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Co-Addition of Potassium Humate and Vinasse Enhances Growth and Yield in "Wonderful" Pomegranate under Sandy Soil

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Abstract

Although "Wonderful" pomegranate has recently been cultivated in large areas of sandy soil in Egypt, it produces a low yield and quality. Soil applications of potassium humate and vinasse could effectively be used in sandy soil to enhance soil nutrient status as well as to enhance crops growth and productivity. "Wonderful" pomegranate trees at the Experimental Research Station of National Research Centre, Nubaria, El Behera governorate, Egypt, were treated with soil application of potassium humate (10 g, 20 g, and 40 g per tree), vinasse (500 mL and 1000 mL) and their combinations or water (control). The following parameters were measured: vegetative growth, leaf (N, P, and K) nutrient content, perfect flower percentage, and fruit set percentage, yield, fruit weight, aril/fruit percentage, TSS, and acidity. All vinasse and potassium humate combinations resulted in significantly increased shoot length, leaf number, and leaf area. Soil applications of 20 g and 40 g potassium humate with 500 mL or 1000 mL vinasse applications recorded the highest values of leaf N, P and K concentrations. All combinations treatments resulted in significantly higher perfect flower%, fruit set%, yield, fruit weight, aril/fruit%. All soil applications resulted in significantly lower acidity. The potassium humate and vinasse combinations did not have significant differences on TSS. The results suggest that soil applications of 20 g and 40 g potassium humate with 500 mL or 1000 mL vinasse could be used to improve growth and yield of "Wonderful" pomegranate under sandy soil.

Keywords: Fruit set; Leaf area; Leaf nutrient status; Perfect flower; Potassium Humate; Vinasse; Yield

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Introduction

Pomegranate (Punica granatum. L) one of the known oldest edible fruits from the family Punicaceae, [1]. Super wealthy biochemical compositions like anthocyanins, vitamins, polyphenols and nutrients are causes for growing demands for pomegranate fruit [2-4]. Pomegranate grows well in arid and semi-arid regions, because of its resistance to high temperatures and drought, the development of certain stress avoidance and tolerance mechanisms and the high activity of SOD, GPOD and CAT enzymes which play a positive role in controlling the ROS cellular level under drought conditions [1,5,6]. Wonderful pomegranate is now mainly grown throughout Egypt, particularly in reclaimed areas mostly with sandy and calcareous soils. Sandy soils have low organic matter content and cation exchange capacity, as well as being prone to erosion and nutrient leaching [7]. Also, sandy soils suffer from poverty of all nutrients scarcity of water irrigation, low capacity to hold water and nutrients [8-10]. Vinasse is used as an organic fertilizer because it contains macronutrients, as well as the ability to chelate organic material with micronutrients. Also, vinasse is used as a soil adjustment by the production of beneficial microorganisms in the soil Because of the high concentration of vitamins and amino acids. According to Fito J, et al. [11], vinasse has distinguishing qualities such as dark color, special aroma, high concentration of organic matter, low pH, and high ash content. Sugarcane vinasse can improve soil fertility and encourage the partial replacement of chemical fertilization [11,12]. Vinasse application to irrigation water of some crops (Wheat, Sugarcane, Pigeon, Pea) increased yield as compared to control [13-15]. Soil application of sugarcane vinasse and humic acid were improved growth traits, The application of vinasse had a significant impact on chemical, physical, and biological soil attributes [16-18]. Vinase increases the diversity of bacteria in the soil and promotes species that participate in the nitrogen and iron cycles [19]. Humic acid is an organic material result from the decomposition of plant material. HS play an important role to improve regulated plant hormones, nutrient absorption, and stress tolerance [20,21]. Humic substances inhanced vegetative growth and yield throught improve soil fertility, root growth [22,23]. Therefore, the main objectives of this investigation were to evaluate the effects of soil applications of potassium humate and vinasse on vegetative growth, leaf nutrient concentrations, yield, fruit quality of "Wonderful" pomegranate.

Materials and methods

Plant materials and treatments

The present investigation was conducted during 2018 and 2019 seasons at the Experimental Research Station of National Research Centre, Nubaria, El Behera governorate, Egypt, on five-year-old Wonderful pomegranate trees. The trees were spaced on 4.0 × 6.0 m and grown in sandy soil under drip irrigation system. Randomized complete block design (RCBD) was the experimental design, and the treatments were done with three replicates, one tree for each replicate. Data trees were selected for uniform vigor, size and health. The experiment consisted of twelve treatments of potassium humate and vinasse soil application, as shown below.

T1, control

T2, 10 g of potassium humate

T3, 20 g of potassium humate

T4, 40 g of potassium humate

T5, 500 ml vinasse

T6, 1000 ml vinasse

T7, 10 g/ Potassium humate + 500 mL/vinasse

T8, 10 g/ Potassium humate + 1000 mL/vinasse

T9, 20 g/ Potassium humate + 500 mL/vinasse

T10, 20 g/ Potassium humate + 1000 mL/vinasse

T11, 40 g/ Potassium humate + 500 mL/vinasse

T12, 40 g/ Potassium humate + 1000 mL/vinasse

Recommended dose of mineral fertilizers was 625 g N + 250 g P + 250 g K and 10 kg cattle manure during both seasons for each tree. All treatments were applied twice, on March 1st and May 1st. Control treatment was by only recommended dose of nutrients supplied through inorganic and organic fertilizers. Potassium humate was dissolved in irrigation water (5 L) and vinasse were diluting to ten percent with water and added to the soil away from the tree trunk by 70 cm. In each season of study (on early April), 20 new shoots (one year old) well distributed around periphery of each replicate tree (5 shoots toward each direction) were randomly selected, labeled and measured their length as well as the number of their leaves. The following parameters were used to evaluate the tested treatments:

Vegetative growth

At the end of growing season, the selected shoots were measured to determine the average length and number of leaves/shoot. Five leaves were collected randomly from the first mature leaves from the tip of the previously tagged shoots and their areas were measured and numbers of fruits/shoot were determined for fruit set percentage.

Yield and fruit quality

The total yield of each replicate tree was calculated using the average fruit weight and the total number of fruits per tree. On the 1st August in both seasons, number of fruits per each experimental tree was counted. At harvesting time, on August 30th, in both seasons, five fruits were taken at random from each replicate to determine average fruit weight. The percentage of total soluble solids (TSS) in each fruit juice sample was determined using a hand refractometer, and the percentage of acidity was determined depending to A.O.A.C. [24]. At harvest, an extra random sample of up to five un-split fruits per data tree were collected to calculate total aril mass as well as the mass of 100 randomly selected arils per fruit.

Leaf mineral content

Nitrogen, phosphorus and potassium was determined according to Evenhuis and Deward [25].

Results

Soil application of potassium humate and vinasse, alone or combined increased significantly growth and yield of pomegranate. Alone applications of potassium humate was more effective than vinasse. All combinations seem to have the best effect on growth and yield compared other treatments.

Vegetative growth

Table 1 shows that shoot length, number of leaves/shoot and leaf area were increased due to all soil applications of potassium humate and vinasse at all concentrations or combinations. The highest means of the two seasons were recorded with a soil application of 40 gm potassium humate + 1000 ml vinasse with increased Shoot length by 53.59%, leaves no by 67.03% and leaf area by 48.4% compared to control. Whereas, no significant differences between potassium humate at 20 or 40 g + (500 or 1000 mL vinasse, followed by potassium humate at 10g + 500 or 1000 mL vinasse while control gave the lowest values in this respect.

Leaf nutrient concentrations

Significant treatment influences were expose for leaf N, P and K contents **(Table 2)**. All soil treatments caused a significant increase in leaf nutrient concentrations during both studied seasons. Soil applications with potassium humate and vinasse combinations resulted in significantly higher leaf N concentration **(Table 3)**, with significantly higher leaf N concentrations in response to 20g and 40g potassium humate with 500 mL or 1000 mL vinasse applications. In both seasons, leaf P concentration was highest in response to the high levels of soil Potassium humate and Vinasse combinations treatments, Potassium humate at 20 or 40 g + (500 or 1000 mL Vinasse) resulting in significantly higher leaf K concentrations than other treatments, There were no significant treatment differences at potassium humate at 20 or 40 g with 500 or 1000 mL vinasse for N, P, or K leaf concentrations **(Tables 4-6)**. In both seasons all Potassium humate and Vinasse treatments resulting in significantly higher leaf K concentrations than the control.

Perfect flower % and fruit set

Soil application of 40 g potassium humate with 1000 mL vinasse was the most successful treatment although the other treatments such as 20 or 40 g of potassium humate with 500 or

Table 1 Effect of potassium humate, vinasse and their combinations on vegetative growth of ""Wonderful"" pomegranate.

Treatment	Shoot Length (cm)		Leaf No.		Leaf Area (cm^2)	
	2018	2019	2018	2019	2018	2019
T1	12.52 d	13.40 d	20.53 d	20.20 d	3.66 d	3.57 d
T2	12.85 d	13.27 d	21.93 d	21.60 d	4.10 c	4.17 bc
T3	13.83 cd	13.27 d	24.00 d	25.00 c	4.46 bc	4.50 bc
T4	14.41 c	14.87 c	26.13 b	26.46 bc	4.63 b	4.70 b
T5	13.77 cd	14.90 c	24.63 bc	25.80 bc	4.37 bc	4.40 bc
T6	13.89 cd	15.00 c	25.16 bc	26.70 b	4.40 bc	4.47 bc
T7	15.94 b	16.70 b	25.80 b	27.33 b	4.50 bc	4.53 b
T8	16.23 b	16.57 b	26.17 b	27.30 b	4.73 b	4.67 b
T9	18.87 a	19.33 a	32.90 a	32.76 a	5.17 a	5.10 a
T10	18.20 a	18.80 a	32.67 a	33.00 a	5.20 a	5.13 a
T11	18.63 a	19.53 a	33.90 a	33.23 a	5.53 a	5.33 a
T12	19.23 a	20.13 a	33.60 a	34.43 a	5.30 a	5.43 a

Within each parameter data followed by the same letter indicate that values are similar (not significant) ($p < 0.05$). T1- control ; T2- 10 g Potassium humate; T3- 20 g Potassium humate; T4- 40 g Potassium humate; T5-500 ml Vinasse; T6-1000 ml Vinasse; T7- 10 g Potassium humat+500 ml Vinasse; T8- 10 g Potassium humate+1000 ml Vinasse; T9- 20 g Potassium humate +500 ml Vinasse; T10- 20 g Potassium humate+1000 ml Vinasse; T11- 40 g Potassium humate +500 ml Vinasse; T12- 40 g Potassium humate+1000ml Vinasse.

Table 2 Average chemical composition of the vinasse.

Ph	Ec s/ml	Organic Carbon	Organic Matter	Density g/ml	N%	P%	K%
4.2	20	3.6	6.2	1.29	0.23	0.39	5.9

Table 3 Effect of potassium humate, vinasse and their combinations on leaf nutrients content of ""Wonderful"" pomegranate.

Treatment	N%		P%		K%	
	2018	2019	2018	2019	2018	2019
T1	0.87 d	0.90 d	0.087 f	0.088 f	0.70 g	0.80 d
T2	0.87 d	0.90 d	0.117 e	0.166 e	0.80 f	0.83 d
T3	1.02 c	0.97 cd	0.122 d	0.120 de	0.97 e	0.97 c
T4	1.05 bc	1.03 c	0.126 d	0.125 c	1.11 c	1.15 b
T5	1.02 c	0.97 cd	0.123 d	0.125 c	1.00 d	1.03 c
T6	1.04 bc	1.03 c	0.126 d	0.126 c	1.03 d	1.05 c
T7	1.08 bc	1.13 b	0.136 b	0.133 b	1.13 b	1.17 b
T8	1.05 bc	1.10 b	0.138 b	0.132 b	1.17 b	1.16 b
T9	1.18 a	1.25 a	0.155 a	0.153 a	1.32 a	1.38 a
T10	1.18 a	1.25 a	0.155 a	0.154 a	1.33 a	1.39 a
T11	1.20 a	1.27 a	0.156 a	0.154 a	1.33 a	1.40 a
T12	1.22 a	1.30 a	0.158 a	0.155 a	1.36 a	1.42 a

Within each parameter data followed by the same letter indicate that values are similar (not significant) ($p < 0.05$)

Table 4 Soil physical properties.

Depth (cm)	Particle size distribution, %				Texture Class	FC	PWP	AW	BD (g/cm)³	TP %
	C. Sand	F. Sand	Silt	Clay		(% on weight basis)				
0-15	14.87	78.9	4.4	1.83	Sand	11	4.16	6.34	1.58	40.38
15-30	14.91	78.93	4.3	1.86	Sand	10	4.1	6.3	1.6	39.62
30-45	14.89	78.73	4.41	1.97	Sand	10	4.13	6.33	1.64	38.11
45-60	14.96	78.66	4.39	1.99	Sand	10	4.2	6.25	1.66	37.36
FC: Field capacity; PWP: Permanent wilting point; AW: Available water; B.D: Bulk density, and TP: Total porosity.										

Table 5 Soil chemical properties.

Depth (cm)	pH 12:01:03 AM	EC dS/m	Soluble Cations, mg/L				Soluble Anions, mg/L			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	SO_4^{--}	Cl^{-}
0-15	8.3	0.35	0.5	0.42	1.05	0.23	0	0.11	0.82	1.27
15-30	8.2	0.36	0.51	0.43	1.04	0.24	0	0.13	0.86	1.23
30-45	8.3	0.34	0.55	0.41	1.05	0.23	0	0.12	0.85	1.27
45-60	8.4	0.73	0.57	0.43	1.06	0.25	0	0.17	0.86	1.28

Table 6 Some chemical properties of irrigation water.

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

1000 mL vinasse were not significantly different under during either year **(Table 7)**. The lowest percentages of perfect flower were observed with control and the application of 500 mL vinasse or 10 g potassium humate in both seasons. Fruit set was also affected significantly by different soil application treatments in similar trend. All treatments caused a significant increase in pomegranate fruit set percentage in both seasons. Application of 20 g potassium humate with 500 mL vinasse recorded the highest fruit set in 2018 season. Soil application of 20 or 40 g of potassium humate with 500 or 1000 ml vinasse were the best treatments to improvement fruit set.

Yield, fruit weight and aril/fruit %

Various soil applications had significant impact on pomegranate yield **(Table 8 and 9)**. Application of 40 g potassium humate with 1000 mL vinasse recorded highest yield in 2018 season (26.53 kg plant-1) at par with 2019 season (27.63 kg plant-1) by increase in yield with 96.51% and 134% higher as compared to control, respectively. Soil application of 20 or 40 g of potassium humate with 500 or 1000 mL vinasse led to significant increases in fruit yield but with no significantlydifferences. Regarding fruit weight was affected significantly with the potassium humate and vinasse applications when compared to control (Tables 8 and 9). However, the highest fruit weight was obtained with the high levels of potassium humate and vinasse (40 g potassium humate + 1000 mL vinasse), with fruits being significantly higher (2.2 to 20.5%) than those obtained with other treatments in both studied seasons. Again, both potassium humate and vinasse seem to have an impact on aril/fruit ratio, but few treatment differences in aril/fruit % were detected.

Principal component analysis (PCA) of various indicators of mean data

To visualize the relationship between the effect of Putassium humate, Vinasse and their combinations on all studied parameter, principal component analysis (PCA) was performed. The results were shown in **Figure 1**. The PCA showed a clear separation of the effects of the different treatments on the parameters. The positions on the biplot of the vectors corresponding to the different variables. It is seen that the three treatments, T9, T10 and T11 that are slightly above the positive horizontal axis, These are close to the directions defined by shoot length, P%, N%, leaves number, fruit set, K%, leaf area, and not far from the directions of yield, TSS, and aril/fruit %, which implies that they have higher than average scores on these variables. While, the treatments, whose positions are in the negative quadrants of diagram. These treatments have high scores on acidity and below average score all other parameters. On the other hand, shoot length, P%, N%, leaves number, fruit set, K%, leaf area are close together, reflecting their relatively large positive correlation. Also, those observations at the bottom of the diagram, (yield, TSS, and aril/fruit %) compared with (shoot length, P%, N%, leaves number, fruit set, K%, leaf area) meaning that these variable showed less values, whereas those at the top have high values for all treatments. The observation of acidity, whose isolated above the negative horizontal axis of the plot. The main distinguishing feature of

Table 7 Effect of potassium humate, vinasse and their combinations on Perfect Flower % and Fruit Set % of "Wonderful" pomegranate.

Treatment	Perfect Flower %		Fruit Set %	
	2018	2019	2018	2019
T1	18.57 fg	21.77 d	12.57 f	13.93 e
T2	20.23 f	20.50 d	14.60 e	15.93 d
T3	27.27 cd	26.53 c	16.17 de	17.67 c
T4	28.23 bc	32.70 ab	17.33 c	17.60 c
T5	17.83 g	20.63 d	15.23 e	16.20 d
T6	23.20 e	26.60 c	16.57 d	16.82 cd
T7	25.97 d	29.53 bc	17.83 c	19.10 b
T8	28.83 c	29.63 bc	19.03 b	20.83 a
T9	32.20 b	30.20 bc	20.25 a	21.17 a
T10	32.10 b	30.67 bc	19.80 ab	20.50 a
T11	31.90 b	34.10 ab	19.33 ab	21.20 a
T12	35.567 a	36.83 a	19.83 ab	21.35 a
Within each parameter data followed by the same letter indicate that values are similar (not significant) ($p < 0.05$)				

Table 8 Effect of potassium humate, vinasse and their combinations on Fruit weight (g)and Yield (kg)/Tree of "Wonderful" pomegranate.

Treatment	Fruit weight (g)		Yield (kg)/Tree	
	2018	2019	2018	2019
T1	334.00 d	332.90 d	13.50 h	11.80 h
T2	353.00 cd	353.00 c	16.50 g	17.33 g
T3	392.00 b	394.60 bc	20.87 e	20.97 e
T4	409.00 ab	400.10 b	21.37 e	22.67 d
T5	342.00 d	347.57 d	18.27 f	19.50 f
T6	380.67 b	382.47 b	21.70 de	22.33 d
T7	368.67 c	374.43 c	20.87 e	23.50 cd
T8	390.67 b	396.57 b	23.07 bcd	24.03 c
T9	397.00 b	402.93 b	22.30 cb	23.63 c
T10	408.33 ab	408.40 ab	24.47 b	26.37 a
T11	416.33 ab	414.77 ab	23.90 bc	26.20 b
T12	424.33 a	425.47 a	26.53 a	27.63 a
Within each parameter data followed by the same letter indicate that values are similar (not significant) ($p < 0.05$)				

Table 9 Effect of potassium humate, vinasse and their combinations on Aril/ Fruit %, TSS and Acidity of ""Wonderful"" pomegranate.

Treatment	Aril/ Fruit %		TSS		Acidity	
	2018	2019	2018	2019	2018	2019
T1	0.45 d	0.43 bc	14.68 b	14.37 b	1.85 a	1.83 a
T2	0.45 d	0.44 b	15.00 a	14.66 b	1.81 ab	1.77 bc
T3	0.48 c	0.43 bc	15.28 a	14.82 b	1.74 b	1.71 c
T4	0.52 ab	0.45 b	15.36 a	14.75 b	1.71 b	1.67cd
T5	0.47 cd	0.46 ab	15.36 a	14.87 ab	1.72 b	1.73 b
T6	0.51 b	0.45 b	15.29 a	14.85 ab	1.74 b	1.73 b
T7	0.48 c	0.43 bc	15.58 a	15.21 a	1.73 b	1.78 bc
T8	0.51 b	0.43 bc	15.41 a	15.07 a	1.70 b	1.72 cd
T9	0.52 ab	0.44 b	15.41 a	14.91 a	1.75 b	1.70 cd
T10	0.52 ab	0.44 b	15.40 a	14.95 a	1.71 b	1.70 cd
T11	0.53 a	0.47 a	15.65 a	15.27 a	1.73 b	1.69 cd
T12	0.54 a	0.48 a	15.73 a	15.09 a	1.70 b	1.66 d
Within each parameter data followed by the same letter indicate that values are similar (not significant) ($p < 0.05$)						

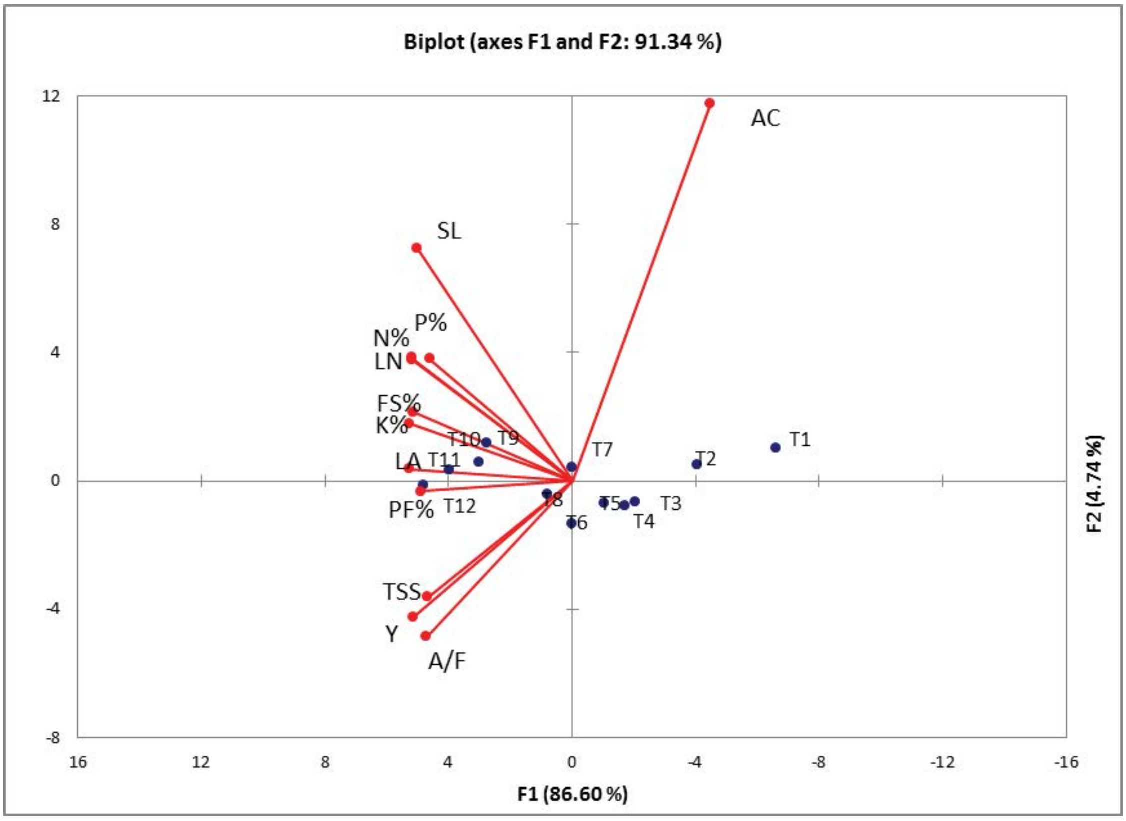

Figure 1 Principal component analysis of different indicators in growth and fruit quality of "Wonderful" pomegranate treated with potassium humate, vinasse. Where, SH- shoot length, LN- leaf number, LA- leaf area, N%- nitrogen%, P%- phosphorus%, K%- potassium%, PF%- perfect flower%, FS%- fruit set%, Y-yield, A/F%-aril/fruit% and AC-acidity.

this parameter is that t9, t10 and t11, treatments recorded the least value compared to all other treatments. But acidity gave the highest value with control whose isolated position in the top left of the plot also. There is a clear opposite correlation between acidity and (yield, TSS, aril/fruit%), since they are in a opposite quadrants.

Total Soluble Solids (TSS) and Titratable Acidity (TA)

Results show that all soil applications significantly increase TSS compared to control. Meanwhile, there were no significant treatment differences for TSS in 2018 season, but few treatment differences were detected in 2019 season **(Table 9)**. As for TA, all soil applications presented values lower than control in both seasons.

Results and Discussion

Vegetative growth

Vegetative growth parameters of the "Wonderful" pomegranate trees were improved by soil application of potassium humate and vinasse. The positive effects of potassium humate on plant growth were demonstrated on several crops [26-33]. The increase of plants growth, under application of potassium humate may be due to the positive effect root growth, biostimulant effects on structural and physiological changes in roots and shoots and beneficial effects of potassium humate on the microorganisms in the root zone, which led to increase plant nutrient uptake [22,23,34-37] Furthermore, potassium humate regulated the plasma membrane H+-ATPase activity and increased nitrogen use efficiency, biomass and photosynthesis of sugarcane,NO_3^- uptake in barley and pinus [38-42]. On the other hand, nutrient N,P,K,Ca and Mg accumulations in leaves were increased by treatment pineapple with potassium humate [43]. While, positive effects of Vinasse on improving vegetative growth were observed in several studied [44,45]. Role of Vinasse on enhancing plant growth is due to improvement biological soil characteristics by increasing bacterial population specially Actinomycetes and encourages prioritising bacteria involved in the cycle of nitrogen and iron [46]. Soil organic matter contents were increased and soil pH were decreased with increasing the application of vinasse. Nitrogen, phosphorus and potassium availability were enhanced with increasing vinasse application [47-50]. Vinasse increases the potassium concentration in sandy soils at depths of 20 - 40 cm [51].

Leaf nutrient concentrations

In this study, leaf nutrient concentrations indicated herein were positively impacted with the soil application of potassium humate or vinasse. Previous studies have reported that leaf nutrient concentrations were increased with humic substance application in several crops this enhancement can be due to the availability of nutrients in root-zone; and moreover, gradual increase of leaf nutrients is also due to the plant growth [52,53]. on the other hand, humic substance application has been resulted in decreased pH on the root surface, thus facilitating the uptake of H+/NO3 symports, availability of NH4+ and enhance N organic compounds in plants, by inhancemed activation of glutamine synthetase and glutamate synthase enzymes increased leaf aminoacids content. While, vinasse application increased plant nutrients concentration [54-57].

Reproductive characteristics

At tow study seasons, the perfect flower, fruit set, yield of "Wonderful" pomegranate trees increased under application of potassium humate and vinasse. Many researchers indicated that humic substance increased productivity of several crops such as onion, pomegranate Valencia orange and apricot [52,53,58,59]. Ghanbarpour E, et al. [60], found that Application of 6% kaolin and 2mll–1 of potassium humate together during the 14 day irrigation schedule of pomegranate resulted in the highest fruit weights. Humic substance improved yield and quality may due to some factors a- increased Water Use Efficiency (WUE) and nitrogen use efficiency (NUE) [34,40]. Similarly, the application of vinasse in Indonesia resulted in the best impact on flowering and bearing fruits of tomato plants [61-68]. While, El-Salhy AM, et al. [10], indicated that used feldspar combined with vinasse inhanced the fruits number and yield of mandarin trees. Also, residuals of sugar cane products (molasses and vinasses) increased significantly fruit length, fruit diameter, fresh fruit weight, T.S.S in pepper fruits as well as dry matter % in the both growing seasons [44]. Vinasse, resulted in improving fruit set and yield since it contain a lot of nutrients. Addition to, its roles in decreased soil pH which led to improving nutrients availability and increasing bacterial population.

Conclusion

The present study indicated that potassium humate and vinasse soil application could improve the vegetative growth of "Wonderful" pomegranate by increasing leaf nutrients concentration, which enhanced fruit set and yield. Overall, this study demonstrated that soil application of 40 gm potassium humate + 1000 ml vinasse resulted in the best effects on vegetative growth, yield and quality of "Wonderful" pomegranate under sandy soil conditions. Further, studies should be conducted in the future to know the effect of the combined addition of phenase and potassium humate on the physical, biological and chemical properties of sandy soils, as well as their effect on improving the efficiency of water and nutrient use.

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