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RESEARCH ARTICLE

Response of Pomegranate Trees (Punica granatum L. cv. Wonderful) to Organic, Nano and Non-Nano-NPK Fertilization

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ABSTRACT

An experiment was conducted during growing season (2020-2021) to study the impact of using Nano-NPK fertilizer, organic fertilizer and non-Nano-NPK (Triplex) fertilizer on the growth, yield and nutritive value of the fruits of wonderful pomegranate grown in Summel district, Duhok, Kurdistan Region, Iraq. Nano NPK fertilizer was added at 0, 0.75 and 1.5 g.l-1 of recommended dose, non-nano-NPK fertilizer (Triplex) was added at 0, 1 and 2 g.l-1 and organic fertilizer (Pigeons manure) at 0 and 10 kg tree-1. It is evident from the obtained results that using pigeons manure fertilizer was effective in improving growth and yield as well as fruits quality as compared to using nano and non-nano-NPK which was the of the same effectiveness. Supplying the Wonderful pomegranate with 10 kg tree-1 of the recommended pigeons dose fertilizer led to significant increased in most studied traits as compared to control. On the other hand, trees sprayed with nano-NPK concentration (1.5 g.l-1) were significantly superior on the control in the most traits of vegetative growth, yield and fruit quality except cracking percentage, aril percentage, and single fruit weight, while trees spraying with non-nano NPK concentration (2 g.l-1) was significant effect on half study parameters. The best dual interaction between three study factors was the interaction between nano-NPK (1.5g l-1) and non-nano-NPK (2 g.l-1) which was significantly effective on the most growth and yield parameters (aril percentage, tree fruit number, marketable fruit number of tree, and tree marketable yield) and the best tri interaction among three study factors was 10kg pigeon manor tree-1 + 1.5g nano-NPK l-1 + 2g NPK l-1 which was significant impact on these growth and yield parameters (tree fruit number, marketable fruit number of tree, tree marketable yield and tree total yield).

INTRODUCTION

Pomegranate (*Punica granatum* L.) is a deciduous tree fruit which belonging to the family Punicaceae. It's planting deploys, thrives and grows in subtropical areas of the world and pomegranate trees can be grow very well under heights from the surface of the sea up to 2300 m. It is more suitable than that the nations of original pomegranates are in Iran and north-west of India and then spread to the Turkey, Greece and also in Iraqi Kurdistan and some European countries like Spain and Italy (Naman, *et al*., 1999). There are several local and global popular cultivars of pomegranate present in Iraqi Kurdistan region, among which Wonderful one of the most is widely used for the production of commercial juice, concentration juice (Serk Hnar or Doshawi Hanar), bread of pomegranate (kaisi Hanar), arils drying (Hab Hanar) which has healthy benefits and the arils are consumed as fresh fruit (Hmid *et al.,* 2018; Bani 2023). Pomegranate's fruit consist high levels of nutritive, non-nutritive, and bio-active substances like phenolics, phenolic acids, flavonoids, anthocyanins, as well as nutritive substances such as essential oils, sugars, carotenoids, minerals and vitamins. They are edible fruits have been continuously well received by consumers as important economic fruits (Colak *et al*., 2019; Senica *et al*., 2019).

Generally, the yielding of pomegranate in the world depends on many factors like climate conditions, agricultural and fertilization processes (Taha, 2018). Because high cost of chemical fertilizers and increasing soil and water pollution, so there is an exigency for sustainable cultivating in which to conserving soil fertility should be use of low-cost renewable resources like sheep manure that are atonally accessible on the farmyard (Baghdadi *et al*., 2018; Bani, 2023).

The usage of organic fertilizers as one of the most way to maintain of soil fertility as alternatives to chemical fertilizers are the main understandable in agricultural production (El-Shazly *et al*., 2015). The major reason to decreasing plant yields is decreased soil fertility by continuous cultivation without the addition of sufficient organic manure and artificial fertilizers (Ndayisaba, 2013). However, (Mahajan, *et al*., 2008) reported that the interacted treatments of organic and chemical fertilizers, which is usually mention as whole soil fertility management, is usually ordinal as a path of sustainably excessing plant productivity. The organic manure may be useful to both the soil and crop for long time (Tirol-Padre *et al*., 2007). Aisueni *et al*. (2009) showed that the chemical fertilizers used in interaction with organic fertilizers to improve plant growth and yield in the short period. The organic manure alone improved the fruit quality, yield and fruit nutritional value of "Flame Seedless" grapes (Kassem and Marzouk, 2002).

Nano-fertilizers are environment-friendly and cost-effective that eventually excess the yield of crops by promotes highly efficient plant nutrition. Nano-fertilizers equips nutrients to crop plants in three methods, the plant nutrition can be covered by the nano-particles in the form of nano-porous fertilizers; enveloped by a thin advocatory film of polymer and supplied as particles or emulsion of nano-scale measures. Nano-elements are slowly, specifically targeted and competently released to the plants. Utilizing nano-fertilizers makes elements more ready to plants thru led to organize the release of elements from fertilizers and consequently resulting in improve nutrient use efficiency and decrease in nutrient amounts (El-Salhy *et al.,* 2021). In horticulture, nano-fertilizers are used to promote vegetative growth, pollination and fertility of flowers, resulting in excessive yield and quality of fruit trees (Zahedi, *et al*., 2020).

The essential nutrients that are needed in comparatively greater amount for good growth and productivity of plants are known as macro-nutrients. To improve their efficiency of usage, many of these nutrients are usually linked with Nano-particles to add a suitable ratio of elements to the target crops and decrease their quantity (Sidorowicz, *et al*., 2019).

The macronutrient nano-fertilizers consists more than one nutrient element in an enveloped form with appointed nano-particles. The NPK fertilizer was usage in crop production is evaluated to rise up to 265 million tons by the year 2020 (Wang *et al*., 2016). Hazra is one of most nanofertilizer used for horticulture sector in Kurdistan region. The cost influence and bazaar availability of the nano-fertilizers convenient greater implementation of these nouveau agro-chemicals. The advantageous influence of using nano-fertilizers on growing and production of crops opposite traditional fertilizers attested by the results of (Bozorgi, 2012; Refaai, 2014 and Jubeir & Ahmed, 2019).

Therefore, this study focused on the beneficial effect of using nano NPK fertilizer as an alternative to conventional fertilizers to reduce fertilizer doses and choose the best dose to improve growth, production and fruit quality of Wonderful pomegranate trees.

MATERIALS AND METHODS

The experiment was conducted at the orchard of Horticulture Department, College of Agricultural Engineering Sciences, University of Duhok located in Summel region, during the period from 1th December 2020 to 15th November 2021. The effect of soil application with organic fertilizer (pigeon manure) and spraying with Nano and non-Nano NPK on some of growth and fruiting of pomegranate trees (*Punica granatum* L. cv. Wonderful) was studied. Twenty years old Wonderful trees used in this study were present in Horticulture orchard and brought from Halabja city, the trees were uniform as

it is possible in growth vigor and all necessary agriculture operations were applied as farmer do it. A factorial Randomized Complete Block Design (RCBD) was used including three factors with all possible interactions and each treatment was replicated three times, therefore the total number of trees included in the study was 54. The first factor was soil applied with two levels of pigeon manure, (0 and 10 kg tree^{-1}), soil application was carried out on 11/12/2020. The second factor was foliar sprays of Nano-NPK (20:20:20) under industry "KHazra" with three concentrations (0, 0.75 and 1.5 g.l^{-1}) duplicated of two equal sprays, first spray was in 25/4/2021, the second spray was applied after one month from the first spray (25/5/2021). The third factor was foliar spray of Non-Nano-NPK (20:20:20) under industry "TriPlex" with three concentrations (0, and 1 and 2g L^{-1}) duplicated of two equal sprays, first spray was in 14/4/2021, the second spray was applied after one month from the first spray (15 /5/2021). All concentrations of the foliar application treatments were prepared by dissolving the chemical material in distilled water very well. A surfactant agent (Tween-80) was added to all spray treatment solutions (0.025%) to reduce surface tension of solutions. The trees were sprayed with different treatment solutions to the run off point, late in evening hours. Thus, the study was consisted of 18 treatments (2 * 3 * 3) with three replications and one tree for each experimental unit. The results were statistically analyzed according to the design used using the computerized program of SAS and the averages were compared using the Duncan polynomial test at the probability level of 0.05.Observations were recorded on single leaf area (cm^2), dry matter of leaves (%), Total chlorophyll (SPAD unit), single fruit weight (g), Arial percentage of fruit (%), fruit cracking (%), marketable yield (kg tree^{-1}) and Total yield (kg).

RESULTS

Single leaf area (cm^2)

The single leaf area of Wonderful trees was significantly influenced by pigeon manure, Nano NPK and NPK. The maximum values of leaf area were recorded from high level of each factor as 6.90cm^2, 7.02cm^2 and 6.75 cm^2 respectively Table 1.

Table 1: Effect of pigeons manure, Nano-NPK, NPK and their interactions on single leaf area (cm^2) of Wonderful pomegranate trees.

Pigeons manure (kg/tree)	Nano NPK (g/L)	NPK (g/L)			Pigeons manure*Nano NPK	Effect of Pigeons manure
		0	1	2		
0	0	4.72 f	5.42 ef	5.98 de	5.38 c	6.17 b
	0.75	6.69 a-d	6.82 a-d	7.41 ab	6.97 a	
	1.5	6.48 a-e	6.08 cde	5.93 de	6.16 b	
10	0	6.36 b-e	6.70 a-d	6.61 a-d	6.56 ab	6.90 a
	0.75	6.28 b-e	7.55 a	7.35 ab	7.06 a	
	1.5	7.02 a-d	6.99 a-d	7.22 abc	7.08 a	
Pigeons manure * NPK	0	5.96 b	6.11 b	6.44 b	Effect of Nano NPK	
	10	6.55 ab	7.08 a	7.06 a		
Nano NPK * NPK	0	5.54 d	6.06 cd	6.30 c	5.97 b	
	0.75	6.48 bc	7.18 ab	7.38 a	7.02 a	
	1.5	6.75 abc	6.54 bc	6.57 bc	6.62 a	
Effect of NPK		6.26 b	6.59 ab	6.75 a		

Means of each factor and their interactions followed by the same or shared letters are not significantly different from each other according to Duncan's multiple range tests at 5% level.

Regarding the interaction of pigeon manure and Nano-NPK, it was significantly affected single leaf

area, the highest value (7.08 cm^2) was obtained from interaction between 10kg $tree^{-1}$ + 1.5g l^{-1}. Also the combination of pigeon manure and NPK was significant increment single leaf area; the best interaction was 10kg $tree^{-1}$ + 1g L^{-1} gave the highest leaf area (7.08 cm^2). Regarding the interaction between Nano-NPK and NPK was significant effect on single leaf area, the maximum value was recorded from interaction of 1.5 g l^{-1} with 2g l^{-1} Table 1.

The results also, indicated that the tri interaction of pigeon manure, Nano-NPK and NPK was significant on single leaf area, the interaction among 10 kg pigeon $tree^{-1}$ + 1.5g Nano-NPK l^{-1} + 1g NPK l^{-1} was the most significant effective tri-interaction treatment as it gave the highest single leaf area (7.55 cm^2), while the lowest single leaf area (4.72 cm^2) was obtained at the control of tri-interaction Table 1.

Leaf dry matter percentage (%)

The effects of pigeon manure application rates, foliar spray with Nano-NPK, NPK and their interactions on leaf dry matter are shown in Table 2. It can be seen that soil application of pigeon manure (10 kg $tree^{-1}$) had a significant effect on leaf dry matter (54.04 %) as compared to the control. Foliar spraying of Nano-NPK at concentration 0.75g l^{-1} was significant surpassed in enhancing the leaf dry matter which gives the highest value (54.15%) as compared to 1.5g l^{-1} and control. No significant effect of tree spray with NPK concentrations on leaf dry matter as shown in Table 2.

Table 2: Effect of pigeons manure, Nano-NPK, NPK and their interactions on leaf dry matter percentage (%) of Wonderful pomegranate trees.

Pigeons manure (kg/tree)	Nano NPK (g/L)	NPK (g/L)			Pigeons manure*Nano NPK	Effect of Pigeons manure
		0	1	2		
0	0	52.80 c	52.78 c	53.18 bc	52.92 b	53.24 b
	0.75	53.91 bc	53.62 bc	53.07 bc	53.53 b	
	1.5	52.74 c	53.19 bc	53.91 bc	53.28 b	
10	0	53.52 bc	54.06 bc	53.22 bc	53.60 b	54.04 a
	0.75	56.67 a	54.54 b	53.11 bc	54.77 a	
	1.5	53.28 bc	53.52 bc	54.46 b	53.75 b	
Pigeons manure * NPK	0	53.15 c	53.20 c	53.38 bc	Effect of Nano NPK	
	10	54.49 a	54.04 ab	53.59 bc		
Nano NPK * NPK	0	53.16 bc	53.42 bc	53.20 bc	53.26 b	
	0.75	55.29 a	54.08 bc	53.09 c	54.15 a	
	1.5	53.01 c	53.36 bc	54.18 b	53.52 b	
Effect of NPK		53.82 a	53.62 a	53.49 a		

Means of each factor and their interactions followed by the same or shared letters are not significantly different from each other according to Duncan's multiple range tests at 5% level.

The Positive effects on leaf dry matter of the interaction between pigeon manure and Nano-NPK have been reported in Table 2. Moreover, the highest leaf dry matter (54.77 %) was obtained from interaction of 10kg pigeon manure $tree^{-1}$ + 0.75g Nano-NPK L^{-1}. The effect on leaf dry matter of the interaction between pigeon manure and NPK was significant Table 2, the maximum leaf dry matter (54.49%) was gotten for the interaction between 10kg pigeon manure $tree^{-1}$+ 0g NPK l^{-1}. Nano-NPK and NPK nutrition are closely related, and there is often a significant interaction between them in relation to the leaf dry matter, the best interaction was 0.75g Nano-NPK l^{-1} and 0g NPK l^{-1} which gave the higher leaf dry matter (55.29%) Table 2.

Results of tri interaction among pigeon manure, Nano-NPK and NPK in the Table 2 indicated that

there was a significant effect on the leaf dry matter, and displayed that the interaction among 10kg pigeon manure tree-1 + 0.75g Nano-NPK l^{-1} + 0g NPK l^{-1} was the paramount tri interaction as it gave the highest leaf dry matter (56.67 %), whereon, the lowest leaf dry matter (52.74%) was gotten from the tri interaction of 0g pigeon manure tree $^{-1}$+ 1.5g Nano-NPK l^{-1} + 0g NPK l^{-1}.

Total Chlorophyll in leaves (%)

Table (3) shows that soil application of pigeon manure had significant effect on total chlorophyll in leaves of Wonderful, also "Wonderful" trees spraying with Nano-NPK and NPK levels had a significant effect on total chlorophyll in leaves especially at level of 1.5g Nano-NPK l^{-1} and 2g NPK l^{-1} respectively.

Table 3: Effect of pigeons manure, Nano-NPK, NPK and their interactions on total chlorophyll in leaves (%) of Wonderful pomegranate trees.

Pigeons manure (kg/tree)	Nano NPK (g/L)	NPK (g/L)			Pigeons manure*Nano NPK	Effect of Pigeon s manur e
		0	1	2		
0	0	58.37 e	59.23 e	59.13 e	58.91 c	59.27 b
	0.75	59.53 de	59.17 e	60.23 b-e	59.64 c	
	1.5	59.60 de	58.05 e	60.10 b-e	59.25 c	
10	0	59.80 cde	60.83 b-e	62.70 ab	61.11 b	61.39 a
	0.75	59.87 cde	58.57 e	62.27 a-d	60.23 bc	
	1.5	63.70 a	62.37 abc	62.40 abc	62.82 a	
Pigeons manure * NPK	0	59.17 cd	58.82 d	59.82 bcd	Effect of Nano NPK	
	10	61.12 ab	60.59 bc	62.46 a		
Nano NPK * NPK	0	59.08 cd	60.03 a-d	60.92 abc	60.01 b	
	0.75	59.70 bcd	58.87 d	61.25 ab	59.94 b	
	1.5	61.65 a	60.21 a-d	61.25 ab	61.04 a	
Effect of NPK		60.14 b	59.70 b	61.14 a		

Means of each factor and their interactions followed by the same or shared letters are not significantly different from each other according to Duncan's multiple range tests at 5% level.

Results in Table 3 exposed that there were a significant interaction between pigeon manure (10 kg tree^{-1}) and Nano-NPK (1.5 g l^{-1}) BA on total chlorophyll in leaves, which gave the highest value (62.82 %). Also the interaction between pigeon manure (10 kg tree^{-1}) and NPK (2g l^{-1}) was effected significantly on total chlorophyll in leaves which gave the highest value (62.46%). On another hand, the interaction between Nano-NPK (1.5g l^{-1}) and NPK (0g l^{-1}) was significant influence on total chlorophyll in leaves which was gave the highest value.

Results of triple interaction among pigeon manure, Nano-NPK and NPK indicated that the most significant effective interaction was 10kg pigeon manure tree^{-1} + 1.5g Nano-NPK l^{-1} + 0g NPK l^{-1} as it gave the highest total chlorophyll in leaves of wonderful trees (63.70 %) (Table 3).

Single fruit weight (g)

Table 4 shows that soil application with pigeon manure (10kg tree $^{-1}$) had a significant effect on single fruit weight. It is obvious from Table 4 that there was no significant effect with spray of two other studied factors (Nano-NPK and NPK) each alone on single fruit weight.

The combination between pigeon manure and Nano-NPK revealed that there was significant

interaction on single fruit weight, where the highest value (314.59 g) was obtained at 10 kg pigeon manure tree^{-1} + 0g Nano-NPK l^{-1} (Table 4).

Results from Table (4), showed that at combination between Nano-NPK and NPK there were negative significant effect on increase single fruit weight.

Table 4: Effect of pigeons manure, Nano-NPK, NPK and their interactions on single fruit weight (g) of Wonderful pomegranate trees.

Pigeons manure (kg/tree)	Nano NPK (g/L)	NPK (g/L)			Pigeons manure*Nano NPK	Effect of Pigeons manure
		0	1	2		
0	0	230.12bc	229.17 bc	196.94 c	218.74 b	245.40 b
	0.75	244.35bc	283.12 bc	259.52 bc	262.33 ab	
	1.5	269.96bc	283.39 bc	212.03 bc	255.13 ab	
10	0	399.98 a	232.09 bc	311.71 ab	314.59 a	290.09 a
	0.75	321.02ab	251.04 bc	309.20abc	293.75 a	
	1.5	255.49bc	299.04 abc	231.24 bc	261.92 ab	
Pigeons manure * NPK	0	248.14bc	265.23 bc	222.83 c	Effect of Nano NPK	
	10	325.50 a	260.72 bc	284.05 ab		
Nano NPK * NPK	0	315.05 a	230.63 b	254.32 ab	266.67 a	
	0.75	282.68ab	267.08 ab	284.36 ab	278.04 a	
	1.5	262.73ab	291.22 ab	221.63 b	258.53 a	
Effect of NPK		286.82 a	262.98 a	253.44 a		

Means of each factor and their interactions followed by the same or shared letters are not significantly different from each other according to Duncan's multiple range tests at 5% level.

Results from Table 4 revealed that single fruit weight of Wonderful fruits affected with the triple interaction among Pigeon manure, Nano-NPK and NPK. Where the best interaction in increase of single fruit weight (399.98 g) was 10 kg pigeon manure + 0g Nano-NPK l^{-1} + 0g NPK l^{-1}. Whereas the lowest single fruit weight (196.94 g) was observed in interaction among 0kg pigeon manure+ 0g Nano-NOK l^{-1} + 2g NPK l^{-1}.

Arial percentage of fruit (%)

The data regarding the Arial percentage of fruit showed obvious no differences as affected by different doses of studied fertilizers and result was no statistically significant. Table 5 shows that soil application by pigeon manure, foliar spraying by Nano-NPK and NPK of Wonderful trees have not significant effect on Arial percentage of fruit.

It is clear from Table 5, that the binary interaction of pigeon manure + Nano-NPK and pigeon manure + NPK had not significant effect on Arial percentage of fruit. Whereas, the interaction of 1.5 g Nano-NPK l-1 + 2 g NPK l-1 appeared to be the most potent interaction treatment, as it gave the highest Arial percentage of fruit, which was (60.275%). Results of triple interaction among pigeon manure, Nano-NPK and NPK indicated that there were no significant effect on Arial percentage of fruit (Table 5).

Table 5: Effect of pigeons manure, Nano-NPK, NPK and their interactions on arial percentage of fruit (%) of Wonderful pomegranate trees.

Pigeons manure (kg/tree)	Nano NPK (g/L)	NPK (g/L)			Pigeons manure*Nano NPK	Effect of Pigeons manure
		0	1	2		
0	0	59.833 a	54.97 a	58.207 a	57.67 a	56.022 a
	0.75	54.12 a	56.467 a	52.457 a	54.348 a	
	1.5	55.94 a	52.853 a	59.36 a	56.051 a	
10	0	58.383 a	55.033 a	52.307 a	55.241 a	57.551 a
	0.75	57.62 a	60.16 a	59.67 a	59.15 a	
	1.5	59.993 a	53.603 a	61.19 a	58.262 a	
Pigeons manure * NPK	0	56.631 a	54.763 a	56.674 a	Effect of Nano NPK	
	10	58.666 a	56.266 a	57.722 a		
Nano NPK * NPK	0	59.108ab	55.002ab	55.257ab	56.456 a	
	0.75	55.87 ab	58.313ab	56.063ab	56.749 a	
	1.5	57.967ab	53.228 b	60.275 a	57.157 a	
Effect of NPK		57.648 a	55.514 a	57.198 a		

Means of each factor and their interactions followed by the same or shared letters are not significantly different from each other according to Duncan's multiple range test at 5% level.

Fruit cracking (%)

Table 6 reveals that soil application with pigeon manure (10 kg tree^{-1}) significantly decreased fruit cracking as compared with control. But Wonderful tree spraying with both Nano-NPK and NPK concentrations did not significantly decrease the fruit cracking.

Table 6: Effect of pigeon manure, Nano-NPK, NPK and their interactions on fruit cracking percentage (%) of "Wonderful" pomegranate trees.

Pigeons manure (kg/tree)	Nano NPK (g/L)	NPK (g/L)			Pigeons manure*Nano NPK	Effect of Pigeons manure
		0	1	2		
0	0	9.393 ab	13.370ab	9.041 ab	10.601 a	8.952 a
	0.75	1.509 b	4.649 b	17.587 a	7.915 a	
	1.5	8.454 ab	7.065 ab	9.496 ab	8.338 a	
10	0	2.727 b	6.871 ab	1.458 b	3.686 a	4.834 b
	0.75	2.362 b	7.057 ab	10.256ab	6.558 a	
	1.5	8.376 ab	2.132 b	2.262 b	4.256 a	
Pigeons manure * NPK	0	6.452 a	8.361 a	12.041 a	Effect of Nano NPK	
	10	4.488 a	5.353 a	4.659 a		
Nano NPK * NPK	0	6.060 ab	10.121ab	5.250 ab	7.144 a	
	0.75	1.936 b	5.853 ab	13.922 a	7.237 a	
	1.5	8.415 ab	4.599 ab	5.879 ab	6.297 a	
Effect of NPK		5.470 a	6.857 a	8.350 a		

Means of each factor and their interactions followed by the same or shared letters are not significantly different from each other according to Duncan's multiple range test at 5% level.

The interaction between pigeon manure and Nano-NPK illustrated that there were no significant

effect on fruit cracking. Also the combination between pigeon manure and NPK was not significant in decrease fruit cracking. But, there was significant effect of combination between Nano-NPK and NPK on decreasing of fruit cracking essentiality at interaction of 0.75g Nano-NPK l^{-1} + 0g NPK l^{-1} which gave the lowest fruit cracking (1.936 %)(Table 6).

The best value of decreasing fruit cracking was from the triple interaction among pigeon manure + Nano-NPK + NPK concentrations was showed from the interaction among 0kg pigeon manure + 0.75g Nano-NPK l^{-1} + 0g NPK l^{-1} as (1.509 %) in comparison with highest value (17.587 %) from triple interaction among 0kg pigeon manure + 0.75g Nano-NPK l^{-1} + 2g NPK l^{-1} (Table 6).

Marketable yield (Kg tree^{-1})

Table 7: Effect of pigeons manure, Nano-NPK, NPK and their interactions on marketable yield (kg tree^{-1}) of Wonderful pomegranate trees.

Pigeons manure (kg/tree)	Nano NPK (g/L)	NPK (g/L)			Pigeons manure*Nan o NPK	Effect of Pigeons manure
		0	1	2		
0	0	18.67 efg	16.11 fg	15.50 fg	16.76 d	21.92 b
	0.75	30.92 b-e	13.33 g	28.65 b-f	24.3o c	
	1.5	23.73 c-g	22.00 d-g	28.33 b-f	24.69 c	
10	0	23.78 c-g	27.87 b-f	40.42 ab	30.69 bc	33.81 a
	0.75	36.71 abc	30.33 b-e	28.92 b-f	31.99 b	
	1.5	37.42 ab	32.83 bcd	46.05 a	38.77 a	
Pigeons manure * NPK	0	24.44 c	17.15 d	24.16 c	Effect of Nano NPK	
	10	32.64 ab	30.34 bc	38.46 a		
Nano NPK * NPK	0	21.23 d	21.99 cd	27.96 b-d	23.72 b	
	0.75	33.81 ab	21.83 cd	28.78 a-d	28.14 ab	
	1.5	30.58 abc	27.42 bcd	37.19 a	31.73 a	
Effect of NPK		28.54 a	23.75 b	31.31 a		

Means of each factor and their interactions followed by the same or shared letters are not significantly different from each other according to Duncan's multiple range tests at 5% level.

The significant effect of the interaction between pigeon manure and Nano-NPK on marketable yield, have been reported in Table 7. Furthermore, the highest marketable yield (38.77 kg tree^{-1}) was obtained from interaction of 10 kg pigeon manure tree^{-1} + 1.5g Nano-NPK l^{-1}. Also, the effect on marketable yield of the interaction between pigeon manure and NPK fertilizer was significant, the highest marketable yield (38.46 kg tree^{-1}) was gotten for the interaction between 10 kg pigeon manure tree^{-1}+ 2g NPK l^{-1}. The nutrition between Nano-NPK and NPK are closely related, and there is a significant interaction between them in relation to the marketable yield, the best bi interaction was 1.5g Nano-NPK l^{-1} and 2g NPK l^{-1} which gave the highest marketable yield (37.19 kg tree^{-1}) Table 7.

The results of interaction of pigeon manure, Nano-NPK and NPK in the Table 7 indicated that there was a significant effect on the marketable yield, and displayed that the interaction among 10kg pigeon manure tree^{-1} +1.5g Nano-NPK l^{-1} + 2g NPK l^{-1} was the best tri interaction as it gave the highest marketable yield (40.05 kg tree^{-1}), whereat, the lowest marketable yield (13.33 kg tree^{-1}) was gotten from the tri interaction of 0g pigeon manure tree $^{-1}$+ 0.75g Nano-NPK l^{-1} + 1g NPK l^{-1}.

Total yield (kg tree^{-1})

The total yield of "Wonderful" trees was significantly affected by pigeon manure and Nano NPK. The maximum values of total yield per tree were recorded from high level of each factor as 59.34 kg tree^{-1} and 54.31 kg tree^{-1} respectively. But foliar spraying of Wonderful trees with NPK fertilizer was not significant effect on total yield (Table 8).

Table 8: Effect of pigeons manure, Nano-NPK, NPK and their interactions on total yield (Kg tree^{-1}) of Wonderful pomegranate trees.

Pigeons manure (kg/tree)	Nano NPK (g/L)	NPK (g/L)			Pigeons manure*Nano NPK	Effect of Pigeons manure
		0	1	2		
0	0	30.88 de	29.65 de	30.30 de	30.28 c	36.13 b
	0.75	32.89 de	29.71 de	28.89 e	30.50 c	
	1.5	58.62 abc	52.24 bcd	31.91 de	47.59 b	
10	0	73.30 ab	42.58 cde	61.05 abc	58.98 ab	59.34 a
	0.75	62.48 abc	42.13 cde	69.40 ab	58.01 ab	
	1.5	46.48 cde	58.45 abc	78.11 a	61.01 a	
Pigeons manure * NPK	0	40.80 bc	37.20 bc	30.37 c	Effect of Nano NPK	
	10	60.75 a	47.72 b	69.52 a		
Nano NPK * NPK	0	52.09 a	36.11 b	45.67 ab	44.63 b	
	0.75	47.69 ab	35.92 b	49.14 ab	44.26 b	
	1.5	52.55 a	55.35 a	55.01 a	54.31 a	
Effect of NPK		50.78 a	42.46 a	49.95 a		

Means of each factor and their interactions followed by the same or shared letters are not significantly different from each other according to Duncan's multiple range tests at 5% level.

Regarding the binary interactions of three studied factors of pigeon manure + Nano-NPK; pigeon manure + NPK and Nano-NPK + NPK were significantly affected on total yield per tree, the highest values (61.01, 69.52 and 55.35 kg tree^{-1}) were obtained from interactions among (10kg pigeon manure tree^{-1} + 1.5g Nano-NPK l^{-1}); (10 kg pigeon manure tree-1+ 2g NPK l^{-1}) and (1.5 Nano-NPK l^{-1} + 1g NPK l^{-1}) respectively (Table 8).

The results of Table 8, indicated that tri-interaction of three studied factors (pigeon manure, Nano-NPK and NPK) was significantly affected on total yield per tree, the interaction among 10 kg pigeon tree^{-1} + 1.5g Nano-NPK l^{-1} + 2g NPK l^{-1} was the best significant effective tri-interaction as it gave the highest total yield per tree (78.11 kg tree^{-1}), while the lowest total yield per tree (28.89 kg tree^{-1}) was obtained at the tri-interaction of 0 kg pigeon tree^{-1} + 0.75g Nano-NPK l^{-1} + 2g NPK l^{-1} (Table 1).

It is clear from the results in Tables (1,2,3,4,6,7 and 8) that the vegetative and yield characteristics of wonderful trees (leaf area, dry matter of leaves, Total chlorophyll, single fruit weight, fruit cracking, marketable yield and Total yield) were affected significantly by soil apply with pigeon manure, evidence supporting this finding has been reported by Marzouk and Kassem 2011; Haggag *et al*., 2015; Akl *et al*., 2017; Baghdadi *et al*., 2018. This may be because that organic fertilizer contained

varied essential macro and micro elements or organic fertilizer aided to facilitate the accessibility and absorb of most elements to the fruit trees (El-Shazly *et al*., 2015). These results can be ascribed to the truth that organic manure helped to simplification the availability and absorb of most elements to the trees, resulting in an improve the yield, and backing reports by Rabeh, El-Koumey & Akasem (1993) and Huang, Zhang & Qian (1995) that treating Balady mandarin (*Citrus deliciosa* Ten.) and Satsuma mandarin (*Citrus unshiu* Marc.) trees with bio-fertilizers alone or in combination with organic manure catalyzed nutrient absorption, and photosynthesis, leading to an increases the yield. Also, Mansour (2018) obtained as similar results, in experiment conducted on "Wonderful" pomegranate trees (8-year-old) in Egypt. The investigate included of two levels of Humic acid (0 and 50 g/tree/season) and five nitrogen fertilizers form chicken manure, cattle manure, compost. He found that the application of chicken manure or compost at a rate of 40 g N/tree/year with or without the addition of Humic acid at a rate of 50 g/tree/year could enhance the chemical and physical characteristics of the fruits and while reducing environmental pollution.

Regarding the effect of foliar spray by Nano-NPK on some growth and yield characteristics of Wonderful trees (single leaf area, dry matter of leaves, Total chlorophyll, marketable yield and Total yield), which was increased significantly by Nano-NPK concentrations (Tables 1, 2, 3, 7 and 8), these results are in accordance with those obtained by Sabir *et al*. (2014); Rao & Gan, 2015; Hussein and Abd-Elall (2018); He *et al*., 2018; Mohasedat et al. (2018) Zulfiqar, 2019; Zahedi *et al*., 2020; El-Salhy *et al*., 2021; Ali & Al-atrakchii, (2022). Many researchers have found that foliar spraying of fruit trees with Nano-fertilizers increments the content of plant organs from nutrients and enhance the vegetative and root growth of these trees (Hussein and Abd-Elall, 2018) in olive trees. Nano-nutrients are used to increase vegetative system, fertility and pollination of flowers, resulting in incremented yield and improved fruits quality for fruit trees (Zahedi, *et al*., 2020). This improve of fruit trees, might be due to the reality that Nano-fertilizer has fared properties due to its more surface area with high absorption because of very small particles, which causes an increase in photosynthesis and leaf area, hence increased the vegetative growth of plants (Sekhon, 2014). Also this might be due to foliar spray of Nano-Nutrients enhanced the availability of nutrients by easy penetration through stomata of leaves via gas exchange. Nano-nitrogen fertilizer activates the enzymes associated with chlorophyll formation hence it increases the chlorophyll content in the leaves. The same results were made by Roshdy and Refai (2016) in palm trees and Abdelaziz *et al*. (2019) in mango trees.

The positive effect of NPK fertilizer in improving growth and fruiting of Wonderful trees (single leaf area, marketable yield and total yield) has been founded in Tables (1, 3 and 7), these results were emphasized by (Tanuo *et al*., 2017; Fernandez and Eichert 2009; Fallahi and Eichert, 2013). As for the impact of foliar spray with the N.P.K. fertilizer, we observed that the level of 2g NPK L^{-1} was significantly superior to other levels, and this is may be due to the role of the macro nutrients, as nitrogen is an important nutrient for accomplishing optimal growth and development of spraying plants, which greatly increments and enhances the yield and its quality through its essential role in the physiological and biochemical functions of plants (Al-Falahi, 2022), while phosphorous is one of the most essential macro-nutrients for plant's life, as it is characterized as being involved in the breakdown of carbohydrates and energy, cell division, stimulation of early growth and development of roots, transfer of genetic traits, and expediting of organs plant maturity (Murray and Grant 2007). As potassium, it has many important essential nutrients as functioned for plants, such as photosynthesis, osmosis regulation, stomata movement, stress resistance, enzyme activation, protein synthesis, energy transfer, transmission through the phloem, and positive-negative ion balance (Marschner, 2012). Abiotic stress like macronutrients deficiency leads towards physiological, biochemical, morphological, and molecular changes of plants which negatively affecting plant growth and productivity (Zargar, *et al*. 2018).

CONCLUSIONS

Based on the results achieved from the current study it can be concluded that the treatments each of pigeon manure 10kg tree^{-1}, Nano-NPK 0.75 and 1.5g L^{-1} and 2g NPK L^{-1} was found the best levels of studied factor in terms of maximum leaf area, leaf dry matter, total chlorophyll of leaves, marketable yield, total yield. But about decreased of fruits cracking percentage, the best treatment was 10 kg Pigeon manure per tree only. Generally, the best factors which promote most studied parameters were pigeon manure then Nano-NPK and finely NPK fertilizer.

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