



## Gibberellic Acid and Benzyl Adenine Improve Garlic Seed Cloves Sprouting and Boost Plant Growth and Productivity in Unfavorable Conditions



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**G**ARLIC production in Egypt faces the challenge of increasing temperatures within the usual planting time, causing delays and uneven garlic seed cloves sprouting. Hence, this investigation aimed to improve the sprouting of garlic seed cloves in unfavorable conditions by soaking them in gibberellic acid (GA<sub>3</sub>) and benzyl adenine (BA) solutions before planting on two different planting dates. Two trials occurred in the successive seasons of 2021-22 and 2022-23 in the experimental farm of the Horticulture Department, Faculty of Agriculture, Ain Shams University, Shoubra El-Kheima, Qalubia Governorate, Egypt, to assess the impact of soaking garlic seed cloves in solutions of 50, 100, and 200 ppm of GA<sub>3</sub> and 25, 50, and 100 ppm of BA for 24 hours before planting on September 20 and October 15 on sprouting, plant vegetative growth characteristics, bulb properties, and yield, as well as the leaf contents of chlorophyll, nitrogen, phosphorus, and potassium. The obtained results indicated that planting the garlic seed cloves in October was more beneficial than in September for promoting the seed cloves' sprouting percentage and rate due to the better weather conditions vs. September. Meanwhile, planting in September allowed for longer vegetative growth before bulbing onset, leading to a longer shoot, more leaf number, a higher plant dry weight, and improved bulb quality in diameter and weight. Nevertheless, bulb yield per plot and feddan were higher in October planting date due to increase plant density from increasing seed clove sprouting percentage. Moreover, the levels of chlorophyll, phosphorus, and potassium in the leaves increased when the seed cloves were planted in October, but the nitrogen content showed no significant increase between the two planting dates. Soaking the cloves in solutions of GA<sub>3</sub> and BA increased clove sprouting, plant growth characteristics, bulb attributes, and yield, as well as an increase in leaf content of chlorophyll, nitrogen, phosphorus, and potassium compared to the control treatment. The effectiveness of GA<sub>3</sub> was greater than that of BA. The 100 ppm GA<sub>3</sub> solution was the most effective for improving seed cloves sprouting and all plant and yield parameters, as well as leaf chemical constituents, for both planting dates. The findings from this study may provide valuable insights for optimizing garlic production, particularly in unfavorable production conditions.

**Keywords:** Garlic, Cloves, Sprouting, Gibberellic acid, Benzyl adenine, Plant growth, Bulb yield, Unfavorable conditions

### Introduction

Garlic, *Allium sativum* L., is the second most popular *Allium* family member, following onion

(Bose and Som, 1986). It is grown for the fresh market and for processing. The history of garlic cultivation dates back to 3200 BC in Egypt. Based on the annual garlic bulb yield production

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(indicate here the approximate production amount of garlic bulbs), Egypt comes in fourth among the garlic-produced countries (Atlasbig, 2020). In addition to its therapeutic properties, it is one of the most popular spices, condiments, and flavors (Singh and Singh, 2019). Garlic has a variety of uses throughout history, from culinary uses to potential health benefits, making it a truly versatile and valuable crop.

Garlic is typically propagated globally by planting cloves (Kamenetsky, 2007). Garlic exhibits a unique growth pattern involving a period of dormancy, which is crucial for the survival of garlic bulbs during the summer months. The temperature is usually the main factor affecting garlic clove sprouting and growth, as garlic bulbs remain dormant for over three months throughout the summer (Rahman et al., 2003, Sasmitaloka et al., 2021). In Egypt, cloves are also routinely used for garlic propagation, with September and most of October being the recommended times for planting (Ali and El-Sayed, 1999, El-Zohiri and Farag, 2014, El-Shabasi et al., 2018). This is likely due to the favorable weather conditions during these months, which provide the proper environment for garlic cloves to sprout and subsequent plant growth and development processes. This allows for sufficient vegetative growth before the bulbing stage, leading to a higher yield (El-Shabasi et al., 2018, Ahmed et al., 2020). Nevertheless, the increased and fluctuating temperatures, especially in September, due to climate change impacts, may cause uneven and delayed sprouting of garlic cloves. This conforms to reports from Rangwala and Miller (2012) and Mahmudah et al. (2021), who stated that climate change often involves rising daily average temperatures and their fluctuations, significantly affecting agricultural practices for various crops, including garlic.

Plant growth regulators (PGRs) have a major impact on the germination, growth, and yield of garlic. Among the important PGRs involved in garlic sprouting is gibberellin (GA). Gibberellins play a key role in regulating plant growth by promoting seed development and germination, elongating plant organs, delaying senescence, controlling the timing of flowering, and breaking dormancy (Ouzounidou et al., 2008, Yamaguchi, 2008, Yu et al., 2009, Ouzounidou et al., 2010, Castro-Camba et al., 2022). In garlic, gibberellins facilitate the sprouting of cloves by disrupting the dormant period and initiating the growth of new

shoots and roots (Rahman et al., 2006, Ahmed and Hemada, 2012, Bizuayehu et al., 2018, El-Shabasi et al., 2018, Bizuayehu et al., 2022 a&b).

Benzyl adenine (BA), as a cytokinin derivative, is a compound that regulates plant growth by promoting cell division, leaf expansion, and the development of lateral buds. Its application to garlic plants can enhance clove sprouting and growth, as well as stimulate the development of side buds, resulting in increased clove formation and improved bulb development. By promoting clove growth, benzyl adenine has the potential to enhance the overall yield and quality of garlic bulbs (Atif et al., 2019, Atif et al., 2020).

There is a lack of information available on how to improve garlic sprouting when planted in unfavorable conditions in Egypt. However, the current study was performed to assess the effects of soaking garlic cloves in GA and BA solutions to enhance sprouting and observe the behavior of the resulting plants when planted at two different times.

#### *Materials and methods*

##### *Description of the experimental site and soil type*

The experiment was conducted in the experimental farm of the Horticulture Department, Faculty of Agriculture, Ain Shams University, Shoubra El-Kheima, Qalubia Governorate, Egypt. The soil employed for the experiment was medium-to-clay-textured. Before the crop planting in each season, soil samples were taken from the 0-20 cm layer and then analyzed. The physical and chemical properties of the experimental soil are shown in Table 1 as an average of both seasons. The irrigation water source is the Nile River. Before planting, the soil was plowed and leveled, and the beds were raised and constructed. Organic manure as a compost at a rate of 20 m<sup>3</sup> per feddan and superphosphate fertilizer as a calcium superphosphate (15.5% P<sub>2</sub>O<sub>5</sub>) at a rate of 400 kg per feddan were added before planting and during experimental soil preparation. The fertigation technique was used to apply the other nutrients once a week. Fertilization started 30 days after planting and lasted until four weeks before harvest. With a mean flow rate of 4 L h<sup>-1</sup>, the drip irrigation system was employed with two hoses per bed and pressure-compensating drippers 25 cm apart. Irrigation was applied once or twice weekly based on the temperature, and the water requirements were calculated based on the crop evapotranspiration method according to Allen et al. (1998). The garlic crop was managed

for irrigation, phytosanitary, and weed control, as well as other agronomic practices, according to the garlic producers' guide and the Egyptian Agriculture Ministry's recommendations.

#### *Experimental design and statistical analysis*

The experimental sub-plot comprised three raised ridges, each one meter in width and 5 meters in length, each involving six planting rows spaced 15 cm apart. The cloves were planted 12 cm apart within each row. A local garlic cultivar, Egaseed-1 (*Allium sativum* L.) was used in the experiment. Similar seed cloves were chosen with the elimination of small cloves. The seed cloves were soaked in three different concentrations of both gibberellic acid (GA<sub>3</sub>) at 50, 100, and 200 ppm and benzyl adenine (BA) at 25, 50, and 100 ppm, as well as distilled water as a control, for 24 hours before planting. Ethanol and sodium hydroxide were used to dissolve the GA<sub>3</sub> and BA, respectively. The cloves were planted on September 20 and on October 15, over the 2021-2022 and 2022-2023 growing seasons. The experiment was laid out in a split-plot design with three replications. Each replicate involved two main plots, each planted at a different time. The main plots were divided into seven sub-plots, each randomly assigned one of the seven clove soaking solutions. The data was analyzed using Duncan's Multiple Range Test (Duncan, 1955) to identify any significant differences at a 5% significance level. The analysis of variance was performed using M-Stat software.

#### *Recording the data*

##### a- Sprouting percent and speed of seed cloves:

After 40 days from planting dates, the sprouted cloves were counted to measure the percentage of cloves sprouting. The speed of clove sprouting was also calculated by monitoring the number of sprouted cloves every five days, starting 15 days after planting dates, using the method outlined by Ranal and de Santana (2006).

##### b- Ten plants were randomly chosen at 110 days from planting dates per sub-plot for determining the vegetative growth characteristics as follows:

- Plant shoot length. It was measured from the base of the swelling sheath to the tip of the largest linear blade in the plant.
- Number of leaves per plant. The leaf number was calculated as the average number of green leaves per plant.

- Plant dry weight. It was determined after drying the plant samples at 70°C in an electric oven to a constant weight.

##### c- Bulb attributes, diameter, fresh weight, and bulb yield per plot (kg) and feddan (tons):

A sample of ten plants was chosen randomly per sub-plot at harvesting stage (182 days from planting dates) and then subjected to measurement of the bulb attributes. Bulb yield per plot was collected by weighing all the produced bulbs from the plot. Bulb yield per feddan was estimated from bulb yield per plot using the relationship between the area of the plot and feddan.

##### d- Leaf chlorophyll, nitrogen, phosphorus, and potassium contents:

- Leaf chlorophyll content as mg/g fresh weight in the third leaf from the plant top at 110 days from planting dates was measured spectrophotometrically, according to the method of Jeffrey and Humphrey (1975).

- In the digested solution, of the dried third leaf samples collected at 110 days from planting dates, total nitrogen was determined according to the method described by Nkonge and Balance (1982) using a micro-Kjeldahl apparatus. Meanwhile, phosphorus was estimated calorimetrically according to the method described by Cavell (1955). Furthermore, potassium was measured photometrically according to Mason (1963).

## **Results**

### *Effect of different planting dates and seed cloves soaking in gibberellic acid (GA<sub>3</sub>) and benzyl adenine (BA) on garlic vegetative growth*

This study examined the impact of both unfavorable and favorable conditions on the sprouting behavior of garlic cloves during two planting times in Egypt. Higher temperatures are unfavorable, prolong cloves' dormancy, and lead to uneven sprouting, ultimately affecting the growth and yield of the garlic crop. Local cultivar Egaaseed-1 garlic seed cloves were soaked in solutions of gibberellic acid (GA<sub>3</sub>) and benzyl adenine (BA) compared to distilled water (DW) as a control, for 24 hours before planting in clay soil in the Nile Delta region, on September 20 and October 15 over two successive seasons of 2021-22 and 2022-23. The data from Tables 2 and 3 regarding some garlic cloves and plants

characteristics, including seed cloves sprouting percentage and speed, shoot length, leaf number, and plant dry weight, displays that the choice of planting date and the use of GA<sub>3</sub> or BA for garlic seed cloves soaking prior planting have a significant impact on these characteristics. Planting cloves on October 15 led to more cloves sprouting percent and rate than planting on September 20. However, shoot length, leaf number, and plant dry weight recorded higher values when the cloves were planted on September 20 than on October 15. Using plant growth regulators GA<sub>3</sub> and BA solutions for soaking seed cloves, showed greater enhancement of all measured clove and plant parameters than the control. Soaking seed cloves in a 100 ppm GA<sub>3</sub> solution led to the highest increase in cloves sprouting percentage and speed, and other vegetative attributes of the plant. Soaking cloves in GA<sub>3</sub> or BA solutions before planting was more effective than the control in increasing sprouting percent and rate, and vegetative attributes of the plants across both planting times. On October 15, planting cloves after soaking them in a 100 ppm GA<sub>3</sub> solution resulted in a higher percentage and faster rate of clove sprouting, attributed to the combined effect of GA<sub>3</sub> soaking and planting at the proper temperature. However, soaking cloves in 100 ppm GA<sub>3</sub> solution and then planting on September 20 led to increased shoot length, leaf number, and plant dry weight. This increment in vegetative attributes is a result of the longer duration between planting and bulbification in September. The data trend was alike across both experimental seasons.

*Effect of different planting dates and seed cloves soaking in gibberellic acid (GA<sub>3</sub>) and benzyl adenine (BA) on garlic bulb characteristics and yield*

Tables 4 and 5 present data regarding the characteristics and yield of garlic bulbs, including bulb diameter, fresh weight, yield per plot, and yield per feddan. These attributes were significantly impacted by the planting dates of September 20 and October 15, as well as by soaking the seed cloves in GA<sub>3</sub>, BA and DW during the 2021-22 and 2022-23 seasons. Planting cloves on September 20 led to larger bulb diameter and fresh weight than planting on October 15, due to a longer period of vegetative growth before bulb formation. However, planting cloves on October 15 resulted in a higher bulb yield per plot and feddan, attributed to an increase in sprouting of planted cloves (tables 3 & 4) and subsequently

a greater number of bulbs per area unit. Soaking garlic seed cloves in GA<sub>3</sub> and BA solutions resulted in higher bulb size, weight, and yield per plot and feddan than the control. The use of 100 ppm GA<sub>3</sub> solution showed the most significant improvement in bulb characteristics and yield per plot and feddan than other soaking solutions and control. The use of growth substances for soaking seed cloves along with planting dates, has an impact on bulb characteristics and yield. Both GA<sub>3</sub> and BA increased bulb characteristics and yield compared to the control for both planting dates. Planting the soaked seed cloves in 100 ppm GA<sub>3</sub> on September 20 resulted in the largest and heaviest bulbs, while the greatest yield per plot and feddan was achieved with planting on October 15. These findings were alike over the two growing seasons.

*Effect of different planting dates and seed clove soaking in gibberellic acid (GA<sub>3</sub>) and benzyl adenine (BA) on garlic leaf chlorophyll and NPK content*

The data in Tables 6 and 7 demonstrates the impact of planting dates and soaking seed cloves in GA<sub>3</sub>, BA and DW on chlorophyll, nitrogen, phosphorus, and potassium levels in garlic leaves. Planting garlic cloves on October 15 resulted in significantly higher chlorophyll, P, and K contents in the leaves than planting on September 20. However, the nitrogen content in the leaves was not influenced by either planting date. Soaking cloves in 50 and 100 ppm GA<sub>3</sub> or 25 ppm BA solutions resulted in a significant higher increase in leaf chlorophyll content compared to the other soaking solutions. Soaking cloves in a 100 ppm GA<sub>3</sub> solution increased leaf nitrogen content the most compared to other soaking solutions. Additionally, soaking in all GA<sub>3</sub> or BA solutions resulted in higher levels of P and K in the leaf compared to the control treatment, the differences between all GA<sub>3</sub> and BA soaking solutions were not significant. The levels of chlorophyll, N, P, and K in garlic leaves were influenced by the combination of planting date and soaking solutions of GA<sub>3</sub>, BA, and DW. The highest leaf chlorophyll content was observed by soaking cloves in 50 ppm GA<sub>3</sub> and planted on October 15. Conversely, soaking cloves in 100 ppm GA<sub>3</sub> and planting on September 20 resulted in the highest leaf nitrogen content. For both planting dates, September 20 and October 15, all GA<sub>3</sub> and BA soaking solutions, as well as DW on October 15, led to higher leaf phosphorus and potassium content compared to the DW soaking solution



on September 20. These findings were consistent across the two tested seasons.

### **Discussion**

There are several reasons for planting garlic in the fall season, which is considered an ideal planting time, with the primary factor being the prevailing temperature. The temperature has a significant impact on the ideal planting time as it influences the sprouting of garlic seed cloves and the emergence of seedlings. Therefore, garlic bulbs remain dormant during the summer and then resume sprouting and thrive in cooler temperatures. Thus, the fall and winter months provide a perfect setting for the garlic plant to develop and reach maturity before bulbing initiation in response to the long photoperiod effect (Rahman et al., 2003, Alsup-Egbers et al., 2020, Sasmitaloka et al., 2021). Given the current situation in Egypt, it has been demonstrated by numerous previous articles that the ideal time for planting garlic is in late September and most of October (Ali and El-Sayed, 1999, El-Zohiri and Farag, 2014, El-Shabasi et al., 2018). This is because the favorable temperature during this period promotes the sprouting and emergence of the seed cloves. Moreover, El-Zohiri and Farag (2014) discovered that planting garlic early in September can result in the highest accumulation of growing degree days, leading to improved growth and yield. However, Ibrahim et al. (2020) found that planting garlic seed cloves in September resulted in the lowest sprouting percentage compared to the October planting time due to the improper high temperature during September. Throughout the current investigation, it was found that planting garlic in October developed a higher percentage and rate of seed clove sprouting as well as bulb yield per plot and feddan compared to the September planting time. This was attributed to the unfavorable temperature conditions during September. Meanwhile, the September planting time exhibited greater shoot length, leaf number, and plant dry weight, as well as a higher bulb diameter and weight, likely due to the higher number of growing degree days (El-Zohiri and Farag, 2014). These results align with those of Atif et al. (2020) who also observed that the timing of garlic planting had a notable influence on plant variables including plant height, fresh weight, pseudo stem diameter, bulb characteristics, bulbing index, and growth period. Their research indicated that planting garlic early had a beneficial impact on these factors. Although

garlic plants planted in September had better vegetative and bulb attributes than those grown in October, the October planting yielded a higher yield due to the higher cloves sprouting.

The utilization of gibberellic acid ( $GA_3$ ) or benzyl adenine (BA) significantly affects garlic seed clove sprouting, plant development, bulb traits, and bulb yield, along with the levels of chlorophyll, nitrogen, phosphorus, and potassium in the leaves. Soaking garlic seed cloves in a  $GA_3$  solution before planting has been found to offer several benefits, including the following: helps in breaking the dormancy of cloves and promotes rapid and uniform sprouting, leading to a higher percentage of seed cloves sprouting and seedlings emerging successfully. It also leads to improvements of shoot and leaf growth, with longer shoots and more leaves developing in garlic plants, contributing to greater biomass production and overall plant health. Additionally, it enhances bulb quality and yield, resulting in larger bulbs with a greater weight. Moreover, it also improves the uptake of essential nutrients such as nitrogen, phosphorus, and potassium by garlic plants, which are crucial for various metabolic processes and overall plant growth. Lastly, it increases the chlorophyll content in garlic leaves, which is responsible for capturing sunlight during photosynthesis, as well as increases photosynthetic efficiency, which is essential for plant food and energy production. According to Bizuayehu et al. (2018), soaking the seed cloves in  $GA_3$  helps in breaking their dormancy by compensating for a lack of low temperatures and decreasing the abscisic acid content, which can delay sprouting. Additionally, the application of  $GA_3$  can enhance the levels of hydrolyzed carbohydrates found in the cloves, which are essential for sprouting and promoting growth (Bizuayehu et al., 2022 a&b). Rahim (1988) mentioned that lower concentrations of  $GA_3$  significantly increased both leaf and root dry weight, and total yield, while higher concentrations showed lethal effects and reduced the final bulb weight of garlic. The results of the current research align with Rahman et al. (2006) as they found that soaking garlic seed cloves in  $GA_3$  solution resulted in a higher sprouting percentage and improved certain early vegetative growth traits such as the number of roots and leaves per plantlet and the height of the plantlet. Similarly, Chattopadhyay et al. (2015) reported that soaking garlic seed cloves in a  $GA_3$  solution before planting resulted in a notable improvement

in seed clove sprouting, plant growth, and the quality and yield of bulbs compared to untreated cloves. Also, Bizuayehu et al. (2022 a&b) found that soaking garlic cloves in GA<sub>3</sub> before planting did not affect germination rate but increased leaf size, plant height, shoot-dry mass, number of cloves per bulb, average clove and bulb weight, bulb dry matter percentage, total bulb yield, neck and bulb diameter, and overall dry biomass of the plant.

Concerning the impact of soaking garlic cloves in BA solution on garlic seed clove sprouting, plant growth, bulb traits, and bulb yield, the obtained results of this study demonstrated that all concentrations of BA used enhanced all the measured parameters compared to the control treatment, but to a lesser extent than GA<sub>3</sub>. In the same vein, Singh et al. (2014), Singh et al. (2018), Samy and El-Zohiri (2021), and Rakesh et al. (2022) conducted studies where they sprayed cytokinin derivatives on garlic plants, while El-Mesirry and Radi (2019) soaked garlic cloves in benzyl amino purine (a cytokinin derivative) before planting. All of these researchers concurred that treating garlic with cytokinin in various ways resulted in improving plant growth, bulb quality, yield, and biochemical composition of the plant, such as leaf number and area, plant length, shoot weight, neck diameter, number of cloves per bulb, bulb diameter and weight, and bulb weight. The mechanism by which BA exerts these effects is thought to be related to its role in promoting cell division and differentiation, and shoot and root development. It is most effective when applied during the early stages of plant growth. By increasing the number of cells in the growing portions of the plant after treating garlic cloves, BA may enhance the growth and development of the plants and bulbs. Additionally, BA may also play

a role in regulating the production of other plant hormones, such as gibberellins and auxins, which are also involved in plant growth stimulation and development, as well as increasing the uptake of nutrients (Mok, 1994, Dewitte et al., 1999, Riou-Khamlichi et al., 1999, Werner et al., 2001, El-Ghamery and Mousa, 2017).

### Conclusion

Climate change in Egypt presents difficulties for garlic production due to rising and fluctuating temperatures during the proper planting time, causing delayed and uneven sprouting of seed cloves. The current study proved that soaking garlic cloves in gibberellic acid (GA<sub>3</sub>) or benzyl adenine (BA) for 24 hours before planting can improve the percentage of seed cloves sprouting and emergence, overall plant performance, and bulb yield when garlic is planted in September and October. The effect of GA<sub>3</sub> was more pronounced than that of BA in stimulating clove sprouting and subsequent plant growth and yielding during both planting times. According to the experiment, using GA3 at 100 ppm was the most effective treatment among the tested ones. The results of this experiment provide valuable insights for optimizing garlic cultivation practices, particularly in unfavorable conditions.

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### Conflict of interest

The author declare that she has no competing interests.

**TABLE 1. Physical and chemical properties of the 0–20 cm soil layer of the experimental soil before cultivation (Data presented as averages for both growing seasons).**

Sand (%)	Silt (%)	Clay (%)	Texture	F.C.%	P.W.P.%	B.d.	
23.30	36.00	40.70	Clay	31.05	14.81	1.32	
pH	Ca <sup>++</sup> (meq/l)	Mg <sup>++</sup> (meq/l)	K <sup>+</sup> (meq/l)	Na <sup>+</sup> (meq/l)	Cl <sup>-</sup> (meq/l)	CO <sub>3</sub> <sup>--</sup> (meq/l)	HCO <sub>3</sub> <sup>-</sup> (meq/l)
7.43	0.61	1.77	1.14	0.56	0.59	0	0.29

F.C. = field capacity,

P.W.P.= permanent wilting point, were determined as percentage in weight,

B.d. = Bulk density.

TABLE 2. Effect of different planting dates and seed cloves soaking in gibberellic acid (GA<sub>3</sub>) and benzyl adenine (BA) on garlic vegetative growth in the 2021-22 season.

Treatments	Sprouting percent	Sprouting rate	Shoot length	Leaf number	Plant dry weight	
<b>Planting date of seed cloves</b>						
<b>September 20</b>	80.38 b	3.57 a	77.74 a	12.171 a	28.757 a	
<b>October 15</b>	86.48 a	3.42 b	75.42 b	11.273 b	26.776 b	
<b>Cloves soaking in growth regulators</b>						
<b>Control</b>	71.33 f	<b>4.13 a</b>	68.31 e	10.533 f	23.933 d	
<b>GA<sub>3</sub> 50 ppm</b>	91.17 b	3.33 c	76.92 c	11.917 c	29.067 b	
<b>GA<sub>3</sub> 100 ppm</b>	97.00 a	2.63 d	86.32 a	13.033 a	33.000 a	
<b>GA<sub>3</sub> 200 ppm</b>	84.50 c	3.40 c	80.52 b	12.400 b	26.833 c	
<b>BA 25 ppm</b>	81.17 d	3.30 c	75.38 cd	11.650 cd	28.533 b	
<b>BA 50 ppm</b>	81.17 d	3.77 b	74.48 cd	11.322 de	26.467 c	
<b>BA 100 ppm</b>	77.67 e	3.90 ab	74.12 d	11.200 e	26.533 c	
<b>Planting date X soaking in growth regulators of seed cloves</b>						
<b>September 20</b>	Control	65.00 h	4.2 a	66.15 f	10.867 fg	24.767 h
	GA <sub>3</sub> 50 ppm	88.67 c	3.27 ef	77.60 cd	12.400 bc	30.100 c
	GA <sub>3</sub> 100 ppm	94.67 b	2.73 g	86.84 a	13.533 a	34.200 a
	GA <sub>3</sub> 200 ppm	82.00 de	3.53 cdef	83.21 b	12.867 b	28.033 de
	BA 25 ppm	78.67 f	3.40 def	77.39 cd	12.100 cd	29.467 cd
	BA 50 ppm	78.33 f	3.87 abcd	76.66 cd	11.767 de	27.467 ef
	BA 100 ppm	75.33 g	4.00 abc	76.30 cd	11.667 de	27.267 efg
<b>October 15</b>	Control	77.67 fg	4.07 ab	70.46 e	10.200 h	23.100 i
	GA <sub>3</sub> 50 ppm	93.67 b	3.40 def	76.240 cd	11.433 def	28.033 de
	GA <sub>3</sub> 100 ppm	99.33 a	2.53 g	85.810 ab	12.533 bc	31.800 b
	GA <sub>3</sub> 200 ppm	87.00 c	3.27 ef	77.843 c	11.933 cd	25.633 gh
	BA 25 ppm	83.67 d	3.20 f	73.363 de	11.200 efg	27.600 ef
	BA 50 ppm	84.00 d	3.67 bcdef	72.303 e	10.877 fg	25.467 gh
	BA 100 ppm	80.00 ef	3.80 abcde	71.940 e	10.733 g	25.800 fgh

Means that have the same letter(s) within the same column are not significantly different at  $P \leq 0.05$  according to Duncan's multiple range test.

**TABLE 3. Effect of different planting dates and seed clove soaking in gibberellic acid (GA<sub>3</sub>) and benzyl adenine (BA) on garlic vegetative growth in the 2022-23 season.**

Treatments	Sprouting percent	Sprouting rate	Shoot length	Leaf number	Plant dry weight	
<b>Planting date of seed cloves</b>						
<b>September 20</b>	82.33 b	<b>3.57 a</b>	79.11 a	12.39 a	28.55 a	
<b>October 15</b>	88.22a	3.37 b	74.61 b	11.53 b	26.88 b	
<b>Cloves soaking in growth regulators</b>						
<b>Control</b>	73.12 f	<b>4.12 a</b>	68.92 e	10.85 e	24.47 d	
<b>GA<sub>3</sub> 50 ppm</b>	92.75 b	3.32 c	78.45 c	12.08 c	28.82 b	
<b>GA<sub>3</sub> 100 ppm</b>	98.02 a	2.90 d	84.78 a	13.17 a	32.14 a	
<b>GA<sub>3</sub> 200 ppm</b>	87.32 c	3.37 c	80.62 b	12.62 b	26.93 c	
<b>BA 25 ppm</b>	83.42 d	3.28 c	75.83 d	11.95 c	28.36 b	
<b>BA 50 ppm</b>	83.10 d	3.58 b	74.87 d	11.60 d	26.62 c	
<b>BA 100 ppm</b>	79.22 e	3.70 b	74.55 d	11.47 d	26.67 c	
<b>Planting date X soaking in growth regulators of seed cloves</b>						
<b>September 20</b>	Control	66.70 h	4.13 a	67.63 g	11.20 h	25.18 h
	GA <sub>3</sub> 50 ppm	90.27 d	3.40 bcd	81.87 bc	12.53 bcd	29.69 c
	GA <sub>3</sub> 100 ppm	97.03 b	3.00 d	87.50 a	13.63 a	33.16 a
	GA <sub>3</sub> 200 ppm	85.23 e	3.47 bcd	83.47 b	13.03 b	27.94 de
	BA 25 ppm	80.37 f	3.40 bcd	78.57 cd	12.43 cd	29.15 cd
	BA 50 ppm	79.83 f	3.77 ab	77.37 d	12.03 def	27.46 ef
	BA 100 ppm	76.90 g	3.80ab	77.37 d	11.87 efg	27.29 efg
<b>October 15</b>	Control	79.53 f	4.10 a	70.20 fg	10.50 i	23.77 i
	GA <sub>3</sub> 50 ppm	95.23 c	3.23 cd	75.03 de	11.63 fgh	27.94 de
	GA <sub>3</sub> 100 ppm	99.00 a	2.80 e	82.07 bc	12.70 bc	31.13 b
	GA <sub>3</sub> 200 ppm	89.40 d	3.27 cd	77.77 d	12.20 cde	25.91 gh
	BA 25 ppm	86.47 e	3.17 cd	73.10 ef	11.47 gh	27.58 ef
	BA 50 ppm	86.37 e	3.40 bcd	72.37 ef	11.17 h	25.77 gh
	BA 100 ppm	81.53 f	3.60 bc	71.73 ef	11.07 h	26.05 fgh

Means that have the same letter(s) within the same column are not significantly different at  $P \leq 0.05$  according to Duncan's multiple range test.



TABLE 4. Effect of different planting dates and seed clove soaking in gibberellic acid (GA<sub>3</sub>) and benzyl adenine (BA) on garlic bulb characteristics and yield in the 2021-22 season.

Treatments	Bulb diameter	Bulb fresh weight	Bulb yield per plot	Bulb yield per feddan	
<b>Planting date of seed cloves</b>					
<b>September 20</b>	5.45 a	87.23 a	45.80 b	11.82 b	
<b>October 15</b>	4.91 b	81.16 b	48.09 a	12.41 a	
<b>Cloves soaking in growth regulators</b>					
<b>Control</b>	4.35 d	69.81 d	41.28 g	10.65 g	
<b>GA<sub>3</sub> 50 ppm</b>	5.41 b	84.96 c	49.68 b	12.82 b	
<b>GA<sub>3</sub> 100 ppm</b>	6.32 a	92.10 a	51.43 a	13.27 a	
<b>GA<sub>3</sub> 200 ppm</b>	5.20 b	90.27 b	47.56 c	12.27 c	
<b>BA 25 ppm</b>	5.09 b	84.30 c	47.11 d	12.15 d	
<b>BA 50 ppm</b>	5.13 b	83.98 c	46.37 e	11.96 e	
<b>BA 100 ppm</b>	4.76 c	83.95 c	45.19 f	11.66 f	
<b>Planting date X soaking in growth regulators of seed cloves</b>					
<b>September 20</b>	Control	4.52 fgh	71.7 d	37.26 i	9.61 i
	GA <sub>3</sub> 50 ppm	5.66 bc	88.07 b	48.86 c	12.60 c
	GA <sub>3</sub> 100 ppm	6.61 a	95.78 a	51.10 b	13.18 b
	GA <sub>3</sub> 200 ppm	5.45 cd	93.82 a	47.18 de	12.17 de
	BA 25 ppm	5.41 cd	87.29 b	46.62 e	12.03 e
	BA 50 ppm	5.31 cde	87.01 b	45.18 g	11.66 g
	BA 100 ppm	5.20 cde	86.98 b	44.42 h	11.46 h
<b>October 15</b>	Control	4.19 h	67.93 e	45.30 g	11.69 g
	GA <sub>3</sub> 50 ppm	5.16 cde	81.86 c	50.50 b	13.03 b
	GA <sub>3</sub> 100 ppm	6.03 b	88.41 b	51.75 a	13.35 a
	GA <sub>3</sub> 200 ppm	4.95 def	86.73 b	47.94 d	12.37 d
	BA 25 ppm	4.76 efg	81.31 c	47.60 d	12.28 d
	BA 50 ppm	4.95 def	80.96 c	47.56 d	12.27 d
	BA 100 ppm	4.31 gh	80.93 c	45.96 f	11.86 f

Means that have the same letter(s) within the same column are not significantly different at  $P \leq 0.05$  according to Duncan's multiple range test.

**TABLE 5. Effect of different planting dates and seed clove soaking in gibberellic acid (GA<sub>3</sub>) and benzyl adenine (BA) on garlic bulb characteristics and yield in the 2022-23 season.**

Treatments	Bulb diameter	Bulb fresh weight	Bulb yield per plot	Bulb yield per feddan	
<b>Planting date of seed cloves</b>					
<b>September 20</b>	5.35 a	86.70 a	48.70 b	12.6 b	
<b>October 15</b>	4.90 b	80.99 b	52.33 a	13.5 a	
<b>Cloves soaking in growth regulators</b>					
<b>Control</b>	4.44 d	70.32 d	41.51 g	10.73 g	
<b>GA<sub>3</sub> 50 ppm</b>	5.32 b	84.57 c	54.86 b	14.2 b	
<b>GA<sub>3</sub> 100 ppm</b>	6.08 a	91.27 a	57.63 a	14.9 a	
<b>GA<sub>3</sub> 200 ppm</b>	5.15 b	89.55 b	51.49 c	13.3 c	
<b>BA 25 ppm</b>	5.05 b	83.94 c	50.77 d	13.1 d	
<b>BA 50 ppm</b>	5.09 b	83.64 c	49.61 e	12.8 e	
<b>BA 100 ppm</b>	4.78 c	83.62 c	47.73 f	12.3 f	
<b>Planting date X soaking in growth regulators of seed cloves</b>					
<b>September 20</b>	Control	4.57 fgh	72.09 d	35.13 i	9.1 i
	GA <sub>3</sub> 50 ppm	5.53 bc	87.49 b	53.55 c	13.8 c
	GA <sub>3</sub> 100 ppm	6.32 a	94.73 a	57.11 b	14.8 b
	GA <sub>3</sub> 200 ppm	5.36 cd	92.88 a	50.90 de	13.2 de
	BA 25 ppm	5.32 cd	86.75 b	49.99 e	12.9 e
	BA 50 ppm	5.24 cde	86.48 b	47.72 g	12.3 g
	BA 100 ppm	5.15 cde	86.46 b	46.51 h	12.0 h
<b>October 15</b>	Control	4.31 h	68.55 e	47.89 g	12.4 g
	GA <sub>3</sub> 50 ppm	5.11 cde	81.65 c	56.16 b	14.5 b
	GA <sub>3</sub> 100 ppm	5.83 b	87.80 b	58.15 a	15.0 a
	GA <sub>3</sub> 200 ppm	4.94 def	86.22 b	52.09 d	13.6 d
	BA 25 ppm	4.78 efg	81.13 c	51.55 d	13.3 d
	BA 50 ppm	4.94 def	80.80 c	51.49 d	13.3 d
	BA 100 ppm	4.41 gh	80.77 c	48.95 f	12.7 f

Means that have the same letter(s) within the same column are not significantly different at  $P \leq 0.05$  according to Duncan's multiple range test.

TABLE 6. Effect of different planting dates and seed clove soaking in gibberellic acid (GA<sub>3</sub>) and benzyl adenine (BA) on garlic leaf chlorophyll and NPK content in the 2021-22 season.

Treatments	Leaf chlorophyll content	Leaf N content	Leaf P content	Leaf K content	
<b>Planting date of seed cloves</b>					
<b>September 20</b>	47.86 b	1.464 a	0.730 b	2.434 b	
<b>October 15</b>	48.85 a	1.469 a	0.741 a	2.444 a	
<b>Cloves soaking in growth regulators</b>					
<b>Control</b>	47.23 b	1.440 e	0.721 b	2.387 b	
<b>GA<sub>3</sub> 50 ppm</b>	48.97 a	1.472 bc	0.739 a	2.450 a	
<b>GA<sub>3</sub> 100 ppm</b>	49.40 a	1.490 a	0.743 a	2.463 a	
<b>GA<sub>3</sub> 200 ppm</b>	48.00 b	1.472 bc	0.735 a	2.430 a	
<b>BA 25 ppm</b>	48.85 a	1.477 b	0.739 a	2.453 a	
<b>BA 50 ppm</b>	48.12 b	1.460 d	0.737 a	2.448 a	
<b>BA 100 ppm</b>	47.92 b	1.456 d	0.735 a	2.442 a	
<b>Planting date X soaking in growth regulators of seed cloves</b>					
<b>September 20</b>	Control	46.15 d	1.420 e	0.699 b	2.334 b
	GA <sub>3</sub> 50 ppm	48.31 abc	1.473 bc	0.736 a	2.453 a
	GA <sub>3</sub> 100 ppm	49.37 ab	1.500 a	0.743 a	2.460 a
	GA <sub>3</sub> 200 ppm	47.90 bc	1.477 bc	0.732 a	2.447 a
	BA 25 ppm	48.33 abc	1.477 bc	0.737 a	2.453 a
	BA 50 ppm	47.60 c	1.450 d	0.733 a	2.450 a
	BA 100 ppm	47.36 c	1.453 cd	0.731 a	2.440 a
<b>October 15</b>	Control	48.31 abc	1.460 bcd	0.743 a	2.437 a
	GA <sub>3</sub> 50 ppm	49.62 a	1.470 bcd	0.744 a	2.447 a
	GA <sub>3</sub> 100 ppm	49.42 ab	1.480 b	0.743 a	2.467 a
	GA <sub>3</sub> 200 ppm	48.10 abc	1.467 bcd	0.738 a	2.413 a
	BA 25 ppm	49.36 ab	1.477 bc	0.743 a	2.453 a
	BA 50 ppm	48.63 abc	1.463 bcd	0.742 a	2.447 a
	BA 100 ppm	48.48 abc	1.467 bcd	0.739 a	2.443 a

Means that have the same letter(s) within the same column are not significantly different at  $P \leq 0.05$  according to Duncan's multiple range test.

**TABLE 7. Effect of different planting dates and seed clove soaking in gibberellic acid (GA<sub>3</sub>) and benzyl adenine (BA) on garlic leaf chlorophyll and NPK content in the 2022-23 season.**

Treatments	Leaf chlorophyll content	Leaf N content	Leaf P content	Leaf K content	
<b>Planting date of seed cloves</b>					
<b>September 20</b>	48.52 b	1.494 a	0.750 b	2.523 b	
<b>October 15</b>	49.46 a	1.497 a	0.755 a	2.530 a	
<b>Cloves soaking in growth regulators</b>					
<b>Control</b>	47.92 b	1.480 d	0.746 b	2.486 b	
<b>GA<sub>3</sub> 50 ppm</b>	49.58 a	1.498 b	0.754 a	2.535 a	
<b>GA<sub>3</sub> 100 ppm</b>	49.99 a	1.510 a	0.756 a	2.545 a	
<b>GA<sub>3</sub> 200 ppm</b>	48.66 b	1.498 b	0.752 a	2.520 a	
<b>BA 25 ppm</b>	49.46 a	1.500 b	0.754 a	2.538 a	
<b>BA 50 ppm</b>	48.77 b	1.490 c	0.753 a	2.534 a	
<b>BA 100 ppm</b>	48.58 b	1.493 bc	0.752 a	2.529 a	
<b>Planting date X soaking in growth regulators of seed cloves</b>					
	Control	46.89 d	1.467 e	0.735 b	2.447 b
	GA <sub>3</sub> 50 ppm	48.95 abc	1.500 bc	0.753 a	2.538 a
	GA <sub>3</sub> 100 ppm	49.96 ab	1.517 a	0.7561 a	2.543 a
<b>September 20</b>	GA <sub>3</sub> 200 ppm	48.56 bc	1.500 bc	0.751 a	2.532 a
	BA 25 ppm	48.97 abc	1.500 bc	0.753 a	2.537 a
	BA 50 ppm	48.28 c	1.487 d	0.751 a	2.535 a
	BA 100 ppm	48.04 c	1.490 cd	0.750 a	2.527 a
	Control	48.95 abc	1.493 bcd	0.756 a	2.525 a
	GA <sub>3</sub> 50 ppm	50.20 a	1.497 bcd	0.756 a	2.532 a
	GA <sub>3</sub> 100 ppm	50.01 ab	1.503 b	0.756 a	2.548 a
<b>October 15</b>	GA <sub>3</sub> 200 ppm	48.75 abc	1.497 bcd	0.754 a	2.507 a
	BA 25 ppm	49.95 ab	1.500 bc	0.756 a	2.538 a
	BA 50 ppm	49.26 abc	1.493 bcd	0.755 a	2.532 a
	BA 100 ppm	49.11 abc	1.497 bcd	0.754 a	2.530 a

Means that have the same letter(s) within the same column are not significantly different at  $P \leq 0.05$  according to Duncan's multiple range test.

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## يحسن حمض الجبريليك والبنزويل أدنين من إنبات فصوص ثوم ويعززان من نمو النباتات وإنتاجيتها في الظروف غير المواتية

نشوة عطية إبراهيم أبو العزم

جامعة عين شمس - كلية الزراعة - قسم البساتين - القاهرة، ١١٥٦٦ - مصر.

يواجه إنتاج الثوم في مصر تحدي ارتفاع درجات الحرارة خلال المواعيد المعتادة للزراعة، مما يتسبب في تأخر وعدم انتظام إنبات فصوص الثوم بعد زراعتها وبالتالي، يهدف هذا البحث إلى تحسين إنبات فصوص الثوم بعد زراعتها تحت الظروف غير المواتية من خلال نقعها في محلول حمض الجبريليك أو البنزويل أدنين قبل زراعتها في مواعيد مختلفين حيث أجريت تجربتان في الموسمين المتعاقبين ٢٠٢١-٢٠٢٢ و ٢٠٢٢-٢٠٢٣ بمزرعة قسم البساتين، كلية الزراعة، جامعة عين شمس، محافظة القليوبية، مصر لتقييم تأثير نقع فصوص ثوم في محاليل ٥٠ و ١٠٠ و ٢٠٠ جزء في المليون من حمض الجبريليك و ٢٥ و ٥٠ و ١٠٠ جزء في المليون من البنزويل أدنين لمدة ٢٤ ساعة قبل زراعتها في مواعيد ٢٠ سبتمبر و ١٥ أكتوبر على إنبات الفصوص وخصائص نمو النباتات وصفات الأصيل والمحصول بالإضافة إلى محتوى الأوراق من الكلوروفيل والنيتروجين والفسفور والبوتاسيوم. أشارت النتائج المتحصل عليها أن زراعة فصوص الثوم في الميعاد الثاني ١٥ أكتوبر كانت أفضل من زراعتها في الميعاد الأول ٢٠ سبتمبر من حيث تحسين نسبة ومعدل إنبات الفصوص وذلك بسبب الظروف الجوية المناسبة (درجة الحرارة) في شهر أكتوبر مقارنة بشهر سبتمبر، وفي الوقت نفسه أتاحت الزراعة في شهر سبتمبر زيادة طول النباتات، وزيادة عدد الأوراق قبل بداية تكون البصلة وزيادة الوزن الجاف للنبات وتحسين جودة البصلة من حيث القطر والوزن ومع ذلك فإن محصول الأصيل لكل قطعة تجريبية وكذلك للفدان كانت أعلى في زراعة شهر أكتوبر ويعزى ذلك إلى زيادة الكثافة النباتية الناتجة من زيادة نسبة إنبات الفصوص وقد زادت مستويات الكلوروفيل والفسفور والبوتاسيوم في الأوراق عند زراعة الفصوص في أكتوبر، لكن محتوى النيتروجين لم يظهر أى اختلافات معنوية بين مواعيد الزراعة. وقد أدى نقع الفصوص في محاليل حمض الجبريليك والبنزويل أدنين إلى زيادة إنبات الفصوص وخصائص نمو النبات وصفات الأصيل وكمية المحصول، بالإضافة إلى زيادة محتوى الأوراق من الكلوروفيل والنيتروجين والفسفور والبوتاسيوم مقارنة بمعاملة المقارنة وقد لوحظ أن نقع الفصوص قبل زراعتها في محلول حمض الجبريليك كان أكثر فاعلية من النقع في محلول البنزويل أدنين وأن محلول حمض الجبريليك بتركيز ١٠٠ جزء في المليون هو الأكثر فاعلية في تحسين إنبات الفصوص وتعزيز جميع معايير نمو النبات ومحصول وجودة الأصيل، بالإضافة إلى المكونات الكيميائية للأوراق وذلك في كلا مواعدي الزراعة خلال شهري سبتمبر وأكتوبر

وتشير نتائج هذه الدراسة أنه يمكن تحسين إنتاج الثوم، وخاصة في ظروف الإنتاج غير المواتية من خلال الزراعة خلال شهر أكتوبر مع نقع فصوص الثوم في محلول حمض الجبريليك بتركيز ١٠٠ جزء في المليون.

**الكلمات الدالة:** الثوم، الفصوص، الإنبات، حمض الجبريليك، البنزويل أدنين، نمو النبات، محصول الأصيل، ظروف النمو غير المواتية.