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Article

Response of Local Garlic to Potassium and Sulfur Fertilization Method

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ABSTRACT
A field experiment was conducted at the Agricultural Research Station of the College of Agriculture, University of Anbar, for the agricultural season 2021-2022. This experiment aimed to study the effect of potassium and sulfur application on local garlic's growth, yield, and quality. The experiment included four levels of potassium soil fertilization (0, 200, 250, and 300 $kg.ha^{-1}$), three levels of foliar spraying of potassium (0, 5, and 10 $g.L^{-1}$), and three levels of soil fertilization of sulfur (0, 40, and 50 $kg.ha^{-1}$). The study used the randomized complete block design (RCBD) in combinations. The results showed significant differences in the characteristics of vegetative growth, yield characteristics, and qualitative characteristics. The combination (300 kg $K_2O.ha^{-1}$ +10 $g.L^{-1}$ + 50 kg $S.ha^{-1}$) significantly exceeded by giving the highest leaves number, leaves area and shoot dry weight, which amounted to 11.42 $leaf.plant^{-1}$ and 795.00 $cm^2.plant^{-1}$ and 10.87 $g.plant^{-1}$, respectively. In comparison, the control treatment gave (8.80 $leaves.plant^{-1}$ and 571.00 $cm^2.plant^{-1}$ and 8.17 $g.plant^{-1}$), for the same above traits, respectively. The same combination achieved a significant increase in yield traits (cloves number, clove weight, yield/plant, and total yield) with 37.58 cloves, 2.71 g, 102.03 g, and 51.01 $t.ha^{-1}$, respectively, compared to the control treatment, which gave (32.00 cloves, 1.81 g, 58.17 g, and 29.08 $t.ha^{-1}$). The same treatment led to an increase in the percentage of potassium and sulfur in the bulbs, which recorded the highest percentage of 1.67% and 0.60%, respectively, compared to the control treatment, which recorded the lowest percentage of 1.36% and 0.40%, respectively.
Keywords: Garlic, Fertilization, Potassium, Sulfur, Growth, Yield.

INTRODUCTION

Garlic, whose scientific name is Allium sativum L., is one of the most important vegetable crops in the world. It is an herbaceous plant belonging to the Alliaceae family and is widely used as a nutritional and seasoning crop worldwide [1]. Garlic is a bulb composed of several cloves of high nutritional value that contains 62.8% moisture, 6.3% proteins, 13 mg / 100 g^{-1} Vitamin C, 29% carbohydrates, 0.03% calcium, 0.31% phosphorous, 0.0031 % iron, as well as its medicinal and therapeutic value [2]. Garlic and its extracts are characterized as an antioxidant. This property is due to sulfur compounds, including allicin, which is the base compound for many sulfur compounds responsible for garlic's taste, flavor, and medicinal and therapeutic properties. Garlic contains over thirty-three sulfur compounds such as allin, ajoene, allicin, diallyl trisulfide, allyl propyl disulfide, s-allyl cysteine , and others [3]. Despite the nutritional, health, and therapeutic importance of garlic, its cultivation in Iraq is still limited due to farmers' ignorance of the nutritional, economic, and therapeutic value of the crop, as well as the lack of studies that identify fertilizer recommendations and service operations necessary for the crop. Many local and imported varieties are widespread in Iraq. The local variety is one of the best varieties spread in Iraq, but it is criticized for its small size of heads and cloves. Besides, there is a lack of yield per unit area, despite the quality of the variety and the high content of its fruits of dry matter, chemical, and therapeutic elements compared to imported varieties. Thus, studies began about using nutrients that improve the growth and productivity of this variety. At the forefront of these nutrients is potassium, one of the most essential nutrients necessary for plant growth after nitrogen and phosphorous (Fageria, 2016). Potassium plays a crucial role in the physiological and chemical processes inside the plant (protein synthesis, ion uptake and transport, photosynthesis, respiration, and increasing plant resistance to diseases and pests) [4, 5]. Potassium is of great importance in the advanced stages of plant life, as it increases dry matter storage in the bulbs, which causes an increase in yield and improves quality [6]. Sulfur plays an important role in increasing garlic yield and improves the quality of fruits, such as taste and flavor. It likewise contains secondary compounds of importance in terms of nutritional value and flavors, and sulfur increases plant resistance to pests and insects [7]. Adding sulfur to the soil increases the plant's ability to absorb many nutrients as it adjusts the soil PH, which increases the availability of the major elements (nitrogen, phosphorous, potassium, and sulfur). This, in turn, leads to an increase in photosynthesis and the transfer of its products to the bulbs, thus increasing the total yield per unit area [8]. The previous study aimed to identify the effect of the potassium and sulfur application method on garlic's growth, yield, and qualitative characteristics.

MATERIALS AND METHODS

A field experiment was carried out at the Agricultural Research Station of the College of Agriculture, University of Anbar, for the agricultural season 2021-2022 to identify the effect of potassium and sulfur nutrition on local garlic's growth, yield, and qualitative characteristics. The study was conducted as a combined field experiment using (RCBD) design. The field was divided into three replicates, and each replicate contained thirteen experimental units with dimensions of 2 m x 0.6 m (1.2 m^2). A field soil sample was taken before planting at a depth of (20 cm) and analyzed to determine the chemical and physical properties of the field soil, as shown in Table 1. Decomposed animal manure (cow waste) was added at 10 $t.ha^{-1}$, and the fertilizer recommendation (70, 120) P, N $kg.ha^{-1}$ was added to all experimental units. The cloves were planted on 15/9/2021 at a depth of 5 cm and in rows, as the bed contained three rows. The distance between one row and another was 20 cm, and between one plant and another was 10 cm, as the experimental unit contained 60 plants. Crop service operations were carried out, including irrigation, weeding, and preventive control whenever needed.

The study included the following combinations.

T_1: Control Treatment, Fertilizing with Fertilizer Recommendation N . P only.

T_2: Potassium 200 kg.ha^{-1} soil application at preparing the soil + spraying with potassium 5 g.L^{-1} + sulfur 40 kg.ha^{-1} soil application at preparing the soil.

T_3: Potassium 200 kg.ha^{-1} soil application at preparing the soil + spraying with potassium 5 g.L^{-1} + sulfur 50 kg.ha^{-1} soil application at preparing the soil.

T_4: Potassium 200 kg.ha^{-1} soil application at preparing the soil + spraying with potassium 10 g.L^{-1} + sulfur 40 kg.ha^{-1} soil application at preparing the soil.

T_5: Potassium 200 kg.ha^{-1} soil application at preparing the soil + spraying with potassium 10 g.L^{-1} + sulfur 50 kg.ha^{-1} soil application at preparing the soil.

T_6: Potassium 250 kg.ha^{-1} soil application at preparing the soil + spraying with potassium 5 g.L^{-1} + sulfur 40 kg.ha^{-1} soil application at preparing the soil.

T_7: Potassium 250 kg.ha^{-1} soil application at preparing the soil + spraying with potassium 5 g.L^{-1} + sulfur 50 kg.ha^{-1} soil application at preparing the soil.

T_8: Potassium 250 kg.ha^{-1} soil application at preparing the soil + spraying with potassium 10 g.L^{-1} + sulfur 40 kg.ha^{-1} soil application at preparing the soil.

T_9: Potassium 250 kg.ha^{-1} soil application at preparing the soil + spraying with potassium 10 g.L^{-1} + sulfur 50 kg.ha^{-1} soil application at preparing the soil.

T_{10}: Potassium 300 kg.ha^{-1} soil application at preparing the soil + spraying with potassium 5 g.L^{-1} + sulfur 40 kg.ha^{-1} soil application at preparing the soil.

T_{11}: Potassium 300 kg.ha^{-1} soil application at preparing the soil + spraying with potassium 5 g.L^{-1} + sulfur 50 kg.ha^{-1} soil application at preparing the soil.

T_{12}: Potassium 300 kg.ha^{-1} soil application at preparing the soil + spraying with potassium 10 g.L^{-1} + sulfur 40 kg.ha^{-1} soil application at preparing the soil.

T_{13}: Potassium 300 kg.ha^{-1} soil application at preparing the soil + spraying with potassium 10 g.L^{-1} + sulfur 40 kg.ha^{-1} soil application at preparing the soil.

The results were statistically analyzed according to the (Genstat) program, and the averages were compared according to the Least Significant Difference LSD test at a probability level of 0.05 [9].

Property	Value	Unit	Property	Value	Unit
EC	0.922	Ds.m^{-1}	Organic matter	0.54	%
PH	6.95		Available nitrogen	0.38	mg.kg^{-1}
Sand	590	g.kg^{-1}	Available phosphorous	67.2	mg.kg^{-1}
Silt	120	g.kg^{-1}	Available potassium	111.2	mg.kg^{-1}
Clay	290	g.kg^{-1}	Sulfates	25.31	Mmol.L^{-1}
Soil texture	Fine loam clay				

Table 1. Physical and chemical properties of field soils at a depth of 20 cm

Studied traits :

Vegetative growth traits: Vegetative growth traits were measured after 120 days of planting, as a random sample of six plants was selected from each experimental unit, and the following traits were estimated.

1. Leaves number ($leaf.plant^{-1}$)

Leaves area ($cm^2.plant^{-1}$): The leaf area was measured by the Digimizer program on the computer, as the fourth leaf was taken from each plant before harvesting. Then, the average was calculated according to the following equation:

$$\text{Leaf area} = \text{number of plant leaves x leaf area}$$

2. Shoot dry weight ($g.plant^{-1}$): It was estimated by taking the leaves and stalks of the bulbs at the end of the season and placing them in the electric oven at a temperature of 70 °C until the weight was constant.
3. Yield characteristics: After harvesting the crop and performing the drying treatment, a random sample of ten plants was selected from the middle of each experimental unit and the following measurements were taken:
4. Cloves number in a bulb.

Clove weight (g) by dividing the average weight of one head by the average number of cloves.

Bulb weight (g) as an average of ten bulbs was taken randomly from each experimental unit.

Total yield ($t.ha^{-1}$): using the following equation:

Total yield ton ha -1 = (experimental unit yield)/((2m) experimental unit area) x 10000m2

$$\text{Total yield t.ha}^{-1} = \frac{\text{experimental unit yield}}{\text{experimental unit area } (m^2)} \times 10000m^2$$

5. Qualitative characteristics, including:

Percentage of potassium in bulbs: The total potassium percentage was estimated according to the method mentioned in [10].

The percentage of sulfur in bulbs: according to the method mentioned in [10].

RESULTS

Vegetative growth characteristics:

The results of Table (2) indicated the superiority of the T_{13} fertilization treatment by giving the highest rate in leaves number, which amounted to $11.42.plant^{-1}$ compared with the control treatment T_1, which achieved 8.80 $leaf.plant^{-1}$, an increase in leaves area was obtained with increasing levels of fertilization, as the T_{13} treatment achieved the highest rate in leaves area, amounting to 795.00 $cm^2.plant^{-1}$, while the control treatment gave the least leaves area of 571.00 $cm^2.plant^{-1}$. The increase in leaf number and area was positively reflected in the increase in shoot dry weight, which amounted to 10.87 $g.plant^{-1}$ compared to the control treatment, which was 8.17 $g.plant^{-1}$.

Treatment	Leaves number (leaf.plant^{-1})	Leaves area (cm^2.plant^{-1})	Dry weight (g.plant^{-1})
T_1	8.80	571.00	8.17
T_2	10.07	667.66	8.72
T_3	10.18	682.00	8.81
T_4	10.31	696.00	9.09
T_5	10.40	704.66	9.21
T_6	10.56	740.00	9.30
T_7	10.68	760.00	9.36
T_8	10.75	767.00	9.50
T_9	10.83	765.66	9.59
T_{10}	10.97	769.00	9.78
T_{11}	11.02	780.33	10.27
T_{12}	11.12	786.66	10.38
T_{13}	11.42	795.00	10.87
LSD $_{0.05}$	0.39	61.61	0.28

Table 2. Effect of potassium and sulfur nutrition on vegetative growth characteristics of local garlic

Yield characteristics

The results of Table 3 indicated significant differences when using potassium and sulfur fertilization, as the T_{13} fertilization treatment achieved the highest rate in cloves number, which amounted to 37.58 cloves, compared to the control treatment, which amounted to 32.00 cloves. The high potassium and sulfur levels led to an increase in average clove weight, as the T_{13} treatment achieved the highest weight of 2.71 g, while the control treatment gave the lowest weight of 1.81 g. The increase in the number and weight of cloves led to an increase in the yield per plant, which amounted to 102.03 g, compared with the control treatment, which gave the lowest value of 58.17 g. The increase in the yield per plant was positively reflected in the increase in the total yield per unit area, which amounted to 51.01 t.ha^{-1}, while the control treatment achieved the lowest value of 29.08 t.ha^{-1}.

Table 4 showed that the T_{13} fertilizer treatment achieved the highest percentage of potassium and sulfur in the cloves, which amounted to 1.67% and 0.60%, respectively, while the comparison treatment recorded the lowest rates of 1.36% and 0.40%, respectively. The increase in the absorption of nutrients is because good nutrition with nutrients led to good vegetative growth and the transfer of photosynthesis products from the source of manufacture (leaves) to the source of storage (bulbs), which led to an increase in yield. Thus, an increase in the absorption of nutrients [17].

Treatment	Cloves number in bulb	Clove weight (g)	Plant yield (g)	Total yield ($t.ha^{-1}$)
T_1	32.00	1.81	58.17	29.08
T_2	34.32	2.37	80.74	40.37
T_3	34.74	2.40	83.59	41.79
T_4	34.78	2.46	85.82	42.91
T_5	34.89	2.49	87.03	43.51
T_6	35.40	2.52	89.25	44.62
T_7	35.41	2.54	90.12	45.06
T_8	35.64	2.56	91.40	45.70
T_9	35.70	2.58	92.32	46.16
T_{10}	36.43	2.60	94.95	47.47
T_{11}	36.83	2.64	97.34	48.67
T_{12}	37.03	2.68	99.32	49.66
T_{13}	37.58	2.71	102.03	51.01
$LSD_{0.05}$	0.74	0.12	1.01	0.50

Table 3. Effect of potassium and sulfur nutrition on the yield characteristics of local garlic

Treatment	%K	%S
T_1	1.36	0.40
T_2	1,40	0.48
T_3	1.43	0.49
T_4	1.45	0.51
T_5	1.47	0.52
T_6	1.51	0.53
T_7	1.53	0.54
T_8	1.55	0.55
T_9	1.57	0.56
T_{10}	1.60	0.57
T_{11}	1.62	0.58
T_{12}	1.64	0.59
T_{13}	1.67	0.60
$LSD_{0.05}$	0.002	0.001

Table 4. Effect of potassium and sulfur nutrition on the quality characteristics of local garlic

DISCUSSION

This superiority is attributed to the great role played by potassium fertilization by increasing the activity of various enzymes and the process of photosynthesis, thus stimulating and increasing plant growth [11]. These results agreed with [12, 13]. As well as the role of sulfur in improving the vegetative growth of plants by adjusting the soil pH, which increased the availability and absorption of nutrients and thus increased vegetative growth [14]. These results are in line with what was found by [15].

The increase in yield is attributed to the presence of potassium in the soil solution in sufficient quantity, which improves absorption efficiency, stimulates and increases plant growth, and is positively reflected in the increase in yield and its components. However, potassium is important in transporting carbohydrates from the leaves to the storage areas (bulbs) [16]. These results agreed with the findings of [6], who showed that the total yield, bulb weight, and clove weight increased significantly with the increase of the soil application and foliar spraying of potassium as well as the role of sulfur in improving the absorption of nutrients by adjusting the soil pH, which increases the availability of the elements and increases their absorption by plants, which may lead to the formation of a good shoot and the transfer of photosynthetic products to the bulbs, thus increasing the total yield [8].

CONCLUSION

From the study results, it can be concluded that the increase in the levels of fertilization with potassium and sulfur gave a significant increase in the characteristics of vegetative growth, and this was positively reflected in the yield components and the total yield, as well as improving the quality of the resulting bulbs, and this was evident through the increase in the concentration of potassium and sulfur in the bulbs. The soil and foliar fertilization with potassium, especially in the early stages of plant life, was effective in increasing the vegetative growth and plant yield, so it is preferable to increase the levels of fertilizing with potassium and sulfur (within the economic limits) to obtain the best growth, yield, and quality.

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