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《Original》

Isotope-Aided Micronutrient Studies in Rice Production with Special Reference to Zinc Deficiency (II)

—Residual Effect of ^{65}Zn Labelled Fertilizers—

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Abstract

A field experiment has been carried out to evaluate the residual effect of zinc fertilizers by rice plant grown under flooded conditions in the field. The results obtained are summarized as follows:

Residual effect of zinc fertilizers on yields of rough and hulled grains showed slight increases. Effect of zinc application methods on yields of the grains were shown that zinc mixed treatment could be more effectively utilized than treatment of zinc on the soil surface. In case of levels of zinc application, 5 kg zinc per hectare represented high yields of the grains than those obtained from 10 kg and 20 kg zinc placement per hectare respectively. Regarding the form of zinc fertilizers, the urea-zinc complex showed less effective on yields of the grains than did the zinc sulfate. This phenomenon was consistent with the previous result. Yields of total zinc in rice plant grown on the rice straw added soils (Treatment No. 2 and 8) and the urea-zinc complex treated soil were increased markedly as compared to those data obtained from the previous year. The percentage of zinc derived from fertilizer decreased largely as compared to that of the first year crop. The yield of fertilizer zinc in rice plant decreased slightly in the most zinc treatments but in the case of treatments of zinc mixed with the straw added soil and the urea-zinc complex increased reversely as compared to the previous results. The mixed application of zinc with soil showed higher yield of fertilizer zinc than the soil surface placement. Approximately from 4.6 to 24.3 per cent of zinc taken up by rice plants were derived from the fertilizer zinc. Zinc fertilizer use efficiency ranged from 0.213 to 0.584 per cent when 5 kg zinc per hectare applied.

요　　약

수도(水稻)에 의한 ^{65}Zn 표지 및 비표지 아연비료의 잔류(殘留) 효과의 포장실험 결과를 요약하면 다음과 같다.

수량면에서 본 아연비료의 잔효(殘效)는 약간 있었다. 수량에 미치는 아연시비법(施肥法)의 영향을 보면 아연 전층시비가 포층시비 보다 효과가 컸다. 아연 시비 수준별로 본 수량은 5 kg Zn/ha 전층 시비가 10,20 kg Zn/ha 전층시비 보다 좋았다. 아연비료 형태별로 수량을 비교해 보면 $^{65}ZnSO_4$가 Urea-^{65}Zn 복합비료 보다 좋았다. 이와 같은 경향은 1차년도 실험 결과와 같았다. 수도체(水稻體)의 아연 전 흡수량은 유기물 첨가토양(처리 2와 8)과 Urea-^{65}Zn 복합비료 시용구에서는 전년도 보다 현저하게 증가되었다. 수도체의 % Zndff 값은 전년도에 얻어진 값 보다 훨씬 감소되었다. 수도체의 비료 아연 흡수량은 대부분의 아연 처리구에서 전년도 보다는 약간 감소되었으나 유기물 시

용토양에 아연을 전층시비했을 때와 Urea-^{65}Zn 복합비료 시용구에서는 전년도의 값 보다는 오히려 증가되었다. 아연 전층시비법은 표층시비법 보다 수도체의 비료 아연 흡수량은 많았다. 수도체의 전 아연 흡수량에 대해서 비료에 유래된 아연의 기여율은 4.6%—24.3% 범위였다. 5 kg Zn/ha 수준에서 ^{65}Zn 표지 아연 비료의 이용 효율은 0.213%—0.584%였다.

I. Introduction

Using ^{65}Zn labelled and unlabelled zinc fertilizers field experiment have been conducting since 1977 to evaluate the efficiency of fertilizer zinc by rice plant grown on under various methods of zinc application. In the first year experiment the efficiency of fertilizer zinc was different by various treatments of zinc. The most efficient method in terms of levels of zinc and method of zinc application was 5 kg Zn per hectare mixed throughout with the soil as compared to the same amount of zinc applied on the soil surface. Among zinc treatments only organic matter (rice straw) addition, the urea-zinc combined fertilizer and zinc mixed application to the straw added soil showed lower utilization of fertilizer zinc.

The present work was carried out to evaluate residual effects of zinc fertilizers with relation to rice yield, yields of total and fertilizer zinc in rice plant and use efficiency of fertilizer zinc etc.

II. Materials and methods

The experiment with identical treatments were established at the same location which the first experiment carried out. Some relevant soil properties for the experimental site are given in Table 1. The experiment consisted of ten treatments in a randomized block design and replicated in four times. The treatment involved Zn rate variables of 5, 10 and 20 kg Zn per hectare had been applied to the soil as mostly $ZnSO_4 \cdot 7H_2O$. In 5 kg Zn/ha treatments the urea-zinc combined fertilizer was involved. Zinc mixed throughout, with and without organic matter added soil, soil surface application and the root-dipping in 2% ZnO suspension methods were used applying zinc fertilizers to the soil (Table 2).

A high yielding local rice variety, Suweon No. 264, was chosen for the field experiment. The nursery bed was prepared on April 16 by the routine method. During the nursery period the seedling was received nitrogen, phosphorus and potassium fertilizers at the rates of 200 kg N, 150 kg P_2O_5 and 150 kg K_2O per hectare respectively. The zinc fertilizer was of course excluded in whole period of rice plant grown on the field. To study the residual effects of applied zinc, the experimental plots maintain the same conditions as did in the previous work. The land for planting was prepared by ploughing and levelling on May 22. Basal dressing of nitrogen (60 kg N/ha as urea), phosphorus (80 kg P_2O_5/ha as triple superphosphate) and potassium (50 kg K_2O/ha as potassium chloride) fertilizers were applied and incorporated into the soil by puddling into a depth of about 6 cm

Table 1. Chemical properties of the second year experimental soil

Texture	Total N %	pH		Exchangeable cations, m. e. /100g			C %	P ppm	0.005M DTPA Zn ppm	0.1N-HCl Zn ppm
		H_2O (1 : 5)	$CaCl_2$ (0.01M)	Ca	Mg	K				
SiCL	0.20	5.75	5.18	5.83	1.20	0.24	2.44	35.5	5.80	11.51

Table 2. Overall treatments for field experiment

Treatment No.	Treatments
1.	5 kg Zn/ha as zinc sulfate mixed throughout the soil (MX-5)
2.	5 kg Zn/ha as zinc sulfate plus organic matter compost mixed throughout the soil (MX-5-OM)
3.	5 kg Zn/ha as combined urea-zinc fertilizer mixed throughout the soil (COMB-5)
4.	5 kg Zn/ha as zinc sulfate at transplanting on surface application (SURF-5)
5.	5 kg Zn/ha as zinc sulfate surface application 2 weeks after transplanting (SURF-5-2W)
6.	10 kg Zn/ha as zinc sulfate mixed throughout the soil (MX-10)
7.	Root dipping in 2% ZnO suspension (ROOT-DIP)
8.	Organic matter compost only (no zinc) (OM)
9.	Control (no zinc) (CONTROL)
10.	20 kg Zn/ha as zinc sulfate mixed throughout the soil (MX-20)

Table 3. Yields of dry matter production, rough grain, hulled grain and straw of rice as affected by various methods of zinc application

Treatment*	Dry matter kg/ha	Rough grain kg/ha	Hulled grain kg/ha	Straw kg/ha
MX-5	8540	4048	3152	4368
MX-5-OM	8496	4120	3208	4208
COMB-5	7668	3792	2952	3728
SURE-5	8044	3664	2844	4216
SURF-5-2W	7460	3832	2980	3472
MX-10	8320	3920	3052	4236
ROOT DIP	8160	3828	2984	4212
OM	9472	3884	3020	5468
CONTROL	7336	3460	2692	3624
MX-20	7488	3892	3028	3456
LSD(5%)	N. S.	347	443	1022

*Description of treatments are given in Table 2.

at transplanting. Immediately after the fertilizers application, irrigated up to a water level of 5 cm above ground on May 28. The rice seedlings were transplanted on May 29. Three seedling per hill was planted and planting distance was

Table 4. Hulled grain and rough grain production by year as affected by various methods of zinc application

Treatment*	Hulled grain yield, kg/ha		Rough grain yield, kg/ha	
	1977	1978	1977	1978
MX-5	2775	3152	3394	4048
MX-5-OM	2695	3208	3256	4120
COMB-5	2688	2952	3293	3792
SURF-5	2492	2844	3070	3664
SURF-5-2W	2602	2980	3176	3832
MX-10	2661	3052	3272	3920
ROOT DIP	2814	2984	3422	3828
OM	2737	3020	3318	3884
CONTROL	2655	2692	3198	3460
MX-20	2502	3028	3048	3892
LSD(5%)	N. S.	443	N. S.	347

*Description of treatments are given in Table 2.

25 cm×25 cm (160, 000 hills/ha). On July 20, the premordial initiation stage, 40 kg N (as urea) and 30 kg K_2O (as KCl) per hectare were applied on the soil surface of all plots. On June 30, Machete, Reldan and Bla-S were applied to prevent weed and to control diseases. On October 9, the plant were harvested and separated into straw and grain. In case of the radioactive microplot rice plant were harvested separately from unlabelled area for analysis of ^{65}Zn. Yields measurement were made on 65°C oven dried basis for all the plant harvested from the plots including radioactive microplot except the border line. Subsamples of plant materials were finely ground and subjected to wet digestion by the use of HNO_3 and $HClO_4$ for analysis. Radioactive zinc was measured by 400 channels pulse height analyzer which was equipped with 5 inches well type scintillation detector. Total zinc was measured by the Atomic absorption spectrophotometer.

III. Results and discussion

Application of zinc fertilizers to the soil

Table 5. Contents of zinc, nitrogen and phosphorus in straw, rough grain and hulled grain as affected by various methods of zinc application

Treatment*	Zn, ppm			N, %			P, %		
	Straw	R. grain	H. grain	Straw	R. grain	H. grain	Straw	R. grain	H. grain
MX-5	39.9	24.8	23.9	0.62	1.26	1.51	0.143	0.281	0.375
MX-5-OM	42.3	22.1	23.0	0.58	1.25	1.49	0.120	0.296	0.371
COMB-5	39.3	22.6	22.9	0.55	1.22	1.44	0.125	0.270	0.364
SURF-5	42.3	21.9	24.3	0.60	1.24	1.47	0.114	0.290	0.359
SURF-5-2W	37.1	23.4	23.0	0.56	1.24	1.46	0.135	0.285	0.380
MX-10	39.4	24.5	22.0	0.55	1.23	1.41	0.127	0.286	0.378
ROOT DIP	45.3	25.8	20.5	0.57	1.21	1.43	0.095	0.296	0.390
OM	46.8	20.8	20.8	0.57	1.17	1.43	0.118	0.291	0.366
CONTROL	43.5	22.8	19.0	0.54	1.18	1.38	0.134	0.299	0.359
MX-20	49.5	21.0	20.6	0.63	1.25	1.47	0.123	0.278	0.362

*Description of treatments are given in Table 2.

Table 6. Amounts of zinc in each plant component and yield of total zinc in rice plants grown on Keumgok soil as affected by various methods of zinc application

Treatment*	Rough grain kg Zn/ha	Hulled grain kg Zn/ha	Straw kg Zn/ha	Yield of total Zn in the plant, kg Zn/ha
MX-5	0.1005	0.0752	0.1735	0.2740
MX-5-OM	0.0912	0.0730	0.1783	0.2695
COMB-5	0.0859	0.0676	0.1470	0.2329
SURF-5	0.0798	0.0691	0.1788	0.2586
SURF-5-2W	0.0891	0.0686	0.1303	0.2194
MX-10	0.0960	0.0671	0.1678	0.2638
ROOT DIP	0.0975	0.0619	0.1915	0.2890
OM	0.0804	0.0625	0.2523	0.3327
CONTROL	0.0787	0.0511	0.1593	0.2380
MX-20	0.0819	0.0616	0.1725	0.2544
LSD(5%)	N.S.	N.S.	0.056	N.S.

*Description of treatments are give in Table 2.

affected slight increases on yield of grains (rough and hulled grains) as shown in Table 3. The increase of yield by zinc application was significant. However, the previous experimental result showed no significant increase of the yield (Table 4). Effect of zinc application me-

Table 7. Yield of total zinc in rice plants grown on Keumgok soil by year as affected by various methods of zinc application

Treatment*	Yield of total zinc in rice plant, kg Zn/ha	
	1977	1978
MX-5	0.2215	0.2740
MX-5-OM	0.1665	0.2695
COMB-5	0.1814	0.2329
SURF-5	0.2001	0.2586
SURF-5-2W	0.2146	0.2194
MX-10	0.3042	0.2638
ROOT DIP	0.2287	0.2890
OM	0.1471	0.3327
CONTROL	0.1445	0.2380
MX-20	0.3032	0.2544

*Description of treatments are given in Table 2.

thods on yields of the grains was shown that when zinc mixed uniformly with the soil the zinc could be more effectively utilized than that on the soil surface application or the root-dipped into 2 per cent of ZnO suspension. In case of zinc levels, 5 kg Zn per hectare treatment showed higher yields of the grains as compared to 10 kg and 20 kg Zn per hectare treatments. Regarding the form of zinc fertilizer the urea-zinc complex

Table 8. Percentage of zinc derived from fertilizer (Zndff) in rough grain, hulled grain and straw of rice plants grown on Keumgok soil by year as affected by various methods of zinc application

Treatment*	% Zndff, Rough grain		% Zndff, Hulled grain		% Zndff, Straw	
	1977	1978	1977	1978	1977	1978
MX-5	14.71	8.48	17.08	8.23	13.89	10.08
MX-5-OM	16.91	9.18	17.69	8.93	13.60	11.71
COMB-5	5.05	4.19	7.07	3.93	4.74	4.78
SURF-5	12.31	6.86	11.50	5.70	10.18	7.32
SURF-5-2W	12.50	8.73	14.86	8.21	11.73	9.57
MX-10	16.56	14.72	18.00	15.52	16.02	17.15
ROOT DIP						
OM						
CONTROL						
MX-20	28.60	19.33	13.24	20.43	17.20	18.66
LSD(1%)		2.78		2.93		4.99

*Description of treatments are given in Table 2.

Table 9. Yields of fertilizer zinc in rough grain and the straw, and total yield of fertilizer zinc in rice plants grown on Keumgok soil by year as affected by various methods of zinc application

Treatment*	Yield of fertilizer zinc in rough grain, kg/ha		Yield of fertilizer zinc in straw, kg/ha		Total yield of fertilizer zinc in plant, kg/ha	
	1977	1978	1977	1978	1977	1978
MX-5	0.0154	0.0084	0.0181	0.0175	0.0335	0.0259
MX-5-OM	0.0129	0.0084	0.0123	0.0208	0.0252	0.0292
COMB-5	0.0034	0.0036	0.0049	0.0070	0.0083	0.0106
SURF-5	0.0094	0.0055	0.0130	0.0126	0.0224	0.0181
SURF-5-2W	0.0097	0.0077	0.0159	0.0122	0.0256	0.0199
MX-10	0.0190	0.0141	0.0312	0.0285	0.0502	0.0426
ROOT DIP						
OM						
CONTROL						
MX-20	0.0288	0.0150	0.0428	0.0468	0.0716	0.0618
LSD(5%)		0.0021		0.0063		

*Description of treatments are given in Table 2.

showed less effective on yields of the grains than did by the zinc sulfate. The residual effect of the urea-zinc complex responded to slightly high on the grain yield as compared to that in the previous year but the complex still showed less effective than other treatments.

Concentration of zinc in rice plant showed slight increase in the plant grown on the plots which received zinc fertilizers (Table 5). Contents of nitrogen and phosphorus in the plant were also represented similar tendency (Table 5). *Yield of total zinc in the plant was increased* by the zinc application but the yield did not showed significant difference among zinc

Table 10. Percentage of fertilizer zinc use efficiency by rice plants grown on Keumgok soil by year as affected by various methods of zinc application

Treatment*	Fertilizer zinc use efficiency, %	
	1977	1978
MX-5	0.630	0.519
MX-5-OM	0.504	0.584
COMB-5	0.174	0.213
SURF-5	0.439	0.361
SURF-5-2W	0.551	0.399
MX-10	0.494	0.425
ROOT DIP		
OM		
CONTROL		
MX-20**	0.360	0.309
LSD(1%)	0.146	0.125

*Description of treatments are given in Table 2.
**Treatment of MX-20 was not involved for statistical analyses because shortage of the $^{65}ZnSO_4$ only one replication received the salt.

treatments (Table 6). Yields of total zinc in the plants grown on the organic matter added soils (Treatment No. 2 and 8) and the urea-zinc treatment were increased markedly as compared to those data of the previous year (Table 7). The reason might be explained that after the zinc fertilizer had been applied to the soil the organic matter is capable of complexing or chelating with the native and applied zinc and that such complexes played an important role as the plant nutrition. So that the zinc could be easily absorbed by the plant grown on the second year. The percentage zinc derived from fertilizer (Zndff) was in the range of 4.78 to 18.66 per cent (Table 8). The soil surface application of zinc fertilizer showed lower percentage of Zndff as compared to the zinc mixed throughout soil treatment. When the zinc fertilizer (as $ZnSO_4 \cdot 7H_2O$) applied to the soil at levels of 10 and 20kg Zn per hectare the per cent Zndff values were increased as compared to level of 5 kg Zn per hectare. Generally speaking the per cent Zndff values decreased largely than those values of the first crop (Table 8). The urea-zinc complex treatment still showed the lowest percentage of Zndff. When 5kg Zn per hectare applied to the soil yields of fertilizer zinc in the plant were ranged from 0.0106 to 0.0292 kg Zn per hectare. These values were equivalent only 4.6 to 10.8 per cent to the yield of total zinc taken up by rice plants. The mixed application of zinc with soil showed higher fertilizer zinc yield of the plant as compared to the soil surface treatment of zinc (Table 9). The urea-zinc complex treatment also showed the lowest yield of fertilizer zinc among the zinc treatments. The effect of residual experiment on fertilizer zinc yield in the plant decreased in the most treatments of zinc except treatments of zinc mixed uniformly with organic matter added soil and the urea-zinc complex fertilizer (Table 9). The zinc fixation occured after the zinc had been applied to the soil[1]. So that fertilizer zinc yield in the plant would be decreased. The Langmuir adsorption isotherm of zinc using this soil also supported above results. The Langmuir adsorption maximum of zinc by the soil showed 3.76 m.e./100 g soil. The value was equivalents to 40 per cent of the cation exchange capacity (9.4 m.e./100 g) of the soil.

Utilization efficiency of the zinc fertilizers were in the range of 0.213 to 0.584 per cent. Zinc mixed uniformly with soil treatment showed more effective than the soil surface application of zinc. It is known that soil applied zinc is immobilized and remains where it is placed[2]. Jurinak and Thorne[3] also reported that the most of zinc applied to surface of soil remained where placed. These informations on the immobility of soil applied zinc have important implications on the placement of zinc fertilizer. The facts may explain why surface application

Table 11. Chemical properties of the fresh soil after harvesting of the first residual effect experiment

Treatment*	0.005M DTPA Zn ppm	0.1N-HCl Zn ppm	Olsen P ppm	C %	Total N %	NH_4-N ppm	NO_3-N ppm
MX-5	7.2	13.0	43.8	2.30	0.21	2311	2311
MX-5-OM	5.5	12.3	43.0	2.56	0.22	4670	1167
COMB-5	4.1	11.3	41.9	2.49	0.20	4556	1139
SURF-5	4.9	14.7	39.3	2.57	0.21	3435	1145
SURF-5-2W	4.0	11.8	39.0	2.41	0.21	4530	1132
MX-10	8.2	18.4	46.9	2.53	0.22	4609	6914
ROOT DIP	5.5	11.6	59.9	2.55	0.19	4655	1164
OM	6.4	9.9	60.7	2.60	0.24	4779	3584
CONTROL	5.6	15.6	39.6	2.50	0.21	2345	2345
MX-20	7.9	16.0	30.8	2.29	0.18	3465	2310

*Description of treatments are given in Table 2.

Table 12. Chemical properties of the air dried soil after harvesting of the first residual effect experiment

105°C dried basis

Treatment*	0.005M DTPA Zn ppm	0.1 N-HCl Zn ppm	Olsen P ppm	C %	Total N %	NH_4-N ppm	NO_3-N ppm
MX-5	3.9	8.8	46.8	2.26	0.19	2285	2285
MX-5-OM	4.3	8.1	47.0	2.51	0.21	2295	2295
COMB-5	2.4	6.2	41.6	2.44	0.19	2291	2291
SURF-5	3.4	8.8	41.6	2.52	0.20	1527	2290
SURF-5-2W	3.0	6.4	41.5	2.36	0.19	2290	763
MX-10	3.9	8.2	57.0	2.49	0.20	3286	1524
ROOT DIP	3.4	7.4	51.4	2.50	0.21	1526	1526
OM	3.0	4.6	90.5	2.55	0.23	2289	2289
CONTROL	4.0	8.5	51.2	2.46	0.19	3044	761
MX-20	3.8	10.8	38.6	2.26	0.18	2281	760

*Description of treatments are given in Table 2.

of zinc fertilizer showed lower effect on absorption of zinc by the plant. The urea-zinc combined fertilizer application also showed the lowest value of use efficiency of the zinc. In reviewing the urea-zinc complex treatment, lower effectiveness in terms of the grain yield, yield of total zinc in the plant, fertilizer zinc yield in the plant, percentage of zinc derived from fertilizer, and fertilizer zinc use efficiency may be deeply related with zinc form. Viets et al.[4], and Boawn et al.[5] reported that zinc uptake by plants are largely affected by the application and the form of nitrogen carrier. In case of levels of zinc fertilizer, 10 and 20 kg Zn per hectare applications decrease the efficiency. The residual effect of zinc fertilizers showed slight increase of zinc efficiency for the treatments of zinc mixed with organic matter added soil and the urea-zinc complex while the remaining treatments the efficiency was decreased in the second year of the experiment.

Some characteristics of the soil after harvesting of rice were shown in Table 11 and 12. The extractable zinc in the soil increased slightly as compared to data of soil before the previous experiment.

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V. Literature cited

1. Kim, T.S., K.W. Han, and K.J. Song, 1978, Effect of radiation irradiation to organic matter mixed soil on availability of the applied zinc in laboratory condition, unpublished.

2. Brown, A.L., B.A. Kranz, and P.E. Martin, 1962, Plant uptake and fate of soil-applied zinc, Soil Sci. Soc. Am. Proc., 26, 167-170.

3. Jurinak, J.J., and D.W. Thorne, 1955, Zinc solubility under alkaline conditions in a zinc-bentonite system, Soil Sci. Soc. Am. Proc., 19, 446-448.

4. Viets, F.G., Jr., L.C. Boawn, and C.L. Crawford, 1957, The effect of nitrogen and types of nitrogen carrier on plant uptake of indigenous and applied zinc, Soil. Sci. Soc. Am. Proc., 21, 197-201.

5. Boawn L.C., F.G., Jr. Viets, C.L. Crawford, and J.L. Nelson, 1960, Effect of nitrogen carrier, nitrogen rate, zinc rate, and soil pH on zinc uptake by sorghum, potatoes, and sugar beets, Soil Sci., 90, 329-337.