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Improving Seed Productivity of Garlic By Using Nitrogen, Potassium Fertilization and Some Growth Regulators

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ABSTRACT

Two field experiments were conducted under Egyptian conditions at Kaha Vegetables Research Farm, Horticulture Research Institute, Agriculture Research Centre to study the effect of the high nitrogen and potassium levels and two growth regulators, Cytokinin at 2.5 ppm and Gibberellic Acid (GA₃) at 100 ppm on the growth and seed yield of garlic (*Allium sativum* L.) cv. Sids 40. The obtained results showed that increasing nitrogen and potassium fertilizer up to 150 % NK. of the recommended rate (120 kg N + 72 kg K₂O fed⁻¹), significantly improved most studied growth traits (plant length, number of leaves, leaf area, total fresh weight, total plant dry weight), bulb characters, chemical constituents, yield, and yield components. Moreover, 150 % NK combined with GA₃ + CPPU foliar spraying resulted in the highest average bulb weight, average glove weight and bulb. The obtained results confirm that garlic seed yield could be improve by N, K nutrition and foliar application of GA₃ and CPPU.

Keywords: Garlic seed, Nitrogen, Potassium, Gibberellic Acid, Cytokinin, Yield, Bulb yield, Bulb quality.

INTRODUCTION

Garlic (*Allium sativum* L.) is a valuable cash crop in Egypt. With an average yield of 280,216 metric tons from an estimated region of 11,875 hectares, Egypt ranks fourth in the world in garlic production, behind China, India, and Bangladesh (Atlasbig, 2020). Egyptian garlic is exported to Arab, African, Eastern and Western European countries. The exported amount is about 35,000 tons, a large part of this amount is green garlic (immature bulbs). The quality of garlic seeds plays a vital role in increasing the quantity and quality of garlic bulbs yield. The high-quality seeds are characterized by large and healthy cloves collected from large size bulbs. Meanwhile, garlic growers use some of the mature bulbs of garlic as seeds for the upcoming season. However, when harvesting green garlic, the growers collect large immature plants in February to obtain large bulbs to fulfill the green garlic exporting requirements while leaving small-sized plants to complete their maturity. With the increase in the exported quantities of green garlic, Egyptian farmers will not find good seeds for planting their fields, except the small bulbs, which will produce low yields.

Nutrients play an essential role in garlic growth and development. Both nitrogen and potassium are among the most responsive nutrients in plant development and production, contributing to increasing the productivity and quality of the bulbs. Several works in literature reported that the growth and yield of garlic plants were improved by the addition of high levels of nitrogen and potassium. In this respect, absorption of adequate nutrients is essential to improve garlic growth, productivity, marketable yield and quality (Nai-hua *et al.*, 1998). Moreover, Mahmoud (1999) stated that bulb height, diameter, and weight were increased with an increasing level of K application up to

300 kg potassium sulfate/feddan. Also, a rate of 200 kg N ha⁻¹ and 200 kg K₂O ha⁻¹ gave the maximum plant height, number of green leaves/plants, number of cloves/bulb, fresh weight of individual bulb and maximum yield of garlic (Shamim and Rahim, 2018; Rad and Alam 2019; Jiku *et al.*, 2020).

Growth regulators like gibberellins and Cytokinin improved the chive (*Allium fistulosum* L) plant height, dry matter accumulation, bulb yield and its quality (Morales-Payan, 1994). Many studies have suggested that the application of GA₃ can affect the growth and development of bulb crops and total yield (Rizk and El-Habbasha, 1996; Abdul *et al.*, 2002; Islam *et al.*, 2007; El-Shraiy and Hegazi, 2009). Gibberellins and Cytokinin have a particularly interesting role in modern agriculture (Ashraf *et al.*, 2010). Also, GA₃ supply promoted increasing onion and garlic growth and yield (Ouzounidou *et al.*, 2011). Moreover, Liu *et al.* (2020) indicated that soaking garlic seed cloves in GA₃ promotes axillary bud formation.

There is a lake in literature dealing with factors affecting garlic seed production, especially under Egyptian conditions. Furthermore, with the increasing export demand for Egyptian green garlic, there is an urgent need to devote studies on garlic seed production. This work was intended to study the role of nitrogen and potassium fertilization and growth regulators (Gibberellin and Cytokinin) on the production of large garlic bulbs as a source of high-quality seeds.

MATERIALS AND METHODS

Site description and soil type:

During the two winter seasons of 2017/2018 and 2018/2019, field experiments were carried out on clay loam soil (Table, 1) at the Kaha Vegetables Research Farm, Horticulture Research Institute, Agricultural

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Research Center (ARC) in Egypt to study the effect of nitrogen and potassium levels and foliar spray of growth regulators, *i.e.*, 100 ppm GA₃ (Gibberellic acid) and (Forchlorfenuron “CPPU”, [N-(2-chloro-4-pyridyl)-N'-phenylurea]) a synthetic Cytokinin at 2.5 ppm on garlic (*Allium sativum* L.) cv. Sids 40 vegetative growth, bulb,

yield and its components as well as chemical constituents. The site is located at an altitude of 21.1 m above sea level, latitude 30°16' N and longitude 31°12' E. The chemical and physical properties of the experimental field are shown in Table 1. The soil is clay loam in texture.

Table 1. The physical and chemical properties of the soil

Physical properties	2017/18	2018/19	Chemical properties	2017/18	2018/19
Clay %	60.25	61.12	N (ppm)	94.20	88.70
Silt %	19.50	19.85	P (ppm)	5.60	5.20
Total sand %	20.25	19.03	K (ppm)	210.3	213.5
Texture	Clay loam		pH	7.58	7.64

Experimental design

The experiment included three levels of nitrogen and potassium fertilization, *i.e.*, 100 %, 125 % and 150 % N.K. of the recommended rates (120 kg N + 72 kg K₂O fed⁻¹), which was combined with four growth regulators treatments [Control (without), 100 ppm GA₃, 2.5 ppm Cytokinin and 100 ppm GA₃ + 2.5 ppm Cytokinin].

The design of the experiment was a split-plot design with three replicates, where mineral fertilizers were distributed in the main plots and the growth regulator treatments were allocated in subplots. Each experimental plot included 4 ridges, 4.5 m in length and 0.7 m in width, with a 12.60 m² area. Four ridges were planted, and the fifth one was left without planting as a guard ridge between each two plots. All data collected were subjected to analysis of variance (ANOVA) to test treatment effects for significance using Statistix 10 software package 2013. The differences among means for all traits were tested for effectiveness by least significant difference (LSD) at a 5 % level of probability, according to Waller and Duncan (1969).

Planting technique and treatments application

Garlic seeds-cloves were planted on 1st October and 4th October in the first and second seasons, respectively. Cloves were manually planted at 10 cm apart between cloves on both sides of ridges. All the treatments were fertilized with the common agricultural rates of 75 kg P₂O₅/fed. (Superphosphate 15.5% P₂O₅) was added once before planting during soil preparation. While, nitrogen (ammonium nitrate, 33.5% N) and potassium (Potassium sulphate, 48% K₂O) were applied in three levels as 100% NK (120 kg N + 72 kg K₂O fed⁻¹, control), 125% NK (150 kg N + 90 kg K₂O fed⁻¹) and 150% NK (180 kg N + 108 kg K₂O fed⁻¹) of the recommended rates where, the source of nitrogen was ammonium sulphate (20.5%) only at the 1st addition before planting and then was ammonium nitrate (33.5 %) repeated each one month for 3 times, *i.e.*, 30, 60 and 90 days after planting. Potassium sulphate (48% K₂O) was applied with nitrogen applications at the four times. Horticultural practices that were common applied in garlic management were followed. On the other hand, 100 ppm GA₃ and 2.5 ppm CPPU were applied as foliar spraying at 30, 45 and 60 days after planting.

Data recorded

A- Vegetative growth characters: Ten plants were randomly chosen 20 weeks after planting from each subplot for the determination of vegetative growth characteristics:

- Plant length (cm): 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 number of leaves calculated as the average number of green leaves per plant.
- Leaves area (cm²): It was determined by cutting out 20 leaf discs from each plant using a cork borer and dried them in an oven at 75 °C (until constant weight). The rest of the leaves were similarly dried. Based on the known dry weight of a known surface area of leaves, *i.e.*, leaf discs, and the total weight of leaves, leaves surface area was determined.
- Total fresh weight of plant foliage (g): It was determined as the average weight of plant after removing bulbs at the neck zone.
- Total plant dry weight (g).

B- Bulb characters: Number of cloves / bulb, neck diameter (cm) and bulb diameter (cm), as well as, bulbing ratio: It was counted as the ratio of the greatest diameter of bulb / the minimum neck diameter).

C- Chemical constituents: Total chlorophyll: chlorophyll was determined in representative samples of leaves as mg/g fresh weight spectrophotometrically, according to the method of Jeffrey and Humphrey (1975). Total nitrogen, phosphorus and potassium were determined according to the methods described by Bremner and Mulvaney (1982), Olsen and Sommers (1982), Jackson (1973), respectively. Total carbohydrates were determined using the method of Ikanone and Oyekan (2014).

D: Yield and its components:

- Bulb characters: Sample was taken at harvest (26 weeks after planting) to record average bulb weight (g), average clove weight (g), average bulb height (cm) and diameter (cm).
- Total yield (ton/fed.). At harvest plants of each experimental plot were harvested, weighed, and the total yield of whole plants (ton/fed.) was calculated.
- Bulbs were classified after curing into three size classes, small bulbs (0-4 mm), medium bulbs (4-8 mm) and large bulbs (over 8 mm).

RESULTS AND DISCUSSIONS

Results

A- Vegetative growth characteristics.

Effect of N and K₂O rates.

Data in Table 2. show that the growth characteristics studied (plant length, the number of leaves,

leaf area, whole plant foliage, and dry weight of plant) increased with increasing rate of fertilizers. However, these increases did not reach the degree of significance in the number of leaves/plants. The maximum NK fertilizer levels (150 % NK-rate of the recommended rate per feddan) resulted in the highest values in this respect, followed by the medium level, *i.e.*, 125 % NK-rate of the recommended dose.

Effect of GA₃ and Cytokinin.

The data in the same Table indicate that the length of the plant, number of leaves/plant and leaf area, as well as dry

weight of plant, were substantially affected by the spraying of garlic plants with 100 ppm GA₃, 2.5 ppm CPPU and their mixture during the growing season comparing with the control treatment. Spraying plants with 100 ppm GA₃ + 2.5 ppm cytokinin revealed the highest value in all measured growth aspects, followed by using Cytokinin alone compared to the GA₃ and the control treatments. The GA₃ application recorded the highest values in plant length during both seasons compared with other treatments.

Table 2. Effect of nitrogen and potassium rates and plant growth regulators on vegetative growth characteristics of garlic, after 20 weeks from planting.

NK-rate of the recommended rate (Kg/fed.)	Plant growth regulators	Plant height (cm)		No. of leave /plant		Leaf area (cm ²)		Whole plant FW (g)		Plant dry weight (g)	
		Season		Season		Season		Season		Season	
		1	2	1	2	1	2	1	2	1	2
100% (120 N, 72 K)		72.42	70.67	7.75	7.50	426.8	418.8	114.5	113.9	24.91	23.42
125% (150 N, 90 K)		88.82	81.81	7.89	7.54	526.4	533.0	128.3	123.7	28.87	25.91
150% (180 N, 108 K)		94.12	85.88	8.14	7.82	561.2	552.3	140.1	136.3	31.45	28.42
L.S.D. at 0.05 level		2.98	2.00	N.S	N.S	9.03	6.24	3.24	1.76	0.28	0.92
	Control (without)	81.00	74.33	7.22	7.33	458.6	455.3	113.5	111.6	24.94	22.59
	GA ₃ at 100 ppm	89.69	85.69	7.93	7.49	519.1	510.4	124.5	119.5	27.37	24.76
	Cytokinin at 2.5 ppm	83.00	77.11	8.22	7.78	500.2	503.8	123.5	122.2	27.37	25.18
	GA ₃ + Cytokinin	86.78	80.67	8.33	7.89	541.3	535.9	148.9	145.3	33.94	30.87
L.S.D. at 0.05 level		1.45	1.44	0.54	0.51	9.21	8.75	2.34	2.15	0.74	0.70

Effect of the interaction.

The interaction effect between combining different fertilizers (N + K₂O) with GA₃, Cytokinin, and GA₃+cytokinin increased growth characters during both seasons (Table 3). The interaction effect between combining different fertilizers (N + K₂O) with GA₃, Cytokinin, and GA₃+cytokinin was significant increase on growth characters during both seasons (Table 3) In this regard, the highest values of the number of leaves per plant

(8.67 and 8.33), leaf area (603 and 582 cm²), the whole plant FW (170.3 and 167.8 g), and dry weight of the plant (39.03 and 35.74 g) were observed in the first and second seasons, respectively, when the optimum rate of nitrogen and potassium fertilizers (180 kg N + 108 kg K₂O / fed) was combined with 100 ppm GA₃ + 2.5 ppm cytokinin. On the other hand, there was steadily increased with increasing fertilizer levels combined with GA₃ at a concentration of just 25 ppm.

Table 3. Effect of the interaction between nitrogen and potassium rates and plant growth regulators on vegetative growth characteristics of garlic, after 20 weeks from planting.

NK-rate of the recommended rate (Kg/fed.)	Plant growth regulators	Plant height (cm)		No. of leave /plant		Leaf area (cm ²)		Whole plant F. W. (g)		Plant dry weight	
		Season		Season		Season		Season		Season	
		1	2	1	2	1	2	1	2	1	2
100% (120 N, 72 K)	Control (without)	71.00	67.33	7.00	7.33	408.3	381.3	105.2	104.4	22.91	20.74
	GA ₃ at 100 ppm	76.00	74.00	7.67	7.33	430.0	424.7	112.1	112.0	24.15	22.59
	Cytokinin at 2.5 ppm	70.67	70.00	8.33	7.66	420.0	416.0	111.7	112.7	24.53	23.06
	GA ₃ + Cytokinin	72.00	71.33	8.00	7.67	449.0	453.0	129.0	126.7	28.04	26.50
125% (150 N, 90 K)	Control (without)	82.00	74.33	7.00	7.33	447.0	459.3	113.2	111.8	24.84	22.70
	GA ₃ at 100 ppm	94.94	91.56	7.89	7.17	558.7	552.0	127.2	119.9	28.46	25.51
	Cytokinin at 2.5 ppm	85.00	78.66	8.33	8.00	528.0	548.0	125.3	121.8	27.41	27.42
	GA ₃ + Cytokinin	93.30	82.67	8.33	7.67	572.0	572.7	147.3	141.4	34.75	30.38
150% (180 N, 108 K)	Control (without)	90.00	81.33	7.67	7.33	520.3	525.3	122.3	118.7	27.06	24.34
	GA ₃ at 100 ppm	98.10	91.50	8.24	7.96	568.7	554.6	134.2	126.7	29.56	26.18
	Cytokinin at 2.5 ppm	93.33	82.67	8.00	7.67	552.7	547.3	133.6	132.1	30.16	27.42
	GA ₃ + Cytokinin	95.00	88.00	8.67	8.33	603.0	582.0	170.3	167.8	39.03	35.74
L.S.D. at 0.05 level		2.37	2.34	0.89	0.83	15.04	14.30	3.82	3.51	1.21	1.15

B- Bulb characters.

Effect of N and K₂O rates.

Neck diameter, bulb diameter, bulb ratio, and the number of cloves /bulb were significantly increased due to the rise in the amounts of nitrogen and potassium from "120 kg N + 72 kg K₂O" to "180 kg N + 92 kg K₂O/fed" for neck and bulb diameter and up to "150 kg N + 82 kg K₂O" for Bulbing ratio (Table, 4) in both studied sessions.

On the other hand, the number of cloves per bulb was not significantly affected.

Effect of GA₃ and Cytokinin.

Growth regulators (GA₃ and CPPU) had a beneficial effect on neck diameter and the number of cloves per bulb during both seasons of the study compared with the control treatment. Spraying garlic plants with GA₃ at 100 ppm and CPPU at 2.5 ppm two times during the

growing season resulted in the maximum values in all bulb parameters tested. Furthermore, utilizing CPPU at 2.5 ppm ranked second in this regard. During both research seasons, comparable findings were obtained. In contrast to the other treatments, the control procedure provided the highest bulbing ratio values (Table 4).

Effect of the interaction.

Application of nitrogen and potassium as a combination fertilizer at the highest level (180 kg N + 92 kg K₂O/fed.) combined with spraying garlic plants with 100 ppm GA₃ mixed with 2.5 ppm CPPU showed the highest values of the neck and bulb diameter only, while using the highest fertilization rate without spraying plant growth regulators gave the highest value of the bulbing ratio (Table, 5).

Table 4. Effect of nitrogen and potassium rates and plant growth regulators on the bulb and its components of garlic.

NK-rate of the recommended rate (Kg/fed.)	Plant growth regulators	Neck diameter (cm)		Bulb diameter (cm)		Bulbing ratio		Number of cloves/bulb	
		Season		Season		Season		Season	
		1	2	1	2	1	2	1	2
100% (120 N, 72 K)		1.39	1.38	4.18	4.13	0.333	0.332	12.83	12.83
125% (150 N, 90 K)		1.56	1.53	5.77	5.65	0.270	0.272	13.00	12.70
150% (180 N, 108 K)		1.59	1.57	6.37	6.21	0.251	0.255	13.08	12.48
L.S.D. at 0.05 level		0.05	0.05	0.22	0.26	0.011	0.013	n.s	n.s
	Control (without)	1.42	1.44	4.93	4.92	0.292	0.296	12.56	12.00
	GA ₃ at 100 ppm	1.48	1.46	5.37	5.17	0.282	0.288	12.67	12.64
	Cytokinin at 2.5 ppm	1.52	1.49	5.50	5.43	0.284	0.281	13.11	13.00
	GA ₃ + Cytokinin	1.62	1.58	5.97	5.80	0.281	0.281	13.56	13.04
L.S.D. at 0.05 level		0.06	0.06	0.15	0.15	n.s	0.005	0.75	0.77

Table 5. Effect of the interaction between nitrogen and potassium rates and plant growth regulators on the bulb and garlic components.

NK-rate of the recommended rate (Kg/fed.)	Plant growth regulators	Neck diameter (cm)		Bulb diameter (cm)		Bulbing ratio		Number of cloves/bulb	
		Season		Season		Season		Season	
		1	2	1	2	1	2	1	2
100% (120 N, 72 K)	Control (without)	1.27	1.30	3.90	4.00	0.235	0.325	12.00	11.67
	GA ₃ at 100 ppm	1.40	1.37	4.20	4.07	0.334	0.336	12.33	12.33
	Cytokinin at 2.5 ppm	1.40	1.37	4.20	4.13	0.334	0.331	13.33	13.67
	GA ₃ + Cytokinin	1.50	1.47	4.43	4.33	0.339	0.338	13.67	13.67
125% (150 N, 90 K)	Control (without)	1.47	1.47	5.33	5.23	0.275	0.280	12.33	12.00
	GA ₃ at 100 ppm	1.49	1.46	5.66	5.48	0.264	0.266	13.00	12.13
	Cytokinin at 2.5 ppm	1.60	1.57	5.87	5.83	0.273	0.269	13.00	13.33
	GA ₃ + Cytokinin	1.67	1.63	6.23	6.03	0.268	0.271	13.67	13.33
150% (180 N, 108 K)	Control (without)	1.53	1.57	5.57	5.53	0.276	0.283	13.33	12.33
	GA ₃ at 100 ppm	1.54	1.55	6.24	5.95	0.249	0.261	12.67	13.47
	Cytokinin at 2.5 ppm	1.57	1.53	7.23	6.33	0.244	0.243	13.00	12.00
	GA ₃ + Cytokinin	1.70	1.63	7.33	7.03	0.236	0.232	13.33	12.13
L.S.D. at 0.05 level		0.09	0.98	0.25	0.25	0.22	0.011	1.46	1.33

C- Chemical constituents.

Effect of N and K₂O rates.

Nitrogen and potassium at different levels were enhanced chlorophyll formation in leaves, and increased nitrogen, potassium percentage and carbohydrates in bulbs compared with control treatment (Table, 6). Fertilized plants with 180 kg N + 92 kg K₂O/feddan recorded the

highest contents of chlorophyll (66.44 and 62.50), N % (3.62 and 3.18), K% (3.66 and 3.64) and bulbs carbohydrates (26.58 and 25.00) in the first and second seasons, respectively. On the other hand, the control treatment recorded the lowest values for all chemical constituents.

Table 6. Effect of nitrogen and potassium rates and plant growth regulators on garlic's chemical constituents.

NK-rate of the recommended rate (Kg/fed.)	Plant growth regulators	Total chlorophyll mg/g		Nitrogen %		Potassium %		Carbohydrates (g/100g d.w)	
		Season		Season		Season		Season	
		1	2	1	2	1	2	1	2
100% (120 N, 72 K)		45.24	40.08	1.45	1.63	2.86	2.84	22.62	20.04
125% (150 N, 90 K)		55.59	53.20	2.30	2.05	3.05	3.11	24.71	23.64
150% (180 N, 108 K)		66.44	62.50	3.62	3.18	3.66	3.64	26.58	25.00
L.S.D. at 0.05 level		1.93	1.43	0.017	0.034	0.016	0.106	0.75	0.48
	Control (without)	52.65	50.19	2.41	2.20	3.03	3.04	23.26	22.10
	GA ₃ at 100 ppm	55.58	51.17	2.44	2.29	3.17	3.17	24.60	22.55
	Cytokinin at 2.5 ppm	55.03	51.90	2.45	2.28	3.17	3.22	24.29	22.88
	GA ₃ + Cytokinin	59.77	54.45	2.53	2.37	3.38	3.37	26.39	24.05
L.S.D. at 0.05 level		1.19	1.06	0.012	0.021	0.018	0.076	0.56	0.48

Effect of GA₃ and Cytokinin.

All tested treatments of GA₃, CPPU and their combinations succeeded in increasing leaf chlorophyll, N, K and Carbohydrates contents in bulbs compared with control in both seasons (Table 6). Moreover, the highest total leaf chlorophyll (59.77 and 54.45), N content (2.53 and 2.37%), K content (3.38 and 3.37%) and carbohydrate (26.39 and 24.05 mg/100g) were recorded for the treatment

of 100 ppm GA₃ + 2.5 ppm CPPU sprayed on plant leaves twice during the growing seasons.

Effect of the interaction.

Garlic plants received 180 Kg N + 82 kg K₂O/fed. with a foliar spray of GA₃ at 100 ppm + CPPU at 2.5 ppm resulted in the highest total chlorophyll in plant leaves, as well as N, K and carbohydrates in the bulbs (Table, 7).

Table 7. Effect of the interaction between nitrogen and potassium rates and plant growth regulators on chemical constituents of garlic.

NK-rate of the recommended (rate Kg/fed.)	Plant growth regulators	Total chlorophyll mg/g		Nitrogen %		Potassium %		Carbohydrates (g/100g d.w)	
		Season		Season		Season		Season	
		1	2	1	2	1	2	1	2
100% (120 N, 72 K)	Control (without)	42.55	37.75	1.38	1.58	2.67	2.65	21.27	18.88
	GA ₃ at 100 ppm	46.36	38.77	1.43	1.63	2.87	2.85	23.18	19.38
	Cytokinin at 2.5 ppm	43.51	39.69	1.44	1.63	2.88	2.88	21.75	19.85
	GA ₃ + Cytokinin	48.55	44.10	1.54	1.67	3.01	3.00	24.27	22.05
125% (150 N, 90 K)	Control (without)	53.12	51.47	2.27	1.94	2.90	2.94	23.61	22.88
	GA ₃ at 100 ppm	55.41	53.56	2.30	2.06	3.00	3.06	24.63	23.80
	Cytokinin at 2.5 ppm	55.70	53.65	2.30	2.05	3.01	3.17	24.75	23.84
	GA ₃ + Cytokinin	58.14	54.11	2.34	2.16	3.28	3.29	25.84	24.05
150% (180 N, 108 K)	Control (without)	62.28	61.36	3.57	3.09	3.52	3.52	24.91	24.54
	GA ₃ at 100 ppm	64.97	61.18	3.60	3.18	3.64	3.61	25.99	24.47
	Cytokinin at 2.5 ppm	65.90	62.36	3.60	3.16	3.63	3.62	26.36	24.94
	GA ₃ + Cytokinin	72.61	65.13	3.72	3.28	3.85	3.83	29.04	26.05
L.S.D. at 0.05 level		2.07	1.84	0.02	0.04	0.03	0.13	0.98	0.84

D- Yield and its components**Effect of N and K₂O rates.**

Table 8. indicates that average bulb weight, average clove weight and total yield showed the highest values when plants were fertilized by with the third level of nitrogen and potassium (180 kg N + 92 kg K₂O/fed.). On the other hand, the lowest average bulb weight, average clove weight and total yield per fed. were resulted from the plants fertilized with the first used level of nitrogen combined with the first used level of potassium (120 kg N + 72 kg K₂O/fed.) during both seasons.

Data regarding the effect of fertilization rates of nitrogen and potassium on bulb size, are shown in Table 9. The medium (4-8 mm) and large size (over 8 mm) bulbs

percentage were obtained when plants were fertilized with the third level of nitrogen + the third level of potassium (180 kg N + 92 kg K₂O/fed.) in the two seasons.

Effect of GA₃ and Cytokinin.

The highest values of yield and its components were recorded under the combinations of GA₃ and CPPU foliar spray in both seasons (Table, 8). As well as, Spraying garlic plants with GA₃ at 100 ppm and CPPU at 2.5 ppm two times during the growth season significantly increased percentage of medium and large size bulbs, as compared to the other treatments (Table 9). Meanwhile, the highest percentage of small size (0-4 mm) bulbs were recorded in the control treatment.

Table 8. Effect of single effect of nitrogen and potassium rates and plant growth regulators on garlic's chemical constituents.

NK-rate of the recommended rate (Kg/fed.)	Plant growth regulators	Average bulb weight(g)		cloves weight /bulb (g)		Average clove weight (g)		Total yield kg/fed.	
		Season		Season		Season		Season	
		1	2	1	2	1	2	1	2
100% (120 N, 72 K)		74.38	72.73	73.36	71.70	5.72	5.59	8702	8509
125% (150 N, 90 K)		78.86	77.18	77.84	76.16	6.00	6.00	9306	9108
150% (180 N, 108 K)		93.43	83.12	92.41	82.10	7.09	6.64	11119	9891
L.S.D. at 0.05 level		1.75	1.15	1.75	1.15	0.47	0.61	202	131.6
	Control (without)	72.27	70.34	71.25	69.32	5.69	5.78	8532	8305
	GA ₃ at 100 ppm	82.08	78.31	81.07	77.29	6.41	6.16	9693	9244
	Cytokinin at 2.5 ppm	82.49	77.54	81.47	76.52	6.02	5.91	10871	9974
	GA ₃ + Cytokinin	92.06	84.50	91.04	83.48	6.96	6.47	9740	9153
L.S.D. at 0.05 level		2.04	1.66	2.04	1.66	0.37	0.37	240.00	195.08

Table 9. Effect of nitrogen and potassium rates and plant growth regulators on bulb size.

NK-rate of the recommended rate (Kg/fed.)	Plant growth regulators	Small size %		Medium size %		Large size %	
		Season		Season		Season	
		1	2	1	2	1	2
100% (120 N, 72 K)		23.5	22.5	62.0	60.0	14.5	17.5
125% (150 N, 90 K)		18.5	17.5	63.0	62.0	18.5	20.5
150% (180 N, 108 K)		8.5	9.5	66.3	65.0	25.3	25.5
L.S.D. at 0.05 level		1.46	0.76	0.93	0.76	0.77	1.00
	Control (without)	22.3	21.7	61.7	60.7	16.0	17.7
	GA ₃ at 100 ppm	18.0	17.3	63.3	62.3	18.7	20.3
	Cytokinin at 2.5 ppm	16.7	16.7	64.7	62.3	18.7	21.0
	GA ₃ + Cytokinin	10.3	10.3	65.3	64.0	24.3	25.7
L.S.D. at 0.05 level		0.82	0.68	0.74	0.60	1.37	1.12

Effect of the interaction.

Combining different rates of fertilizers (N + K₂O at 150 % of the recommended rate/fed.) with GA₃ + CPPU foliar spray achieved a significant increase in yield and its

components as compared to the different rates of fertilizers without plant growth regulators alone. These results were true in both seasons (Table, 10).

Table 10. Effect of the interaction between nitrogen and potassium rates and plant growth regulators on chemical constituents of garlic.

NK-rate of the recommended rate (Kg/fed.)	Plant growth regulators	Average bulb weight(g)		cloves weight /bulb (g)		Average clove weight (g)		Total yield kg/fed.	
		Season		Season		Season		Season	
		1	2	1	2	1	2	1	2
100% (120 N, 72 K)	Control (without)	65.37	63.87	64.35	62.85	5.39	5.40	7648	7472
	GA ₃ at 100 ppm	74.67	72.83	73.65	71.81	5.98	5.83	8736	8522
	Cytokinin at 2.5 ppm	76.13	74.80	75.12	73.77	5.50	5.41	9516	9290
	GA ₃ + Cytokinin	81.33	79.40	80.31	78.38	6.02	5.73	8908	8750
125% (150 N, 90 K)	Control (without)	74.03	71.33	73.01	70.31	5.93	5.86	8736	8417
	GA ₃ at 100 ppm	77.23	78.63	76.24	77.61	5.88	6.40	9116	9279
	Cytokinin at 2.5 ppm	77.00	74.33	75.98	73.31	5.56	5.50	10286	9963
	GA ₃ + Cytokinin	87.17	84.43	86.15	83.41	6.64	6.26	9086	8771
150% (180 N, 108 K)	Control (without)	77.40	75.83	76.38	74.81	5.76	6.08	9211	9024
	GA ₃ at 100 ppm	94.33	83.47	93.31	82.45	7.38	6.24	11226	9933
	Cytokinin at 2.5 ppm	94.33	83.50	93.31	82.48	7.00	6.82	12812	10670
	GA ₃ + Cytokinin	107.67	89.67	106.65	88.65	8.23	7.43	11226	9937
L.S.D. at 0.05 level		3.54	2.87	3.54	2.87	0.63	0.64	415.80	337.89

Data in Tables (11) showed that the large size percentage of bulbs was substantially affected by the spraying of garlic plants with 100 ppm GA₃, 2.5 ppm CPPU, and their mixture between them two times during

the growing season comparing with the control treatment. On the other hand, there was decreased in the large size percentage of bulbs under control in both seasons.

Table 11. Effect of the interaction between nitrogen and potassium rates and plant growth regulators on bulb size.

NK-rate of the recommended rate (Kg/fed.)	Plant growth regulators	Small size %		Medium size %		Large size %	
		Season		Season		Season	
		1	2	1	2	1	2
100% (120 N, 72 K)	Control (without)	30.0	27.0	60.0	57.0	10.0	16.0
	GA ₃ at 100 ppm	24.0	25.0	62.0	60.0	14.0	15.0
	Cytokinin at 2.5 ppm	24.0	23.0	62.0	61.0	14.0	16.0
	GA ₃ + Cytokinin	16.0	15.0	64.0	62.0	20.0	23.0
125% (150 N, 90 K)	Control (without)	25.0	25.0	60.0	58.0	15.0	17.0
	GA ₃ at 100 ppm	20.0	18.0	62.0	62.0	18.0	20.0
	Cytokinin at 2.5 ppm	18.0	16.0	66.0	63.0	16.0	21.0
	GA ₃ + Cytokinin	11.0	11.0	64.0	65.0	25.0	24.0
150% (180 N, 108 K)	Control (without)	12.0	13.0	65.0	67.0	23.0	20.0
	GA ₃ at 100 ppm	10.0	9.0	66.0	65.0	24.0	26.0
	Cytokinin at 2.5 ppm	8.0	11.0	66.0	63.0	26.0	26.0
	GA ₃ + Cytokinin	4.0	5.0	68.0	65.0	28.0	30.0
L.S.D. at 0.05 level		1.42	1.18	1.29	1.03	2.38	1.94

Discussions

The increase in the morphological parameters, chemical constituents of garlic plants with increased levels of nitrogen and potassium can be related to the beneficial effects of N on the stimulation of meristematic activity in the growth of more tissues and organs because N plays a significant role in the synthesis of structural proteins and other structural proteins. However, the potassium status of the soil available to plants significantly affects nitrogen absorption by crops. The obtained results agree with those recorded by Kaker *et al.* (2002); Kilgori *et al.* (2007) and El-Zohiri and Abdou (2009) who reported that all garlic growth traits were increased with increasing nitrogen application. Similarly, Arisha *et al.* (2017) and Rad and Alam (2019) suggested that the highest garlic plant growth, plant height and the maximum leaves number/plant, TSS, and potassium uptake were significantly enhanced due to the applications of higher levels of potassium fertilizer.

Similar results were also reported by El-Bassiony (2006) and Yadav *et al.* (2007) who reported that the application of nitrogen had a significant effect on the growth and yield of garlic, as well as the efficiency of nitrogen increases significantly in the presence of an adequate amount of potassium in garlic. In addition, Jiku *et al.* (2020) indicated that all the parameters, *i.e.*, plant height, number of leaves per plant, fresh and dry weights of leaves, fresh and dry weights of the bulb, bulb diameter, and number of cloves/bulbs significantly varied due to different doses of K application. Furthermore, the same authors indicated an increased total yield and size of garlic bulb was obtained with increasing potassium.

Higher endogenous phytohormones are beneficial for garlic bulbing (Atif *et al.*, 2020). The obtained improvement of vegetative growth traits after spraying with gibberellin may be due to its role in increasing cell division and elongation or stimulating auxin production

and increasing activation of enzymes responsible for cell division and elongation (Taiz and Zeiger, 2010). Our results conform with those recorded by Rahim (1988), who reported that lower concentrations (100 ppm) of gibberellic acid significantly increased both leaf and root dry weight and total yield while higher concentrations (200 ppm) of GA₃ showed deleterious effects and reduction in final bulb weight. Furthermore, Ahmed and Hemada (2012) recommended soaking garlic cloves in 5 ppm GA₃ for higher yields of Cvs Sids 40 or Eggassed 1 under Egyptian conditions. Also, Liu *et al.* (2019a) indicated that soaking seed clove in 1 mM L⁻¹ GA₃ solution increase bulb weight while injecting plant with one mM L⁻¹ GA₃ increased clove number per bulb. Moreover, injecting garlic plants with one mM L⁻¹ GA₃ led to a sharp increase in the number of cloves and mean bulb weight significantly decreased for plants treated with 10 mM L⁻¹ GA₃ (Liu *et al.*, 2019b). Islam *et al.* (2007), Pratap (2014) Samy *et al.* (2014) and Alexopoulos *et al.* (2017) on potato reported enhanced vegetative growth with treatment with gibberellic acid, which could reflect on yield by transporting assimilates to storage organs. In accordance with our results from 100 ppm foliar application, Akter *et al.* (2016) reported the best response for vegetative growth, total yield and its components with the same concentration.

On the other hand, Rahman *et al.* (2004) mentioned that foliar spray of GA₃ (100 or 200 ppm) caused deleterious effects and control produced higher yield than treated plants environmental differences could explain this contradictory result. The obtained Cytokinin (CPPU) beneficial effects may be due to promoting protein synthesis, increasing cell division, and enlargement (Cheema and Sharma, 1982).

CONCLUSIONS

The increasing of nitrogen and potassium nutrition above the recommended (up to (180 kg N + 92 kg K₂O/fed.) under Egyptian conditions could enhance the production of a higher yield of large bulbs for high-quality seeds of Sids 40 garlic cv. Furthermore, the application of 100 ppm GA₃ and 2.5 ppm CPPU enhanced the production of garlic seed.

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تحسين إنتاج تقاوى الثوم باستخدام التسميد النيتروجيني والبوتاسى وبعض منظّمات النمو محمود محمد سامي محمود و سمير شديد محمد الزهيري

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تم إجراء تجربتين حقليتين بمزرعة بحوث الخضر بقها بمعهد بحوث البساتين بمركز البحوث الزراعية، لدراسة تأثير إرتفاع مستويات التسميد النيتروجيني والبوتاسي وإثنين من منظمي النمو (سيتوكينين اصطناعي بتركيز 2.5 جزء في المليون و حامض الجبريليك بتركيز 100 جزء في المليون) على نمو وإنتاج تقاوى الثوم صنف سدس 40. أظهرت النتائج المتحصل عليها أن زيادة معدلات التسميد الأزوتي والبوتاسي بنسب مختلفة (120 و 150 %) عن المعدلات الموصى بها 100 % تسميد (120 كجم نيتروجين و 72 كجم بوتاسيوم للفدان) أدت إلى تحسن معنوي في معظم صفات النمو المدروسة والمكونات الكيميائية والمحصول الكلي للفدان ومكونات المحصول. علاوة على ذلك، أظهرت النتائج أن استخدام 150 % من معدل التسميد الموصى به مع رش النباتات بحمض الجبريليك + السيتوكينين أدت إلى الحصول على أعلى متوسط لوزن البصلة ومتوسط لوزن الفصوص والمحصول الكلي. كما تؤكد النتائج التي تم الحصول عليها أنه يمكن تحسين محصول تقاوى الثوم عن طريق التغذية بالنيتروجين والبوتاسيوم مع الرش الورقي بالجبريللين والسيتوكينين.