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Effect of Foliar Spraying of Some Plant Bio-Stimulants on Growth, Productivity and Storability of Cassava

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A CURRENT experiment was carried out at a private farm under sandy soil conditions in El-Bostan area, El-Behera Governorate, Egypt over two consecutive seasons of 2019/2020 and 2020/2021. The aim was to investigate the effect of some plant growth bio-stimulants on cassava plants (Indonesian cultivar) growth and yield as well as the roots storability. The experiment contained thirteen treatments: potassium humate (1, 2, and 4 g/l), fulvic acid (1, 2, and 4 g/l), chitosan (1, 2, and 4 g/l), and seaweed extract (1, 2, and 4 g/l), in addition to a control treatment. Cassava plants were sprayed four times with the experimental treatments at 60, 90, 120, and 150 days after planting date. The experiment was set up with three replicates in a completely randomized block design. The obtained results showed that foliar spraying with seaweed extracts, fulvic acid, or chitosan at rates of 2 or 4 g/l resulted in the highest values for plant height, the number of main stems, number and weight of roots/plant, root length, and root diameter. Furthermore, cassava plants sprayed with seaweed extracts, fulvic acid and potassium humate at a rate of 2 g/l, had the highest levels of starch content in the roots, while treatment with seaweed extract at a rate of 4 g/l recorded the highest levels of N, P, and K in the shoots. The recommendations are that foliar spraying with seaweed extract at a rate of 4 g/l could be used to increase the production and quality of cassava roots, as well as the content of mineral elements in the shoots and the starch content in the roots. In addition, a storage period of 40 days at a temperature of 5 ˚C could be attained by using chitosan at a rate of 1 g/l or seaweed extract at 4 g/l as a field treatment.

Keywords: *Manihot esculenta* Crantz, Potassium humate, Fulvic acid, Chitosan, Seaweed extract, Cold storage.

Introduction

Manihot esculenta Crantz, cassavas are perennial, vegetative, woody shrubs with edible roots. It grows in subtropical and tropical regions worldwide. Cassava originated in tropical America and was introduced into Africa in the Congo basin by the Portuguese around 1558. Cassava now sustains the livelihoods of over 300 million Africans. Cassava production in the world totaled 302,662,494 million metric tonnes in 2020, with Africa accounting for approximately 61% (FAOSTAT, 2022). Universal production of cassava has increased by 240 million metric tonnes since 2010. According to FAO projections, by 2025, Sub-Saharan Africa countries will account for approximately 62% of global cassava production (FAOSTAT, 2022). It is rich in carbohydrates, available year-round, tolerant to low soil fertility, and resistant to diseases, drought, and pests tolerant (Ewubare and Ologhadien, 2019, Inegbedion et al., 2020).

Foliar application of mineral fertilizers is a faster way of delivering nutrients to plants than soil application. Some authors have suggested that active uptake *via* stomata pores, rather than cuticular uptake, could occur. The use of bio-stimulants in crop production is needed. In a similar vein, bio-stimulants that encourage vegetative growth, mineral nutrient uptake, and plant productivity are available.

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Potassium humate has also been shown in previous studies to affect plant hormonal levels and improve the growth and development of crops under a variety of stressful conditions (Man-hong et al., 2020). Several studies have shown that potassium humate increases cell membrane permeability, photosynthesis rate, protein and hormone assimilation, and root cell elongation (Cimrin et al., 2010). Treatment with potassium humate improved potato plant growth, photosynthetic indicators, and tuber yield under various levels of water deficiency (Man-hong et al., 2020). Other researchers have found that potassium humate treatment improves biochemical indicators like chlorophyll content, ascorbic acid content, nitrogen content, starch, soluble solids, and protein content, as well as growth and productivity indicators in Spunta potatoes grown under stress conditions (Selim et al., 2012).

Fulvic acid plays an important role in the retention and release of macro- and micronutrients, as well as the biological availability and mobility of organic chemicals in soil (Hu et al., 2019). Because fulvic acid contains more electronegative oxygen atoms than any other humate molecule, it has the greatest influence on chemical reactions (Priya et al., 2014). According to Anjum et al. (2011) fulvic acid application increased the chlorophyll and water contents of leaves. It also increased spiration, thus leading to growth stimulation and water loss reduction. Potassium fulvate foliar or soil application has many beneficial effects, including stimulation of plant metabolism, increased enzyme activity (transaminase and invertase), and increased nutrient bioavailability and uptake, which ultimately reflect on crop growth and yield.

Chitosan strengthens plant defense and can even increase plant pathogen resistance (Sharma et al., 2019). Chitosan was derived from the antitoxic substance chitin. Chitosan, especially in low doses, can boost a plant's resistance to pathogens by boosting its immune system. Recently, the use of bio-fertilizers as part of bio-stimulants in plants has generated many benefits. Chitosan has featured among this round of these compounds due to its fast release through enzymatic processes without affecting the beneficial rhizosphere microbiome and its ability to induce symbiotic exchange between microorganisms and plants (Sharif et al., 2018). Chitosan is an individual product that has a bright future in the development of sustainable agricultural practices, at a very economical price, and available in large quantities, its application as a bio-fertilizer has been shown to have positive effects on the absorption of other nutrients without negatively affecting soil or plants (Sharif et al., 2018).

Seaweed extracts are among the most important sustainable bio-stimulants used (Ashour et al., 2020). Seaweed extracts have been used as bio-stimulants in agricultural practices since early plant breeding. Seaweed extracts are qualified to be utilized as bio-fertilizer not only because they have a biological impact but also because they share with plants common biological compounds. Thus, this significant advantage has propelled seaweed to the top of the plant bio-stimulant list and facilitated many plant treatment processes, primarily for serving and facilitating organic and sustainable agriculture (Ashour, 2019). In addition to the positive effects of seaweed extracts as a plant bio-stimulant that enhance stress tolerance, fast nutrient uptake, increased growth and yield, seaweed-based bio-stimulants have also been shown to help reduce seed dormancy, promote flowering, enhance root systems (Ali et al., 2019), and improve fruit quality and taste (Kapur et al., 2018).

Few previous studies on the effect of foliar application of bio-stimulants on cassava plant growth and yield have been conducted. As a result, this study aimed to determine how different bio-stimulants benefited the growth and productivity of cassava plants grown on newly reclaimed sandy soils.

Materials and Methods

The experiments of this research study were conducted at a private farm under sandy soil conditions with a pH of 8.8 and an EC of 0.21 ds/m in El-Bostan area, El Beheira Governorate, Egypt, for two successive seasons of 2019/2020 and 2020/2021 aiming to study the effect of foliar spraying with some plant stimulants on cassava plants (*Manihot esculenta* Crantz) growth, yield, and quality. The Indonesian cassava cultivar was used a plant material for its consumption and the industry's desirable characteristics. The experiment was designed as a complete randomized block design (CRBD) in three replicates. The plantation was done in single rows with 4 m length and 80 cm width with a spacing of 50 cm between plants. Cassava cuttings measuring 25-30 cm long were planted vertically in holes manually constructed at a depth of approximately 10-12 cm. The experiment plot area was 9.6 m^2 (2.4×4 m) and consisted of three drip irrigated rows. The plantation dates were on the 15^{th} and 25^{th} of April in the first and second seasons, respectively. Ammonium nitrate (33%) at a rate of 50 units of N/feddan, calcium super phosphate (15.5% P_2O_5) at a rate of 80 units/feddan, and potassium sulfate (48% K_2O) at a rate of 100 units/feddan were added along the growing season under drip irrigation system. The experiment included thirteen treatments as follows:

1- Control (tap water). 2- Potassium humate at 1 g/l.

3- Potassium humate at 2 g/l. 4- Potassium humate at 4 g/l.

5- Fulvic acid at 1 g/l. 6- Fulvic acid at 2 g/l.

7- Fulvic acid at 4 g/l. 8- Chitosan at 1 g/l.

9- Chitosan at 2 g/l. 10- Chitosan at 4 g/l.

11- Seaweed extract at 1 g/l. 12- Seaweed extract at 2 g/l.

13- Seaweed extract at 4 g/l.

Treatments were conducted as foliar spraying four times, 60, 90, 120, and 150 days after planting date and during the growth period of cassava plants.

Data Recorded

Vegetative Growth

Three plants/replicate were randomly collected 180 days after planting date to record vegetative growth parameters, i.e., plant height, number of main shoots/ plants, leaf area, and stem diameter.

Yield Components

Three plants/replicate were randomly collected after 270 days from planting date to record the yield components. Root numbers/plant, root length, root diameter, and total and marketable yield of roots were calculated.

Weight Loss Percentage

Weight loss was recorded at the start of the cold storage experiment as initial root weight and then every 7 days during the storage period (40 days). It was expressed as a percentage of weight loss relative to the initial weight, as described in the equation by Lemoine et al. (2009).

$$\text{Weight loss } (\%) = [(A-B/A)] \times 100$$

Where A: the initial weight, and B: weight at inspection date.

Decay Percentage

Cassava roots were assessed in each treatment for the percentage of the surface showing visible rotting every 7 days at room temperature and then in cold storage, respectively. Decay was calculated for each treatment based on the over 10% of the surface showed visible rotting for every root. Overall, roots showing extensive rotting (over 50% surface) were removed from the experiment (Wenzhong et al., 2004). Decays are determined as scores, 1 = none, 2 = slight, 3 = moderate, 4 = moderately severe, and 5 = severe.

Leaf Mineral Contents

Nitrogen, phosphorus, potassium, and iron were determined after 180 days from the planting date, cassava leaf samples were oven dried at 60 - 70°C, and then dry leaf samples were ground to a fine podwer and then wet digested using sulphuric acid (H_2SO_4 98%) and oxygen peroxide (H_2O_2 30%). Total nitrogen was determined using the Kjeldahl method as described by Piper (1950) Phosphorus content was measured using spectrophotometer method according to Watanabe and Olsen (1965). Potassium content was analyzed using the flame photometer method as described by Chapman and Pratt (1961). Iron content was determined by thiocyanate colorimetry, a spectrophotometric method according to Woods and Mellon (1941).

Root Starch Content

After 270 days from planting date, samples of cassava roots were dried in a forced-air oven at 70 ºC until constant weight, and then ground to a fine powder and used to determine starch contents in the roots according to the method described by Somogyl (1952).

Statistical Analysis

All the data obtained were subjected to a statistical analysis of variance (ANOVA) procedure of one-way. The means were separated using Duncan's multiple range test at a 5% level of significance according to the method described by Snedecor and Cochran (1989).

Results and Discussion

Vegetative Growth Characteristics

Data in Table 1 showed that foliar spraying with seaweed extract at 4 g/l resulted in the highest plant height values in both tested seasons. Furthermore, foliar spraying with both 1 and 2 g/l potassium humate, 2 and 4 g/l fulvic acid and 1 and 2 g/l seaweed extract provided the greatest results in plant height in the second season compared to the control treatment. Our findings are consistent with those reported by Kavya et al. (2021). Foliar spraying with seaweed extract at 4 g/l resulted in the highest values of leaf area in the two tested seasons, with no significant differences with fulvic acid at 1 and 4 g/l, and chitosan at 2 g/l in the first season only. In addition, the attained results showed that foliar application of seaweed extract at 4 g/l produced the maximum number of stems/plant in the two seasons. Furthermore, potassium humate at 1 and 4 g/l, fulvic acid at 4 g/l, and seaweed extract at 1 and 2 g/l had the highest values in both tested seasons when compared to the control treatment. The results also indicated that foliar spraying of seaweed extract at 4 g/l gave the highest values of stem diameter in both tested seasons, with no significant differences with almost all other treatments, except for the treatments of 1 g/l chitosan and the control in the first season. The improvement in cassava growth could be attributed to the seaweed extract, which contains a variety of plant hormones that can improve the efficiency of the metabolic process, increase the efficiency and capacity

TABLE 1. Effect of foliar spraying of some plant bio-stimulants on vegetative growth of cassava plants 180 days after planting date during the growing seasons of 2019/2020 and 2020/2021.

	Plant height (cm)		Leaf area (cm^2)		Number of stems/plant		Stem diameter (cm)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	156.67 e	231.1 de	420.9 d	266.1 b	2.33 b	2.11 bc	5,258 c	6,71 e
Potassium humate 1 g/l	218.33 b	250.7 ab	437.7 d	316.1 b	3.00 ab	2.67 a	6,30 ab	7,21 bcd
Potassium humate 2 g/l	196.67 d	258.2 a	461.2 c	301.9 b	2.78 b	2.56 ab	6,32 ab	7,62 b
Potassium humate 4 g/l	197.78 d	242.2 bcd	477.1 bcd	279.6 b	2.89 ab	2.78 a	6,15 ab	6,71 e
Fulvic acid 1 g/l	201.11 cd	224.4 e	526.8 ab	319.0 b	2.44 b	2.56 ab	6,43 ab	7,14 b-e
Fulvic acid 2 g/l	211.67 bcd	254.1 a	458.4 cd	307.8 b	2.44 b	2.44 abc	6,02 b	7,54 bc
Fulvic acid 4 g/l	216.67 bc	251.7 ab	527.4 ab	290.2 b	3.33 ab	2.89 a	6,35ab	7,09 cde
Chitosan 1 g/l	201.67 cd	238.3 cd	481.2 bcd	331.3 b	3.11 ab	2.00 c	5,92 bc	7,37 bcd
Chitosan 2 g/l	218.89 b	249.1 abc	531.5 ab	316.2 b	3.22 ab	2.44 abc	6,28 ab	7,18 b-e
Chitosan 4 g/l	196.67 d	221.1 e	428.1 d	344.9 b	3.33 ab	2.44 abc	6,07 b	7,11 cde
Seaweed extract 1 g/l	205.56 bcd	252.4 ab	471.5 bcd	310.3 b	3.00 ab	2.56 ab	6,15 ab	7,24 bcd
Seaweed extract 2 g/l	211.67 bcd	255.8 a	504.9 abc	302.9 b	3.33 ab	2.44 abc	6,43 ab	7,01 de
Seaweed extract 4 g/l	240.00 a	257.8 a	549.1 a	608.7 a	3.89 a	2.89 a	6,81 a	8,18 a

Means within a column followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's multiple range test.

of photosynthesis, and promote plant cell division (Tomasz and Wanda, 2020). These findings are also in harmony with Kavya et al. *(*2021).

The results in Table 2 showed that the foliar application of seaweed extract at 4 g/l had the highest values of root numbers/plant in both tested seasons, with no significant differences with spraying potassium humate at a rate of 1/l, both fulvic acid at rates of 2 and 4 g/l, and both chitosan at rates of 2 and 4 g/l in the first season. In addition, spraying fulvic acid at a rate of 1 g/l and seaweed extract at rates of 1 and 2 g/l had no significant differences relative to seaweed extract at a rate of 4 g/l in the second season. Regarding root yield per plant, data in Table (2) also indicated that foliar application of seaweed extract at a rate of 4 g/l provided the highest values of root numbers/plant in both tested seasons, with no significant differences with spraying fulvic acid at a rate of 2 g/l and chitosan at a rate of 4 g/l in the first season. However, in the second season all treatments achieved the highest insignificant value of root numbers/plant compared to control treatment. In addition, the obtained results revealed that the highest insignificant root length was attained from foliar spraying chitosan at a rate of 1 g/l as well as seaweed extract at a rate of 4 g/l in both tested seasons. In addition, all the treatments produced greater root length in the first season and all stimulants and controls had no significant differences among them in the second season. Also, data shown in Table (2) indicated that foliar treatments of fulvic at a rate of 1 g/l, chitosan at a rate of 4 g/l, and seaweed extract at a rate of 4 g/l achieved the highest values of root diameter compared to the other treatments and control in both studied seasons. The application of seaweed extract promoted root growth, which can be linked to the alginate oligosaccharide-induced synthesis of an auxin-related gene, which improved auxin concentrations and promoted root formation and elongation. Furthermore, it is possible that seaweed extract increased auxin and cytokinin assimilation and localization, resulting in the production of branching and adventitious roots as well as greater root biomass (Abbas et al. 2020). In this regard, seaweed extracts enhance cell proliferation while also increasing nutrient intake and photosynthetic rate, which has a good effect on the number and length of roots (Mohamad et al. 2021, Sourav et al. 2021). Furthermore, chitosan has significant anti-disease activities, stimulates plant hormone production, helps to absorb soil nutrients, stimulates solubility, root durability, stimulates root growth, and promotes carbohydrate metabolism, as mentioned by Seyyed et al. (2021) and Alshymaa et al. (2022).

Data presented in Table 3 clearly illustrated that foliar spraying with 4 g/l seaweed extract resulted in the maximum nitrogen content in cassava leaves in both tested seasons. In addition, spraying 1 g/l fulvic acid in the first season and 1 g/l of potassium humate in the second season had greater values of N percentage in cassava leaves compared to the control treatment. The showed results in the same table indicated that spraying with 4 g/l of seaweed extract resulted in the maximum phosphorus percentage in leaves in both experimental seasons. Furthermore, spraying with 1 g/l of each fulvic acid, seaweed extract, and chitosan gave the greatest results in phosphorus percentage compared to the control. The obtained results also indicated that the highest values of potassium percentage were observed when cassava plants sprayed with 4 g/l seaweed extract in both seasons. Additionally, foliar spraying with 2 g/l potassium humate and 1 g/l fulvic acid exhibited significant increments in the percentage of K in the first season, as well as 1 g/l seaweed extract in the second season compared to the control treatment. Regarding iron content in the cassava leaves, data in Table 3 revealed that spraying with 4 g/l of both seaweed extract and chitosan resulted in the highest significant iron content values in both tested seasons. Also, foliar spraying with 1 g/l fulvic acid and 2 g/l seaweed extract in the first season and 2 and 4 g/l of chitosan and 1 g/l seaweed extract in the second season exhibited considerable values of iron (ppm) when compared to the control. Increasing nutrients in cassava leaves could be attributed to seaweed extracts improving the antioxidant system of examined plants, which led to optimal growth, accelerated growth, and nutrient uptake, which can increase the capacity of plants for tolerance of stressful conditions, increase yield, and enhance crop nutritional content, as supported by Małgorzata et al. (2019). They showed that seaweed has a substantially beneficial effect on potato tubers, improving growth as measured by an increase in carbon and nitrogen assimilating. The beneficial effect of spraying seaweed extracts on improving N, P and K percentages resulted in elevated biosynthesis and carbohydrate translocation, which are essential for accelerating cell division and the formation of DNA and RNA (Tomasz and Wanda, 2020, Mohamed et al. 2021). The foliar application of seaweed extract can increase crop root growth, improve root ability to absorb macronutrients and translocate them upward to the aboveground parts (Chen et al. 2021).

Roots Weight Loss

Results in Table 4 showed that spraying with chitosan at a rate of 1 g/l resulted in the lowest value of loss weight of cassava roots after 40 days of cold storage, however, spraying 1 g/l of potassium humate as a field treatment resulted in the greatest loss of root weight in both studied seasons. These findings are consistent with Mahmoud (2017) who stated that chitosan functions as a plant defense trigger and maybe a powerful of anti-transparent to protect water content in plant organs, improve plant growth, and protect, and stimulate the plant's immune system.

Roots Decay

The data in Table 4 showed that the control treatment had the highest percentages of decayed roots after 40 days of cold storage at 5°C in both tested seasons. In contrast, potassium humate treatment at rates of 1 and 4 g/l, fulvic acid at a rate of 4 g/l, chitosan at a rate of 2 g/l and seaweed extract at rates of 1 and 2 g/l produced the lowest percentages of decayed roots than the rest treatments in both seasons. Chitosan has been widely used as a foliar treatment to inhibit the growth, spread, and development of several diseases caused by bacteria, fungi, and pests (Rabea, et al. 2003, Abdel-Gayed et al. 2017).

Root Starch

Data in Table 4 revealed that foliar spraying of seaweed extract at a rate of 4 g/l gave the highest percentage value of starch in cassava roots in the first season, however, in the second season, fulvic acid at a rate of 2 g/l recorded the highest percentage values of starch, without significant differences with potassium humate treatment at a rate of 1 g/l compared to the other treatments. Carbohydrate accumulation is related to the biosynthesis of plant hormone signals, which is in line with the physiological responses triggered by the application of exogenous hormone molecules to sugarcane (Chen et al. 2021).

Conclusion

A current experiment was carried out at to investigate the effect of some plant growth bio-stimulants on cassava plants (Indonesian cultivar) growth and yield as well as the roots storability. This study recommended that foliar spraying with seaweed extract at a rate of 4 g/l could be used to increase the production and quality of cassava roots, as well as the content of mineral elements in the shoots and the starch content in the roots. In addition, a storage period of 40 days at a temperature of 5 °C could be attained by using chitosan at a rate of 1 g/l or seaweed extract at 4 g/l as a field treatment.

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TABLE 2. Effect of foliar spraying of some plant bio-stimulants on root's physical quality characters of cassava plants 270 days after planting date during the growing seasons of 2019/2020 and 2020/2021.

	Root numbers/plant		Yield per plant (kg)		Root length (cm)		Root diameter (cm)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	7.44 abc	7.44 d	1.581 b	2.089 a	26.78 b	28.22 a	7,04 e	8,99 d
Potassium humate 1 g/l	9.22 ab	9.11 bcd	1.667 b	2.197 a	28.89 ab	30.89 a	9,14 a	10,19 abc
Potassium humate 2 g/l	5.56 c	8.67 bcd	1.709 b	2.202 a	30.78 ab	27.56 a	8,79 abc	10,64 abc
Potassium humate 4 g/l	7.00 bc	9.89 abc	1.727 b	2.258 a	31.89 ab	32.33 a	7,90 d	10,64 abc
Fulvic acid 1 g/l	7.56 abc	10.00 ab	1.551 b	2.396 a	26.89 b	32.56 a	9,04 ab	10,87 ab
Fulvic acid 2 g/l	8.33 ab	9.89 abc	1.824 ab	2.286 a	33.44 ab	30.78 a	8,59 a-d	9,86 bcd
Fulvic acid 4 g/l	8.22 ab	9.56 a-d	1.642 b	2.247 a	28.11 ab	31.11 a	8,18 cd	10,57 abc
Chitosan 1 g/l	7.33 bc	8.56 bcd	1.611 b	2.019 a	36.56 a	32.22 a	7,90 d	9,68 cd
Chitosan 2 g/l	8.22 ab	7.78 cd	1.648 b	2.130 a	28.78 ab	31.78 a	8,64 abc	10,69 abc
Chitosan 4 g/l	9.67 a	9.44 a-d	1.806 ab	2.333 a	29.44 ab	31.00 a	9,19 a	10,87 ab
Seaweed extract 1 g/l	7.11 bc	10.11 ab	1.771 b	2.253 a	35.89 ab	27.78 a	8,38 bcd	10,21 abc
Seaweed extract 2 g/l	7.44 abc	10.22 ab	1.741 b	2.142 a	29.67 ab	29.56 a	8,89 abc	10,46 abc
Seaweed extract 4 g/l	9.67 a	11.33 a	2.095 a	2.263 a	37.00 a	32.89 a	9,17 a	11,27 a

Means within a column followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's multiple range test.

TABLE 3. Effect of foliar spraying of some plant bio-stimulants on N, P, K and Fe contents of cassava leaves 180 days after planting date during the growing seasons of 2019/2020 and 2020/2021.

	Nitrogen (%)		Phosphorus %		Potassium (%)		Iron (ppm)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	2.109 ef	2.489 b-e	0.323 bc	0.226 e	2.157 f	1.583 bcd	35.01 e	38.87 bcd
Potassium humate 1 g/l	2.329 b-e	2.790 ab	0.320 bc	0.356 c	2.566 abc	1.616 bc	37.03 cde	35.84 cde
Potassium humate 2 g/l	2.420 a-d	2.444 cde	0.324 bc	0.320 cd	2.640 ab	1.436 d-g	38.69 b-e	29.83 f
Potassium humate 4 g/l	2.239 cde	2.753 abc	0.299 cd	0.351 c	2.285 ef	1.406 fg	35.52 de	33.13 ef
Fulvic acid 1 g/l	2.569 ab	2.581 a-e	0.350 b	0.379 bc	2.625 ab	1.500 c-f	42.25 ab	35.07 de
Fulvic acid 2 g/l	2.400 a-d	2.476 b-e	0.317 bc	0.323 cd	2.698 a	1.430 efg	40.21 a-d	32.45 ef
Fulvic acid 4 g/l	2.447abc	2.607 a-e	0.326 bc	0.267 de	2.430 b-e	1.632 bc	40.69 abc	40.10 bc
Chitosan 1 g/l	2.284 cde	2.608 a-e	0.319 bc	0.443 ab	2.235 ef	1.347 g	38.51 b-e	32.09 ef
Chitosan 2 g/l	2.252 cde	2.299 e	0.337 bc	0.282 de	2.520 a-d	1.641 bc	37.61 b-e	41.30 ab
Chitosan 4 g/l	2.188 de	2.638 a-d	0.301 cd	0.271 de	2.314 def	1.582 b-e	44.10 a	41.31 ab
Seaweed extract 1 g/l	2.310 cde	2.400 de	0.352 b	0.262 de	2.397 cde	1.711 ab	38.39 b-e	41.44 ab
Seaweed extract 2 g/l	1.861 f	2.563 a-e	0.276 d	0.363 c	2.324 def	1.666 b	42.36 ab	40.72 abc
Seaweed extract 4 g/l	2.632 a	2.872 a	0.392 a	0.470 a	2.700 a	1.846 a	44.57 a	45.45 a

Means within a column followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's multiple range test.

TABLE 4. Effect of foliar spraying of some plant bio-stimulants on weight loss, decay, and starch content of cassava roots stored at 5 °C temperature after planting date during the growing seasons of 2019/2020 and 2020/2021.

	Root weight loss (%)		Root decay (%)		Root starch (%)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	2.444 bc	2.345 cd	3.111 a	3.111 a	21.070 e	23.697 cde
Potassium humate 1 g/l	8.848 a	7.207 a	2.000 b	2.000 b	23.160 de	28.176 ab
Potassium humate 2 g/l	4.641 bc	4.120 bc	2.556 ab	2.556 ab	26.360 bc	24.221 cde
Potassium humate 4 g/l	2.859 bc	2.682 bcd	1.889 b	1.889 b	21.312 e	24.680 cd
Fulvic acid 1 g/l	3.336 bc	2.618 bcd	2.222 ab	2.222 ab	27.864 b	25.145 cd
Fulvic acid 2 g/l	5.056 b	4.460 b	2.556 ab	2.556 ab	23.154 de	29.275 a
Fulvic acid 4 g/l	3.667 bc	3.263 bcd	2.000 b	2.000 b	23.560 cde	26.051 bc
Chitosan 1 g/l	1.943 c	1.593 d	2.222 ab	1.778 b	23.545 cde	23.450 cde
Chitosan 2 g/l	3.983 bc	2.241 cd	1.889 b	1.889 b	23.071 de	19.643 f
Chitosan 4 g/l	3.983 bc	3.474 bcd	2.556 ab	2.556 ab	25.184 bcd	24.370 cde
Seaweed extract 1 g/l	4.656 bc	3.914 bc	2.000 b	2.000 b	21.947 e	23.167 de
Seaweed extract 2 g/l	3.481 bc	3.121 bcd	1.889 b	1.889 b	27.791 b	21.759 ef
Seaweed extract 4 g/l	3.003 bc	2.456 bcd	1.778 b	2.222 ab	31.221 a	25.071 cd

Means within a column followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's multiple range test.

Conflicts of interest

The authors declare that they have no competing interests.

References

Abbas, M., Anwar, J., Zafar-ul-Hye, M., Khan, R.I., Saleem, M., Rahi, A.A., Danish, S. and Datta, R. (2020) Effect of seaweed extract on productivity and quality attributes of four onion cultivars. *Horticulturae,* **6**(28), 1-13.

Abdel-Gayed, A.A., Shaarawi, S.A.M.A., ELKhishen, M.A. and ELsherbini, N.R.M. (2017). Pre-harvest application of calcium chloride and chitosan on fruit quality and storability 'early swelling' peach during cold storage. *J. Food Sci. Technol.,* **41**(2), 220-231.

Ali, O., Ramsubhag, A. and Jayaraman, J. (2019) Biostimulatory activities of *Ascophyllum nodosum* extract in tomato and sweet pepper crops in a tropical environment. *PLoS ONE,* **14**, e0216710.

Alshymaa, Z.A., Abd El-Aleem, M.A., Ahmed, G.M., Ahmed, R.S., Mahmoud, R.S., Abdel Kareem, S.H.M., Mostafa, M.A.A., Khaled, M.E., Noura, F.G.S., Mohamed, E.E. and Mona, S.A. (2022) Foliar application of chitosan and phosphorus alleviate the *Potato virus Y*-induced resistance by modulation of the reactive oxygen species, antioxidant defense system activity and gene expression in potato. *Agronomy*, **12**, 3064. https://doi.org/10.3390/agronomy12123064

Anjum, S.A., Wang, L., Farooq, M., Xue, L. and Ali, S. (2011) Fulvic acid application improves the maize performance under well-watered and drought conditions. *J. Agro. Crop Sci.,* **197** (6), 409- 417.

Ashour, M. (2019) Bioactive compounds extracted from marine algae improve the growth and immunity of plants, fish and marine Crustaceans. Egypt Patent Application, 2046.

Ashour, M., El-Shafei, A.A., Khairy, H.M., Abd-Elkader, D.Y., Mattar, M.M., Alataway, A. and Hassan, S.M. (2020) Effect of *Pterocladia capillacea* seaweed extracts on growth parameters and biochemical constituents of Jew's Mallow. *Agronomy*, *10*, 420.

Chapman, H.D. and Pratt, P.F. (1961) *Methods of Analysis for Soils, Plants and Water*, Univ. California, Berkeley, CA, USA.

Chen, D., Wenling, Z., Jin, Y., Junhua, A., Ying, H., Dachun, Sh., Yong, J., Zhenrui, H. and Hong, Sh. (2021) Effects of seaweed extracts on the growth, physiological activity, cane yield and sucrose content of sugarcane in China. *Front. Plant Sci.,* **12**, 659130.

Cimrin, K.M., Türkmen, O., Turan, M. and Tuncer, B. (2010) Phosphorus and humic acid application alleviate salinity stress of pepper seedlings. *Afr. J. Biotechnol.,* **9**, 5845–5851.

Ewubare, D.B. and Ologhadien, S.T. (2019) Impact of agricultural financing on cassava production in Nigeria. *Int. J. Econ. Financ. Manag.,* **4**, 50–57.

FAOSTAT, (2022) FAO Statistics, Food and Agriculture Organization of the United Nations, Rome, Italy. Available online at: http://www.fao.org/faostat/en.

Hu, J., Sharaf, J., Wu, A., Sun, J. and Qu, X. (2019) Effects of organic wastes on structural characterizations of fulvic acid in semiarid soil under plastic mulched drip irrigation. *Chemosphere,* **234**, 830-836.

Inegbedion, H.E., Inegbedion, E.E., Obadiaru, E.D., Asaleye, A.J., Ayeni, A. and Aremu, C. (2020) Cassava attractiveness in Nigeria: a policy improvement approach. *J. Agribus. Dev. Emerg. Econ.,* **10**, 157–175. doi: 10.1108/JADEE-05-2019-0068.

Kapur, B., Sarıdas, M.A., Çeliktopuz, E., Kafkas, E., Payda,¸S. and Kargı, S.P. (2018) Health and taste related compounds in strawberries under various irrigation regimes and bio-stimulant application. *Food Chem.,* **263**, 67-73.

Kavya, P., Singh, S., Hinduja, N., Tiwari, D. and Sruthi, S. (2021) Effect of foliar application of micronutrients on growth and yield of greengram (*Vigna radiata* L.). *Legum. Res. An Int. J.,* **44**(12), 1460-1464.

Lemoine, M.L., Civello, P., Chacez, A. and Martinez, G. (2009) Hot air treatment delays senescence and maintains quality of fresh cut broccoli florets during refrigerated storage. *Food Sci. Technol.,* **42**, 1076-1081.

Mahmoud Safa. Z. (2017) Effect of xhitosan and calcium nano-particles on quality and storability of strawberry fruits. Ph.D. thesis, Faculty of Agriculture, Ain shams university.

Małgorzata, G.S., Bożena, C.A., Agnieszka, W., Karel, H. and Adam, P. (2019) The effect of biostimulants on the health status and content of chlorogenic acids in potato tubers (*Solanum tuberosum* L.) with colored flesh. https://doi.org/10.1007/s10343-018-00441-7.

Man-hong, Y., Lei, Z., Sheng-tao, X., McLaughlin, N. and Jing-hui, L. (2020) Effect of water soluble humic acid applied to potato foliage on plant growth, photosynthesis characteristics and fresh tuber yield under different water deficits. *Sci. Rep.,* **10**(1), 7854.

Mohamad, H.S., Christina, Ch., Nikolaos, P. and Spyridon, A.P. (2021) Biostimulants application: A low input cropping management tool for sustainable farming of vegetables. *Biomolecules,* **11**, 698. *https://doi.org/10.3390/biom11050698*. https://www.mdpi.com/journal/biomolecules.

Piper, C.S. (1950) *Soil and Plant Analysis*, 1st ed., Interscience Publishers Inc., New York, USA, pp. 30-59.

Priya, B.N.V., Mahavishnan, K., Gurumurthy, D.S., Bindumadhava, H., Upadhyaya, A.P. and Sharmaa, N.K. (2014) Fulvic acid (FA) for enhanced nutrient uptake and growth: Insights from biochemical and genomic studies. *J. Crop Improv.,* **28**(6), 740-757.

Rabea, E.I., El-Badawy, M.T., Stevens, C.V., Smagghe, G, and Steurbaut, W. (2003) Chitosan as antimicrobial agent: Applications and mode of action. *Biomacromolecules,* **4**, 1457–1465.

Selim, E.M., Shedeed, I.S.H., Asaad, F.F. and El-Neklawy, A.S. (2012) Interactive effects of humic acid and water stress on chlorophyll and mineral nutrient contents of potato plants. *J. Appl. Sci. Res.,* **8**(1), 531-537.

Seyyed, A.M., Sadrabadi, R., Noferest, K.Sh., Darban, A.S. and Salati, M. (2021) Effects of foliar application chitosan and salicylic acid on physiological characteristics and yield under deficit irrigation condition. *J. Agric. Sci.,* **43**(1), 101–113.

Sharif, R., Mujtaba, M., Ur Rahman, M., Shalmani, A., Ahmad, H., Anwar, T. and Wang, X. (2018) The multifunctional role of chitosan in horticultural crops, a review. *Molecules,* **23**(4), 872. https://doi.org/10.3390/molecules23040872

Sharma, N., Singh, D., Rani, R., Sharma, D., Pandey, H. and Agarwal, V. (2019) Chitosan and its nanocarriers: Applications and opportunities. In: D.K. Tripathi, P. Ahmad, S. Sharma, D.K. Chauhan & N.K. Dubey (Ed.), *Nanomaterials in Plants, Algae and Microorganisms: Concepts and Controversies*. Vol. 2 (pp. 267–286). Academic Press, London, UK. https://doi.org/10.1016/B978-0-12- 811488-9.00013-5

Snedecor, G.W. and Cochran, W.G. (1989) *Statistical Methods,* 8th ed. Iowa State Univ., Press. Ames, Iowa, USA.

Somogyl, M. (1952) Noted on sugar determination. *J. Biol. Chem.,* **195**, 19-23.

Sourav, G., Brahmachar, K., Sarkar, S., Mondal, M., Banerjee, H., Nanda, M.K. and Chakravarty, K. (2021). Impact of seaweed sap foliar application on growth, yield, and tuber quality of potato (*Solanum tuberosum* L.). *J. Appl. Phycol.,* 33(3), 1-12. https://doi.org/10.1007/s10811-021-02386-3.

Tomasz, D. and Wanda, W. (2020) Possibility of increasing early crop potato yield with foliar application of seaweed extracts and humic acids. *J. Cent. Eur. Agric.,* **21**(2), 300-310.

Watanabe, F.S. and Olsen, S.R. (1965) Test of an ascorbic acid method for determining phosphorus in water and sodium bicarbonate extracts from soil. *Soil Sci. Soc. Amer. Proc.,* **29**, 677-678.

Wenzhong, H., Shun-ichiro, T. and Yoshiaki, H. (2004) Effect of heat treatment on quality of sweet potato in wrapper type cold store during long term storage. *J. Fac. Agr., Kyilshu Univ.,* **49** (1), 129-138.

Woods, J.T. and Mellon, M.G. (1941) Thiocyanate method for iron. A spectrophotometric study. *Industrial & Engineering Chemistry Analytical Edition,* **13**(8), 551–554.

تأثير الرش الورقي ببعض محفزات النمو على النمو والإنتاجية والقدرة التخزينية لنبات الكسافا

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أجريت تجربة حقلية في مزرعة خاصة بمنطقة البستان بمحافظة البحيرة خلال موسمي 2019/2020 و 2020/2021 لدراسة تأثير الرش الورقي ببعض محفزات النمو على نمو وإنتاجية نباتات الكسافا (Manihot esculenta Crantz) الصنف الإندونيسي وكذلك القدرة التخزينية لجذور الكسافا وقد اشتملت التجربة على 13 معاملة رش هي كالتالي: هيومات البوتاسيوم بتركيز 1، 2، 4 جم/لتر، حمض الفولفيك بتركيز 1، 2، 4 جم/لتر، الشيتوزان بتركيز 1، 2، 4 جم/لتر ومستخلص الأعشاب البحرية بتركيز 1، 2، 4 جم/لتر وكذلك معاملة الكنترول (الرش بالماء فقط) . تم رش نباتات الكسافا أربع مرات خلال موسم النمو بعد 60 و 90 و 120 و 150 يوماً من الزراعة. نفذت التجربة بتصميم القطاعات الكاملة العشوائية بثلاث مكررات. وتم تخزين جذور الكسافا الناتجة من كل المعاملات تحت درجة حرارة 5 درجة مئوية وحساب نسبه الفقد في الوزن للجذور ونسبه التلف بالجذور المخـزنه بعد 40 يوم من التخزين المبرد.

وقد أظهرت النتائج المتحصل عليها أن الرش الورقي بمستخلص الأعشاب البحرية أو حمض الفولفيك أو الشيتوزان قـد أدى إلى الحصول على أعلى القيم لكل من ارتفاع النبات وعدد السيقان الرئيسية وكذلك عدد ووزن الجذور/ نبات وطول الجذور وقطرها. كما أظهرت النباتات التي تم رشها بمستخلص الطحالب والفولفيك اسيد وهيومات البوتاسيوم بتركيز2 جم/لتر أعلى القيم لمحتوي النشا بالجذور كما أدت المعاملة بمستخلص الطحالب البحرية بتركيز 4 جم/لتر الي الحصول علي أعلى القيم لكلا من النيتروجين والفوسفور والبوتاسيوم بالأوراق.
وفى النهاية توصي الدراسه بالرش الورقي كمعاملة حقلية تحت ظروف الأراضي المستصلحه الجديده بمستخلص الطحالب البحرية بمعدل 4 جم/لتر أو الشيتوزان بمعدل 1 جم/لتر لزيادة إنتاج وجوده جذور الكسافا وكذا زيادة محتواها من العناصر المعدنية في الأوراق ومحتوى النشا فى الجذور وكذلك اطاله فترة التخزين لمده 40 يوم تحت درجه حراره 5 درجة مئوية.

الكلمات الدالة: الكسافا ، محفزات النمو النباتية ، النمو الخضرى ، محصول الجذور ، المحتويات المعدنية ، محتوى نشا بالجذر ، التخزين المبرد.