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

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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 folair 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 parmemters 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 moast 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.

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

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(Shafeek et al., 2015) and it was successfully used as a bud induction agent in organic agriculture of table grape (Vargas-Arispuro et al., 2008). Due to its economic and medicinal profits, the sustainable production of garlic should be insured in order to meet the ever-growing demand in local and foreign markets.

Plant stimulants, natural or synthetic substances, can be used to enhance plant growth aiming to increase plant productivity and tolerance to several stresses (Du Jardin, 2015). Earlier studies reported that application of active plant stimulants have the potential to increase plant nutrition efficiency, tolerance to a biotic stress leading to high plant productivity (Mukherjee and Patel, 2020, Hassan et al., 2020, Mutale-joan et al., 2020). Various subcategories of growth stimulants were proposed by the Biostimulant Coalition, such as antioxidants, amino acids, biomolecule,enzymatic extracts, fulvic acid, humic acid, microbial inoculants, mycorrhizalfungi, plant growth-promoting rhizobacteria (PGPRs), phytohormones, and seaweed extracts (Du Jardin, 2015). However, the selection of the appropriate stimulant is critical as the effects can vary markedly between species (Hunt et al., 2010, Van Oosten et al., 2017, De Vasconcelos and Chaves, 2019).

Among several types of plant growth regulators, indole 3-butyric acid (IBA), an auxin precursor that is converted to IAA in a peroxisomal β-oxidation process (Strader and Damodran, 2019), plays important roles in plant development either under normal or stressful conditions. IBA is now applied generally in order to accelerate and regulate root formation in cuttings and seedlings, and consequently to promote crop growth and productivity. Nevertheless, it has a variety of different effects on plant growth and development when applied exogenously. For instance, Amin et al. (2007) reported that the foliar application of IBA at 25 to 100 mg/L significantly improved the vegetative growth, bulb yield and biochemical constitutes in onion plants. Also, total photosynthetic pigments were significantly increased in response to IBA exogenous application and resulted in higher yield components over untreated chickpeas plans (Amin et al., 2013). In addition, Bidmeshki et al. (2012) concluded that IBA significantly 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.

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 m^3 organic manure, 300 kg of calcium superphosphate (15.5 % P_2O_5) and 60 kg sulpher/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% K_2O) 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 orderd 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, Ca^{+2} 1.22 $meql^{-1}$, Mg^{+2} 0.84 $meql^{-1}$, Na^{+} 1.35 $meql^{-1}$, K^{+} 0.34 $meql^{-1}$, HCO_3^{-} 1.26 $meql^{-1}$, Cl^{-} 1.63 $meql^{-1}$, SO_4^{-2} 0.86 $meql^{-1}$ and CO_3^{-2} 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 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 ºC 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).

- 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 in both seasons as shown in Table 1. Whereas, the treatment of MI at rates of 1.5 or 2 mM achieved the highest values of plant height, plant fresh weight, bulb fresh weight and total yield in both seasons, without a significant difference between both of them. It is obvious that foliar application of IBA at a rate of 0.5 mM combined with 2 mM of MI recorded the maximum plant height and plant fresh weight, however, the foliar application of IBA at a rate of 0.5 mM in combination with 1.5 mM of MI recorded the maximum values of bulb weight and total yield than the rest of treatment combinations.

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	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
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	61.80bcd	63.60ab	65.20a	**62.85A**
IBA 1 mM	61.40bcde	61.80abcde	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**	
Plant fresh weight (g/plant)										
IBA 0 mM	67.96g	81.41e	86.46d	87.06cd	**80.72C**	68.48e	84.86cd	87.24cd	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**	**89.33B**	**95.66A**	**97.38A**	
Bulb weight (g/bulb)										
IBA 0 mM	43.50g	53.89ef	56.02de	58.22bcd	**52.91C**	43.09f	57.11de	58.24cde	63.50bcd	**55.48C**
IBA 0.5 mM	58.88bcd	61.33b	65.41a	65.27a	**62.72A**	57.83de	62.80bcd	72.01a	67.52ab	**65.04A**
IBA 1 mM	51.70f	56.84cde	61.84ab	60.65bc	**57.76B**	54.40e	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**	
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	7.34cd	7.63bcd	8.06a	8.11a	**7.79A**	7.23cd	7.94b	8.47a	8.40ab	**8.01A**
IBA 1 mM	6.45f	7.21de	7.95ab	7.73abc	**7.34B**	6.92d	7.45c	8.31ab	8.20ab	**7.72B**
Mean	**6.50C**	**7.23B**	**7.76A**	**7.72A**		**6.63C**	**7.50B**	**8.04A**	**8.18A**	

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 2. Effect of foliar applications of IBA and MI and their interactions on chemical constituents 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
Leaf cholorphyll contents (SPAD readings)										
IBA 0 mM	59.80f	61.27f	67.47de	67.57de	**64.03C**	61.51f	63.28f	69.84de	69.68de	**66.08C**
IBA 0.5 mM	67.67de	71.20bc	74.53a	73.40ab	**71.70A**	69.74de	73.54bc	77.44a	75.71ab	**74.11A**
IBA 1 mM	65.97e	69.53cd	69.40cd	67.60de	**68.13B**	66.95e	70.93cd	71.47cd	69.81de	**69.79B**
Mean	**64.48C**	**67.33B**	**70.47A**	**69.52A**		**66.07C**	**69.25B**	**72.92A**	**71.73A**	
Soluble solids (%)										
IBA 0 mM	30.33c	31.00c	32.50b	30.17c	**31.00B**	30.83c	31.67c	33.00b	30.77c	**31.57C**
IBA 0.5 mM	30.17c	32.50b	34.03a	32.67b	**32.34A**	31.10c	33.30ab	34.67a	33.27ab	**33.08A**
IBA 1 mM	30.83c	33.53ab	32.50b	30.83c	**31.93A**	31.27c	34.13ab	33.07b	31.37c	**32.46B**
Mean	**30.44C**	**32.34A**	**33.01A**	**31.22B**		**31.07B**	**33.03A**	**33.58A**	**31.80B**	
Total sugars (mg/g FW)										
IBA 0 mM	417.03e	408.06e	543.78bcd	414.06e	**445.73B**	422.27d	413.90d	549.79bc	424.30d	**452.57B**
IBA 0.5 mM	500.85d	570.16bc	595.96b	655.81a	**580.70A**	506.16c	576.90b	603.70b	662.72a	**587.37A**
IBA 1 mM	510.68cd	415.77e	487.82d	424.77e	**459.76B**	516.59c	421.82d	494.57c	429.88d	**465.72B**
Mean	**476.19B**	**464.66B**	**542.52A**	**498.21B**		**481.68BC**	**470.87C**	**549.35A**	**505.63B**	
Total Phenolics (mg/100g FW)										
IBA 0 mM	215.06b	179.63gh	150.37i	199.23def	**186.07B**	222.07bc	188.00f	158.66g	205.57de	**193.58B**
IBA 0.5 mM	242.78a	143.87i	187.78fg	173.33h	**186.94B**	252.40a	155.11g	178.14f	164.54g	**187.55C**
IBA 1 mM	201.11cde	190.56efg	204.44bcd	212.22bc	**202.08A**	210.25cde	200.70e	213.90bcd	223.29b	**212.03A**
Mean	**219.65A**	**171.35D**	**180.86C**	**194.93B**		**228.24A**	**181.27C**	**183.57C**	**197.80B**	

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	21.00bcd	22.00bcd	**17.97C**	12.99f	18.22e	22.51bcd	23.20bcd	**19.23C**
IBA 0.5 mM	20.33cde	23.00bc	26.33a	24.10ab	**23.44A**	22.33bcd	24.89bc	28.33a	25.62ab	**25.29A**
IBA 1 mM	19.33de	21.00bcd	22.00bcd	20.33cde	**20.67B**	20.50de	22.00cd	23.40bcd	21.93cd	**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	3.55bc	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 CO_2 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., 1978 and Karner et al., 2004). In this regard, Hu et al. (2018) reported that the pretreatment with MI application enhanced the levels of glucose and galactose levels in salt-stressed plants of apple. However, it has no effect on quantity of sucrose or fructose, which indicates that MI treatment could slightly alter the accumulation of soluble sugars in plants when exposed to stress conditions. Interestingly, the lowest value of total phenols recorded in this study was documented in garlic plants treated with 0.5 mM of IBA followed by 1 mM of MI. In fact, phenolic compounds are mainly involved in plant response to stresses including, temperature, mineral deficiencies, wounding and pathogen attack. Whereas, one of the most common mechanisms of plant to tolerant to harsh conditions is to increase either phenolic synthesizing enzyme levels or their activities, consequently lead to an increase in phenolics content in stressed plants (Chalker-Scott and Fuchigami, 2000). Therefore, this study suggests that MI application might be improved 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.

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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 الخارجى بحامض اندول بيوترك و ميوانيسيتول على تحسين نمو وانتاجية وجودة الثوم

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تم إجراء تجربتين حقليتين متتابعتين عامى ٢٠١٩/٢٠١٨ و ٢٠٢٠/٢٠١٩ بالمزرعة البحثية لكلية الزراعة – جامعة قناة السويس – محافظة الاسماعيلية – مصر لدراسة تأثير الرش بمستويات صفر ، ٠,٥ ، ١ ملليمول من حامض اندول بيوترك وتأثير الرش بمستويات صفر، ١، ١,٥ و ٢ ملليمول من ميوانيسيتول كل منهم منفرداً أو معاً, وكذلك تأثيرهما التفاعلي على صفات النو الخضري، ومحصول الأبصال، والمواد العضوية والمحتوي المعدني فى نبات الثوم صنف سيدس ٤٠. وتمت المعاملة بعد مرور ٣٠ يوم من تاريخ ولمدة ٨ مرات وبفاصل زمنى ١٥ يوم بين كل مرة والاخرى. وصممت التجربة فى تصميم قطاعات منشقه أظهرت نتائج التجربة استجابة نباتات الثوم للمعاملة بكل من حامض إندول بيوترك وميوانيسيتول سواء منفردين أو مع بعضهما. كما أوضحت نتائج الدراسة أن معاملة نباتات الثوم بحامض إندول بيوترك بتركيز ٠,٥ ملليمول قد حققت أعلى القيم لصفات طول النبات، وزن النبات، وزن الأبصال، المحصول الكلي للأبصال، محتوى الكلوروفيل، محتوى المواد الصلبة الذائبة، محتوى السكريات الكلية، المحتوي المعدني من النيتروجين، والفسفور، والبوتاسيوم بينما حققت المعاملة بحامض إندول بيوترك بتركيز ١ ملليمول أعلى القيم لمحتوي الفينولات الكلية. وفى نفس السياق أدت معاملة الرش بميوانيسيتول بتركيز ١,٥ و ٢ ملليمول إلى حدوث زيادة معنوية فى كل الصفات المدروسة مقارنة بالنباتات غير المعاملة وبالتركيزات الأخرى من الميوانيسيتول ماعدا صفة المحتوى من الفينولات الكلية والمحتوى من البوتاسيوم فى كلا الموسمين. وقد أظهر التفاعل الثنائي أختلافات معنوية بالنسبة لكل الصفات التى تم دراستها ماعدا صفة المحتوي من البوتاسيوم. ولقد حققت المعاملة بحامض اندول بيوترك بتركيز ٠,٥ المتبوعة بمعاملة ميوانيسيتول بتركيز ١,٥ او ٢ ملليمول أعلى متوسطات فى معظم الصفات سابقة الذكر .وفى النهاية تشير نتائج هذه الدراسة إلى أن التأثير التفاعلي لحامض اندول بيوترك وميوانيسيتول كان فعالاً فى زيادة النمو الخضري ومحصول وجودة الأبصال الناتجة والمحتوي المعدني من العناصر الكبرى وبناءاً على ذلك توصى الدراسة بإمكانية استخدام حامض اندول بيوترك وميوانيسيتول فى الإنتاج التجاري للثوم.