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Effect of bio-stimulants foliar applications on growth, yield, and product quality of two Cassava cultivars

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Abstract

Background: Cassava is a major staple food crop for the people in tropical and sub-tropical areas, a non-traditional vegetable root crop in Egypt. It has important industrial raw materials for the production of starch, alcohol, pharmaceuticals, and livestock feed. The current study is evaluating two cassava cultivars: American and Brazilian types under three bio-stimulants: glutamine, lysine, and active dry yeast, as foliar applications. Vegetative growth characters, tuber yield, and its quality as well as chemical contents of cassava tubers were evaluated.

Results: The results showed that American cassava cultivar recorded the highest vegetative growth characters (plant height, leaves number, main stems, lateral branches, leaf area, and chlorophyll content), tuber yield (number and weight), and tuber quality (length, diameter, dry matter, and tubers-shoots ratio) as well as chemical composition (starch, total carbohydrates, N, P, and K). The foliar application of glutamine at the rate of 200 mg/L increased vegetative growth characters and tuber yield as well as tuber quality and improved chemical contents of cassava tubers. On the contrary, the lowest values of cassava growth and its productivity as well as chemical composition were associated to Brazilian cultivar when foliar sprayed by yeast at the concentration of 2 g/L.

Conclusion: From this study, it could be concluded that American type of cassava is the most suitable under Egyptian conditions, which ranked the first in all vegetative growth characters, tuber yield, tuber quality, and chemical composition, with foliar sprayed by glutamine at the rate of 200 mg/L.

Keywords: Cassava, Cultivars, Bio-stimulants, Yield, Quality

Background

Cassava is a carbohydrate food source for people in the tropical and sub-tropical areas (FAO 2004; Abdullahi et al. 2014). The storage roots of cassava are the most important parts due to its contents of 80% starch. Cassava leaves are also widely consumed as a vegetable for protein, vitamins, and minerals (Berry 1993; Dahniya et al. 1994). Crop roots have gained industrial importance as a source of raw materials using in production of ethanol, flour for production of bread, and glucose syrup. The starch is using in the food industry in many preparations including sauces, gravies, mustard powder, baby foods, and tapioca products such as puddings, glucose production, and some kind of bakery products (IITA 1990). As food, feed, and its promising industrial markets, there is an increasing focuses on cassava by governments, research, and development institutes in Africa (FAO 2004). Cassava is cultivated as annual crop in wide areas of tropical and subtropical countries for its edible starchy tuberous roots as a major source of carbohydrates (Kenneth 2011). The crop is a low cost production and is one of the cheapest foods (Shams 2011). It seems that the markets for cassava as a substitute of wheat flour and as a source in animal feed are expanded. Although considerable efforts were previously conducted by Egyptian researches to introduce cassava plants as a new non-traditional crop and enhance its productivity (El-

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Fieshawy 1986; Mansour 1992; Sherif et al. 2003; Nagwa et al. 2007; Nagwa 2008; Neama et al. 2016), the cultivated area of cassava is still so limited. In response to continuous interest for cassava cultivation in Egypt, new cultivars have to introduce to our farmers after their evaluation in newly reclaimed lands. It can be cultivated in newly reclaimed lands where cassava plants need little attention once they get established, then support its productivity by using foliar spraying of several additives of nutrients sources (Neama et al. 2016). Indeed, cassava realizes its high yield potential when it is supplied with adequate irrigation and nutrients. Therefore, cassava plants have tremendous future in Egypt, where its flour can be mixed with wheat flour at a ratio about 15% for bread making (Mansour 1992; Sherif et al. 2003; Nagwa et al. 2007). Also, we can depend on its rich starch as a cheapest alternative raw material source for many industrial products (El-Fieshawy 1986; Nagwa 2008; Neama et al. 2016). For this reason, we are seeking to introduce and evaluate new cassava cultivars to know suitable one for Egyptian conditions and to set practical recommendations for sustain and expand cassava cultivation in Egypt as a food industrial crop. It is well known that chemical fertilizers may not keep pace with time in maintaining the soil health and its sustainability. Also, the overuse of chemical fertilizers is detrimental to the environment and human health (Arisha and Bardisi 1999). The conventional use of chemical fertilizer can increase the yield but its inordinate use has negative effects on product quality, environment pollution, public health, and economical losses (Najm et al. 2011). On the other hand, the universe is going now on the way of minimizing pollution sources and using safe agriculture. The essential rates of amino acids are well known as safe means to enhance plant productivity and improve product quality (Awad et al. 2007). Thus, the foliar application of amino acids may contribute to enhance cassava productivity by improving plant growth under newly reclaimed lands (Neama et al. 2016). The current study is aiming to evaluate two cassava varieties: American and Brazilian types and improve the productivity of cassava plants by using foliar application of bio-stimulants, i.e., glutamine, lysine and active dry yeast, as foliar applications.

Materials and methods

Two field experiments were carried out in the experimental station of the National Research Centre (Research and Production Station, El-Nubaria region, El-Behira Governorate, Egypt). The experiments were conducted during the two successive seasons of 2016/2017 and 2017/2018 to study the effect of foliar application of different bio-stimulants treatments: glutamine, lysine, and yeast on vegetative growth, yield, and quality of two cultivars of cassava plants: American and Brazilian cultivars.

Cassava plants were sprayed with the bio-stimulants treatments at three times during the growth period. The first one was applied after 45 days from seed planting. The second one was applied 2 weeks later from the first one. The third one was applied 2 weeks later from the second one. The experimental design was split plot design with three replicates. The two cultivars were in the main plots, and the foliar application of bio-stimulants treatments randomly distributed in the sub plots.

Cassava was planted on 26 April during the two growing seasons of 2016/2017 and 2017/2018. Cassava stalks of similar thickness of approximately 2.5–3.0 cm in diameter were cut into stalk cuttings of 25–30 cm in length and planted vertically by burring two thirds of the cuttings into the soil and keeping one third of them over ground, then irrigated directly after planting. The standard agricultural practices were carried out uniformly in all treatment plots as recommended, wherever they were necessary. Twenty cubic meter of organic manure and 500 kg calcium super phosphate (15.5% P_2O_5) per feddan (4200m^2) were added during land preparation through the ditches before planting, and ditches were covered by soil. Drip irrigation lines were used and spread over the ditches. Also, 250 kg ammonium sulphate (20.5% N) as a source of nitrogen and 200 kg potassium sulphate (48% K_2O) as a source of potassium as recommended doses for cassava were added for all experimental plots. The total amounts of nitrogen and potassium fertilizers were divided into four equal doses. Fertilization program started at the fourth week after planting, and then other doses were monthly applied.

Both amino acids (glutamine and lysine) were obtained as commercial chemical substances from El-Gomhorya Company (Egypt). The pure dry yeast powder was activated by using sources of carbon and nitrogen with the ratio of 6: 1 to get the highest vegetative production of yeast. It allowed yeast cells to be grown and multiplied efficiently during conductive aerobic and nutritional conditions to produce beneficial bio constituents, i.e., phytohormones, carbohydrates, proteins, amino acids, fatty acids, vitamins, enzymes, and minerals, and hence allowed such constituents to release out of yeast cells in readily form. Such technique for yeast preparation based on nutritional media of glucose and casein as favorable sources of C, N, and other essential elements, i.e., P, K, Ca, Mg, Fe, Mn, Cu, B, and Mo as well as Na and Cl in suitable balance and adjusting incubation temperature (Barnett et al. 1990). Analysis of prepared yeast stock solution was total protein (5.3%), total carbohydrates (4.7%), N (1.2%), P (0.13%), K (0.3%), Mg (0.013%), Ca (0.02%), Na (0.01%); micro-elements (ppm), Fe (0.13), Mn (0.07), Zn (0.04), Cu (.04), B (0.016), Mo (0.0003), IAA (0.5 mg/ml), and GA (0.3 mg/ml) according to Fathy et al. (2000).

Data recorded

1- Vegetative growth parameters: Representative random samples of eight plants were labeled in each replicate for every treatment at 180 days after planting, and the following characters were recorded: Plant height, leaves number per plant, number of main stems and number of lateral branches, leaf area, and total chlorophyll content.
2- Tuber yield and yield components: The following data were recorded: Number of tubers per plant and tuber fresh weight, and root/shoot ratio were calculated according the following equation: Weight of tubers (g)/weight of shoot (g).
3- Tuber characters: The following data were recorded: Length and diameter of tubers and dry matter percentage of tubers.
4- Chemical composition of tubers: Starch percentage was determined as described by Smith and Zeeman (2006). Total carbohydrate percentage was determined colorimetrically as gram of glucose per 100 g dry weight of tubers according to the method of James (1995). Total fiber percentage of root tubers was determined as described by A.O.A.C. (1990). Nitrogen was determined in cassava tubers according to method of Horneck and Miller (1998). Phosphorus was determined colorimetrically, and potassium was determined using flame photometer according to the method of Page et al. (1982).

Statistical analysis

The treatment effects were evaluated by analysis of variance. The differences among treatment mean values were compared using Duncan's multiple range test at $P < 5\%$ as reported by Gomez and Gomez (1984).

Results

Vegetative growth characters

Effect of cultivars

Data in Table 1 shows that the two different cassava varieties have significant variations in their vegetative growth parameters, i.e., plant height, leaves number, main stems, lateral branches, leaf area, and chlorophyll content in both growing seasons. The highest values of vegetative growth parameters were related to American cultivar, while Brazilian cultivar produced lower amounts of growth characters. These results were true during both growing seasons.

Effect of bio-stimulants applications

Vegetative growth parameters in relation to foliar application of bio-stimulants, glutamine, lysine, and active dry yeast, are presented in Table 1. Generally, the application of glutamine, lysine, and active dry yeast had significant responses on vegetative growth parameters, i.e., plant height, number of leaves and main stems per plant, lateral branches per plant, leaf area, and chlorophyll content. Whereas, the highest amounts of all vegetative growth characters were recorded by foliar sprayed treatment of glutamine at 200 mg/L. On the contrary, foliar application of active dry yeast at rate of 2 g/L resulted in the lowest amounts of all growth characters. These findings were true during the two growing seasons.

Effect of the interaction between cultivars and bio-stimulants applications

The interaction effects of two cassava cultivars and some bio-stimulants treatments showed significant variations at level of 5% during both growing seasons (Table 1). Whereas, the highest amounts of the vegetative growth parameters of cassava plants are found by using American cassava cultivar with foliar spray of glutamine at the rate of 200 mg/L. On the contrary, the lowest amounts of vegetative growth parameters of cassava plants were recorded by Brazilian cassava cultivar with foliar application of yeast at the rate of 2 g/L. These results were true in the both growing seasons.

Tuber yield and tuber characters

Effect of cultivars

Data in Table 2 clearly shows that cassava cultivars have significant effects on total tuber yield and tuber characters of cassava plants in both growing seasons. Whereas, the highest values of all vegetative growth parameters were found by American cassava cultivar. Conversely, the lowest vegetative growth parameters were recorded by using Brazilian cassava cultivar. These results were true during both growing seasons.

Effect of bio-stimulants applications

The measured data of tuber yield and its quality in relation to foliar application treatments by bio-stimulants, glutamine, lysine, and active dry yeast, were presented in Table 2. Generally, application of bio-stimulants had significant effects on the total tuber yield and tuber quality, i.e., tubers number per plant, tuber shoots ratio, tuber length, tuber diameter, and dry matter during the two growing seasons. Furthermore, the highest value of tuber yield and yield parameter were obtained by the foliar application of glutamine at a rate of 200 mg/L. On the contrary, the lowest amount of tuber yield and yield parameter was found by foliar spray treatment of active dry yeast at 2 g/L. These findings were true in the two growing seasons.

Table 1 Effect of different bio-stimulants on vegetative growth characters of cassava cultivars in 2016/2017 and 2017/2018 seasons

Treatments		First season (2016/2017)						Second season (2017/2018)					
		Plant height (cm)	Leaves number/ plant	Number of main stems/plant	Lateral branches/ plant	Leaf area (cm^2)	Chlorophyll content	Plant height (cm)	Leaves number/ plant	Number of main stems/plant	Lateral branches/ plant	Leaf area(cm^2)	Chlorophyll content
Effect of cultivars													
American cassava		169.7a	156.3a	4.1a	5.9a	161.9a	49.0a	170.8a	155.0a	3.2a	167.6a	159.5a	47.9a
Brazilian cassava		127.2b	126.0b	2.7b	4.5b	137.5b	34.9b	129.3b	126.4b	1.8b	126.4b	136.5b	34.5b
Effect of bio-stimulants													
Glutamine (200 mg/L)		166.3a	149.6a	3.9a	5.7a	155.5a	44.6a	167.4a	148.4a	3.1a	164.1a	153.1a	44.2a
Lysine (100 mg/L)		148.2b	141.0b	3.5b	5.4b	151.1b	43.3b	149.3b	139.7b	2.6b	146.1b	148.8b	42.4b
Yeast (4 g/L)		143.1c	138.2c	3.0c	5.0c	147.1c	41.1c	144.8c	137.7c	2.2c	141.7b	146.5b	40.0b
Yeast (2 g/L)		136.9d	135.7d	2.9d	4.6d	144.9d	39.0d	138.8d	137.1d	2.1d	136.0c	143.7c	38.1c
Effect of interaction													
American cassava	**Glutamine (200 mg/L)**	187.8a	165.8a	4.9a	6.3a	166.2a	51.1a	188.9a	164.5a	4.0a	185.7a	163.8a	50.7a
	Lysine (100 mg/l)	171.7b	155.1b	4.3b	6.1b	163.0b	50.6b	172.8b	153.8b	3.4b	169.6b	160.6b	49.2b
	Yeast (4 g/L)	164.5c	152.7c	3.6c	5.8c	160.3c	48.4c	165.6c	151.4c	2.7c	162.4c	157.9c	47.0c
	Yeast (2 g/L)	154.8d	151.7c	3.4d	5.4d	158.1d	46.0d	155.9d	150.4d	2.5d	152.7d	155.7d	44.6d
Brazilian cassava	**Glutamine (200 mg/L)**	144.7e	133.5d	3.0e	5.1e	144.9e	38.1e	145.8e	132.2e	2.1e	142.6e	142.5e	37.7e
	Lysine (100 mg/L)	124.7f	126.9e	2.7f	4.7f	139.3f	35.9f	125.8f	125.6f	1.8f	122.5f	136.9f	35.5f
	Yeast (4 g/L)	121.8g	123.7f	2.5g	4.3g	134.0g	33.7g	124.0g	124.0g	1.7g	121.0g	135.1g	33.0g
	Yeast (2 g/L)	119.0h	119.7g	2.4h	3.8h	131.7h	32.0h	121.6h	123.8h	1.6h	119.3h	131.6h	31.6h

The means within each column within main effects and interactions followed by same letter are not significant at $P < 5\%$

Table 2 Effect of different bio-stimulants on tuber yield and tuber characters of Cassava cultivars in 2016/2017 and 2017/2018 seasons

Treatments		First season (2016/2017)						Second season (2017/2018)					
		Tubers number/ plant	Tuber weight (g)	Tuber/ shoot ratio	Tuber length (cm)	Tuber diameter (cm)	Dry matter (%)	Tubers number/ plant	Tuber weight (g)	Tuber/ shoot ratio	Tuber length (cm)	Tuber diameter (cm)	Dry matter (%)
Effect of cultivars													
American cassava		13.9a	321.2a	2.14a	35.9a	4.4a	36.6a	13.7a	320.3a	2.25a	38.7a	4.5a	35.5a
Brazilian cassava		11.3b	277.3b	1.73b	26.2b	2.9b	30.4b	10.7b	282.4b	1.91b	31.1b	2.9b	29.9b
Effect of bio-stimulants													
Glutamine (200 mg/L)		13.6a	316.0a	2.04a	34.8a	4.1a	36.2a	13.4a	315.1a	2.20a	38.1a	4.1a	35.0a
Lysine (100 mg/L)		12.5b	308.1b	2.01b	32.0b	3.8b	34.4b	12.3b	307.2b	2.17a	35.9b	3.8b	33.2b
Yeast (4 g/L)		12.3c	288.8c	1.86c	29.9c	3.6d	33.1c	11.9c	294.9c	2.00b	33.6c	3.5c	32.0b
Yeast (2 g/L)		12.0d	283.6d	1.84d	27.7c	3.4c	30.4d	11.1d	288.1d	1.97b	32.1d	3.3d	30.4c
Effect of interaction													
American cassava	**Glutamine (200 mg/L)**	14.8a	332.7a	2.28a	39.3a	4.8a	39.1a	14.6a	331.8a	2.41a	41.4a	4.9a	38.0a
	Lysine (100 mg/L)	13.8b	327.1b	2.25b	35.8b	4.5b	37.3b	13.6b	326.2b	2.38a	40.4b	4.6b	36.2b
	Yeast (4 g/L)	13.6c	313.8c	2.03c	34.9c	4.3c	36.0c	13.4c	312.9c	2.12b	36.9c	4.2c	34.9c
	Yeast (2 g/L)	13.2d	311.2d	1.99d	33.7d	4.2d	33.8d	13.0d	310.3d	2.09b	36.0d	4.1d	32.7d
Brazilian cassava	**Glutamine (200 mg/L)**	12.4e	299.3e	1.79e	30.3e	3.3e	33.2e	12.2e	298.4e	1.98c	34.8e	3.2e	32.1e
	Lysine (100 mg/L)	11.1f	289.1f	1.77f	28.2f	3.0f	31.4f	10.9f	288.2f	1.96c	31.4f	3.0f	30.3f
	Yeast (4 g/L)	11.0g	263.8g	1.69g	24.8g	2.8g	30.2g	10.4g	276.9g	1.87d	30.2g	2.8g	29.1g
	Yeast (2 g/L)	10.8h	255.9h	1.68h	21.6h	2.6h	26.9h	9.2 h	265.9h	1.84d	28.1h	2.5h	28.1h

The means within each column within main effects and interactions followed by same letter are not significant at $P < 5\%$

Effect of the interaction between cultivars and bio-stimulants applications

The obtained results of the interaction effects between the different cultivars and the different bio-stimulants recorded significant variations at 5% level (Table 2) in the two growing seasons. Whereas, American cassava cultivar recorded the highest tuber yield and tuber yield quality when foliar sprayed by glutamine at the rate of 200 mg/L in both growing seasons. On the contrary, the lowest amounts of tuber yield and tuber quality parameters of cassava plants were found by using foliar application of active dry yeast at 2 g/L with Brazilian cassava cultivar during both growing seasons.

Chemical contents

Effect of cultivars

The presented data in Table 3 shows that cassava varieties have significant effects on chemical contents, i.e., starch, total carbohydrates, total fibers, N, P, and K (%) of cassava tubers in both growing seasons. American cassava cultivar recorded the higher values of starch, total carbohydrates, N, P, and K, while Brazilian cassava cultivar gave the lowest values of starch, total carbohydrates, N, P, and K. No significant differences between the two cultivars concerning their effects on the value of total fibers. These results were true during the two growing seasons.

Effect of bio-stimulants applications

Data of the measured chemical contents, i.e., starch, total carbohydrates, total fibers, N, P, and K (%) in cassava tubers as affected by application of different bio-stimulants are presented in Table 3. Generally, the foliar application of glutamine at the rate of 200 mg/L had the highest values of starch, total carbohydrates, N, P, and K (%) during the two growing seasons. Total fibers were increased by foliar application of lysine at the rate of 100 mg/L. On the contrary, the lowest values of all chemical contents, i.e., starch, total carbohydrates, total

Table 3 Effect of different bio-stimulants on chemical contents of tuber roots of Cassava cultivars in 2016/2017 and 2017/2018 seasons

Treatments		First season (2016/2017)						Second season (2017/2018)					
		Starch (%)	Total carbohydrates (%)	Total fibers (%)	N (%)	P (%)	K (%)	Starch (%)	Total carbohydrates (%)	Total fibers (%)	N (%)	P (%)	K (%)
Effect of cultivars													
	American cassava	50.8a	62.4a	2.3a	0.89a	0.29a	1.03a	49.8 a	59.0a	2.4a	0.95a	0.31a	1.02a
	Brazilian cassava	46.1b	56.5b	2.5a	0.68b	0.24b	0.77b	39.0 b	47.5b	2.5a	0.70b	0.21b	0.78b
Effect of bio-stimulants													
Glutamine (200 mg/L)		49.7a	62.4a	2.4b	0.88a	0.28a	1.00a	48.7 a	57.4a	2.5b	0.96a	0.29a	0.98a
Lysine (100 mg/L)		48.1b	60.2b	2.5a	0.83b	0.26b	0.97b	47.1 b	55.2b	2.6a	0.84b	0.27b	0.90b
Yeast (4 g/L)		44.6c	58.4c	2.4c	0.74c	0.23c	0.84c	43.1 c	51.5c	2.5b	0.78c	0.24b	0.88b
Yeast (2 g/L)		40.5d	57.3d	2.3d	0.69d	0.21d	0.81d	38.8 d	48.8d	2.4c	0.74d	0.22c	0.82c
Effect of interaction													
American cassava	**Glutamine (200 mg/L)**	54.2a	65.4a	2.2f	0.97a	0.33a	1.11a	53.1 a	63.4a	2.4d	1.10a	0.34a	1.09a
	Lysine (100 mg/L)	53.1b	63.0b	2.3d	0.92a	0.31b	1.06b	52.0 b	60.2b	2.4d	0.94b	0.32b	1.07a
	Yeast (4 g/L)	49.7c	60.8c	2.4c	0.85b	0.28c	0.99c	48.6 c	57.8c	2.4d	0.91b	0.29c	1.00c
	Yeast (2 g/L)	46.5d	60.4d	2.4c	0.81b	0.26d	0.96c	45.4 d	54.4d	2.4d	0.86c	0.27d	0.91d
Brazilian cassava	**Glutamine (200 mg/L)**	45.3e	59.4e	2.6b	0.79c	0.23e	0.88d	44.2 e	51.4e	2.6b	0.81c	0.24e	0.86e
	Lysine (100 mg/L)	43.2f	57.4f	2.7a	0.74c	0.21f	0.87d	42.1 f	50.1f	2.7a	0.74d	0.22f	0.80f
	Yeast (4 g/L)	39.6g	56.1g	2.4c	0.63d	0.19g	0.68e	37.5 g	45.2g	2.5c	0.64e	0.19g	0.75g
	Yeast (2 g/L)	34.5h	54.3h	2.2e	0.56e	0.17h	0.65e	32.1 h	43.2h	2.3e	0.61e	0.17h	0.72g

The means within each column within main effects and interactions followed by same letter are not significant at $P < 5\%$

fibers, N, P, and K (%) of cassava tubers were recorded by foliar spray of active dry yeast at rate of 2 g/L. These findings were true in the two growing seasons.

Effect of the interaction between cultivars and bio-stimulants applications

The interaction treatments between the two cassava cultivars and different bio-stimulants foliar applications recorded significant variations concerning their effects on chemical contents of cassava tubers at 5% level in the two growing seasons (Table 3). American cassava cultivar produced the highest values of starch, total carbohydrates, N, P, and K (%) when foliar sprayed by glutamine at the rate of 200 mg/L during the two growing seasons. The highest contents of total fibers were found in cassava tubers of Brazilian cultivar when foliar sprayed by lysine at rate of 100 mg/L. On the contrary, the lowest amounts of all chemical contents, i.e., starch, total carbohydrates, total fibers, N, P, and K (%) in cassava tubers were related to Brazilian cultivar and foliar application of active dry yeast at rate of 2 g/L. These results were true in both growing seasons.

Discussion

Our obtained results reported that American type of cassava is the most suitable under Egyptian condition, which ranked the first in all vegetative growth characters, tuber yield, tuber quality, and chemical composition, with foliar sprayed by glutamine at a rate of 200 mg/L. It could be attributed by the genetic variations between the different cultivars, i.e., American and Brazilian cultivars. It is well known that the actual performance of any cultivar depends on its genetic parameters interacted with all surrounded environmental conditions (Saleh et al. 2018). The obtained variations between American and Brazilian cultivars in vegetative characters are mainly due to the genotype of each cultivar. This may be due to high demand toward assimilation of vegetative growth phase and may affect tuber production. Therefore, the highest plant productivity can be achieved by using suitable cultivar and application of the best management of all agricultural practices. The management and sustainable cultural practices are highly needed and must be preferable. For instance, the foliar application of amino acids may contribute to enhance plant productivity and improve product quality (Takeuchi et al. 2008;

Mazher et al. 2011). The enhancement effects for amino acids due to their positive role protein assimilation and plant metabolism, which important for cell formation, and consequently increase growth and dry matter. Glutamic could enhance plant growth and plant development by its effect on gibberellins biosynthesis. Glycine and glutamic acids are fundamental metabolites in the process of vegetable tissues and chlorophyll synthesis. Moreover, the amino acid of glutamic acts as a cytoplasm osmotic agent of the guard cell and regulate opening of the stomata (Abdel-Mawgoud et al. 2011). These increases in the above mentioned data due to this amino acid "Glutamine" can directly or indirectly influence the physiological activities of cassava productivity. The regulatory effect of amino acids on growth could be explained by the notion that some amino acids can affect plant growth and development through their influence on gibberellins biosynthesis. Also, amino acids may play an important role in plant metabolism and protein assimilation which is necessary for cell formation and consequently increase in fresh and dry matter. Similarly, significant positive effects of amino chelate fertilizers on plant growth and yield have also been reported by several previous works (Machado et al. 2008; Datir et al. 2012; Ghasemi et al. 2013, 2014; Sadak et al. 2015; Fahimi et al. 2016; Souri and Yarahmadi 2016).

Bio-stimulants are composed of single- or multi-ingredient plant extracts containing hormones, enzymes, proteins, amino acids, vitamins, microelements, and other biologically active compounds (Basak 2008). Bio-stimulants affect plant metabolism when applied in small quantities through stimulation of natural hormone synthesis and activity, enhancement of nutrients uptake, stimulation of root growth, and increase of resistance to unfavorable conditions. The multiple functions of bio-stimulants have induced many researchers to investigate such effects on crops (Fawzy et al. 2010; Paradikovic et al. 2011; Neama et al. 2016). The dose of bio-stimulants, time and way of application, crop species or cultivar, growth conditions, and other environmental factors can affect the bio-stimulant action. Foliar application of bio-stimulants can be treated as systemic agents, so they must successfully penetrate the cuticle to reach active sites in the plant tissues.

El- Shabasi et al. (2005) reported that foliar spraying of garlic plants with mixture of glaycine, alanin, cysteine, and arginine (each at 100 ppm) gave the highest plant height, leaf blade area, neck and bulb diameter, fresh weight of leaves, and markedly produced higher total yield as well as crude protein. Shaheen et al. (2013) found that foliar spraying by amino mix compound caused an enhancement in onion plant growth characters, i.e., length of plant, leaves number, and fresh and dry weight of plant. Also, bulb yield and TSS recorded their highest values when amino mix sprayed at level within 2–3 cm/L. El- Zohiri and Asfour (2009) reported that foliar applications of amino acids at 0.25 ml/L enhanced vegetative growth parameters, i.e., plant height and dry matter of potato plants. Amino acids are the fundamental ingredients for the process of protein synthesis. Other several authors reported that the foliar application of amino acids enhanced plant growth, yield, and improve product quality (Kamar and Omar 1987 on cucumber; Karuppaiah et al. 2000 on potato; Awad et al. 2007 on potato). Kamar and Omar (1987) mentioned that amino acids are widely used for biosynthesis of non-protein nitrogenous compounds such as coenzymes, vitamins, pigments, purine, and pyrimidine bases.

More attention was focused for minimization of environmental pollution and its impacts on human health through reducing chemical fertilizers in plant production (FAO/TTC 2001). According to Sarojnee et al. (2009), amino acids can improve fertilizer assimilation, increase uptake of nutrients and water, enhance the photosynthetic rate and dry matter partitioning, and hence increase yield and quality. Paradikovic et al. (2011) found that the application of bio-stimulants could be considered as a good production strategy for obtaining high yields of nutritionally valuable vegetables with lower impact on the environment. Amino acids are well known as bio-stimulants that have positive effects on plant growth, yield, and significantly mitigate the injuries caused by abiotic stresses (Kowalczyk and Zielony 2008). Furthermore, amino acids are also used to alleviate the negative effects of some environmental stress, e.g., salinity (Neeraja et al. 2005; Tantawy et al. 2009; Abdel-Mawgoud et al. 2011).

However, in response to continue interest for cassava cultivation and entrepreneurship, new cultivars should introduce to the farmers after several on-farms evaluation in different locations to know their actual performance under preferable management of all agricultural practices.

Conclusion

The American type of cassava is the most suitable under Egyptian conditions, which recorded the highest vegetative growth characters, tuber yield, tuber quality, and chemical composition, with foliar application of glutamine at a rate of 200 mg/L.

Abbreviations

N: Nitrogen; P: Phosphorus; K: Potassium; g/L: Gram per liter

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Authors' contributions
This work is a combined effort of all of the authors. NM Hassan and NA Marzouk designed this work, conducted the field experiments, and performed the chemical analysis of the samples. ZF Fawzy and SA Saleh wrote the manuscript and revised it. All authors read and approved the final manuscript.

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Availability of data and materials
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Competing interests
The authors declare that they have no competing interests.

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