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Effete of Nitrogen Forms and Zinc Levels on Yield, Quality of Onion (*Allium cepa* L.) and Soil Fertility

El-Zehery, T. M. [1*], Asmaa F. M. Badawy[2] and Sara A. El-Shabasy[3]

[1] Soil Department, Faculty of Agriculture, Mansoura University, EL-Mansoura, 35516, Egypt

[2]Soil Improvement and Conservation Research Department, Soils, Water and Environment Research Institute (SWERI), Agricultural Research Center (ARC), Giza, Egypt

[3] Soil Chemistry and Physics Research Department, Soil, Water and Environment Research Institute of Agriculture Research Center, Giza,12619, Egypt.

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ABSTRACT

Nitrogen (N) is an essential nutrient, which often limits crop production. Due to their sparse and shallow root system, the N fertilizer use efficiency in onion production is often low and the risk of nitrate leaching losses is high. Micronutrients play a crucial role in enabling crops and vegetables to achieve optimum productivity, improve storage quality, and overcome physiological disorders. A field experiment was conducted to determine the effect of foliar application of micronutrients on growth and yield of onion (*Allium cepa* L.) cv. Giza 20 during season of 2022/ 2023. The main factor was the forms of nitrogen fertilizer N1: Urea $(NH_2)_2CO$, N2 $(NH_4)_2SO_4$ and N3 $Ca(NO_3)_2$ .The sub main factor treatments consisted of two levels of foliar application of ZnSO4 (1% and 1.5%) that laid out in spilt plot design with three replications. Data on growth, yield, bulb quality and storage life parameters were recorded and analyzed using co-stat. Optimizing N and zn fertilization strategies, particularly through the combined application of urea and 1.5% ZnSO4, can significantly enhance fresh weight (14176.17 and 14200.67 kg/fed) for both season respectively and overall plant productivity. Also urea and foliar application of 1% ZnSO4gave the most effective content of zn (44.5 and 46 ppm) respectively.. The 1% Zn treatment is recommended for maximizing zinc uptake and overall plant health.. The application of zinc, particularly at a rate of 1.5% with calcium nitrate, was proved to enhance soil nitrogen availability(54.22 and 54.77 mg/kg) respectively, potentially improved crop growth and yield.

Keywords: Onion, nitrogen source, zinc, yield, quality.

INTRODUCTION

Onion crop is considered as a very important vegetable crop in Egypt and in the world. The demand for onion crop is growing worldwide in Egypt and the exported onion reaches 32 thousand tones with a value of 33 million US dollars (FAO, 2004). It is characterized by its high nutritional, medicinal, and economic values as it contains many vitamins, nutrients, and medicinal compounds such as the anti-oxidant and cancer-fighting quercetin compound and some secondary organic compounds that include sulfur as an essential element in their composition (Hassan, 2000). Onions are considered strategic vegetable crops, so many countries have sought to increase its cultivated areas of onions and improve its production and quality. Global onion production has increased considerably from less than 2 million ha in 1990 to more than 5 million ha in 2019. The gross production value of onions produced the second worldwide ranks second among vegetable crops after tomatoes (FAO, 2021). Onion is more susceptible to nutrient deficiencies than most crops because of their shallow and un-branched root system; hence they require and often respond well to addition of the fertilizers (Goldman, 2022).

Nitrogen mineral nutrient is often referred to as the primary essential macronutrients, which is often a yield limiting factor in crop production. It is required by plants in larger amounts compared to most other nutrients. Compared to other vegetables, onions require high N fertilizer application rates (Greenwood and Hunt 1986). Nitrogen comprises 7% of total dry matter of plants and is a constituent of many fundamental cell components (Marschner, 1995 , Bungard et al., 1999 and Abdel-Mawgoud et. al , 2005). So, Nitrogen nutrient can be satisfied from a combination of soil residual nutrients and chemical or organic fertilizers to ensure optimum growth.

Soils in Egypt are exposed to multi-micronutrient deficiencies that closely associated with the crop yield and quality. Micronutrients play a crucial role in enabling crops and vegetables to achieve optimum productivity, improve storage quality, and overcome physiological disorders. In addition, they play a vital role in improving plant growth through biosynthesis of endogenous hormones which is responsible for promoting plant growth. Zinc is essential for the cell division and other physiological processes like photosynthesis and nitrogen metabolism (Ballabh et al., 2013) and it is also an activator of several other enzymes such as superoxide dismutase and catalase, which prevents oxidative stress in the plant cells. Also, dehydrogenase, aldolase, isomerases, proteinase, peptidase and phosphohydrolase are just a few of the enzymes that require Zinc (Mousavi 2011). Zinc plays an important role in production of tryptophan which in turn is a precursor of auxin, which acts as essential growth hormone for proper growth of plant. Foliar application of micronutrients during active crop growth stage was

*** Corresponding author.**
E-mail address: dr_tarekragab@mans.edu.eg

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successfully used for correcting their deficits and improving the mineral status of the plants as well as increasing the crop yield and quality of vegetables in general and onion in particular. (Kolota and Osinska, 2001, Barman et al., 2018 and Vandana and Solanki 2021)

The different forms of nitrogen had different reaction in the soil; and also in vegetables crops as well as micronutrients such as zinc which has a vital role in many physiological processes, and as the Egyptian soil had shortage in micronutrients. Therefore the aim of this study was to investigate the interactive effect of different forms of nitrogen and foliar zinc applications on the growth and productivity of onion.

MATERIALS AND METHODS

A field experiments were conducted at the Experimental Farm of Agricultural Faculty of Agriculture, Mansoura University, Egypt, (31°22' 59.88" N latitude and 31°05' 31.38 "E longitude) during the two successive winter seasons (2022/2023 and 2023/2024). Onion plant (*Allium cepa* L.) Giza 20. The thirty days age - onion seedlings were obtained from the Horticulture Research Unit, Sakha. The onion seedlings were planted in plots on January 1st, 2022, in the 1st season and at January, 2023 in the 2nd season. The experimental plots were performed in split design with plant spacing of 25*10 cm^2. After 110 days from the transplanting, onion samples were harvested, bulb diameter and TSS were determined.. The onion bulbs were weighted to determine fresh weight then dried at 60°C to determine N, P, K and Zn contents in base of dry weight. Table (1) points out the initial soil characteristics before planting, where the soil samples were analyzed depending on the standard methods reported by Sparks et al. (2020) and Dane and Topp (2020).

Table 1. Some physical and chemical properties of the experimental soil

Season	pH in soil paste	EC. dS.m^{-1} in soil paste extract	Soluble cations meq.L^{-1}				Solubleanions, meq.L^{-1}			
			Ca^{2+}	Mg^{2+}	K^+	Na^+	CO_3^{-2}	HCO_3^-	Cl^-	SO_4^{-2}
2022	8.11	3.16	0.36	0.25	0.96	1.59	0	0.30	0.43	2.43
2023	8.00	3.21	0.36	0.27	0.98	1.60	0	0.33	0.35	2.53

	Particle size distribution %				Soil texture	OM. %	F.C	Available nutrients mg.kg^{-1}		
	C.sand	F.sand	Silt	Clay				N	P	K
2022	6.22	23	31.5	39.28	Clay Loam	1.3	39.4	25.57	9.07	100.00
2023	5.36	24.11	30.33	40.2	Clay Loam	1.4	40.2	26.25	9.80	112.22

Experiment design.

The experiments were conducted during winter seasons of 2022 and 2023 season. they were laid out in a split plot design with three replications. There were altogether 27 treatments with Zn and N. The Main Factor: Represents different nitrogen forms (N1=urea, N2=ammonium sulfate and N3=calcium nitrate) and the sub-main factor: Represents foliar spray of zinc treatments (Zn0=control without Zn, Zn1=1% $ZnSO_4$, and Zn2=1.5% $ZnSO_4$) (1% and 1.5% as salt) to find out its efficiency on onion plant. Each combination of main factor and sub-main factors has 3 replicates. At harvest stage plants were selected from each treatment for observation on yield and quality parameters.

The crop was fertilized with complex NPKS fertilizer (150: 50: 50: 30). The N fertilizer consisted of three forms [$(NH)_2CO$, $(NH_4)_2SO_4$ and $Ca(NO_3)_2$] .The first dose of N (100 units) was applied after 30 days of transplanting which had been added-as follows: (first dose) for Urea: 217 kg/fad = 827 g of urea/plot, Ammonium sulfate: 478 kg/fad = 1.821 kg of ammonium sulfate/plot and Calcium nitrate 645 kg/fad = 2.457 kg of calcium nitrate/plot. The remaining 50 units of N were applied after 45 days of transplanting of onion seedlings. K fertilizer was applied in two equal doses after 30 and 45 days of the transplanting (381 g K_2SO_4 /plot equivalent to 50 unit of K_2O). Full dose of P was applied at the time of planting with (323 kg/fed = 1.229 kg superphosphate /plot). Finally 114 g S / plot was added after 45 days from the transplanting. At harvest time, plants were selected from each treatment for determining the yield and quality parameters.

Zn micronutrient fertilizer was foliar sprayed on onion plants as ZnSO4.7 H_2O in two levels (1% and 1.5%). Zinc sulfate solution in water was prepared at two times after 60 and 75 days after transplanting by using at a concentration of 1 and 1.5 % (10 and 15 grams/liter, respectively). Also, the control plots (zero Zn) was sprayed by irrigation water (13.5 liters/9 plots).

Nutritional analysis of plant samples:

The oven-dried onion plant sample was digested by using a sulfuric-perchloric acids mixture as described by Peterburgski (1968). Zn was determined in digested plant material using atomic absorption according to Chapman and Pratt (1961). Then N, P and K % were measured depending on the standard methods of Jackson (1967) and Black (1965) using micro-Kjeldahl, spectrophotometer and flame photometer. Then the nutrients uptake were calculated.

Onion fresh weight, dry weight, diameter and TSS were measured. Total soluble solids are the concentration of soluble solids in vegetables. Total soluble solids were measured using a Pocket hand refractometer (ATAGO). Homogenate ground tissues were filtered through filter paper Whatman No. 1 and the total soluble solid (%) were determined according to Javanmardi and Kubota (2006).

Available N was determined as mentioned by Bremner (1965). Available P was determined according to Olsen and Sommers (1982). Available K was determined in extraction of soil sample as mentioned by Black (1965).

Statistical Analyses

Analysis of variance was conducted according to Snedecor and Cochran (1980). The experimental data were computed using the procedures available in the (co-state) package. Means comparison under the effect of nitrogen types and zinc level treatments was measured using Duncan's test at the probability level of 5% (Gomez and Gomez ,1984),

RESULTS AND DISCUSSION

Fresh Weight:

The fresh weight data demonstrated in Table (2) showed a clear response to both nitrogen forms and zinc foliar application. Urea (N1) consistently resulted in the highest fresh weight in both seasons (11559.72 and 11600.00 kg/fed, respectively),, indicating its effectiveness in promoting biomass accumulation. This could be attributed to urea's rapid conversion to ammonium and its subsequent role in nitrogen assimilation and protein synthesis, which are crucial for plant growth, this process is known to enhance protein synthesis and cell expansion, leading to increased biomass (Marschner, 2012). Conversely, Ammonium Sulfate (N_2) resulted in the lowest fresh weight in both growing seasons (9428.22 and 9525.56 kg/fed), potentially due to its acidifying effect on the soil, which might have negatively impacted root function and nutrient uptake (Haynes, 1983). Calcium Nitrate (N_3) showed intermediate fresh weight values, suggesting a moderate effect on biomass production. At the initial measurement stage, plants treated with Urea (N_1) and Calcium nitrate (N_3) exhibited statistically similar and the highest fresh weight values (11559.72 and 11108.61 kg/fed, respectively). Conversely, Ammonium sulfate (N2) resulted in a significantly lower fresh weight (9428.22 kg/fed). The F-test indicated a highly significant effect of nitrogen source on fresh weight at both measurement growing seasons ($p < 0.05$).

Table 2. Effect of different treatments of foliar application of micro nutrients on quality parameters of onion:

Treatment	Fresh weight kg/fed		dry weight kg/fed		onion diameter cm	
	2022	2023	2022	2023	2022	2023
Urea (N_1)	11559.72 a	11600.00 a	1762.11 a	1772.00 a	5.11 a	5.13 a
$(NH_4)_2SO_4$ (N_2)	9428.22 b	9525.56 b	1530.78 b	1552.11 b	3.87 c	4.12 b
$Ca_2(NO_3)_2$ (N_3)	11108.61 a	11197.44 a	1659.22 a	1682.78 a	4.68 b	4.93 a
F-test	**	**	**	*	**	**
LSD at 5%	748.65902	810.50454	106.89822	113.08002	0.293745	0.457224
Control (ZN_0)	8650.06 c	8725.44 c	1332.89 c	1344.44 c	4.06 c	4.24 c
ZN 1% (ZN_1)	10589.83 b	10659.89 b	1623.78 b	1655.89 b	4.67 b	4.82 b
ZN 1.5% (ZN_2)	12856.67 a	12937.67 a	1995.44 a	2006.56 a	4.93 a	5.12 a
F-test	**	**	**	**	**	**
LSD at 5%	504.17871	495.83367	61.520956	61.95305	0.263349	0.194678
Interaction						
N_1 ZN_0	9642.50 cd	9651.67 cd	1481.33 e	1492.33 d	4.53	4.60
N_1 ZN_1	10860.50 b	10947.67 b	1646.00 d	1680.00 c	5.20	5.17
N_1 ZN_2	14176.17 a	14200.67 a	2159.00 a	2143.67 a	5.60	5.63
N_2 ZN_0	7138.83 e	7272.33 e	1172.33 g	1188.33 f	3.40	3.67
N_2 ZN_1	10183.83 bc	10225.33 bc	1625.33 d	1636.67 c	3.90	4.23
N_2 ZN_2	10962.00 b	11079.00 b	1794.67 c	1831.33 b	4.30	4.47
N_3 ZN_0	9168.83 d	9252.33 d	1345.00 f	1352.67 e	4.23	4.47
N_3 ZN_1	10725.17 b	10806.67 b	1600.00 d	1651.00 c	4.90	5.07
N_3 ZN_2	13431.83 a	13533.33 a	2032.67 b	2044.67 a	4.90	5.27
F-test	**	**	**	*	NS	NS
LSD at 5%	873.26315	858.80910	106.55742	107.30583	--	--

Also, the F-test revealed a highly significant effect of zinc application on fresh weight at both season compared to the control (ZN0). A similar pattern was evident especially at the second season, where ZN1 (10659.89 Kg/fed) and ZN2 (12937.67 Kg/fed) resulted in significantly greater fresh weight than the control (8725.77 Kg/fed). Plants treated with 1% ZN (ZN1) and 1.5% ZN (ZN2) demonstrated statistically similar and significantly higher fresh weight than the control in both seasons, these results highlight the importance of zinc for plant growth this may be due to that Zinc plays a crucial role in various physiological processes, including enzyme activation, protein synthesis, and hormone regulation (Vandana and Solanki 2021). The control treatment (ZN0) resulted in the lowest fresh weight, underscoring the necessity of zinc supplementation, especially in zinc-deficient soils as Egyptian soil

The significant interactions between N forms and foliar zinc application for fresh weight emphasize the importance of tailored nutrient management. The N1ZN2 combination resulted in the highest fresh weight (14176.17 and 14200.67 Kg/fed) in both seasons respectively, indicating a synergistic effect where urea and 1.5% Zn together optimize biomass production. Conversely, the N2ZN0 combination resulted in the lowest fresh weight, highlighting the detrimental impact of relying solely on Ammonium Sulfate without zinc supplementation. The same result was previously reported by Singh and Tiwari (1995) and Meena and Singh (1998) where foliar application of Zn had a positive effect on all plant vegetative growth.

Dry Weight

As mentioned in Table 2 urea (N1) yielded the highest dry weight (1762.11 and 1772.00 Kg/fed) in booth seasons. This suggests that Urea promoted greater overall dry matter accumulation compared to other forms of nitrogen. This discrepancy could be attributed to differences in nitrogen utilization efficiency, as well as the influence of different nitrogen sources on other physiological processes such as photosynthesis and water relations (Taiz and Zeiger, 2015).

The significant increase in dry weight with (ZN1) and (ZN2) treatments underscores its importance for plant growth and dry matter accumulation. (ZN2) yielded the highest dry weight (1995.44 and 2006.56 Kg/fed) in booth seasons. Zinc is a crucial cofactor for numerous enzymes, all of which contribute to dry matter production (Alloway, 2008). The control treatment (ZN0) resulted in the lowest dry weight, highlighting the necessity of zinc supplementation, particularly in zinc-deficient soils. The above facts indicated that the optimum use of micronutrient might improve all growth parameters in present investigation, similar results were also indicated to support the study with earlier findings of Acharya *et al.*, 2015; Shukla *et al.*, 2015; Manna and Maity 2016 Gameili *et al.*,2018 and Maurya *et al.*,2018.

The significant interactions between nitrogen sources and zinc applications for dry weight emphasize the importance of tailored nutrient management. The N1ZN2 combination resulted in the highest dry weight (2159.00 and 2143.67 Kg/fed) in both seasons, also the N3ZN2 combination gave the same trend without any difference between means according to Duncan's analysis especially in the second season. These combinations likely provide both efficient nitrogen nutrition and adequate zinc to support key metabolic processes. In contrast, the N2ZN0 combination resulted in the lowest dry weight, indicating that with Ammonium sulfate, a higher zinc application might be required or another nitrogen form would be preferred.

Onion Diameter:

The nitrogen source significantly ($P < 0.05$) affected onion diameter at both sampling times (2022-2023), Urea (N1) resulted in the largest bulb diameters (5.11 cm and 5.13 cm, respectively). Ammonium Sulfate (N2) and Calcium Nitrate (N3) led to smaller bulb diameters, with N2 gave (3.87 and 4.12 cm), whereas N3 produced (4.68 and 4.93 cm) at the first and second seasons, respectively. The larger onion diameter observed with Urea (N1) compared to Ammonium Sulfate (N2) and Calcium Nitrate (N3) aligns with the zinc content findings. Urea's potential to enhance zinc availability, coupled with its role in nitrogen nutrition, likely contributed to improved onion bulb development. Nitrogen has a much stronger effect on bulb size and weight in the field (Tekle, 2015; Tekeste et al., 2018), Urea promoted greater overall biomass accumulation. This could be due to differences in N utilization efficiency or the impact of different N sources on other physiological processes, such as photosynthesis and water relations (Taiz and Zeiger, 2015).

Zinc application significantly ($P < 0.05$) influenced onion diameter at both seasons. In the first season, plants treated with (ZN1) and (ZN2) exhibited larger bulb diameters (4.67 cm and 4.93 cm, respectively) compared to the control (ZN0) (4.06 cm). The observed correlations between foliar addition of zinc and onion diameter suggest that zinc plays a crucial role in onion growth and development. The significant increase in onion diameter with (ZN1) and (ZN2) underscores the importance of zinc for growth characteristics. Zinc fertilization likely contributed to improve physiological processes, such as enzyme activity, protein synthesis, and cell division, ultimately leading to larger onion bulbs and quality a mentioned by Pramanik, *et. al*., (2018).

The significant interaction between nitrogen source and zinc application for onion diameter emphasizes the importance of balanced nutrient management. The N1ZN2 combination, which resulted in the highest onion diameter, highlights the synergistic effect of urea and 1.5% Zn in promoting bulb growth. Conversely, the N2ZN0 combination, which resulted in the smallest onion diameter (3.40 and 3.67 cm) in 2022 and 2023 respectively, suggests that relying solely on Ammonium Sulfate without zinc supplementation can negatively impact bulb development.

Nutrient content:

The nitrogen content data showed that urea (N1) generally resulted in the highest N%, while Ammonium Sulfate (N2) showed the lowest N%, this could be due to differences in nitrogen utilization efficiency or the impact of different nitrogen sources on other physiological processes. However, there was no significant between means as affected by nitrogen sources in both sasons , The observed differences in N% among nitrogen sources can be attributed to several factors related to nitrogen uptake and assimilation in onions, the form of nitrogen can influence its availability and how the onion plant utilizes it (Marschner, 2012). Furthermore, the nitrogen source can influence soil pH, which in turn can affect nutrients availability (Mengel et. al.,, 2001).

Whereas, zinc application also significantly affected N% at both seasons ($P < 0.05$). Plants treated with (ZN1) and (ZN2) showed statistically similar and higher N% values (2.83 and 2.85%) and (2.86% for bot seasons) respectively, compared to the control (ZN0). Also (ZN1) and (ZN2) showed no statistically differences between means of N% so it would be preferred to add the smaller dose (ZN1). The significant positive effect of zinc application on N% is consistent with the established role of zinc in nitrogen metabolism. Zinc is a crucial component of several enzymes involved in nitrogen assimilation in onions, including nitrate reductase, which catalyzes the reduction of nitrate to nitrite, a key step in nitrogen assimilation (Alloway, 2008 and Brewster, 2008). Zinc deficiency can impair nitrogen metabolism, leading to reduced growth and yield in onions (Rahman, 2019). Therefore, adequate zinc availability is essential for efficient nitrogen utilization by onion plants.

A non-significant interaction was observed between nitrogen source and zinc application for N% at both seasons. However, the highest N% was observed for the N1ZN2 combination (2.88 and 2.88 %) for both season respectively, while the lowest was for N2ZN0 (2.72 and 2.73%).

The non-significant interaction between nitrogen source and zinc application underscores the complexity of nutrient management in onion production. Even though there was a superior performance of the N1ZN2 combination (Urea with 1.5% Zn) suggests a synergistic effect as well as N3ZN2 combination (Calcium nitrate with 1.5% Zn). This interaction suggests that the optimal nitrogen and zinc fertilization strategies need to be tailored to the specific combination of nitrogen source and zinc application to maximize nitrogen uptake and utilization in onions. Previous studies have consistently reported that foliar application of N and Zn fertilizer significantly increased yield in various field crops such as onion (Rafie, *et al*.2017).

Phosphorus Content

The analysis of variance revealed no significant differences ($P > 0.05$),among nitrogen sources for P% Ammonium Sulfate (N2) resulted in the highest P% in both measurements (0.086567 and 0.089778 in the first and second season respectively,, while Urea (N1) and Calcium Nitrate (N3) resulted in significantly lower P% values (0.0774 and 0.07787) respectively. This suggests that ammonium sulfate enhances phosphorus uptake, possibly due to its soil acidification effects, which increase phosphorus solubility and availability Havlin *et al.*, (2016)

A significant differences in P% were observed among zinc treatments in both seasons as mentioned in Table 3. In both seasons, the 1.5% Zn treatment (ZN2) resulted in the highest P% (0.0833 and 0.0839), then 1% Zn (ZN1) while the Control (ZN0) treatments showed significantly lower values (0.072 and 0.0722, respectively). P Balanced nitrogen and zinc fertilization is crucial to maximize phosphorus availability and uptake. High zinc levels in soil may reduce phosphorus availability, requiring careful management of both nutrients. So foliar application of Zn is recommended to enhance nutrients dynamics in plant. This indicates a dynamic relationship between zinc and phosphorus, where an optimal zinc level may facilitate phosphorus uptake initially but could reduce its availability over time due to complex interactions in soil chemistry Zinc's role in phosphorus uptake and translocation is complex Fageria *et al.*, (2010).

A non-significant interaction between nitrogen sources and zinc application was observed in both seasons. Meanwhile, the highest P% values were found with the combination of Ammonium Sulfate with 1.5% Zn (N2ZN2) resulted in the highest P% (0.0863 and 0.0876%), then with urea then with calcium nitrate combinations in both seasons. While, Calcium nitrate with control (Zn0) (N3ZN0) had the lowest P% (0.0700 and 0.0710%).

Table 3. Effect of nitrogen forms and zinc application on some yield aspects of onion plant

Treatment	N%		P%		K%		TSS	
	2022	2023	2022	2023	2022	2023	2022	2023
Urea (N_1)	2.83	2.84	0.0774	0.07778	2.66 a	2.69 a	12.56	13.33 a
$(NH_4)_2SO_4$ (N_2)	2.79	2.80	0.0774	0.07787	2.52 b	2.55 b	11.78	12.17 b
$Ca_2(NO_3)_2$ (N_3)	2.82	2.83	0.0757	0.07656	2.66 a	2.68 a	12.89	13.56 a
F-test	NS.	NS.	NS.	NS.	**	**	NS.	*
LSD at 5%	--	--	--	--	0.037094	0.03791	--	0.854181
Control (ZN_0)	2.74 b	2.75 b	0.0720 b	0.0722 c	2.47 b	2.49 b	11.11 c	12.00 c
ZN 1% (ZN_1)	2.83 a	2.85 a	0.0752 b	0.0761 b	2.59 ab	2.64 ab	12.44 b	12.89 b
ZN 1.5% (ZN_2)	2.86 a	2.86 a	0.0833 a	0.0839 a	2.79 a	2.80 a	13.67 a	14.17 a
F-test	**	**	**	**	*	*	**	**
LSD at 5%	0.040097	0.039211	0.0041134	0.0035263	0.24111	0.22687	0.74617	0.601177
Interaction								
N_1 ZN_0	2.75	2.76	0.0737	0.0743	2.42	2.48	12.00	13.00 bc
N_1 ZN_1	2.87	2.87	0.0763	0.0770	2.63	2.64	12.67	13.00 bc
N_1 ZN_2	2.88	2.88	0.0823	0.0820	2.94	2.94	13.00	14.00 ab
N_2 ZN_0	2.72	2.73	0.0723	0.0714	2.38	2.35	10.00	10.33 d
N_2 ZN_1	2.80	2.82	0.0736	0.0746	2.48	2.59	12.00	12.33 c
N_2 ZN_2	2.84	2.85	0.0863	0.0876	2.72	2.73	13.33	13.83 ab
N_3 ZN_0	2.75	2.77	0.0700	0.0710	2.63	2.63	11.33	12.67 c
N_3 ZN_1	2.83	2.86	0.0757	0.0767	2.65	2.69	12.67	13.33 bc
N_3 ZN_2	2.87	2.86	0.0813	0.0820	2.72	2.73	14.67	14.67 a
F-test	NS.	NS.	NS.	NS.	NS.	NS.	NS.	*
LSD at 5%	--	--	--	--	--	--	--	1.041270

Potassium content

As mentioned in Table (3) Significant differences ($P < 0.05$) were observed among nitrogen sources for K% at both seasons. Calcium Nitrate (N3) and urea (N1) resulted in the highest K% (2.66 and 2.69) in the first and second season respectively, while ammonium sulfate (N2) resulted in the lowest K% (2.52 and 2.55%) in both seasons. The consistently higher K content observed with Calcium Nitrate (N3) across both sampling times aligns with the established role of nitrate in enhancing cation uptake (Marschner, 2012). Nitrate's negative charge facilitates the uptake of positively charged ions like potassium, potentially through charge balance mechanisms or by influencing membrane potential (Epstein and Bloom, 2005). Furthermore, the enhanced growth associated with nitrogen can lead to increased demand and uptake of potassium, a macronutrient essential for various physiological processes, including osmotic regulation, enzyme activation, and phloem loading Mengel et. al., (2001).

Significant differences ($P < 0.05$) were observed among zinc treatments for K% at both season. The 1.5% Zn treatment (ZN2) resulted in the highest K (2.79 and 2.80%), while the Control (ZN0) resulted in the lowest K% (2.47 and 2.49%) in both seasons. The 1% Zn treatment (ZN1) showed intermediate values. The significant increase in K content with the 1.5% Zn treatment (ZN2) compared to the control suggests a positive influence of zinc on potassium uptake. While the exact mechanisms remain to be fully elucidated, zinc's involvement in maintaining membrane integrity and potentially influencing the activity of ion transporters, including potassium channels, could contribute to this effect (Alloway, 2008).

The absence of a significant interaction between nitrogen and zinc for potassium suggests that their effects on potassium uptake are largely independent and additive at either seasons this means that K% values were not have deference between the treatments, this may due that nitrogen and zinc exert independent effects on potassium uptake rather than a synergistic or antagonistic interaction for potassium content. Even though the highest mean values were observed with urea and 1.5% Zn (N1Zn2)

Total Soluble Solids (TSS%)

Significant differences ($P < 0.05$) in TSS% were observed among nitrogen sources at just the second season where, Calcium Nitrate (N3) resulted in the highest TSS (13.56%) in the second season, while Ammonium Sulfate (N2) resulted in the lowest TSS% (12.17 in the respective season). Urea (N1) showed intermediate values. These results indicate that nitrate-based nitrogen enhances carbohydrate accumulation and TSS content in onions more effectively than ammonium-based nitrogen. The influence of nitrogen sources on TSS is well-documented, with nitrate-based fertilizers promoting efficient nitrogen assimilation and carbohydrate biosynthesis (Marschner, 2012). Also TSS may also affected due to nitrate role in enhancing carbon metabolism enzyme activity (Kaiser and Huber, 1997). Ammonium-based nitrogen, in contrast, may direct more nitrogen toward vegetative growth rather than sugar accumulation (Mengel et. al.,, 2001).

Also, zinc application significantly affected TSS in both seasons. The 1.5% Zn (ZN2) gave the highest TSS values (13.67 and 14.17%), while the Control (ZN0) exhibited the lowest (11.11 and 12%). This highlights zinc's crucial role in carbohydrate metabolism, photosynthesis, and sugar accumulation, sucrose synthase and UDP-glucose pyrophosphorylase, which regulate sugar formation. The present results in onion also corroborate with those of Fageria et al., (2010); Trivedi and Dhumal (2013); Manna and Maity (2016) and Aske *et al* (2017).

A significant interaction between nitrogen source and zinc application was observed for TSS just in the second season. The highest TSS (14.67) was recorded in the combination of Calcium Nitrate with 1.5% Zn (N3ZN2), while the lowest TSS (10.33) was recorded in the combination of Ammonium Sulfate with the control zinc treatment (N2ZN0). This suggests that optimal nitrogen and zinc combinations are necessary to maximize sugar accumulation and improve onion quality. The significant interaction for TSS highlights the combined effect of nitrate-nitrogen and zinc in improving onion quality which, indicated that nitrate enhances carbohydrate synthesis and zinc optimizes sugar metabolism. This result, further emphasizes the importance of balanced nutrient management for achieving desired onion quality. This interaction suggests that zinc deficiency can be exacerbated by the use of ammonium-based nitrogen fertilizers, potentially due to competition for uptake or other physiological interactions.

Zinc Content

This study investigated the effects of different nitrogen sources and zinc applications on zinc content as showed in Fig 1(a, b and c). The results demonstrate a highly significant effects of both nitrogen source and zinc application, with notable interactions observed for both parameters.

The consistently higher zinc content (35.72 and 36.41 ppm) observed with Urea (N1) compared to Ammonium Sulfate (N2) and Calcium Nitrate (N3) could be attributed to several factors. Urea's influence on soil pH, specifically its tendency to slightly increase pH initially through ammonium production, might enhance zinc solubility and uptake. Conversely, the acidifying effect of Ammonium Sulfate could potentially lead to zinc complexity with other soil components, reducing its availability. Calcium Nitrate is not as strongly acidifying as Ammonium Sulfate, might influence zinc uptake through competitive interactions with calcium ions.

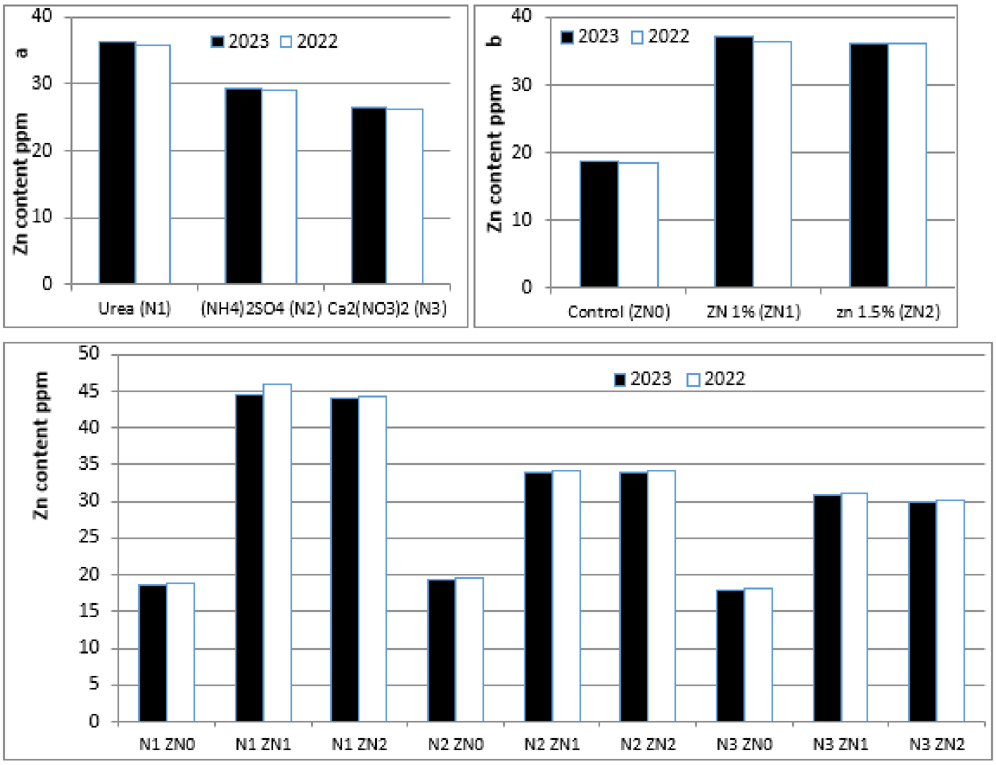

Fig 1 :Effect of N forms and Zn application on Zn content of onion plant (a,b and c)

The significant increase in zinc content with 1% Zn (ZN1) and 1.5% Zn (ZN2) treatments compared to the control (ZN0) was expected, directly reflecting the application of supplemental zinc. This confirms the effectiveness of zinc fertilization in increasing zinc accumulation in onion tissues. The strong interaction between nitrogen source and zinc application highlights the complex interplay between these nutrients. The highest zinc content (44.5 and 46 ppm) observed with the N1ZN1 combination suggests a synergistic effect, where urea and 1% Zn together optimize zinc uptake. The lowest zinc content with N3ZN0 emphasizes the importance of zinc fertilization, particularly when using Calcium Nitrate. Sliman *et al* (1999) mentioned that foliar spray treatments of ZnSO4 increased Zn concentration to its highest concentration and content.

Soil properties

This study investigated the influence of three different nitrogen sources – Urea (N1), Ammonium Sulfate (N2), and Calcium Nitrate (N3) – on soil nitrogen content over two consecutive seasons. The results, as illustrated in Figure (2, 3 and 4), demonstrate a clear variation in soil nitrogen content based on the nitrogen source applied.

The results of this study clearly demonstrate that the choice of nitrogen fertilizer significantly influences soil nitrogen content. The observed differences between Urea (N1), Ammonium Sulfate $(NH_4)_2SO_4$, (N_2), and Calcium Nitrate $Ca(NO_3)_2$, (N3) highlight the importance of considering the specific characteristics of each nitrogen source and their interactions with soil processes. Nitrate is the main N form absorbed by onions. The calcium component of Calcium Nitrate may also contribute to improved soil structure and enhanced nutrient availability, indirectly benefiting nitrogen retention. Nitrate is the main N form absorbed by plants as an anion (Geisseler *et al.*, 2022). Nitrogen (N) varies across treatments. for example, N1 (urea) has lower Av. soil nitrogen compared to N2 (ammonium sulfate) and N3 (calcium nitrate).

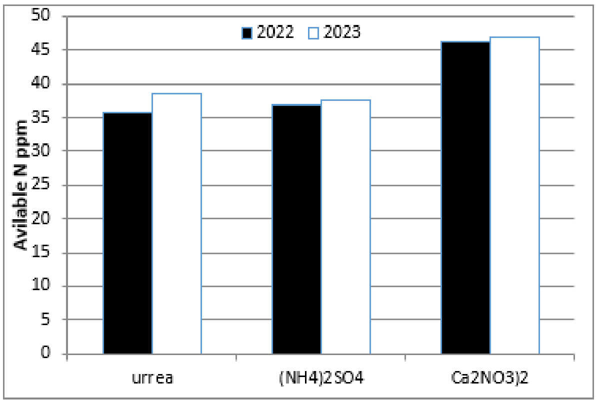

Fig 2. Effect of nitrogen forms on available nitrogen

Zinc treatments also influence soil nitrogen, with higher nitrogen observed in the 1.5% Zn treatment. In the first and second season the control treatment (ZN0) exhibited a soil nitrogen content of (33.23-33.05 mg/kg). The highest value found with the application of 1.5% zinc treatment (ZN2). The data indicates a consistent increase in soil nitrogen content with increasing zinc application rates across both seasons. The 1.5% zinc treatment (ZN2) consistently yielded the highest Av. nitrogen levels (50.08 and 50.72 mg/kg), suggesting a positive correlation between zinc application and soil nitrogen availability. The results, presented in Figure 3, clear that increased soil nitrogen with increasing zinc application.

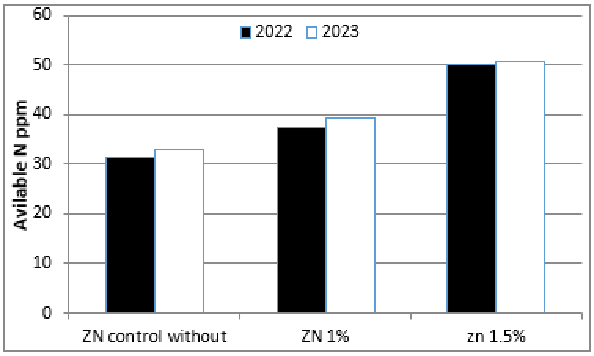

Fig 3. Effect of different foliar Zinc application on available nitrogen

The observed increase in soil nitrogen content with increasing zinc application rates can be attributed to several factors. Zinc plays a crucial role in various physiological processes in plants, including nitrogen metabolism. nitrogen is found to be the significant factor in inhibiting the growth and yield of crops. Thus, In the absence of zinc, Av. nitrogen were lower, emphasizing the beneficial role of zinc in improving nitrogen use efficiency in soils, which could increase total biomass as well as root which affect rhizo-sphere activity lead to increase enzymes and microbes activity which may increase nutrients availability, (Shri and Pillay, 2017).

The results as shown in Fig 4 indicated that the Av. nitrogen in soil was higher in the second season compared to the first season for the same treatment. The N2ZN0 treatment showed the lowest nitrogen content, with approximately (26.99 and 28.18 mg/kg) in the first and second season respectively.

The results clearly that both nitrogen and zinc application rates significantly influenced soil nitrogen content. In zinc-deficient soils, nitrogen fertilization alone may not be enough to achieve optimal nitrogen availability. Zinc application, especially at higher rates, significantly enhances nitrogen uptake and utilization by plants, potentially improving crop productivity, and this may affect rhizo-sphere activity lead to increase enzymes and microbes activity which may increase nutrients availability, (Shri and Pillay, 2017).

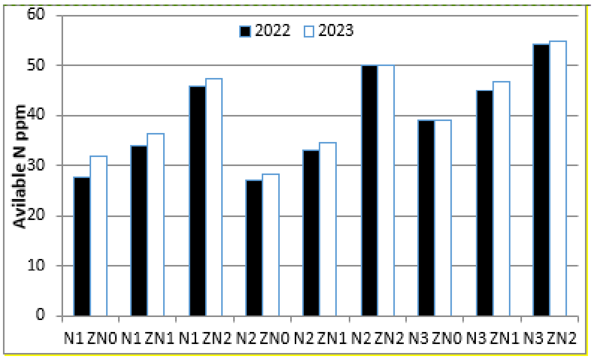

Fig 4. Effect of interaction treatments of nitrogen and zinc on available nitrogen

The results in Fig (4) observation that the highest values soil nitrogen content in both seasons was observed with N3ZN2 treatment which showed the highest nitrogen content in both seasons, reaching approximately (54.22 and 54.77 mg/kg) in the first season and in the second season respectively. Within each zinc treatment (ZN1, ZN0, ZN2), soil nitrogen content generally increased with nitrogen forms (N3, N2, N1) in both seasons. The lower nitrogen content observed with Urea can be attributed to Ammonia Volatilization urea is highly susceptible to ammonia volatilization, especially in alkaline soils. This leads to significant nitrogen loss and reduced soil nitrogen content.

Figure 5 show that the available phosphorus (mg/kg soil) in two seasons under three different nitrogen fertilizer treatments, which observed in an increase in P content in the soil could be attributed to several factors, including enhanced mineralization of organic matter due to increased temperatures and microbial activity (Stevenson and Cole, 1999). Additionally, the residual effects of fertilizer application from the first season may have contributed to the higher P levels in the second season. The superior P content (24.11 and 24.62 mg/kg soil) observed with $(NH_4)_2SO_4$ (N2) can be explained by the acidification effect of ammonium sulfate, which enhances P availability by increasing its solubility (Tisdale et al., 1993). Acidification can reduce the pH of the soil, which can increase the amount of phosphorus. Also, the lower P content with $Ca_2(NO_3)_2$ (N3) may be due to the alkaline nature of calcium nitrate, which can lead to P fixation by calcium ions, reducing its availability (Brady and

Weil, 2017). The intermediate P content with urea could be due to its neutral effect on soil pH compared to the other two fertilizers.

These findings highlight the importance of selecting appropriate nitrogen fertilizers to optimize P availability in soil. The use of $(NH_4)_2SO_4$ (N2) appears to be particularly effective in enhancing P content, which has significant implications for crop productivity.

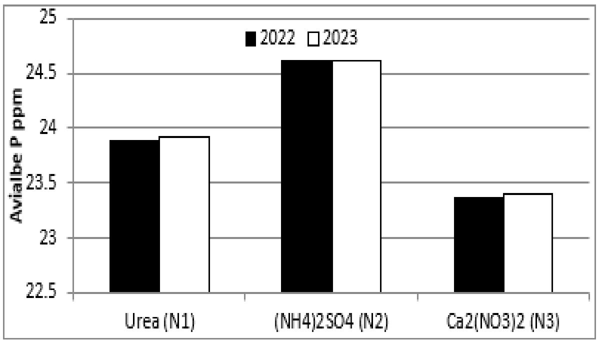

Fig 5. Effect of nitrogen forms on available phosphorus

Figure (6) depicts the phosphorus (P) content (mg/kg soil) across two seasons under three zinc (Zn) treatments which ranged between 22.9 till 24.57, the results consistently showed an increase in P content in the Control (ZN0) exhibited the highest P content in both seasons, reaching approximately (24.54 and 24.57 mg/kg) in both seasons. Both (ZN1) and (ZN2) treatments resulted in lower P content compared to the control, the higher P content in the Control (ZN0) suggests that the addition of zinc (Zn) at both 1% and 1.5% may have negatively impacted P availability. This could be due to several factors. Zinc can interact with phosphorus in the soil, potentially forming insoluble zinc phosphate compounds, thus reducing the availability of P for plant uptake (Lindsay and Vlek, 1977) as some of the foliar addition may affect or reach the soil.

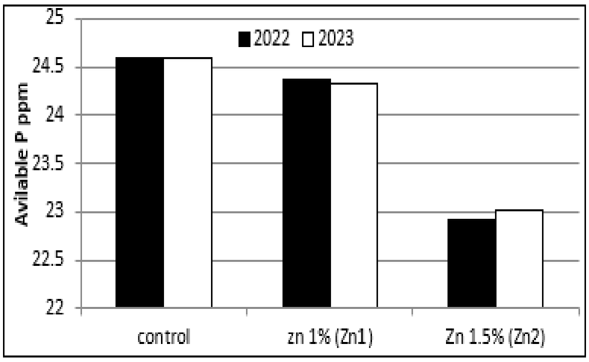

Fig 6. Effect of different foliar Zinc application on available phosphorus

Additionally, high concentrations of zinc can negatively affect soil microbial populations, which play a crucial role in P mineralization and availability (Giller et al., 2009). The similar P content observed between the ZN 1% (ZN1) and Zn 1.5% (ZN2) treatments suggests that the effect of zinc on P availability might be concentration-dependent, with both concentrations leading to a comparable reduction in P availability compared to the control.

Figure 7 illustrates the phosphorus (P) content (mg/kg soil) across two seasons under various combinations of nitrogen (N) and zinc (Zn) treatments. The results demonstrate a consistent trend of increased P content in both season across most treatments. Notably, the N2ZN0 treatment, representing $(NH_4)_2SO_4$ with no zinc, exhibited the highest P content in both seasons (), reaching approximately (25.50 and 25.52 mg/kg) in the first and second season. Conversely, treatments involving zinc application (ZN1 and ZN2), especially when combined with N3 ($Ca(NO_3)_2$), generally resulted in the lowest P content. The control treatments (ZN0) consistently showed higher P content compared to their corresponding ZN1 and ZN2 counterparts. The N2 of treatments, as a whole, showed a higher P content than the N1 or N3 of treatments.

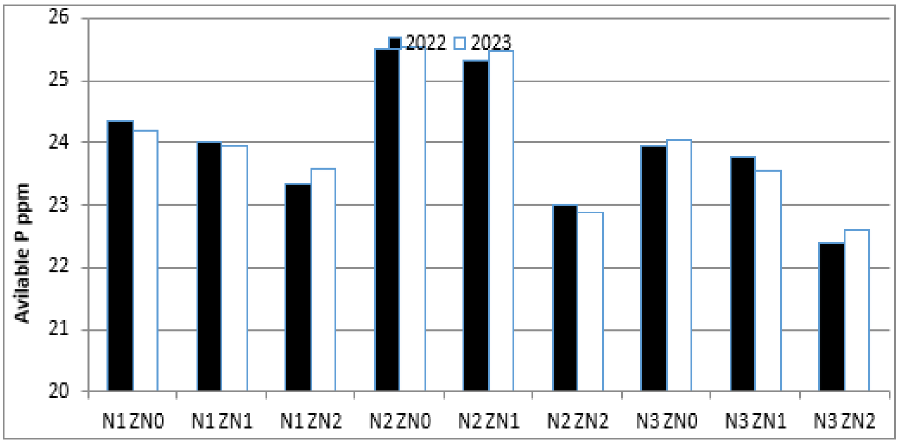

Fig 7. Effect of interaction treatments of nitrogen and zinc on available phosphorus

The higher P content observed with the N2ZN0 treatment aligns with previous findings indicating that $(NH_4)_2SO_4$ can enhance P availability due to its acidifying effect on soil, increasing P solubility (Tisdale et al., 1993). The reduction in P content with Zn application (ZN1 and ZN2) suggests that zinc can interfere with P availability, potentially through the formation of insoluble zinc phosphate compounds (Lindsay and Vlek, 1977). This effect is more pronounced when zinc is combined with N3 ($Ca(NO_3)_2$), likely due to the alkaline nature of calcium nitrate, which can further promote P fixation.The consistent trend of higher P content in the control (ZN0) treatments reinforces the negative impact of zinc on P availability. These results highlight the importance of careful consideration of zinc application rates,

Figure (8) investigate the result and discussion section with references, focusing on available potassium in the soil (mg/kg soil) in two seasons under three different nitrogen fertilizer treatments found that the highest value (420.57 and 425.63 mg/kg soil) of K content in both seasons with $(NH_4)_2SO_4$ (N2) treatment. While Urea (N1) treatment resulted in the lowest Av. K content (350.89 and 360.82 mg/kg soil) in both seasons.

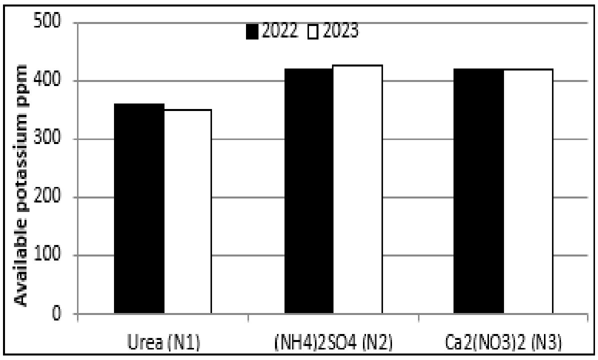

Fig 8. Effect of nitrogen forms on available potassium

The observed decrease in Av. K content can likely be attributed to increased crop uptake of K and potential leaching losses due to seasonal variations in rainfall and irrigation (Havlin *et al.,* 2016 and Sparks, 2003).

Concerning zinc treatments as illustrated in Fig 9 the higher Av. K content was found with (ZN2) (426.86 and 426.40 mg/kg soil) for both seasons, suggests that the application of zinc may positively impact K availability. This could be due to several factors. Zinc can interact with soil components, potentially influencing the release or fixation of potassium. High concentrations of zinc can also affect soil microbial populations, which play a role in nutrient cycling, including potassium availability (Giller *et al*., 2009). Whereas there were not high difference between means of Av. potassium in both treatments Zn1 and Zn2.

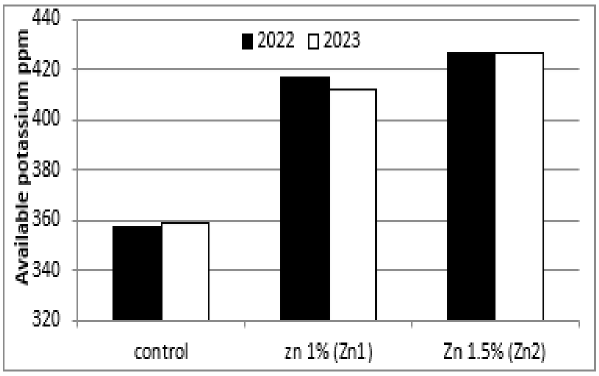

Fig 9. Effect of different foliar Zinc application on available potassium

As illustrated in Figure 10 the Av. potassium in soil (mg/kg soil) demonstrated the highest K content , with (N2ZN2) treatment (449.39 and 453.63 mg/kg soil) for both seasons . Conversely, the interaction effect of Urea (N1) with control (Zn0) consistently exhibited the lowest K levels (314.90 and 329.50 mg/kg soil). The superior Av. K content associated with the $(NH_4)_2SO_4$ with 1.5% Zn_2SO_4 treatment may be attributed to the acidifying effect of anion SO_4^{-2}, a known phenomenon, likely enhances K release from soil minerals, a process particularly relevant in the Nile Delta (Tisdale et al., 1993), potentially reducing K fixation.

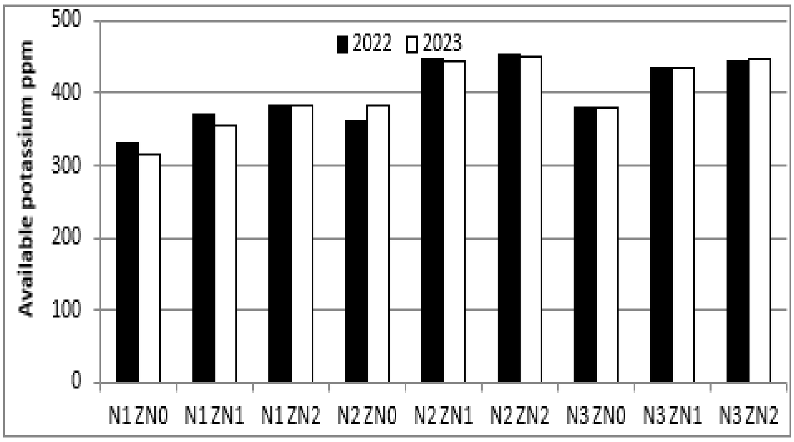

Fig 10. Effect of interaction treatments of nitrogen and zinc on available potassium

The Fig (11) suggests that the application of different nitrogen sources appear to have influenced zinc availability in the soil. The highest concentration of Av. Zn (0.55 and 0.58 mg/kg soil) was found with urea (N1) whereas the lowest one (0.51 and 0.52 mg/kg soil) was found with calcium nitrate treatment (N3). The observed changes in Zn concentration from across different treatments underscore the dynamic nature of Zn in the soil environment. Factors such as soil pH, organic matter content, and the presence of other ions (especially Ca+2 and SO4-2) in our situation can all influence Zn availability and mobility. However, the minerals, chemical structure, amount of organic matter, and pH of the soil all affect the availability of Zn (Wang et al., 2017).

The Fig (12) suggests that the application of 1.5 % zinc increased Av. Zinc (0.57 and 0.59 mg/kg soil) in soil compared to control (Zn0), suggesting that foliar Zn supplementation was the primary driver of soil Zn concentration, which was even more effective (Khan et al, 2002).

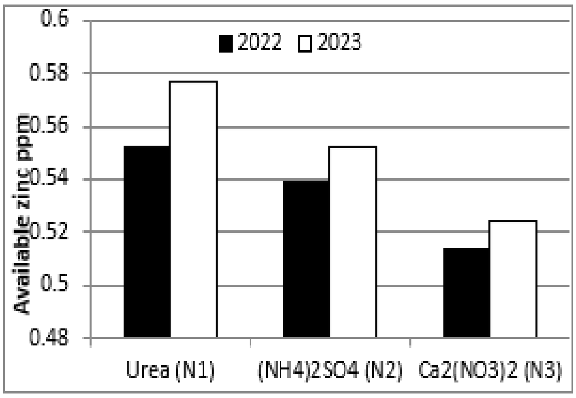

Fig 11. Effect of nitrogen forms on available zinc

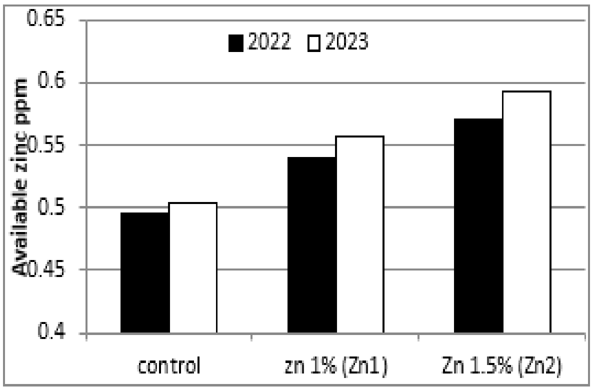

Fig 12. Effect of different foliar Zinc application on available zinc

The results, as presented in Fig (13), indicated variations in Zn levels across the different fertilizers and treatments. Urea-treated soil exhibited the highest Av. Zn in soil (0.60 and 0.63 mg/kg soil), possibly due to its effect on soil microbial activity and nitrogen transformations. The hydrolysis of urea increases microbial activity, which can influence Zn mobility. Additionally, urea can temporarily lower soil pH during nitrification, enhancing Zn solubility.

The Calcium Nitrate with control (N3ZN0) showed the lowest Zn levels (0.45 and 0.46 mg/kg soil), indicating that without Zn supplementation, this N source did not contribute to increased soil Zn. This might imply that Calcium Nitrate alone does not release Zn from soil reserves or that any released Zn is rapidly immobilized or taken up by other soil constituents (Weaver, 1985).

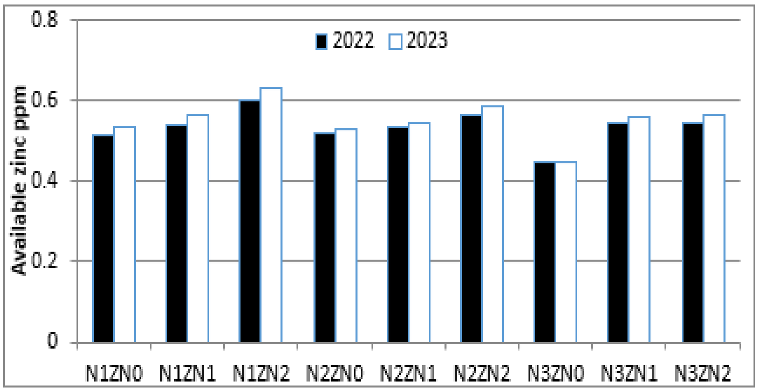

Fig 13. Effect of interaction treatments of nitrogen and zinc on available zinc

CONCLUSION

The findings of this study have significant implications for onion plant growth and nutrient management. Optimizing nitrogen and zinc fertilization strategies, particularly through the combined application of urea and 1.5% Zn, can significantly enhance fresh weight and overall plant productivity. The observed differences in fresh weight and nitrogen content across treatments highlight the complex interplay between nutrients and their impact on plant physiological processes. This study examined the effects of different N sources and zinc levels on onion dry weight alongside N percentage and fresh weight which will affect the export of this vital crop.

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تأثير صور النيتروجين ومستويات الزنك على إنتاجية وجودة البصل (Allium cepa L.) وخصوبة التربة

طارق محمد الزهيري[1] ، أسماء بدوي[2] وسارة الشباسي[3]

[1]قسم الأراضي ، كلية الزراعة، جامعة المنصورة، المنصورة، ٣٥٥١٦، مصر
[2] قسم بحوث تحسين وصيانة الأراضى، معهد بحوث ألأراضى والمياه والبيئة ، مركز البحوث الزراعية، الجيزة، مصر
[3] قسم بحوث كيمياء وطبيعة الأراضى ، معهد بحوث ألأراضى والمياه والبيئة، مركز البحوث الزراعية، الجيزة ، ١٢٦١٩، مصر

الملخص

النيتروجين (N) هو عنصر غذائي أساسي، والذي غالبًا ما يحد من المحصول في إنتاج المحاصيل. ونظرًا لنظام الجذر الضحل ، فإن كفاءة استخدام سماد النيتروجين في إنتاج البصل غالبًا ما تكون منخفضة ونسبة الفقد من غسيل النترات كبيرة. كما تلعب المغذيات الدقيقة دورًا حاسمًا في تمكين المحاصيل والخضروات من تحقيق الإنتاجية المثلى وتحسين جودة التخزين والتغلب على الاضطرابات الفسيولوجية. أجريت تجربة ميدانية لتحديد تأثير التطبيق الورقي للمغذيات الدقيقة على نمو وغلة البصل (Allium cepa L.) صنف جيزة ٢٠ خلال موسم ٢٠٢٢/٢٠٢٣. العامل الرئيسي كان صور النيتروجين بالسماد :N_1 اليوريا $(NH_2)_2CO$ وسلفات النشادر N_2 $(NH_4)_2SO_4$ ونترات الكالسيوم N_3 $Ca(NO_3)_2$. بينما تتكون معاملات العامل الفرعي من ثلاثة مستويات من الرش بكبريتات الزنك: Zn0 كنترول Zn1 (1 $ZnSO_4$) ٪ وZn2 (1.5 $ZnSO_4$) ٪ تم وضعهما في تصميم قطع منشقة بثلاث مكررات. تم تسجيل بيانات النمو والعائد وجودة الأبصال ومعايير عمر التخزين وتحليلها باستخدام .co-stat يمكن أن يؤدي تحسين استراتيجيات التسميد بالنيتروجين والزنك، وخاصة من خلال التطبيق المشترك لليوريا و ١,٥٪ ZnSO4، إلى تعزيز الوزن الطازج بشكل كبير (١٤١٧٦,١٧ و ١٤٢٠٠,٦٧ كجم / فدان) لكلا الموسمين على التوالي والإنتاجية الكلية للنبات. كما أعطى اليوريا والتطبيق الورقي لـ ١٪ ZnSO4المحتوى الأكثر فعالية من الزنك (٤٤,٥ و ٤٦ جزء في المليون) على التوالي. يوصى بمعاملة ١٪ Znلزيادة امتصاص الزنك والصحة العامة للنبات. يتأثر توافر الفوسفور والبوتاسيوم في التربة بأشكال النيتروجين ومصادر الأسمدة. وقد ثبت أن تطبيق الزنك، وخاصة بمعدل ١,٥٪ مع نترات الكالسيوم، يعزز توافر النيتروجين في التربة (٥٤,٢٢ و ٥٤,٧٧ مجم / كجم) على التوالي، مما قد يحسن نمو المحصول والعائد.