88 b	6.83 b	1.48 b	1.54 b	258 a	289 a	1.027 a	1.024 a
T3 = 1st week Dec	10.39 ab	10.78 ab	6.78 b	6.97 b	1.53 b	1.55 b	279 a	296 a	1.025 a	1.024 a
T4 = 1st week Jan	10.83 a	11.06 a	7.25 a	7.50 a	1.50 b	1.48 b	283 a	307 a	1.025 a	1.023 a

Means in a column have the same letter (s) are not statistically different at level of 5%

*The customers like fruit shape index (length/width) in the range 1.50 ± 5

two years. Concerning the fruit volume, all treatments (T2, T3, and T4) had the highest values (258, 279, and 283 cm³ in 1st year and 289, 296, and 307 cm³ in 2nd year, respectively) compared to the control (225 and 235 cm³). As fruit specific gravity, all treatments (T2, T3 & T4) recorded high values (1.027, 1.025, and 1.025 g/cm³ in 1st season and 1.024, 1.024, and 1.023 g per cm³ for the second year) over the untreated trees (1.022 & 1.021 g per cm³).

Table 8 pint out the influence of foliar spray of ammonium nitrate combined the date of start water irrigation on chemical characteristics for the fruit of 'mango trees cv. 'Ewais' during two years. It is explained from Table 8 that T2, T3 & T4 improved the total soluble solids % (T.S.S), T.S.S/ acid ratio & L-ascorbic acid content of fruits; however, the acidity % of fruit slightly decreased in comparison with the control during the two years. In this respect T4 gave the highest significant value of T.S.S % (24.7 & 24.9%), T.S.S./acid ratio (130.0 and 146.5), L- ascorbic acid (25.0 and 27.2 mg/100 g fresh pulp) and decrease acidity (0.19 and 0.17%) compared with the control (19.9 and 20.2%, 62.2 and 73.9, 20.0 and 19.5 mg/100 g and 0.32 and 0.27%). This was true in 1st and 2nd seasons, respectively. However, other treatments T2 & T3 followed the same trend in respect of the total soluble solids % (T.S.S) and T.S.S/ acid ratio, L- ascorbic acid & acidity % compared with control for both seasons, but their values lack significance.

Discussion

The remarkable increment in the vegetative growth parameters (length of terminal shoots, No. leaves per terminal shoots, and leaf area) may be due to ammonium nitrate spray, which is reflected in increased panicle characteristics (panicle length, width, and number of secondary branches per panicle), resulted in improving fruit set, number of fruit per tree and yield. This is in agreement with Bondad and Linsangan (1979), and Nunez-Elisea (1987) who mentioned that ammonium nitrate spray presumably promotes bud break caused mature vegetative

flush that reflected in enhancement the flowering parameters and consequently fruit set and yield. Other investigators supported these results who mentioned that the foliar spray of ammonium nitrate had given excellent results as promoters of flowering in a wide range of mango cultivars (Salazar-Garcia et al. 2000). Also, the results had been confirmed by Sudha et al. (2012) who found that NH₄NO₃ at 1% or 2% enhanced early flowering and increased fruit set% in 'Alphonso' cv. The effect of NH₄NO₃ on tree growth & productivity might be due to its bio-regulatory influence, especially during the translocation of photosynthesis to sink and the mobilization of dry matter (Mishra et al. 2011). On the other hand, nitrogen in the trial trees as a foliar spray increased the reserves of carbohydrates that warranted great fruit set percentage (Patoliya et al. 2017). Moreover, Morales-Martinez et al. (2020) confirmed that foliar application of ammonium nitrate 2%, 3%, and 4% alone or combined with paclobutrazol improved floral induction and fruit production science, it enhanced flowering & increased No. panicles per tree for mangoes, especially cv. Tommy Atkins.

According to the results mentioned above of physical & chemical soil properties and irrigation water analyses of this experiment, it is clear that soil is slightly alkaline sandy soil, and irrigated with freshwater of the Nile River, which classified as a good irrigation water (FAO 1994). In this regard, irrigation of sandy soils must be considered carefully (Alhammadi and Al-Shrouf 2013) due to it requires high attention to the timing and amount of irrigating water applied (Sánchez et al. 2012). Therefore, using the drip irrigation method in this experiment is considered one of the most efficient methods for this type of soil (Liu et al. 2012). In this experiment, it is used adapted irrigation of 5m³/feddan (4200)/week up to four, eight, or twelve weeks (started from the 2nd week of October) to manage soil moisture, control leaves damage, and delay the early flowering of mango trees since, managing soil moisture is promoting the desired yield response (Thompson et al. 2007). However, moderate

Table 8 Influence of foliar spray of ammonium nitrate combined with the date of start water irrigation on chemical characteristics of fruit in 'mango trees cv. 'Ewais' during two years

Treatments	Total soluble solids % (T.S.S)		Acidity (%)		T.S.S /acid ratio		Vitamin C (L- ascorbic acid) mg/100 g fresh pulp	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year
T1 = Untreat. Trees	19.9 b	20.2 b	0.32 a	0.27 a	62.2 c	73.9 b	20.0 b	19.5 d
T2 = 1st Nov	22.2 ab	21.9 ab	0.26 ab	0.25 ab	85.4 bc	98.2 b	20.8 ab	22.3 c
T3 = 1st Dec	23.1 ab	23.2 ab	0.22 bc	0.23 b	105.0 ab	99.8 b	21.3 ab	24.0 b
T4 = 1st Jan	24.7 a	24.9 a	0.19 c	0.17 c	130.0 a	146.5 a	25.0 a	27.2 a

Means in a column have the same letter (s) are not statistically different at level of 5%

water stress can constrain excessive vegetative growth in mango trees and stimulate flowering and productivity of mango (Shaban et al. 2020).

Furthermore, our results are supported by Faria et al. (2016) who reported that an irrigation level reduction is suitable for floral induction of 'Tommy Atkins' mango. Also, the results in the same trend of Sarker and Rahim (2013) who stated that the mango trees cv. Amrapali those were irrigated twice on 15th October & 15th November gave the better No. panicles as well as had the highest No. fruits and maximum yield compared to the other application where the plants were irrigated 6 times on 15th monthly from 15th October until 15th March that had the minimum value of the No. panicles & No. fruits as well as the yield.

Also, it could explain that the enhancement of flowering by spraying ammonium nitrate might be due to the role of some enzymes like the nitrate reductase, which is considered the key enzyme in the pathway of nitrate assimilatory the synthesis of amino acids. In this respect, Maity et al. (1972), as well as Davenport and Nunez-Elisea (1997b) found that the enzyme of methionine is considered the promoter for inflorescence in mango tree, and it is reported as the ethylene's precursor, which is reflected in increasing fruit set % than the untreated trees.).

Furthermore, the explanations impact of water irrigation starting dates after comparatively periods of drought that increased the fruit set%, yield, and improved the fruit quality could be explained by those of Nunez-Elisea and Davenport (1994). They mentioned that the deficit of irrigated water limits the new leave's growth and increases the rate of mature inductive leaves. Also, Lu and Chacko (2000) reported that the flowering response was related to the intensity of the soil water deficit before flowering and maintained high vegetative growth, while water stress adjusted the growth such as branch diameter and predisposed floral stimulus.

The increase in fruit set, yield, and the improvement of fruit quality could be explained by the findings of Singh (2002). He confirmed that the mango leaves absorb most nutrients 24–72 h after the spraying; afterwards, the leaves nutrient content depletion occurs due to translocating NPK to the actively growing tissues through the plant system.

Based on results above, it is evident that irrigation of 'Ewais' mango trees after comparatively periods of drought up to twelve weeks of adapted irrigation as 5m³/feddan (4200)/week has a great influence on improving the productivity of mangoes. In other words, adapted water as 5m³/feddan/week for three months from October to January did not show unfavorable effects on mango trees cv. 'Ewais'.

Conclusions

Generally, the results showed that spraying NH₄NO₃ 2% at 1st week of November plus start normal irrigation program at 1st week of November or December or January after 4 or 8 or 12 weeks of adapted irrigation as 5m³/feddan (4200 m²)/week (T2, T3, and T4) increased the vegetative growth i.e. length of terminal shoots, No. leaves/terminal shoots & leaf area as well as the fruiting behavior such as fruit set percentage, No. fruits & yield (kg/tree) and improved fruit quality not only the physical fruit characteristics i.e. weight, dimensions, volume & specific gravity but also the chemical characteristics i.e. total soluble solids % (T.S.S.), acidity %, T.S.S / acid ratio and vitamin C (L- ascorbic acid) in comparing with the control (T1). Among treatments during the two seasons, NH₄NO₃ 2% foliar spraying at 1st week of November plus start normal irrigation program at 1st week of January after 12 weeks of adapted irrigation as 5m³/feddan/week (T4) is recommended since; it is only treatment had the superiority effect on trees yields.

Abbreviations

Feddan: Unit of area = 4200 m². It is used in Egypt, the Sudan, Syria and the Sultanate of Oman; FAO: Food and Agriculture Organization of the United Nations; AOAC: The Association of Official Analytical Chemists.

Acknowledgements

Not applicable.

Authors' contributions

Our article was carried out in cooperation among all colleagues. Author MAMA, prepared the proposal, arranged the farm visits and participated in the writing of the last copy of article; Author EA the review of literature, conducted the farm application, collected the field's samples & data, prepared the samples for chemical analyses, carried out the statistical analyses, and participate in writing the first and final copy of the article. Author HAMA conducted the farm treatments, tabled the data for the analyses of statistics, conducted the fruit physical measurements participate in writing the first draft of article. Author NA performed in the field's work & reviewed final draft of manuscript. All authors read and approved the final manuscript.

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Funding

None.

Availability of data and materials

The datasets generated and/or analyzed during the current study are included in this published study.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Received: 24 June 2021 Accepted: 6 February 2022

Published online: 19 February 2022

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