

Impact of Irradiated Compost on Growth and Nutritional Status of Valencia Orange Grown in the Desert Areas

ABSTRACT

Aims: To evaluate the effect of compost application whether irradiated or not in addition to recommended mineral fertilization on growth and nutritional status of Valencia orange trees.

Study design: The design of the study is a randomized complete block design. The study was done on five-years-old Valencia orange grown in a loamy sand soil.

Place and Duration of Study: The study was conducted in El-Shrouk yard -Cairo-Alexandria Desert Road through five successive seasons 2014, 2015, 2016, 2017 and 2018. Compost irradiation was done at the National Centre for Radiation Research and Technology, Atomic Energy Authority.

Methodology: In addition to mineral fertilization, four main treatments were applied to Valencia orange trees, T1 three years application of non-irradiated compost, T2 four years application of non-irradiated compost, T3 and T4 similar to T1 and T2 while irradiated compost was applied. Shoot length and thickness, leaf number and area were calculated. Leaf N, P and K% as well as Fe, Mn, Zn and total chlorophyll content were measured.

Results: Data revealed that application of compost especially irradiated form in combination with chemical fertilizers has a positive effect on vegetative growth of Valencia orange trees in addition to leaf content of nitrogen, phosphorus, potassium, iron, manganese, zinc and total chlorophyll. Four years application of compost regardless irradiation was superior to three years application. Combination of irradiated compost and four years application gave the highest values for the previously mentioned parameters. **Conclusion:** Addition of compost to chemical fertilizers improved the vegetative growth and nutritional status of Valencia orange trees. Irradiation of compost increased its efficiency that might reduce the time of application. Also, using compost, particularly in the newly reclaimed soil, greatly increase water and mineral fertilizers use efficiency, which in turn lead to saving in irrigation water and fertilization nutrients.

Keywords: Radiation, organic, fertilizer, citrus, chlorophyll, minerals.

1. Introduction

Valencia orange (*Citrus sinensis* L. Osbeck) is one of the most consumed fruits for being a good source of vitamin C. Moreover, it considered as one of the main export fruits in Egypt [1]. Valencia orange trees cultivated successfully in Egypt however trees grown in newly reclaimed soils facing many challenges including poor nutrient content and low organic matter of the soil as well as leaching of nutrients that affect the growth of the trees and the quality of the fruits. Such conditions require alternative agricultural practices to improve soil properties [2].

The massive use of inorganic fertilizers in conventional agriculture associated with continuous decay of soil properties mainly due to insufficiency of the organic matter content of the soil. Integrated systems using organic amendments with chemical fertilizer are a hopeful fertilization practice for more valid crop production [3].

Maintenance of soil ingredients and productivity in addition to supplementation of organic matter could be achieved through organic fertilizers including animal manures, crop residues, and green manuring [4]. Organic farming not only increased soil biological activity but also soil aggregate stability with positive correlation to microbial biomass. Also, it provides efficient utilization of nutrients and energy than the conventionally managed soils [5]. Also, organic fertilization enhanced the primary metabolites including soluble carbohydrates, chlorophyll and carotenoid pigments and secondary metabolites such as proteins, polyphenols and auxins [6].

Using compost as a partial substitution to mineral fertilizers under different soil properties has been recommended [7]. It boosted plant growth and productivity; diminished inorganic fertilizer use thus produced health nutritional crops in addition to income increase through a reduction of crop production cost [8].

The use of ionizing radiation, mainly gamma-ray, as an effective and rapid method for sludge disinfection is well established [9, 10]. Gamma radiation increased the amount of dissolved organic matter, availability and uptake of essential elements [11]. Therefore, the present study aimed to evaluate the effect of compost application whether irradiated or not in addition to recommended mineral fertilization on growth and nutritional status of Valencia orange trees.

2. Materials and method

The present study was conducted during five successive seasons 2014, 2015, 2016, 2017 and 2018 in El-Shrouk yard located at Cairo-Alexandria Desert Road. Five years-old Olinda Valencia orange budded on Volcamer lemon rootstock grown in a loamy sand soil with line spacing 3.0 x 7.0 m was used in this investigation. Orange trees were irrigated through the drip irrigation system. Thirty six uniform Valencia orange trees were chosen for this study (4 treatments x 3 replicates x 3trees/ replicate). The orange trees were uniform in vigour and received common horticultural practices.

The properties of the soil before the start of the experiment as well as compost analysis were illustrated in Table (1). It worth noting that compost properties all over the five years of the experiment were almost similar and composition variation did not exceed 3%.

The mineral fertilization NPK (M) was added as N in the form of ammonium nitrate (75 g/tree per season), P₂O₅ in the form of superphosphate (62.5 g/tree per season) and K₂O in the form of potassium sulphate (125 g/tree per season). For each tree, 4 Kg of non-irradiated (NIC) or irradiated compost (IC) were added once to the soil before the beginning of budburst at the first week of January for all seasons, at 30 cm depth then covered with the soil and irrigated with water. Irradiated compost was exposed to gamma irradiation using Co⁶⁰ gamma source at a dose of 10 k Gy absorbed dose at the National Center for Radiation Research and Technology (NCRRT). The different fertilization treatments were presented in Table (2).

Table 1. Some mechanical and chemical characteristics of Soil and compost

Soil properties	Season 2014	Compost properties	Season 2014
Soil texture	loamy sand	Weight of m ³	620 Kg
Sand	80.3%	Humidity	20 %
Clay	5.3%	pH (1 : 10)	7.2

Silt	14.4%		EC (1 : 10)	5.9 dSm ⁻¹
pH (1:2.5)	8.1		Organic matter	43 %
EC _e (dSm ⁻¹)	1.82		Organic carbon	22.1 %
Cl ⁻	6.9	(m mole _c L ⁻¹)	Total N	1.72 %
(HCO ₃) ⁻	2.6		C / N %	12.8 : 1
(SO ₄) ⁻²	8.7		N (NH ₄)	750 ppm
Ca ⁺⁺	6.6		N (NO ₃)	110 ppm
Mg ⁺⁺	2.1		Ash	57 %
Na ⁺	8.0		Total P	0.9 %
K ⁺	1.5		Total K	0.93 %

Morphological measurements of shoot length and thickness and leaves number and area were calculated as a rate of change from 1st and 2nd read in March and September, respectively and expressed as a percentage. Leaves area was measured in 12 leaves/tree using leaf area meter, Model CI 203, U.S.A. Mineral contents including NPK (%) and Fe, Zn, Mn (ppm) were determined in oven-dried mature leaves. Total nitrogen was determined by the modified micro-kejl-dahl method Phosphorus was colourimetrically determined and potassium was flame photometrically determined according to Westerman [12]. Mature leaves were used for measuring of total chlorophyll content by the use of Minolta chlorophyll meter model SPAD 502[13].

Table 2. The different fertilization treatments

	T1	T2	T3	T4
1 st year	M + NIC	M + NIC	M + IC	M + IC
2 nd year	M	M + NIC	M	M + IC
3 rd year	M + NIC	M	M + IC	M
4 th year	M	M + NIC	M	M + IC
5 th year	M + NIC	M + NIC	M + IC	M + IC

M: mineral fertilization, NIC: non-irradiated compost and IC: irradiated compost

The statistical analysis of the present data was carried out according to Snedecor and Cochran [14]. The analysis of variance (ANOVA) was done for determination of significant differences among various treatments at 5% level using M-STAT computer software program.

3. Results and Discussion

3.1 Percentages of change in shoot length and thickness, leaf area and number

Data in Table (3) expressed shoot length and thickness and leaves number and area. T2 and T4 treatments significantly increased the increment percentage of all studied vegetative growth parameters as compared to T1 and T3, respectively. In other words, 5 years evaluation, four times application of compost regardless its irradiation significantly enhanced the percentage of increase of shoot length and thickness in addition to leaves number and area as compared to three times application except for leaf number in non-irradiated compost application. Regarding irradiation effect, T3 and T4 (irradiated compost) significantly reinforced the rate of increment of shoot length and thickness as well as leaf number and area as compared to T1 and T2 (non-irradiated compost), respectively. The interaction effect revealed that the highest value for all mentioned parameters obtained in T4 while the lowest value in T1.

Similar results were obtained by AL-Kahtani and Ahmed [15] where they found a significant increase in shoot length of Picual olive trees when treated with manure as compared to chemical fertilizers. Organic fertilization using manure significantly increased the leaf area of sour orange [16], Newhall Naval Orange [17], Picual olive [15] and Apricot [18]. Application of recommended nitrogen fertilization to Washington Navel orange through a combination of mineral, organic and bio-fertilizers gave the highest leaf area as compared to mineral fertilization [19]. Also, combined chemical and organic fertilizers increased shoot length and leaf area of Flame seedless grape [20]. Application of nitrogen in mineral form, as well as compost, significantly increased plant height of wheat as compared to mineral fertilization only. The combined effect of mineral and organic fertilizers was increased as mineral nitrogen level increased [21]. Low and moderate levels of sewage sludge (15 and 30 g kg⁻¹ soil, respectively) with different gamma absorbed doses (0, 5, 10 and 20 KGy), significantly increased the basil leaf area compared to the control. Moreover, it was found that irradiation of sludge enhanced its positive effect as radiation dose increased [22]. Another study of Awad [23] declared that dry soil and extract soil and foliar application of poultry manure to grape transplants significantly increased the plant height and leaves the number as compared to the control. He added that dry soil application had a more superior effect than extract application. Moreover, an irradiated form of the manure induces a more significant increment as compared to non-irradiated one

Table 3. Effect of different non-irradiated and irradiated compost applications on percentages of change in shoot length and thickness and leaf number and area of Valencia orange.

Year	Shoot length (%)				Shoot thickness (%)			
	T1	T2	T3	T4	T1	T2	T3	T4
1 st	163.9 n	153.3 o	173.4 lm	187.0 hi	117.0 n	141.6 kl	132.8 m	145.5 jk
2 nd	176.0 klm	181.6 ijk	185.4 hij	216.9 de	140.9 kl	147.3 j	139.7 l	179.8 g
3 rd	185.3 hij	178.5 jkl	197.9 fg	222.5 cd	172.1 h	158.4 i	172.6 h	184.6 fg
4 th	169.9 mn	190.6 gh	198.7 f	240.1 b	174.5 h	186.6 ef	187.0 ef	223.4 b
5 th	188.6 hi	214.7 e	226.6 c	250.9 a	190.7 e	210.4 c	205.2 d	241.6 a
Mean	176.8 D	183.8 C	196.4 B	223.5 A	159.0 C	168.9 B	167.5 B	195.0 A
Year	Leaf area (%)				Leaf number (%)			
	T1	T2	T3	T4	T1	T2	T3	T4
1 st	141.7 n	136.9 n	122.4 o	186.7 j	23.10 j	38.72 hi	36.01 i	38.84 hi
2 nd	160.7 l	150.0 m	256.9 e	281.9 d	41.90 gh	47.94 ef	46.83 f	51.07 e
3 rd	150.0 m	184.9 j	245.8 f	220.9 h	58.33 d	42.77 g	55.10 d	51.18 e
4 th	173.2 k	190.5 j	298.9 c	240.0 f	68.09 b	57.50 d	57.00 d	63.44 c
5 th	229.8 g	212.2 i	333.3 b	349.3 a	66.42 bc	63.87 c	66.13 bc	77.68 a
Mean	171.1 D	174.9 C	251.5 B	255.8 A	51.57 BC	50.16 C	52.21 B	56.44 A

Means followed by different letter/s was significant at 5%

3.2 Leaf content of chlorophyll, N%, P%, and K%

Data in Table (4) revealed that four times compost application (T2 and T4) had superior effect on leaf nitrogen, phosphorus and potassium% as well as chlorophyll content than three times application (T1 and T3). The differences in all previously mentioned parameters were significant between four and three times compost application

treatments. Irradiation had similar effect to four times compost application that irradiated compost significantly increased nitrogen and phosphorus% and chlorophyll content as compared to non-irradiated compost. On the other hand, irradiation of compost had no significant effect on potassium%. Concerning the combined effect, four times the application of irradiated compost gave the highest N%, P% and total chlorophyll content in contrary to three times application of non-irradiated compost that gave the lowest value. Potassium% was affected in a different manner, where the highest value recorded in four times compost application and the lowest one in three times compost application regardless of irradiated or not.

The increased total chlorophyll content in response to organic fertilization was also reported by Barakat [17] on Newhall Navel Orange, AL-Kahtani and Ahmed [15] on picual olive and Duhoky [18] on apricot. Compost addition with or without bio-fertilizers significantly increased leaf pigment content of *Dracocephalum moldavica* L [24] and Flame seedless grapevine [25]. The fertilization of basil using sewage sludge significantly increased leaf chlorophyll content in particular when irradiated [20]. Similarly, Awad [23] found a significant enhancement of leaf total chlorophyll of grape transplants fertilized with irradiated poultry manure followed by those treated with non-irradiated manure. Moreover, foliar application of poultry manure extract had a significant positive effect on total chlorophyll content however; its effect was inferior to dry soil application.

Table 4. Effect of different non-irradiated and irradiated compost applications on total chlorophyll, nitrogen, phosphorus, and potassium content of Valencia orange leaves.

Year	Total chlorophyll (mg/ 100 g F. Wt.)				Nitrogen %			
	T1	T2	T3	T4	T1	T2	T3	T4
1 st	59.67 j	61.33 ij	60.00 j	61.67 ij	2.10 kl	2.15 jkl	2.08 l	2.17 jk
2 nd	61.67 ij	64.00 ghi	63.00 hi	65.33 fgh	2.17 jk	2.26 hi	2.21 ij	2.35 fg
3 rd	64.00 ghi	67.33 ef	66.67 fg	69.67 de	2.29 gh	2.39 ef	2.35 fg	2.53 cd
4 th	67.00 ef	71.67 cd	70.33 d	75.33 b	2.44 e	2.56 cd	2.53 d	2.74 b
5 th	70.67 d	76.33 b	74.33 bc	79.67 a	2.61 c	2.75 b	2.73 b	2.96 a
Mean	64.60 D	68.13 B	66.87 C	70.33 A	2.32 D	2.42 B	2.38 C	2.55 A
	Phosphorus %				Potassium %			
Year	T1	T2	T3	T4	T1	T2	T3	T4
1 st	0.185 l	0.193 kl	0.182 l	0.192 kl	1.33 i	1.40 hi	1.34 i	1.39 hi
2 nd	0.197 kl	0.207 jk	0.209 jk	0.223 hij	1.37 i	1.46 fgh	1.40 ghi	1.48 efg
3 rd	0.217 ij	0.235 gh	0.230 hi	0.249 fg	1.45 fgh	1.55 de	1.46 fgh	1.58 cd
4 th	0.238 gh	0.272 de	0.258 ef	0.278 cd	1.53 def	1.65 bc	1.58 cd	1.69 b
5 th	0.269 de	0.297 b	0.293 bc	0.322 a	1.64 bc	1.77 a	1.66 bc	1.83 a
Mean	0.221 C	0.241 B	0.234 B	0.253 A	1.46 B	1.57 A	1.49 B	1.59 A

Means followed by different letter/s was significant at 5%

Concerning the increased leaf N, P and K%, AL-Kahtani and Ahmed [15] reported a significant increase in leaf N and K% of picual olive trees treated with organic fertilizer. Barakat [17] found a significant increase in K% in response to organic fertilization alone or in combination with biofertilizers while N and P% increased when bio-organic fertilization was used as compared to mineral fertilization only. On the contrary, the leaves of Washington Navel orange trees fertilized with mineral, organic and bio-

fertilizers showed higher N% while P and K% decreased [19]. Irradiated sludge had a more significant positive effect on basil shoot and root N, P and K% rather than non-irradiated one. The promotion effect of irradiation increased as the radiation dose increased [22]. The form and application method of the organic fertilizer affected the leaf content of N, P, and K%. Awad [23] studied the effect of dry soil, extract soil and extract foliar application of irradiated poultry manure on grape transplants. He found that poultry manure fertilization of grape transplants significantly increased leaf N%. The highest value obtained with irradiated manures whatever the method of application. Leaf P% was significantly increased with irradiated manures with different application method and dry soil application of non-irradiated manure. Dry soil application of poultry manure either irradiated or not and soil application of irradiated extract significantly increased leaf K%.

3.3 Leaf content of Fe, Mn and Zn

Data of leaf content of iron, manganese and zinc presented in Table (5) showed that highest value obtained in T2 and T4 (four times compost application) treatments when compared to T1 and T3 (three times compost application), respectively. Application of irradiated compost significantly increased Fe content regardless of the number of application as compared to non-irradiated one. Leaf Mn and Zn content were significantly increased in response to three and four times irradiated compost application, respectively as compared to non-irradiated one. T4 expressed the highest content of Fe, Mn and Zn in addition to T2 in case of Mn. On the other hand, T1 showed the lowest content of Fe, Mn and Zn as well as T3 in case of Zn.

Table 5. Effect of different non-irradiated and irradiated compost applications on Fe, Mn and Zn content of Valencia orange leaves.

Year	Fe (ppm)				Mn (ppm)			
	T1	T2	T3	T4	T1	T2	T3	T4
1st	352.4 k	361.9 j	352.8 k	361.7 j	146.5 j	149.1 hij	146.9 j	148.7 hij
2nd	359.5 j	371.6 hi	364.7 j	378.1 g	148.5 ij	151.6 fgh	150.3 ghi	153.1 fg
3rd	369.6 i	384.2 f	371.2 hi	389.2 ef	152.4 fg	156.7 de	152.7 fg	156.8 de
4th	376.2 gh	395.9 d	387.5 f	407.2 c	154.1 ef	162.9 bc	157.6 d	164.1 b
5th	392.8 de	419.8 b	404.2 c	425.1 a	160.4 c	170.7 a	164.5 b	172.4 a
Mean	370.1 D	386.7 B	376.1 C	392.3 A	152.4 C	158.2 A	154.4 B	159.0 A
			Zn (ppm)					
Year	T1		T2		T3		T4	
1 st	53.76 jk		56.17 hij		53.01 k		55.84 hij	
2 nd	54.80 ijk		58.29 fgh		56.61 ghi		60.07 ef	
3 rd	58.79 fg		61.48 e		58.12 fgh		62.59 de	
4 th	61.61 e		64.21 d		62.64 de		67.72 bc	
5 th	66.74 c		69.64 b		68.77 bc		74.67 a	
Mean	59.14 C		61.96 B		59.83 C		64.18 A	

Means followed by different letter/s was significant at 5%

These results were by Rizk [26] who investigated the effect of nitrogen fertilization (compost vs. mineral fertilizer) on 'Thompson seedless' grapevine grown in clay loam soil. He found that cover crop and compost treatment increased mineral content in leaf petioles in the third season. They concluded that using compost with cover crop treatments reduces the amount of required mineral nitrogen fertilizer and produces healthy fruits with a reduction in environmental pollution. Organic fertilization of

Valencia late orange using compost from citrus byproducts increased leaf content of Fe, Mn and Zn as compared to mineral fertilization however the increase was significant in case of Mn and Zn [27]. Similarly, Awad [23] found that the addition of poultry manure to grape plants significantly increased Fe and Zn with a more superior effect to either manure irradiation or dry soil application. Leaf Mn content increased significantly in response to only dry soil application of irradiated manure.

Crop production was adversely affected by soil nutrient loss due to intensive agriculture. There is an increase in agrochemical inputs including chemical fertilizers in for optimum crop production [28, 29]. Chemical fertilizers have the advantage of rapid nutrients release into soil for crop use however, it has negative side effects on the soil physical and chemical properties and leads to loss of biodiversity and changes in species compositions in ecosystems when they are used extensively. One major disadvantage is the increase of hydrogen ions concentration in freshwater ecosystems without much acid-neutralizing capacity, resulting in acidification of those systems [30]. Moreover, it could impair the ability of aquatic animals to survive, grow and reproduce [31]. Mineral fertilizers are commonly used to enhance the agricultural production, however, due to high cost and continuous degradation of soil productivity; organic fertilizers provided a safe channel to supplement the nutrients for soil health regeneration and enhanced crop productivity [32].

In the present study, four times the application of compost either irradiated or not improved the measured growth parameters of Valencia orange trees as compared to three times. Such improvement in the growth parameters possibly related to enhanced content of macro- and micronutrients. Macronutrients such as nitrogen, phosphorus and potassium play a major role in plant nutrition that reflected on the growth and development of the plant [33]. Compost applications increased nutrient release with subsequent increase in total NPK content of the soil [34]. Organic fertilizers had a powerful fertilizing effect through reduction of soil bulk density and increased pH, water-holding capacity by increasing capillary capacity and aeration porosity with increasing rates of application thus improving soil properties. In addition, they enhanced soil organic matter accumulation and available nutrient elements concentration [35-37]. Application of compost, one of common organic matter, markedly increased water moisture thus improves soil physical properties [38, 39]. Additionally, it decreased electrical conductivity values compared to mineral fertilizer and this could be attributed to the forming of dry stable aggregates as a result of added various compost treatments which led to increase salt leaching to the deepest layers of soil and consequently, reduction in the electrical conductivity values [40]. Organic fertilizers play a key-role for constitution of soil C-sink with superiority for compost in increasing soil organic C and humification degree that is the ability of the soil to stock organic matter from the extractable organic fraction into humified substances [41].

Combined application of organic and full mineral fertilizers significantly increased leaf mineral content as well as nutrient availability in the soil. This could be attributed to the synergistic effect between mineral and organic fertilizers for increasing soil available macro and micro nutrient status. Moreover, the combined use of insoluble mineral fertilizers with organic matter was essential in order to take the utmost benefit on the native elements in mineral fertilizers [42]. Most of crop improvement could be related essentially to N in addition to application of P and K that provide adequate nutrient concentration [43]

The enhanced macro- and micro-nutrients found with high frequency compost application in particular when irradiated could be attributed to degradation effect of irradiation on soluble organic complexes resulted in more easily adsorbed free forms of

metals thus increase their mobility [10]. Moreover, irradiation had a positive effect on organic fertilizer properties through increased sludge-borne N and P bioavailability as well as mineralization of organic N in sludge, changing the chemical forms of organic N, forming large amounts of dissolved organic matter and breaking down the large molecular-weight fractions of dissolved organic matter [44]. Humic acid, one of the degraded organic compounds from compost application, improved nitrogen assimilation, synthesis of chlorophyll, sugars, vitamins, essential amino-acids, and oils [45]. Moreover, the role of humic acid could be related to the importance of nitrogen in nucleic acids and protein synthesis, phosphorus as an essential component of the energy compounds (ATP and ADP) and phosphoprotein in addition to the role of potassium as an activator of many enzymes [46].

4. Conclusion

This study demonstrated that application of compost in combination with chemical fertilizers improved the vegetative growth of Valencia orange trees in the form of shoot length, thickness, leaf area and number and its nutritional status in the form of leaf content of NPK%, Fe, Mn, Zn and total chlorophyll. Also, increased time of compost application enhanced the vegetative growth and nutritional status. Moreover, irradiation of compost increased its efficiency that might reduce time of application. Finally, application of compost, especially irradiated one, to coarse-textured soil improved its properties that reflected on plants.

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