Journal of the Korean Nuclear Society
Volume 11, Number 2, June, 1979

《Original》

Effect of Gamma Ray Irradiation on the Availability of ^{65}Zn Applied to Organic Matter Added Soils under Laboratory Conditions

Tai Soon KIM* and Kang Wan HAN**

(Received Nov. 22, 1978)

Abstract

In order to evaluate the effect of gamma ray irradiation to the soils added with several organic matters on release and fixation of ^{65}Zn, a soil incubation test was carried out by use of an acidic and a calcareous soil. The results obtained were summarized as follows:

DTPA extractable ^{65}Zn decreased gradually with elapsed time of incubation owing to fixation of ^{65}Zn by the soils but after four weeks DTPA extractable ^{65}Zn was reached an equilibrium state. The most parts of ^{65}Zn activity in the equilibrium state was found in the solid phase. The extent of zinc fixation in acidic Keumgok and calcareous Jecheon soils represented as activity basis was 89 and 93.7 per cent of applied ^{65}Zn respectively. Increased tendency of DTPA extractable zinc was shown by irradiating gamma ray to both soils because of ^{65}Zn fixation could be decreased by irradiation. The extractability of fixed ^{65}Zn by DTPA solution was 38.9 per cent in acidic Keumgok soil and only 9.5 per cent in calcareous Jecheon soil. Release of fixed ^{65}Zn by irradiation of gamma ray is closely related to pH of both soils. Much more ^{65}Zn could be released under low pH condition. Effect of gamma ray irradiation to organic matter sources on release of ^{65}Zn could not be differentiated. But in the case of nonirradiated soils, however, glucose treated soils couldrelease much more the extractable zinc as compared to those of the straw or cellulose treatment.

요 약

3종의 유기물을 첨가한 산성, 알카리성 답 토양에 방사성 아연비료($^{65}ZnSO_4$)를 시용(施用)하고 ^{60}Co gamma선을 조사(照射)하였을때 시용한 ^{65}Zn의 고정(固定)과 방출(放出)에 어떤 영향을 주는가를 보기 위하여 실험실내에서 항온방치 실험을 행한 결과를 요약하면 다음과 같다.

산성, 알카리성 답 토양에 시용한 $^{65}ZnSO_4$는 이들 토양에 고정되므로 DTPA 용액에의 가용성 ^{65}Zn는 방치시간이 경과 할수록 감소되다가 항온방치 4주 부터 고액상(固液相) 간에 평형을 유지하게된다. 이 평형상태하에서 $^{65}ZnSO_4$의 대부분은 고상(固相)에 흡착 고정되는데 그 정도는 산성인 금곡토양에서는 ^{65}Zn의 89% (방사능 기준) 이었고, 알카리성인 석회암질 제천토양에서는 93.7% 이었다. 산성, 알카리성 답 토양에 gamma선을 조사(照射)하면 ^{65}Zn의 고정은 감소되므로 가용성 ^{65}Zn는 증가한다.

고정된 ^{65}Zn의 DTPA 용액에의 가용정도는 산성인 금곡토양에서는 38.9% 이었고 알카리성 석회암질 제천토양에서는 9.5%에 불과 하였다.

* The Korea Atomic Energy Research Institute, Seoul, Korea
**The Korea Ginseng Research Institute, Seoul, Korea

고정된 ^{65}Zn의 gamma선 조사(照射)에 의한 방출은 답 토양의 pH에 밀접한 관계가 있었다. 즉 고정된 ^{65}Zn의 방출은 pH가 얕은 산성토양에서 현저했고 알카리성 토양에서는 적었다.

금곡토양에 gamma선을 조사하면 ^{65}Zn의 유효도가 커지는 것으로 봐서 산성조건에서는 고정된 아연은 더 가용화 된다고 본다.

유기물 급원(給源) 별 방사선 영향 차이는 인정되지 않았다. 그러나 gamma선을 조사하지 않았을 때 Glucose 처리는 Cellulose나 생고분말(生藁粉末)을 첨가했을 때 보다 DTPA 가용성 ^{65}Zn은 더 방출(放出)되었다.

I. Introduction

Effect of ionizing radiation on the availability of nutrients and on soil fertility were studied by many workers[1,2,3,4,5]. For the macronutrients, irradiation increases the availability of nitrogen and phosphorus in soil[5]. The release of nitrogen and phosphorus was closely related to soil type and more particularly to its organic matter content. In each case the soil containing larger amount of organic matter showed larger increase in extractable nitrogen and phosphorus after irradiation[5]. As for the exchangeable cations such as calcium, magnesium, and potassium, there were no measurable changes in the availability of these elements by irradiation[5]. But smaller increases in the amounts of potassium, magnesium, copper, and manganese in the soil solution was reported by other worker[3]. Furthermore, substantial increases in the amount of carbon, phosphorus, ammonia, and organic nitrogen in the soil solution were found by irradiation[3]. In respect to zinc, on the other hand, it seems that the effect of radiation irradiation on the availability of zinc is not yet fully understood. The purpose of present study was to evaluate release and fixation of ^{65}Zn applied to organic matter added soils as affected by gamma ray irradiation.

II. Materials and Methods

1. Soils

Two surface soils were collected and used for this experiment. Keumgok soil which is the same soil as used for the efficiency studies on zinc fertilizers[9,10]. Another one is high pH calcareous soil which has lower concentration of available zinc (Table 1).

Table 1. Chemical and physical properties of the soils

105°C oven dried basis

Soil name	Texture	Organic matter %	C %	Total N %	Olsen P ppm	Exchangeable cations m.e./100g			DTPA Zn ppm	0.1N-HCI Zn ppm
						Ca	Mg	K		
Keumgok	SiCL	4.2	2.4	0.18	35.5	5.83	1.20	0.24	10.87	21.87
Jecheon	SL	2.9	1.7	0.13	46.1	19.93	5.61	0.42	1.01	0.04

2. Laboratory incubation test

Soil incubation test was carried out by applying ^{65}Zn on the acidic and the calcareous soils. Overall design was consisted of three kinds of organic matters such as glucose, rice straw, and cellulose applied to both soils with three replications. Two soils were exposed or not exposed to ^{60}Co gamma rays to compare with the radiation effect on the zinc availability.

2-1. Procedure

The soils were air dried and passed through a 2mm-sieve. Glucose and cellulose used were reagent grades and the rice straw was used as a powdered form. 20 g of the soils were weighed and placed into 100 ml capacity tall polyethylene beaker to incubate the soils. The samples were received 40 mg of each organic matter and mixed thoroughly with the soils. 20 ml of ^{65}Zn solution (as $ZnSO_4 \cdot 7H_2O$, $8.38\times10^{-3}\mu Ci/ml$; $13.87\mu Ci/g$ Zn) and 15 ml of sterilized distilled water were added to the soils so as to maintain submerged condition. After that the samples were exposed to gamma rays emitted from 5,839 Ci of ^{60}Co irradiator for 45 hours at mean dose rate of 2.45×10^5 rads per hour. The total dosages received by the soils were 11 Megarads. The samples were incubated for 1, 2, 4 and 6 weeks in an oven at temperature of $30\pm1°C$. After incubation period as required elapsed, the samples were taken out from the oven and subjected to extract soluble zinc using 30 ml of 0.005 M DTPA (diethylenetriaminepentaacetic acid) solution. Activity of DTPA extractable ^{65}Zn was measured by use of 400 channels pulse height analyzer equipped with 5 inches well type scintillation detector. In this study, the term "fixed ^{65}Zn" denotes that ^{65}Zn which could not be removed by the DTPA extractant.

Ⅲ. Results and Discussion

Activities of DTPA extractable ^{65}Zn in both control soils decreased rapidly from beginning of incubation period but with the time elapsed nearly constant activities were reached after four weeks (Fig.1). But in case of irradiated Keumgok soil decrease of extractable ^{65}Zn showed a slower decrease pattern as compared to that of ^{65}Zn in Jecheon irradiated soil (Fig.1).

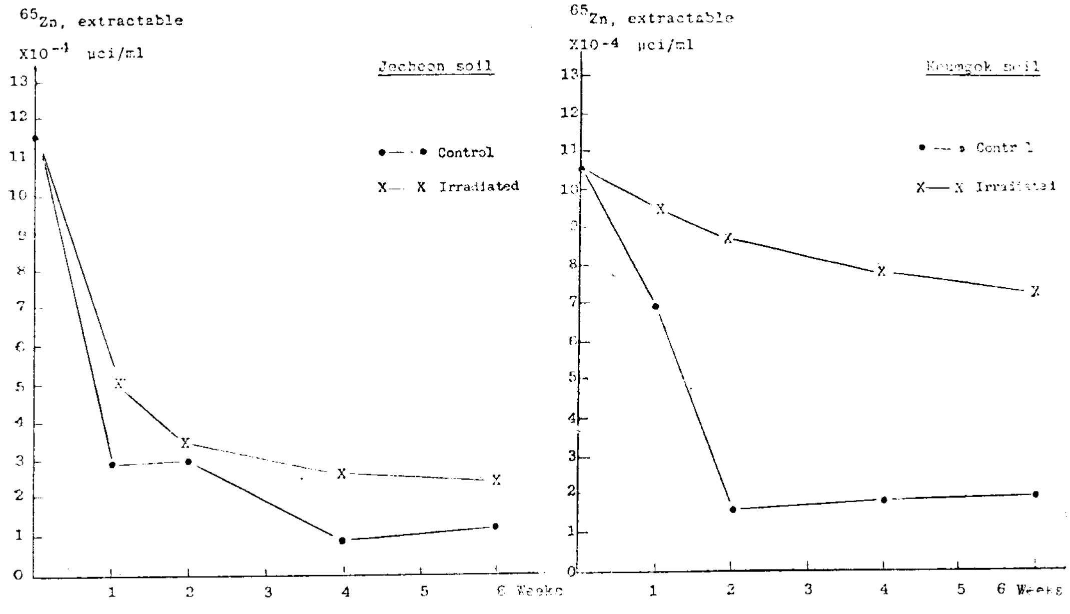

Fig.1. Effect of gamma ray irradiation on release of zinc-65 during incubation period

After the equilibrium state was attained, the percentage of ^{65}Zn released (DTPA extractable ^{65}Zn activity to ^{65}Zn activity applied) from the nonirradiated control soils showed 6.9 per cent in Jecheon soil and 11.5 per cent in Keumgok soil respectively. As fio the irradiated soils, on the other hand, remarkable increasing tendency of the extractable ^{65}Zn was found in Keumgok soil, while Jecheon soil showed slight increase (Fig.1).

As shown in Fig. 2 the most parts of ^{65}Zn applied to the soils would become difficultly extractable by the DTPA solution. The percentage of ^{65}Zn fixation by nonirradiated Keumgok and Jecheon soils was 88.7 and 92.8 per cent respectively. The fixation may be attributed to be due to addition of organic matters to both soils. During incubation period, pH values of both soils were not changed much (Table 4). Bowen et al. reported that ionizing radiation irradiation has not appreciable effects on soil pH or their available contents of zinc, potassium, iron etc.[1]. Ten et al. reported that organic matter in soil accounts for the accumulation of zinc, possibly by formation of complex compound[6]. It is also known that the fixation of zinc occurs markedly in calcareous soil than that in acid soil[7].

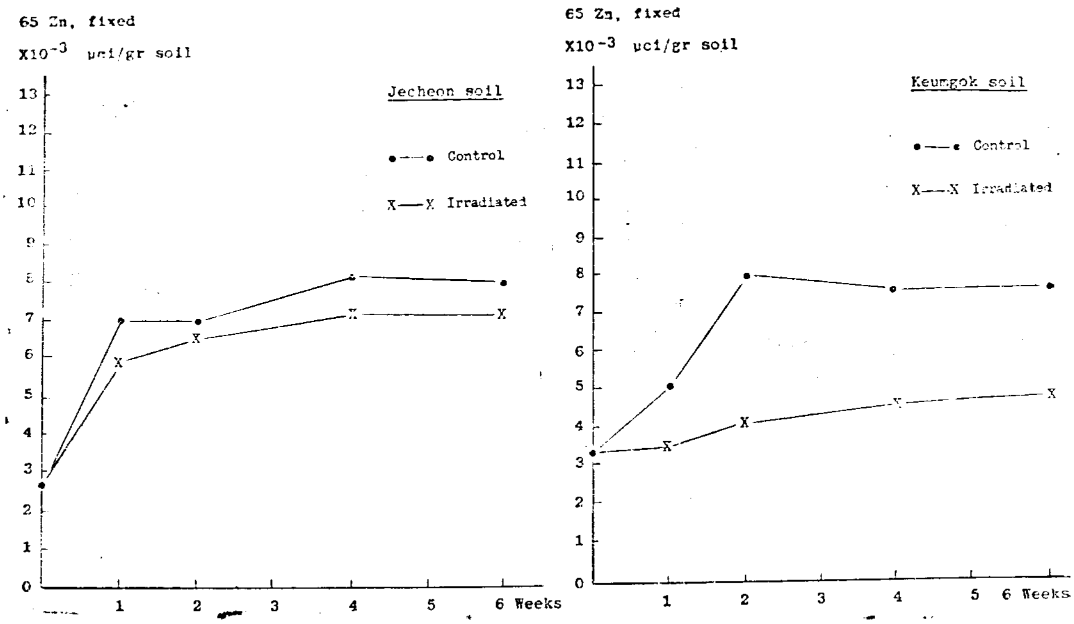

Fig. 2. Effect of gamma ray irradiation on fixation of Zinc-65 during incubation period

Effect of the gamma ray irradiation of soils on ^{65}Zn fixation showed that the fixed ^{65}Zn activity decreased significantly in acidic Keumgok soil, while smaller decrease showed in calcareous Jecheon soil (Fig.2 and Table 2). Accordingly, extent of ^{65}Zn release showed different patterns by different soil types (Table 3). Nearly 39 per cent of the fixed ^{65}Zn was extracted in Keumgok soil, while Jecheon soil released only 10 per cent of the fixed ^{65}Zn. These results suggest that extent of ^{65}Zn release by the gamma ray irradiation depend upon pH value of soil. That is, the acid soil could release much more

Table 2. DTPA extractable and nonextractable ^{65}Zn activities in equilibrium state

Soil name	DTPA extractable ^{65}Zn, $\mu Ci/ml$		Fixed ^{65}Zn, $\mu Ci/g$ soil	
	Control	Irradiated	Control	Irradiated
Keumgok	1.85×10^{-4}	7.65×10^{-4}	7.46×10^{-3}	4.56×10^{-3}
Jecheon	1.05×10^{-4}	2.55×10^{-4}	7.86×10^{-3}	7.11×10^{-3}

Table 3. Effect of gamma ray irradiation on fixation of zinc and extractable zinc

Soil name	Fixed ^{65}Zn, pCi/g soil		DTPA extractable ^{65}Zn after irradiation pCi/g soil
	Control	11 Megarads	
Keumgok	7455	4555	2900
Jecheon	7855	7105	750

Table 4. Change of soil pH during soil incubation period as affected by irradiation of gamma ray

Soil name	Gamma ray treatment	Incubation period, week			
		1	2	3	4
Keumgok	−	5.37	5.49	5.45	5.39
〃	+	5.54	5.34	5.06	5.52
〃 organic matter added	−	5.81	6.04	5.86	5.89
〃 〃	+	5.68	5.28	5.47	5.49
Jecheon	−	7.33	7.43	7.34	7.20
〃	+	7.40	7.22	7.23	7.25
〃 organic matter added	−	6.99	7.09	7.07	7.06
〃 〃	+	7.12	7.25	7.20	7.30

Table 5. DTPA extractable ^{65}Zn activity in equilibrium state as affected by sources of organic matter

Soil name	Gamma ray treatment	Organic matter source	^{65}Zn, pCi/ml		
			4 weeks	6 weeks	mean
Keumgok	−	Glucose	186	219	203
	−	Rice straw	192	183	188
	−	Cellulose	151	178	165
Jecheon	−	Glucose	83	137	110
	−	Rice straw	109	111	110
	−	Cellulose	80	98	89
Keumgok	+	Glucose	742	726	734
	+	Rice straw	742	747	745
	+	Cellulose	873	739	806
Jecheon	+	Glucose	252	207	230
	+	Rice straw	279	251	265
	+	Cellulose	269	260	265

zinc than the calcareous soil. It is well known that normally soils abundant in organic matter and high pH show zinc deficiency in the plants growing on them. However, soils with low pH and high organic matter content may not produce zinc deficient plants[8].

Among the organic matter sources applied to soils, the glucose treatment seems to liberate much more ^{65}Zn from the nonirradiated control soils than release of that from cellulose treated soils (Table 5). The rice straw treatment showed also lower release of ^{65}Zn than the glucose treated soils. But when the soils were to be irradiated no clear differences on releasing ^{65}Zn could be found among the sources (Table 5). It can be concluded that increase of DTPA extractable ^{65}Zn by gamma ray irradiation might be caused decomposition of the organic matters in the soils.

References

1. Bowen, H.J.H. and P.A. Cawse, 1962, The effect of ionizing radiation on the availability of inorganic ions in soils, Radioisotopes in Soil-Plant Nutrition Studies, pp.17-30, IAEA, Vienna.
2. Bowen, H.J.H. and P.A. Cawse, 1964, Effects of ionizing radiation on soils and subsequent crop growth, Soil Sci., 97, 252-259.
3. Bowen, H.J.H. and P.A. Cawse, 1964, Some effects of gamma radiation on the composition of the soil solution and soil organic matter, Soil Sci., 98, 358-361.
4. Popenoe, H. and C.F. Eno, 1962, The effect of gamma radiation on the microbial population of the soil, Soil Sci. Soc. Am. Proc., 26, 164-167.
5. Eno, C.F. and H. Popenoe, 1963, The effect of gamma radiation on the availability of nitrogen and phosphorus in soil, Soil Sci. Soc. Am. Proc., 27, 299-301.
6. Tan, K.H., L.D. King, and H.D. Morris, 1971, Complex reaction of zinc with organic matter extracted from sewage sludge, Soil Sci. Soc. Am. Proc., 35, 748-752.

7. Kim, T.S., 1974, Study of zinc availability in the paddy field, Proc. of the International Symposium Commemorating the 30th Anniversary of Korea Liberation, National Academy of Sciences, Republic of Korea, 805-818.

8. Katyal, J.C., 1972, A study of zinc equilibria in flooded soils and amelioration of zinc deficient soils of Agusan Del Norte, Terminal Report, pp.14-15, Philippines.

9. Kim, T.S., K.W. Han, Z.K.U, and K.J. Song, 1978, Isotope-aided micronutrient studies in rice production with special reference to zinc deficiency(I), J. Korean Nuclear Soc., 10, 4, 215-222.

10. Kim, T.S., J.S. Kim, and Jin S. Kim, 1979, Isotope-aided micronutrient studies in rice production with special reference to zinc deficiency(II), J. Korean Nuclear Soc., 11, 1, 47-54.