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Response of sugarcane Irrigated with diluted seawater to the spraying of stimufol amino and potassium citrate

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SALINITY stress is a major constraint for sugarcane growth and productivity, particularly in areas that irrigated with saline water, low quality water or diluted seawater. A pot experiment was conducted to evaluate the growth and mineral status of early stage sugarcane plants that spread with two different plant growth promoters (Stimufol-amino or potassium citrate at rate of 2g/L and distilled water used as a control) and irrigated with diluted sea water (S1=2000, S2=4000 ppm and tap water (TW) as a control). Sugarcane plants that irrigated with saline water affected negatively compared to irrigated plants with tap water. Stimufol-amino and potassium citrate have been shown to improve sugarcane growth parameters compared to control. The highest values of fresh weight (FW) of stem, root, whole plant and the dry weight (DW) of roots resulted from potassium citrate treated plants. The differences between Stimufol-amino or potassium citrate were not substantial enough to be statistically significant in all studied parameters except for the fresh weight of stem. Thus, the application of neither of them can be an effective strategy to enhance sugarcane growth and productivity under salinity stress conditions. Although, foliar applications increased sugarcane growth particularly under salinity stress conditions, they led to discrepancy in nutrient balance where they decreased calcium % and Ca(Na+K) while they increased Na%, Na/K, and Na/Ca ratio compared with control.

Keywords: Sugarcane, growth promoters, diluted seawater, saimufol amino, potassium citrate.

Introduction

Sugarcane (*Saccharum officinarum* L.) is an essential crop, renewable, providing sugar, biofuel, fodder, organic fertilizers, bagasse, fibers, molasses, given mud cake for covering fertilizers (El-Hassanin et al., 2021) and other important co-products (Singh, 2020). Sugarcane has essential elements and compound that improve immunity and human health (Arif et al., 2019).

The world sugarcane yield (tonnes/ha), area harvested (million ha) and production (million tonnes) increased from 72.0, 26.07 and 1877.8 in 2020 to 73.7, 26.09 and 1922.1 in 2022, respectively, even though the area harvested (ha) decreased from 217625 ha in 2021 to 151425 ha in 2022 (FAO, 2024). In Egypt, although the harvested area severely decreased from 217,625 in 2020 to 151,425 ha in 2022, the production slightly increased from 15.86 million ton into ٢٠٢٠ 15.98 million ton in 2022 this is due to the increase in the yield per ha from 72.9 ton/ha in 2020 to 105.5 ton/ha in 2022 (FAO, 2024).

Due to the adverse effects of salts on the growth and development of sugarcane growth, the semiarid region imposes significant constraints on the exploitation of some regions for the production of sugar cane (Simões et al., 2016). Sugarcane productivity is being impacted by environmental stress as salinity, affecting physiological, biochemical, and metabolic responses (Ashraf et al., 2009 and Kumar et al., 2023).

Plant growth promoters (PGPs) are natural or synthetic compounds that can enhance the growth and yield of plants. These compounds may be

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hormones, microbes, organic or inorganic PGPs. For example, increasing stimufol-amino application rate to 450 g/fed. significantly increased all growth parameters, yield, yield components and chemical composition of maize with the highest values in protein and carbohydrate in grains (Hassanein et al., 2015). Also, potassium is a second essential element after nitrogen for the growth of whole plants. It participates in activation of over 60 enzymes and plays a necessary role as a regulator. Additionally, potassium is a key in detoxification of reactive oxygen species (ROS) and in providing plants with resistance to abiotic stressors (Ashraf et al., 2009 and Johnson et al., 2022). Applying potassium citrate spray to stressed cotton plants resulted in an increase in plant height, fruiting branch count, number of open bolls per plant, seed index, boll weight, lint percentage, seed cotton yield per feddan, and some chemical content in the cotton leaves, such as proline, antioxidant enzyme activities, total chlorophyll and carotein, and chlorophyll a and b (Gebaly et al., 2013). Spraying cotton plants with potassium citrate ($2.5gL^{-1}$) under salt conditions (1200, 8000 and 4000 diluted seawater) enhances growth and yield, increases leaf chemical composition, and prolongs cell shelf life (El-Beltagi et al., 2017).

As such, it is imperative that we search for some growth promoter compounds that contribute to improve sugarcane growth under salinity conditions. Therefore, the aim of this work is investigating if the foliar addition of stimufol-amino or potassium citrate might encourage sugarcane development and its nutrient status in salinity conditions.

Materials and Methods

A polyethylene pot experiment was conducted in the greenhouse of the National Research Centre (NRC), Dokki, Cairo, Egypt to study the influence of spraying Stimufol-amino or potassium citrate to sugarcane under salinity stress conditions. The 50 X 60 cm pots are filled with 36 kilogram of soil. The texture of Giza Governorate soil is clay loam (Klute, 1986). The soil pH tends to be slightly alkali (7.9) and EC value is 1.5 dSm^{-1} (Page et al., 1982).

Two sugarcane (*Saccharum officinarum* L. var. Giza 3) buds (obtained from Aswan governorate) were cultivated in Jan., 2019 in earthenware pots. The plants were thinned to one plant per pot following the appearance of the first sprout. Then plants were irrigated with diluted sea water (S1=2000, S2=4000 ppm and tap water (TW) as a control) and spread with two different plant growth promoters (Stimufol-amino or potassium citrate at rate of 2g/L and distilled water used as a control). The foliar treatments were applied three times in fifteen days interval.

Nitrogen in the form of ammonium sulphate (20.5 N%) added in the rate of 3.0g/pot in two equal portions, the 1^{st} 21days after sowing and the 2^{nd} two weeks later. Single superphosphate (15.5% P_2O_5) and potassium sulphate (48.5% K_2O) mixed at rate of 1.5 and 3.0 g/pot with the upper soil surface layer. The other agricultural regimes were applied according to the Egyptian Ministry of Agriculture, recommendations.

At 60 day of planting, one plant from each replicate was picked, cleaned, dried at 65℃, ground and digested. Each plant was separated into leaves, stem and roots before drying process. The fresh (FW) and dry weight (DW) of each plant part was recorded (g/plant). After digesting a portion of a dried leaves, N, P and K were measured using Kjeldahl, ascorbic acid, and flame-photometery methods, respectively (Cottenie et al., 1982).

The design of the experiment was 2way randomized blocks (2WRB) in six replicates. All records were analyzed statistically through ANOVA and $LSD_{0.05}$ according to Gomes and Gomes (1984).

Results and Discussion

The results showed that the irrigation with diluted seawater, the spraying of plant growth promoters and the interaction between affected fresh weight (FW) and dry weight (DW) of leaves, stem, root and whole sugarcane plant.

Salinity effect on the growth parameters

Both of leaves fresh weight and stem dry weight (g/plant) significantly declined with increasing salinity level from control (TW) to S2 (Table 1 and Fig. 1). While the differences between TW and S1 or between S1 and S2 was not significant. Furthermore the fresh weight of stem, root and whole plant as well as the dry weight of leaves, roots and whole plant not affected significantly with the different dilutions tested of seawater.

Plant growth promoters effect on growth parameters

Irrespective of the salinity level of irrigation water, both of stimufol-amino and potassium citrate significantly increased plant growth parameters (Table 1 and Fig. 1). Interestingly, there are differences between the effect of stimufol-amino and potassium citrate according to the plant part. The highest values of leaves-FW, stem-DW and whole plant-DW were produced by using stimufol-amino, while the highest values of stem-FW and whole plant-FW were produced by potassium citrate. The other parameters; root-FW, leaves-DW and root-DW were not affected significantly by the foliar treatments (Table 1 and Fig. 1).

The interaction effect of salinity and growth promoters on growth parameters

Except for the fresh and dry weight of whole sugarcane plant, the effect of the interaction between the two studied factors (S X GP) was not significant (Table 1). Under normal condition (irrigation with TW), potassium citrate increased whole plant-FW significantly compared with control (sprayed distilled water) and/or with stimufol-amino. While under salt stress condition (S1 and S2 treatments), both of stimufol-amino and potassium citrate enhanced the whole plant-FW compared with control without significant difference between them. In contradict line of FW, stimufol-amino produced the highest values of whole plant-DW in the plants that irrigated with TW without significant difference compared with potassium citrate. While under salinity conditions (S1 and S2), the highest values of whole plant-DW were resulted from the foliar application of potassium citrate also without significant difference compared with stimufol-amino. Since the significant differences were achieved only by using potassium citrate (Table 1 and Fig. 1).

Table 1. Fresh weight (FW) and dry weight (DW) of sugarcane irrigated with three levels of diluted seawater and sprayed by stimufol-amino and potassium citrate.

Salinity treatments (S)	Growth promoters (GP)	FW g/plant				DW g/plant			
		Leaves	Stem	Root	Whole plant	Leaves	Stem	Root	Whole plant
TW	Control	12.87	14.18	5.54	32.59	11.25	8.28	3.08	22.61
	Stimufol -amino	50.71	20.4	9.27	80.38	21.29	25.29	2.7	49.28
	potassium citrate	26.72	73.76	14.25	114.73	16.07	10.01	5.34	31.42
S1	Control	18.97	15.55	6.94	41.46	10.98	4.95	2.51	18.44
	Stimufol -amino	30	48.27	12.58	90.85	17.94	12.63	4.92	35.49
	potassium citrate	24.17	44.84	12.24	81.25	17.22	15.1	3.96	36.28
S2	Control	9.62	18.49	4.43	32.54	11.36	4.04	1.55	16.95
	Stimufol -amino	22.19	52.05	6.6	80.84	14.27	4.66	2.6	21.53
	potassium citrate	22.61	39.2	4.3	66.11	13.58	5.17	4.14	22.89
Mean of S treatments	Tw	30.10	36.11	9.69	75.90	16.20	14.53	3.71	34.44
	S1	24.38	36.22	10.59	71.19	15.38	10.89	3.80	30.07
	S2	18.14	36.58	5.11	59.83	13.07	4.62	2.76	20.46
Mean of GP treatments	Control	13.82	16.07	5.64	35.53	11.2	5.76	2.38	19.34
	Stimufol -amino	34.3	40.24	9.48	84.02	17.83	14.19	3.41	35.43
	potassium citrate	24.5	52.6	10.26	87.36	15.62	10.09	4.48	30.19
$LSD_{0.05}$	S	9.7	N.S	N.S	N.S	N.S	8.0	N.S	N.S
	GP	15.2	4.9	N.S	26.4	N.S	4.9	N.S	8.7
	GPxS	N.S	N.S	N.S	28.9	N.S	N.S	N.S	18.0

TW: tap water, S1:1st salinity level, S2: 2nd salinity level

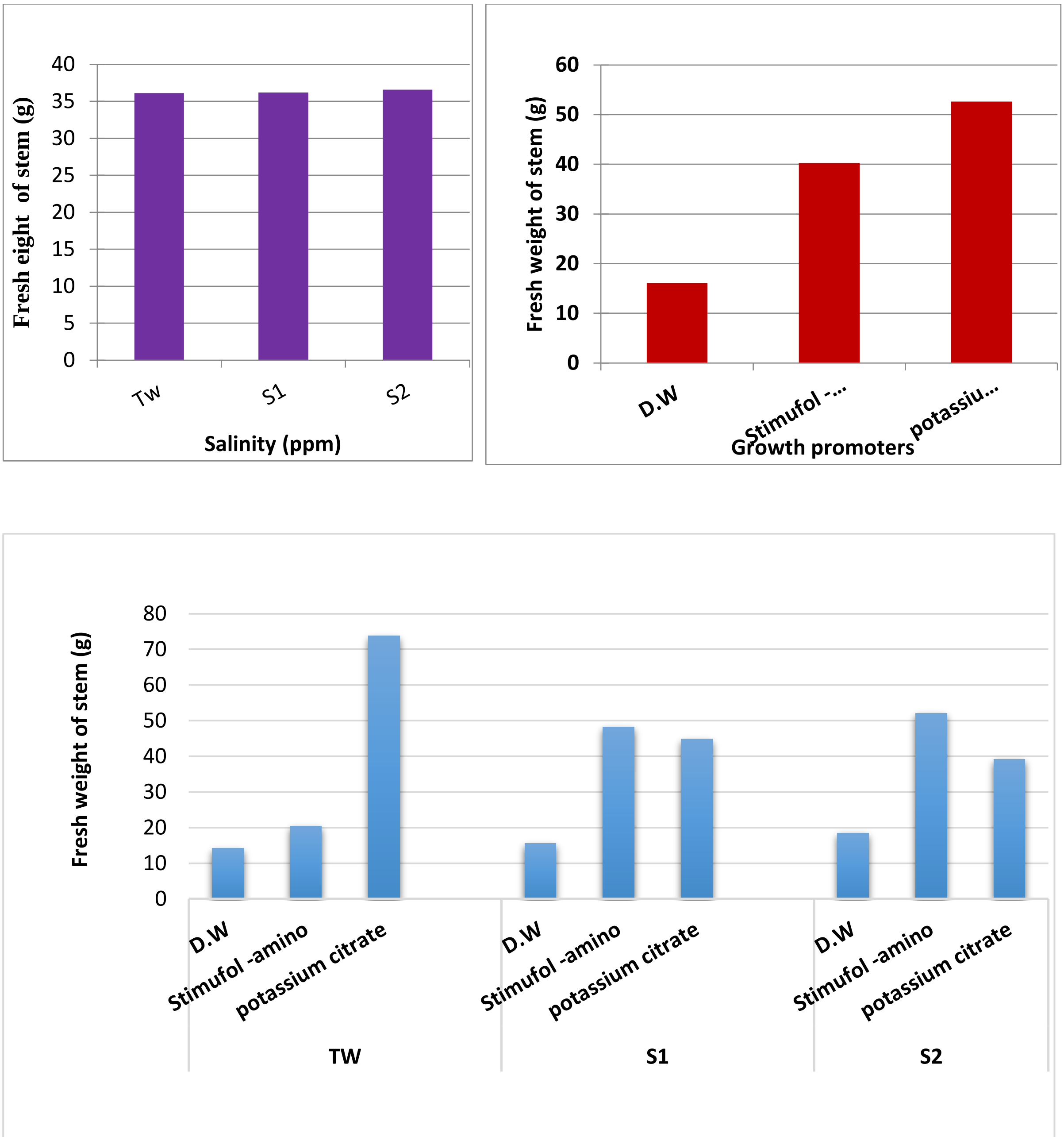

Fig. 1. Fresh weight of sugarcane stem irrigated with three levels of diluted seawater and sprayed by stimufol-amino and potassium citrate.

TW: tap water, S1:1st salinity level, S2: 2nd salinity level

Nutrients status

Salinity effect on the nutrient concentration of leaves

Irrespective of the effect of GP, the nutrient concentration of sugarcane leaves were increased by irrigation with diluted seawater without significant difference in case of N, P and K and with significant difference in case of Ca, Na, Na/K, Na/Ca and Ca(Na+K) as shown in Table (2).

Plant growth promoters effect on the nutrient concentration of leaves

Only K concentration and Na/K values were affected significantly by spraying both stimufol-amino and potassium citrate. Whereas the K concentration values followed the same order of N and P: potassium citrate > stimufol-amino > control. While the ratio of Na to K followed different order: stimufol-amino > control > potassium citrate (Table 2).

Table 2. Nutrient status of sugarcane leaves that irrigated with three levels of diluted seawater and sprayed by stimufol-amino and potassium citrate.

Salinity treatments (S)	Growth promoters (GP)	**N (%)**	**P (%)**	**K (%)**	**Ca (%)**	**Na (%)**	**Na/K**	**Na/Ca**	**Ca/(Na+K)**
TW	Control	1.602	0.042	1.190	0.042	0.212	0.142	5.036	0.025
	Stimufol - amino	1.638	0.068	1.264	0.068	0.208	0.165	3.045	0.046
	potassium citrate	1.547	0.064	1.264	0.064	0.120	0.095	1.863	0.047
S1	Control	1.893	0.034	0.907	0.340	0.176	0.194	0.517	0.314
	Stimufol - amino	1.747	0.080	0.972	0.080	0.256	0.263	3.192	0.065
	potassium citrate	1.843	0.097	1.879	0.097	0.308	0.164	3.169	0.044
S2	Control	1.393	0.124	1.253	0.124	0.301	0.240	2.433	0.080
	Stimufol - amino	2.348	0.085	1.491	0.085	0.400	0.268	4.717	0.045
	potassium citrate	2.803	0.090	1.937	0.090	0.348	0.180	3.871	0.039
Mean of S treatments	Tw	1.596	0.058	1.239	0.058	0.180	0.134	3.315	0.039
	S1	1.828	0.070	1.253	0.173	0.247	0.207	2.293	0.141
	S2	2.181	0.099	1.560	0.099	0.350	0.229	3.674	0.055
Mean of GP treatments	Control	1.629	0.067	1.117	0.169	0.230	0.192	2.662	0.140
	Stimufol - amino	1.911	0.078	1.242	0.078	0.288	0.232	3.651	0.052
	potassium citrate	2.064	0.084	1.693	0.084	0.259	0.146	2.968	0.043
$LSD_{0.05}$	S	N.S	N.S	N.S	0.1***	0.3*	0.1*	0.1**	0.24*
	GP	N.S	N.S	0.25**	N.S	N.S	0.1*	N.S	N.S
	GPxS	N.S	N.S	0.44**	N.S	N.S	N.S	N.S	0.41*

TW: tap water, S1:1st salinity level, S2: 2nd salinity level

The interaction effect of salinity and growth promoters on the nutrient concentration of leaves

The values of K concentration and Ca/(Na+K) ratio were affected significantly by the second interaction (S x GP). While the other studied nutrients and ratios not affected significantly by the interaction between salinity levels and spraying growth promoters. The K values (%) followed the rank: potassium citrate > stimufol-amino > control. While the ratio of Ca/(Na+K) followed the opposite order: control > stimufol-amino > potassium citrate (Table 2).

Discussion

Only the difference between control (TW) and the highest salinity level (S2) on their effect on leaves-FW and stem-DW was significant. While the differences between TW and S1 or between S1 and S2 was not significant. Moreover the effect of salinity levels on FW of stem, root and whole plant was not significant. Also, the N, P and K concentrations of sugarcane leaves were increased gradually by irrigation with diluted seawater without significant difference. While, Ca, Na, Na/K, Na/Ca and Ca(Na+K) values were significantly increased with using the diluted seawater in irrigation. These findings may be due to 1) diluted seawater differs than the other salinity sources because it contains different components acts as plant growth promoters, 2) the tested salinity levels are high dilutions which not affected significantly on these parameters. 3) Sugarcane not classified as a sensitive plant to salinity. Most varieties of sugarcane being are considered moderately sensitive to salinity (Simões, et al 2016). Salinity stress induced decrease in rate of several physiological processes such as transpiration, photosynthetic, turgor pressure, elongation, cell division and dry matter accumulation (Vasantha et al., 2012, Taiz and Zeiger, 2013, Hussain et al 2019 and Hussein et al., 2020). In this concern, Hussein et al. (2017) reported that gogoba growth parameters were adversely influenced by seawater irrigation, even though the differences were not substantial enough to be statistically significant. Hight salinity levels may led to disturbance of protein and carbohydrate metabolism, increasing plant metabolism, reducing water and carbon uptake subsequently reducing photosynthesis rate (Ahanger et al., 2017), increasing accumulation of reactive oxygen species (Kumar et al., 2023). Although there is a negative relationship between salt stress degree and moringa growth characters, shoot/root ratio and leaf water content were increased with salinity level in diluted seawater increased (Hussein and Abou-Baker, 2014). The effects of variations in salinity levels on maize growth were minimized by the considerable dilution of seawater and the maximum fresh weight was obtained at the lowest salinity level (Abou-Baker et al., 2020). There is a negative relationship between nitrogen and sodium under salinity stress. Both of glutamine enzyme and glutamate synthase - that form the major route of NH_3^+ assimilation in sugarcane plants - are markedly impacted under high Na conditions (Singh and Singh, 1994). Although most otton growth parameters affected with salt stress (1200, 8000 and 4000 ppm diluted seawater), no significant changes was found on cotton fiber characteristics that irrigated with the three different rates of dilluted seawater (El-Beltagi et al., 2017).

Both of stimufol-amino and potassium citrate significantly increased plant growth parameters and the nutrient status of sugarcane leaves. This may be attributed to the GP works by improving nutrient uptake, increasing photosynthesis, or stimulating root growth. These compounds are widely used in agriculture to increase crop yield and improve the quality of agricultural products. These GP also increased the antioxidant enzymes activities and reduced the reactive oxygen species (ROS) accumulation in sugarcane plants, suggesting an improvement in osmotic regulation and reducing of oxidative stress. All growth characters increased with spraying of (Si+SA) as a GP (Hussein and Abou-Baker, 2014). Cotton growth and yield was increased by one spraying of K fertilizer (Hussein et al., 2014).

Interestingly, the highest values of leaves-FW, stem-DW and whole plant-DW were produced by using stimufol-amino, while the highest values of stem-FW and whole plant-FW were produced by potassium citrate. Furthermore, the interaction effect between the two studied factors (S x GP) confirms that the significant differences were achieved only by using potassium citrate. This result sheds light on the effect of potassium, which exists in potassium citrate, on increasing the ability of sugarcane stem cells to reserve water. Potassium participates in activation of over 60 enzymes and plays a necessary role as a regulator. It is also essential for the detoxification of ROS and for giving plants defense against abiotic stresses (Johnson et al., 2022). Sugarcane yield and K, Ca, and Mg concentration in its leaves were improved by spraying bio-stimulant at three-month growth (Junior et al., 2013). Increasing foliar application rate of stimufol-amino increased most growth parameters of maize (Hassanein et al., 2015). The highest values of onion growth, yield, and N, P, K concentrations in bulb were resulted from spraying stimufol at rate of $3gL^{-1}$ compared to the rates of 1 and 2 gL^{-1} (Shaheen et al., 2011). Spraying potassium citrate to stressed cotton plants resulted in an increase in plant growth parameters, yield and the chemical status of leaves, such as proline, antioxidant enzyme activities, total chlorophyll and carotein, and chlorophyll a and b (Gebaly et al., 2013). This may be due to citrate is considered a non-enzymatic antioxidant that chelating the harmful bioactive substances like free radicals, plays a crucial role in plant metabolism and protect plants from abiotic stress (El-Beltagi et al., 2017).

Increasing K concentration (%) as the order: potassium citrate > stimufol-amino > control is a logic trend because potassium citrate is a source of K. Also, increasing the Na/K ratio as the rank: stimufol-amino > control > potassium citrate is logic. This may be due to raising the K concentration in leaves by spraying potassium citrate tend to increase the denominator of the Na/K ratio and then reduces the net result. Although, spraying each of GPs increased sugarcane growth particularly under salinity stress conditions, they led to discrepancy in nutrient balance where they decreased calcium percentage and Ca(Na+K) values, while they increased Na%, Na/K, and Na/Ca values compared with control. The function of K in reducing the negative effects of Na has received a lot of attention. This indicates that salt affected the Ca level (Dang et al., 1998). Potassium counteracted the deleterious effects of high salinity in sugarcane by decreasing the sodium uptake and raising potassium absorption subsequently enhancing K/Na ratio which is a proper factor to estimate salinity resistance by plant (Ashraf et al., 2009). Spraying of K increased N, P and K % and content (mg/plant) of cotton' leaves that irrigated with diluted seawater (Hussein et al., 2014). Salt stress impacted the concentrations and uptake of macro and micronutrients, where it increased the accumulation of Na and decreased K, Ca and K/Na (Gomathi and Thandapadi, 2005). Nitrogen, phosphorus and potassium concentrations in cotton leaves increased as the salt concentration increased in irrigation water (Hussein et al., 2014). Nitrogen % or content (mg/plant) and P content (mg/plant) in moringa were decreased as a result of irrigating with high concentrated seawater (Hussein and Abou-Baker, 2014).

Conclusion

Salinity stress can cause a range of negative effects such as reduced growth and yield, lower leaf area, and decreased photosynthetic activity. The effect of diluted seawater is differing from artificial saline solutions. Some of plant GPs compounds are used in agriculture to increase crop yield and improve the quality of agricultural products under normal condition (irrigation with fresh water). The role of plant growth-promoters in sustaining productivity under salinity stress condition cannot be failing to notice. Suggesting that foliar application of plant growth promoters can be used to develop salinity-tolerant of sugarcane. Stimufol-amino and potassium citrate can improve plant growth by providing essential nutrients, increasing photosynthesis, or stimulating root growth. These GP also increased the antioxidant enzymes activities and reduced the reactive oxygen species (ROS) accumulation in sugarcane plants, suggesting an improvement in osmotic regulation and reducing of oxidative stress. Potassium citrate is superior tool for improving the growth of stressed sugarcane by salinity, subsequently its yield and quality. The differences between Stimufol-amino or potassium citrate were not substantial enough to be statistically significant in all studied parameters except for the fresh weight of stem. Thus, the application of neither of them can be an effective strategy to enhance sugarcane growth and productivity under salinity stress conditions. Irrespective of salinity level effect, there are some discrepancies in K, Ca and Na balance by application of each of studied GP. The spraying of Stimufol-amino or potassium citrate decreased calcium % and Ca(Na+K) in sugarcane leaves, while they increased Na%, Na/K, and Na/Ca ratio compared with control. Studying the different types of GPs that can develop more effective strategies for promoting agricultural productivity under salinity conditions is recommended. Also, future research should focus on identifying the optimal application dosage and timing of these PG to maximize their benefits on different plants.

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