**Co-addition of potassium humate and vinasse enhances growth and yield in "Wonderful" pomegranate under sandy soil**

**Hassan A. M. Ali1\**,* E. Abd El-Razek2 , M.M.M. Abd El-Migeed2 , Fatma El-Zahraa M. Gouda3**

**1**Hort. Dept., Fac. of Agric., Bani-Suef Univ., Egypt

2Pomology Department, National Research Centre, Dokki, Giza, Egypt.

**3**Pomology Department, Fac. Agric, Assiut University

**Corresponding author:** hassan.ahmed@agr.bsu.edu.eg (Hassan Ali)

**Abstract**

Although the recent cultivation of "Wonderful" pomegranate in large areas of sandy soil in Egypt, it product a low yield and quality. soil applications of potassium humate and vinasse could potentially be used in sandy soil, not only to improve soil nutrient status, but also 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 (10g, 20g, and 40 g per tree), vinasse (500 mL and 1000 mL ) and thier combinations (10g/ Humic acid + 500mL/vinasse, 20g/ Humic acid + 500mL/vinasse, 40g/ Humic acid + 500mL/vinasse, 10g/ Humic acid + 1000mL/vinasse, 20g/ Humic acid + 1000mL/vinasse, 40g/ Humic acid + 1000mL/vinasse) or water (control). vegetative growth were measaured, leaf (N, P and K) nutrient concentrations were determined and fruit were analyzed for perfect flwoer%, fruit set%, yield, , fruit weigth, aril/fruit% , TSS, and acidity. shoot lenght, leaves number and leaf area were significantly higher in response to all vinasse and potassium humate combinations . soil applications of 20g and 40g potassium humate with 500 mL or 1000 mL vinasse applications resulted in significant increases in leaf N, P and K concentrations. All combinations treatments resulted in significantly higher perfect flwoer%, fruit set%, yield, , fruit weigth, aril/fruit%. All soil applications resulted in significantly lower acidity.The potassium humate and vinasse combinations did not have a significant deffirences on TSS. The results suggest that soil applications of 20g and 40g potassium humate with 500 mL or 1000 mL vinasse could be used to improve growth and yield of "Wonderful" pomegranate under sandy soil.

**Key words:** Fruit set, Leaf area, Leaf nutrient status, Perfect flower, Potassium Humate, Vinasse, Yield,

**Introduction**

Pomegranate (Punica granatum L.), one of the known oldest edible fruits from the family Punicaceae, (da Silva et al., 2013). Super wealthy biochemical compositions like anthocyanins, vitamins, polyphenols and nutrients are causes for growing demands for pomegranate fruit (Jasuja et al., 2012; Ghavipour et al., 2017; Singh et al., 2018). Pomegranate grows well in arid and semi-arid regions, Due to its resisting to elevated temperature and drought (da Silva et al., 2013d), the development of certain stress avoidance and tolerance mechanisms (Rodríguez et al. 2012) and the high activity of SOD, GPOD and CAT enzymes wich play a positive role in controlling the ROS cellular level under drought conditions (Pourghayoumi et al. 2017). Nowadays Wonderful pomegrante is widely cultivated throughout the egyptian areas, particularly in the reclaimed areas, which are mostly sandy and calcareous soils. In general, sandy soils are characterised by depressed soil organic carbon, low (CEC) cation exchange capacity, exposed to stripping and nutrient leaching (Blanchart et al. 2007). Also, sandy soils suffer from poverty of all nutrients (Shermeen and Petra 2016), scarcity of water irrigation (Emanuele et al 2014), low capacity to hold water and nutrients (Wafaa et al 2016). The fate of vinasse, the primary wastewater from ethanol production, represents one of the main burdens of the sucro-alcohol industry in Egypt. vinasse is used as feedstock in biofuel production and as an agricultural fertilizer and soil conditioner. Vinasse has important qualities as an organic fertilizer, containing macro nutrients such as nitrogen, potassium, calcium sulfate and magnesium, and chelate organic material with micronutrients such as iron, manganese, zinc, and copper. Due to the high content of complex B vitamins and amino acids from yeast autolysis, vinasse is also used as a soil conditioner for the production of beneficial microorganisms in the soil. Sugarcane vinasse has a characteristic odor and dark color, high percentage of organic matter, low pH, high ash content and high chemical and biological oxygen demand (COD and BOD) (Fito et al., 2019). Due to its high organic load, there is no conventional treatment capable of reaching legal standards to allow its release into water bodies. Over the years, industries have been able to neutralize this polluting potential through fertigation, i.e. direct application of vinasse as a source of nutrients for sugarcane crops. This practice, applied at average doses of 150 m3 ha1 according to Brazilian legislation (CETESB, 2015), can enhance soil fertility and promote partial or total substitutionof chemical fertilization (Parsaee et al., 2019). Vinasse application to irrigation water of some crops (Wheat, Sugarcane, Pigeon, Pea) increased yield as compared to control (Pande 1994; Gounez 1996; Arafat and Yassen 2002).

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 (Jiang et al. 2012; Laime et al. 2011; Silva et al. 2006) . Vinase increases the diversity of bacteria in the soil and promotes species that participate in the nitrogen and iron cycles (Omori et al. 2016).Humic acid is a complex organic material derived from the decomposition of plant matter that exists as a mixture of soluble substances. These organic supplements can be used to regulate hormone levels, improve nutritional uptake, and enhance stress tolerance (Khattab et al. 2012; Lotfi et al. 2015; Moghadam 2015). Humic acids have recently been shown to improve soil fertility and increase plant growth and yield (Canellas et al. 2015). Furthermore, application of HS positively influences root growth, especially lateral root emergence and root hair initiation which are involved in plant nutrient uptake (Canellas and Olivares, 2014; Puglisi et al., 2013). 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.

1. **Materials and methods**
	1. **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 Wonder Full pomegranate trees. The trees were spaced on 4× 6 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. Treatments consisted of soil application of potassium humate (10g, 20g, and 40 g per tree), vinasse (500 mL and 1000 mL ) and there combinations (10g/ Potassium humate + 500mL/vinasse, 20g/ Potassium humate + 500mL/vinasse, 40g/ Potassium humate + 500mL/vinasse, 10g/ Potassium humate + 1000mL/vinasse, 20g/ Potassium humate + 1000mL/vinasse, 40g/ Potassium humate + 1000mL/vinasse). Recommended dose of mineral fertilizers was 625 g N + 250 g P + 250 g K and 10kg cattle manure during both seasons for each tree. All treatments were applied on march at the beginning of growth season. 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:

* 1. **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.

* 1. **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 fruit quality expressed as average fruit weight (g), diameter (cm) and length (cm). In juice of each fruit sample, total soluble solids (TSS) percentage was determined by a hand refractometer and the percentage of acidity was measured according to A.O.A.C. (2000). An additional random sample of up to five unsplit fruit per data tree was collected at harvest to determine total aril mass and the mass of 100 randomly selected arils per fruit.

**2.4. Leaf mineral content:**

Nitrogen, phosphorus and potassium was determined according to Evenhuis and Dewaard (1980).

 **3. 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.

 **3.1. Vegetative growth**

Table 4 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 season 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.

**3.2. Leaf nutrient concentrations**

Significant treatment effects were detected for leaf N, P and K concentrations (Table 5). 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 6), 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 (Table 1), 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. In both seasons all Potassium humate and Vinasse treatments resulting in significantly higher leaf K concentrations than the control.

**3.3. 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 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.

**3.4. Yield, fruit weight and aril/fruit %**

Various soil applications had significant impact on pomegranate yield (Table 8,9 ). 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 significantly differences.

Regarding fruit weight was affected significantly with the potassium humate and vinasse applications when compared to control (table 8,9 ). 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.

**3.5. 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 Fig.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 scores 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 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**.**

 **3.5. 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.

1. **Discussion**
	1. **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 (Canellas et al., 2013; Caporale et al. 2018; Delfine et al., 2005; Ekin, 2019; El-Shall et al.2010; Esringu et al., 2016; Liala, Haggag et al. 2015; Olivares et al., 2015; Puglisi et al., 2013; Schoebitz et al., 2016; Suh et al., 2014; Zhou et al. 2019). 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 (Canellas et al. 2015; Canellas and Olivares, 2014; Dobbss et al., 2007; Puglisi et al., 2008;2009;2013) Furthermore, potassium humate regulated the plasma membrane H+-ATPase activity (Canellas et al., 2002; Busato et al. 2010 ) and increased nitrogen use efficiency, biomass and photosynthesis of sugarcane (Leite et al. 2020), NO−3 uptake in barley (Albuzio et al. 1986) and pinus (Panuccio et al. 2001) . On the other hand, nutrient N,P,K,Ca and Mg accumulations in leaves were increased by treatment pineapple with potassium humate (Bladotto et al. 2009). While, positive effects of Vinasse on improving vegetative growth were observed in several studied (Haggag Liala et al. 2015; Gaafar Mona et al. 2019; El-Salhy, et al., 2017; Kusumaningtyas et al. 2017; Maradiaga-Rodriguez et al. 2017). Role of Vinasse on enhancing plant growth is due to improvement biological soil characteristics by increasing bacterial population specially Actinomycetes (Prado et al. 2013; Omori et al. 2016) and encourages prioritising bacteria involved in the cycle of nitrogen and iron (Omori et al. 2016). Soil organic matter contents were increased (Arafat and Yassen, 2002; Madejon et al., 2001) and soil PH were decreased (El Leboudi et al., 1988) with increasing the application of vinasse. Nitrogen, phosphorus and potassium availability were enhanced with increasing vinasse application (Delin and Engstrom,2010; Osman Mona et al. 2016; Vadivel et al., 2014). Vinasse increases the potassium concentration in sandy soils at depths of 20 - 40 cm (De Carvalho et al. 2011).

* 1. **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 (Bettoni et al. 2016; El-Shall et al. 2010; Haggag Liala, et al. 2015; Leite et al. 2020; Mansour Noha 2018), 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. 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 (Nardi et al., 2000; Quaggiotti et al., 2004), availability of NH4+ and enhance N organic compounds in plants, by inhancemed activation of glutamine synthetase and glutamate synthase enzymes (Ertani et al., 2011), increased leaf aminoacids content (Schiavon et al., 2010). While, vinasse application increased plant nutrients concentration (El-Salhy, et al., 2017; Osman Mona et al. 2016; Gaafar Mona et al. 2019; Osman Mona 2010

* 1. **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 (Bettoni et al. 2016), pomegranate (Mansour Noha 2018)Valencia orange (Khalil Hoda and El-Ansary 2015), kiwifruit (Mahmoudi et al. 2013) and apricot (Fathy et al. 2010; Mahmoudi et al. 2013). Ghanbarpour et al. 2018 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) (Zhou et al. 2019) and nitrogen use efficiency (NUE) (Leite et al. 2020). Similarly, the application of vinasse in Indonesia resulted in the best impact on flowering and bearing fruits of tomato plants (Kusumaningtyas et al. 2017). While, El-Salhy, et al., 2017 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(Osman Mona et al. 2016). 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.

**Supplementary data**

There is no

**Author contribution**

Hassan A. M. Ali: designed the experiment.;Wrote the paper

Fatma El-Zahraa M. Gouda: performed the lab research analysis.

E. Abd El-Razek and M.M.M. Abd El-Migeed: Performed the experiments; Analyzed and interpreted the data.

All authors agreed on final manuscript.

**Acknowledgements**

The authors thanked the management of the Experimental Research Station of the National Research Centre, Nubaria, for facilitating research and thanked the Department of pomology, faculty of Agriculture, Assuit University, Assiut, Egypt for providing laboratory analysis.

**Declaration of competing interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**Data availability**

The data that support the findings of this study are available from the corresponding author.

**References**

A.O.A.C, 2000. Official Methods of Analysis, 17th ed. As-sociation of Official
Analytical Chemists, USA.

Albuzio A., Ferrari, G., Nardi, S., 1986. Effects of humic substances on nitrate uptake and assimilation in barley seedlings. Can J Soil Sci 66:73l–736l

Arafat, S., Yassen, A. E., 2002. Agronomic evaluation of fertilizing efficiency of vinasse. 17th World Cong.,Soil Sci. Symp.14 : 1-6 .

Baldotto, L. B. E., Baldotto, M.A., Canellas, L. P., Bressan-Smith, R., Olivares, F.L., 2010.Growth promotion of pineapple ‘Vitória’ by potassium humates and Burkholderia spp. during acclimatization. R Bras Ci Solo.34, (1) 593–600.

Berthelsen, S., Noble, A. D., Ruaysoongnern, S., Huan, H., Yi, J., 2007. Addition of clay based ameliorants to light textured soils to reduce nutrient loss and increase crop productivity. In: Management of tropical sandy soils for sustainable development. Proceedings of the International Conference on the Management of tropical sandy soils, Khon Kaen, Nov. 2005. FAO Regional Office for Asia and the Pacific, Bangkok, pp 373–382

Bettoni, Marcelle M., Mogor, Á. F., Pauletti, V., Goicoechea, N., Aranjuelo, I., Garmendia, I., 2016. Nutritional quality and yield of onion as affected by different application methods and doses of humic substances, Journal of Food Composition and Analysis, 51, 37-44. https://doi.org/10.1016/j.jfca.2016.06.008.

Busato, J.G., Zandonadi, D.B., Dobbss, L.B., Façanha, A.R., Canellas, L.P., 2010. Humic substances isolated from residues of sugar cane industry as root growth promoter. Sci. Agric. 67, 206–212.

Canellas, L.P., Balmori, D.M., M edici, L.O., Aguiar, N.O., Campostrini, E., Rosa, R.C., Façanha, A.R., Olivares, F.L., 2013. A combination of humic substances and Herbaspirillum seropedicae inoculation enhances the growth of maize (Zea mays L.). Plant Soil 366, 119–132.

Canellas, L.P., Olivares, F.L., 2014. Physiological responses to humic substances as plant growth promoter. Chem. Biol. Tec. Agric. 1, 1–11.

Canellas, L.P., Olivares, F.L., Aguiar, N.O., Jones, D.L., Nebbioso, A., Mazzei, P., Piccolo, A., 2015. Humic and fulvic acids as biostimulants in horticulture. Sci. Hortic-Amsterdam 196, 15-27.

Canellas, L.P., Olivares, F.L., Okorokova-Façanha, A.L., Façanha, A.R., 2002. Potassium humates isolated from earthworm compost enhance root elongation, lateral root emergence: and plasma membrane H+-ATPase activity in maize roots. Plant Physiol. 130, 1951–1957.

Canellas, L.P., Olivares, F.L., Okorokova-Façanha, A.L., Façanha, A.R., 2002. Potassium humates isolated from earthworm compost enhance root elongation, lateral root emergence: and plasma membrane H+-ATPase activity in maize roots. Plant Physiol. 130, 1951–1957.

Da Silva, J.A.T., Rana, T.S., Narzary, D., Verma, N., Meshram, D.T., anade, S.A., 2013d. Pomegranate biology and biotechnology: a review. Sci. Hortic. 160, 85–107. https:// doi.org/10.1016/j.scienta.2013.05.017.

DE CARVALHO, L., MEURER, I., DA SILVA JUNIOR, C. A., SANTOS, C. F.B., LIBARD, P. L., 2014. Spatial variability of soil potassium in sugarcane areas subjected to the application of vinasse. Anais da Academia Brasileira de Ciências (2014) 86(4),1999-2011. <http://dx.doi.org/10.1590/0001-3765201420130319>

Delfine, S., Tognetti, R., Desiderio, E., Alvino, A., 2005. Effect of foliar application of N and potassium humates on growth and yield of durum wheat. Agron. Sustain. Dev. 25, 183–191.

Delin, S., Engstrom, L., 2010. Timing of organic fertilizer application to synchronise nitrogen supply with crop demand "Acta Agriculturae" Scandinavica, Section B- soil Plant Sci. 60, 78- 88.

Dobbss, L.B., Medici, L.O., Peres, L.E.P., Pino-Nunes, L.E., Rumjanek, V.M., Façanha, A. R., Canellas, L.P., 2007. Changes in root development of Arabidopsis promoted by organic matter from oxisols. Ann. Appl. Biol. 151, 199–211.

Ekin, Z., 2019. Integrated use of potassium humate and plant growth promoting rhizobacteria to ensure higher potato productivity in sustainable agriculture. Sustainability 11, 3417.

El- Leboudi, A., Ibrahim, S., Abdel-Moez, M., 1988. A trial for getting benefit from organic wastes of food industry: I. effect on soil properties. Egypt J. Soil Sci. 28,289-396.

El-Rhman, I. A., 2010. Physiological studies on cracking phenomena of
pomegranates. J Appl Sci Res 6, 696–703

El-Salhy, A.M., Abdel-Galil, H. A., , Ebtsam- Badawy, F.M., and Eman-Abou-Zaid, A.A., 2017 Effect of Different Potassium Fertilizer Sources on Growth and Fruiting of Balady Mandarin Trees. Assiut J. Agric. Sci. 48 (1), 202-213.

Eman -Abd-Ella, E.K., Mervate, S.S., Wafaa, A.Z. (2010) Effect of some organic and mineral fertilizer applications on growth and productivity of pomegranate trees. Alexandria Science Exchange Journal, 31 (3), 296 – 304Albuzio A, Ferrari G, Nardi S (1986) Effects of humic substances on nitrate uptake and assimilation in barley seedlings. Can J Soil Sci 66,73l–736

Emanuele, F., McDonald, S., Rehab-Osman., 2014. Water Scarcity and Irrigation Efficiency in Egypt. On Global Economic Analysis “New Challenges in Food Policy, Trade and Economic Vulnerability”, June 18- 20, 2014, Dakar.

Ertani, A., Francioso, O., Tugnoli, V., Righi, V., Nardi, S., 2011. Effect of commercial lignosulfonate-humate on Zea mays L. Metabolism J Agri Food Chem 59,11940–11948

Esringu, A., Kaynar, D., Turan, M., Ercisli, S., 2016. Ameliorative effect of potassium humate and plant growth-promoting rhizobacteria (PGPR) on Hungarian vetch plants under salinity stress. Commun. Soil Sci. Plant Anal. 47, 602–618

Evenhuis, B., Dewaard, P.W., 1980. Principles and practices in plant analysis. FAO .Soil Bull. 38 (1),152-163.

Fathy, M. A., Gabr, M. A., El Shall, S. A., 2010. Effect of potassium humate treatments on ’Canino’ apricot growth, yield and fruit quality. N Y Sci J 3,109–115

Gardener, W. H., 1986. Water content. Klute, A. (Editor), Methods of soil analysis, Part 1, 2nd edition Agronomy Monograph No.9, ASA and SSSA, Madison, WI, USA, 493-54.

Gee, G. W., Bauder, J. W., 1986. Particle-size analysis: core method. Klute, A. (Editor), Methods of soil analysis, Part 1, 2nd edition Agronomy Monograph No.9, ASA and SSSA, Madison, Wisconsin,USA,383-411.

Ghavipour, M., Sotoudeh, G., Tavakoli, E., Mowla, K., Hasanzadeh, J., Mazloom, Z., 2017. Pomegranate extract alleviates disease activity and some blood biomarkers of inflammation and oxidative stress in heumatoid arthritis patients. Eur. J. Clin. Nutr. 71, 92–96. <https://doi.org/10.1038/ejcn.2016.151>.

Glozer, K., Ferguson, L., 2008. Pomegranate Production in Afghanistan. University of California, Davis. College of Agricultural and Environmental Sciences, pp. 32.

Hoda-Khalil, A., El-Ansary, D.O. 2015. Impacts of deficit irrigation and potassium humate application on growth, yield and fruit quality of Valencia orange trees. Egypt. J. Hort. 42, (1), 441-452

Jasuja, N.D., Saxena, R., Chandra, S., Sharma, R., 2012. Pharmacological characterization and beneficial uses of Punica granatum. Asian J. Plant Sci. 11, 251–267. <https://doi>. org/10.3923/ajps.2012.251.267.

Jose M. l., Pavithra S. P. A., Ignacio. A. C., Gangam M. H., Leila, M., Paulo, C.O., T., d, Vara Prasad, P.V., John Sunoj, S.V., 2020. Co-addition of humic substances and potassium humates with urea enhances foliar nitrogen use efficiency in sugarcane (Saccharum officinarum L.). Heliyon 6 (2020) e05100. https://doi.org/10.1016/j.heliyon.2020.e05100

Liala, F.Haggag, Mustafa, N.S., Shahin, M.F.M., Hassan H.S.A. Fikria, Khalil, H., Amira, A. Fouad, 2015. Effect of NPK, Potassium humate, Vinasse and Soyabean Amino Acid on Growth Performance and Mineral Content of Fig “White Adci” Seedlings. Middle East J. Agric. Res., 4(4) 914-918

Madejon, E., Lopez, R., Murillo, j. M., Cabrera, F. 2001. Agricultural use of three (sugar- beet) vinasse composts. Effect of crops and chemical properties of a cambisol soil in the Guadalquivir river vally (SW Spain) Agric. Ecosyst. Environ, 84, 53-65.

Maradiaga-Rodriguez, W. D., Pêgo-Evangelista, A. W., Júnior, J. A., and Costa, R. B., 2018. Effects of vinasse and lithothanmium application on the initial growth of sugar cane (Saccharum sp. cv. RB 86-7515) irrigated and not irrigated. Acta Agron. 67 (2), 252-257 <https://doi.org/10.15446/acag.v67n2.66082>

Mona S. Gaafar, Nahed M. M. EL-Shimi and M. M. Helmy. EFFECT OF FOLIAR AND SOIL APPLICATION OF SOME RESIDUALS OF SUGAR CANE PRODUCTS (MOLASSES AND VINASSES) WITH MINERAL FERTILIZER LEVELS ON GROWTH, YIELD AND QUALITY OF SWEET PEPPER. Menoufia J. Plant Prod., Vol. 4October (2019): 353 – 373

Nardi, S., Pizzeghello, D., Gessa, C., Ferrarese, L., Trainottic, L., Casadoro, G., 2000. A low molecular weight humic fraction on nitrate uptake and protein synthesis in maize seedlings. Soil Biol Biochem 32, 415–419

Noha A.I. Mansour, 2018. Promising Impacts of Potassium humate and Some Organic Fertilizers on Yield, Fruit Quality and Leaf Mineral Content of "Wonderful" Pomegranate (Punica granatum L.) Trees. Egypt. J. Hort. 45(1), 105 - 119

Oktafiani, Ratna Dewi Kusumaningtyas, , Hartanto, D., Handayani, P. A., 2017. Effects of Solid Vinasse-Based Organic Mineral Fertilizer on Some Growth Indices of Tomato Plant. JBAT 6 (2), 190-197. DOI: [10.15294/jbat.v6i2.12507](https://www.researchgate.net/deref/http%3A//dx.doi.org/10.15294/jbat.v6i2.12507?_sg%5B0%5D=q8-bF81NK22-0a4_LBTKJdJueBBoOiFzWfBh3rGu3Dv14nLD1ykZGJBzt-RMVSs68dnzG5-05gTiPHVpgH23ebD5-w.P44-sY5RrakjshGsbiEj5HXhpL797yGKA_jVahFzdG9kShXHn_nta87e_bK8qMbRCsMMZ54gfEtnG2EtXp1DIw)

Olivares, F.L., Aguiar, N.O., Rosa, R.C.C., Canellas, L.P., 2015. Substrate biofortification in combination with foliar sprays of plant growth promoting bacteria and humic substances boosts production of organic tomatoes. Sci. Hortic. 183, 100–108.

Omori, W. P., De Camargo, A. F., Goulart, K. C. S., Lemos, E. G. de Macedo, and de Souza, J. A. M., 2016. Influence of Vinasse Application in the Structure and Composition of the Bacterial Community of the Soil under Sugarcane Cultivation. International Journal of Microbiology Volume, Article ID 2349514, 11 pages <http://dx.doi.org/10.1155/2016/2349514>

Panuccio, M. R., Muscolo, A., Nardi, S., 2001. Effect of humic substances on
nitrogen uptake and assimilation in two species of pinus. J Plant Nutr 24, 693–704

Prado, R., de Mello, Caione, G., Campos C. N. S., 2013. Filter Cake and Vinasse as Fertilizers Contributing to Conservation Agriculture. Applied and Environmental Soil Science Volume, Article ID 581984, 8 pages <http://dx.doi.org/10.1155/2013/581984>

Puglisi E, Fragoulis, G, Del, R. A. A., Spaccini, R., Piccolo, A., Gigliotti, G., SaidPullicino, D., Trevisan, M., 2008. Carbon deposition in soil rhizosphere following amendments with compost and its soluble fractions, as evaluated by combined soil–plant rhizobox and reporter gene systems. Chemosphere 73, 1292–1299

Puglisi, E., Fragoulis, G., Ricciuti, P., Cappa, F., Spaccini, R., Piccolo, A., Trevisan, M., Crecchio, C., 2009. Effects of a potassium humate and its size-fractions on the bacterial community of soil rhizosphere under maize (Zea mays L.). Chemosphere 77, 829–837

Puglisi, E., Pascazio, S., Suciu, N., Cattani, I., Fait, G., Spaccini, R., Crecchio, C., Piccolo, A., Trevisan, M., 2013. Rhizosphere microbial diversity as influenced by humic substance amendments and chemical composition of rhizodeposits. J. Geochem. Explor. 129, 82–94.

Quaggiotti, S., Ruperti, B., Pizzeghello, D., Francioso, O., Tugnoli, V., Nardi, S., 2004. Effect of low molecular size humic substances on nitrate uptake and expression of genes involved in nitrate transport in maize (Zea mays L.). J Exp Bot 55,803–813

Schiavon, M., Pizzeghello, D., Muscolo, A., Vaccaro, S., Francioso, O., Nardi, S., 2010. High molecular size humic substances enhance phenylpropanoid metabolism in maize (Zea mays L.). J Chem Ecol 36:662–669

Singh, B., Singh, J.P., Kaur, A., Singh, N., 2018. Phenolic compounds a beneficial phytochemicals in pomegranate (Punica granatum L.) peel: a review. Food Chem. 261, 75–86. <https://doi.org/10.1016/j.foodchem.2018.04.039>.

Suh, H.Y., Yoo, K.S., Suh, S.G., 2014. Tuber growth and quality of potato (Solanum tuberosum L.) as affected by foliar or soil application of fulvic and potassium humates. Hortic. Environ. Biotechnol. 55, 183–189.

Tahir S., and Marschner, P., 2016. Clay addition to sandy soil effect of clay concentration and ped size on microbial biomass and nutrient dynamics after addition of low C/N ratio residue. Journal of Soil Science and Plant Nutrition, 16 (4), 864-875.

Vadivel, R., Paramjit, S. M., Suresh, K. P., Yogeswar, Nageshwar, S. R.D.V.K., Avinash, N., 2014. Significance of vinasses waste management in agriculture and environmental quality- Review.
African J. Agric. Res. 9, 2862-2873.

Wafaa, M. T. El-etr, Aly, E. M., Eid, T. A., 2016. Effect of Irrigation
Regime and Natural Soil Conditioner on Crop Productivity in Sandy Soil. Egypt. J. Soil. Sci.Vol.56, No. 2, pp.327-350.

Zhoua, L., Monrealc, C. M., Xu, S., McLaughlinc, N. B., Zhanga, H., Haoe, G., Liu, J., 2019. Effect of bentonite-potassium humate application on the improvement of soil structure and maize yield in a sandy soil of a semi-arid region. Geoderma 338,269–280. <https://doi.org/10.1016/j.geoderma.2018.12.014>

Pourghayoumi, M., Rahemi, M., Bakhshi, D., Aalami, A., Kamgar-Haghighi, A. A., 2017. Responses of pomegranate cultivars to severe water stress and recovery: changes on antioxidant enzyme activities, gene expression patterns and water stress responsive metabolites/. Physiol Mol Biol Plants 23(2), 321–330 DOI 10.1007/s12298-017-0435-x

Rodríguez, P., Mellisho, C.D., Conejero, W., Cruz, Z. N., Ortuno, M. F., Galindo, A., Torrecillas, A., 2012. Plant water relations of leaves of pomegranate trees under different irrigation conditions. Environmental and Experimental Botany 77, 19–24. doi:10.1016/j.envexpbot.2011.08.018

|  |
| --- |
| Table 1.Soil physical properties. |
| Depth(cm) | Particle size distribution, % | TextureClass | FC | PWP | AW | BD(g/cm)³ | TP(%) |
| C. Sand | F. Sand | Silt | Clay |  | (% on weight basis) |  |  |
| 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 |

**FC: Field capacity; PWP: Permanent wilting point; AW: Available water; B.D: Bulk density, and TP: Total porosity.**

 Table 2. Soil chemical properties

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Depth,(cm) | pH1:2.5 | EC,dS/m | Soluble Cations, mg/L | Soluble Anions, mg/L |
| Ca++ | Mg++ | Na+ | K+ | CO3-- | HCO3- | SO4-- | 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 |

Table 3. Some chemical properties of irrigation water.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| pH | EC, dS/m | Soluble cations, mg/L | Soluble anions, mg/L | SAR |
| Ca++ | Mg++ | Na+ | K+ | CO3-- | HCO3- | SO4-- | Cl-- |  |
| 7.20 | 0.36 | 0.75 | 0.23 | 2.50 | 0.11 | 0.00 | 0.90 | 0.33 | 2.52 | 3.67 |

Table 4. Average chemical composition of the vinasse

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Ph | Ec s/m-1 | Organic carbon | Organic mater | Density g/ml | N% | P% | K% |
| 4.2 | 20 | 3.6 | 6.2 | 1.29 | 0.23 | 0.39 | 5.9 |

**Table 5. Effect of potassium humate, vinasse and their combinations on vegetative growth of ""Wonderful"" pomegranate.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | Shoot length (cm) |  | Leaf No. |  | Leaf area (cm)2 |
| Treat. |  | 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- 10g Potassium humate ; T3- 20g Potassium humate; T4- 40g Potassium humate; T5-500 ml Vinasse; T6-1000 ml Vinasse; T7- 10g Potassium humate +500ml Vinasse; T8- 10g Potassium humate +1000 ml Vinasse;; T9- 20g Potassium humate +500ml Vinasse;; T10- 20g Potassium humate +1000 ml Vinasse;; T11- 40g Potassium humate +500ml Vinasse; T12- 40g Potassium humate +1000ml Vinasse.

**Table 6. Effect of potassium humate, vinasse and their combinations on leaf nutrients content of ""Wonderful"" pomegranate.**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **N%** | **P%** | **K%** |
| **Treat.** | **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 7. Effect of potassium humate, vinasse and their combinations on Perfect Flower % and Fruit Set % of "Wonderful" pomegranate**.

|  |  |  |
| --- | --- | --- |
|  | **Perfect Flower %** | **Fruit Set %** |
| **Treat.** | **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.**

|  |  |  |
| --- | --- | --- |
|  | **Fruit weight (g)** | **Yield (kg)/Tree** |
| **Treat.** | **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.**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Aril/ Fruit %** | **TSS** | **Acidity** |
| **Treat.** | **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) |

**Fig. (1).** Principal component analysis of different indicators in growth and fruit quality of "Wonderful" pomegranate treated withpotassium 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%, AC-acidity.