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Effect of N and Zn Use Efficiency on Yield and both nutrients uptake by Wheat

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Abstract: *This study was conducted to know the effect of added nitrogen and zinc interaction and their use efficiency on their uptake and the yield of wheat in two different texture soils. The study included an experiment (planting in plastic pots) in which five N levels of 0, 100, 200, 300, and 400 kg N ha^{-1}; five Zn levels of 0, 10, 20, 30, and 40 kg Zn ha^{-1} and two soils, clay loam (S1) and Sandy (S2), were used. Wheat plant (Triticum aestivum L.) was used as a plant indicator. A factorial experiment, according to Complete Randomized Block Design (CRBD) with three replicates, was used. The level 100 kg N ha^{-1} showed higher straw, grain yield, and N use efficiency of 19.15, 15.89 g pot^{-1}, and 60.40%, respectively. The level 20 kg Zn ha^{-1} gave higher straw and grain yield of 14.99 and 26.82 g pot^{-1}, respectively, while the level 40 kg Zn ha^{-1} gave a higher Zn use efficiency of 1.50%. The clay loam soil showed a superiority of increasing the plant indicators compared with the sandy soil. The interaction of N and Zn had a significant effect on all plant indicators, the interaction treatment (200 N and 20 Zn) had a higher N and Zn use efficiency. A significant correlation relationship (quadratic equation) had been found between the added N and Zn levels with all plant indicators.*

Keywords: *Fertilizer, fertilizer use efficiency, nitrogen, quadratic equation, zinc*
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I. Introduction

The interaction of nitrogen and zinc was one of the aspects that had a considerable attention in recent studies. It was a positive interaction occurred into soil and plant systems, its importance was due to increasing availability of both nutrients in the soil and absorbing by the plant, then increasing the bio-physiological activities which contribute to increasing plant growth, yield, and improving the yield quality as well as raising the use efficiency of both fertilizers, when be added together [1,2].

In the soil system, the interaction of these two nutrients depended on the added of nitrogenous fertilizers source. When adding nitrogenous fertilizers as ammonium, a biological oxidation of ammonium will occur across the nitrification process due to releasing hydrogen ions which contribute to reducing soil pH in the rhizosphere, then increasing the availability of some micronutrients, including zinc. Thus zinc uptake by the plant will increase. On the contrary, adding nitrogenous fertilizers as nitrate will lead to a lack of zinc availability due to the high soil pH [3].

In the plant system, nitrogen increased the plant uptake of zinc by increasing plant response to zinc, which contributed to increasing plant resistance to zinc deficiency or increasing zinc efficiency as well as adding nitrogen led to increasing dilution factor of plant zinc content to increase the growth as soon as adding nitrogen which led to increasing uptake of zinc. The nitrogen had a role in increasing the zinc content in the leaves and stems through promoting transmitting and movement of zinc, from the root to shoot system of the plant [1,4,5]. The effect of zinc on the interaction was also positive due to its role in the bio-physiological processes within the plant. Zinc had a responsibility of nitrogen metabolic processes, entering in amino acids (lysine and tryptophan) formation, contribution to the formation of nucleic acids and large number of enzymes such as those responsible to protein formation [6]. It had been found that the zinc deficiency resulted in protein metabolism decrement [7]. The results of [2] and [8] found a positive effect of the nitrogen and zinc interaction on the growth and yield of various crops such as wheat and sunflower, also they indicated that adding the both nutrients together contributed to raising the efficiency use of both fertilizers.

For the purpose of raising the nitrogen and zinc use efficiency through the use of the optimum level of both nutrients and their interaction to achieve the maximum yield and to reduce a waste amount of added fertilizer as studies are still in this regard is limited in Iraq, this study was conducted.

II. Materials and Methods

Two different texture soils were chosen and the samples of these soils were collected from the depth of 0 – 30 cm, the clay loam soil samples were collected from Al-Kifil Township while the sandy samples were from the shoulder of Tigris River in Hilla city. The samples were air dried, sieved through 2.0 mm sieve, and kept into big plastic containers. Some soil physical and chemical properties were evaluated according to [9,10] (table 1). A biological experiment was conducted including planting into plastic pots, carried out in the canopy of Soil Science and Water Resources Dept. – College of Agriculture, University of Babylon in the planting season of 2012 under atmospheric conditions to know the effect of adding nitrogen and zinc levels and their interaction on the straw and grain of wheat, nitrogen and zinc uptake by the plant, and fertilizer use efficiency of both nutrients in two different texture soils. The experiment included 5 levels of nitrogen: 0, 100, 200, 300, and 400 kg N ha^{-1} soil as a Urea (46% N) and 5 levels of zinc: 0, 10, 20, 30, and 40 kg Zn ha^{-1} soil as a mineral zinc, $ZnSO_4.H_2O$ (23 % Zn). Pots of 5 Kg capacity were used, 5 Kg of both soils were weighted, and the grains of the wheat (*Triticum aestivum* L.) were planted as 10 grains per pot, reduced to 5 seedlings after 10 days of germination. Nitrogen and zinc fertilizers were added to the soil surface as a liquid form. Nitrogen fertilizer were added as three batches: at the planting, at the branching stage, and at pre-flowering stage, while zinc was added as two batches: at the planting and at the branching stage. The water content was reserved at the field capacity. Phosphorus was added as 50 mg Kg^{-1} soil as Triple Superphosphate (TSP) (20% P) and potassium was added as 60 mg Kg^{-1} soil as potassium sulfate, K_2SO_4 (42% K). The wheat was harvested at the final maturation (150 days after the planting) and dried under 65˚C for 48 h by the oven until weight stability. Nitrogen and zinc contents, in the straw and grains, were evaluated according to [9].

Table 1. Soil chemical and physical properties.

Property		Soil 1	Soil 2	Units
pH		7.75	7.21	
ECe		3.24	2.76	dS m^{-1}
C_{tot}		6.16	1.80	g kg^{-1}
N_{tot}		1.13	0.52	
Total $CaCO_3$		245.0	96.0	
Active $CaCO_3$		68.0	45.5	
CEC		304.0	63.0	$mmol_+$ kg^{-1}
Available nutrients	$N\text{-}NH_4^+$	11.30	3.17	mg kg^{-1}
	$N\text{-}NO_3^-$	14.65	5.87	
	P_{olsen}	8.13	1.52	
	K	240.0	112.2	
	Zn	1.10	0.32	
Particles size analysis				g kg^{-1}
Sand		406.5	931.4	
Silt		222.5	35.0	
Clay		371.0	33.6	
Texture		Clay loam	Sandy	

Soil available zinc was evaluated according to [11]. Fertilizer Use Efficiency (FUE) of nitrogen and zinc was calculated using the following formula

$$FUE = \frac{\text{uptake nutrient of fertilized treatment} - \text{uptake nutrient of control}}{\text{Nutrient added quantity}} \times 100$$

A factorial experiment was used according to Complete Randomized Block Design (RCBD) with three replicates. Regression equations were used to find the relationship between plant indicators and the added levels of nitrogen and zinc. Least Significant Difference (LSD) was used to compare the means of different treatments at 5% [12].

III. Results and Discussion

3.1 Straw and grains yield

The results (table 2) showed there were significant differences (at 5%) of straw and grains yield among all added nitrogen levels. Increasing nitrogen levels of 100, 200, 300 and 400 kg ha^{-1} soil led to increasing straw yield of 82.8, 254.2, 207.2 and 162.7%, and grains yield of 94.2, 356.3, 227.1 and 173.9%, respectively, compared with control treatment.

The high response to previous plant indicators due to adding nitrogen attributed to decrement of both soils available nitrogen contents as well as the active role of nitrogen in the plant across contributing in chlorophyll formation and amino acids that essential for protein anabolism as well as entrance in nucleic acids, enzymes, vitamins, and mitochondria [6]. The nitrogen level, 100 kg ha^{-1} soil, achieved a higher increment in these indicators, thus it was an optimum level required for wheat to achieve the higher response under current study conditions. Obtained results agreed with those found by other studies.[13] found an increment in the yield of wheat grains of 91.0, 104.9, 122.7 and 130.3% at increasing nitrogen levels of 150, 200, 250 and 300 kg ha^{-1}. Also, the current study agreed with those obtained by [14,15].

The results showed a significant effect of zinc on the yield of straw and grains of wheat. The increment ratios of straw yield were 12.8, 29.2, 14.0 and 6.7% at adding zinc levels of 10, 20, 30 and 40 kg ha^{-1}, respectively, compared with the control while the increment ratios of grains yield were 23.6, 24.1, 13.0 and 4.1, respectively. The increased plant indicators by adding zinc attributed to its role in the plant across the entrance in the important compounds and enzymes that responsible to anabolism and catabolism, oxidation and reduction processes, and the composition of essential hormones and amino acids [6].

Increasing zinc level led to increasing the yield of straw and grains, the third added level of zinc (20 kg ha^{-1}) had a superiority in achieving the higher response of these indicators compared with other levels. The obtained results agreed with those of [16, 17, 18]. [19] explained that the yield of straw and grains, and the total wheat yield had increased by 24.0, 22.9, and 25.8%, respectively, with adding zinc level to 5 kg ha^{-1}, as zinc sulfate, compared with the control treatment.

Also, the results showed the effect of soil texture on the yield of straw and grains which increased by 31.3 and 18.6% in clay loam soil compared with the sandy soil, respectively. The superiority of the clay loam soil, compared with the sandy, attributed to the higher content of available nitrogen and zinc, and had a higher content of organic material and CEC, this was confirmed by many studies [20].

The results (table 2) showed a significant effect of the nitrogen and zinc interaction on the yield of straw and grain. Adding nitrogen and zinc together led to increasing straw and grain yield where the interaction treatment (200 N and 20 Zn) gave higher values of 21.79 and 17.23 g pot^{-1} for straw and grain, respectively, compared with control interaction treatment (0 N and 0 Zn). The results showed high achieved response in straw and grain of wheat due to adding nitrogen and zinc together,

that was due to the positive interaction effect of both nutrients on their uptake by wheat. That was confirmed by [1,21,22].

Table 2: The effect of N and Zn level and their interaction on yield of straw and grain (g pot^{-1}).

Soil	N Kg ha^{-1}	Straw yield Zn level (kg ha^{-1})					N mean	Grain yield Zn level (kg ha^{-1})					N Mean
		0	10	20	30	40		0	10	20	30	40	
Clay Loam	0	5.50	6.44	7.48	6.69	5.66	5.41	4.27	5.27	5.54	5.08	4.25	4.14
	100	10.55	12.28	13.46	11.98	10.73		8.35	9.30	9.89	8.91	8.60	
	200	19.72	21.11	24.19	20.33	19.87	9.89	15.23	17.40	18.26	17.50	15.89	8.04
	300	18.03	18.54	19.76	18.36	18.04		13.28	15.30	16.38	14.60	13.57	
	400	15.20	16.24	17.83	16.75	15.69	19.15	11.52	12.57	13.78	11.78	10.40	15.89
Zn S1 mean		13.80	14.92	16.55	14.82	14.00		10.53	11.97	12.77	11.58	10.60	
S1 mean		14.82					16.62	11.49					13.54
Sandy	0	3.34	4.74	5.60	4.58	4.10		3.10	3.33	3.85	3.19	3.23	
	100	6.97	7.32	9.67	8.15	7.82	14.21	6.15	6.99	8.20	7.35	6.62	11.34
	200	14.90	17.53	19.39	17.96	16.46		13.50	14.88	16.21	15.37	14.60	
	300	12.46	14.18	17.39	15.22	14.17		11.06	12.34	14.21	12.46	12.14	
	400	9.34	12.39	15.14	12.18	11.30		9.07	10.26	12.14	11.66	9.87	
Zn S2 mean		9.40	11.23	13.44	11.62	10.77		8.58	9.63	10.92	10.01	9.29	
Zn mean		11.60	13.08	14.99	13.22	12.38		9.55	10.80	11.85	10.79	9.94	
S2 mean		11.29						9.69					

LSD0.05		
N	0.11	0.09
Zn	0.11	0.09
Soil	0.07	0.06
N X Zn	0.24	0.21
N × Zn × Soil	0.34	0.29

3.2 Nitrogen Uptake by Straw and Grain

The results (table 3) showed a significant effect of the study factor (N and Zn levels, and soil texture) on N uptake by straw and grain. Increasing added nitrogen levels of 100, 200, 300 and 400 kg ha^{-1} led to increasing nitrogen uptake by straw of 178.9, 413.8, 402.6 and 384.6%, and by grain of 123.5, 420.3, 393.2 and 351.6%, respectively, for each nitrogen level compared with the control According to the results, it could be observed that the third level (200 kg ha^{-1}) had a superiority in achieving the higher nitrogen uptake by straw and grain. The results showed that the added zinc levels had a significant effect on nitrogen uptake by straw and grain. Increasing added zinc levels of 10, 20, 30 and 40 kg ha^{-1} led to increasing nitrogen uptake by straw of 16.0, 33.5, 26.8 and 26.7%, and by grain of 17.1, 43.4, 37.3 and 31.7%, respectively, compared with the control. Increasing nitrogen uptake by straw and grain with increasing the added zinc level might be due to the positive effect of zinc element on increasing the nitrogen uptake and increasing its content in the plant, and this was also confirmed by [2,23].

The results showed a significant effect of soil texture on nitrogen uptake by straw and grain. The nitrogen uptake by straw and grain had increased in clay loam soil of 69.9% compared with the sandy soil of 60.4%.

The results (table 4) showed a significant effect of the nitrogen and zinc interaction on nitrogen uptake by straw and grain. Adding nitrogen and zinc together led to increasing nitrogen uptake by straw and grain where the interaction treatment (200 N and 20 Zn) gave higher nitrogen uptake values of 165.20 and 257.95 mg pot^{-1} for straw and grain, respectively, compared with control interaction treatment (0 N and 0 Zn). The results showed high achieved response in nitrogen uptake by wheat. That was confirmed by [5,24].

Table 3: The effect of N and Zn level and their interaction on N uptake (mg pot^{-1}).

Soil	N Kg ha^{-1}	N uptake in Straw					N mean	N uptake in Grain					N mean
		Zn level (kg ha^{-1})						Zn level kg ha^{-1})					
		0	10	20	30	40		0	10	20	30	40	
Clay Loam	0	30.25	37.35	44.35	41.48	36.77	28.85	51.66	66.36	71.51	67.27	61.68	44.37
	100	72.82	86.36	98.27	89.88	84.03		112.72	134.18	145.38	132.51	128.66	
	200	163.67	171.82	205.66	176.90	180.13	64.47	239.16	283.68	308.55	298.63	274.96	99.17
	300	171.29	181.73	195.46	191.56	193.07		231.14	275.46	303.04	276.01	258.28	
	400	145.02	168.37	189.61	178.07	175.17	148.23	213.18	238.32	268.78	233.17	216.81	230.87
Zn S1 mean		118.91	129.13	146.67	135.58	133.83		173.17	199.60	219.45	201.52	188.08	
S1 mean		132.53					144.99	195.64					219.27
Sandy	0	11.36	18.33	24.63	21.82	21.75		18.07	21.18	29.87	27.31	28.78	
	100	28.57	33.45	53.20	47.27	50.86	139.80	46.33	54.99	75.47	77.69	83.82	200.39
	200	80.47	101.66	124.74	123.35	126.72		128.97	132.92	202.59	217.28	221.95	
	300	83.48	48.33	129.29	116.18	121.90		106.22	133.28	204.69	197.80	206.79	
	400	74.43	106.77	135.16	110.82	106.19		114.30	136.95	198.70	204.14	129.54	
Zn S2 mean		55.66	61.70	93.40	83.89	85.49		82.78	95.87	142.27	144.84	134.18	
Zn mean		86.55	100.36	120.04	109.73	109.66		126.17	147.73	180.86	173.18	166.13	
S2 mean		78.01						121.99					
LSD0.05													
N		1.31						1.85					
Zn		1.31						1.85					
Soil		0.83						1.17					
N × Zn		2.94						4.13					
N × Zn × Soil		4.16						5.84					

3.3 Zinc Uptake by Straw and Grain

Table 4 showed a significant effect of nitrogen, zinc and soil texture on zinc uptake by wheat. Increasing added nitrogen levels of 100, 200, 300 and 400 kg ha^{-1} led to increasing zinc uptake by straw of 157.9, 586.4, 617.3 and 596.1%, and by grain of 149.8, 533.0, 562.0 and 559.7%, respectively, compared with the control. Zinc uptake by straw and grain had increased with increasing added nitrogen level where the level 300 kg had achieved higher value of zinc uptake of 1144.8 and 945.3 µg pot^{-1} for straw and grain, respectively. Increasing zinc uptake by straw and grain, with increasing added nitrogen level, was attributed to increment in zinc availability and its uptake by plant due to the low soil pH, particularly in rhizosphere due to adding nitrogenous fertilizer [1,4].

Also, the results showed the effect of adding zinc level on zinc uptake by straw and grain. Zinc uptake by straw had increased of 64.8, 128.5, 130.4 and 142.0%, and by grain of 52.2, 76.7, 100.8 and 112.3% for added zinc levels of 10, 20, 30 and 40 kg ha^{-1}, respectively, compared with the control. Zinc uptake by straw and grain had decreased with increasing added zinc levels, where the higher increment was occurred in the level (40 kg ha^{-1}) of 981.6 and 829.7 µg pot^{-1} for straw and grain, respectively. This was confirmed by many researchers [17,25].

The results showed a significant effect of soil texture on zinc uptake by straw and grain. Zinc uptake by straw and grain, in clay loam soil, had increased by 64.5 and 51.1%, respectively, compared with the sandy soil.

The results (table 4) showed a significant effect of nitrogen and zinc interaction on zinc uptake by straw and grain. Zinc uptake had increased with the interaction of adding nitrogen and zinc together, where the higher value of zinc uptake by straw was at the level (300 N and 40 Zn) of 1420.4 µg pot^{-1}, while the lower value was at the level (0 N and 0 Zn) of 83.0 µg pot^{-1}, and by grain, the higher value was at the level (200 N and 40 Zn) of 119.7 µg pot^{-1}, while the lower value was at the level (0 N and 0 Zn) of 170.7 µg pot^{-1}. [1,4,23].

Table 4: The effect of N and Zn level and their interaction on Zn uptake (μg pot^{-1}).

Soil	N Kg ha^{-1}	Zn uptake in Straw					N Mean	Zn uptake in Grain					N mean
		Zn level (kg ha^{-1})						Zn level (kg ha^{-1})					
		0	10	20	30	40		0	10	20	30	40	
Clay Loam	0	109.8	168.3	223.7	262.7	235.8	159.6	115.8	175.9	205.7	213.7	205.2	142.8
	100	253.4	448.6	595.6	657.4	714.5		266.0	395.4	477.3	540.4	570.5	
	200	778.3	943.2	1676.7	1575.4	1743.7	406.8	913.9	954.9	1103.3	1359.6	1376.4	356.7
	300	837.9	1122.5	1549.4	1652.4	1769.4		949.1	1051.3	1191.6	1373.7	1382.7	
	400	841.6	1148.8	1544.9	1676.9	1829.6	1095.5	720.9	1095.7	1106.4	1350.1	1307.4	903.9
Zn S1 mean		564.2	767.5	1118.1	1165.0	1258.6		593.1	734.7	816.9	967.5	968.4	
S1 mean		974.6					1144.8	792.1					945.3
Sandy	0	54.7	101.3	144.7	146.1	147.4		59.9	77.7	115.6	124.9	133.5	
	100	137.3	225.8	331.1	331.7	363.8	1110.9	145.9	205.4	319.4	315.5	330.6	942.0
	200	361.6	819.8	1007.0	1046.7	984.3		422.1	600.6	743.9	847.1	1017.1	
	300	372.1	876.1	1139.9	1056.8	1071.4		452.1	698.0	851.2	844.1	959.5	
	400	308.5	828.9	1055.9	923.2	955.7		462.2	692.6	792.7	877.8	1013.8	
Zn S2 mean		246.9	570.4	735.7	704.5	704.5		308.4	454.9	564.6	601.9	690.9	
Zn mean		405.7	668.7	926.9	934.7	981.6		390.8	594.8	690.7	784.7	829.7	
S2 mean		592.4						524.1					
LSD0.05													
N		13.5						22.0					
Zn		13.5						22.0					
Soil		8.5						13.9					
N × Zn		30.1						49.3					
N × Zn × Soil		42.6						69.7					

3.4 Nitrogen Use Efficiency (NUE)

The results (table 5) showed that NUE had been affected by adding nitrogen, zinc levels and soil texture which were 36.25, 60.40, 39.14 and 26.67% for nitrogen levels of 100, 200, 300 and 400 kg ha^{-1}, respectively. The level 200 kg ha^{-1} achieved higher NUE which represented the optimum level of wheat requirements to achieve maximum response under the conditions of current study. That could be attributed to adding nitrogen led to be available in the soil thus increasing wheat uptake which reflected on increasing the activity in bio-physiological processes inside the plant [6]. The obtained results had agreed with those of [15,26]. [13] indicated that the higher wheat NUE at the level 150 kg ha^{-1} was

Table5: The effect of N and Zn level and their interaction in N use efficiency (%)

Soil	N kg ha^{-1}	NUE					N mean
		Zn level (kg ha^{-1})					
		0	10	20	30	40	
Clay loam	Soil	41.30	46.73	51.09	45.36	46.70	36.25
	200	63.07	70.36	79.66	72.16	71.33	
	300	42.72	47.13	50.85	47.03	47.05	60.40
	400	28.49	30.30	34.12	30.25	29.35	
Zn S1 mean		43.89	48.63	53.93	48.70	48.61	39.14
S1 mean		48.75					
Sandy	100	18.19	19.55	29.67	30.26	33.66	26.67
	200	36.00	39.02	54.56	58.26	59.63	
	300	21.37	25.59	37.26	35.29	37.09	
	400	15.83	20.36	27.93	26.57	23.52	
Zn S2 mean		22.85	26.13	37.36	37.59	38.48	
Zn mean		33.37	37.38	45.64	43.15	43.54	
S2 mean		32.48					
LSD0.05							
N		0.55					
Zn		0.62					
Soil		0.39					
N × Zn		1.24					
N × Zn × Soil		1.75					

56%, while were 46.8, 39.8 and 34.2% for the levels of 200, 250 and 300 kg ha^{-1}, respectively. According to the results, it could be observed that NUE was higher at the level 200 kg ha^{-1} which indicated to the high response of wheat at this level of nitrogen, compared with other levels.

Also, results (table 5) showed an effect of adding zinc on NUE which was 33.37, 37.38, 45.84, 43.15 and 43.54% for zinc levels of 0, 10, 20, 30 and 40 kg ha^{-1}, respectively. NUE had increased with increasing added zinc level, the higher NUE was the higher at the level of 20 kg ha^{-1}. That was attributed to the important role of zinc inside the plant, it was responsible to the nitrogen metabolic processes, contributing to formation of enzymes that responsible to forming protein as well as its entrance in forming amino acids; the lack of zinc contributed contributing to increasing plant nitrogen uptake. These results had agreed with [13].

The results showed that the soil texture had an effect on NUE which was 48.75% for the clay loam, and 32.48% for the sandy soil, with increment ratio of 50.1%.

The results showed the effect of adding nitrogen and zinc interaction on NUE. The NUE increased with increasing added nitrogen and zinc levels together where a higher NUE of 67.11% at the interaction treatment (200 N and 20 Zn) with increment ratio of 125.6%, compared with the control interaction treatment (0 N and 0 Zn). dding nitrogen with zinc fertilizer led to raising NUE of wheat and which confirmed that adding zinc led to increasing nitrogen uptake by plant and adding both fertilizers together had more advantage for the plant than adding nitrogen only. This interaction gave a great importance through the maximum benefit of the fertilizer nitrogen that giving an optimum production as well as the economic importance of fertilizer use.

3.5 Zinc Use Efficiency (ZnUE) The results (table 6) showed increasing ZnUE with increasing nitrogen added level. The ZnUE was 1.44, 1.60, 1.39, 1.34 and 1.22% for nitrogen levels of 0, 100, 200, 300 and 400 kg/ha. According the results, it could be observed that the level 50 kg/ha of added nitrogen achieved a higher ZnUE due to the effect of nitrogen on increasing zinc

Table 6**:** The effect of N and Zn level and their interaction in Zn use efficiency (%)

Soil	N Kg ha^{-1}	ZnUE				N mean
		Zn level (kg ha^{-1})				
		10	20	30	40	
Clay loam	0	0.47	1.33	1.87	2.75	1.44
	100	1.36	0.41	1.11	2.70	
	200	2.51	2.18	0.33	0.90	1.60
	300	2.01	2.05	1.95	0.25	
	400	0.76	1.69	1.67	1.57	1.39
Zn S1 mean		1.42	1.53	1.39	1.63	
S1 mean		1.49				1.34
Sandy	0	0.26	0.59	2.54	3.00	
	100	3.01	0.29	0.74	1.93	1.22
	200	2.33	2.16	0.21	0.49	
	300	1.50	1.43	1.37	0.17	
	400	0.41	1.22	1.21	1.19	
Zn S2 mean		1.50	1.14	1.21	1.36	
Zn mean		1.46	1.34	1.30	1.50	
S2 mean		1.30				
LSD0.05						
N		0.07				
Zn		0.06				
Soil		0.04				
N × Zn		0.14				
N × Zn × Soil		1.20				

availability for wheat plant as well as its role in increasing plant zinc uptake, bio-physiological processes that contributed by zinc inside the plant, and plant response to zinc. Adding nitrogen fertilizer led to raising ZnUE to achieve maximum plant response [1,15].

The results showed that adding zinc had an effect on ZnUE which was 1.46, 1.34, 1.30 and 1.50% for the zinc levels of 10, 20, 30 and 40 kg/ha, respectively. The level 40 kg ha^{-1} gave the higher ZnUE. Increasing ZnUE with increasing zinc was attributed to that fertilization with zinc led to increasing its availability then increasing its uptake by plant and increasing the responsible biological processes. This had agreed with [17,27].

The results indicated that the soil texture had an effect on ZnUE which was 1.49 and 1.30% for the clay loam and sandy soils, respectively. ZnUE had increased in clay loam soil of 14.62%, compared to the sandy.

The results showed a significant effect of the interaction between nitrogen and zinc on ZnUE which had increased with increasing of adding nitrogen and zinc together. The higher ZnUE was at the level (200 N and 20Zn) of 2.17%. The interaction of both fertilizers was a positive in increasing ZnUE due to the role of added nitrogen in increasing zinc availability and uptake by plant which led to increasing the growth and yield of plant [18,22]. Certainly, adding nitrogen fertilizer with zinc was more important than adding each other separately.

3.6 Correlation Relationships

The results of regression analysis (tables: 7 and 8) showed a positive significant correlation relationship between the added nitrogen and zinc levels (X) and plant indicators in both soils and described using the quadratic equation. The obtained quadratic equations confirmed that the added nitrogen and zinc levels led to increasing the availability of both nitrogen and zinc more than plant requirement. Optimum FUE of nitrogen level was achieved at 200 kg/ha and the zinc was at 20 kg/ha. These relationships or response curves had a great importance. Through these relationships, the extent of wheat response of added nitrogen and zinc could be predicted as well as the level of optimum nitrogen and zinc could be determined to achieve a higher response and maximum yield of wheat [20.26].

Table 7: The relationship between plant parameters (Y) and N level (X) according to the quadratic equation.

Parameter	Clay loam		Sandy	
	Equation	R	Equation	R
Straw yield	$Y = 5.614 + 0.208X - 0.0008X^2$	0.954	$Y = 3.471 + 0.182X - 0.0007X^2$	0.892
Grain yield	$Y = 4.187 + 0.174X - 0.0007X^2$	0.943	$Y = 2.633 + 0.162X - 0.0006X^2$	0.923
N uptake in straw	Y = 28.821 + 1.927X - 0.0059X2	0.973	$Y = 12.209 + 1.185X - 0.0035X^2$	0.935
N uptake in grain	Y = 47.591 + 3.049X - 0.00105X2	0.953	$Y = 14.123 + 2.002X - 0.0062X^2$	0.951
NUE	$Y = 14.725 + 3.429X - 4.041X^2$	0.898	Y = 49.896 + 0.592X - 0.0033X2	0.943

*R value at 0.05 and 0.01 levels are 0.878 and 0.959.

Table 8: The relationship between plant parameters (Y) and Zn level (X) according to the quadratic equation.

Parameter	Clay loam		Sandy	
	Equation	R	Equation	R
Straw yield	Y = 13.724 + 0.420X - 0.021X2	0.892	$Y= 11.525 + 0.509X - 0.024X^2$	0.908
Grain yield	Y = 10.564 + 0.385X - 0.020X2	0.964	$Y= 8.506 + 0.364X - 0.016X^2$	0.943
Zn uptake in straw	$Y = 47.591 + 3.049X - 0.00105X^2$	0.953	$Y= 262.040 + 69.186X - 2.410X^2$	0.986
Zn uptake in grain	$Y = 542.766 + 65.572X - 1.492X^2$	0.985	$Y= 314.969 + 28.949X - 0.535X^2$	0.993
ZnUE	$Y = 1.452 + 0.0097X - 0.0013X^2$	0.671	$Y = 1.483 - 0.084X + 0.0051X^2$	0.960

*R value at 0.05 and 0.01 levels are 0.878 and 0.959.

IV. Conclusions

The interaction of nitrogen and zinc has a positive effect on the soil and plant systems by increasing nutrient availability in the soil and absorption by the plant. So it is preferable to add both nutrients together to raise the efficiency of their use to obtain the highest plant yield without loss large amounts of fertilizer used as well as reduce the cost**.**

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