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Effect of N, Zn and Fe application on corn in alluvial soil

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Abstract

In a lysimeter experiment on alluvial loamy soil, the effect of an increasing level of urea with the addition of $ZnSO_4$ or $FeSO_4$ or both were tested on the yield and mineral composition of *Zea mays* plants. A response was found only to N application and it was of a diminishing return nature. The effect of the increasing N level in plants was reflected mostly in leaf composition and least in grain composition.

INTRODUCTION

Optimization of the nutritional balance under different soil conditions needs still further studies. Micro-nutrients deficiency, with special reference to Zn and Fe due to its retention and fixation are considered to be related to high soil pH and excess of $CaCO_3$ (Thorne, 1957; Navrot and Ravikovitch, 1969; Viets, 1966).

Additional data reported by Wallace (1971) indicated that $CaCO_3$ alone decreased Zn content in corn, while Fe was little affected. Viets et al. (1953, 1957) indicated that both the rate of application and the form of N affected the uptake of Zn applied to the soil and was greatly increased by simultaneous application of NH_4NO_3. On the other hand, Rogers and Wu (1948) and Epstein and Stout (1951) have shown that Zn and Fe utilization by plants was related to the pH of the soil.

It is also suggested that N per se may either enhance Zn and Fe uptake directly or perhaps by promoting more extensive root development.

The present work was aimed at finding the effect of N as urea, Zn as $ZnSO_4$ and Fe as $FeSO_4$, applied on corn plants in alluvial soil.

MATERIAL AND METHODS

The experiment was conducted under greenhouse conditions on *Zea mays* L., var. 'Pioneer', obtained from the U.S.A. The corn was planted in 8 hills per cement lysimeter 150 × 75 × 90 cm, containing a loamy soil, each hill thinned to a single plant, i.e. 8 plants per lysimeter.

Nitrogen as urea 0.45, 90 and 135 kg N/acre, $ZnSO_4 \cdot H_2O$ 0, 10 kg acre, $FeSO_4 \cdot 7H_2O$ 0, 10 kg/acre in 3 replicates were applied in the experiment in various combinations.

Super-phosphate and potassium sulphate were applied at the rate of 100 kg/acre. Zinc and iron salts were added after thinning 10 days from planting. Nitrogen fertilizer was applied in two additions, one half at the age of 28 days, and the other a month later. Tap water was used for irrigation throughout the season as needed.

At harvest, plant height, dry weight and yield of grain were measured. Samples of roots, leaves, stems and grains were ovendried and kept in tight bottles for chemical analysis. Zn, Fe, Mn, Cu, K, Ca, and Mg were determined in the samples by means of atomic absorption. Total nitrogen of grains was determined in the flour. Phosphorous was determined colorimetrically by the method described by Olsen et al. ⟨1954⟩. Characteristics of the soil used are: 45% sand, 46% silt, 9% clay, 3% $CaCO_3$, E. C. 1.03 and pH 7.3 in H_2O ⟨Chapman and Parker, 1961⟩.

RESULTS AND DISCUSSION

Growth vigour is here indicated by both height and total dry weight of plant, the yield by both weight of ears and of grain per plant. As shown in Table 1 the height was not affected by the addition of either $ZnSO_4$ or $FeSO_4$ or both, but increased significantly by the addition of urea. The yield, and the weight of ears or grains ⟨Table 1⟩ also showed no response to either $ZnSO_4$ or $FeSO_4$ or both, but the height and dry weight of plants was increased remarkably by the addition of urea. Moreover, there, was a significant interaction of the weight of both grains and ears, e.g. higher grain yield associated with the application of $ZnSO_4 + FeSO_4$ at a higher rate of urea application, lower ear weight associated with the application of $ZnSO_4 + FeSO_4$ at lower urea application. These differences due to the interaction effect were, however, inconsistent. This would lead to conclusion that corn plants responded to urea application rather than to $ZnSO_4$ or $FeSO_4$ or both. For example, by addition of 135 kg N/acre the mean height of plants reached about 1.5 times that of the control, the total dry weight more than 2.5 times, the grain weight a little lower than 8 times and the ears weight about 6 times. The response of grain yield was of diminishing return nature, as after the addition of the first 45 kg N/acre, it increased about 5 times, after the second 45 kg N/acre the increase was about 2 times while after the last 45 kg N/acre the increase was about 0.5 times as compared with the control.

These results are in accordance with these of Harada et al. ⟨1968⟩ in tomatoes. Experiments conducted by Viets et al. ⟨1957⟩ showed a significant response of 'Milo' and 'Lamido' cultivars of clover to nitrogen and the

Table 1

Effect of N, Zn and Fe application on growth and yield of corn plants

Nitrogen treatment kg N/acre	$ZnSO_4$ or $FeSO_4$ added, kg/acre					L.S.D. p=0.05
	0	$ZnSO_4$	$FeSO_4$	$ZnSO_4$ $FeSO_4$	Mean	
A. Height, cm						
0	153	159	165	152	157	
45	195	201	200	201	199	
90	228	217	207	234	222	
135	235	229	227	241	233	
Mean	203	202	200	207		N.S.
L.S.D., p=0.05			Interaction N.S.		8.8	
B. Dry weight, g/plant						
0	76.0	93.1	96.9	90.6	89.2	
45	111.3	115.0	113.6	114.8	113.7	
90	143.4	138.8	134.2	148.8	141.3	
135	222.6	217.9	216.1	235.2	223.0	
Mean	138.3	141.2	140.2	147.4		N.S.
L.S.D., p=0.05			Interaction N.S.		7.7	
C. Ears weight, g/plant						
0	42.0	52.0	45.0	29.0	42.5	
45	158.0	150.0	153.0	160.0	155.3	
90	216.0	222.0	218.0	238.0	223.5	
135	253.0	228.0	247.0	254.0	245.5	
Mean	167.3	163.0	165.8	170.3		N.S.
L.S.D., p=0.05			Interaction N.S.		5.7	
D. Grain yield, g/plant						
0	21.0	33.2	23.1	16.1	23.5	
45	106.4	102.0	103.7	106.8	104.7	
90	151.5	150.3	145.1	167.3	153.6	
135	160.7	153.7	173.7	175.2	165.8	
Mean	109.9	109.8	111.4	116.5		N.S.
L.S.D., p=0.05			Interaction N.S.		4.8	

significant difference in the yield was due to the type of nitrogen applied. The results of B l a i r et al. 〈1970〉 also showed that corn plants will grow equally well either with NO_3 or NH_4 nitrogen sources added when the pH of the culture solution is maintained in the constant flow culture system.

No interaction effects between nitrogen, $ZnSO_4$ or $FeSO_4$ additions on nutrient contents of the different plant parts seemed to occur. Therefore, the

Table 2

Nutrients content in different parts of corn plant as affected by N-fertilizer addition

Plant organ	N-added kg N/acre	N %	P %	K %	Ca %	Mg %	Fe %	Zn ppm	Mn ppm	Cu ppm
Roots	0	0.44	–	0.50	0.75	0.13	0.20	55	95.0	19.0
	45	0.45	–	0.62	0.64	0.15	0.19	29	50.0	16.0
	90	0.54	–	0.70	0.61	0.15	0.12	33	34.0	18.0
	135	0.70	–	0.88	0.75	0.17	0.13	35	30.0	19.0
Stems	0	0.14	0.07	2.85	0.24	0.19	0.02	102	3.8	3.0
	45	0.19	0.06	3.00	0.20	0.11	0.01	67	3.1	2.5
	90	0.27	0.05	2.87	0.22	0.14	0.01	60	3.8	2.8
	135	0.42	0.04	2.33	0.26	0.17	0.01	44	3.8	3.1
Leaves	0	0.53	0.25	1.29	0.93	0.36	0.02	53	12.0	8.0
	45	0.61	0.23	1.09	0.98	0.36	0.02	81	23.0	10.0
	90	0.98	0.18	1.09	1.30	0.44	0.05	118	36.0	17.0
	135	1.54	0.14	0.82	1.50	0.58	0.07	163	47.0	21.0
Grains	0	1.31	0.34	0.29	0.004	0.11	0.002	33	5.0	2.2
	45	1.19	0.32	0.29	0.005	0.10	0.002	34	5.0	2.2
	90	1.48	0.29	0.30	0.004	0.11	0.002	33	5.0	2.2
	135	1.62	0.28	0.30	0.003	0.11	0.002	34	5.0	2.0

effects due to nitrogen application rate on the average $ZnSO_4$ or $FeSO_4$ content or both, and owing to the latter treatments, on the average nitrogen levels are tabulated in Tables 2 and 3, respectively.

Summarizing the foregoing results it may be concluded that as nitrogen increased in the growth substrate its concentration increased remarkably almost equally in both stem and leaves, to a lesser extent in roots and still less in grains. Phosphorus decreased slightly in stem and leaves and very slightly in grains. Potassium increased in roots, decreased in leaves, but did not change in either stem or grains. Magnesium increased slightly in roots and leaves but did not change in either stem or grains. Calcium increased slightly in leaves, but did not change in other plant parts. Manganese and iron decreased most in roots, increased most in leaves, but did not alter in either stem or grain. Zinc and Cu increased in leaves, but did not change in either roots, stems or grains.

It may be stated, therefore, that the increasing N uptake by corn plants through raising its concentration in the growth media influenced almost all mineral constituents of the leaf part rather than any other part of the plant. Grain composition was least changed. In this respect Classen and Wilcox ⟨1974⟩ found that the NH_4-N had a greater effect on the reduction

Table 3

Nutrients content in different parts of corn plant as affected by the addition of $ZnSO_4$ or $FeSO_4$

Plant organ	Treatment kg/acre	Nutrient element								
		N %	P %	K %	Ca %	Mg %	Fe %	Zn ppm	Mn ppm	Cu ppm
Roots	0	0.51	–	0.76	0.67	0.15	0.14	48	25.0	21
	10 $ZnSO_4$	0.45	–	0.62	0.66	0.14	0.19	32	65.0	66
	10 $FeSO_4$	0.50	–	0.60	0.65	0.14	0.15	37	50.0	17
	10 $ZnSO_4$ + 10 $FeSO_4$	0.61	–	0.79	0.77	0.13	0.13	34	45.0	19
Stems	0	0.28	0.06	2.26	0.24	0.18	0.016	59	2.5	3.5
	10 $ZnSO_4$	0.22	0.05	3.10	0.23	0.12	0.017	62	2.5	2.9
	10 $FeSO_4$	0.28	0.05	2.67	0.23	0.14	0.012	83	3.1	3.1
	10 $ZnSO_4$ + 10 $FeSO_4$	0.25	0.05	3.01	0.21	0.17	0.012	69	6.3	3.2
Leaves	0	0.96	0.21	1.19	1.19	0.45	0.024	144	33.0	17.0
	10 $ZnSO_4$	0.77	0.18	1.11	1.11	0.37	0.033	96	25.0	11.0
	10 $FeSO_4$	0.84	0.20	0.95	1.10	0.40	0.037	67	29.0	11.0
	10 $ZnSO_4$ + 10 $FeSO_4$	1.10	0.20	1.29	1.30	0.52	0.054	109	32.0	16.0
Grains	0	1.39	0.32	0.30	0.006	0.10	0.002	35	5.0	2.3
	10 $ZnSO_4$	1.38	0.30	0.27	0.004	0.11	0.002	34	5.0	2.3
	10 $FeSO_4$	1.35	0.31	0.26	0.003	0.11	0.002	35	5.0	2.3
	10 $ZnSO_4$ + 10 $FeSO_4$	1.49	0.30	0.33	0.003	0.11	0.002	29	5.0	2.3

of Ca and Mg absorption than the level of potassium in corn seeds. Grunes et al. ⟨1970⟩ claims that the NH_4-N source and Mg level in the soil were the two factors reducing the Mg composition of the corn tissue. Although potassium reduced Mg absorption, the reduction was not as high as with N as NH_4-N. Hansen ⟨1972⟩ studying the relationship between the form and amount of added nitrogen and absorption of N, K^+, Na, Ca^{+2} and Mg^{+2} showed a very high correlation between total cation and N concentration in barley grown for 51 days. He concluded that total cations were governed by N– metabolic processes in the plant, whereas ratios of absorbed cations are influenced by cation activity ratios in the soil solution.

Table 3 shows the effect of $ZnSO_4$ or $FeSO_4$ or both applied to experimental soil on the composition of different corn plant parts. Examination of these data reveals no effects on any of the mineral constituents in any part of the plant. The differences are not only small, but also inconsistent indicating that either those elements were fixed in the growth substrate beyond the reach of the absorbing organs of roots or they were sufficient to meet plant requirement. Safaya and Gupta ⟨1979⟩ showed that there are no significant differences in the mean uptake values for Cu, Mn and Fe both in Zn-supplied and Zn-deficient plants. respectively. They assume that the fluxes of these elements Zn-deficient plants were also higher. Safaya ⟨1976⟩ also reported significant decreases in fluxes of P, Cu, Mn and Fe with Zn-application in corn.

Table 4 presents the average nutrient contents in roots, stems, leaves and grains of corn plants. As seen in the table, grains had a higher content of N and P and lower of K, Ca, Mg, Fe, Zn, Mn and Cu than any other plant part. Leaves were richer in N, P, Ca and Mg than either stem or roots, while they contained less Fe. The stem had the lowet content of N, P, Ca and Cu.

Table 4

Distribution of nutrients among different parts of corn plants

Plant nutrient	Plant organs			
	roots	stems	leaves	grains
N %	0.52	0.26	0.92	1.40
P %	–	0.05	0.20	0.41
K %	0.69	2.76	1.14	0.29
Ca %	0.69	0.23	1.18	0.004
Mg %	0.14	0.15	0.43	0.110
Fe %	0.15	0.014	0.044	0.002
Zn ppm	38.0	68.0	104.0	33.0
Mn ppm	46.0	36.0	30.0	5.0
Cu ppm	18.0	3.2	14.0	2.1

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Wpływ podawania N, Zn i Fe na kukurydzę rosnącą na glebie aluwialnej

S t r e s z c z e n i e

W doświadczeniu z zastosowaniem lizymetrów badano wpływ różnych dawek mocznika z dodatkiem $ZnSO_4$ i $FeSO_4$ lub obu związków razem na plon i zawartość składników mineralnych kukurydzy uprawianej na glebie aluwialnej gliniastej.

Wrażliwość roślin była wykazana tylko dla azotu, który spowodował spadek plonu. Wpływ wzrastających dawek azotu miał odbicie głównie w składzie liści i w niewielkim stopniu w składzie ziarniaków.