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ROLE OF ACIDIFIED WATER, PHOSPHORUS, IRON AND ZINC LEVELS IN NUTRIENT UPTAKE OF P, Fe, Zn AND PRODUCTIVITY OF CABBAGE

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ABSTRACT

A field experiment was conducted to study the role of acidified water, phosphorus, iron and zinc levels in nutrient uptake of P, Fe, Zn and the productivity of Cabbage (*Brassica Oleracea* L.) in the field of agricultural engineering sciences university of Baghdad/ Iraq for autumn season 2021 in silty loam texture soil classified to sub under great group Typic-Torriflovent. A Randomized Complete Block Design (RCBD) was used with three replicates including acidified water with Sulphuric acid H_2SO_4 added at concentration of (0 and 0.02 *N*) with irrigation water using drip irrigation system, phosphorus was added to the soil at a level of (0, 50, 75 and 100%) from the fertile recommendation (65 kg P ha^{-1}), iron was added to the soil at a level of 10 kg Fe ha^{-1}, and zinc was added to the soil at a level of 5 kg Zn ha^{-1}. The results show that there were significant effect of a result of adding Sulfuric acid H_2SO_4, Phosphorus, Iron and Zinc to the soil and their interactions on phosphorus, iron and zinc uptake in the leaves, head diameter and plant yield, However, the addition of Sulfuric acid, Phosphorus and zinc to the soil (0.02 *N* + 65 kg P ha^{-1} + 5 kg Zn ha^{-1}) achieved the highest of phosphorus, iron and zinc uptake in the leaves which was 2029.44 mg P $plant^{-1}$, 588.808 mg Fe $plant^{-1}$ and 240.319 mg Zn $plant^{-1}$ respectively and head diameter was 19.04 cm and plant yield was 1.82 kg $plant^{-1}$ with an increasing of 55.55% compared to the $A_0P_0S_0$ treatment which achieved a head weight of 1.17 kg $plant^{-1}$.

We recommend to adding Sulphuric acid, Phosphorus and zinc for increasing the availability of phosphorus and micronutrients in soil that are necessary for plant growth.

Keywords: Acidified water; Phosphorus; Zinc; Iron; Cabbage.

دور المياه المحمضة ومستويات الفسفور والحديد والزنك في محتوى P و Fe و Zn في النبات وانتاجية اللهانة

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الخلاصة

نفذت تجربة حقلية في احد الحقول الزراعية التابعة لكلية علوم الهندسة الزراعية/ جامعة بغداد مجمع الجادرية خلال الموسم الزراعي الخريفي 2021 لدراسة دور المياه المحمضة ومستويات الفسفور والحديد والزنك في محتوى P و Fe و Zn في النبات وانتاجية اللهانة، اضيف حامض الكبريتيك التجاري H_2SO_4 بتركيز 0 و 0.02 *N* ، اضيف مع ماء الري بأستعمال نظام الري بالتنقيط، واضيف الفسفور الى التربة بمستوى (0 ، 50 ، 75 و 100 %) من التوصية السمادية، واضيف الحديد الى التربة بمستوى 10 كغم Fe هـ-1 واضيف الزنك الى التربة بمستوى 5 كغم Zn هـ-1 .

[*]**The article is taken from the doctoral thesis of the first researcher.**

أظهرت النتائج التاثير المعنوي لاضافة المياه المحمضة والفسفور والحديد والزنك الى التربة وتداخلاتها في الفسفور والحديد والزنك الممتص في اوراق اللهانة وقطر الرأس وحاصل النبات، اذ اعطت معاملة التداخل بين إن إضافة حامض الكبريتيك والفوسفور والزنك إلى التربة بمستوى (0.02 *N* + 65 كغم P ه-1 + 5 كغم Zn ه-1) اعلى فوسفور والحديد والزنك ممتص في الاوراق بلغ 2029.44 ملغم P نبات-1، 588.80 ملغم حديد نبات-1 و 240.319 ملغم زنك نبات-1 على التوالي وقطر رأس بلغ 19.04 سم وحاصل النبات الواحد بلغ 1.82 كغم نبات-1 وبنسبة زيادة بلغت 55.55% مقارنة بمعاملة المقارنة والتي أعطت وزن رأس بلغ 1.17 كغم نبات-1.

نوصي بإضافة حامض الكبريتيك التجاري والفوسفور والزنك لزيادة جاهزية الفوسفور والمغذيات الصغرى في التربة والضرورية لنمو النبات.

الكلمات المفتاحية : المياه المحمضة، فسفور، زنك، حديد، لهانة

INTRODUCTION

Iraq's soil is characterized by a high content of $CaCO_3$ which ranges between 10-45% and soil pH tends to be alkaline and is saturated with calcium ions. This soil suffers from a lack of availability of many nutrients such as phosphorus, which is subject to sedimentation and sedimentation in the soil or interaction with calcium carbonate, which leads to a lack of availability for plants **(Al-Hassoon *et al.*, 2019; Ali *et al.*, 2022)**. Therefore, recent studies tended to add conditioners to soil with acidic action in order to reduce the problems of these calcareous soils and increase their ability to process and absorb nutrients by the plant, reflecting an increase in the plant's yield and components **(Jozdaemi & Golchin, 2017; Umar, 2021)**. Thus, H_2SO_4 commercial sulphuric acid can be used in Iraqi soil by adding directly to the soil or with irrigation water, especially when commercial sulphuric acid is cheap to spread its production sources in Iraq for the purpose of increasing the availability of phosphorus and other elements such as iron, zinc in the soil **(Al-Dulaimi & Marjan, 2014 ; Al-Fatlawi & Al-Dulaimi, 2015 ; Salih, 2021)**.

Phosphorus is an essential nutrient in plant growth and nutrition and is called the key to life for its immediate role in most vital processes within plants. Nitrogen and potassium components, a major essential nutrient that is important to the plant but needs it in smaller quantities than nitrogen and potassium, the ratio in plant tissue ranges from 0.2 to 0.5% of the plant's dry weight with a lower degree than nitrogen. Phosphorus is involved in the formation of phospholipids and enzyme accompaniments such as Nicotinamide adenine dinucleotide and Nicotinamide adenine dinucleotide phosphate which play an important role in most oxidation processes and the formation of most energy-rich compounds that act as co-factors for enzymes in the plant such as adenosine triphosphate. This energy is formed as a result of photosynthesis by photosphorylation or as a result of breathing by oxygenation and Nicotinamide adenine dinucleotide phosphate which gives an estimated energy of 52,000 kcal mol^{-1} **(Havlin *et al.*, 2017)**.

Iron is one of the most important micronutrients necessary for plant growth and development, a vital ingredient for many participating enzymes or as cofactors in metabolism and atmospheric nitrogen stabilizers, which has a positive effect on improving plant growth and increasing plant production in quantity and quality. Iron contributes to the synthesis and activity of many enzymes, including: NO_2 reductase, NO_3 reductase, Nitrogenase, oxidase Cytochrome, Aconitase, Catalase, Peroxidase and dehydrogenase enzymes, as well as contributing significantly to the synthesis, representation and degradation of chlorophyll, although it does not enter into its chemical composition **(Ali *et al.*, 2022)**.

Zinc is a micronutrient necessary for plant growth that plays an important role in various physiological processes occurring within a plant such as carbon metabolism, protein synthesis, grain production, plant growth regulation and its lack of physiological pathways that adversely affect plant productivity leading to lower yield and poor quality**.** Zinc is involved in the formation of nuclear acids Ribonucleic acid (RNA) and deoxyribonucleic acid (DNA) and in the formation and representation of protein as well as has an important role in nitrogen transitions. Zinc has an important role to play in increasing immunity in humans and so scientists are biologically enriching it in fruits, seeds and vegetable crops **(Ali *et al.*, 2022)**.

Cabbage (*Brassica oleracea* L.) is a winter and major vegetable crop grown in Iraq in most of its regions and belonging to the Crusader family. (Brassicaceae), and there are about 300 genders and 3,000 species of this family all over the world, It has a high nutritional value with every 100 gm of wrapped leaves containing 94% water, 1 gm protein, 6.1-11.2% dry matter, 1-2% fat, 3.0-5.4% carbohydrate, 24 calories and contains a group of vitamins that the human body needs about 30-50 mg vitamin C, 130 mg Vitamin A and Vitamin B1, B2 and C and contains 49mg P, 238mg K, 1.20mg Fe, 9mg Mg, and 0.05mg thiamine **(Porras *et al.*, 2011)**.

The aim of the study is to study the Role of acidified water, phosphorus, zinc and iron levels in nutrient uptake of P, Fe, Zn and the productivity of Cabbage (*Brassica Oleracea* L.)

MATERIALS AND METHODS

A field experiment was conducted to study the role of acidified water, phosphorus, iron and zinc levels in nutrient uptake of P, Fe, Zn and the productivity of Cabbage (*Brassica Oleracea* L.) in the field of agricultural engineering sciences university of Baghdad/ Iraq for autumn season 2021 in silty loam texture soil classified to sub under great group Typic-Torriflovent, located within latitude 33.270 north and longitude 44.390 east, A randomized complete block design RCBD was used with three replicates. The field was divided into three replicates. The area of the experimental unit was 6 m^2. The experimental unit included four lines of 2 m in length and the distance between lines was 70 cm, and spacing of 1 m between each experimental unit, and spacing of 2 m between sectors. The spacing between plants was 40 cm. The number of experimental units was 72 experimental unit. Soil samples were taken before planting at (0-30 cm) depth. A representative sample was taken from it for chemical and physical analysis of soil (Table 1).

Acidified water with Sulphuric acid H_2SO_4 added at concentration of 0 and 0.02 *N*, with irrigation water using drip irrigation system and symbolized as A_0 and A_1 respectively, phosphorus TSP (20% P) was added to the soil at four levels (0, 50, 75 and 100%) from the fertile recommendation (65 kg P ha^{-1}) symbolized by P_0, P_1, P_2 and P_3 respectively, Iron was added to the soil using $FeSO_4.7H_2O$ (20% Fe) at 10 kg Fe ha^{-1} its symbolized as S_1. Zinc was added to the soil using $ZnSO_4.7H_2O$ (23 %Zn) at 5 kg Zn ha^{-1} and it is symbolized as S_2, and a treatment without addition it is symbolized as S_0. Nitrogen fertilizer was added to the soil at 150 kg N ha^{-1}, while potassium fertilizer was added to the soil at 125 kg K ha^{-1}.

Table (1): Physical and Chemical properties of the soil.

Properties	Value	Unit
EC (1:1)	3.66	ds m^{-1}
pH (1:1)	7.34	-
$CaCO_3$	287.00	gm kg^{-1} soil
active lime	80.57	gm kg^{-1} soil
O.M	15.97	gm kg^{-1} soil
Available N	41.08	mg kg^{-1} soil
Available P	14.53	
Available K	207.49	
Available Zn	2.12	
Available Fe	3.07	
Clay	643	gm kg^{-1} soil
Sand	155	
Silt	202	
Soil texture	Silty loam	

Cabbage (Glob Master) were planted on 2/10/2021, and the seedlings were transferred to the field on 9/11/2021. They were planted with spacing of 40 cm with 5 plants in each line and with 20 plants in each experimental unit.

RESULTS AND DISCUSSION

Phosphorus uptake in leaves

The results of table (2) showed that there were significant effect of adding phosphate to the soil in the phosphorus uptake in the leaves, the treatment P_3 excelled and achieved phosphorus uptake of 1621.37 mg P $plant^{-1}$ with an increase of 92.92% compared to P_0 which achieved phosphorus uptake of 840.40 mg P $plant^{-1}$, this is attributed to the increase in the availability of phosphorus in the soil when adding phosphate fertilizer to the soil as a result of its containing phosphorus, which led to its availability for the plant and then increased its uptake by plants and its accumulation in the leaves. The uptake sites in the roots are an important source of energy for the biological uptake of phosphorus from the soil solution **(Havlin *et al.*, 2017)**, the results agree with **Zbar *et al.* (2021); Al-Mashhadany & Al-Mharib (2023)**.

The results of the same table showed a significant effect of adding iron on soil, as S_1 excelled and achieved phosphorus uptake in the leaves of 1216.58 mg P $plant^{-1}$ with an increase of 12.66% compared to S_0 which It achieved phosphorus uptake of 1079.82 mg P $plant^{-1}$, the reason is attributed to the increase in the availability of phosphorus in the soil as the addition of ferrous sulfate to the soil as a result of the oxidation of sulfur and the formation of sulfuric acid and the increase in the concentration of hydrogen ions in the soil and thus the dissolution of some phosphorus-containing compounds and the liberation of the retained phosphorus and its transformation into the ready form and its uptake by plants **(Li *et al.*, 2023)** the results agree with **Sahin *et al.* (2013)**.

The results of the same table showed a significant effect of adding zinc on soil, as S_2 treatment exceeded and achieved phosphorus uptake in the leaves of 1346.53 mg P plant^{-1} with an increase of 24.69% compared to S_0 which It achieved phosphorus uptake of 1079.82 mg P plant^{-1}, the reason is attributed to the role of zinc sulfate fertilizer contains zinc, which has an important role in stimulating plant growth and increasing the process of carbon metabolism, which is related to the respiration process, formation of chlorophyll, activity of various enzymes, development of root cells and increase in the growth of the root system **(Reddy & Kumari, 2022)**, the results agree with **Rivera-Martin *et al.* (2020)**.

The results of table (2) also showed a significant effect of adding sulfuric acid H_2SO_4 with irrigation water to the soil on phosphorus uptake in the leaves. Treatment A_1 excelled and achieved phosphorus uptake in the leaves of 1392.23 mg P plant^{-1}, with an increase of 34.33% compared to A_0 which It achieved phosphorus uptake of 1036.39 mg P plant^{-1}, the reason is attributed to the role of sulfuric acid in the interaction with soil components which led to the release the nutrients, including phosphorous, which encouraged plants to uptake it from the soil solution **(Ryan & Stroehlein, 1979 ; Goulding, 2016)**, the results agree with **Al-Dulaimi & Morgan (2014); Salih (2021); Abdul Qadir *et al.* (2022)**.

Table (2): Effect of Irrigation with acidified water and phosphorous, iron and zinc on phosphorus uptake in the leaves (mg P plant^{-1}).

Sulfuric Acid H_2SO_4 A	Phosphorus P	Iron and Zinc S			Mean A x P
		S_0	S_1	S_2	
A_0	P_0	576.72	677.44	717.68	657.28
	P_1	756.97	918.95	1010.60	895.50
	P_2	1002.24	1158.82	1316.89	1159.32
	P_3	1286.48	1396.12	1617.77	1433.46
A_1	P_0	883.28	1036.86	1150.46	1023.53
	P_1	1088.95	1267.58	1237.27	1197.93
	P_2	1413.10	1509.24	1692.14	1538.16
	P_3	1630.80	1767.64	2029.44	1809.29
Sulfuric Acid H_2SO_4		Mean A x S			Mean A
A_0		905.60	1037.83	1165.73	1036.39
A_1		1254.03	1395.33	1527.33	1392.23
Phosphorus P		Mean P x S			Mean P
P_0		730.00	857.15	934.07	840.40
P_1		922.96	1093.26	1123.93	1046.72
P_2		1207.67	1334.03	1504.51	1348.74
P_3		1458.64	1581.88	1823.60	1621.37
Iron and Zinc S		1079.82	1216.58	1346.53	
$LSD_{0.05}$	A	P	S	A * P	
	170.57	87.74	57.96	142.49	
$LSD_{0.05}$	A x S		P x S	A x P x S	
	132.48		110.73	175.75	

The results of table (2) also show that there are significant effect of the triple interaction between the addition of sulfuric acid H_2SO_4 with irrigation water and fertilization with phosphorus, iron and zinc to the soil in the phosphorus uptake in the leaves, the results of the same tables showed a significant effect, as the treatment $A_1P_3S_2$ excelled and achieved phosphorus uptake of 2029.44 mg P plant^{-1} with an increase of 251.89% compared to $A_0P_0S_0$, which gave an phosphorus uptake of 576.72 mg P plant^{-1}.

This result confirms the importance of adding sulfuric acid with phosphorous, iron and zinc to the soil in increasing the availability of phosphorus in the soil and its uptake by the plant to obtain the highest phosphorus uptake in the leaves.

Iron uptake in leaves

The results of table (3) showed that there were significant effect of adding phosphate to the soil in the iron uptake in the leaves, as P_3 treatment excelled and achieved iron uptake in the leaves of 485.414 mg Fe plant^{-1} with an increase of 95.595% compared to P_0 which achieved iron uptake of 248.172 mg Fe plant^{-1}, the reason is attributed to the role of microorganisms already present in the soil in the respiration processes of them and the roots and in reducing the degree of interaction of the rhizosphere region, which results in an increase in the availability of iron in the soil and thus in increasing its uptake by the plant. The rhizosphere region chelates iron, thus preserving it from stabilization and sedimentation processes in the soil **(Dotaniya & Meena, 2015)**, the results agree with **Zbar *et al.* (2021)**.

The results of the same table showed a significant effect of adding iron on soil, as S_1 excelled and achieved iron uptake in the leaves of 385.893 mg Fe plant^{-1} with an increase of 20.297% compared to S_0 which achieved iron uptake of 320.782 mg Fe plant^{-1}, the reason is attributed to the increase in the concentration of availability of iron in the soil as a result of the addition of iron sulfate fertilizer contains the iron nutrient and the increase in root secretions and thus increasing the absorption of nutrients from the soil as well as the role of iron in increasing the content of leaves from chlorophyll which led to an increase in the process of carbon metabolism and thus improved vegetative growth and thus increased the uptake of iron in the plant **(Connorton *et al.*, 2017)**, the results agree with **Sahin *et al.* (2013); Jozdaemi & Golchin (2017)**.

The results of the same table showed a significant effect of adding zinc on soil, as S_2 treatment exceeded and achieved iron uptake in the leaves of 391.732 mg Fe plant^{-1}, respectively with an increase of 22.117% compared to S_0 which achieved iron uptake of 320.782 mg Fe plant^{-1}, the reason attributed to the role of zinc in activating the vital activities in the leaves and in increasing the absorption of iron from the soil and thus increasing its uptake in the leaves **(Reddy & Kumari, 2022)**, the results agree with **Kumar et al. (2023)**.

The results of table (3) also showed a significant effect of adding sulfuric acid H_2SO_4 with irrigation water to the soil on the iron uptake in the leaves. Treatment A_1 excelled and achieved iron uptake in the leaves of 414.868 mg Fe plant^{-1} with an increase of 30.707% compared to A_0 which achieved iron uptake of 317.403 mg Fe plant^{-1}, the reason is attributed to the role of sulfuric acid in dissolving iron-containing compounds in the soil such as iron oxides and silicate minerals, which leads to liberation Iron from these compounds into the soil solution, thus increasing the available iron in the soil, as well as dissolving calcium carbonate, which has a negative relationship in the availability of micronutrients in the soil, including iron, and thus its absorption by the plant and increasing its uptake in the leaves **(Sheikh-Abdullah, 2019)**, the results agree with **Al-balawna & Abu-Abdoun (2021)**.

Table (3): Effect of Irrigation with acidified water and phosphorous, iron and zinc on iron uptake in the leaves (mg Fe plant^{-1}).

Sulfuric Acid H_2SO_4 A	Phosphorus P	Iron and Zinc S			Mean A x P
		S_0	S_1	S_2	
A_0	P_0	173.842	218.919	212.543	201.768
	P_1	237.520	303.703	309.117	283.447
	P_2	317.956	369.560	377.331	354.949
	P_3	391.857	448.157	448.336	429.450
A_1	P_0	249.614	323.853	310.258	294.575
	P_1	303.558	380.507	375.341	353.135
	P_2	409.164	489.867	512.124	470.385
	P_3	482.747	552.576	588.808	541.377
Sulfuric Acid H_2SO_4		**Mean A x S**			**Mean A**
A_0		280.294	335.085	336.832	317.403
A_1		361.271	436.701	446.633	414.868
Phosphorus P		**Mean P x S**			**Mean P**
P_0		211.728	271.386	261.400	248.172
P_1		270.539	342.105	342.229	318.291
P_2		363.560	429.713	444.728	412.667
P_3		437.302	500.366	518.572	485.414
Iron and Zinc S		320.782	385.893	391.732	

LSD 0.05	A	P	S	A * P
	16.170	14.640	15.830	19.420

LSD 0.05	A x S	P x S	A x P x S
	16.800	21.430	27.960

The results of table (3) also show that there are significant effect of the triple interaction between adding commercial sulfuric acid H_2SO_4 with irrigation water and fertilizing with phosphorus, iron and zinc to the soil in the iron uptake in the leaves, as $A_1P_3S_2$ excelled and achieved iron uptake of 588.808 mg Fe plant^{-1}, with an increase of 238.702% compared to $A_0P_0S_0$ which achieved iron uptake of 173.842 mg Fe plant^{-1}.

Zinc uptake in leaves

The results of table (4) showed that there were significant effect of adding phosphate fertilizer to the soil in the zinc uptake in the leaves, as the P_3 treatment of adding phosphate fertilizer excelled and achieved zinc uptake in the leaves of 192.707 mg Zn plant^{-1} with an increase of 101.29% compared to P_0 which achieved zinc uptake of 95.734 mg Zn plant^{-1}, the reason is attributed to the role of phosphate fertilizer in reducing of soil pH in the rhizosphere as well as root secretions, especially in arid and semi-arid regions, which help in the process of increasing the availability of zinc and its transfer to the root surface and increase It is uptake by the plant **(Ali, 2022)**, the results agree with **Zbar *et al.* (2021)**.

The results of the same table showed a significant effect of adding iron on soil, as S_1 excelled and achieved zinc uptake in the leaves of 141.013 mg Zn plant^{-1} with an increase of

18.071% compared to S_0, which achieved zinc uptake of 119.430 mg Zn plant^{-1}, the reason is attributed to the role of iron in encouraging root and vegetative growth, and then increasing the ability of the roots to uptake water and nutrients from the soil, and this was reflected in the zinc uptake in the leaves **(Al-Mousli *et al.*, 2019)**, the results agree with **Jozdaemi & Golchin (2017)**.

Table (4): Effect of Irrigation with acidified water and phosphorous, iron and zinc on zinc uptake in the leaves (mg Zn plant^{-1}).

Sulfuric Acid H_2SO_4 A	Phosphorus P	Iron and Zinc S			Mean A x P
		S_0	S_1	S_2	
A_0	P_0	72.378	87.580	92.646	84.201
	P_1	83.981	108.319	125.541	105.947
	P_2	112.887	140.270	164.191	139.116
	P_3	154.350	168.960	194.132	172.481
A_1	P_0	87.290	105.806	128.705	107.267
	P_1	107.688	128.594	152.395	129.559
	P_2	149.650	177.307	210.327	179.095
	P_3	187.216	211.264	240.319	212.933
Sulfuric Acid H_2SO_4		Mean A x S			Mean A
A_0		105.899	126.282	144.128	125.436
A_1		132.961	155.743	182.936	157.213
Phosphorus P		Mean P x S			Mean P
P_0		79.834	96.693	110.675	95.734
P_1		95.835	118.456	138.968	117.753
P_2		131.268	158.789	187.259	159.105
P_3		170.783	190.112	217.226	192.707
Iron and Zinc S		119.430	141.013	163.532	

LSD 0.05	A	P	S	A * P
	7.661	6.208	7.389	8.429

LSD 0.05	A x S	P x S	A x P x S
	8.080	9.669	12.913

The results of the same table showed a significant effect of adding zinc on soil, as S_2 treatment exceeded and achieved zinc uptake in the leaves of 163.532 mg Zn plant^{-1} with an increase of 36.927% compared to S_0, which achieved zinc uptake of 119.430 mg Zn plant^{-1}, the reason is attributed to the addition of zinc sulfate fertilizer and contains zinc as well as root secretions that work to reduce soil pH and thus increase the availability of zinc in the soil solution and thus its uptake by the plant as well as the positive role of zinc in increasing the total radical, which contributes to increasing the uptake of nutrients, including zinc **(Reddy & Kumari, 2022)**, the results agree with **Slosar *et al.* (2017)**.

The results of table (4) also showed a significant effect of adding sulfuric acid H_2SO_4 with irrigation water to the soil on zinc uptake in the leaves. The treatment A_1 was excelled and achieved zinc uptake in the leaves of 157.213 mg Zn plant^{-1} with an increase of 25.333% compared to A_0, which achieved zinc uptake of 125.436 mg Zn plant^{-1}, the reason is attributed to the role of sulfuric acid in dissolving some compounds containing zinc such as carbonates and oxides, which leads to the liberation of zinc from those compounds to the soil solution and increase the concentration of available zinc in the soil and thus increase its uptake by the plant **(Goulding, 2016)**, the results agree with **Abdul Qadir *et al.* (2022)**.

The results of table (5) also show that there are significant effect of the triple interaction between adding commercial sulfuric acid H_2SO_4 with irrigation water and fertilizing with phosphorus, iron and zinc to the soil in the zinc uptake in the leaves, as $A_1P_3S_2$ treatment excelled and achieved zinc uptake of 240.319 mg Zn plant^{-1} with an increase of 232.033% compared to $A_0P_0S_0$ which achieved zinc uptake of 72.378 mg Zn plant^{-1}, the reason is due to the amount of micronutrients, especially zinc, which are uptake by the plant, which depends mainly on the extent of the vital availability in the soil, the ability of the soil to supply it, the rate of its uptake, soil pH, the form of its presence in the soil, root secretions, its movement within the plant, and other factors affecting the availability of zinc in the soil.

Head diameter of cabbage (cm)

The results of table (5) showed that there were significant effect of adding phosphate fertilizer to the soil in head diameter of Cabbage, as the treatment P_3 excelled and achieved head diameter of 17.71 cm with an increase of 18.30% compared to P_0 which achieved head diameter of 14.97 cm, the reason is attributed to the increase in the availability of phosphorus in the soil solution when adding phosphate fertilizer to the soil and containing phosphorus, which led to its availability to the plant and then increased its uptake by the plants which was reflected positively in plant growth and improved vegetative growth and thus increased head diameter of Cabbage **(Al-Mowsili *et al.*, 2019)**, the results agree with **Al-Mharib *et al.* (2020).**

The results of the same table showed a significant effect of adding iron on soil, as S_1 excelled and achieved head diameter of 16.62 cm with an increase rate of 6.74% compared to S_0, which achieved head diameter of 15.57 cm, the reason is attributed to the fact that iron increases respiration activity and carbon metabolism, which is reflected in increased nutrient uptake from the soil solution, concentration in plant, carbon metabolism products and cell division and elongation, in addition to the role of iron in regulating vital activities within the plant and thus increasing growth, thus increasing the head diameter of Cabbage **(Ali *et al.*, 2022)**, the results agree with **Sahin *et al.* (2013)**.

The results of the same table showed a significant effect of adding zinc on soil, as S_2 treatment exceeded and achieved head diameter of 16.84 cm with an increase of 8.15% compared to S_0, which achieved head diameter of 15.57 cm, the reason is attributed to the inclusion of zinc in the formation of the amino acid tryptophan, which is the basic substance for the IAA hormone, which is necessary for cell elongation and thus increases the growth and area of leaves and increases the head diameter of Cabbage, as well as regulating the metabolic processes of protein and carbohydrates and the biosynthesis of plant hormones, especially auxins, which work It regulates cell elongation and thus increases growth rates **(Gupta *et al.*, 2016)**, the results agree with **Kumar *et al.* (2023)**.

Table (5): Effect of Irrigation with acidified water and phosphorous, iron and zinc on head diameter of Cabbage (cm).

Sulfuric Acid H_2SO_4 A	Phosphorus P	Iron and Zinc S			Mean A x P
		S_0	S_1	S_2	
A_0	P_0	13.53	14.55	14.40	14.16
	P_1	14.62	15.01	15.13	14.92
	P_2	15.45	16.67	16.96	16.36
	P_3	16.53	17.20	17.54	17.09
A_1	P_0	14.36	16.57	16.41	15.78
	P_1	15.54	16.85	17.02	16.47
	P_2	16.91	17.78	18.29	17.66
	P_3	17.62	18.36	19.04	18.34
Sulfuric Acid H_2SO_4		**Mean A x S**			**Mean A**
A_0		15.03	15.85	16.00	15.63
A_1		16.10	17.39	17.69	17.06
Phosphorus P		**Mean P x S**			**Mean P**
P_0		13.94	15.56	15.40	14.97
P_1		15.08	15.93	16.07	15.69
P_2		16.18	17.22	17.62	17.01
P_3		17.07	17.78	18.29	17.71
Iron and Zinc S		15.57	16.62	16.84	
$LSD_{0.05}$	**A**	**P**	**S**	**A * P**	
	3.832	1.535	0.993	2.973	
$LSD_{0.05}$	**A x S**		**P x S**	**A x P x S**	
	3.276		1.801	3.113	

The results of Table (5) also showed a significant effect of adding commercial sulfuric acid H_2SO_4 with irrigation water to the soil in head diameter of Cabbage, Treatment A_1 excelled and achieved head diameter of 17.06 cm with an increase of 9.14% compared to A_0 which achieved head diameter of 15.63 cm, the reason is attributed to the role of sulfuric acid added with irrigation water in increasing the availability of nutrients such as N, P and K in the soil as a result of reducing the degree of soil reaction pH and their uptake by the plant and increasing their content in the leaves, which in turn achieved an increase in the activity of vital processes and regulation of the level of hormones. The plants control the division and growth of meristem tic cells and increase the surface area of leaves and thus increase the head diameter of Cabbage **(Ryan & Stroehlein, 1979)**, the results agree with **Al-Fatlawi & Al-Dulaimi (2015)**.

The results of Table (5) also show that there are significant effect for the triple interaction between adding commercial sulfuric acid H_2SO_4 with irrigation water and fertilizing with phosphorus, iron and zinc to the soil in head diameter of Cabbage, the treatment $A_1P_3S_2$ excelled and achieved head diameter of 19.04 cm with an increase of 40.72% compared to $A_0P_0S_0$ which achieved head diameter of 13.53 cm.

Plant yield of cabbage

The results of Table (6) showed that there was significant effect of adding phosphate fertilizer to the soil in head weight, as P_3 excelled and achieved head weight of 1.70 kg $plant^{-1}$, with an increase of 29.77% compared to P_0, which achieved head weight of 1.31. kg $plant^{-1}$, the reason is attributed to the role of phosphate fertilizer in increasing the availability of phosphorus in the soil, increasing its uptake by plants, and forming a good, strong, dense, and branched root system, which increases the absorption of nutrients from the soil, increases its concentration in the plant, and increases the synthetic materials in the leaf, which in turn is reflected in the growth characteristics of the plant and Plant yield **(Al-Mousli *et al.*, 2019)**, the results agree with **Mahmood *et al.* (2020); Salman & Abdul Razzaq (2022); Al-Halfi & Al-Azzawi (2022); Al-Silmawy & Abdul-Ratha (2023); Al-Mashhadany & Al-Mharib (2023)**.

The results of the same table showed a significant effect of adding iron on soil, as S_1 excelled and achieved head weight of 1.51 kg $plant^{-1}$ with an increase of 4.86% compared to S_0, which achieved head weight of 1.44 kg. $plant^{-1}$, the reason is due to the increase in the availability of iron in the soil and its uptake by plants and the increase in chlorophyll content, which increased the products of carbon metabolism and the accumulation of carbohydrates and proteins, which increased the vegetative growth of the plant and thus increased the weight of the head **(Li *et al.*, 2023)**, the results agree with **AL-Tameemi *et al.* (2019)**.

The results of the same table showed a significant effect of adding zinc on soil, as S_2 exceeded and achieved head weight of 1.57 kg $plant^{-1}$, with an increase of 9.02% compared to S_0, which achieved head weight of 1.44 kg. $plant^{-1}$, the reason is attributed to the role of zinc in increasing the process of plant cell division and elongation, increasing the process of carbon metabolism, and increasing the synthetic materials in the leaf as a result of providing the energy needed to absorb water and nutrients, thus increasing the head weight of the plant **(Gupta *et al.*, 2016)**, the results agree with **Slosar *et al.* (2017)**.

The results of Table (6) also showed a significant effect of adding commercial sulfuric acid H_2SO_4 with irrigation water to the soil on head weight. Treatment A_1 was excelled and achieved head weight of 1.59 kg $plant^{-1}$, with an increase of 11.18% compared to A_0 which achieved head weight of 1.43 kg $plant^{-1}$, the reason is due to the effect of adding sulfuric acid to the soil with irrigation water contributes to increasing the availability of some nutrients important for plant growth, transforming them to available form for plants, such as phosphorus, iron, and zinc, which led to It leads to an improvement in the nutritional status of the plant and an increase in head weight **(Ryan & Stroehlein, 1979)**, the results agree with **Al-Fatlawi & Al-Dulaimi (2015); Al balawna & Abu-Abdoun (2021)**.

The results of table (6) also show that there is significant effect for the triple interaction between adding commercial sulfuric acid H_2SO_4 with irrigation water and fertilizing with phosphorus, iron and zinc to the soil in head weight. The results of the same table showed a significant effect as $A_1P_3S_2$ was excelled and achieved head weight of 1.82 kg $plant^{-1}$, with an increase of 55.55% compared to $A_0P_0S_0$, which achieved head weight of 1.17 kg $plant^{-1}$.

Table (6): Effect of Irrigation with acidified water and phosphorous, iron and zinc on plant yield of cabbage (kg plant^{-1}).

Sulfuric Acid H_2SO_4 A	Phosphorus P	Iron and Zinc S			Mean A x P
		S_0	S_1	S_2	
A_0	P_0	1.17	1.25	1.30	1.24
	P_1	1.26	1.37	1.42	1.35
	P_2	1.42	1.51	1.54	1.49
	P_3	1.59	1.65	1.68	1.64
A_1	P_0	1.31	1.38	1.45	1.38
	P_1	1.46	1.53	1.57	1.52
	P_2	1.62	1.70	1.78	1.70
	P_3	1.71	1.75	1.82	1.76
Sulfuric Acid H_2SO_4		Mean A x S			Mean A
A_0		1.36	1.44	1.48	1.43
A_1		1.52	1.59	1.65	1.59
Phosphorus P		Mean P x S			Mean P
P_0		1.24	1.31	1.37	1.31
P_1		1.36	1.45	1.49	1.43
P_2		1.52	1.60	1.66	1.59
P_3		1.65	1.70	1.75	1.70
Iron and Zinc S		1.44	1.51	1.57	
$LSD_{0.05}$	A	P	S	A * P	
	0.29	0.22	0.07	0.30	
$LSD_{0.05}$	A x S		P x S		A x P x S
	0.23		0.25		0.35

CONCLUSIONS

The results show that there were significant effect of adding Sulfuric acid H_2SO_4, Phosphorus, Iron and Zinc in the soil and their interactions on phosphorus, iron, zinc uptake in the leaves, head diameter and plant yield. Sulphuric acid can be used in Iraqi soil by adding with irrigation water, especially when commercial sulphuric acid is cheap to spread its production sources in Iraq for the purpose of increasing the availability of phosphorus and some micronutrients important for plant growth, transforming them to available form such as iron, and zinc, which led to an improvement in the nutritional status of the plant.

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