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Effect of Bio and Mineral Potassium Fertilizers on the Growth, Yield, and Quality of Some Garlic Cultivars Under Clay Soil Conditions

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Abstract: A field experiment was conducted during the two consecutive growing seasons of 2023/2024 and 2024/2025 at the Qaha Vegetable Research Station, affiliated with the Horticultural Research Institute, Agricultural Research Center, Egypt. The study aimed to evaluate the performance of three garlic cultivars (Sids 40, Balady, and Egaseed 1) under different combinations of mineral and bio-potassium fertilization. Four fertilization treatments were applied: 100% mineral potassium (MK) alone as the control, 75% MK supplemented with bio-potassium fertilizer (Potassumag at 3 kg /fed.), 50% MK supplemented with Potassumag, and Potassumag alone. Results revealed that Sids 40 outperformed the other cultivars in terms of vegetative growth, yield, and bulb quality. Applying 75% mineral potassium (MK) supplemented with Potassumag enhanced vegetative growth, total leaf chlorophyll content, and leaf mineral nutrient concentrations at 135 days after planting, as well as yield and bulb quality, with no significant differences compared with the application of 100% mineral potassium in the three tested cultivars. Regarding the interaction between cultivar and fertilization treatment, Sids 40 with 75% MK supplemented with Potassumag resulted in the highest values of leaf dry weight, chlorophyll content, leaf nutrient concentrations, number of cloves per bulb, average bulb weight, total yield and bulb N, P, and K contents, as well as bulb dry matter and total carbohydrate contents, with no significant differences compared with the control treatment (100% MK) within the same cultivar. These results indicate that supplementing 75% of the recommended MK rate with bio-potassium fertilizer can reduce mineral potassium application by 25% without significantly compromising garlic productivity or bulb quality, thereby potentially reducing production costs and promoting sustainable nutrient management.

Key words: Garlic, cultivars, potassium, Potassumag, biofertilizer, yield and bulb quality.

1. Introduction

Garlic (*Allium sativum* L.), a member of the family Alliaceae, is one of the major bulb vegetable crops worldwide and ranks second in importance after onion. Enhancing garlic productivity has

become increasingly important to satisfy the growing demand for both domestic consumption and exportation **(El-Hifny, 2010)**. In Egypt, cultivating garlic for both local markets and exportation, making it an economically significant horticultural crop. According to the Agricultural Statistics Bulletin issued by the Economic Affairs Sector of the **Egyptian Ministry of Agriculture and Land Reclamation (2024)**, garlic cultivation in Egypt during the 2023/2024 agricultural season covered approximately 53,921 feddans, producing 563,887 tons, with an average yield of 10.46 tons per feddan.

In Egypt, boosting garlic productivity has recently gained considerable attention to meet the rising demand in the domestic market and the continued expansion of export opportunities. From an economic standpoint, selecting suitable cultivars is essential for enhancing bulb quality features and maximizing yield per unit area **(Ibrahim *et al.*, 2020)**.

There were significant differences among garlic cultivars in plant growth (**Zaki *et al.*, 2014, Hassan *et al.*, 2016),** productivity (**Ezzat *et al.*, 2020, Shehata, 2021 and Zail, and Abdaly, 2023**) and bulb quality (**Abdel-Razzak and El-Sharkawy, 2013 and Zaki *et al.* 2014).**

Potassium is an essential macronutrient that plays a vital role in various physiological and biochemical functions in plants, including photosynthetic activity, osmotic adjustment, enzyme activation and the regulation of water and nutrient movement throughout plant tissues **(Jiku *et al.*, 2020)**. Determining appropriate potassium application rates and strategies remains an important area of research for optimizing plant growth and yield **(Wang *et al.*, 2022).** An eco-friendly substitute for conventional mineral potassium fertilizing is biofertilization. By converting soil-bound potassium into forms that plants may easily absorb, these helpful bacteria lessen the need for artificial fertilizers (**Mounir *et al.*, 2020**). In this concern, potassium fertilization enhanced plant growth, chemical constituents, yield and bulb quality of garlic (**Wang *et al.* 2022, Zail, and Abdaly, 2023 and Metwally *et al.* 2024**).

According to **Hassan (2015),** garlic plants treated with bio-potassium treatments grew more vegetative than untreated plants in terms of plant length, number of leaves per plant, fresh and dry weight of the entire plant, chemical composition, and yield. Furthermore, **Mohamed *et al.* (2022)** investigated the effects of three lower potassium levels (80, 60, and 40% RD) combined with *Bacillus circulans*, a potassium-solubilizing bacteria on onions, against the recommended potassium dose (100% of the recommended rate). They demonstrated that applying K_2O at 80% RD+ bio-potassium produced the best results in terms of growth, yield, and bulb quality, with no discernible changes when compared to 100% KRD.

This study aimed to evaluate the performance of three garlic cultivars under various combinations of mineral and bio-potassium fertilization treatments with the goal of reducing mineral potassium fertilizer application and to assess the resulting effects on growth, yield and bulb quality under clay soil conditions.

2. Materials and Methods

A field experiment was conducted under Egyptian conditions at Kaha Vegetables Research Farm, Horticulture Research Institute, Agriculture Research Centre, during the two successive winter seasons of 2023 /2024 and 2024/2025, to study the behavior of three garlic cultivars under some mineral and bio potassium fertilizer treatments and its effect on growth, yield and bulb quality under clay soil conditions.

Twelve treatments were used in this investigation, consisting of three garlic cultivars (Sids 40, Balady and Egaseed 1) and four combinations of K_2O and bio potassium treatments as follows: 100% of the recommended rate (RD) of K_2O (control treatment), 75% K_2O RD + bio potassium, 50% K_2O RD + bio potassium, and bio potassium only. These treatments were dispersed using a split plot design with three replicates. Garlic cultivars were placed in the main plots, while K_2O and bio potassium treatments were distributed in the sub plots.

Physical and chemical properties of the experimental soil were presented in Table A.

Table (A). The physical and chemical properties of soil during 2023/2024 and 2024/2025 seasons

Characters	Values	
Soil particles distribution	**20232024**	**2024/2025**
Sand (%)	18.91	20.03
Clay (%)	58.05	57.59
Silt (%)	23.04	22.38
Texture	Clay loam	Clay loam
Organic matter (%)	1.15	1.11
pH*	7.62	7.59
Avalable nutriments (mg/kg soli)		
Available N	89.9	87.26
Available P	9.53	8.64
Available K	197.21	189.24

* Soil water suspension 1:2.5 ** soil water extract 1:5

On both sides of the row, the cloves were seeded 10 cm apart. In both of the study's growth seasons, sowing took place during the first week of October in both seasons. The plot area was 12.6 m^2. It had three rows that were 60 cm wide and 7 m long. The samples were divided into two rows for yield determination and one row for measuring vegetative growth characteristics.

The source of mineral potassium (MK) was potassium sulphate (48%K_2O), 100 %RD of potassium was 72 kg K_2O/fed. while the source of bio potassium was Potassumag which contained *Bacillus circulans*, a potassium-solubilizing bacteria, provided from ARC. It was added at the rate of 3kg/fed., mixed with wet soft dust at (1:10 ratio) and applied to the root absorption zone of plants, just before irrigation. The various rates of potassium levels and sources were added at three portions, one month apart from the beginning. Moreover, applying nitrogen and phosphorus fertilization and agricultural practices in both seasons were carried out as commonly followed in the district. Four combinations of mineral and bio potassium fertilization were applied; 100% mineral potassium alone as a control treatment, 75% MK+bio-potassium (Potassumag), 50% MK+ Potassumag and Potassumag alone.

Data recorded

1. Growth parameters

A random sample of ten plants was taken from each plot at 135 days after planting in both seasons of study for measuring the growth characters of garlic plants expressed as follows:

a. Morphological characters

1. Plant height (cm), number of leaves/plant, neck diameter (cm) and bulb diameter (cm) as well as bulbing ratio which calculated as follows:

$$\text{Bulbing ratio} = \frac{\text{Neck diameter (cm)}}{\text{Bulb diameter (cm)}}$$ according to **(Mann, 1952)**

b. Fresh and dry weight of leaves

Fresh leaves were weighed and expressed as g/plant. Subsequently, the leaves were oven dried at 70° C until a constant weight and dry weight of leaves was recorded as g/plant.

2- Plant chemical composition:

a- Nitrogen, phosphorus and potassium contents

The dried leaf samples were finely pulverized and subjected to wet digestion to determine their N, P and K contents according to the methods of **Bremner and Mulvaney (1982), Olsen and Sommers (1982) and Jackson (1970),** respectively**.**

B. Leaf total chlorophyll (SPAD): the photosynthetic capacity (SPAD) was assessed by the use of a spade meter through the measurement of chlorophyll material which was analyzed as described by **Picazo *et al*. (2013**).

3- Yield and its components

At 180 days after planting, bulbs were collected from each experimental unit, and several parameters related to crop productivity and bulb characteristics were subsequently evaluated. Five bulbs were randomly selected from each experimental unit for measuring bulb diameter (cm), which was determined at the widest point using a digital caliper, as well as counting the number of cloves per bulb and determining the average clove weight (g).

A representative sample of bulbs from each experimental plot was weighed to calculate the mean bulb weight (g). The total bulb yield per plot (kg/plot) was also determined and subsequently converted into total yield per feddan (ton/fed.).

4- Bulbs chemical constituents

The chosen bulb samples of each experimental plot were separated into individual cloves, sliced, and oven-dried at 70°C until a constant weight was attained. Then, dry weight percentage (%) was calculated. Nitrogen, phosphorus, and potassium content in the garlic bulbs were determined over the two growing seasons using the same analytical procedures previously applied to leaf samples. Additionally, the total carbohydrate content (%) was determined according to the method described by **Dubois *et al*. (1956**).

Statistical Analysis

Recorded data were subjected to the statistical analysis of variance according to **Snedecor and Cochran (1980)**, and means separation were done according to **Duncan (1955).**

3. Results and discussion

1. Vegetative growth

1.1. Effect of cultivars

Data presented in Table 1 revealed significant difference in vegetative growth among the three garlic cultivars (Sids 40, Balady, and Egaseed 1). Sids 40 recorded the highest values for number of leaves per plant, neck diameter, bulb diameter, and bulbing ratio compared with Balady and Egaseed 1 cultivars. In contrast, Balady exhibited the greatest plant height at 135 days after planting (DAP) in the 1st and 2nd growing seasons. These results may be attributed to the genetic constitution of each cultivar and the genetic variability among the tested genotypes. These results are agreeing with those reported by **Zaki *et al*. (2014)** and **Youssef and Tony (2014)** on garlic.

Table (1). Effect of garlic cultivars on vegetative growth parameters at 135 days after planting during 2023/2024 and 2024/2025 seasons

Treatments	Plant height (cm)	Number of leaves / plant	Neck diameter (cm)	Bulb diameter (cm)	Bulbing ratio
	2023/2024				
Sids 40	73.73 b	10.51 a	1.75 a	4.56 a	0.382 a
Balady	81.58 a	9.38 c	1.46 b	4.01 b	0.363 b
Egaseed 1	74.17 b	10.16 b	1.42 b	3.99 b	0.356 b
	2024/2025				
Sids 40	64.27 b	10.09 a	1.77 a	4.67 a	0.379 a
Balady	82.47 a	8.18 c	1.42 b	3.90 c	0.363 b
Egaseed 1	64.16 b	9.42 b	1.41 b	4.04 b	0.350 c

1.2. Effect of potassium levels and sources

Data presented in Table 2 show that fertilizing garlic plants with 75 % Mk+bio-potassium (Potassumag) significantly increased plant height, number of leaves/plant, neck diameter, bulb diameter and bulbing ratio followed by 100 % MK (control treatment) in the two tested seasons. There were no significant differences between 75 %MK+bio and 100 % MK on plant height in both seasons, bulbing ratio in the 1st season and number of leaves/plant in the 2nd season. Conversely, treated garlic plants with biofertilzer alone produced the lowest values in all vegetative growth parameters in both seasons.

These results could be attributed to the essential role of potassium in regulating metabolic activities and various physiological processes that support and enhance vegetative growth and plant development. Potassium is also involved in several physiological and biochemical functions, including cell division and elongation, as well as carbohydrate and protein metabolism (**Marschner, 1995**).

This potassium application effect is harmony with those obtained by **Mansour (2013), Zyada and Bardisi, (2018)** from their investigations on garlic. In this connection, **Hassan (2015)** reported that application of bio-potassium treatments enhanced garlic plant growth, as evidenced by increased plant height and number of leaves per plant compared with untreated plants.

Table (2). Effect of potassium levels and sources on vegetative growth parameters of garlic at 135 days after planting during 2023/2024 and 2024/2025 seasons

Treatments	Plant height (cm)	Number of leaves / plant	Neck diameter (cm)	Bulb diameter (cm)	Bulbing ratio
	2023/2024				
100 % M K	79.92 ab	10.35 b	1.61 b	4.24 b	0.379 a
75% MK+bio	80.24 a	10.66a	1.68 a	4.41 a	0.381 a
50%MK+bio	77.55 b	9.91 c	1.48 c	4.11 c	0.359 b
Bio only	68.27 c	9.15 d	1.40 d	4.00 d	0.349 c
	2024/2025				
100 % M K	72.02 ab	9.77 a	1.60 b	4.30 b	0.371 b
75% MK+bio	73.09 a	9.79 a	1.69 a	4.42 a	0.382a
50%MK+bio	69.78 b	8.97 b	1.45 c	4.11 c	0.354 c
Bio only	66.32 c	8.38 c	1.40 d	3.99 d	0.350 c

100 % MK=96 kg K_2O/fed., 75 % MK=72 kg K_2O/fed., 50 % MK=48 kg K_2O/fed. and Bio= Potassumag at 3 kg /fed.

1.3. Effect of the interaction

Data in Table 3 indicate that fertilizing Balady cultivar with 75 %MK+bio-fertilizer gave the highest values of plant height, whereas fertilizing Sids 40 with the same treatment gave the highest values of number of leaves/plant, both neck and bulb diameter as well as bulbing ration without significant differences compared with 100 % MK in both seasons. The lowest vegetative growth values were detected for the three tested cultivars that treated with only bio-fertilizer in the two tested seasons.

These results could be attributed to the essential involvement of potassium in metabolic activities and various physiological functions that support and stimulate vegetative growth and overall plant development as stated by (**Marschner, 1995**). Moreover, he reported that potassium plays an essential role in numerous physiological and biochemical processes, including cell division and elongation, as well as carbohydrate and protein metabolism.

Obtained results are harmony with those of **Mansour, (2013), Zyada and Bardisi, (2018)** on garlic. Moreover, **Hassan (2015) indicated that** treated garlic plants with bio-potassium treatments grew more vegetative than untreated plants in terms of plant length, number of leaves per plant. In Addition, bio-chemical fertilization produced the greater bulb diameter, neck diameter, and bulbing ratio **(Abou El-Magd *et. al*., 2014)**.

Table (3). Effect of the interaction between garlic cultivars and potassium levels and sources on vegetative growth parameters at 135 days after planting during 2023/2024 and 2024/2025 seasons

Treatments		Plant height (cm)	Number of leaves / plant	Neck diam.(cm)	Bulb diam. (cm)	Bulbing ratio
Cultivars	**K levels and sources**	**2023/2024**				
Sids 40	**100 %MK**	76.88 cd	11.00ab	1.83 b	4.63 b	0.395 a
	75%MK+bio	77.88 bcd	11.00ab	1.93a	4.79a	0.403 a
	50%MK+bio	74.44 cd	10.40 cd	1.67 c	4.48 c	0.373 b
	Bio only	65.72 e	9.66 ef	1.57 d	4.36 d	0.360 c
Balady	**100 %MK**	86.22 a	9.60 ef	1.53 de	4.06 f	0.377 b
	75%MK+bio	84.55 a	9.93 cde	1.57 d	4.23 e	0.371 b
	50%MK+bio	82.88 ab	9.46 ef	1.42 f	3.93 g	0.361 c
	Bio only	72.66 d	8.53 g	1.32 g	3.85 h	0.343 d
Egaseed 1	**100 %MK**	76.66 cd	10.46 bc	1.48 ef	4.03 f	0.367 bc
	75%MK+bio	78.27 bc	11.06 a	1.56 d	4.22 e	0.370 bc
	50%MK+bio	75.33 cd	9.86 de	1.35 g	3.92 g	0.344 d
	Bio only	66.44 e	9.26 f	1.31 g	3.79 i	0.346 d
		2024/2025				
Sids 40	**100 %MK**	64.50 c	10.46 a	1.89 b	4.81 b	0.393ab
	75%MK+bio	66.52 c	10.70 a	1.95a	4.93 a	0.396a
	50%MK+bio	64.21 c	9.46 bcd	1.65 c	4.54 c	0.363 de
	Bio only	61.86 c	9.75 bc	1.61 d	4.42 d	0.364 de
Balady	**75%MK+bio**	86.53a	8.60 e	1.58 de	4.14 f	0.382 bc
	50%MK+bio	81.89a	8.06 e	1.38 g	3.81 h	0.362 de
	Bio only	74.88 b	7.33 f	1.28 i	3.72 i	0.344 fg
Egaseed 1	**100 %MK**	64.97 c	10.13 ab	1.46 f	4.13 f	0.354 ef
	75%MK+bio	66.22 c	10.09 abc	1.55 e	4.20 e	0.369 cd
	50%MK+bio	63.25 c	9.40 cd	1.34 gh	3.98 g	0.337 g
	Bio only	62.22 c	8.06 ef	1.32 hi	3.85 h	0.343 fg

100 % MK=96 kg K_2O/fed., 75 % MK=72 kg K_2O/fed., 50 % MK=48 kg K_2O/fed. and Bio= Potassumag at 3 kg /fed.

2. Fresh and dry weight of leaves

2.1. Effect of cultivars

Data in Table 4 illustrate that Sids 40 cultivar recorded maximum values of fresh weight and dry weight of leaves, followed by Balady cultivar, whereas Egaseed 1 cultivar recorded minimum values of fresh and dry weight of leaves/plant.

2.3. Effect of the interaction

The interaction of Sids 40 cultivar with either 75 %MK+ biofertilzer or 100 %MK gave the best fresh and dry weight of leaves/plant at 135 days after planting without significant differences between the two tested treatments in both seasons (Table 5).

In general, fertilizing the three cultivars (Sids 40, Balady and Egaseed 1) with 75%MK+bio-potassium or 100 % MK gave the highest values of fresh and dry weight of leaves/plant, whereas fertilizing the same cultivars with only bio fertilizer (Potassumag) gave the lowest values of fresh and dry weight of leaves in both seasons.

Table (4). Effect of garlic cultivars and potassium levels and sources on fresh and dry weight of leaves at 135 days after planting during 2023/2024 and 2024/2025 seasons

Treatments	Fresh weight of leaves (g)		Dry weight of leaves (g)	
	Effect of garlic cultivars			
	2023/2024	2024/2025	2023/2024	2024/2025
Sids 40	38.12 a	37.49 a	11.44 a	11.36 a
Balady	34.08 b	31.38 b	10.49 b	9.73 b
Egaseed 1	29.49 c	29.20 c	8.93 c	8.76 c
	Effect of potassium levels and sources			
100 % M K	36.85 a	35.02 a	11.37 a	10.86 a
75% MK+bio	37.86 a	35.52 a	11.74 a	11.01 a
50%MK+bio	31.71 b	31.39 b	9.60 b	9.54 b
Bio only	29.17 c	28.83 c	8.46 c	8.40 c

100 % MK=96 kg K_2O/fed., 75 % MK=72 kg K_2O/fed., 50 % MK=48 kg K_2O/fed. and Bio= Potassumag at 3 kg /fed.

Table (5). Effect of the interaction between garlic cultivars and potassium levels and sources on fresh and dry weight of leaves at 135 days after planting during 2023/2024 and 2024/2025 seasons

Treatments		Fresh weight of leaves (g)		Dry weight of leaves (g)	
Cultivars	K levels and sources	2023/2024	2024/2025	2023/2024	2024/2025
Sids 40	100 %MK	41.28a	40.39a	12.63 a	12.52a
	75%MK+bio	41.21a	40.68a	12.78 a	12.61a
	50%MK+bio	36.72 bc	36.84 b	10.88 bc	11.03 b
	Bio only	33.28 d	32.05 cd	9.48 de	9.27 ef
Balady	100 %MK	36.36 c	32.58 c	11.27 b	10.10 cd
	75%MK+bio	39.14ab	33.90 c	12.13 a	10.51 bc
	50%MK+bio	31.78 d	30.27 de	9.66 de	9.54 de
	Bio only	29.04 e	28.75 ef	8.91 ef	8.79 fg
Egaseed 1	100 %MK	32.91 d	32.08 cd	10.20 cd	9.95 cde
	75%MK+bio	33.23 d	32.00 cd	10.30 bcd	9.92 cde
	50%MK+bio	26.64 ef	27.05 fg	8.26 f	8.05 g
	Bio only	25.20 f	25.69 g	6.98 g	7.13 h

100 % MK=96 kg K_2O/fed., 75 % MK=72 kg K_2O/fed., 50 % MK=48 kg K_2O/fed. and Bio= Potassumag at 3 kg /fed.

3. Total chlorophyll, N, P and K contents in leaves

3.1. Effect of cultivars

Data in Table 6 show that Sids 40 cultivar recorded maximum values of total chlorophyll, N, P and K in leaves in the 1st and 2nd seasons followed by Balady cultivar, whereas Egaseed 1 cultivar recorded minimum values. There was no significant difference between Sids 40 and Balady cultivars in leaves content of K in the 1st season and among the three tested cultivars in the 2nd season. Similar differences among garlic cultivars in total chlorophyll and mineral leaves content were reported by **Zaki *et al*. (2014) and Hassan *et. al.* (2016).**

3.2. Effect of potassium levels and sources

There were significant differences among potassium sources and levels in total chlorophyll in leaf tissues and N, P and K in leaves in both seasons (Table 6). Fertilizing with both 75 % MK +bio and100% MK fertilizer increased total chlorophyll in leaf tissues, N, P and K in leaves with no significant differences between them in both seasons.

Table (6). Effect of garlic cultivars and potassium levels and sources on total chlorophyll and N, P and K contents in leaves at 135 days after planting during 2023/2024 and 2024/2025 seasons

Treatments	Total chlorophyll (SPAD)		N (%)		P (%)		K (%)	
	2023/ 2024	2024/ 2025	2023/ 2024	2024/ 2025	2023/ 2024	2024/ 2025	2023/ 2024	2024/ 2025
	Effect of garlic cultivars							
Sids 40	74.34 a	73.95 a	3.38 a	3.28 a	0.457a	0.410 a	1.66 a	1.57 a
Balady	66.87 b	64.39 b	2.98 b	3.09 b	0.435b	0.377 b	1.59 a	1.46 a
Egaseed 1	60.25 c	60.62 c	2.44 c	2.47 c	0.425c	0.372 c	1.44 b	1.50 a
	Effect of potassium levels and sources							
100 %MK	72.70 a	72.06 a	3.20 a	3.12 b	0.456 b	0.413 b	1.78 a	1.63 a
75%MK+bio	73.96 a	73.56 a	3.31 a	3.44 a	0.476 a	0.426 a	1.84 a	1.67 a
50%MK+bio	63.67 b	62.47 b	2.73 b	2.73 c	0.420 c	0.386 c	1.49 b	1.46 b
Bio only	58.28 c	57.19 c	2.49 c	2.50 d	0.403 d	0.320 d	1.14 c	1.29 c

100 % MK=96 kg K_2O/fed., 75 % MK=72 kg K_2O/fed., 50 % MK=48 kg K_2O/fed. and Bio= Potassumag at 3kg/fed.

Fertilizing garlic plants with bio-fertilizer (Potassumag) alone gave the lowest values of total chlorophyll, N, P and K contents in leaves in both seasons. The beneficial effect of 75% K_2O as potassium sulfate + bio-potassium on the dry weight of garlic could be attributed to the fact that K_2SO_4 contains SO_4. Sulfur is an essential nutrient involved in plant growth and plays a vital role in chlorophylls and protein synthesis. Moreover, sulfur application may improve soil structure, enhance water infiltration, and increase nutrient availability in the rhizosphere, thereby promoting garlic growth **(Hilal *et al.*, 1992).** Chemical constituents in garlic plants increased by potassium fertilization of garlic as stated by **Wang *et al*. (2022).**

3.3. Effect of the interaction

Data in Table 7 show that fertilizing Sids 40 cultivar with 75 % MK+ biofertilzer or 100 % MK led to increment of total chlorophyll, N, P and K contents in leaves at 135 days after planting than the tested interactions in both tested seasons. In contrast, the interaction between Egaseed 1 and fertilizing with bio-fertilizer (potassumag) alone gave the lowest values of total chlorophyll, N, P and K contents in leaves in both seasons. Similar superior for Sids 40 garlic cultivar in its productivity compared with Balady was observed by **Merwad, 2018, Mohamed 2019, Ezzat *et al*., 2020, Shehata, 2021 and Zail and Abdaly (2023).**

Table (7). Effect of the interaction between garlic cultivars and potassium levels and sources on total chlorophyll and NPK contents in leaves of garlic after 135 days after planting during 2023/2024 and 2024/2025 seasons

Treatments		Total chlorophyll (SPAD)		N (%)		P (%)		K (%)	
Cvs	K levels and sources	2023/ 2024	2024/ 2025	2023/ 2024	2024/ 2025	2023/ 2024	2024/ 2025	2023/ 2024	2024/ 2025
Sids 40	100 % M K	79.02a	80.03a	3.60 a	3.31 c	0.480 b	0.440 b	1.82abc	1.67a
	75% MK+bio	80.12a	81.24a	3.68 a	3.87a	0.500a	0.450 a	1.93 a	1.77a
	50%MK+bio	73.02 b	72.02 b	3.28 b	3.06 d	0.430 g	0.410d	1.67 cd	1.52a-d
	Bio only	65.22ef	62.54 e	2.98 c	2.88 de	0.420 h	0.340 h	1.24 e	1.32 cd
Balady	100 % M K	71.50 bc	69.06 cd	3.39 ab	3.54 b	0.450 e	0.400 e	1.82abc	1.56abc
	75% MK+bio	71.89 bc	70.68 bc	3.54 ab	3.69ab	0.470 c	0.420c	1.87 ab	1.62ab
	50%MK+bio	64.78 f	60.24 ef	2.61 de	2.73ef	0.420 h	0.370g	1.51 d	1.37bcd
	Bio only	59.32 g	57.60 fg	2.39 def	2.42 gh	0.400 j	0.320 i	1.17 ef	1.31 cd
Egaseed 1	100 % M K	67.58 de	67.10 d	2.63 d	2.53 fg	0.440 f	0.400 e	1.72 bc	1.67a
	75% MK+bio	69.88cd	68.78cd	2.71 cd	2.76 e	0.460d	0.410 d	1.74 bc	1.62ab
	50%MK+bio	53.22 h	55.17 g	2.32 ef	2.41 gh	0.410 i	0.380 f	1.30 e	1.49a-d
	Bio only	50.32 h	51.44 h	2.11 f	2.21 h	0.390 k	0.300 j	1.02 f	1.25 d

100 % MK=96 kg K_2O/fed., 75 % MK=72 kg K_2O/fed. and 50 % MK=48 kg K_2O/fed. Bio k= Potassumagat 3kg /fed.

4. Yield and its components

4.1. Effect of cultivars

From data illustrated in Table 8, it can be observed that Balady cultivar recorded maximum number of cloves/bulb followed by Sids 40. Besides, Sids 40 cultivar recorded maximum average clove weight, bulb diameter and bulb weight as well as total yield followed by Balady cultivar, whereas Egaseed 1 cultivar recorded minimum values of yield and its components. These results might be referred to the genetic variation among garlic cultivars and their abilities to benefit from the environmental sources, particularly nutrients.

Table (8). Effect of garlic cultivars on yield and its components during 20232024 and 2024/2025 seasons

Treatments	Number of cloves/bulb	Average clove weight (g)	Bulb diameter (cm)	Average bulb weight (g)	Total yield (ton/fed.)
	2023/2024				
Sids 40	15.32 b	4.58 a	5.99 a	70.17 a	8.905 a
Balady	43.15 a	1.23 b	5.30 b	53.10 b	8.027 b
Egaseed 1	15.60 b	4.71 a	4.91 c	73.48 c	7.358 c
	2024/2025				
Sids 40	15.55 c	4.71 a	6.05 a	73.24 a	9.078 a
Balady	40.45 a	1.26 b	5.30 b	50.97 b	7.712 b
Egaseed 1	17.02 b	5.35 a	4.84 c	91.06 c	7.246 c

100 % MK=96 kg K_2O/fed., 75 % MK=72 kg K_2O/fed.,50 % MK=48 kg K_2O/fed. and Bio= Potassumag at 3 kg /fed.

4.2. Effect of potassium level and sources

Significant potassium sources and levels impact on yield and its components in both seasons is illustrated in (Table 9). Treating garlic plants with 75 % MK + bio and 100 % MK recorded the highest values of number of cloves/bulb, average clove weight, bulb diameter and average bulb weight as well as total yield with no significant differences in both seasons. Treating plants with bio-fertilizer alone resulted in the lowest values of yield and its components. Potassium is a vital macro-nutrient to plant physiology and biochemistry. It facilitates photosynthesis, osmoregulation, enzymatic processes, and the control of water and nutrient transport within the plant (**Jiku *et al.*, 2020**). This could explain potassium association with higher weight, better bulb quality. To maximize development and productivity, research is still being done on the best ways to apply potassium and the exact amount (**Wang *et al.*, 2022**).

Table (9). Effect of potassium levels and sources on yield and its components during 2023/2024 and 2024/2025 seasons

Treatments	Number of cloves/bulb	Average clove weight (g)	Bulb diameter (cm)	Average bulb weight (g)	Total yield (ton/fed.)
	2023/2024				
100 % MK	26.33 a	3.87 a	5.81 a	101.90 a	8.739 a
75% MK+bio	27.86 a	4.12 a	5.91 a	114.78 a	8.876 a
50%MK+bio	23.46 c	3.30 b	5.15 b	77.42 b	7.796 b
Bio only	21.10 d	2.75 c	4.73 c	58.03 c	6.976 c
	2024/2025				
100 % M K	25.93 a	4.18 a	5.77 a	108.39 a	8.538 a
75% MK+bio	27.56 a	4.39 a	5.88 a	120.99 a	8.846 a
50%MK+bio	23.60 c	3.72 b	5.19 b	87.79 b	7.618 b
Bio only	20.26 d	2.80 c	4.75 c	56.73 c	7.046 c

100 % MK=96 kg K_2O/fed., 75 % MK=72 kg K_2O/fed.,50 % MK=48 kg K_2O/fed. and Bio= Potassumag at 3 kg /fed.

An eco-friendly substitute for conventional mineral fertilizing is biofertilization. By converting soil-bound potassium into forms that plants may easily absorb, these helpful bacteria lessen the need for artificial fertilizers (**Mounir *et al.*, 2020**). Similar improvements resulted in potassium fertilization was demonstrated by **Mansour, (2013), Zyada and Bardisi (2018).** Besides, **Hassan (2015)** stated that garlic plants treated with bio-potassium treatments grew more productivity. Furthermore, **Mohamed *et al.* (2022**) investigated the effects of three lower potassium levels (80, 60, and 40% RR) combined with *Bacillus circulans*, a potassium-solubilizing bacteria on onions, against the recommended potassium dose (100% of the recommended rate). They demonstrated that applying K_2O at 80% RD + biofertilizer produced the best results in yield with no discernible changes when compared with 100% KRD.

4.3. Effect of the interaction

As illustrated in Table 10, the interaction between Balady cultivar and fertilizing with 75% MK+ bio increased number of cloves/bulb as shown in Table 10. Respecting average clove weight, the interaction between Sids 40 cultivar and fertilizing with 75 %MK+bio or 100 %MK gave the highest values of clove weight with no significant differences with the interaction between Egaseed 1 cultivar with the same fertilization treatments in both seasons. The interaction between Sids 40 cultivar fertilized with 75 %MK+bio or 100 %MK were outstanding in bulb diameter, average bulb weight and total yield/fed without significant differences between them.

5. Dry matter and chemical components in bulbs

5.1. Effect of cultivars

As shown in Table 11, Sids 40 cultivar recorded maximum values of N, P and K, dry matter and total carbohydrates followed by Balady cultivar, while Egaseed 1 cultivar recorded minimum values of all parameters of bulb quality in both seasons. These obtained variations among cultivars in chemical contents refers to differential among cultivars in their benefiting from nutrients and their physiological acts.

Obtained results are compatible with those of **Abdel-Razzak and El-Sharkawy (2013) and Zaki *et al*. (2014).** In this regard, **Merwad (2018)** showed that, Sids 40 cultivar gave higher N, P and K contents in bulb than Balady cultivar.

5.2. Effect of potassium levels and sources

Data in Table 12 clears that fertilizing garlic with 75 %MK+ fertilizer or 100% MK gave the highest values of N, P and K, dry matter and total carbohydrates (%) in bulb at harvesting time with no significant differences within the 2nd season except for P. This means that 75 %MK+ biofertilzer increased N, P and K, dry matter and total carbohydrates in bulbs. In this connect, fertilizing with only bio-fertilizer gave the lowest values.

5.3. Effect of the interaction

The interaction between Sids 40 cultivar and fertilizing with 75 %MK+bio-potassium or 100 %MK increased N, P and K contents, dry matter and total carbohydrates in bulb at harvesting time in both seasons (Table 13). These results may be attributed to the enhancement of potassium availability through the secretion of organic acids by microorganisms, which lower soil pH and facilitate the conversion of insoluble potassium into soluble forms that are more readily available for plant uptake (**Sugumaran and Janarthanam, 2007).**

Table (10). Effect of the interaction between garlic cultivars and potassium levels and sources on yield and its components during 2023/2024 and 2024/2025 seasons

Treatments		Number of cloves/bulb	Average clove weight (g)	Bulb diameter (cm)	Average bulb weight (g)	Total yield (ton/fed.)
Cvs	K levels and sources	2024/2025				
Sids 40	100 % MK	16.2 fg	5.05 ab	6.32 a	81.81 a	9.489 a
	75% MK+bio	17.5 e	5.35 a	6.41 a	93.63 a	9.624 a
	50%MK+bio	14.7 hi	4.35 c	5.84 b	63.95 b	8.767 b
	Bio only	12.9 j	3.60 d	5.42 d	46.44 d	7.742 e
Balady	100 % MK	45.7 b	1.38 ef	5.72 bc	63.10 b	8.583 bc
	75% MK+bio	48.9 a	1.63 e	5.75 bc	79.71 b	8.615 bc
	50%MK+bio	40.8 c	1.01 f	4.98 e	41.21 d	7.785 e
	Bio only	37.2 d	0.92 f	4.75 f	34.22 e	7.128 f
Egaseed 1	100 % MK	17.1 ef	5.18 a	5.41 d	88.58 cd	8.146 d
	75% MK+bio	17.2 ef	5.38 a	5.59 cd	92.54 bc	8.391 cd
	50%MK+bio	14.9 gh	4.54 bc	4.64 f	67.65 e	6.837 f
	Bio only	13.2 ij	3.74 d	4.03 g	49.37 f	6.059 g
		2024/2025				
Sids 40	100 % MK	16.2 fg	5.21 bc	6.44 a	84.40 a	9.597 ab
	75% MK+bio	17.8 ef	5.48 ab	6.50 a	97.54 a	9.789 a
	50%MK+bio	14.4 gh	4.76 cd	5.96 b	68.54 b	8.974 bc
	Bio only	13.8 h	3.40 e	5.32 de	46.92 d	7.955 de
Balady	100 % MK	42.8 b	1.43 f	5.52 cd	61.20 c	8.296 cd
	75% MK+bio	45.8 a	1.50 f	5.65 bc	68.70 c	8.460 cd
	50%MK+bio	39.8 c	1.12 f	5.22 e	44.58 e	7.249 ef
	Bio only	33.4 d	1.02 f	4.82 f	34.07 f	6.843 fg
Egaseed 1	100 % MK	18.8 e	5.90 ab	5.36 cde	110.92 d	7.722 de
	75% MK+bio	19.1 e	6.20 a	5.50 cde	118.42 d	8.289 cd
	50%MK+bio	16.6 f	5.30 bc	4.41 g	87.98 fg	6.632 fg
	Bio only	13.6 h	4.00 de	4.12 h	54.4 g	6.342 g

100 % MK=96 kg K_2O/fed., 75 % MK=72 kg K_2O/fed., 50 % MK=48 kg K_2O/fed. and Bio= Potassumag at 3 kg /fed.

Table (11). Effect of garlic cultivars on dry matter percentage and chemical components of bulb during 2023/2024 and 2024/2025 seasons

Treatments	Dry matter (%)	N (%)	P (%)	K (%)	Total carbohydrates (%)
	2023/2024				
Sids 40	38.82 a	2.42 a	0.520 a	1.28 a	31.88 a
Balady	38.43 a	2.26 b	0.482 b	1.20 ab	31.77 a
Egaseed 1	37.00 b	2.07 c	0.442 c	1.12 b	29.83 b
	2024/2025				
Sids 40	39.71a	2.44 a	0.480 a	1.24 a	32.77 a
Balady	37.92 b	2.21 b	0.455 b	1.14 b	31.46 b
Egaseed 1	37.88 b	2.18 b	0.395 c	1.01 c	29.47 c

Table (12). Effect of potassium levels and sources on dry matter percentage and chemical components of bulb during 2023/2024 and 2024/2025 seasons

Treatments	Dry matter (%)	N (%)	P (%)	K (%)	Total carbohydrates (%)
	2023/2024				
100 % M K	39.74 b	2.54 a	0.523 b	1.28 ab	32.57 b
75% MK+bio	41.21 a	2.60 a	0.576 a	1.35 a	34.32a
50%MK+bio	36.84 c	2.01 b	0.446 c	1.18 b	30.30 c
Bio only	34.54 d	1.85 c	0.380 d	1.01 c	27.43 d
	2024/2025				
100 % M K	40.42 a	2.53 a	0.500 b	1.21 a	33.12a
75% MK+bio	41.59 a	2.56 a	0.523 a	1.26 a	34.03a
50%MK+bio	37.20 b	2.12 b	0.400 c	1.07 b	30.26 b
Bio only	34.80 c	1.89 c	0.350 d	0.99 b	27.53 c

100 % MK=96 kg K_2O/fed., 75 % MK=72 kg K_2O/fed., 50 % MK=48 kg K_2O/fed. and Bio k= Potassumag at 3 kg /fed.

Table (13). Effect of the interaction between garlic cultivars and potassium levels and sources on dry matter percentage and chemical components of bulb during 2023/2024 and 2024/2025 seasons

Treatments		Dry matter (%)	N (%)	P (%)	K (%)	Total carbohydrates (%)
Cvs	K levels and sources	2023/2024				
Sids 40	100 % M K	41.56 a	2.80 a	0.570 c	1.38 ab	33.52ab
	75% MK+bio	42.30 a	2.83 a	0.620 a	1.44 a	34.77a
	50%MK+bio	37.05 cde	2.19 c	0.490 e	1.19 bcd	30.63 cd
	Bio only	34.37 fg	1.86 d	0.400 g	1.14 cd	28.60 d
Balady	100 % M K	39.07 b	2.54 b	0.520 d	1.24 a-d	33.11abc
	75% MK+bio	41.83 a	2.65 ab	0.600 b	1.36 abc	34.56 a
	50%MK+bio	37.38 cd	1.95 d	0.420 f	1.17 bcd	30.73 cd
	Bio only	35.47 efg	1.91 d	0.390 g	1.04 de	28.69 d
Egaseed 1	100 % M K	38.61 bc	2.28 c	0.480 e	1.22 a-d	31.09 bcd
	75% MK+bio	39.51 b	2.34 c	0.510 d	1.25 a-d	33.65a
	50%MK+bio	36.10 def	1.89 d	0.430 f	1.18 bcd	29.56 d
	Bio only	33.79 g	1.79 d	0.350 h	0.86 e	25.02 e
		2024/2025				
Sids 40	100 % M K	42.17ab	2.68 a	0.540 bc	1.32 a	34.66 ab
	75% MK+bio	43.49a	2.64 ab	0.570 a	1.36 a	35.75 a
	50%MK+bio	37.32 ef	2.36 cd	0.420 ef	1.21 abc	31.67 de
	Bio only	35.88 fgh	2.10 e	0.390 g	1.09 cde	29.03 f
Balady	100 % M K	39.87 cd	2.52 abc	0.530 c	1.21 abc	32.77 cd
	75% MK+bio	41.08 bc	2.57 abc	0.550 b	1.29 ab	33.77 bc
	50%MK+bio	36.33 fg	1.89 ef	0.410 f	1.08 cde	30.86 e
	Bio only	34.42 gh	1.87 ef	0.330 i	1.01 def	28.47 f
Egaseed 1	100 % M K	39.23 cde	2.40 bc	0.430 e	1.10 cde	31.95 de
	75% MK+bio	40.22 bc	2.49 abc	0.450 d	1.14 bcd	32.59 cde
	50%MK+bio	37.95 def	2.11 de	0.370 h	0.94 ef	28.26 f
	Bio only	34.12 h	1.72 f	0.330 i	0.88 f	25.11 g

100 % MK=96 kg K_2O/fed., 75 % MK=72 kg K_2O/fed. and 50 % MK=48 kg K_2O/fed. Bio k= Potassumag at 3 kg /fed.

Furthermore, microorganisms can produce amino acids and growth-promoting substances, such as IAA and GA_3 which stimulate root elongation, enhance nutrient uptake and promote vegetative growth (**Sheng, 2005)**. On the other hand, vegetative growth of garlic, chemical composition, yield and its quality were improved by potassium fertilization as stated by **Jiku *et al*. (2020).** Additionally**, Shafeek *et al*. (2016)** found that application of the bio-potassium supplement (Potassine) at 2 kg/fed resulted in the greatest improvement in garlic plant growth, bulb output, and nutritional qualities (N, P, and K) compared with the untreated plants (control).

4. Conclusion

Sids 40 garlic cultivar outperformed Balady and Egaseed 1 in morphological and physiological traits, yield components and bulb quality. Application of 75 % MK+bio-fertilizer) markedly improved vegetative growth, total leaf chlorophyll content, and leaf mineral nutrient concentrations at 135 days after planting as well as yield and its components.

Sids 40 supplied with 75% mineral potassium plus Potassumag achieved the most favorable results, exhibiting the highest leaf dry weight, chlorophyll content, and leaf N, P, and K concentrations. This treatment also enhanced the number of cloves per bulb, average bulb weight, total yield and bulb N, P, and K contents, dry matter percentage and total carbohydrate content at harvest. These findings highlight the effectiveness of integrating bio-potassium with a reduced mineral potassium rate in maximizing garlic productivity and improving bulb quality.

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تأثير الأسمدة البوتاسية الحيوية والمعدنية على النمو والمحصول والجودة لبعض أصناف الثوم تحت ظروف التربة الطينية

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الملخص العربى

أُجريت تجربة حقلية خلال موسمي 2024/2023 - 2025/2024 بمحطة بحوث الخضر بقها، التابعة لمعهد بحوث البساتين بمركز البحوث الزراعية، مصر. وهدفت الدراسة إلى تقييم أداء ثلاثة أصناف من الثوم هي: سدس 40 والبلدي وإيجاسيد 1 تحت تأثير معاملات مختلفة تجمع بين التسميد البوتاسي المعدني والحيوي حيث طُبقت أربع معاملات للتسميد وهي: إضافة البوتاسيوم المعدني بالكامل بنسبة 100% من المعدل الموصى به (المقارنة) وإضافة 75% من البوتاسيوم المعدني مع مركب بوتاسيوماج (البوتاسيوم الحيوي)، وإضافة 50% من البوتاسيوم المعدني مع بوتاسيوماج وكذلك إضافة بوتاسيوماج وحده. أدى استخدام 75% من التسميد البوتاسي المعدني مع مركب بوتاسيوماج إلى تحسين النمو الخضري ومحتوى الأوراق الكلي من الكلوروفيل والعناصر المعدنية عند 135 يومًا من الزراعة وكذلك المحصول وجودته دون وجود فروق معنوية مقارنةً بالتسميد الكامل بالبوتاسيوم المعدني فى الأصناف الثلاثة المختبرة. كما أظهرت النتائج تفوق صنف سدس 40 على الصنفين الآخرين من حيث النمو الخضري والمحصول وجودة الأبصال. كما أدت إضافة 75% من البوتاسيوم المعدني مع بوتاسيوماج إلى تحسين صفات النمو الخضري ومحتوى الأوراق من الكلوروفيل الكلي وتركيزات العناصر الغذائية (النيتروجين والبوتاسيوم والفوسفور) في الأوراق فضلًا عن زيادة المحصول وتحسين التركيب الكيميائي للأبصال. وفيما يتعلق بالتفاعل بين الصنف ومعاملة التسميد، حقق صنف سدس 40 عند تسميده بنسبة 75% من البوتاسيوم المعدني مع بوتاسيوماج أفضل النتائج من حيث الوزن الجاف للأوراق ومحتوى الكلوروفيل الكلي وتركيزات النيتروجين والفوسفور والبوتاسيوم في الأوراق وعدد الفصوص لكل بصلة ومتوسط وزن البصلة والمحصول الكلي بالإضافة إلى محتوى الأبصال من العناصر(النيتروجين والبوتاسيوم والفوسفور) وكذلك نسبة المادة الجافة ومحتوى الكربوهيدرات الكلية عند الحصاد. وكانت الاختلافات فى هذه النتائج غير معنوية مقارنة بتلك المسجلة في معاملة التسميد الكامل بالبوتاسيوم المعدني للصنف نفسه. وتشير هذه النتائج إلى أن إحلال البوتاسيوم الحيوي ضمن برنامج التسميد مع خفض معدل البوتاسيوم المعدني إلى 75% من المعدل الموصى به يتيح توفير 25% من السماد البوتاسي المعدني دون التأثير معنويًا على إنتاجية الثوم أو جودة أبصاله بما قد يسهم في خفض تكاليف الإنتاج وتعزيز استدامة إدارة العناصر الغذائية.

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