Arab J. Nucl. Sci. Appl., Vol. 57, 2, 49-62 (2024)

ISSN 1110-0451

Arab Journal of Nuclear Sciences and Applications

Web site: ajnsa.journals.ekb.eg

(E S N S A)

Impact of Spraying with Some Micronutrients on Onion (*Allium Cepa* L.) Yield and Nutrients Uptake with Application of ^{15}N

T. M. S. El-Sherbeny[1], M. E. Hashim[1] and M. A. Hekal [2]

[1]*Plant Research center Department, Nuclear Research Center, Egyptian Atomic Energy Authority, Egypt*

[2]*Soil and Water Research Department, Nuclear Research Center, Egyptian Atomic Energy Authority, Egypt*

ARTICLE INFO

Article history:

Received: 11th Dec. 2023

Accepted: 11th Jan. 2024

Available online: 10th Mar. 2024

Keywords:

Foliar application;

Micronutrients;

Nutrients Uptake,

15N isotope dilution,

Onion,

Sandy soil.

ABSTRACT

Micronutrients are essentially as important as macronutrients to improve growth, yield and quality in plants, especially when growing in reclaimed lands. Onion was grown on sandy soil under field conditions and exposed to different rates of Fe, Mn, Cu and Zn either individually or in combination of them in order to follow up its impact on some growth traits, micronutrients uptake and nitrogen derived from mineral-N fertilizer, phosphorus and potassium uptake by whole plant. Two successive field experiments were carried out during winter seasons of 2019-2020 and 2020-2021 under drip irrigation system. Sprayed individual Fe, Mn, Cu, Zn and combination of them were applied in different rates. Experiments were designed in a split-plot design. Micronutrients mixture added at medium concentration induced the highest plant height, number of leaves, fresh and dry weight, blub yield and quality, bulb diameter, total soluble solids, ascorbic acid concentration, macro and micronutrient uptake, nitrogen (as ^{15}N) derived from fertilizer and fertilizer nitrogen (as ^{15}N) recovery. Additionally, zinc treatment came to the next after the mixed solution in increasing all tested parameters, followed by individual iron, then manganese, and finally copper.

1- INTRODUCTION

One of the earliest domesticated plants, are the onion (*Allium cepa* L.), contains approximately 500 species, each with a unique form, color, and flavour but with comparable biochemical components [1]. Every kitchen uses this big and significant vegetable to provide taste and scent to a wide range of recipes. Immature and mature onion bulbs, which may be consumed fresh or utilized in vegetable dishes, are the major edible parts of the onion. The nutritional value of onions varies depending on the variety. 64 calories, 2.72 g of fiber, 0.16 g of fat, 0 g of cholesterol, 1.76 g of protein, 6.78 g of sugar, and a minor amount of the antioxidants Ca, Mg, K, P, Fe, and S are found in one cup of chopped mature bulbs. Inorganic fertilizers or synthetic mixtures of macro and microelements that supply nutrients to improve plant growth and yield. Chemical fertilizers often come in fast release formulas that provide nutrients to plants quickly. Even though they are typically needed in modest amounts, micronutrients are essential for plant development [2]. One of the most crucial application techniques is foliar nutrition since it makes it easier for nutrients to reach the plant [3]. Foliar application of micro elements raised plants' mineral status and enhanced crop output [4]. Plant growth, yield, and quality were significantly impacted by foliar spraying with microelements [5, 6]. Onions requires an adequate amount of macro and micro-elements and responded well to added nutrients [7]. Numerous researches revealed that various microelements, including zinc, iron, manganese, and copper, might have a significant influence in raising onion output and quality.

Zinc is one of the most important micro-element and essential for carbohydrate metabolism, auxin metabolism and synthesis of cytochrome [8]. Higher plants include a variety of enzymes containing zinc, including alcohol dehydrogenase, RNA polymerase, and carbonic anhydrase. Zinc is a micro nutrient which usually required for plant growth and development relatively in small amount. Zinc is involved in a diverse range of

Corresponding author: mehashim@yahoo.com

DOI: 10.21608/ajnsa.2024.254765.1798

enzyme system [9]. Zinc is necessary for plant enzymatic response [10]. Zinc also involved in the regulation of gene transcription [11]. Manganese is most important for photosynthesis and nitrogen metabolism [12]. Manganese contributes to the production of chloroplasts, the preservation of hormonal balance, the synthesis of lipids, and plant resilience to biotic and abiotic stressors [13]. The activities of respiration, photosynthesis, energy transmission, chlorophyll synthesis, and nitrogen fixing all require iron. It is crucial for the metabolism of nucleic acids [14]. Iron plays important role in metabolic processes such as DNA synthesis, respiration, and photosynthesis, and it is also involved in electron transport chain, synthesis of chlorophyll, maintenance of chloroplast structure [15]. Copper plays an essential role in cell wall metabolism, oxidative phosphorylation and Iron metabolism [16, 17]. Through an enzyme that is a part of the photosystem I electron transport chain, copper can impact how plants use nitrogen and carbohydrates [18]. Copper have a role in plant rooting, absorption of water and nutrients uptake [19], formation of pollen and seed production [20]. Therefore, the main aim of this study is to investigate the impact of foliar application of some micronutrients on onion plant vegetative development, yield and quality as well as fertilizer nitrogen recovery (FNR) for onion plants, using ^{15}N isotope.

2- MATERIALS AND METHODS

Two field experiments were conducted at the experimental farm of Plant Research Department, Nuclear Research Center, Atomic Energy Authority, Inshas, Egypt, during the two growing successive winter seasons of (2019-2020) and (2020-2021) using onion plant as a tested crop. Plants were sprayed with some micronutrients, i.e. Fe, Mn, Cu and Zn at three different concentration, in addition to the untreated control, and followed its impact on vegetative growth, yield and quality as well as FNR by onion plant under drip irrigation system. The soil type of experimental site was sandy in texture which is shown in Table 1.

Experimental soil was prepared for cultivation of Onion seeds where the seedlings were transplanted after two months from nursery to the sustainable field in November 30, 2019 and December 2, 2020 growing seasons, respectively. The seedlings were cultivated on both sides of the drip irrigated ridges with 30 cm width and 15 cm between dripper. The plot area was 9 m^2 (3 m long ×3 m width) and the micro-plot area was 0.18 m^2 (0.6m long × 0.3m width) was designed for the application of ^{15}N labeled. The experimental treatments were distributed in a split-plot design in two factors with three replicates. The experimental treatments were as follows:

The first factor was Micronutrient (M) contain 5-treatments i.e. Fe, Mn, Cu, Zn and Mixture of them. The other factor was the different concentration (C) of the sprayed micronutrients containing 4-treatment i.e. C_0, C_1, C_2 and C_3. Details of micronutrient concentrations are presented in Table 2.

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

Clay (%)	**Sand** (%)	**Silt** (%)	**Texture**	**Bulk density** (g cm^3)	**O.M.** (g kg^{-1})	**pH** (1:2.5)	**EC** (dS m^{-1})
3.76	88.66	7.58	Sand	0.64	15.70	7.82	0.76
			Available nutrients (mg kg^{-1})				
N	**P**	**K**	**Zn**	**B**	**Fe**	**Mn**	**Cu**
1.95	0.23	2.37	0.02	0.45	0.72	0.40	0.03

Table 2: Concentration of all nutrients used in the study

Concentration (mg L^{-1})	**Micronutrients**				
	Fe	**Mn**	**Cu**	**Zn**	**Mixture**
C_0	Distilled water (untreated)				
C_1	100	0.25	1	3	Sum. of Raw=Mix_1
C_2	200	0.50	3	6	Sum. of Raw=Mix_2
C_3	300	0.75	5	9	Sum. of Raw=Mix_3

Notes: C_0, C_1, C_2 and C_3 are without, low, medium and high spray solution concentration, respectively.

Micronutrients were sprayed in a chelate form as Fe-EDTA (6% Fe), $ZnSO_4.7H_2O$ (24% Zn), $CuSO_4.5H_2O$ (24.5% Cu) and Mn-EDTA (12% Mn). Micronutrients were sprayed at two times starting at 30 and 60 days after transplanting. All spraying treatments were done in the morning time using a hand pressure sprayer and covering the onion plant with spraying solution. Nitrogen fertilizer was applied at the rate of 144 kg N ha^{-1} as ordinary ammonium sulfate (21%N) with three equal splits (20, 40 and 60 days after transplanting). Labeled nitrogen fertilizer (^{15}N as ammonium sulfate enriched with 5 % atom excess) was applied in a micro plot, it was added in only one replication in both seasons. Phosphorus fertilizer was added at rate of 600 kg ha^{-1} as calcium mono phosphate (15.5%P_2O_5). Potassium fertilizer was added at rate of 240 kg ha^{-1} as potassium sulfate (48% K_2O), both Phosphate and potassium fertilization were added during the soil preparation process.

2.1-Crop parameters measurements

A- Vegetative growth:

One sample of plants onion (0.50 m^2) from each sub-plot at 90 days after transplanting (DAT) in both seasons was taken to estimate the following characteristics:

1- Plant height (cm) was measured using ruler from the soil surface to the top of the longest mature leaf of the plants as average of 10 plants from each sub- plot.

2- Number of leaves per plant was calculated by counting all leaves of the plant as average of ten plants randomly taken from each sub-plot.

3- Fresh and dry weight of (bulb + shoot) kg m^{-2}.

B- Yield and quality characteristics:

1- Bulb yield or economical yield (ton ha^{-1}). At harvesting time (155 days after transplanting), onion yield was calculated from the whole sub- plot.

2- Bulb diameter (cm) the transverse section (diameter) of each of the bulbs sampled was measured in centimeters using a measuring tape [21].

3- Total soluble solids (T.S.S) % was determined in bulbs after harvesting by a hand refractometer [22].

4- Ascorbic acid (mg $100g^{-1}$) was extracted from bulb using 2% oxalic acid and was determined using 2.6 Dichlorophenol indophenol dye method by titration according to Ranganna [23].

C- Chemical composition of bulb:

1- Total nitrogen (g kg^{-1}) in bulb was determined using Kjeldahl method according to Jones et al. [24].

2- Phosphorus (g kg^{-1}) was determined using vanadate-molybdate method and measured calorimetrically using the UV-VIS Spectrophotometer (Shimadzu) at 430 nm [25].

3- Potassium (g kg^{-1}) in bulb was determined by Atomic absorption Spectrometry model Shimadzu 6800.

4- Zn, Cu, Fe and Mn concentration (mg L^{-1}) was determined in bulb and analyzed by the Atomic Absorption Spectrometry - Graphite Furnace (Shimadzu 6800), according to Westerman [26].

D- ^{15}N analysis:

Atom excess in plant sample was measured using the Emission Spectrometry ^{15}N Analyzer (Model NoI-6PC) according to IAEA [27]. Nitrogen derived from fertilizer was calculated using the following equations:

1-N-derived from fertilizer (Ndff) (%) = $\frac{\%\ ^{15}N \text{ atom excess in plant sample}}{\%\ ^{15}N \text{ atom excess in fertilizer}} \times 100$

2-Ndff (g kg^{-1}) = % Ndff × total N uptake (kg ha^{-1})

3- Fertilizer nitrogen recovery (FNR) = $\frac{\text{Ndff (g/area)}}{\text{Fertilizer rate}} \times 100$

The experiments were designed in a split-plot design in three replicates whereas, micronutrients treatments occupied the main plots while concentration treatments occupied in the sub-plots. All experimental data were subjected to ANOVA analysis to estimate the least significant differences (LSD) at $p \leq 0.05$ to compere the variation between treatments using SPSS program software version 20.

3- RESULTS

3.1- Plant height:

Results presented in Table 3, mentioned that there was a significant effect of foliar spraying of micronutrients on plant height in both seasons. The highest plant height was detected with onion plants treated with mixture solution and medium concentration ($MixC_2$) which relatively increased by about 76.0 and 84.7 % over the untreated plants in the first and second season, respectively. The main effect of the micronutrients gave a pattern of Mix > Zn > Fe > Mn >

Cu. It means that the micronutrients mixture caused a positive and significant increase in onion plant height (cm). These increases in plant height were done under any condition of the concentration. The main effect of spray solution concentration showed that the medium one gave the highest plant height with a significant increase between the other concentrations.

3.2- Number of leaves:

Data in Table 3, clearly revealed that there was a significant effect of foliar spraying of micronutrients on number of leaves per plant in the two growing seasons, foliar application of onion plants with mixed solution at medium concentration (MixC_2) resulted in the highest values on number of leaves in the first and the second season, as there was no significant differences between mixed solution at low, medium as well as high concentration in both seasons. Also, there is was non-significant differences in the number of leaves for plant when sprayed by zinc medium concentration and medium concentration of mixed solution in the second season.

Table 3: Foliar application of micronutrients and its effect on onion plant height and number of leaves at 90 DAT in the two growing seasons.

Micronutrient spray (M)	**Spray solution concentration** (C)									
	C_0	**C_1**	**C_2**	**C_3**	**Mean**	**C_0**	**C_1**	**C_2**	**C_3**	**Mean**
	First season					**Second season**				
Plant height (cm)										
Fe	29.48	44.33	43.33	42.43	39.89	27.24	42.43	41.57	40.50	37.93
Mn	26.29	40.30	41.33	42.20	37.53	24.67	38.57	39.57	40.27	35.77
Cu	27.35	37.13	37.93	38.73	35.29	25.24	35.90	36.57	37.37	33.77
Zn	30.47	46.43	47.47	45.20	42.39	26.88	44.47	45.60	43.43	40.10
Mix	28.65	49.33	50.43	48.37	44.20	26.79	48.53	49.47	46.87	42.91
Mean	28.45	43.51	44.10	43.39		26.16	41.98	42.55	41.69	
LSD 0.05:	**M: 0.53 ; C: 0.47 ; MC: 1.06**					**M: 0.77 ; C: 0.69 ; MC: 1.55**				
No. of leaves										
Fe	6	10	11	10	9	7	10	10	10	9
Mn	7	9	9	10	9	7	9	9	10	9
Cu	7	10	10	9	9	6	8	8	9	8
Zn	7	11	11	11	10	7	11	11	10	10
Mix	7	12	13	12	11	6	11	12	12	10
Mean	7	10	11	10		6	10	10	10	
LSD 0.05:	**M: 0.83 ; C: 0.74 ; MC: 1.66**					**M: 0.70 ; C: 0.62 ; MC:1.40**				

Notes: C_0, C_1, C_2 and C_3 are without, low, medium and high spray solution concentration, respectively.

3.3- Fresh and dry weight:

The results in Table 4, indicated that foliar spraying of micronutrients caused a significant increase in fresh and dry weight in seasons of 2019/2020 and 2020/2021. The highest fresh weights were 6.78 and 6.60 kg m^{-2} obtained by plants received the medium concentration of mix spray solution at the first and the second season, respectively (Table 4). The lowest onion fresh weight was ranged from 4.55 to 4.64 kg m^{-2} in the first and from 4.56 to 4.72 kg m^{-2} in the second season. These low fresh weights were obtained by treatments that not received any of microelements spray solution. Thus, plant receiving microelements (in or not in mix) spraying gave a positive effect in fresh weight with a significant increase. On the other hand, the highest dry weights were 1.39 and 1.36 kg m^{-2} obtained by plants received mixC_2 spray solution at the first and second season, respectively. The lowest onion dry weight was ranged from 0.55 to 0.71 kg m^{-2} in the first season and from 0.56 to 0.72 kg m^{-2} in the second season. These lowest dry weights were obtained by treatments that not received any of microelements spray solution. The main effect of the microelements shows that the mixed solution was more effective than adding each element alone. Also, zinc element follows the mixed solution in the increase in the fresh weight, followed by iron, then manganese, and finally copper, whether in the first season or the second season. As for the main effect of the concentration of spray solution, it was clear that the medium concentration was higher than the other concentrations, but any of the three concentrations gave a clear significant increase compared to the non-sprayed treatment.

Table 4: Foliar application of micronutrients and its effect on fresh and dry weight of onion plants at 90 DAT in the two growing seasons.

Micronutrient spray (M)	**Spray solution concentration** (C)									
	C_0	**C_1**	**C_2**	**C_3**	**Mean**	**C_0**	**C_1**	**C_2**	**C_3**	**Mean**
	First season					**Second season**				
Fresh weight (kg m^{-2})										
Fe	4.62	6.22	6.08	6.05	5.74	4.56	5.97	5.97	5.94	6.62
Mn	4.57	5.90	5.93	6.00	5.60	4.69	5.78	5.82	5.91	5.55
Cu	4.56	5.76	5.82	5.86	5.50	4.65	5.61	5.67	5.73	5.41
Zn	4.64	6.22	6.36	6.19	5.85	4.62	6.00	6.12	6.07	5.71
Mix	4.55	6.40	6.78	6.33	6.01	4.72	6.15	6.60	6.19	5.91
Mean	4.59	6.10	6.20	6.08		4.65	5.91	6.04	5.97	
LSD $_{0.05}$:	**M: 0.91 ; C: 0.82 ; MC: 1.06**					**M: 1.23 ; C: 1.10 ; MC:2.45**				
Dry weight (kg m^{-2})										
Fe	0.71	1.11	1.04	1.00	0.97	0.70	1.07	1.00	0.96	0.93
Mn	0.60	0.86	0.90	0.94	0.83	0.62	0.82	0.86	0.91	0.80
Cu	0.60	0.78	0.80	0.81	0.75	0.60	0.73	0.75	0.76	0.71
Zn	0.69	1.12	1.27	1.23	1.11	0.72	1.20	1.24	1.16	1.08
Mix	0.55	1.32	1.39	1.28	1.14	0.56	1.26	1.36	1.26	1.11
Mean	0.63	1.06	1.08	1.05		0.64	1.02	1.04	1.02	
LSD $_{0.05}$:	**M: 0.87 ; C: 0.61 ; MC: 1.37**					**M: 0.62; C: 0.55 ; MC: 1.24**				

Notes: C_0, C_1, C_2 and C_3 are without, low, medium and high spray solution concentration, respectively.

3.4- Bulb yield (Economical yield):

From Table 5, it could be observed that foliar spraying of micronutrients had a significant effect on bulb yield in the two growing seasons. Mixture solution at medium concentration ($MixC_2$) gave the maximum mean values blub yield which equal to 39.78 and 38.45 ton ha^{-1}in the first and second seasons, respectively. Whereas, the minimum one was 23.92 and 23.44 ton ha^{-1} in two seasons, respectively produced from treatment without spraying concentrations (C_0). In general, the spraying solution with a mixture of microelements gave a positive effect on increasing the onion economical yield when spraying with any single element, in the first season or the second season. Micronutrient main effect indicated spraying with the Mixture solution gave a significant increase in the onion bulb yield at the two seasons. The concentration of spray solution main effect showed that increasing the concentration of micronutrient (alone or in Mix) in the spray solution over the medium rate led to negative effect on the onion bulb yield.

3.5- Bulb diameter and Total Soluble Solids (TSS):

It is observed from Table 6, that treatments does not receive any of micronutrients spray solutions gave the lowest bulb diameter and TSS in the first and the second season. The highest bulb diameter and TSS were given by treatments received the mixed micronutrients spray solution. The increases in bulb diameter were 72.5 and 100.3% due to $MixC_2$ compared with $MixC_0$ at the first and the second season, respectively, but the increases in TSS were 30.0 and 35.4% due to $MixC_2$ compared with $MixC_0$ at the first and second season, respectively. All treatments receiving sprayed with one of microelements are given a decrease in bulb diameter and TSS. But when a mixture of these elements was made and sprayed on plants, it gave the optimum effective in bulb diameter and TSS with a significant increase. Also, spraying with zinc alone gave a significant increase in bulb diameter and TSS compared with the other microelements, But spraying with other microelements every an element alone gave a significant decrease in bulb diameter and total soluble solids. The microelement main effect gave a significant increase caused by the mixed solution.

It was clear from Table 7 that the highest concentrations of ascorbic acid were 14.79 and 14.55 mg L^{-1} at the first and the second season, respectively obtained by treatments received $MixC_2$. At the two seasons onion plants which not receive any microelements spray solutions gave the same concentration of ascorbic acid these concentrations of ascorbic acid were the lowest with a significant decrease compared with the other all treatments. Treatments received $MixC_1$ gave the second-high ascorbic acid concentrations at the first and the second seasons. The microelement main effect gave patterns of Mix>Zn>Fe>Mn>Cu at the first and the second season. The main effect of spray solution concentration showed that low and medium concentrations were gave the highest ascorbic acid concentration with no significant differences between them.

Table 5: Foliar application of micronutrients and its effect on bulb yield in the two growing seasons.

Micronutrient spray (M)	**Spray solution concentration** (C)									
	C_0	**C_1**	**C_2**	**C_3**	**Mean**	**C_0**	**C_1**	**C_2**	**C_3**	**Mean**
	First season					**Second season**				
	Bulb yield (ton ha^{-1})									
Fe	24.38	36.44	35.76	35.46	33.01	23.80	34.94	34.63	34.46	31.96
Mn	24.01	34.40	34.63	34.93	31.99	23.46	33.74	33.86	34.10	31.29
Cu	24.18	33.52	33.71	34.12	31.38	23.44	32.24	32.46	32.82	30.24
Zn	24.20	37.47	37.87	28.89	32.11	23.52	36.10	36.75	36.09	33.11
Mix	23.92	38.82	39.78	38.30	35.20	23.83	37.87	38.45	37.24	34.35
Mean	24.14	36.13	36.35	34.34		23.61	34.98	35.23	34.94	
LSD $_{0.05}$:	**M: 0.57 ; C: 0.46 ; MC: 0.89**					**M: 0.38 ; C: 0.34 ; MC: 0.77**				

Notes: C_0, C_1, C_2 and C_3 are without, low, medium and high spray solution concentration, respectively.

Table 6: Foliar application of micronutrients and its effect on onion bulb diameter and total soluble solids in the two growing seasons.

Micronutrient spray (M)	**Spray solution concentration** (C)									
	C_0	**C_1**	**C_2**	**C_3**	**Mean**	**C_0**	**C_1**	**C_2**	**C_3**	**Mean**
	First season					**Second season**				
	Bulb diameter (cm)									
Fe	4.21	5.54	5.52	5.46	5.18	3.57	5.34	5.31	5.27	4.87
Mn	4.09	5.35	5.38	5.42	5.06	3.38	5.17	5.20	5.23	4.75
Cu	4.11	5.21	5.27	5.31	4.98	3.67	4.97	5.02	5.10	4.69
Zn	4.14	5.68	5.74	5.52	5.27	3.64	5.46	5.51	5.41	5.00
Mix	3.73	6.25	6.47	6.06	5.63	3.17	6.05	6.35	5.85	5.36
Mean	4.06	5.61	5.67	5.55		3.49	5.40	5.48	5.37	
LSD $_{0.05}$:	**M: 0.11 ; C: 0.09 ; MC: 0.21**					**M: 0.12; C: 0.10 ; MC: 0.23**				
	Total soluble solids (%)									
Fe	10.06	12.41	12.28	12.14	11.72	9.61	12.18	12.09	11.91	11.45
Mn	10.11	11.90	11.91	12.07	11.50	9.55	11.72	11.73	11.80	11.20
Cu	10.02	11.46	11.64	11.72	11.21	9.80	11.25	11.49	11.63	11.04
Zn	10.17	12.63	12.71	12.51	12.01	9.58	12.34	12.47	12.49	11.72
Mix	10.17	13.04	13.22	12.83	12.32	9.40	12.69	12.73	12.55	11.84
Mean	10.11	12.29	12.35	12.25		9.59	12.04	12.10	12.07	
LSD $_{0.05}$:	**M: 0.09 ; C: 0.08 ; MC: 0.19**					**M: 0.16; C: 0.14 ; MC: 0.32**				

Notes: C_0, C_1, C_2 and C_3 are without, low, medium and high spray solution concentration, respectively.

Table 7: Foliar application of micronutrients and its effect on Ascorbic acid concentration in onion plants in the two growing seasons.

Micronutrient spray (M)	**Spray solution concentration** (C)									
	C_0	**C_1**	**C_2**	**C_3**	**Mean**	**C_0**	**C_1**	**C_2**	**C_3**	**Mean**
	First season					**Second season**				
	Ascorbic acid (mg $100g^{-1}$)									
Fe	9.06	13.91	13.71	13.47	12.54	8.58	12.89	12.73	12.57	11.69
Mn	9.02	12.97	12.84	12.36	11.80	8.56	11.91	11.53	11.26	10.82
Cu	9.00	11.99	11.85	11.47	11.08	8.59	11.01	10.75	10.36	10.18
Zn	9.03	14.02	14.11	14.19	12.84	8.66	13.26	13.52	13.80	12.31
Mix	8.77	14.60	14.79	14.50	13.17	8.47	14.31	14.55	13.93	12.81
Mean	8.98	13.50	13.46	13.20		8.57	12.68	12.62	12.38	
LSD $_{0.05}$:	**M: 0.21 ; C: 0.19 ; MC: 0.43**					**M: 0.22 ; C: 0.20 ; MC: 0.45**				

Notes: C_0, C_1, C_2 and C_3 are without, low, medium and high spray solution concentration, respectively.

4.7- Iron and manganese uptake:

At the first season, the highest Fe and Mn uptake was given by $MixC_2$ and at the second season the highest Fe uptake was given by FeC_3 on the other hand, the highest Mn uptake was obtained by $MixC_1$ (Table 8). Increasing the uptake of iron by onion plants was the result of mixing the other three microelements, as it turned out that spraying with zinc and iron, each of them separately, was more effective than spraying with manganese and copper, whether in the first season or the second season. As for the uptake of manganese by onion plants (excluding spraying with mixed solution), we find that zinc, iron and manganese were more effective than copper. Thus, it is the clear competitive relationship between the microelements and some of them regarding the uptake of iron and manganese in the two seasons. The main effect of microelements in Fe uptake gave a patterns of Fe>Mix>Zn≥Mn≥Cu and Mix≥Fe>Mn≥Zn≥Cu at the first season and second seasons, respectively, but the main effect of microelements in Mn uptake gave a pattern of Mix>Mn>Fe>Zn>Cu at the two seasons.

4.8- Copper and Zinc uptake:

4.8.1- Copper uptake:

Under the conditions of spraying with iron or zinc, the highest uptake of copper was obtained when spraying with low concentration (Table 9). On the other hand, spraying with copper or with the mixture had the highest uptake of copper at medium concentration. But when spraying with manganese, the highest Cu uptake was at the high concentration. This trend was in the first and second season, except under conditions of copper spraying. The highest Cu uptake was when spraying with high concentration. The main effect of micronutrient gave a pattern of Mix>Cu>Fe>Mn>Zn at the first and the second seasons. The main effect of the concentration of the spraying solution did not show significant differences between the three concentrations (C_1, C_2 and C_3), but all concentrations gave a clear significant difference compared to the non-spray condition (C_0).

4.8.2- Zinc uptake:

Zinc uptake took the same trend in the two seasons (Table 9). The medium concentration of the spray solution gave the highest Zn uptake under the conditions of spraying with manganese, zinc or a mixture, but the low concentration gave the highest Zn uptake in the case of spraying with iron or copper. It is clear that the extent of the difference between the microelements and some of them in the range between the harmful and beneficial concentration and the possibility of toxicity to onion plants in the case of high concentration in the spray solution. The main effect of micronutrient gave a pattern of Mix>Zn>Mn>Fe>Cu at the first and the second seasons. The main effect of the concentration of the spraying solution did not show significant differences between the three concentrations (C_1, C_2 and C_3), but all concentrations gave a clear significant difference compared to the treatment without spraying concentration (C_0).

Table 8: Foliar application of micronutrients and its effect on Fe and Mn uptake by onion plants in the two growing seasons.

Micronutrient spray (M)	**Spray solution concentration** (C)									
	C_0	**C_1**	**C_2**	**C_3**	**Mean**	**C_0**	**C_1**	**C_2**	**C_3**	**Mean**
	First season					**Second season**				
	Iron uptake (kg ha^{-1})									
Fe	0.395	0.711	0.752	0.775	0.658	0.365	0.666	0.710	0.733	0.618
Mn	0.372	0.606	0.62	0.634	0.558	0.350	0.573	0.587	0.602	0.528
Cu	0.374	0.553	0.548	0.542	0.504	0.350	0.508	0.505	0.496	0.465
Zn	0.382	0.624	0.641	0.496	0.536	0.357	0.580	0.601	0.600	0.535
Mix	0.365	0.712	0.743	0.736	0.639	0.349	0.677	0.703	0.700	0.607
Mean	0.378	0.641	0.661	0.637		0.354	0.601	0.621	0.626	
LSD $_{0.05}$:	**M: 0.045 ; C: 0.040 ; MC: 0.089**					**M: 0.009; C: 0.008; MC: 0.018**				
	Manganese uptake (kg ha^{-1})									
Fe	0.115	0.204	0.207	0.214	0.185	0.107	0.187	0.193	0.201	0.172
Mn	0.115	0.234	0.244	0.255	0.212	0.107	0.218	0.205	0.236	0.192
Cu	0.110	0.168	0.166	0.164	0.152	0.102	0.157	0.153	0.150	0.141
Zn	0.113	0.192	0.201	0.157	0.166	0.105	0.179	0.187	0.188	0.165
Mix	0.108	0.235	0.256	0.238	0.209	0.101	0.237	0.235	0.221	0.199
Mean	0.112	0.207	0.215	0.206		0.104	0.196	0.195	0.199	
LSD $_{0.05}$:	**M: 0.017 ; C: 0.015 ; MC: 0.038**					**M: 0.008; C: 0.008; MC: 0.016**				

Notes: C_0, C_1, C_2 and C_3 are without, low, medium and high spray solution concentration, respectively.

Table 9: Foliar application of micronutrients and its effect on Cu and Zn uptake by onion plants in the two growing seasons.

Micronutrient spray (M)	Spray solution concentration (C)									
	C_0	C_1	C_2	C_3	Mean	C_0	C_1	C_2	C_3	Mean
	First season					Second season				
Copper uptake (kg ha^{-1})										
Fe	0.060	0.104	0.099	0.096	0.090	0.049	0.088	0.086	0.083	0.077
Mn	0.057	0.089	0.091	0.093	0.082	0.048	0.077	0.078	0.080	0.071
Cu	0.058	0.100	0.103	0.105	0.091	0.048	0.085	0.089	0.094	0.079
Zn	0.053	0.085	0.083	0.059	0.070	0.045	0.073	0.071	0.066	0.064
Mix	0.057	0.112	0.116	0.113	0.100	0.051	0.097	0.100	0.098	0.086
Mean	0.057	0.098	0.098	0.093		0.048	0.084	0.085	0.084	
LSD $_{0.05}$:	**M: 0.006 ; C: 0.005 ; MC: 0.011**					**M: 0.001; C: 0.001; MC: 0.003**				
Zinc uptake (kg ha^{-1})										
Fe	0.161	0.262	0.253	0.244	0.230	0.148	0.237	0.232	0.225	0.211
Mn	0.158	0.263	0.263	0.263	0.236	0.144	0.242	0.242	0.242	0.218
Cu	0.157	0.218	0.212	0.209	0.199	0.141	0.201	0.193	0.189	0.181
Zn	0.162	0.298	0.304	0.239	0.251	0.148	0.268	0.276	0.280	0.243
Mix	0.162	0.306	0.310	0.296	0.268	0.150	0.279	0.281	0.270	0.245
Mean	0.160	0.269	0.268	0.250		0.146	0.245	0.245	0.241	
LSD $_{0.05}$:	**M: 0.021 ; C: 0.019 ; MC: 0.043**					**M: 0.005; C: 0.004; MC: 0.009**				

Notes: C_0, C_1, C_2 and C_3 are without, low, medium and high spray solution concentration, respectively.

4.9- Nitrogen uptake:

Spraying the mixture solution (with any concentration) gave the highest nitrogen uptake and higher than spraying with each element separately (Table 10), as it turned out that there were no significant differences between the low concentration and the higher concentration, but the medium concentration gave the highest nitrogen uptake with significant differences between the other concentrations of the mixture. At the two seasons, microelements main effect gave a pattern of Mix>Zn>Fe>Mn>Cu. This pattern was agreeing with the interaction effect under conditions of C_1, C_2 and C_3. The medium concentration of Mix, Zn and Fe gave high N uptake but the high concentration of Mn and Cu gave high N uptake under conditions of each spray solution.

4.10- Nitrogen (as ^{15}N) derived from fertilizer (Ndff) and Fertilizer nitrogen recovery as ^{15}N (FNR):

It is illustrated in Table 10, that the microelements have a varying role in stimulating the onion plants to nitrogen uptake. As for spraying with the mixture solution, it had the highest aspect in encouraging onion plants to uptake nitrogen element. We also noticed from Table 10, that the zinc element follows the mixture solution in stimulating the plant to uptake nitrogen, followed by iron, then manganese, and finally copper. This gradation between microelements in nitrogen uptake is consistent with the main effect of them, but the medium concentration of all spray solutions was on the treatment that encourages onion plants to uptake nitrogen. This gradation of nitrogen uptake is consistent with that of nitrogen recovery.

4.11- Phosphorus and potassium uptake:

Phosphorus and potassium uptake were taking the same trend in increasing at the two seasons (Table 11). The highest P uptakes were 34.17 and 32.32 kg ha^{-1} at the first and second season, respectively due to treatments receiving MixC_2. On the other hand, the highest K uptakes were 33.45 and 91.28 kg ha^{-1} at the first season and second season, respectively due to treatments receiving MixC_2. The main of microelements in K uptake and P uptake at the first season took the same trend in N uptake Table 10, at the first and second season, but the microelement main effect in P uptake at the second season showed that there was a non-significant difference between Mix and Zn spray solutions

Table 10: Foliar application of micronutrients and its effect on Nitrogen uptake, Ndff and FNR by onion plants with application of stable ^{15}N isotope in the two growing seasons.

Micronutrient spray (M)	**Spray solution concentration** (C)									
	C_0	**C_1**	**C_2**	**C_3**	**Mean**	**C_0**	**C_1**	**C_2**	**C_3**	**Mean**
	First season					**Second season**				
	Nitrogen uptake (kg ha^{-1})									
Fe	61.3	96.3	95.7	92.4	86.4	57.6	90.4	90.7	88.3	81.7
Mn	59.8	94.8	95.5	94.3	86.1	56.5	89.4	90.8	89.5	81.5
Cu	59.2	92.9	93.4	97.8	85.8	55.3	87.5	88.5	92.4	80.9
Zn	63.8	110.0	110.2	87.6	92.9	59.3	102.3	105.1	106.2	93.2
Mix	58.8	118.1	132.9	123.1	108.2	57.6	110.2	123.1	114.0	101.2
Mean	60.6	102.4	105.5	99.0		57.3	96.0	99.6	98.1	
LSD $_{0.05}$:	**M: 8.4 ; C: 7.3 ; MC: 16.7**					**M: 2.8 ; C: 2.5 ; MC: 5.6**				
	Nitrogen (as ^{15}N) derived from fertilizer (kg ha^{-1})									
Fe	17.3	80.5	89.6	80.3	66.9	13.4	61.8	75.1	63.7	53.5
Mn	16.9	52.8	56.0	54.4	45.0	12.8	40.2	44.3	41.1	34.6
Cu	15.6	44.8	56.3	60.3	44.3	12.2	65.4	44.8	48.1	42.6
Zn	19.0	80.0	84.0	64.9	62.0	14.1	60.3	66.9	65.9	51.8
Mix	16.8	63.3	73.7	64.6	54.6	12.9	46.6	55.0	48.2	40.7
Mean	17.1	64.3	71.9	64.9		13.1	54.9	57.2	53.4	
	Recovery (as ^{15}N) of fertilizer nitrogen (%)									
Fe	12.1	56.4	62.7	56.2	46.8	9.4	43.3	52.6	44.6	37.5
Mn	11.8	37.0	39.2	38.1	31.5	9.0	28.1	31.0	28.8	24.2
Cu	10.9	31.4	39.4	42.2	31.0	8.6	45.7	31.4	33.7	29.8
Zn	13.3	56.0	58.8	45.5	43.4	9.8	42.2	46.8	46.1	36.3
Mix	11.7	44.3	51.6	45.2	38.2	9.0	32.6	38.5	33.7	28.5
Mean	12.0	45.0	50.3	45.4		9.2	38.4	40.1	37.4	

Notes: C_0, C_1, C_2 and C_3 are without, low, medium and high spray solution concentration, respectively. Ndff and FNR were calculated with no statistical analysis.

Table 11: Foliar application of micronutrients and its effect on P and K uptake by onion plants in the two growing seasons.

Micronutrient spray (M)	**Spray solution concentration** (C)									
	C_0	**C_1**	**C_2**	**C_3**	**Mean**	**C_0**	**C_1**	**C_2**	**C_3**	**Mean**
	First season					**Second season**				
	Phosphorus uptake (kg ha^{-1})									
Fe	10.80	25.16	23.33	23.17	20.62	10.22	22.82	19.99	22.02	18.76
Mn	10.05	25.47	25.29	25.09	21.47	9.58	24.53	24.42	23.63	20.54
Cu	10.38	21.40	21.13	21.63	18.64	9.64	19.92	20.08	20.64	17.57
Zn	10.91	28.31	29.82	23.29	23.08	10.09	26.68	28.38	35.06	25.05
Mix	9.45	33.41	34.17	31.30	27.08	9.33	32.28	32.32	30.14	26.02
Mean	10.32	26.75	26.75	24.90		9.77	25.25	25.04	26.30	
LSD $_{0.05}$:	**M: 2.16 ; C: 1.93 ; MC: 4.31**					**M: 2.38 ; C: 2.13 ; MC: 4.75**				
	Potassium uptake (kg ha^{-1})									
Fe	10.47	23.79	20.64	22.66	19.39	20.08	64.36	62.40	57.32	51.04
Mn	9.80	25.01	24.99	24.20	21.00	19.89	71.48	68.95	64.49	56.20
Cu	9.95	20.72	20.86	21.46	18.25	20.61	72.33	73.32	75.50	60.44
Zn	10.39	27.69	29.24	29.71	24.26	20.90	83.86	86.08	84.71	68.89
Mix	9.38	33.10	33.45	31.01	26.73	20.66	89.36	91.28	88.73	72.51
Mean	10.00	26.06	25.83	25.81		20.43	76.28	76.41	74.15	
LSD $_{0.05}$:	**M: 3.81 ; C: 3.41 ; MC: ns**					**M: 1.35 ; C: 1.20 ; MC: 2.69**				

Notes: C_0, C_1, C_2 and C_3 are without, low, medium and high spray solution concentration, respectively.

5- DISCUSSION

The positive impact of micronutrients on plant growth and yield as well as quality might be due to its role in many physiological processes also cellular functions within the plants. In addition, it plays a role in improving plant growth, by biological synthesis of endogenous hormones which accountable for comforting of plant growth [28, 29]. Furthermore, by increasing photosynthetic activity, chlorophyll production, nitrogen metabolism, and auxin concentration in plants, copper sulphate foliar spraying at key developmental phases of the crop eventually boosted plant height and breadth. These results are consistent with those of Goyal et al. [30] and Pramanik et al. [31]. The process of photosynthesis depends heavily on copper, which is also component of the plastocyanin protein found in chloroplasts [32].

Moreover, the positive increase of micronutrients on yield and quality might be due to that micronutrients play a momentous role in consolidation plant cell walls and translocation of carbohydrates from leaves to other plant parts, this means that a prospect of increment dry matter percentage as well as yield. So, it is strongly required for improve the productivity of many crops since it could serve as counter ion [33, 34]. Similar results were almost in agreement with those obtained by Abdel-Samad et al. and Alam et al. [34, 35]. They found that bulb yield and quality of onion was mostly reinforced by foliar spraying of Zn followed by Fe. Combined application of NPK and $CuSO_4$ increases the yield which might be due to the role of Cu as essential micronutrient for plant growth and its involvement in the activation of many enzymes [36]. $CuSO_4$ role as a crucial micronutrient for plant growth and the activation of several enzymes may account for the increase in onion production, quality, and Cu absorption seen following foliar application of $CuSO_4$ at 0.30%. The same outcomes were reported by Rahman et al. [37] and El- Hadidi et al. [38]. However, significant increase in Cu uptake of the bulb onion might be due to the foliar spraying of $CuSO_4$ which confirm that fertilizers are absorbed right at the site where they are used and are effective sources of traits and better nutrient uptake by onion bulb under foliar fertilization than soil application [39, 40].

By foliar spraying Cu at various intervals, onion quality may be improved, and spraying 0.40% $CuSO_4$ was determined to be the most effective method. The increased metabolic activities involved in the manufacture of TSS, such as carbohydrates, organic acids, amino acids, and other inorganic elements, may be responsible for the improvement in TSS content in fresh onion bulbs following copper treatment. This might potentially be as a result of increased glucose production during the photosynthesis process [31]. Between the number of sprays, better quality parameters were associated with the $CuSO_4$ spray twice while reduction in quality attributes were observed with increasing number of $CuSO_4$ spray from twice to thrice. Nitrogen addition and moving can significantly influence micronutrient cycling in grassland ecosystems. It remains largely unknown about how different forms of added N affect micronutrient status in plant-soil system [41]. Meanwhile, high soil micronutrient concentrations (such as Mn) caused by environmental changes could be toxic to plants [42] and suppress the absorption of other nutrients by plants [43]. For example, excess Mn in soil inhibits plant Fe absorption and causes Mn toxicity, thereby driving plant species loss [44, 45]. In addition, excess Zn may inhibit the transportation of copper (Cu) in plants, while excess Cu has no effect on plant Zn uptake [46]. Because of these complex interactions between micronutrients, environmental change-induced alterations in soil micronutrient cycling are expected to affect plant nutrient absorption efficiency and above-ground plant productivity.

6- CONCLUSION

Spraying with microelements in the form of the mixture gave a positive effect on the growth characteristics of the onion plant and its uptake of macro and micro nutrients. But spraying with each micronutrient separately gave lower effect than the mixture on onion plants. In addation, results indicated that spraying onion plants with micronutrient led to an increase in N uptake, and thus increased Ndff and FNR.

7- REFERENCES

[1] Amagase, H., Petesch, B.L., Matsuura, H., Kasuga, S. and Itakura, Y. (2001). Intake of garlic and its bioactive components. J. Nut. 131(3):955-962S. https://doi.org/10.1093/jn/131.3.955s

[2] Benepal, P.S. (1967). Influence of micronutrients on growth and yield of potatoes. Am. Potato J. 44(10) 363-369. https://doi.org/10.1007/BF02865033

[3] Latha, M.R. and Nadanassababady, T. (2003). Foliar nutrition in crops. Agric. Rev. 24:229-234.

[4] Rahman, I.U., Afzal, A., Iqbal, Z. and Manan, S. (2014). Foliar application of plant mineral nutrients on wheat: A review. Res. and Rev.: J. Agric. Allied Sci. 3: 19-22.

[5] El-Tohamy, W.A., Khalid, A.K., El-Abagy, H.M. and Abou-Hussein, S. D. (2009). Essential oil, growth and yield of onion (*Allium cepa* L.) in response to application of some micronutrients. Aus. J. Basic Appl. Sci. 3(1):201-205.

[6] Pirzadeh, M., Afyuni, M., Khoshgoftarmanesh, A. and Schulin, R. (2010). Micronutrient status of calcareous paddy soils and rice products: implication for human health. Biology and Fertility of Soils 46: 317-322. https://doi:10.1007/s00374-009-0428-

[7] Alam, M.N., Abedin, M.J., and Azad, M.A.K. (2012). Effect of micronutrients on growth and yield of onion under calcareous soil environment. Inter. J. Biosci. 2(8): 95-101. http://www.innspub.net/wp-content/upl.

[8] Tisdale, S.L., Nelson, W.L. and Beaton, J.D. (1985). Elements required in plant nutrition. In soil fertility and fertilizers, Zinc, pp:85- 86. Macmillan Publishing Company 866 third avenue, New York, 10022.

[9] Thakur, O. and Kumar, V. (2021). Review on impact of micronutrients (zinc and boron) in relation to growth, yield and quality of onion. Int. J. Curr. Microbiol. App. Sci. 10(3): 1733-1740. https://doi.org/10.20546/ijcmas.2021.1003.216

[10] Eide, D.J. (2011). The oxidative stress of zinc deficiency. *Metallomics 3*: 1124-1129. https://doi.org/10.1039/c1mt00064k

[11] García-Bañuelos, M.L., Sida-Arreola, J.P. and Sánchez, E. (2014). Biofortification-promising approach to increasing the content of iron and zinc in staple food crops. J. Elementol. 19:865–888. https://doi:10.1104/pp.17.00672

[12] Shen, W., Xue, H., Gao, N., Shiratori, Y., Kamiya, T., Fujiwara, T., Isobe, K. and Senoo, K. (2019). Effects of copper on nitrous oxide (N_2O) reduction in denitrifiers and N_2O emissions from agricultural soils. Biol. Fert. Soils 56:39-51. https://doi.org/10.1007/s00374-019-01399-y

[13] Socha, A.L. and Guerinot, M.L. (2014). Mn-euvering manganese: the role of transporter gene family members in manganese uptake and mobilization in plants. Fron. Plant Sci. 5:1-16. https://doi.org/10.3389/fpls.2014.00106

[14] Havlin, J.L., Tisdale, S.L., Nelson, W.L. and Beaton, J.D. (2021). Soil fertility and nutrient management: an introduction to nutrient management. 8th Ed. Pearson, Upper Saddle River, New Jersey. United States:505.

[15] Rout, G.R. and Sahoo, S. (2015). Role of iron in plant growth and metabolism. In Reviews in Agri. Sci. 3:1-24. https://doi.10.7831/ras.3.1.

[16] Pilon, M., Abdel-Ghany, S.E., Cohu, C.M., Gogolin, K.A. and Ye, H. (2006). Copper cofactor delivery in plant cells. Current Opinion in Plant Biol. 9:256–263. https://doi: 10.1016/j.pbi.2006.03.007

[17] Puig, S., Andrés-Colás, N., García-Molina, A. and Peñarrubia, L. (2007). Copper and iron homeostasis in Arabidopsis: responses to metal deficiencies interactions and biotechnological applications. Plant Cell Envir. 30:271–290. https://doi:10.1111/j.1365-3040.2007.01642.x

[18] Mortvedt, J.J. (1991). Micronutrients in agriculture. Madison, WI: Soil Sci. https://doi.org/10.2136/sssabookser4.2ed.c14

[19] Alhasany, A.R., Noaema, A.H. and Alhmadi, H.B. (2019). The role of spraying copper and zinc on the growth and yield of *Vicia faba* L. IOP Conf. Series: Materials Science and Engineering 571: 012048. https://doi:10.1088/1757-899X/571/1/012048

[20] Kumar, M. (2023). Effect of secondary and micronutrients on yield and quality of fox nut (*euryale ferox* salisb.) In subtropical climate. J. Plant Nut. 46(2): 212-218. https://doi.org/10.1080/01904167.2022.2067051

[21] Ibrahim, N.D. (2010). Growth and yield of onion (*allium cepa* L.) In sokoto, nigeria. Agri. Biol. J. North Am. 1(4):556- 564. http://www.scihub.org/ABJNA

[22] AOAC (1980). Official method of analysis AOAC (International Association of Official Analytical Chemists). Washington, D.C:108.

[23] Ranganna, S. (2007). Handbook of analysis and quality control for fruit and vegetable products.

Tata Mc Graw Hill Publishing Co. New Delhi. 8: 182-186.

[24] Jones Jr., J.B., Wolf, B. and Mills, H.A. (1991). Plant analysis handbook: a practical sampling, preparation, analysis, and Interpretation Guide. Micro-Macro Publishing, Athens.

[25] Cotteine, A., Verioo, M., Kiekens, L., Velghe, G. and Camerlynck, R. (1982). Chemical analysis of plant and soils. Lab. Anal. Agro. State University, Ghent, Brussel-Belgium

[26] Westerman, R.L. (1990). Soil Testing and Plant Analysis. Third Edition in the SSSA Book Series 3, Soil Sci. Soc. Am., Inc. Madison, Wisconsin, USA.

[27] IAEA (2008). Training courses series. International Atomic Energy Agency (IAEA) No. 14, Vienna, Austria.

[28] Battal, P. (2004). Effects of some mineral nutrients on gibberellic acid levels in maize plants. Econo. Bot. 58(2): 195-203.

[29] Hänsch, R. and Mendel, R.R. (2009). Physiological functions of mineral micronutrients (Cu, Zn, Mn, Fe Ni, Mo, B, Cl). Current Opinion in Plant Biol. 12: 259-266.

[30] Goyal, R., Uike, V. and Verma, H. (2017). Effect of foliar application of micronutrients on growth and yield of onion (*Allium cepa* L.) cv Agri found dark red. Agri. Sci. Dig. 37(2). https://doi:10.18805/asd.v37i2.7995

[31] Pramanik, K., Tripathy, P., Mandal, P., Pradhan, M. and Biswal, M. (2018). Effect of micronutrients on quality of onion (*Allium cepa* L.). Inter. J. Chem. Studies 6(6):1324-1327. https://doi.10.13140/RG.2.2.25937.97121

[32] Reineeke, A.J., Reinecke, S.A. and Lambrechts, H. (1997). Uptake and toxicity of copper and zinc for the African earthworm, Eudrilus eugeniae (Oligochaeta). Biol. Fertil. Soils 24:27-31.

[33] Barker, A.V. and Pilbeam, D.J. (2007). Handbook of plant nutrition. CRC Press, London, New York.

[34] Abdel-Samad, E.H., Khalifa, R.K.M., Lashine, Z.A. and Shafeek, M.R. (2011). Influence of urea fertilization and foliar application of some micronutrients on growth, yield and bulb quality of onion. Aust. J. Basic App. Sci. 5(5): 96-103. https://www.ajbasweb.com/old/ajbas/2011/96-103.pdf

[35] Alam, M.N., Abedin, M.J., and Azad, M.A.K. (2010). Effect of micronutrients on growth and yield of onion under calcareous soil environment. Inter. Res. J. Plant Sci. 1(3): 56-61.

[36] Chitdeshwari, T., Jagadeeswari1, D., Gnanasundari1, R. and Shukla, A.K. (2021). Foliar fertilization of copper on the growth, yield and quality of aggregatum onion (*Allium cepa* L.). Ind. J. Pure App. Biosci. 9(2):89-97. https://dx.doi.org/10.18782/2582-2845.8608

[37] Rahman, I.U., Afzal, A., Ijaz, F., Khan, S.M., Khan, S.A., Khan, K. and Ali, N. (2015). Influence of foliar nutrients application on growth and yield of onion grown in nutrient deficient soil. Bangladesh J. Bot.44(4): 613-619. https://doi.org/10.3329/bjb.v44i4.38598

[38] El-Hadidi, E., Mosaad, I., Fouda, K. and Gomaa, N. (2016). Effect of organic manure, zinc and sulfur application on rice yield and some nutrient uptake. J. Soil Sci. Agri. Eng. 7(7):493- 499. https://doi:10.21608/jssae.2016.39700

[39] Fouda, K.F. (2016). Response of onion yield and its chemical content to NPK fertilization and foliar application of some micronutrients. Egypt. J. Soil Sci. 56(3):549-561. https://doi:10.21608/ejss.2017.1083

[40] Samad, A., Khalifa, R.K.M., Lashine, Z.A. and Shafeek, M.R. (2011). Influence of urea fertilization and foliar application of some micronutrients on growth, yield and bulb quality of onion. Aust. J. Basic App. Sci 5:96-103.

[41] Liu, H., Wang, R., Lü, X.-T., Cai, J., Feng, X., Yang, G., Li, H., Zhang, Y., Han, X. and Jiang, Y. (2021). Effects of nitrogen addition on plant-soil micronutrients vary with nitrogen form and mowing management in a meadow steppe. Envir. Pol. 289:1-8. https://doi.org/10.1016/j.envpol.2021.117969

[42] Richardson, J.B. (2017). Manganese and Mn/Ca ratios in soil and vegetation in forests across the northeastern US: insights on spatial Mn enrichment. Sci. Total Envir. 581:612–620. https://doi.org/10.1016/j.scitotenv.2016.12.170.

[43] Rietra, R.P.J.J., Heinen, M., Dimkpa, C.O. and Bindraban, P.S. (2017). Effects of nutrient antagonism and synergism on yield and fertilizer use efficiency. Commun. Soil Sci. Plan. 48:1895–1920. https://doi.org/10.1080/00103624.2017.1407429

[44] Tian, Q., Liu, N., Bai, W., Li, L., Chen, J., Reich, P.B., Yu, Q., Guo, D., Smith, M.D., Knapp, A.K., Cheng, W., Lu, P., Gao, Y., Yang, A., Wang, T., Li, X., Wang, Z., Ma, Y., Han, X. and Zhang, W.H. (2016). A novel soil manganese mechanism drives plant species loss with increased nitrogen deposition in a temperate steppe. Ecol. 97: 65–74. https://doi.org/10.1890/15-0917.1.

[45] Cai, J., Weiner, J., Wang, R., Luo, W., Zhang, Y., Liu, H., Xu, Z., Li, H., Zhang, Y. and Jiang, Y. (2017). Effects of nitrogen and water addition on trace element stoichiometry in five grassland species. J. Plant Res. 130:659–668. https://doi.org/10.1007/s10265-017-0928-2.

[46] Li, G., Li, C., Rengel, Z., Liu, H. and Zhao, P. (2020). Excess Zn-induced changes in physiological parameters and expression levels of TaZips in two wheat genotypes. Envir. Exper. Bot. 177: 1-10. https://doi.org/10.1016/j.envexpbot.2020.104133