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EFFECT OF PLANTING LOCATIONS AND BIOSTIMULANTS ON GROWTH TRAITS OF THE BANANA (*MUSA* SPP.)

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SUMMARY

Summary: The use of silicon is an option for reducing the adverse effects of water deficit conditions. The recent study took place at the Agricultural Research and Experiment Station of the Faculty of Agriculture, Cairo University, Giza, Egypt (30°02′ N and 31°13′ E, with an altitude of 30 m) in two seasons of 2019 and 2020. The study's chief objective aimed to investigate the effect of water deficit at flowering on maize and its relation to silicon spraying. The study included two water treatments: non-stress (NS) and water stress (WS); three silicon treatments: (0, 3, and 6 mM L^{-1}); and five single-cross hybrids. A split-split plot under the concentration of 6 mM L^{-1}. The most interesting observation in the study showed the noteworthy increase in oil yield/ha for all studied hybrids, ranging from 13.33% (SC-3444) to 29.41% (SC-3433). It resulted from the application of the concentration of 6 mM L^{-1}. The hybrids SC-30N11, SC-3433, and SC-3444 proved the best hybrids, displaying tolerance to water.

Keywords: Maize (*Zea mays* L.), water stress, silicon, yield, carbohydrate, protein, oil, stress-tolerance index

Key findings: The water deficit condition at the flowering stage caused a significant reduction in yield and its components in maize. The silicon treatment 6 mM L^{-1} concentration notably enhanced the grain and oil yields and carbohydrates.

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INTRODUCTION

Banana (*Musa* spp.) belongs to the Musaceae family, which is one of the tropical fruits. Many believed that its original habitat is Southeast Malaysia and the Philippines (Al-Qatrani, 2016; Jasim *et al*., 2016). Some species of bananas, such as *Musa acuminata* and *Musa balbisiana*, were visibly growing wild in those areas, with their fruits containing seeds. The banana plant, a monocotyledon, had India as the largest banana-producing country in the world, with production in 2006 of about 21.77 million metric tons (FAO, 2006).

The banana is one of the massive growing herbaceous plants, which does not have a woody stem above the soil surface. It is a fast-growing herbaceous perennial reaching a height of about three meters. Bananas are the largest fruit crop produced in the world. Its growth prevails in 130 countries, mainly in the tropical and subtropical regions of the Southern Hemisphere, with global production of bananas in 2019 reaching about 21 million metric tons (FAO, 2023). Banana cultivation began in the ’50s of the last century in date palm orchards in the Basrah Governorate, Iraq, as mixed cultivation in the Shatt al-Arab Regions and on a limited scale. Its cultivation did not show positive results, and among the introduced cultivars to Iraq for its experiment are Kassala, Muhammad Ali, Brodica, Moroccan, Indian, Sindhi, and other foreign cultivars (Jassim *et al*., 2016).

The plant tissue culture technique is the perfect choice for traditional vegetative propagation methods called micropropagation. This technology plays an important role in serving humanity, especially in the field of economic plant propagation (Safana *et al*., 2022). It is one of the modern methods presently utilized in propagating many species of herbaceous and woody plants (Salih *et al*., 2019; Ibrahim and Yassin, 2020; Ibrahim and Draaj, 2020). This technique has advantages, the most crucial of which is obtaining numerous plants similar to the mother plant in a relatively short time and at any time of the year. Additionally, it ensures the possibility of producing plants free of various diseases and insect infestations (Ibrahim *et al*., 2020; Al-Drisi *et al*., 2022). The banana plant seemed to be one of the plants being propagated vegetatively via the plant tissue culture technique. Such a technique is one of the modern tools used in plant propagation, with many plants obtained being free from viral diseases and genetically identical to the mother plant (Mohsen *et al*., 2021).

Bananas are dominant in most areas with high humidity throughout the year. It is famous for cheap prices, and its consumption is usually as a fresh fruit or as an ingredient in the manufacture of juices. Moreover, banana fruits are an essential food item because they contain many nutrients, providing humans with the necessary calories, as every 100 grams contains approximately 90 calories. Bananas are also rich in carbohydrates, antioxidants, vitamins, and minerals necessary for the human body. It helps treat and improve the immune system, healing many diseases, including diarrhea and dyspepsia, the risk of cancer and blood cholesterol levels, fever and joint pain, and an improved blood flow in the human body (Nyombi *et al*., 2010; Mengstu *et al*., 2021).

Biostimulants are a group of natural organic compounds that are either added to the soil to improve its properties or sprayed on the plant to ensure higher availability of the elements, activating the action of fertilizers. Similarly, their mixture with fertilizers and foliar pesticides serves the same purpose and resists stress factors on the plant (Du-Jardin, 2015). The biostimulant market has expanded, although it is young and growing annually at a high rate compared with the rest of the inputs in the agriculture sector. The size of the biostimulants’ market exceeded USD 2.6 billion in 2019, with an expectation to register a compound annual growth rate of more than 11.24% between 2020 and 2025 (Bulgari *et al*., 2019). The rise in new farming techniques, due to the limited availability of arable land, opened up new avenues for the biostimulants’ industry to grow even further.

An increasing focus on enhancing productivity, coupled with rapid soil degradation, is likely to drive the market further. Sustainable farming practices and organic farming encourage the expansion of

biostimulants. The multiple functions of biostimulants include enhanced fertilization, improved metabolism and water-holding capacity, and chlorophyll production. Biostimulants enhance the antioxidant activity of the plant, thus reducing environmental stress. They greatly help in combating the main challenge of extreme climate variability in the agriculture sector. These also enabled the production of seasonal crops for longer periods and enhanced yield in the market (Bulgari *et al*., 2019; Sible *et al*., 2021). Given the banana plant's specificity concerning its growth nature and broad leafy area, plus the increase in salt or heat-stress conditions, using some antibiotic compounds will increase the plant juice flow activity and stimulate cytoplasm (De-Vasconcelos and Chaves, 2019). Bioenhancers are a group of crude organic compounds applied to soil or leaves to enhance plant growth and development by providing elements that activate foliar fertilizers' and pesticides' functions and withstand the effects of environmental stress on plants (Khan *et al*., 2009; Sedera, 2017).

Simplex is one of the biostimulants, as it increases leaf growth and stem elongation, enhances photosynthesis and chlorophyll and protein formation, and contributes to increased cell division (Sidhu and Nandwani, 2016; Ozbay and Demirkiran, 2019). Spann and Little (2010) showed from their research in Canada the effect of Stimplex on drought-stressed sweet orange trees. The results revealed drought-stressed trees treated with Stimplex by two methods—root treatment and foliar spraying—had significantly greater overall growth than untreated drought-stressed trees. The ability to maintain growth by Stimplex under drought-stress conditions occurred by carbon fixation, with the activation of photosynthesis in all trees exposed to drought stress. The effect of Stimplex could be parallel to the improvement of water relations in the plant or its role in activating the physiological processes of the plant (Spann and Little, 2010), as well as many other biostimulants (Bulgari *et al*., 2019).

Chitosan is one of the straight polymers, as the units of the polymeric chain reach from 2000 to 3000 units. It is the most abundant polymer for the number of polysaccharides and the second most common organic compound after cellulose in nature. Its extraction can come from various natural sources and constitutes 20%–30% of the waste of shrimp, crab, and lobster shells (Ahmed and Salem, 2020). Meénard *et al*. (2004) confirmed chitosan works to increase plant growth by raising the availability of some plant nutrients in the root periphery. Ahmed and Salem (2020) showed the added chitosan works to stimulate the plant to produce phytohormones responsible for the root system formation.

As the banana crop is one of the fruit crops with increased demands and considerably one of the non-endemic crops in Iraq, experiments in introducing this crop met with many problems. Given the specificity of this plant, it is essential to determine the optimal site for banana plant cultivation and the use of some biostimulants that activate the flow of plant cell sap and stimulate cytoplasm. Hence, this research aimed to study the role of foliar spraying with combinations of Stimplex, Biogrand, and Chitosan in enhancing the vegetative growth of the offshoot banana Grand Nian cultivar, planted in Garmat Ali and Al-Hartha districts. Similarly, the study sought its successful cultivation in the conditions of Basrah Governorate, Southern Iraq.

MATERIAL AND METHODS

The experiment, as conducted in two locations, comprised the Garmat Ali and Al-Hartha districts. The first one is an affiliate of the Agricultural Experiment Station, College of Agriculture, University of Basrah, and the second is the Basrah Agriculture Directorate, conducting for the autumn of 2021–2022. The study determined the effect of the planting location and some combinations of biostimulants on some indicators of vegetative growth of the *Musa* spp. CV. Grand Nain. The preparation of the soil for cultivation included service operations of plowing, smoothing, and leveling the soil. The orchard soil, as divided into three lines, had a length of 10 m, with the distance between one line and another at 2 m.

Afterward, the digging of seven holes had a depth of 60 cm and a diameter of 60 cm in each line. Adding a mixture of organic matter and decomposed animal manure to each hole had a ratio of 1:1. The sterilization comprised the systemic pesticide Metalaxyl 5 G at a concentration of 4.6 g m^{-2} and 10% Furadan Nematicide. Then, the planting of 21 banana offshoots of homogeneous size, free from pathogens, and three months old proceeded on November 20, 2021, with a planting distance of 1.50 m between each plant in both earlier-mentioned locations. Weeding and hoeing continued manually two weeks after the transfer of offshoots in the orchard. Random sampling of the orchard soil from both locations transpired before starting the experiment, at a depth of 0–30 cm. Afterward, their mixing homogeneously ensued before air-drying, grinding, and sieving them with a 2-mm sieve to estimate some physical and chemical properties of the soil and irrigation water. The process took place in the laboratories of the Department of Soil and Water Sciences, College of Agriculture, University of Basrah (Tables 1 and 2).

The treatment with biostimulants began on March 20, 2022, by foliar spraying of four sprays, with one spray between a week and another. The adding of Tween20 to the spray solution helped increase its absorption by foliar tissues. Using a 15-liter hand pump aided foliar spraying, with the spraying process carried out in the early morning until complete wetness. The banana plants' covering with polyethylene succeeded before placing them in the form of arcs to protect the plants from the cold during winter. During summer, the workers raised the nylon to cover the plants with green saran. The added nozzles raised the humidity levels in the air due to the plants' need for them.

Table 1. Some chemical and physical properties of the experimental soil and irrigation water of the Garmat Ali location.

Property		Value
pH of Soil		7.9
Electrical Conductivity (EC) of Soil		8.42 dS m^{-1}
Dissolved positive ions	Ca^{+2}	10.30 mmol L^{-1}
	Mg^{+2}	7.61 mmol L^{-1}
	Na^{+2}	24.33 mmol L^{-1}
	K^{+}	1.40 mmol L^{-1}
Organic matter		0.74%
Dissolved negative ions	SO_4^{-2}	22.60 mmol L^{-1}
	HCO_3^{-}	3.10 mmol L^{-1}
	Cl^{-}	60.0 mmol L^{-1}
	CO_3^{-2}	0.0
Nitrogen uptake		191 ppm
Phosphorus uptake		74 ppm
Potassium uptake		215 ppm
Soil texture	Clay	26.4%
	Silt	10.6%
	Sand	63.0%
Soil classification	Clay sandy	
pH of water irrigation		7.85
Electrical Conductivity of water irrigation		6.10 dS m^{-1}

Table 2. Some chemical and physical properties of the experimental soil and irrigation water of the Al-Hartha location.

Property		Value
pH of Soil		7.9
Electrical Conductivity (EC) of Soil		5.22 dS m^{-1}
Dissolved positive ions	Ca^{+2}	7.11 mmol L^{-1}
	Mg^{+2}	5.80 mmol L^{-1}
	Na^{+2}	18.41 mmol L^{-1}
	K^{+}	1.12 mmol L^{-1}
Organic matter		0.86%
Dissolved negative ions	SO_4^{-2}	19.30 mmol L^{-1}
	HCO_3^{-}	2.20 mmol L^{-1}
	Cl^{-}	43.05 mmol L^{-1}
	CO_3^{-2}	0.0
Nitrogen uptake		216 ppm
Phosphorus uptake		82 ppm
Potassium uptake		260 ppm
Soil texture	Clay	14.9%
	Silt	14.0%
	Sand	71.1%
Soil classification	Clay sandy	
pH of water irrigation		7.61
Electrical Conductivity of water irrigation		3.10 dS m^{-1}

Study factors

Experimental factors

The study locations (Districts Garmat Ali and Al Hartha, Iraq) were the two assigned factors. Both locations have seven treatments of biostimulants, including the control (with no spray) and two concentrations each of the biostimulants Stimplex (0 and 1.5 g L^{-1}), Biogrand (0 and 1.5 g L^{-1}), and Chitosan (3 and 6 g L^{-1}) (Table 3).

Vegetative growth traits

The plant height (cm) measurement began from the soil surface to the end tip with a tape measure for each experimental unit. The circumference measurement of the pseudostem (cm) came from the place of contact of the pseudostem with the soil surface for each experimental unit utilizing the measuring tape. The leaf length (cm) estimation by measuring tape occurred for each experimental unit from the contact of the leaf to the pseudostem to the end of the leaf blade. The number of offshoots per plant underwent counting for each experimental unit. The offshoot length (cm) valuation for each experimental unit also used a tape measure from the place where the stem has contact with the soil to the end tip of the plant.

Statistical analysis

The experiment design was a factorial experiment with two factors according to a randomized complete block design (RCBD) with three replications. The data's statistical assessment employed the analysis of variance method based on the statistical program Genstat version 13. A comparison between the means of the treatments proceeded according to the least significant difference test at 5% probability described by Al-Rawi and Khalafallah (2000).

RESULTS AND DISCUSSION

Plant height

The results in Table 4 indicate that the location had a significant effect on the plant height

Table 3. Concentrations of biostimulant combinations.

Symbol	Biostimulant combination (g L^{-1})
S0	0 Chitosan + 0 Stimplex + 0 Biogrand
S1	3 Chitosan + 0 Stimplex + 1.5 Biogrand
S2	3 Chitosan + 1.5 Stimplex + 0 Biogrand
S3	3 Chitosan + 1.5 Stimplex + 1.5 Biogrand
S4	6 Chitosan + 0 Stimplex + 1.5 Biogrand
S5	6 Chitosan + 1.5 Stimplex + 0 Biogrand
S6	6 Chitosan + 1.5 Stimplex + 1.5 Biogrand

Table 4. The effect of the planting location and biostimulant combination and the interaction between them on the plant height (m) of the Grand Nain banana cultivar.

Locations	Biostimulant combination (g L^{-1})							Means
	S0	S1	S2	S3	S4	S5	S6	
Garmat Ali	1.63	1.70	1.76	1.85	1.96	2.00	2.30	1.88
Al-Hartha	1.71	1.83	1.80	1.90	2.06	2.22	2.65	2.02
Means	1.67	1.76	1.78	1.87	2.01	2.11	2.47	
$LSD_{0.05}$								
Locations			Biostimulants			Interaction		
0.05			0.09			0.13		

characteristic. The Al-Hartha location showed a notable increase, recording the tallest plant height of 2.02 m compared with the Garmat Ali location, which gave a shorter height of 1.88 m. As appearing in the same table, the biostimulant caused a substantial effect, as it led to a remarkable rise of 2.47 m for the S6 combination. The spraying with the control treatment had a lower value at 1.67 m. The results in the table further show the interaction between the location and the biostimulant combination caused significant differences in plant height, with the combination S6 and Al-Hartha location showing superiority. They recorded the highest value of 2.65 m in plant height compared to the control treatment, which recorded the lowest plant height of 1.63 m.

The planting location has a major and influential role in improving the growth and vegetative indicators of plants. Geographical locations vary in their effect on vegetative growth in plants, depending on the type of soil, its fertility, soil pH, texture type, and porosity (Huntley, 2023). Soils with good physical and chemical properties will play a direct role in improving the vegetative growth of plants (Abdul-Khalil *et al*., 2015; Horel and Zsigmond, 2023). Climate factors also vary from one geographical location to another for temperature, light intensity, and air humidity, which cause differences in the vegetative growth of plants, contingent on their geographical location (Ariyanto *et al*., 2021; Lin *et al*., 2023).

Pseudostem circumference

The data in Table 5 provide that the Al-Hartha location showed a significant increase in the circumference of the pseudostem, as the value reached 42.40 cm. The spraying with biostimulants at S6 g L^{-1} concentrations had a remarkable effect on this characteristic. The S6 combination was considerably superior compared with the other combinations, which recorded 48.60 cm. Likewise, the combinations at S1, S2, and S3 differed significantly, with increased rates of 36.40, 36.87, and 39.87 cm, respectively, compared with the control treatment. The interaction between the locations and the biostimulants has a nonsignificant effect on the pseudostem circumference of the plant.

Table 5. The effect of the planting location and biostimulant combination and the interaction between them on the pseudo-stem circumference (cm) of the Grand Nain banana cultivar.

Locations	Biostimulant combination (g L^{-1})							Means
	S0	S1	S2	S3	S4	S5	S6	
Garmat Ali	31.17	35.27	34.33	39.30	42.37	45.20	45.33	39.00
Al-Hartha	35.33	37.53	39.40	40.43	46.10	46.13	51.87	42.40
Means	33.25	36.40	36.87	39.87	44.23	45.67	48.60	
$LSD_{0.05}$								
Locations			Biostimulants			Interaction		
1.30			2.44			N.S		

Table 6. The effect of the planting location and biostimulant combination and the interaction between them on the leaf length (cm) of the Grand Nain banana cultivar.

Locations	Biostimulant combination (g L^{-1})							Means
	S0	S1	S2	S3	S4	S5	S6	
Garmat Ali	86.00	90.67	95.00	98.67	108.33	110.00	115.00	100.52
Al-Hartha	88.33	96.67	90.33	101.00	110.33	116.67	129.00	104.62
Means	87.17	93.67	92.67	99.83	109.33	113.33	122.00	
$LSD_{0.05}$								
Locations			Biostimulants			Interaction		
2.75			5.15			7.29		

The S6 combination is ideal compared with other combinations through its notable superiority in most vegetative indicators studied. This is due to the role of chitosan and biostimulants in enhancing the vegetative growth of the Grand Nain banana offshoots (Sohby *et al*., 2023). Chitosan is an influential biostimulant in plants that stimulates the production of plant hormone promoters with an important role in stimulating cell division and enlargement (Hidangmayum *et al*., 2019; Chakraborty *et al*., 2020). This contributes to improving the vegetative characteristics and growth of banana offshoots. The biostimulants Stimplex and Biogrand have an effective and critical role in activating cellular metabolism and producing plant pigments, which are crucial in photosynthesis, such as chlorophyll (Mystkowska, 2022; Raza *et al*., 2022). These biostimulants also play an essential role in reducing the effect of environmental stress on plant growth and development (Van-Oosten *et al*., 2017; Ali *et al*., 2020).

Leaf length

It is clear from the results of Table 6 that the location significantly affected the leaf length. The Al-Hartha location was visibly superior in this characteristic, as it recorded a noteworthy increase of 104.62 cm compared with the Garmat Ali location, which had a lesser effect (100.52 cm). The S6 combination recorded the highest value of leaf length versus the other combinations, which reached 122.00 cm. The control treatment exhibited the lowest value for the leaf length, which reached 87.17 cm. The interaction treatment between the location and the biostimulant combinations provided a prominent effect on banana leaf length. The interaction between the Al-Hartha location and the S6 combination displayed the premier value for leaf length compared with the other interactions, which recorded 129.00 cm. The interaction between the Garmat Ali or Al-Hartha location with the control treatment recorded the lowest leaf length value at 86.00 cm.

Number of offshoots

The results in Table 7 revealed that the Al-Hartha location recorded the most number of offshoots, which amounted to 2.71, compared with the Garmat Ali location, providing the least offshoots at 2.33. The spraying with an S6 combination of biostimulants considerably affected the increase in the number of offshoots, reaching 3.83 compared with the control treatment, with the least increase in this characteristic (1.50 offshoots). As for the bilateral interaction between the location and the biostimulant, it did not substantially influence the rise in the number of offshoots per plant.

Offshoot length

The outcomes shown in Table 8 detailed that the planting location had a weighty effect on increasing the length of the offshoot. The Al-Hartha location recorded the highest value for this characteristic, which amounted to 67.19 cm, compared with the Garmat Ali location at 60.24 cm. The two concentrations of the biostimulant (S5 and S6) led to a marked increase in this characteristic versus the control plants, with an increase of 69.33 and 78.33 cm, respectively. The control treatment demonstrated the lowest value of offshoot length, which reached 54.00 cm. The bilateral interaction between the location and the biostimulant did not have a significant effect on this characteristic.

The reason for the positive effect of the Al-Hartha location on vegetative growth indicators is due to the lower salinity of irrigation water in the Al-Hartha location than in the Garmat Ali location (Table 2). The high salinity of irrigation water leads to inhibiting the processes of plant growth and development, causing a decrease in the value of water potential and an increase in the osmotic potential. This especially decreases cell expansion and the closure of stomata, affecting a decline in photosynthesis (Ma *et al*., 2020). The presence of salts causes an imbalance in the hormonal balance and reduces the level of plant hormones that regulate plant growth (promoters), such as auxins and gibberellins. Meanwhile, the level of growth inhibitors, such as abscisic acid, increases the closure of stomata. Moreover, the significant decrease in

Table 7. The effect of the planting location and biostimulant combination and the interaction between them on the offshoot number of the Grand Nain banana cultivar.

Locations	Biostimulant combination (g L^{-1})							Means
	S0	S1	S2	S3	S4	S5	S6	
Garmat Ali	1.33	2.00	1.66	2.33	2.66	3.00	3.33	2.33
Al-Hartha	1.66	2.00	1.66	2.66	3.00	3.66	4.33	2.71
Means	1.50	2.00	1.66	2.50	2.83	3.33	3.83	
$LSD_{0.05}$								
Locations			Biostimulants			Interaction		
0.33			0.63			N.S		

Table 8. The effect of the planting location and biostimulant combination and the interaction between them on the offshoot length (cm) of the Grand Nain banana cultivar.

Locations	Biostimulant combination (g L^{-1})							Means
	S0	S1	S2	S3	S4	S5	S6	
Garmat Ali	50.00	52.33	50.33	60.67	68.33	68.67	71.33	60.24
Al-Hartha	58.00	61.00	60.33	66.33	69.33	70.00	85.33	67.19
Means	54.00	56.67	55.33	63.50	68.83	69.33	78.33	
$LSD_{0.05}$								
Locations			Biostimulants			Interaction		
3.75			7.02			N.S		

the level of transpiration in the plant leads directly to a rise in the plant temperature, especially the leaves, which negatively impacts plant growth and development (Razzaghi *et al*., 2011; Sosnowski *et al*., 2023; Sarraf *et al*., 2023).

As for the noteworthy effect of biostimulants on vegetative growth indicators, this refers to the role of biostimulants in increasing leaf growth and stem elongation, enhancing photosynthesis and the formation of chlorophyll and protein, and contributing to increased cell division. The ability to maintain growth by Stimplex under drought-stress conditions was evident by carbon fixation as photosynthesis' activation ensued in all trees exposed to drought stress. The effect of Stimplex could have links to the improvement of water relations in the plant or its role in activating the physiological processes of the plant (Spann and Little, 2010), as well as many other biostimulants (Bulgari et al., 2019). It also works to increase flowering rates (De-Vasconcelos and Chaves, 2019). Additionally, it works to boost the tolerance of plants to stress and enhance growth. As Stimplex fixes carbon and activates photosynthesis in all trees exposed to drought stress, its effect may be relevant to enriching water relations in the plant or its role in the plant's physiological processes' activation (Spann and Little, 2010; Ozbay and Demirkiran, 2019).

CONCLUSIONS

The study concludes from the research that the location has a significant effect, as it gave positive results in growth and increased some vegetative traits in banana offshoots of the Grand Nain cultivar. It is also possible to rely on the use of Stimplex, Biogrand, and Chitosan stimulants, which contribute to improving water relations in the plant or their role in activating the physiological processes of the plant.

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