Exogenous Application Effect of Indole 3-Butyric Acid and Myo-inositol on Improving Growth, Productivity and Bulb Quality of Garlic

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Introduction
Garlic (*Allium sativum* L.) is one of the oldest and most economic vegetables. It has been demonstrated that garlic was grown and consumed by ancient Egyptian, about 2780 - 2100 B.C., (Yamaguchi, 1983). Egypt is one the world’s top garlic producing countries, it is ranked as the fourth country among garlic producers, with an annual production of 286,213 tones produced from 127,82 ha (FAO, 2018). In Egypt, garlic is grown mainly for local consumption, however Egypt is one of the top ten garlic exporter countries with 0.9% of total worldwide garlic exportations with a net return of 27 million dollars. Garlic cloves have several bioactive compounds, such as allicin, alliin, diallyl sulfide, diallyl disulfide, diallyl trisulfide, ajoene, and S-allyl-cysteine, which contribute to the garlic’s taste (Kilgori et al., 2007, Shang et al., 2019). Owing to its diverse and valuable compounds, several earlier studies have been reported that garlic and its bioactive ingredients can positively contribute to human health as anti-oxidant, anti-inflammatory, anti-microbial, anti-cancer, anti-diabetic and anti-obesity (Shang et al., 2019). In addition, garlic’s oil has several agriculture actions, such as herbicide, acaricide and insecticide (Abouziena et al., 2009, Ismail et al., 2011, Sharaby et al., 2012). Furthermore, it has a stimulatory effect on onion plants grown under sandy soil conditions.

Two successive field trials were performed at the Agricultural Research Farm of the Faculty of Agriculture, Suez Canal University during the two successive of 2018/2019 and 2019/2020, to investigate the influence of 0, 0.5 and 1 mM of indole 3-butyric acid (IBA) and 0, 1, 1.5 and 2 mM myo-inositol (MI) and their interactive as foliar application on vegetative growth, bulb yield, biochemical constituents and mineral contents of garlic plants cv. Seds 40. The treatments were laid out in a split plot order with three replicates. The obtained results reported that garlic plants positively responded to the exogenous treatments of IBA and MI individually or interactively. It showed generally that application of IBA at 0.5 mM recorded the highest values of vegetative growth, yiled, quality parameters as well as the mineral content (N, P and K). In the same regard, application of MI at 1.5 and 2 mM significantly promoted most of studied traits compared to control and the rest of MI concentration, in both growing seasons. Furthermore, the two-factor interaction was found to be significant for all measured traits in both seasons, except for K content. Whereas, exogenous treatment of IBA at 0.5 mM along with exogenous treatment of MI at 1.5 and/or 2 mM resulted in the highest means of most of the above mentioned traits. Thus, it could be suggested that applying a combination of IBA and MI was found to be effective for enhancing vegetative growth, bulb yield and quality as well as macro-elements content.

Keywords: *Allium sativum*, Growth regulators, Indole 3-butyric acid, Myo-inositol, Vegetative growth, Bulb yield and quality, Mineral contents.
respectively, compared to control plants, while it improved plant fresh weight, bulb yield, and allicin content by 30%, 19% and 25%, respectively, compared to control plants, while it had no effect on total yield and bulb quality under water deficit conditions. The exogenous treatment with IBA (0.0375 g ha⁻¹) recorded higher grain yield than untreated plants, which was mainly due to the notable increase in the number of seeds per pod (Buzzello et al., 2017). Moreover, foliar application of IBA derivative, indole acetic acid (IAA), to salt-stressed tomato plants rescued the plants and had significantly positive effects on growth and yield of tomato plants (Alam et al., 2020).

Another important plant stimulant is myo-inositol (MI), carbocyclic sugar, which is physiologically the most favored stereoisomer of inositol. It takes a part in several crucial biological processes during plant growth and development, including stress response, cell wall formation, regulation of tissue growth, osmotic adjustment, auxin transport and membrane transport (Stevenson-Paulik et al., 2005, Perera et al., 2008, Khurana et al., 2012 and Zhai et al., 2016). It is commonly used in in vitro plant tissue culture media for successful growth because it’s synergetic effect with cytokinin (Hanke et al. 1990). However, it has possible applications in agriculture production. It was demonstrated that MI can help in maintaining growth and development of Malus hupehensis plants grown under salinity stress by supporting the plant’s antioxidant defense system and mediating Na⁺ and K⁺ homeostasis as well as the osmotic balance (Hu et al., 2018). Also, results of Chatterjee and Majumder (2010) showed that MI application (100 – 150 mM) is effective in preventing internucleosomal fragmentation which is the first symptom in roots under salinity stress. In addition, Yildizli et al. (2018) reported that external application of MI significantly decreased hydrogen peroxide, membrane damage, proline level, ascorbate peroxidase and catalase activity in drought-stressed pepper plants, compared with untreated plants. Therefore, MI is a useful plant stimulant that could be alleviated the negative effects of several types of stresses. Nevertheless, little comprehensive information is available about the effect of external MI on growth, productivity and quality of garlic plants.

The present study was performed to investigate the effect of IBA and MI, applied as foliar spraying individually or interactively, on vegetative growth, bulb yield, biochemical constituents and mineral contents of garlic plants.
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Materials and Methods

Experimental site and plant materials

Two field experiments were carried out at the Agricultural Research Farm of the Faculty of Agriculture, Suez Canal University, Ismailia Governorate, Egypt during the two successive of 2018/2019 and 2019/2020. Garlic plants cv. Seds 40 were used in the current investigation.

Cultural practices

The soil was firstly cleared and ploughed. Later, 20 m³ organic manure, 300 kg of calcium superphosphate (15.5 % P₂O₅) and 60 kg sulphur/fadden were applied during the final preparation of the experimental soil and thoroughly mixed with the soil. Homogenous and healthy cloves were steeped in running water for 24h. Afterwards, the moistened cloves were sown on 10th October in both seasons under drip irrigation system in two rows (one row on each side of drip hose) at 10 cm apart and 100 cm between the drip hoses. Subsequently, 300 kg/feddan of ammonium nitrate (33.5% N) and 200 kg/feddan of potassium sulphate (48% K₂O) were supplied during growing season by fertigation system. The other cultural practices, such as control of insects and pests were carried out according to the guideline of the Egyptian Ministry of Agriculture.

Experimental design and treatments

IBA and MI were ordered from Sigma-Aldrich Company, Germany. Twelve treatments, three concentrations (0, 0.5 and 1 mM) of IBA and four concentrations (0, 1, 1.5 and 2 mM) of MI, were laid out in a split plot order with three replicates. IBA levels were assigned to the main plot, while MI levels were assigned to sub-plots. The experimental unit area (plot) was 3 m x 3 m in size and consisted of 3 ridges (6 rows) and included 180 plants. IBA and MI treatments were applied for 8 times as foliar spraying on garlic plant starting at 30 days after sowing date with 15 days intervals, during the growth period of garlic plants. The control plants were sprayed with distilled water alone. For the interplay treatments, the MI treatments were applied in the next week following IBA application. All IBA and MI sprayed levels were carried out in the morning. The volume of IBA and MI solutions was ranged from 150 to 450 L/feddan, according to foliage plant size.

Soil analysis and metrological data

Soil texture was sandy (87.31% sand, 3.18%, clay and 9.51% silt), with pH 7.94, EC 0.56 dS m⁻¹, available N 65 ppm, available P 30.12 ppm, available K 76 ppm, Ca²⁺ 1.22 meqL⁻¹, Mg²⁺ 0.84 meqL⁻¹, Na⁺ 1.35 meqL⁻¹, K⁺ 0.34 meqL⁻¹, HCO₃⁻ 1.26 meqL⁻¹, Cl⁻ 1.63 meqL⁻¹, SO₄²⁻ 0.86 meqL⁻¹ and CO₃²⁻ 0.00 meqL⁻¹ and organic matter 0.36%. These values of physical and chemical properties represent the means of the experimental site in both growing seasons and determined according to the methods of Jackson (1973), Chapman and Pratt (1978) and Klute (1986).

Data recorded

Ten mature plants, after 182 days from sowing, were randomly taken from each replicate in order to estimate the following traits:

Vegetative growth and yield traits

• Plant height (cm), plant fresh weight (g), bulb weight (g) and total bulb yield (Tonne/feddan).
• The chlorophyll content (SPAD value) in the full expanded fourth leaf from the top were assessed by a SPAD-502 meter Minolta Co. Ltd., Osaka, Japan).

Chemical composition parameters

Three bulbs per replicate were randomly selected to measure of the following biochemical measurements:

Organic compounds

• Total phenols (mg/100g FW) were determined by the methods of Mazumdar and Majumder (2003).
• Total sugars (mg/g FW) were determined by the methods of Dubois et al. (1956).
• Soluble solid content (%) was measured by a digital refractometer (Atago- N1, Brix 0 - 32%, ATAGO Co. LTD, Tokyo, Japan).

Minerals analyses

Three bulbs per replicate were oven dried at 70 °C till constant weight. Then, bulb samples were grounded into powder. Later, 0.5 g of fine ground powder was digested with sulfuric acid and hydrogen peroxide mixture and adjusted with distilled water to the final volume of 100 ml. Afterward, the digested solution was used for measuring of the following macro-elements:

• Total nitrogen (mg/g DW): It was determined using semi-micro-Kjeldahl method as described by Ling (1963).

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• Phosphorus (mg/g DW): It was measured using a colorimetric method according to methods of Jackson (1973).

• Potassium (mg/g DW): It was determined using Flame photometer according to the method described by Page (1982).

Statistical analysis

Two-way analysis of variance and Duncan’s multiple range test for means of all studied traits were carried out using CoStat software, Ver. 6.303 1998–2004, CoHort software, Monterey, CA, USA. Duncan’s test was performed at 5% significance level in order to compare the treatment means.

Results

Effect of foliar application of IBA and MI on vegetative growth and yield parameters

Data presented in Table 1 show the effect of foliar applications of IBA and MI as well as their interaction on plant height, plant fresh weight, bulb fresh weight and total yield. It is undoubtedly obvious that IBA and MI treatments significantly increased vegetative growth and yield parameters as compared to untreated plants in both growing seasons. It also shows that there were highly significant differences among IBA doses for all measured traits except for plant height in both growing seasons. Whereas, the plants treated with IBA at a rate of 0.5 mM/L have recorded the highest significant means for plant fresh weight, bulb weight and total yield. In addition, there were significant differences among MI doses for all studied traits except for plant height in both growing seasons. Whereas, the plants treated with MI at a rate of 1.5 or 2 mM achieved the highest values of total sugars content in both seasons. However, the combination of IBA at a rate of 0.5 mM with MI at a rate of 2 mM gave a remarkable increase in total sugars content in both seasons compared to control plants. Interestingly, the combination of IBA and MI at a rate of 0.5 mM and 1 mM, respectively, recorded the lowest value of total phenol content in both seasons compared to the rest of combination treatments.

Effect of foliar application of IBA and MI chemical components

Data illustrated in Table 2 demonstrate the effect of foliar applications of IBA and MI as well as their interaction on leaf chlorophyll content and chemical components of garlic plants cv. Seds 40. It displays that the application of both IBA and MI significantly altered the contents of leaf chlorophyll, soluble solids percentage, total sugars and total phenols. Generally it could be reported that foliar application of IBA at a rate of 0.5 mM achieved notable increases in content of leaf chlorophyll, soluble solids percentage and total sugars. However, application of IBA at a rate of 2 mM recorded the maximum values of total phenols content in the first and second seasons. As for IBA application, it is obvious that MI addition remarkably enhanced leaf chlorophyll content, soluble solids percentage and total sugars content, however it appreciably reduced total phenol contents in both seasons. Among the MI treatments, treated garlic plants with 1.5 mM recorded the maximum values of leaf chlorophyll content, soluble solids percentage and total sugars content. Regarding the interaction effect between IBA and MI treatments, Table 2 displays that this interplay was significant. It is evident that supplementation of IBA at a rate of 0.5 mM along with MI at a rate of 1.5 mM resulted in a significant increment in content of leaf chlorophyll and soluble solids percentage and total sugars content in both seasons. However, the combination of IBA at a rate of 0.5 mM with MI at a rate of 2 mM gave a remarkable increase in total sugars content in both seasons compared to control plants. Interestingly, the combination of IBA and MI at a rate of 0.5 mM and 1 mM, respectively, recorded the lowest value of total phenol content in both seasons compared to the rest of combination treatments.

Effect of foliar application of IBA and MI on mineral contents

The effect of foliar treatments of IBA and MI individually or interactively on mineral content of bulbs of garlic cv Seds 40 is presented in Table 3. It displays clearly that both N and K contents were significantly increased at all IBA applied levels than the control treatment. However, P content in bulbs was only increased by application of IBA at a rate of 0.5 mM. In the same regard, MI treatments also enhanced N and P contents compared to untreated plants, however they have no significant effect on K content. Obviously, it could be noticed that treatments by 1.5 and 2 mM MI have the highest significant N and P contents in garlic bulbs, without a significant difference between them, as compared with the other MI treatments (0 and 1 mM). The highest significant N and P contents were observed with those garlic plants exogenously treated with IBA at a rate of 0.5 mM with MI at a rate of 1.5 mM in both
### TABLE 1. Effect of foliar applications of IBA and MI and their interactions on vegetative growth and yield parameters of garlic plants cv. Seds 40 during the growing seasons of 2018/2019 and 2019/2020.

| Treatments | MI 0 mM | MI 1 mM | MI 1.5 mM | MI 2 mM | Mean | MI 0 mM | MI 1 mM | MI 1.5 mM | MI 2 mM | Mean |
|------------|---------|---------|-----------|---------|------|---------|---------|-----------|---------|------|
| Plant height (cm) | | | | | | | | |
| IBA 0 mM | 57.60f | 60.40cde | 61.40bcde | 60.20de | 59.90B | 58.20e | 60.80cde | 60.40de | 62.20bcd | 60.40B |
| IBA 0.5 mM | 63.60ab | 60.00e | 62.40abcd | 63.80a | 62.45A | 60.80cde | 61.80cde | 63.60ab | 65.20a | 62.85A |
| IBA 1 mM | 61.40bcde | 61.80bcde | 63.60ab | 62.60abc | 62.35A | 63.40abc | 60.20de | 63.80ab | 64.00ab | 62.85A |
| Mean | 60.87B | 60.73B | 62.47A | 62.20A | 60.80B | 60.93B | 62.60A | 63.80A | 62.20B |

| Plant fresh weight (g/plant) | | | | | | | | |
| IBA 0 mM | 67.96g | 81.41e | 86.46d | 87.06cd | 80.72C | 68.48e | 84.86cd | 87.24de | 94.42b | 83.75C |
| IBA 0.5 mM | 87.43cd | 90.83bcd | 95.97a | 96.53a | 92.69A | 86.04cd | 94.51b | 100.85a | 100.03ab | 95.36A |
| IBA 1 mM | 76.82f | 85.85de | 94.67ab | 92.00abc | 87.33B | 82.36d | 88.64c | 98.87ab | 97.67ab | 91.89B |
| Mean | 77.40C | 86.03B | 92.37A | 91.87A | 78.96C | 86.03B | 92.37A | 91.87A | 78.96C | 86.03B |

| Bulb weight (g/bulb) | | | | | | | | |
| IBA 0 mM | 43.50g | 53.89ef | 56.02de | 58.22bcd | 52.91C | 50.20f | 57.11de | 58.24bcd | 63.50bcd | 55.48C |
| IBA 0.5 mM | 58.88bcd | 61.33b | 65.41a | 65.27a | 62.72A | 60.80bcd | 62.80bcd | 62.01a | 67.52ab | 65.04A |
| IBA 1 mM | 51.70f | 56.84cde | 61.84ab | 60.65bc | 57.76B | 60.80bcd | 58.92cde | 64.99bc | 62.08bcd | 60.09B |
| Mean | 51.36C | 57.35B | 61.09A | 61.38A | 51.77C | 59.61B | 65.08A | 64.37A | 51.77C | 59.61B |

| Yield (Tons/feddan) | | | | | | | | |
| IBA 0 mM | 5.71g | 6.84e | 7.26d | 7.31cd | 6.78C | 5.75e | 7.13cd | 7.33cd | 7.93b | 7.04C |
| IBA 0.5 mM | 7.34ed | 7.63bcd | 8.06a | 8.11a | 7.79A | 7.23cd | 7.94ab | 8.47a | 8.40ab | 8.01A |
| IBA 1 mM | 6.45f | 7.21de | 7.95ab | 7.73abc | 7.34B | 6.92d | 7.45e | 8.31ab | 8.20ab | 7.72B |
| Mean | 6.50C | 7.23B | 7.76A | 7.72A | 6.63C | 7.50B | 8.04A | 8.18A | 6.63C | 7.50B |

Values followed by the same letters within each group are not significantly differed at 5% level according to Duncan’s multiple range test. IBA = Indole 3-butyric acid, MI = Myo-inositol.
| Treatments | 2018/2019 Season | 2019/2020 Season | 2018/2019 Season | 2019/2020 Season |
|------------|------------------|------------------|------------------|------------------|
| IBA        | Leaf cholorphyll contents (SPAD readings) | Leaf cholorphyll contents (SPAD readings) | Leaf cholorphyll contents (SPAD readings) | Leaf cholorphyll contents (SPAD readings) |
| 0 mM IBA   | 59.80f           | 61.27f           | 67.47de          | 64.03C           |
| 1 mM IBA   | 67.67de          | 71.20bc          | 74.53a           | 71.70A           |
| 1.5 mM IBA | 65.97e           | 69.53cd          | 69.40cd          | 68.13B           |
| Mean       | 64.48C           | 70.47A           | 69.52A           | 62.92A           |
| IBA        | Soluble solids (%) | Soluble solids (%) | Soluble solids (%) | Soluble solids (%) |
| 0 mM IBA   | 30.33c           | 31.00c           | 32.50b           | 30.17c           |
| 1 mM IBA   | 30.17c           | 32.50b           | 34.03a           | 32.67b           |
| Mean       | 30.44C           | 33.01A           | 31.22B           | 33.03A           |
| IBA        | Total sugars (mg/g FW) | Total sugars (mg/g FW) | Total sugars (mg/g FW) | Total sugars (mg/g FW) |
| 0 mM IBA   | 417.03c          | 408.06c          | 543.78bcd        | 414.06e          |
| 1 mM IBA   | 500.85d          | 570.16bc         | 595.96b          | 655.81a          |
| Mean       | 476.19B          | 464.66B          | 542.52A          | 498.21B          |
| IBA        | Total Phenolics (mg/100g FW) | Total Phenolics (mg/100g FW) | Total Phenolics (mg/100g FW) | Total Phenolics (mg/100g FW) |
| 0 mM IBA   | 215.06b          | 179.63gh         | 150.37i          | 199.23def        |
| 1 mM IBA   | 242.78a          | 143.87i          | 187.78g          | 173.33h          |
| Mean       | 219.65A          | 171.35D          | 180.86C          | 194.93B          |

Values followed by the same letters within each group are not significantly differed at 5% level according to Duncan’s multiple range test.

IBA = Indole 3-butyric acid, MI = Myo-inositol.
### TABLE 3. Effect of foliar applications IBA and MI and their interactions on mineral contents of garlic plants cv. Seds 40 during the growing seasons of 2018/2019 and 2019/2020.

| Treatments | 2018/2019 Season | 2019/2020 Season |
|------------|------------------|------------------|
|            | MI 0 mM | MI 1 mM | MI 1.5 mM | MI 2 mM | Mean | MI 0 mM | MI 1 mM | MI 1.5 mM | MI 2 mM | Mean |
| N (mg/g DW) |         |         |         |         |       |         |         |         |         |       |
| IBA 0 mM   | 11.87f   | 17.00e  | 21.00bde| 22.00bcde| 17.97C | 12.99f | 18.22e  | 22.51bcde| 23.20bcde| 19.23C |
| IBA 0.5 mM | 20.33cde| 23.00bc | 26.33a  | 24.10ab  | 23.44A | 22.33bcde| 24.89bc | 28.33a  | 25.62ab | 25.29A |
| IBA 1 mM   | 19.33cde| 21.00bde| 22.00bcde| 20.33cde | 20.67B | 20.50de | 22.00cd | 23.40bcde| 21.93cde| 21.96B |
| Mean       | 17.18C   | 20.33B  | 23.11A  | 22.14AB  | 18.61C | 21.70B  | 24.75A  | 23.58A  |
| P (mg/g DW) |         |         |         |         |       |         |         |         |         |       |
| IBA 0 mM   | 2.90c    | 3.01c   | 3.50ab  | 3.59a    | 3.25B  | 3.03d   | 3.14d   | 3.65bc  | 3.75ab  | 3.39B  |
| IBA 0.5 mM | 3.46ab   | 3.60a   | 3.76a   | 3.62a    | 3.61A  | 3.61bc  | 3.77ab  | 4.02a   | 3.83ab  | 3.81A  |
| IBA 1 mM   | 2.97c    | 3.42ab  | 3.64a   | 3.23bc   | 3.32B  | 3.09d   | 3.58bc  | 3.76ab  | 3.34cd  | 3.43B  |
| Mean       | 3.11C    | 3.35B   | 3.63A   | 3.48AB   | 3.24C  | 3.49B   | 3.81A   | 3.64AB   |
| K (mg/g DW) |         |         |         |         |       |         |         |         |         |       |
| IBA 0 mM   | 12.97a   | 13.03a  | 13.40a  | 13.40a   | 13.20B | 13.59a  | 13.67a  | 14.43a  | 13.40a  | 13.17B |
| IBA 0.5 mM | 14.80a   | 14.80a  | 14.77a  | 14.40a   | 14.70A | 15.30a  | 15.70a  | 15.87a  | 15.50a  | 15.59A |
| IBA 1 mM   | 14.40a   | 14.80a  | 15.20a  | 14.80a   | 14.80A | 15.10a  | 15.20a  | 15.83a  | 15.50a  | 15.41A |
| Mean       | 14.06A   | 14.21A  | 14.46A  | 14.20A   | 14.66A | 14.86A  | 15.38A  | 14.80A   |

Values followed by the same letters within each group are not significantly differed at 5% level according to Duncan’s multiple range test.

**IBA = Indole 3-butyric acid, MI = Myo-inositol.**
growing season, nevertheless this combination had not record the highest value of K content.

Discussion

The application of plant growth stimulants has become general practice in agriculture production as a result of providing various profits, including enhancing vegetative growth, yield and fruit quality as well as increasing plant tolerant to several types of stressful conditions such as salinity, drought and cold (Yildizli et al., 2018, Abd Elwahed et al., 2019, Waheed et al., 2019, Yousef and Ali, 2019, Alam et al., 2020). In this regard, there are several types of plant stimulants such as phytohormones, plant extracts, polyamines and synthetic chemicals. Nevertheless, these different stimulants vary strongly in their promotive effects, due to their different active compounds (Van Oosten et al., 2017 and Hassan et al., 2020).

The current investigation roughly stated that exogenous application of IBA and MI as well as their interaction significantly enhanced vegetative growth, total bulb yield/feddan and bulb quality parameters of garlic cv. Seds 40 during the both seasons of study. For example, the total bulb yield/feddan increased by 42.03% and 46.09%, when the garlic plants treated with IBA at 0.5 mM followed by MI at a rate of 2 mM compared to those plants of control in the first and second seasons, respectively. In the same context, garlic bulb yield was enhanced by 63.6% and 71.4% when IBA was applied at a rate of 50 and 100 ppm (Abd Elwahed et al., 2019). As for IBA, application of MI also increased the vegetative growth and development of apple and pepper plants grown under salinity and drought stresses (Hu et al., 2018, Yildizli et al., 2018). The result of current investigation also showed the powerful influence of IBA and MI on garlic plants, whereas supplementation of IBA at a rate of 0.5 followed by MI at a rate of 1.5 mM enhanced the leaf total chlorophyll content (SPAD readings) by about 24.30% and 20.04% in both growing seasons, respectively, compared to the control plants, accordingly improved vegetative growth and bulb productivity in both seasons. Similar results have been reported by Amin et al. 2007), who demonstrated that different photosynthetic pigments (Chl. a, Chl. b and total carotenoids) were significantly increased in onion leaves with increasing the concentration of IBA up to 100 mg/l. Also, MI application improved leaf chlorophyll content and photosynthetic characteristics, including photosynthesis rate (Pn), intercellular CO₂ concentration (Ci), stomatal conductance (Gs), and transpiration rate (Tr) in apple and Creeping bentgrass plants under salinity and drought stresses, respectively, (Hu et al., 2018, Li et al., 2020). Therefore, the increase in the growth and yield of garlic plant in this study might be attributed to increase photosynthetic pigments and photosynthetic characteristics in response to exogenous application of IBA and MI.

The exogenous application of IBA significantly improved contents of soluble solids, total sugars and total phenols in garlic bulbs and the maximum mean values of soluble solids, total sugars and total phenols contents were attained in garlic plants by treated with IBA at a rate of 0.5 mM in a comparison with other treatments in both growing seasons. In this regard, several previous investigations demonstrated that the application of IBA significantly improved the quality parameters in various vegetable crops. For instance, it was found that quality traits (e.g. total sugars, total phenols and total soluble solids) increased in response to the exogenous application of IBA in bulbs of garlic and onion as well as seeds of chickpea (Amin et al., 2007, Amin et al., 2013 Abd Elwahed et al., 2019 and Waheed et al., 2019). Also, current study clearly showed that the application of MI has a positive effect on soluble solids and total sugars contents in garlic bulbs. An increment in total sugars content recorded in this study might be due to the conversion of MI into glucose and galactinol (Rosenfield et al., 2013, Abd Elwahed et al., 2019 and Waheed et al., 2019). Also, current study clearly showed that the application of MI has a positive effect on soluble solids and total sugars contents in garlic bulbs. An increment in total sugars content recorded in this study might be due to the conversion of MI into glucose and galactinol (Rosenfield et al., 2013, Abd Elwahed et al., 2019 and Waheed et al., 2019). Also, current study clearly showed that the application of MI has a positive effect on soluble solids and total sugars contents in garlic bulbs.
the tolerance of garlic plants to harsh conditions during both growing seasons through enhancing photosynthetic pigments and photosynthetic characteristics as well as the plant’s antioxidant defense system and consequently led to a reduction in the total phenols content.

It is realized from the obtained result of this experiment that contents of N, P and K in garlic bulbs significantly increased with application of IBA. Where, the treatment of IBA at a rate of 0.5 mM given the highest means for N and P contents, however there was no significant difference was detected between both treatments of 0.5 and 1 mM in terms of K content. These findings were true in both seasons of the study. Also, MI application improved the N and P contents but it has no significant effect on K content in both seasons. In the same regard, Amin et al. (2013) found that application of IBA at 100 mg/L was more effective than the other IBA treatments and untreated plants in terms of N, P and K content. Subsequently, IBA and MI might improve garlic productivity through enhancing elements absorption from the soil, which might lead to a reduction in amount of chemical fertilizers. The positive influence of MI on P content in bulbs of garlic might be explained by fact that MI is strongly involved in the phosphate storage via the phosphorylation of inositol polyphosphates and stored in seeds and other storage tissues as a phytic acid, inositol-1,2,3,4,5,6-hexakisphosphate (Jia et al., 2019).

Thus, we can conclude that foliar application of IBA and MI either individually or together could be considered as an efficient plant stimulants treatment for enhancing growth and yield of garlic. However, these two plant stimulants vary strongly in their stimulation effect ways. For instance, IBA has vital roles in several key physiological and metabolites processes inside the plant during its growth and development, including enhancing nutrient uptake, nitrate reduction and photosynthesis, translocation, cytoplasmic streaming, cell division, cell elongation and synthesis of amino acids which in turn reflected on the increasing plant yield (Amin et al., 2007, Olaiya, 2010, Singh et al., 2014). On the other hand, MI exogenous application improves the plant growth, development and productivity through supporting the plant’s antioxidant defense system such as activities of superoxide dismutase (SOD), catalase (CAT), peroxidase (POD), and ascorbate peroxidase (APX) activities as well gene expression, particularly under a biotic stress conditions (Hu et al., 2018, Yildizli et al., 2018, Hu et al., 2020, Li et al., 2020).

Conclusion

The foliar application of IBA at a rate of 0.5 mM along with MI at 1.5 and/or 2 mM was most effective treatment than the other treatments. Therefore, we can conclude that the foliar application of IBA and MI, individually or together, is a successful approach in improving the vegetative growth, total yield, biochemical constituents and macro-elements in garlic plant.

Acknowledgment

Authors wish to express their thanks to all members of Horticulture Department, Faculty of Agriculture, Suez Canal University.

Funding statement

Authors wish to express their appreciation to the Horticulture Department, Faculty of Agriculture, Suez Canal University for supplying the chemicals and working space for this work.

Conflict of interest

All authors declare that they have no conflict of interest. They have read and agreed to the submitted version of the manuscript.

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تأثير الرش الخارجي بحامض إنول بيوترك و ميوانيسيتول على تحسين نمو وانتاجية وجدارة الثوم

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تم إجراء تجربتين حقلتين متتابعتين عامي 2018/2019 و 2019/2020 في المزرعة البحثية بكلية الزراعة - جامعة قناة السويس - محافظة الاسماعيلية - مصر، لدراسة تأثير الرش بمستويات 0.5 و 1 مليمول من حامض إنول بيوترك وتاثير الرش بمستويات صفر، 0.5 مليمول من ميوانيسيتول كل منها منفرداً أو معاً، وكذلك تأثيرهما التفاعلي على صفات النبات الخضري، ومحصول الأصل، والمحتوى المعدني والمحتوى الطبيعي في نبات الثوم.

تمت المعالجة بعد مرور 20 يوماً بفصل زمني 15 يوم بين كل مرة. وصممت التصاميم التصاميم المتتابعة المغلقة علمياً. كما أوضح تأثير الإنتاج أن معالمة نباتات الثوم بحمض إنول بيوترك يرقى إلى 0.5 مليمول قد حققت أعلى قيم لصفات طول النبات، وزن النبات، وزن الأصل، المحصول المحتوي للأصل، محتوى الكربوهيدرات، محتوى المواد السائلة، محتوى الفيتامينات، النبات والتوت. وتمت المعالجة بعد مرور 40 يوماً بين كل مرة.

النتائج ملحوظة من خلال تفاعلات الزيادة في معظم الصفات المدروسة. كما أظهرت نتائج الدراسة أن معالمة بحامض إنول بيوترك بتركيز 1.5 مليمول أعلى بالنسبة لكل سابقة المحتوى من المواد العضوية والمحتوى المعدني من العناصر الجذرية. ونضجت نباتات الثوم بحمض إنول بيوترك بتركيز 0.5 مليمول. وقيت نتائج الدراسة إلى أن التأثير المحفز للمحيط معالمة إنول بيوترك ميوانيسيتول كان يناسب في زيادة النمو الخضري ومحتويات وجدارة الثوم.

وقد أظهر التفاعل التفاعلي بين حامض إنول بيوترك وميوانيسيتول مع معالمة صفر متوسطاً في معظم الصفات المدروسة. وتشير نتائج هذه الدراسة إلى أن التأثير المحفز للمحيط معالمة إنول بيوترك ميوانيسيتول يمكن استخدامهما في الإنتاج التجاري للثوم.