Vegetative Growth, Yield, and Fruit Quality of Guava (*Psidium guajava* L.) cv. 'Maamoura' as Affected by Some Biostimulants

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The present study was performed during two successive seasons 2019 and 2020 to investigate the effect of the soil application of fulvic acid (FA), seaweed extract (SE), and their different combinations on vegetative growth, yield, and fruit quality of six-years-old guava (*Psidium guajava* L.) cv. 'Maamoura'. The trees were planted 4 × 4 m^2 apart in clay soil under a flood irrigation system. They were treated three times starting from mid-March with one-month intervals with the following treatments: Control (water only), 3 and 4 g/L FA, 3 and 4 g/L SE, and their different combinations; 3 g/L FA + 3 g/L SE, 3 g/L FA + 4 g/L SE, 4 g/L FA + 3 g/L SE, and 4 g/L FA + 4 g/L SE. The results clearly showed that the application of FA or SE solely or in combinations increased shoot length and diameter, as well as leaf chlorophyll compared with the control. The treatments also increased fruit set percentage, fruit yield, and fruit physical and chemical characteristics such as fruit weight, size, TSS%, total reduced and non-reduced sugars, as well as leaf mineral content, while they decreased the fruit acidity compared with the control in the two seasons.

Keywords: Guava; Seaweed extract; Fulvic acid; Yield; Fruit quality; Biostimulant

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INTRODUCTION

Guava (*Psidium guajava* L.) belongs to the family of Myrtaceae, which is an important subtropical fruit crop. This fruit is rich in ascorbic acid and pectin and has a moderate content of calcium, phosphorus, and other vitamins (Lall *et al.* 2017).

The application of chemical fertilizers is important in increasing the yield of crops and improving the food security effectively (Ni *et al*. 2011; Duan *et al*. 2016; Suhag 2016). However, the excessive usage and the insistence on the use of chemical fertilizers has created some environmental problems, such as soil deterioration, water pollution, destruction of the soil ecology, and reduced fertility of the soil; thus it causes harmful influences on human health (Liu *et al.* 2013; Stuart *et al*. 2014; Youssef and Eissa 2014; Sierra *et al*. 2015; Smith, and Siciliano 2015; Suhag 2016; Uphoff and Dazzo 2016). So, the implementation of the organic substances instead of chemical fertilizers is necessary to raise and maintain soil fertility and health as well as food quality (Suhag 2016; Hui *et al*. 2017; Ning *et al*. 2017; Wanga *et al*. 2018).

Fulvic acid (FA) plays a crucial role in promoting the photosynthesis process. It minimizes the opening of stomata and the transpiration rate, thus minimizing the loss of water under well-watered and also drought conditions (Lu and Beamish 2001; Li *et al.* 2005; Anjum *et al.* 2011; Huang *et al.* 2020). Besides, the use of FA promotes the growth of roots (Canellas *et al.* 2002) thereby increasing the uptake of nutrients (Razavi and BahramParvar 2007; Yang *et al.* 2013; Priya *et al.* 2014; El-Helaly 2018; Justi *et al.* 2019; Wang *et al.* 2019). It was found by Zimmerli *et al*. (2008) that FA has the ability to remain in the soil under high salt concentration as well as a large range from pH. Wassel *et al*. (2014) stated that FA has the ability to promote the vegetative growth in plants because it can raise the plants' hormones, such as indole acetic acid, gibberellic acid, and cytokines, as well as antioxidants and vitamins. El-Kenway (2017) performed a study during 2015 and 2016 seasons on 'Thompson seedless' grapevines to investigate the influence of the spray of FA at 500 ppm three times, at the beginning of the growth, after berry with one week set, and at the start of the ripening. The obtained results showed that the application of FA improved the length of shoots, leaf area, and leaf content from total chlorophyll, as well as minerals from nitrogen, phosphorous, and potassium. Moreover, it also raised the obtained yield and fruit physical and chemical characteristics in terms of weight of clusters and berry, berry cohesion, soluble solids percentage, while it reduced the percentages of juice acidity, weight loss of clusters, deterioration, and breaking down of berries compared with control in both experimental seasons. In addition, it was reported that FA enhanced the chlorophyll leaf content, roots dry matter, carbohydrates, and carotenoids (El-Helaly 2018).

Seaweed extract (SE) has a good effect on the time of flowering because of balanced carbohydrate and nitrogen content (Neumann and Zur Nieden 2001) and it contains a large variation of plant growth regulators such as auxins and cytokinin (Zhang and Ervin 2004), as well as organic compounds and polysaccharides (Sivasankari *et al.* 2006; Rioux *et al.* 2009). The application of SE to the soil increased the organic carbon, and the uptake of nitrogen, phosphorus, potassium calcium, sulfur, magnesium, zinc, manganese, and iron (Mancuso *et al.* 2006; Rathore *et al.* 2009; Zodape *et al.* 2011) and water content (Kocira *et al.* 2018). It was found that the foliar spraying of seaweed extracts (SE) was beneficial for four apple cultivars, 'Gala Must', 'Golden Delicious', 'Jonagold Decosta', and 'Elstar'. The spraying was done at the end of bloom, and subsequently four times at intervals of 4 weeks, the last time being about 4 weeks before harvest. Both preparations encouraged shoot and leaf growth, improving the quality of flower formation, extending the time of blooming, as well as raising the percentage of fruit set percentage and the fruit size (Basak 2008). SE could be applied in low quantities as soil or foliar spraying, and it can improve the resistance to insect and pathogen attack and abiotic stress such as drought, frost, salinity, and high or low temperature (Khan *et al.* 2009; Craigie 2011; Battacharyya *et al*. 2015; Elansary *et al.* 2016). Because of the high content of SE from nutrients, hormones, amino acids, vitamins, and antioxidants, it can be defined as a stimulant, which can increase the cell division in plants (Prasad *et al.* 2010; Colavita *et al.* 2011). de Sousa *et al*. (2019) reported that spraying SE on 'Gala' apple cultivars at 0.1, 0.2, 0.3, 0.4, and 0.6% increased the percentage of fruit set, number, weight, and length of fruits compared with control, and the prior treatment was 0.3%. The literature suggests that SE plays an important role in raising the tolerance of stresses, the absorption of minerals, growth, and yield. In addition, it has been shown to reduce seed dormancy and enhance root systems and flowering (Ali *et al*. 2019).

Therefore, this study was conducted to demonstrate the possibility of depending on FA and SE as natural sources for the nutrition of fruit trees and safe alternatives to alleviate the undesirable effects of chemical fertilizers in increasing water, soil, and environment pollution.

EXPERIMENTAL

Materials

This study was conducted at a private orchard located at Abou El Matamir region, Beheira, Governorate, Egypt over two successive seasons 2019 and 2020. The study investigated the effect of the soil application of FA (X-HUMATE Fulvic Acid - 100% Water Soluble Powder- Humate (Tianjin) International Ltd., Tianjin, China), SE (seaweed extract composition: Alginic acid 15-18%, Organic matter 45-55%, Potassium K2O 16%, N 2.5-3%, P2O5 4.5-5% and Water solubility 99.1% - Hebei Hontai Biotech Co., Ltd., Shijiazhuang, Hebei, China), and their combinations on vegetative growth, yield, and fruit quality of six-year-old guava (*Psidium guajava* L.) cv. 'Maamoura'.

The trees were about 200 cm in height and were planted 4 m × 4 m apart in clay soil under a flood irrigation system. The physicochemical characteristics of the experimental soil according to Sparks *et al.* (2016) are presented in Table 1. A total of 80 trees, similar in vigor and size, were randomly chosen, arranged in a randomized complete block design (RCBD), and subjected to the same applied agricultural practices in the field during the two seasons. The following treatments of a Control (water only), FA at 3 and 4 g/L, and SE at 3 and 4 g/L, as well as their combinations – 3 g/L FA + 3 g/L SE, 3 g/L FA + 4 g/L SE, 4 g/L FA + 3 g/L SE, and 4 g/L FA + 4 g/L SE – were applied to the trees three times by solubilizing SE or FA. This was done in separate containers and by adding the material to the trees by hand. The study began in mid-March with application intervals of one month. In total, 2 L of solution for each tree/replicate were employed.

Table 1. Physicochemical Properties for the Soil of the Experiment

Depth (cm)	Texture	pH	Electrical Conductivity (EC) (ds/cm)	N (%)	P (%)	K (%)	Fe (mg/L)	Zn (mg/L)	Mn (mg/L)
0 to 60	Clay	7.6	0.2	24.50	26.82	34.25	0.35	0.13	0.02

Vegetative growth parameters

Starting from the vegetative season, four shoots from each side of each replicate/tree were selected and labeled, whereas, at the end of each growing season, the shoot length and diameter were measured in centimeters. The average leaf area (cm^2) was determined using the following equation as reported by Demirsoy (2009),

$$LA = 0.70\ (L\ x\ W) - 1.06 \quad (1)$$

where LA is a leaf area (cm^2), L is the maximum length of leaf (cm), and W is the maximum width of the leaf (cm).

Total chlorophyll (μ Mol/m^2) in the fresh leaves was determined as SPAD units by using a Minolta chlorophyll meter (SPAD - 502; Konica Minolta, Osaka, Japan).

Fruit set percentage, fruit yield, and fruit quality

From each side of each tree/replicate, four branches were chosen and labeled carefully in March 2019 and 2020. The number of flowers on each branch was calculated, and then the percentage of fruit set was estimated according to Eq. 2:

$$\textbf{Fruit set}\ (\%) = \frac{\textbf{\textit{Number of set fruitlets}}}{\textbf{\textit{Number of total flowers}}} \times \mathbf{100} \tag{2}$$

The fruit yield was obtained in October, which is the typical time for harvesting. The yield of each treatment was estimated as fruit weight in kg per tree and ton per hectare.

The fruit quality was evaluated by sampling 10 fruits per tree/replicate. A total of 80 fruits for each treatment were picked randomly at harvest time in both seasons and then transported to the laboratory of Plant Production Department, Faculty of Agriculture, Saba Basha, Alexandria University, Alexandria, Egypt to determine the fruits' physical and chemical characteristics.

Characterization Methods

Physical and chemical characteristics of fruits

Fruit weight (g) was estimated by calculating the average weight of 10 fruits from each tree/replicate. Average fruit length, fruit diameter (D), were measured by using a Digital Vernier Caliper (Suzhou Sunrix Precision Tools Co., Ltd., Suzhou, Jiangsu, China).

The fruit volume (cm^3) was calculated by dipping the fruit in water and weighing the removed water. The pulp weight (g), seed weight (g), juice weight (g), and fruit firmness (Lb/ $inch^2$) were estimated using a Magness and Taylor pressure tester with a $^7/_{18}$-inch plunger using a Magness-Taylor pressure tester (mod. FT 02 (0-2 Lb., Via Reale, 63 - 48011 Alfonsine, Italy). Total soluble solids (TSS) were measured using a hand refractometer (ATAGO CO., LTD., Tokyo, Japan), from the fresh-cut guava fruit. The result was expressed as a percentage (%). The total and reducing sugars were estimated calorimetrically using the Nelson arsenate–molybdate colorimetric method (Nielsen 2010). Non-reducing sugars were accounted as the value between total sugars and reducing sugars. The titratable acidity (%) in fruit juice was found using an AOAC method (AOAC 2005) where it was expressed as the amount of citric acid in g/100 mg fruit juice. The TSS/acid ratio was calculated by dividing the value of TSS over the value of titratable acidity. The ascorbic acid content of the juice (Vitamin C mg/100 mg juice) was estimated by titration with 2,6 dichloro phenol-indo-phenol (Nielsen 2017) and calculated as mg/100 mL of juice.

Leaves chemical composition

After the harvest time in November, samples of 30 leaves taken from the middle of vegetative shoots (Arrobas *et al.* 2018) were randomly selected from each replicate to determine their chemical composition of nitrogen (N), phosphorus (P), and potassium (K). The leaf samples were washed with tap water and then with distilled water, and dried at 70 °C until a constant weight was obtained; finally, the dried leaf samples were ground and acid digested using H_2SO_4 and H_2O_2 until the digested solution became clear. The digested solution was used for the determination of nitrogen using the micro-Kjeldahl method (Wang *et al.* 2016), phosphorus by vanadomolybdate method (Weiwei *et al.* 2017), and potassium using a flame photometer (SKZ International Co., Ltd., Jinan Shandong, China) (Arrobas *et al.* 2018).

Statistical analysis

The results were statistically analysed using a one-way analysis of variance (ANOVA) according to Ott and Longnecker (2015), and the least significant difference

(LSD) at 0.05% was utilized for comparing between the means of treatments and measured with CoHort Software (Pacific Grove, CA, USA).

RESULTS AND DISCUSSION

Vegetative Growth Parameters

Data in Table 2 show that shoot length, shoot diameter, leaf area, and leaf total chlorophyll content were significantly increased by the soil application of SE or FA individually or in combination compared to the control in both two seasons. Moreover, the obtained results showed that the combination between FA and SE was more effective than the usage of each one of them individually. The highest increments were obtained by the soil application of 4 g/L FA combined with 3 g or 4 g/L SE in both experimental seasons.

These results agree with the previous findings of Piccolo and Mbagwu (1999). They reported that due to the structure of FA, which contains groups of COOH, OH, and phenolic compounds, it can improve the soil texture, fertility, and stability. Moreover, FA can increase the chemical elements uptake, particularly those that engaged in the process of photosynthesis like iron, zinc, and manganese (Mackowiak *et al.* 2001; Nardi *et al.* 2002; Eyheraguibel *et al.* 2008; Yang *et al.* 2013; Wang *et al.* 2019). Besides, FA also plays an important role in increasing length and number of root hairs in plants (Canellas *et al.* 2002; Schmidt *et al.* 2007), the rate of photosynthesis, and minimizing the opening of stomata, transpiration rate, and water loss so it can stimulate the growth of plants under drought and water lack conditions (Li *et al.* 2005; Anjum *et al*. 2011; Huang *et al.* 2020).

Table 2. Influence of Soil Application of SE and FA on Shoot Length, Shoot Diameter, Leaf Area, and Leaf Total Chlorophyll in Guava cv. 'Maamoura'

Treatment	**Shoot Length (cm)**		**Shoot Diameter (mm)**		**Leaf Area (cm^2)**		**Total Chlorophyll SPAD (µ Mol m^{-2})**	
	2019	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**
Control	22.73e ±1.51	24.73e ±0.3	2.19f ±0.04	2.30g ±0.04	35.44f ±0.93	38.50f ±1.6	41.11e ±96	43.20f ±0.03
FA (3 g/L)	24.7d ±1.00	27.71cd ±1.03	2.78e ±0.02	3.16e ±0.01	44.03d ±0.59	46.87de ±0.52	45.05d ±0.69	46.52e ±1.02
FA (4 g/L)	27.73c ±1.06	29.56c ±1.16	2.90d ±0.07	3.29d ±0.04	46.21c ±0.57	51.96c ±1.48	49.99b ±1.58	51.73c ±0.75
SE (3 g/L)	24.63d ±0.94	27.63d ±1.01	2.78e ±0.06	2.77f ±0.08	42.3e ±0.98	45.28e ±1.08	43.73d ±0.55	45.41e ±0.25
SE (4 g/L)	27.66c ±1.09	27.94cd ±1.57	2.79e ±0.05	3.22de ±0.04	45.32cd ±1.28	48.79d ±1.34	47.07c ±0.5	48.81d ±1.33
FA (3 g/L + SE 3 g/L)	28.66bc ±0.96	32.00b ±0.16	3.58c ±0.06	3.61c ±0.04	46.61c 0.96	54.28b ±0.98	50.39b ±1.01	52.01c ±0.67
FA (3 g/L + SE 4 g/L)	29.66b ±1.12	32.08b ±1.01	3.73b ±0.04	3.76b ±0.6	46.82c ±0.94	56.70a ±1.10	50.39b ±1.59	53.26^{bc} ±1.55
FA (4 g/L + SE 3 g/L)	32.11a ±0.97	33.04b ±1.21	3.81ab ±0.04	4.16a ±0.01	48.89b ±104	57.25a ±0.96	52.89a ±0.65	53.70b ±0.59
FA (4 g/L + SE 4 g/L)	33.61a ±0.96	35.57a ±0.94	3.82a ±0.02	4.16a ±0.04	53.78a ±1.16	57.88a ±1.44	54.29a ±0.97	56.57a ±0.83
LSD (0.05)	1.87	1.85	0.09	0.08	1.71	2.15	1.73	1.60

Means not sharing the same letter(s) within each column are significantly different at 0.05 level of significance

In the same trend, it was reported that because SE contains a high content from micro and macronutrients, such as iron, copper, sulfur, manganese, nitrogen, phosphorous, and gibberellic acid, indole acidic acid, cytokines, and amino acids. So, it could be classified as a biostimulant for the growth of the plant and has a great ability to enhance the plant cell division (Abdel-Mawgoud *et al.* 2010; Prasad *et al.* 2010; Hayyawi *et al*. 2020), as well as magnesium, which is very important for the synthesis of chlorophyll (Almaroai and Eissa 2020). Besides, it was reported that FA can increase the plant growth because its effect, which is similar to that of auxin, gerbilline, and cytokinin (Samavat and Samavat 2014). Additionally, the foliar application of FA was also more effective in improving leaf area and shoot length in apple (Taha *et al*. 2016; Khan *et al*. 2019). The application of SE enhanced leaf total chlorophyll, photosynthesis, transpiration, and the conductance of stomata (Fan *et al.* 2013; Al-Ghamdi and Elansary 2018; Rouphael *et al*. 2018; Kulkarni *et al.* 2019).

Fruit Set Percentage and Fruit Yield

Results in Table 3 make it clear that fruit set percentage, fruit yield in kg per tree, and fruit yield in ton per hectare were significantly enhanced by the soil application of SE or FA at 3 or 4 g/L individually or in combinations. This may be due to the role of SE and FA in improving the vegetative growth parameters and leaf total chlorophyll as well as improving the availability of nutrients. The results showed also that mixing FA with SE was more effective in their effect than the individual application in the two seasons. The combination of 4 g/L FA with 4 g/L SE was the superior treatment as compared to the control and the other applied treatments in both experimental seasons. Additionally, fruit set and yield were significantly increased by the combinations of 3 g/L FA + 4 g/L SE and 4 g/L FA + 3 g/L SE, in the two seasons compared with control. These results were previously explained in several studies (Stirk *et al.* 2003; Craigie 2011; Gupta *et al.* 2011; Khan *et al.* 2011; Stirk and Van Staden, 2014; Battacharyya *et al*. 2015; Aremu *et al*. 2016; Patel *et al*. 2018; Renaut *et al*. 2019; Yalçın *et al*. 2019; Al-Juthery *et al*. 2020). These groups reported that, as SEs are rich in polysaccharides, auxins, gibberellins, cytokinins, indole-3-acetic acid (IAA), vitamins, oils, fats, acids, amino acids, polyphenols antioxidants, pigments, antimicrobial factors, Fe, Cu, Zn, Co, Mo, Mn, and Ni, they can improve the yield and yield components.

The foliar application of fulvic acid was more effective in improving the fruit set percentage and yield in kg/tree in apple (Basak 2008; Khan *et al*. 2019). In the same trend, it was reported previously that the application of SEs increased the flower set percentage and fruit yield in "Koroneiki" olive cultivar (Chouliaras *et al*. 2009), in pear (Calvo *et al*. 2014) and in "Fagri Kalan" mango cultivar (El-Sharony *et al*. 2015). Besides, SE enhanced the plant resistance to biotic (Machado *et al*. 2014; Ben Salah *et al*. 2018) and abiotic stress (Bradáčová *et al*. 2016; Cabo *et al*. 2019; Khompatara *et al*. 2019), stimulated the growth of crops, and increased yield (Renaut *et al*. 2019; El Boukhari *et al*. 2020). In addition, treating orange with SEs increased the maturity index and yield, while it decreased the fruit drop (Arioli *et al*. 2015; Gomathi, *et al*. 2017). Spraying SE on apple (*Malus domestica* L.) increased fruit set and fruit yield (Soppelsa *et al*. 2018; Valencia *et al*. 2018; de Sousa *et al*. 2019). The application of SEs at 0, 2, 4, and 8 gL^{-1} on 'Albion' strawberry cultivar *via* fertigation system increased the number of flowers per plant, and the yield, compared with the control, was also increased (Al-Shatri *et al*. 2020).

Table 3. Influence of Soil Application of SE and FA on Fruit Set Percentages, Fruit Yield in kg per Tree, and Fruit Yield in Ton per Hectare in Guava cv. 'Maamoura'

Treatment	Fruit Set (%)		Fruit Yield (kg/Tree)		Yield (ton)/Hectare	
	2019	2020	2019	2020	2019	2020
Control	54.9d ±0.54	58.95f ±1.45	40.52f ±2.03	46.19f ±2.65	24.31f ±1.22	27.72f ±1.59
FA (3 g/L)	67.2bc ±1.43	66.39e ±0.68	61.28d ±1.32	66.96de ±1.5	36.77d ±0.79	40.18de ±0.90
FA (4 g/L)	68.72b ±1.24	68.69cd ±1.41	65.31c ±1.04	72.64bc ±1.90	39.19c ±0.63	43.59bc ±1.14
SE (3 g/L)	66.37c ±0.97	65.25e ±1.59	58.48e ±1.80	65.4e ±1.13	35.09e ±1.08	39.24e ±0.67
SE (4 g/L)	67.78bc ±2.00	67.49de ±1.02	64.27c ±1.24	70.2cd ±3.08	38.56c ±0.74	42.12cd ±1.85
FA (3 g/L + SE 3 g/L)	69.03b ±1.78	70.65bc ±0.11	71.05b ±1.23	74.25b ±0.86	42.63b ±0.74	44.55b ±0.52
FA (3 g/L + SE 4 g/L)	71.67a ±1.76	71.09b ±1.10	72.34b ±2.11	75.93b ±2.50	43.40b ±1.27	45.56b ±1.50
FA (4 g/L + SE 3 g/L)	72.09a ±1.73	71.49b ±1.82	73.52b ±1.98	81.65a ±3.18	44.11b ±1.19	48.99a ±1.90
FA (4 g/L + SE 4 g/L)	72.83a ±0.85	74.33a ±1.57	76.29a ±0.82	83.25a ±0.64	45.77a ±0.49	49.95a ±0.39
LSD (0.05)	2.31	2.27	2.60	3.83	1.56	2.30
Means not sharing the same letter(s) within each column are significantly different at 0.05 level of significance						

Fruit Physical Characteristics

The data shown in Table 4 demonstrates that fruit weight, volume, length, and diameter were significantly increased by the soil application of FA or SE at 3 or 4 g/L alone or in combination with the other in the two seasons compared to the control. Moreover, the same fruit physical characteristics were increased with the combinations of FA at 3 or 4 g/L with SE at 3 or 4 rather than the usage of FA, SE alone, or control treatment in both experimental seasons. It was noticed that the effect of 4 g/L FA + 4 g SE combination was superior in comparison with 4 g/L FA + 3 g SE, 3 g/L FA + 4 g SE, and 3 g/L FA + 3 g SE combinations as compared to control in both experimental seasons. Similar results were obtained by El-Boray *et al.* (2015). They reported that spraying 'Superior seedless' grape cultivar with FA at 9 mL/L per vine significantly increased the average cluster weight, size, length, and width. Additionally, the foliar application of FA was more effective in improving fruit weight, fruit length, and diameter in apricot (Haggag *et al*. 2016). Al-Musawi (2018) stated that the spraying of sour orange with algae extracts increased fruit weight, length, width, and size, width and weight of peel, and moisture content in fruit and peel. Al-Shatri *et al*. (2020) reported that the application of SEs at 0, 2, 4, and 8 gL^{-1} on 'Albion' strawberry cultivar *via* fertigation system increased fruit weight and volume, as compared with control. The obtained results also agree with the prior findings of Harhash *et al* (2021a). They reported that the foliar application of 'Flame seedless' grape trees with FA at 1000, 1500, and 2000 ppm, and SE at 2000, 3000, and 4000 ppm, before flowering, during the full bloom, and three weeks later improved weight, length, width, size, and number of clusters as well as the weight of 100 berries as compared to control. The current results are in agreement with the findings of Harhash *et al*. (2021b). They found that spraying pomegranate cultivar cv. 'Wonderful' at the beginning of flowering, full bloom, and one month later three times with FA at 0.2%, 0.3%, and 0.4%, improved weight, size, length, number, and width of fruit.

Table 4. Influence of Soil Application of SE and FA on Fruit Weight, Volume, Length, and Diameter of Guava cv. 'Maamoura'

Treatment	Fruit Weight (g)		Fruit Volume (cm^3)		Fruit Length (cm)		Fruit Diameter (cm)	
	2019	2020	2019	2020	2019	2020	2019	2020
Control	136.96e ±1.58	143.48f ±1.60	149.68e ±0.15	154.88d ±4.49	7.17g ±0.06	7.18g ±0.04	4.37e ±0.12	4.38f ±0.03
FA (3 g/L)	155.43cd ±1.79	156.82de ±2.35	166.2d ±2.59	171.62c ±1.85	8.35e ±0.02	8.46e ±0.03	5.20c ±0.07	5.3d ±0.06
FA (4 g/L)	161.48b ±2.65	162.93c ±0.36	172.23c ±4.30	174.97bc ±1.51	8.5cd ±0.06	8.55cde ±0.06	5.48b ±0.03	5.56bc ±0.01
SE (3 g/L)	152.90d ±2.18	155.04e ±1.94	164.48d ±0.80	170.47c ±1.90	8.1f ±0.02	8.12f ±0.02	5.02d ±0.08	5.07e ±0.10
SE (4 g/L)	156.33c ±1.38	158.37d ±1.80	166.42d ±1.12	171.86c ±4.72	8.49d ±0.05	8.53de ±0.06	5.47b ±0.12	5.50c ±0.09
FA (3 g/L + SE 3 g/L)	162.58b ±0.97	164.34bc ±2.14	173.6c ±2.94	177.38ab ±2.57	8.59bc ±0.04	8.62bcd ±0.05	5.53b ±0.08	5.58bc ±0.05
FA (3 g/L + SE 4 g/L)	164.22b ±1.55	165.06bc ±2.12	175.85bc ±0.46	178.01ab ±0.46	8.63b ±0.10	8.64bc ±0.01	5.51b ±0.11	5.58bc ±0.13
FA (4 g/L + SE 3 g/L)	164.23b ±0.93	166.63ab ±1.61	178.25ab ±3.04	178.55ab ±1.81	8.65b ±0.05	8.68b ±0.04	5.54b ±0.02	5.63b ±0.04
FA (4 g/L + SE 4 g/L)	167.46a ±1.02	168.37a ±2.30	180.19a ±1.63	181.83a ±1.83	8.8a ±0.02	8.9a ±0.13	5.81a ±0.03	6.14a ±0.02
LSD (0.05)	2.83	2.41	4.08	4.56	0.09	0.11	0.13	0.11
Means not sharing the same letter(s) within each column are significantly different at 0.05 level of significance								

Table 5 shows that the weight of juice and pulp and fruit firmness were statistically increased by the soil application of FA or SE at 3 or 4 g/L solely or in combinations in the two seasons. The effect of mixing of FA with SE have a higher effect on the same forementioned fruit characteristics than the single application of each one of, where the highest increments were obtained from 3 g/L FA + 4 g/L SE, 4 g/L FA + 3 g/L SE, and 3 g/L FA + 3 g/L SE g/L. The impact of 4 g/L FA + 4g/L SE combination was superior as compared to the rest of the applied treatments and control in both experimental seasons. In contrast, the control treatment significantly increased the seed weight compared with the usage of FA or SE at 3 and 4 g/L or their combinations in both experimental seasons. These results are in parallel with the results obtained by Haggag *et al.* (2016) on apricot and Taha *et al*. (2016) on apple, where they reported that spraying FA enhanced the fruit firmness. Additionally, Ravi *et al.* (2018) stated that spraying strawberry with SE improved bunch weight, hands, and fingers of banana cv. 'Grand Naine'. Spraying grape cv. 'Flame seedless' with FA at 1000, 1500, and 2000 ppm, and SE at 2000, 3000, and 4000 ppm, before flowering, during the full bloom, and three weeks later improved juice percentage of 100 berries and fruit firmness compared with the control (Harhash *et al*. 2021a). Similarly, Harhash *et al*. (2021b) found that the foliar application of FA at 0.2%, 0.3%, and 0.4% on eight-year-old pomegranate cultivar cv. 'Wonderful' improved fruit firmness and juice weight.

Table 5. Influence of Soil Application of SE and FA on Weight of Juice, Pulp, and Seed and Fruit Firmness of Guava cv. 'Maamoura'

Treatment	Juice Weight (g)		Pulp Weight (g)		Seed Weight (g)		Fruit Firmness (lb/inch^2)	
	2019	2020	2019	2020	2019	2020	2019	2020
Control	86.10e ±1.47	86.42e ±1.59	115.29e ±2.22	121.79f ±2.75	21.68a ±0.67	21.69a ±1.19	5.12f ±0.05	5.15f ±0.06
FA (3 g/L)	89.15cd ±1.05	90.55d ±1.90	136.16c ±1.66	136.73de 2.08	19.27c 0.13	20.09bc 0.30	5.88d 0.02	6.00de ±0.04
FA (4 g/L)	91.34bc 2.18	92.29bc ±1.60	144.41b ±2.60	143.55c ±1.01	18.68d ±0.49	19.41cd ±0.86	5.92d ±0.03	6.05d ±0.11
SE (3 g/L)	88.55de ±1.03	89.43d ±1.00	133.07d ±2.06	134.05e ±1.68	19.83b 0.17	20.99ab 0.61	5.72e ±0.07	5.84e ±0.10
SE (4 g/L)	90.15bcd ±1.66	90.61cd ±0.55	137.50c ±1.35	138.50d 1.47	18.83cd ±0.07	19.86c ±0.45	5.92d ±0.02	6.00de ±0.09
FA (3 g/L + SE 3 g/L)	91.44bc ±1.09	93.06b ±0.52	144.73b ±0.58	146.25bc ±1.98	17.85e ±0.43	19.38cd ±0.65	6.08c ±0.02	6.07d ±0.06
FA (3 g/L + SE 4 g/L)	92.24ab ±1.59	93.27b ±0.54	145.55b ±1.34	146.55b ±2.24	17.25f ±0.13	18.51de ±0.12	6.29b ±0.05	6.36c ±0.10
FA (4 g/L + SE 3 g/L)	94.49a ±1.01	95.05a ±0.48	146.97b ±1.54	147.22b ±0.89	17.33f ±0.15	18.31e ±0.12	6.40b ±0.05	6.57b ±0.15
FA (4 g/L + SE 4 g/L)	94.61a ±4.03	95.51a ±2.00	150.13a ±0.91	150.07a ±2.4	17.07f ±0.09	18.09e ±0.21	7.37a ±0.15	7.6a ±0.2
LSD (0.05)	2.56	1.72	2.95	2.79	0.50	1.05	0.11	0.20
Means not sharing the same letter(s) within each column are significantly different at 0.05 level of significance								

Fruit Chemical Characteristics

According to the results in Table 6, it was noticed that the soil application of FA and SE at 3 or 4 g/L and their combinations improved TSS and vitamin C, while they decreased the juice acidity percentage in the two experimental seasons, and the influence of FA and SE increased by mixing them together. In addition, 4g/L FA + 4g/L SE combination gave a significant increment in the percentage of TSS and fruit content from vitamin C, while it reduced the juice acidity percentage comparing with the combinations of 3 g/L FA + 3 SE g/L, 3 g/L FA + 4 g/L SE, and 4 g/L FA + 3 g/L SE in both seasons. On the opposite side, control treatment raised the percentage of juice acidity comparing with the rest applied treatments in the two seasons. The optimal treatment that achieved the best results was 4 g/L FA + 4 g/L SE in the two seasons. The present obtained results are similar with those found by Suh *et al.* (2014). They reported that the application of FA on tomato raised soluble solids concentration and SSC/acidity ratio, while it minimized total acidity percent. In the same orientation, it was noticed that treating orange with SEs increased fruit content from vitamin C and TSS (Arioli *et al*. 2015; Gomathi *et al*. 2017). Moreover, the application of FA on grape cultivars such as 'Superior seedless' (El-Boray *et al.* 2015) with at 9 mL/L per vine, 'Thompson seedless' (El-Kenawy 2017) with 500 ppm, 'King Ruby' (Mostafa *et al.* 2017) with 9 mL/L/vine and 'Flame seedless' (Harhash *et al*. 2021a) with 2000 ppm improved TSS, TSS/acid ratio, while it reduced the percentage of titratable acidity. Spraying of FA increased total soluble solids, and vitamin C, while it reduced the percentage of fruit juice acidity comparing with control in apricot (Haggag *et al*. 2016) and in apple (Khan *et al*. 2019). The application of SEs at 0, 2, 4, 8 g.L-1 on 'Albion' strawberry cultivar *via* fertigation system increased TSS, TSS/TA ratio, while decreased the fruit titratability acidity comparing with control were increased (Al-Shatri *et al*. 2020). Harhash *et al*. (2021b) found that spraying eight years old pomegranate cv. Wonderful with FA at 0.2%, 0.3%, and 0.4%, at the beginning of flowering, full bloom, and one month later three times increased total soluble solids, total reduced and non-reducing sugars, and TSS/acid ratio, while it minimized the percentages of fruit acidity as compared to the control.

Table 6. Influence of Soil Application of SE and FA on TSS and Acidity Percentages and Vitamin C in Guava cv. 'Maamoura'

Treatment	TSS (%)		Acidity (%)		Vitamin C (mg/100 mL)	
	2019	2020	2019	2020	2019	2020
Control	8.54 h ±0.2	9.55g ±0.12	0.5a ±0.05	0.51a ±0.03	175.93e ±1.81	176.91f ±2.11
FA (3 g/L)	10.33f ±0.05	11.18e ±0.04	0.42b ±0.01	0.44b ±0.01	184.88d ±2.39	182.82de ±2.56
FA (4 g/L)	11.92d ±0.15	12.10c ±0.14	0.37c 0.006	0.38c ±0.02	185.5d ±1.91	185.19de ±2.19
SE (3 g/L)	9.6g 0.25	10.22f ±0.06	0.49a ±0.04	0.50a ±0.04	177.55e ±2.83	181.84e ±1.07
SE (4 g/L)	11.25e ±0.10	11.57d ±0.18	0.38c ±0.006	0.39c ±0.01	185.42d ±1.00	185.09de 2.37
FA (3 g/L + SE 3 g/L)	12.6c ±0.31	12.74b ±0.08	0.36c ±0.006	0.37c ±0.01	187.39d ±1.91	185.89d ±1.14
FA (3 g/L + SE 4 g/L)	12.67c 0.13	12.99b ±0.19	0.29d ±0.01	0.32d ±0.01	195.83c ±1.09	196.58c ±2.15
FA (4 g/L + SE 3 g/L)	13.61b ±0.36	14.12a ±0.03	0.29d ±0.02	0.31d ±0.01	200.09b ±2.94	203.13b ±3.20
FA (4 g/L + SE 4 g/L)	14.06a ±0.25	14.2a ±0.37	0.24e ±0.01	0.26e ±0.006	207.42a ±2.00	208.11a ±2.52
LSD (0.05)	0.36	0.28	0.04	0.04	3.37	3.35
Means not sharing the same letter(s) within each column are significantly different at 0.05 level of significance						

From the results in Table 7, the addition of FA and SE to the soil greatly improved the fruit content from total, reduced, and non-reduced sugars compared to the control in the two seasons. This perhaps was because of their influence in raising the leaf total chlorophyll, TSS, and leaf surface area in the two seasons as well as their role in reducing the juice acidity percentages. Combining FA with SE was more effective in improving the fruit content from total, reduced and non-reduced sugars more than the individual addition of FA or SE in the two seasons. It was seen from the results that 4 g/L FA + 4 g/L SE and 4 g/L FA + 3 g/L SE statistically increased these fruit chemical characteristics. Next in order of effectiveness were 3 g/L FA + 4 g/L SE and 3 g/L FA + 3 g/L SE as compared to control. These results are in parallel with the findings of (El-Miniawy *et al*. 2014; Kapur *et al*. 2018; Mattner *et al*. 2018). They stated that treating strawberry with SE increased crown carbohydrate. Similarly, spraying FA improved total carbohydrates in grape cvs. 'Thompson seedless' (El-Kenawy 2017) and 'King Ruby' (Mostafa *et al.* 2017). Kapur *et al.* (2018) found that the foliar application of SEs on strawberry improved the fruit chemical content from sucrose and fructose. In the same trend, it was found by Harhash *et al.* (2021a) that spraying grape cv. 'Flame seedless' with FA at 1000, 1500, and 2000 ppm, and with SE at 2000, 3000, and 4000 ppm before flowering, during the full bloom, and three weeks later improved the percentages of total sugars and total soluble solids as compared to the control in the two seasons. Moreover, in another study, it was reported that treatment of pomegranate cv. 'Wonderful' with FA improved the fruit content from total, reduced and non-reduced sugars compared with the control (Harhash *et al*. 2021b).

Table 7. Influence of Soil Application of SE and FA on the Percentages of the Total, Reduced, and Non-reduced Sugars in Guava cv. 'Maamoura'

Treatment	**Total Sugar (%)**		**Reduced Sugar (%)**		**Non reduced Sugar (%)**	
	2019	**2020**	**2019**	**2020**	**2019**	**2020**
Control	7.11h ±0.03	7.19g ±0.04	5.07g ±0.06	5.13f ±0.03	2.03e ±0.07	2.06f ±0.06
FA (3 g/L)	7.91f 0.07	7.97f ±0.13	5.56de ±0.10	5.53de ±0.13	2.35d ±0.03	2.45e ±0.100
FA (4 g/L)	8.57e ±0.02	8.46e ±0.09	5.39ef ±0.08	5.43e ±0.07	3.18b ±0.09	3.03c ±0.09
SE (3 g/L)	7.63g ±0.02	7.93f ±0.06	5.25f ±0.08	5.40e ±0.07	2.37d ±0.06	2.53de ±0.12
SE (4 g/L)	8.01f ±0.11	8.09f ±0.12	5.55de ±0.09	5.61d ±0.08	2.46d ±0.06	2.48e ±0.06
FA (3 g/L + SE 3 g/L)	8.83d ±0.07	8.86d ±0.08	5.69d ±0.11	6.22b ±0.04	3.14b ±0.06	2.64d ±0.11
FA (3 g/L + SE 4 g/L)	8.97c ±0.14	9.41c ±0.15	6.26c ±0.07	6.01c ±0.09	2.71c ±0.18	3.40b ±0.06
FA (4 g/L + SE 3 g/L)	9.32b ±0.07	9.68b ±0.15	6.55b ±0.10	6.55a ±0.10	2.77c ±0.07	3.13c ±0.10
FA (4 g/L + SE 4 g/L)	10.25a ±0.06	9.85a ±0.1	6.73a ±0.11	6.22b ±0.10	3.53a ±0.06	3.63a ±0.10
LSD (0.05)	0.14	0.16	0.17	0.15	0.16	0.14
Means not sharing the same letter(s) within each column are significantly different at 0.05 level of significance						

Leaf Nitrogen (N), Phosphorous (P) and Potassium (K) Composition

Leaf mineral composition from N, P, and K macronutrients was significantly increased by the soil application of SE or FA at 3 or 4 g/L even when each was added alone or in combination compared with the control during the two seasons (Table 8). The combinations between FA and seaweed gave the most pronounced effect rather the single application. Moreover, the addition of 4 g/L FA + 4 g/L SE statistically increased NPK leaf mineral content more than 4 g/L FA + 3 g/L SE, 3 g/L FA + 4 g/L SE, and 3 g/L FA + 3 g/L SE in the two experimental seasons. Similar results were earlier obtained by Chen *et al*. (2004). Based on their findings, they stated that FA plays an important role in transporting the mineral nutrients directly to the sites of metabolism in the plant cells. In addition, because FA can increase significantly chelating, absorption, and distribution of elements in roots and shoots, it can encourage their growth (Bocanegra *et al*. 2006; Razavi, and BahramParvar 2007; Yildirim 2007; Yang *et al*. 2013; Canellas *et al*. 2015; Lotfi *et al*. 2015; Wang *et al*. 2019). Additionally, SE is rich in macro-nutrients including C, Mg, P, K, and S and micronutrients such as B, Co, F, Mn, Mo, Se, Si, Zn (Parthiban *et al*. 2013; Circuncisão *et al*. 2018), and it can increase the uptake of plants to soil nutrients (Renaut et al., 2019; EL Boukhari *et al*. 2020). Moreover, the results of the present experiment are in parallel with the findings of El-Miniawy *et al*. (2014), Kapur *et al.* (2018), and Mattner *et al*. 2018). They mentioned that the spray of strawberry with SE increased leaf mineral content of phosphorus and potassium. The foliar application of FA raised the leaf mineral content of nitrogen, phosphorous, potassium, zinc, manganese, and iron in comparison to the control in apricot (Haggag *et al*. 2016) and in apple (Taha *et al*. 2016; Khan *et al*. 2019). The foliar spraying of "Wonderful" pomegranate cultivar with FA at 0.2%, 0.3%, and 0.4% raised the leaf mineral content from N, P, and K in the two seasons, as compared to control (Harhash *et al*. 2021b).

Table 8. Influence of Soil Application of SE and FA on Leaf Composition of N, P, and K in Guava cv. 'Maamoura'

Treatment	N (%)		P (%)		K (%)	
	2019	2020	2019	2020	2019	2020
Control	1.99e ±0.04	2.07d ±0.02	0.31e ±0.01	0.31d ±0.01	2.49g ±0.04	2.56f ±0.03
FA (3 g/L)	2.11d ±0.03	2.20c ±0.04	0.36d ±0.01	0.34d ±0.01	2.72f ±0.07	2.81e ±0.05
FA (4 g/L)	2.28c ±0.06	2.33b ±0.03	0.39cd ±0.02	0.41c ±0.02	3.01e ±0.05	3.05d ±0.04
SE (3 g/L)	2.06de ±0.02	2.11cd ±0.04	0.32e 0.01	0.34d 0.006	2.71f ±0.05	2.78e ±0.09
SE (4 g/L)	2.23c ±0.06	2.31b ±0.04	0.37cd ±0.01	0.4c ±0.04	2.96e ±0.08	3.04d ±0.08
FA (3 g/L + SE 3 g/L)	2.62b ±0.16	2.72a ±0.13	0.39cd 0.01	0.42c ±0.02	3.47d 0.05	3.52c ±0.03
FA (3 g/L + SE 4 g/L)	2.66b ±0.04	2.72a ±0.06	0.40c 0.02	0.43bc ±0.01	3.88c ±0.03	3.98b ±0.06
FA (4 g/L + SE 3 g/L)	2.76a ±0.07	2.79a ±0.09	0.44b 0.02	0.45b ±0.02	3.99b ±0.05	4.09a ±0.01
FA (4 g/L + SE 4 g/L)	2.85a ±0.10	2.8a ±0.02	0.5a ±0.03	0.51a ±0.03	4.14a ±0.01	4.18a ±0.02
LSD (0.05)	0.10	0.09	0.03	0.03	0.10	0.09
Means not sharing the same letter(s) within each column are significantly different at 0.05 level of significance						

CONCLUSIONS

1. The soil application of fulvic acid (FA) and seaweed extract (SE), as well as their combinations, had significant effects in improving shoot length, shoot diameter, leaf area, and leaf total chlorophyll content when comparing results within two seasons.
2. The soil treating of the trees with FA and SE increased fruit set percentage, yield in kg per tree and in ton per hectare, as well as and fruit physical and chemical characteristics such as fruit weight, volume, firmness, and juice, TSS%, total, reduced and non-reduced sugars, and vitamin C, while they reduced that fruit acidity percentage comparing with control in both experimental seasons.
3. FA or SE can be used as safe and effective alternatives to the chemical fertilizers in the nutrition of fruit trees to produce safe food, keep the soil fertility, and reduce the environmental contamination.

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