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# A Study on the Efficiency of Zinc Fertilizers Using Zn-65

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# Zn-65를 利用한 亞鉛肥料의 有効度에 關한 硏究

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## Abstract

Using tracer technique of Zn-65, a pot experiment has been carried out in order to evaluate the efficiency of zinc fertilization on two paddy soils; an acidic from Kimpo and an alkaline from Yeongweol.

The sources of zinc were zinc sulfate, zinc carbonate, zinc chloride and zinc oxide. Two rates of zinc were applied to the soils and control treatment was also included for this study.

The methods of zinc application were uniform mixing throughout the soil, applying to the soil surface and irrigation water, and root dipping with zinc oxide at transplanting.

In general, Yeongweol soil had higher efficiency of zinc fertilizers than Kimpo soil.

The results showed that zinc fertilizer application should be required to improve the rice growing conditions in Yeongweol soil especially at early stage of growth after transplanting. As to the application method of zinc fertilizers, mixing treatment appeared to be most superior to any other methods in both soils. In addition, it is found that root dipping in the zinc oxide suspension would be a rather effective method of zinc application. In aspect of fertilizer efficiency there was no superiority or inferiority among the zinc sources used in this experiment.

## 1. Introduction

Since Sommer and Lipman demonstrated the essentiality of zinc for higher plants, zinc deficiency in low land rice was recognized for the first time as field problem in India in 1966[1], although in upland crops numerous instances of zinc deficiency had been reported. After that many investigators have conducted various kinds of researches to find out more effective sources and methods of zinc application.[11)12)] However, very little information exists with regard to evaluation of zinc status of paddy soils, much less of interrelationship between other macro and micro elements.[8)] In Korea there are some parts of paddy field derived from limestone rock material. Such paddy soil containing plenty of calcium, accordingly showing high pH value, is chosen to compare with acidic soils because it has been reported that zinc availability in paddy

**Table 1.** Overall design of treatment

| Soils | Acidic soil and Alkaline soil | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Zinc levels | Low zinc and High zinc | | | | | | | |
| Placements | Mixed | | | Soil Surface | | | Surface Water | Root Dipping |
| Zinc Sources | $ZnSO_4$ | $ZnCO_3$ | $ZnCl_2$ | $ZnSO_4$ | $ZnCO_3$ | $ZnCl_2$ | $ZnSO_4$ | ZnO |

soils depends on soil acidity.[2)6)]

## 2. Materials and Methods

### 2.1 Variety and nursery

One rice plant variety, Tongil proved high yield, was selected for the pot experiment. For seedling preparation the seeds were chosen by the gravimetric method using the salt solution (S.G.1.06) and steriled with 0.1% $HgCl_2$ solution for 7 hours.

After sieving the sands to pass 0.5mm-2.0mm screen, they were washed with 2N-HCl and continuously enough with distilled water. When the germination began, the seeds were placed on the sand bed and grown in the growth chamber at 27°C with about 5000 lux light intensity in the daytime and at 16°C in the nighttime for 20 days. During the sand bed nursery the seedlings received the diluted culture solution excluding only zinc element.

### 2.2 Soils

Two kinds of soils were taken from Ssangyong 3 Ri, Seo-Myeon, Yeongweol-Gun, Gangweon-Do for alkaline soil and Seonsu-Ri, Kimpo-Gun, Gyeonggi-Do for acidic soil.

### 2.3 Treatments (Placements and Zn Sources)

The experimental design consisted of eight application treatments combining four placements and four zinc sources, two levels of zinc application, and two soils with three replication. In addition eight controls for two soils with four placement treatments were involved with three replications as shown in Table 1.

The first placement treatment is zinc application mixed throughout the pot with zinc sulfate, zinc chloride, and zinc carbonate. The second one is zinc application to surface of pot soil with zinc sulfate, zinc chloride, and zinc carbonate. The third is zinc application in irrigation water two weeks after transplanting with only zinc sulfate. The fourth is zinc application as zinc oxide on seedling roots. Two rates of zinc application were different depending on the soils. For the acidic soil, high level was 1.8kg Zn/10a and low level 0.8kg Zn/10a. For the alkaline soil, high level was 2.3kg Zn/10a and low level 0.9 kg Zn/10a. The above application rates were for the treatment of 'mixed', 'soil surface', and 'surface water'. For the root dipping treatment the concentration of zinc oxide suspension was varied with the soil type; 0.8% for low and 1.8% for high in the acidic soil, and 0.9% and 2.3% in the alkaline soil.

### 2.4 Procedure

Twenty days after sprouting the seedlings were transplanted. The water tight plastic pots lined with a vinyl bag were used to contain 2kg of soils. The types and rates of nitrogen, phosphorous, and potassium fertilizers are as follows. Urea was applied at the rate of 30kg N/10a, 20 kg of that as basal and the rest 10kg as topdress at the stage of vigorous tillering. In the form of potassium chloride 16kg $K_2O$/10a was used as basal fertilizer. Also super-doublephosphate as basal was used at the rate of 16kg $P_2O_5$/10a.

In order to make uniform mixing, urea and potassium chloride were dissolved with distilled water and labelled with carrier free Zn-65 solution. The total activity of Zn-65 added was 150 $\mu$ci per pot. After adding the adequate amount of the water soluble zinc materials to the mixed solution according to the treatments, they were poured to the pot mixing with the soils and adding the weighed super-doublephosphate powder little by little. After leaving the prepared and potted soils for two weeks with care not to be dried, the small seedlings raised in the growth chamber were transplanted to the pots.

### 2.5 Harvest and analysis of zinc

The upper parts of the rice plants were cut 4cm above the soil surface at the harvest time. The harvested plants were rinsed well with distilled water before being dried at 65°C in an oven. Dried plant material was weighed and subsequently pulverized in vinyl bags to avoid contamination. 10ml of 1N HCl was added to 300 mg of the ground plant sample in order to extract the micro elements. After 24 hours 5ml of the filtrate was taken up in the glass vials to determine the Zn-65 activity. The used scaler was Tracerlab 132 MA equipped with Model EA-5W 5" well type scintillation detector. Determination of Zn, Cu, Mn and Fe was carried out by atomic absoption analysis using Nippon Jarrell Ash Model AA-1.

### 2.6 Analysis of Soils

Before the experiment soil pH was determined based on 1 : 5 soil/water extract.[3] Ten gram of air dried soil sample was extracted with 20ml of 0.005M DTPA(Diethylene Triamine Pentaacetic Acid) buffer reagent,[4][13] shaking for two hours on the wrist action shaker. After filtration the concentration of Zn, Cu, Mn and Fe was determined by atomic absoption spectrometry. The data was corrected to oven dry base(105°C) and shown in Table 2.

**Table 2.** pH values and analysis of DTPA extractable micro elements in the soils used

| Soils | pH | DTPA extractable ions(ppm) | | | |
|---|---|---|---|---|---|
| | | Zn | Cu | Mn | Fe |
| Kimpo | 5.4 | 2.6 | 2.0 | 25.8 | 98.9 |
| Yeongweol | 7.6 | 1.7 | 2.3 | 3.3 | 30.7 |

## 3. Results and Discussion

After transplanting, the growing status of rice plants was obviously different between Kimpo soil (acidic) and Yeongweol soil (alkaline).

In Yeongweol soil the rice plants seemed to be under very bad growing conditions; discoloration of leaves, rather weak root development, and withered plants were observed. On the other hand Kimpo soil brought about better growing status of rice plants as compared to Yeongweol soil. Clear explanation to elucidate such phenomena could not be given at the present time but it is suggested that there must be somewhat nutritional unbalance due to high alkalinity. Anyway one fourth of the transplanted rice failed to grow in Yeongweol soil owing to the poor growing conditions.

At harvest time the average weight of dry matter per hill seemed not to be affected by rates, sources, and methods of zinc application as well as soil types. As indicated by the figures in table 3 and 4, all of the zinc sources such as zinc sulfate, zinc carbonate, zinc chloride, and zinc oxide are effectively utilized to increase the zinc content of the rice plants. In control pots, zinc concentration of rice plants grown in Yeongweol soil seems to be lower than that of Kimpo soil. This is well agreed with that in Kimpo soil much more zinc was extracted by DTPA buffer solution than in Yeongweol soil. Another pots in which zinc fertilizers were applied, however, brought about higher zinc content of rice plants in Yeongweol soil than that of Kimpo soil. This is well consisted with the fact that Yeongweol soil, in general, has higher efficiency of zinc fertilizers than Kimpo soil (Table 5 and 6).

Namely, Yeongweol soil contains less amount of DTPA extractable zinc, therefore the applied zinc fertilizer should be easily utilized by the rice plants.

As listed in table 5 and 6, zinc contents of rice plants are ranged from 17 to 30ppm. The plant copper content varied from 5.0ppm to 12 ppm showing average value of 8.0ppm which was a satisfactory range for growth. No tendancy related to copper content was found among the soil types and zinc fertilizer treatments. In case of manganese content of rice plant, there was a big difference between Yeongweol soil and Kimpo soil. The plant manganese content of Kimpo soil was almost four times that of the rice plants

**Table 3.** Effect of methods, sources, and rates of zinc applicationion mineral composition of rice plants grown in Yeongweol soil(mean of three replication, ppm).

| Treatments | Zn applied kg/ha | Zinc* Sources | Zn | Cu | Mn | Fe |
|---|---|---|---|---|---|---|
| Mixed | 0 | ** | 17.8 | 8.1 | 84.2 | 43.6 |
| | 0.9 | Z.S. | 20.0 | 8.1 | 56.6 | 42.4 |
| | | Z.C. | 20.5 | 4.5 | 81.8 | 44.2 |
| | | Z.L. | 23.2 | 6.0 | 56.1 | 47.4 |
| | 2.3 | Z.S. | 24.5 | 9.1 | 70.8 | 40.7 |
| | | Z.C. | 26.8 | 9.3 | 61.2 | 36.3 |
| | | Z.L. | 25.3 | 5.9 | 56.3 | 42.4 |
| Soil | 0 | ** | 15.3 | 4.9 | 63.3 | 46.4 |
| Surface | 0.9 | Z.S. | 21.9 | 7.4 | 68.0 | 58.3 |
| | | Z.C. | 26.0 | 8.5 | 58.2 | 40.0 |
| | | Z.L. | 30.0 | 11.6 | 49.5 | 43.6 |
| | 2.3 | Z.S. | 24.2 | 10.6 | 70.8 | 41.1 |
| | | Z.C. | 24.7 | 12.5 | 58.9 | 47.8 |
| | | Z.L. | 25.7 | 8.5 | 71.8 | 46.3 |
| Surface | 0 | ** | 15.5 | 6.7 | 72.8 | 38.2 |
| Water | 0.9 | Z.S. | 21.4 | 5.7 | 66.6 | 40.1 |
| | 2.3 | Z.S. | 23.2 | 9.1 | 66.1 | 36.7 |
| Root Dip*** | 0 | ** | 14.7 | 12.7 | 89.1 | 51.9 |
| | 0.21 | Z.O. | 23.4 | 7.0 | 82.7 | 44.5 |
| | 0.55 | Z.O. | 29.0 | 9.8 | 86.0 | 51.7 |

* Z.S.: Zinc Sulfate  Z.C.: Zinc Carbonate  Z.L.: Zinc Chloride  Z.O.: Zinc Oxide
** Control: No zinc applied, only labelled with carrier-free Zn-65
*** 0.19kg Zn/ha and 0.43kg Zn/ha: equivalent to the amount of zinc applied to one hill, 0.8mg Zn/hill and 1.8mg Zn/hill respectively.

**Table 4.** Effect of methods, sources, and rates of zinc application on mineral composition of rice plants grown in Kimpo soil(mean of three replication, ppm).

| Treatments | Zn applied kg/ha | Zinc* Sources | Zn | Cu | Mn | Fe |
|---|---|---|---|---|---|---|
| Mixed | 0 | ** | 17.8 | 7.6 | 230.0 | 35.3 |
| | 0.8 | Z.S. | 21.4 | 11.8 | 313.7 | 31.2 |
| | | Z.C. | 21.3 | 8.8 | 339.0 | 32.7 |
| | | Z.L. | 21.7 | 7.8 | 276.4 | 33.4 |
| | 1.8 | Z.S. | 21.5 | 8.6 | 313.7 | 29.3 |
| | | Z.C. | 20.7 | 6.6 | 296.9 | 31.6 |
| | | Z.L. | 20.2 | 6.1 | 318.8 | 28.8 |
| Soil | 0 | ** | 17.3 | 5.6 | 207.1 | 22.9 |
| Surface | 0.8 | Z.S. | 19.8 | 9.0 | 267.1 | 32.7 |
| | | Z.C. | 20.9 | 10.0 | 219.5 | 31.8 |
| | | Z.L. | 22.5 | 11.3 | 355.4 | 32.9 |
| | 1.8 | Z.S. | 21.8 | 6.3 | 304.5 | 30.2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | Z.C. | 20.7 | 5.8 | 262.7 | 25.7 |
| | | Z.L. | 23.8 | 5.3 | 360.3 | 32.0 |
| Surface | 0 | ** | 18.5 | 7.6 | 245.4 | 33.4 |
| Water | 0.8 | Z.S. | 23.3 | 6.4 | 374.3 | 39.1 |
| | 1.8 | Z.S. | 22.2 | 6.7 | 230.7 | 24.0 |
| Root Dip*** | 0 | ** | 16.9 | 8.6 | 314.4 | 39.7 |
| | 0.19 | Z.O. | 17.9 | 5.5 | 255.1 | 19.6 |
| | 0.43 | Z.O. | 18.2 | 7.3 | 233.0 | 20.4 |

* Z.S.: Zinc Sulfate Z.C.: Zinc Carbonate Z.L.: Zinc Chloride Z.O.: Zinc Oxide

** Control: No zinc applied, only labelled with carrier-free Zn-65

*** 0.19kg Zn/ha and 0.43kg Zn/ha: equivalent to the amount of zinc applied to one hill, 0.8mg Zn/hill and 1.8mg Zn/hill respectively.

**Table 5.** Dry matter weight of rice plants and zinc fertilizer efficiency as affected by rates, sources, and methods of zinc application in Yeongweol soil.

| Treatments | Zn applied kg/ha | Zinc Sources | Dry Matter per Pot (gr) | Total Zinc Uptake per Pot (ug) | Spec. Act. of Zn-65 in Plant(mci/Zngr) | Zn dff (%) | Fertilizer Efficiency (%) | L-value (Zn ug/g soil) |
|---|---|---|---|---|---|---|---|---|
| Mixed | 0 | * | 11.2 | 199.4 | 1.1 | — | — | 6.8 |
| | 0.9 | Z.S. | 13.4 | 268.0 | 0.799 | 79.9 | 1.43 | — |
| | | Z.C. | 17.2 | 352.6 | 0.544 | 54.3 | 1.28 | — |
| | | Z.L. | 14.0 | 324.8 | 0.558 | 55.8 | 1.21 | — |
| | 2.3 | Z.S. | 11.6 | 284.2 | 0.341 | 87.0 | 0.65 | — |
| | | Z.C. | 14.0 | 375.2 | 0.326 | 83.0 | 0.81 | — |
| | | Z.L. | 13.6 | 344.1 | 0.312 | 80.0 | 0.72 | — |
| Soil | 0 | * | 14.4 | 220.3 | 1.005 | — | — | 7.5 |
| Surface | 0.9 | Z.S. | 11.6 | 254.0 | 0.295 | 33.5 | 0.57 | — |
| | | Z.C. | 12.8 | 332.8 | 0.330 | 33.0 | 0.73 | — |
| | | Z.L. | 7.2 | 216.0 | 0.337 | 33.6 | 0.48 | — |
| | 2.3 | Z.S. | 11.6 | 280.7 | 0.276 | 70.4 | 0.52 | — |
| | | Z.C. | 9.2 | 227.2 | 0.184 | 47.0 | 0.28 | — |
| | | Z.L. | 8.0 | 205.6 | 0.200 | 51.0 | 0.27 | — |
| Surface | 0 | * | 14.8 | 229.4 | 0.981 | — | — | 7.7 |
| Water | 0.9 | Z.S. | 12.4 | 265.4 | 0.211 | 21.1 | 0.37 | — |
| | 2.3 | Z.S. | 10.0 | 232.0 | 0.223 | 56.9 | 0.34 | — |
| Root | 0 | * | 12.4 | 182.3 | 0.172 | — | — | 4.4 |
| Dipping | 0.21 | Z.O. | 9.6 | 224.6 | 0.075 | 38.7 | 2.2 | — |
| | 0.55 | Z.O. | 11.6 | 336.4 | 0.084 | 86.2 | 3.8 | — |

grown in Yeongweol soil. The average plant manganese value of 68ppm in Yeongweol soil is considered to be above the deficiency level for rice growing and 289ppm of average plant manganese in Kimpo soil seems to be ample amount for normal plant growth, still being under the toxic level of manganese. But zinc fertilization did not affect the manganese content of rice plants in both soils. On the other hand the plant iron content was higher in Yeongweol soil than Kimpo soil. This is inconsistent with the fact that the amount of DTPA extractable iron in Kimpo soil is much more than in Yeongweol soil. The reason might be considered that there

**Table 6.** Dry matter weight of rice plants and zinc fertilizers efficiency as affected by rates, sources, and methods of zinc application in Kimpo soil.

| Treatments | Zn applied kg/ha | Zinc Sources | Dry Matter per Pot (gr) | Total Zinc Uptake per Pot (ug) | Spe. Act. of Zn-65 in Plant(mci/Zngr) | Zn dff (%) | Fertilizer Efficiency (%) | L-value (Zn ug/g soil) |
|---|---|---|---|---|---|---|---|---|
| Mixed | 0 | * | 15.2 | 270.6 | 0.67 | — | — | 11.2 |
| | 0.8 | Z.S. | 10.4 | 222.6 | 0.489 | 43.3 | 0.72 | — |
| | | Z.C. | 12.0 | 255.6 | 0.398 | 35.2 | 0.68 | — |
| | | Z.L. | 12.4 | 269.1 | 0.495 | 43.8 | 0.88 | — |
| | 1.8 | Z.S. | 12.0 | 258.0 | 0.318 | 63.5 | 0.55 | — |
| | | Z.C. | 11.6 | 240.1 | 0.308 | 61.5 | 0.49 | — |
| | | Z.L. | 12.4 | 250.5 | 0.316 | 63.2 | 0.53 | — |
| Soil | 0 | * | 13.6 | 235.3 | 0.835 | — | — | 9.0 |
| Surface | 0.8 | Z.S. | 12.4 | 245.5 | 0.232 | 20.5 | 0.38 | — |
| | | Z.C. | 14.0 | 292.6 | 0.252 | 22.4 | 0.49 | — |
| | | Z.L. | 13.6 | 306.0 | 0.449 | 33.5 | 0.77 | — |
| | 1.8 | Z.S. | 12.4 | 250.5 | 0.261 | 52.1 | 0.44 | — |
| | | Z.C. | 11.2 | 231.8 | 0.184 | 36.8 | 0.28 | — |
| | | Z.L. | 14.4 | 342.7 | 0.263 | 52.5 | 0.599 | — |
| Surface | 0 | * | 14.8 | 273.8 | 1.393 | — | — | 5.4 |
| Water | 0.9 | Z.S. | 12.4 | 288.9 | 0.265 | 23.5 | 0.51 | — |
| | 1.8 | Z.S. | 13.6 | 301.9 | 0.515 | 88.1 | 0.886 | — |
| Root | 0 | * | 12.0 | 202.8 | 0.117 | — | — | 6.4 |
| Dipping | 0.19 | Z.O. | 11.6 | 207.6 | 0.080 | 31.9 | 2.2 | — |
| | 0.43 | Z.O. | 12.8 | 233.0 | 0.070 | 80.9 | 2.17 | — |

must be antagonism between manganese and iron.[7] That is, comparatively very high amount of manganese ion competed with iron ion in Kimpo soil and retarded the uptake of iron by rice plants. As like zinc, copper, and manganese the plant iron content was not changed by the rates, sources, and methods of zinc application.

Turning to percentage of zinc derived from fertilizer(% Zn dff)[9,10] much higher values of % Zn dff were obtained in Yeongweol soil than in Kimpo soil as given in table 5 and 6. This fact means that native zinc in Yeongweol soil is less available for the rice plants as compared to that in Kimpo soil. In other words, the zinc uptake by rice plants in Yeongweol soil could be largely increased by zinc fertilization.

When zinc fertilizers were mixed with the soils, % Zn dff was comparatively higher as compared to soil surface treatment regardless of soil types and application rates. It seems to be quite natural thing that higher rates of zinc application bring about higher % Zn dff and less fertilizer efficiency irrespective of soil types and treatment methods of zinc fertilizers, although there are only few exceptions in the treatments of soil surface and root dipping. Any special tendancy regarding to % Zn dff was not shown among the zinc sources. Consequently it might be suggested that all the used zinc sources such as zinc sulfate, zinc carbonate, and zinc chloride have almost same availability in both soil conditions. In case of root dip treatment, fertilizer efficiency was remarkably increased in both soils. Refering to L-value,[5,6] 11.2μg Zn per soil gram obtained from the mixed treatment of Kimpo soil was rather higher than 6.8μg zinc per soil gram of Yeongweol soil, proving that much more native zinc in Kimpo soil could be available for rice plants. Although the reason is not explained, L-value (5.4 Zn μg/g soil) from surface water treatment in Kimpo soil gives the lowest as compared to other treatments while surface water treatment in Yeongweol soil shows the highest L-value (7.7 Zn μg/g soil).


## 요 약

Zn-65 추적자를 이용하여 아연비료의 효율을 평가하기 위해서 산성인 김포토양과 알카리성인 영월토양을 사용하여 pot 실험을 수행하였다. 아연원은 황산아연 탄산아연 염화아연 그리고 산화아연을 이용했고 고저의 두가지 수준으로 처리했으며 사용방법은 토양전체에 혼합하는 방법, 토양표면 또는 관개수에 뿌리는 법과 이앙시 수도의 뿌리를 산화아연 용액에 담그는 법을 시도했다.

알카리성인 영월토양이 산성인 김포토양보다 아연비료의 효율이 컸으며 특히 이앙후 초기에는 영월토양에서 아연비료의 시용이 필수적임을 알았다. 아연의 처리방법으로는 토양에 혼합해주는 것이 가장 효과적이었으며 수도근을 아연 용액에 담그는 방법은 이용율의 면에서 우수하였으며 아연원별에 의한 효과의 차이는 나타나지 않았다.


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