ARTICLE / INVESTIGACIÓN

Effect of chemical fertilizer and humic acid on cabbage leaves' N, P, K and S concentrations (*Brassica oleracea* var. capitata L.)

Miaad Ibrahim Turki, Basem Rahem Bader*
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Department of Soil Science and Water Resources, College of Agriculture, University of Diyala, Iraq.
Corresponding author: basemrbader@uodiyala.edu.iq

Abstract: A field study was carried out in one of the fields of Jdeidet Al-Shatt district is, located 30 km from the center of Baquba in Diyala governorate, during the autumnal season 2021-2022 on silty loam soil classified to a level under the Typic Torrifluvent according to the modern American classification to know the effect of adding chemical fertilizer and humic acid on the availability of nitrogen, phosphorus and potassium concentrations for cabbage leaves, according to of randomized complete block design (RCBD) by using three replicates. The first factor was the chemical compound fertilizer NPK(20:20:20) added at three different levels 0, 150 kg ha^{-1}, 300 kg ha^{-1}, while the second factor was humic acid at three levels 0, 15 kg ha^{-1}, 30 kg ha^{-1}. Fertilizers were added to the soil by making an incision around the plant and were added in two stages, the first when planting and the second 43 days after the date of the first batch. The results of the study showed that adding chemical fertilizer at a level of 300 kg ha^{-1} led to significant differences in the concentrations of nitrogen, phosphorous, potassium and sulfur elements in the inner leaves, where the concentrations of elements reached 2.55%,0.34%, 2.95%,1.36% respectively, the outer leaves. In contrast, the concentrations of nitrogen, phosphorous and potassium reached 4.00 %, 0.34%, and 2.67%, respectively, While the superiority of the humic acid at the level of 30 kg ha^{-1} to 2.33%, 0.32%, 2.77%,1.47% in the inner leaves, respectively, while in the outer leaves 3.80 %,0.31 %,2.49%.

Key words: Chemical fertilizer, humic acid, concentrations of N,P, K and S, cabbage.

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Introduction

The cabbage crop is one of the most important winter vegetables in Iraq. It is a vegetable of great economic importance all over the world. It has high nutritional properties that are low in fat and protein and a high content of vitamins, fiber and minerals[1]. What distinguishes it from other vegetables is that it contains glucosinolate compounds, which are sulfur-rich compounds that protect against cancer[2]. Nitrogen, phosphorous and potassium are essential elements for the plant of cabbage, as this nutrient faces many challenges in the soils of dry and semi-arid regions of the world, including Iraqi soils due to high temperatures and low rainfall, which causes a decrease in its content of organic material and a high degree of interaction Soil resulting from the presence of calcium carbonate, which causes a decrease in soil fertility as a result of exposure of the added elements to the soil to the processes of loss and stabilization[3]. Nitrogen is an important and crucial element in plant growth and development. Its deficiency leads to a decrease in plant productivity by reducing the content or activity of enzymes involved in the process of carbon metabolism, leaf area and the longevity of green leaves, As well as its deficiency leading to plant aging[4]. Phosphorous is one of the main elements in regulating the reactions of the carbonic metabolism process and an essential source of energy and regulation of the breathing process. It is also included in the composition of the cytoplasm, the nucleus, nuclear proteins and lipid derivatives, as well as some enzymes. It is essential in cell division; it helps roots to early growth and spread in the soil. It also helps in early flowering, seed production and fruit ripening[5]. Potassium is one of the essential nutrients for plants, and it is required in large quantities for the growth and reproduction of plants. Potassium is in second place after nitrogen; its deficiency leads to a severe change in various physiological processes[6]. To increase the amount of agricultural production to meet the world's food requirements, it is necessary to find alternative and cheap ways at the same time working to reduce the loss of elements from the soil, as the use of humic acid (HA) is a major component of humic substances, which were found in different sources such as soil, humus, peat, lignite, and coal, and that the molecular structure of humic acid is the reason for the activity of these compounds due to the large number of functional groups present in each loop[7,8]. It effectively influences nutrients from the soil, as it increases the availability or transfer of significant elements, including nitrogen, phosphorous and potassium; it was considered a supplement to chemical fertilizers and reduces the costs of production inputs of agricultural crops. It doesn't take time to decompose free from seeds, weeds, bushes and pathogens compared to conventional organic fertilizers[9-11]. The use of humic acid with chemical fertilizer, according to the fertilizer's recommendation, works to hold the elements in the soil when added as a mixture or feed in the soil. This makes it ready for absorption by the plant for a long time in the soil. This leads to an increase in the availability of elements in the soil[12]. Because of the importance of cultivating the cabbage plants in Iraq, the study aimed to: Know the effect of adding NPK and humic acid fertilizers and the interaction between them on nitrogen, phosphorus and potassium concentrations for cabbage leaves.

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Materials and methods

A field study was carried out in one of the agricultural fields in Jdeidet Al-Shatt sub-district of Al-Khalis district, located 30 km from the center of Baquba in Diyala gover during the autumnal season 2021-2022 norate on silty loam soil classified to a level under the Typic Torrifluvent according to the modern American classification. It is located at 44°25'33.2868" east longitude and 33°37'29.172" north latitude to study the effect of adding chemical fertilizer NPK and humic acid on the nitrogen concentration, phosphorus and potassium in cabbage leaves. It can be conducted by adding the balanced compound chemical fertilizer NPK(20:20:20) at three different levels, which are 0 without addition, 150 kg ha^{-1}, and 300 kg ha^{-1} according to the Fertilization Recommendation[13]. It is also symbolized by C1, C2, and C3 in sequence, and the second factor is humic acid in three levels, 0(without adding), 15 kg ha^{-1} and 30 kg ha^{-1}. A sample was taken randomly from different places at a depth of 30 cm. It was mixed to become a composite sample representative of the study soil. The soil was dried and ground with a wooden hammer and passed through a sieve with a holes diameter of 2 mm to conduct some physical and chemical analyses, whose results are shown in Table 1.

Soil preparation processes for cultivation include plowing and softening the soil. It has been divided into three sectors; each sector contains 9 factors, the dimensions of the experimental unit are 3 * 2.5m2, and the experimental unit contains 4 lines. The number of plants in the experimental unit was 24, and the number of plants in each line was 6 plants. The planting was also done on the terraces; the width of the balcony was 50 cm. The seedlings were planted on one side of the terrace. The distance between one plant and another was 40 cm, between one experimental unit and another was 100 cm, and between one sector and another was 100 cm. The seedlings were also planted in the field on 9/24/2021, and the ground addition of the chemical fertilizer NPK and humic acid was conducted in two stages. The first is during the planting process, and the second is in the stage before the appearance of the head, which is after 43 days. This can be accomplished by making an incision in the soil around the plant. Measurements were also taken from plant samples in two stages, the first stage before the emergence of the head and the second stage of completion of the maturity of the head. The plant samples were prepared for elemental determination in the soil science and water resources laboratories College of Agriculture, University of Diyala.

Measuring the concentration of nitrogen in leaves (%)

Nitrogen was estimated by adding sodium hydroxide to the digested vegetable sample and extracted by using the Micro Kjeldahl apparatus[14].

Measuring the concentration of phosphorous in leaves (%)

It was estimated by adding ammonium molybdate and ascorbic acid. As well as it was measured at a wavelength of 882 nm by using a spectrophotometer[15].

Measurement of potassium concentration in leaves (%)

It was estimated by the flame apparatus[14].

Measurement of sulfur concentrations in leaves (%)

It was estimated by the turbidity method by adding barium chloride and measured at a wavelength of 420 nm using a spectrophotometer[16].

Results

The concentration of nitrogen in the Inner leaves (%)

Table 3 shows significant differences between adding chemical fertilizers and humic acid effect on the means of nitrogen element concentrations in the inner leaves. The C2 and C3 treatments were significantly superior, with the highest norm reaching 2.03 and 2.55% compared to the C1 treatment, which amounted to 1.57%, with an increased rate of 29.29% and 62.42%, respectively. It was the effect of adding humic acid, the mean of H2 and H3 treatments which amounted to 2.06% and 2.33%, respectively, showed significant superiority over the H1 treatment, which amounted to 1.76%, with an increase of 17.04% and 32.38%,

Soil Properties		values	Unit
Electrical conductivity EC (1:1)		2.6	dSm^{-1}
Soil pH (1:1)		7.7	
Calcium Carbonate		242.06	$g\ kg^{-1}$
Organic matter		8.08	
Available nutrients			
available nitrogen		30.00	$mg\ kg^{-1}$
available phosphorous		12.87	
available potassium		307.01	
Bulk density		1.36	$Mg\ m^{-3}$
Soil particles			
	clay	27.68	%
	silt	51.68	
	sand	20.64	
soil texture		Silty loam	
Field capacity		27	%

Table 1. Soil properties study before planting

Adjective	the value
Humic acid	53%
Fulvic acid	12%
K2O	17%

Table 2. Guaranteed contents of organic fertilizer (humistar).

	C1	C2	C3	
H1	1.09 g	1.97 def	2.23 bc	1.76 C
H2	1.75 f	2.01 cde	2.43 b	2.06 B
H3	1.88 ef	2.11 cd	3.01 a	2.33 A
	1.57 C	2.03 B	2.55 A	

Table 3. Effect of adding chemical fertilizer, humic acid and the interaction between them on nitrogen concentrations in the inner leaves at the stage of full maturity of the head (%).
* The symbols in the table indicate: C = chemical fertilizer where C1 = 0 without addition, C2 = 150 kg ha^{-1}, C3 = 300 kg ha^{-1} and H = humic acid where H1 = 0 without addition, H2 = 15 kg ha^{-1},H3= 30 kg ha^{-1}. Means with similar letters are not significantly different from each other according to Duncan's polynomial test at 0.05% probability level.

respectively. As for the effect of the interaction, the C3H3 treatment showed that it was significantly superior, which amounted to 3.01%, the maximum value and the minimum value when the C1H1 control treatment, which amounted to 1.09%, and an increased rate of 176.14%.

The concentration of phosphorous in the Inner leaves (%)

Table 4 shows that the addition of chemical fertilizer and humic acid in the average phosphorous element concentrations in the inner leaves was significantly superior to the C2 and C3 treatment, which reached the highest average of 0.28 and 0.34% compared to the C1 treatment, which amounted to 0.25%, respectively with an increase of 12% and 36%.

Results in table 4 show the effect of adding humic acid on phosphorus concentrations in the inner leaves; the treatment H3 reached 0.32% and showed a significant superiority to the H1 treatment, which amounted to 0.27%, with an increase of 18.51%. As well as the effect of the interaction, it gave the C3H3 treatment was significantly superior, which amounted to 0.39%, with the maximum value and the minimum in the treatment C1H1 control, which amounted to 0.23% and an increase of 69.56%.

The concentration of potassium in the inner leaves (%)

Table 5 shows significant differences in the addition of chemical fertilizer and humic acid on potassium concentrations in the inner leaves, as the C2 and C3 treatments were significantly superior, which reached the highest mean of 2.67 and 2.95%, respectively, compared with the C1 treatment, which amounted to 2.39%, with an increase of 11.71% and 23 .43%. Results in table 5 show the effect of adding humic acid on potassium concentrations in the inner leaves; the treatment H3 reached 2.77% and showed a significant superiority over the H1 treatment, which amounted to 2.59%, with an increase of 6.94%. As for the effect of the interaction, the C3H3 treatment showed that it was

	C1	C2	C3	
H1	0.23 d	0.27 cd	0.30 bc	0.27 B
H2	0.26 cd	0.27 cd	0.33 b	0.28 B
H3	0.27 cd	0.29 bc	0.39 a	0.32 A
	0.25 C	0.28 B	0.34 A	

Table 4. Effect of adding chemical fertilizers and humic acid and the interaction between them on phosphorous concentrations in the inner leaves at the stage of full maturity of the head (%).
* The symbols in the table indicate: C = chemical fertilizer where C1 = 0 without addition, C2 = 150 kg ha^{-1}, C3 = 300 kg ha^{-1} and H = humic acid where H1 = 0 without addition, H2 = 15 kg ha^{-1}, H3= 30 kg ha^{-1}. Means with similar letters are not significantly different from each other according to Duncan's polynomial test at 0.05% probability level.

	C1	C2	C3	
H1	2.31 e	2.62 cd	2.86 abc	2.59 B
H2	2.33 e	2.66 cd	2.93 ab	2.64 B
H3	2.54 de	2.74 bcd	3.05 a	2.77 A
	2.39 C	2.67 B	2.95 A	

Table 5. Effect of adding chemical fertilizer and humic acid and the interaction between them on potassium concentrations in the inner leaves at the stage of full maturity of the head (%).
* The symbols in the table indicate: C = chemical fertilizer where C1 = 0 without addition, C2 = 150 kg ha^{-1}, C3 = 300 kg ha^{-1} and H = humic acid where H1 = 0 without addition, H2 = 15 kg ha^{-1},H3= 30 kg ha^{-1}. Means with similar letters are not significantly different from each other according to Duncan's polynomial test at 0.05% probability level.

significantly superior, which amounted to 3.05%, the maximum value and the minimum when the C1H1 control treatment, which amounted to 2.31%, and an increased rate of 32.03%.

The concentration of sulfur in the Inner leaves (%)

Table 6 shows significant differences in the addition of chemical fertilizer and humic acid on concentrations of sulfur in the inner leaves; there were no significant differences in the treatments of the chemical fertilizer, humic acid, the average H3 treatment, which amounted to 1.47%, showed a significant superiority over the H1 treatment, which amounted to 0.59%, with an increase of 149.15%,As for the effect of the interaction, the treatment of it gave C3H3 showed significant superiority, which amounted to 1.85%, the maximum value and the minimum with value for treatment C1H1 control which amounted to 0.56% and an increase of 230. 35%.

The concentration of nitrogen in the outer leaves (%)

Table 7 shows The effect of adding chemical fertilizer and humic acid on the means concentrations of nitrogen in the outer leaves. The C2 and C3 treatments were significantly superior, which reached the highest average of 3.71 and 4.00%, respectively, compared to the C1 treatment, which amounted to 3.44%, with an increase of 7.84% and 16.27 %, respectively. The effect of adding humic acid treatment was 3.63%, and the average H3 treatment amounted to 3.80%, with an increase of 4.68%. As for the effect of the interaction, the C3H3 treatment showed that it was significantly superior, which amounted to 4.12%, the maximum value and the minimum value when the C1H1 control treatment, which amounted to 3.34%, and an increased rate of 23.35%.

The concentration of phosphorous in the outer leaves (%)

Table 8 shows the effect of adding chemical fertilizers and humic acid phosphorous concentrations in the outer leaves, as the C2 and C3 treatments were significantly superior, which reached the highest mean of 0.28 and 0.34% compared to the C1 treatment, which amounted to 0.25%, respectively, with an increase of 12% and 36% respectively. Results in table 8 show the effect of adding humic acid on concentrations of phosphorous in the outer leaves; the treatment H3 reached to 0.31%, showed a significant superiority over the H1 treatment, which amounted to 0.27%, with an increase of 14.81%, As for the effect of the interaction, it gave the C3H3 treatment showed that it was significantly superior, which amounted to 0.37%, the maximum value and the minimum value when the C1H1 control treatment, which amounted to 0.23%, and an increased rate of 60.86%.

The concentration of potassium in outer leaves (%)

Table 9 shows the effect of adding chemical fertilizers and humic acid concentrations of potassium in the outer leaves, as the C2 and C3 treatments were significantly superior, which reached a higher mean of 2.35 and 2.67% compared to the C1 treatment, which amounted to 2.06%, respectively, with an increase of 14.07 % 29.61%. Concerning the addition of humic acid, the average H3 treatment, which amounted to 2.49%, showed a significant superiority to the H1 treatment, which amounted to 2.24%, with an increase of 11.16%. As for the effect of the interaction, the treatment of it gave C3H3 showed that it was significantly superior, which amounted to 2.82%,%, the maximum value and the minimum with value when the treatment C1H1 control, which amounted to 1.92%, and an increased rate of 46.87%.

Discussion

It is evident from tables (3,4,6,7,8,9) that there were significant differences between the treatments of the compound chemical fertilizer NPK. The reason may be due to the role of fertilizer and increasing the leaves' concentrations of nutrients N, P, and K. This increases the activity of

	C1	C2	C3	
H1	0.56 c	0.58 c	0.63 bc	0.59 B
H2	1.20 abc	1.26 ab	1.59 a	1.35 A
H3	1.26 ab	1.30 a	1.85 a	1.47 A
	1.01 A	1.04 A	1.36 A	

Table 6. Effect of adding chemical fertilizer and humic acid and the interaction between them on sulfur concentrations in the inner leaves at the stage of full maturity of the head (%).
* The symbols in the table indicate: C = chemical fertilizer where C1 = 0 without addition, C2 = 150 kg ha^{-1}, C3 = 300 kg ha^{-1} and H = humic acid where H1 = 0 without addition, H2 = 15 kg ha^{-1}, H3= 30 kg ha^{-1}. Means with similar letters are not significantly different from each other according to Duncan's polynomial test at 0.05% probability level.

	C1	C2	C3	
H1	3.34 e	3.66 d	3.90 bc	3.63 B
H2	3.44 e	3.71 cd	3.99 ab	3.71 AB
H3	3.55 de	3.74 cd	4.12 a	3.80 A
	3.44 C	3.71 B	4.00 A	

Table 7. Effect of adding chemical fertilizers and humic acid and the interaction between them on the nitrogen concentrations of the outer leaves after the head maturity (%).
* The symbols in the table indicate: C = chemical fertilizer where C1 = 0 without addition, C2 = 150 kg ha^{-1}, C3 = 300 kg ha^{-1} and H = humic acid where H1 = 0 without addition, H2 = 15 kg ha^{-1},H3= 30 kg ha^{-1}. Means with similar letters are not significantly different from each other according to Duncan's polynomial test at 0.05% probability level.

	C1	C2	C3	
H1	0.23 f	0.27 de	0.32 bc	0.27 B
H2	0.26 ef	0.29 cde	0.33 b	0.29 AB
H3	0.27 def	0.30 bcd	0.37 a	0.31 A
	0.25 C	0.28 B	0.34 A	

Table 8. Effect of adding chemical fertilizers and humic acid and the interaction between them on phosphorous concentrations in the outer leaves at the stage of full maturity of the head (%).
* The symbols in the table indicate: C = chemical fertilizer where C1 = 0 without addition, C2 = 150 kg ha^{-1}, C3 = 300 kg ha^{-1} and H = humic acid where H1 = 0 without addition, H2 = 15 kg ha^{-1},H3= 30 kg ha^{-1}. Means with similar letters are not significantly different from each other according to Duncan's polynomial test at 0.05% probability level.

	C1	C2	C3	
H1	1.92 g	2.29 de	2.53 bc	2.24 B
H2	2.07 fg	2.33 cde	2.65 ab	2.35 B
H3	2.21 ef	2.44 cd	2.82 a	2.49 A
	2.06 C	2.35 B	2.67 A	

Table 9. Effect of adding chemical fertilizer and humic acid and the interaction between them on potassium concentrations in the outer leaves at the stage of full maturity of the head (%).
* The symbols in the table indicate: C = chemical fertilizer where C1 = 0 without addition, C2 = 150 kg ha^{-1}, C3 = 300 kg ha^{-1} and H = humic acid where H1 = 0 without addition, H2 = 15 kg ha^{-1},H3= 30 kg ha^{-1}. Means with similar letters are not significantly different from each other according to Duncan's polynomial test at 0.05% probability level.

physiological processes in the plant, including building proteins, carbohydrates and the process of carbon metabolism, which causes rapid growth, which reflects positively on the plant, and this is what had reached[17]. They explained that the nitrogen, phosphorous and potassium concentrations range between 2.77 -3.17%, 0.27-0.20% and 3.97-2.80%, respectively. These concentrations fall within their standard limit. As for the moral increase achieved by humic acid, it may be attributed to the role of acid in increasing the plant's content of nutrients and plant hormones such as auxins and cytokinins, which work to increase the division of meristematic cells, which leads to an increase in the size of the plant and stimulates enzymatic reactions and humic acid works to improve the permeability of the membranes. Thus, it increases the uptake of elements, including N, P, K, Mg, and Ca, which become available and ready for uptake in the plant's root system[18,19]. As for Table 6, there was a significant difference between the treatments of humic acid in the percentage of sulfur in the leaves. It may help to release the nutrients associated with minerals and salts in the soil. As well as it was found that 95% of the sources of sulfur are linked in the soil organically, as humic acid improves the biological properties of the soil as the soil microorganisms work to convert organic sulfur into mineral sulfur as $SO4^{-2}$ is ready for plant uptake[9,20-22].

Conclusions

The addition of the chemical fertilizer 300 kg ha^{-1} led to an increase in the concentrations of nutrients (N, P, and K) in the inner and outer leaves of cabbage. The addition of humic acid 30 kg ha^{-1} led to increased nitrogen, phosphorous, potassium and sulfur concentrations in the leaves.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

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