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THE CRITICAL LEVELS AND THE MAXIMUM METAL UPTAKE FOR WHEAT AND RICE PLANTS WHEN APPLYING METAL OXIDES TO SOIL

Key words: Wheat, Rice plants, Metal oxides (CdO, ZnO, PbO), Critical levels, Maximum uptake by plants

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ABSTRACT

Wheat is more sensitivity to CdO and ZnO compared with rice plant. The yield of wheat decreased by 30 % in the presence of 30 ppm Cd, but that of rice plants by only 8 %. The critical levels of meal uptake by wheat and rice plants for applying metal oxides to soil (CdO, ZnO, PbO) were determined. The highest concentration obtained for wheat grain was 141 μg/g Cd at the Cd 10,000 ppm in soil. This value is higher the value of 4.97 μg/g for unpolished rice and higher than any other we have seen in the reports for treatment with CdO. Also, as concentration of more than 1.0 μg/g Cd in wheat was obserlced at 5 ppm Cd, while similar concentrations for rice plants were observed at 30 ppm Cd in soil.

INTRODUCTION

Most of the reports on the relationship between the metal uptake or the growth damage and the metal concentration in soil have been performed at the average concentration levels of Cd pollution in Japan. There have been as lot of reports on the

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relationships between metal contents in the soil and in rice plants(Fujiwara and Kikuchi 1951, Lagerwerff and Specht 1971, Kobayashi and Muramoto 1971, Koshino 1973, Chino 1973, Homma and Hirata 1974, Ito and Iimuras 1976).

However, these reports have not been dealing with concentrations close to the critical levels of wheat and rice plants. Also, there have been few reports on the comparison of metal torelance or metal uptake between two diferents.

In this research, the effects of cadmium oxide, zinc oxide, and lead oxide on the plant growth and the metal content of wheat and rice plants up to a metal concentration in soil of 50,000 ppm (5 %) for Zn, 10,000 ppm for Cd and 30,000 ppm for Pb were studied.

The critical levels of plant growth for wheat and rice plants were investigated. After cropping, the Cd, Zn, Pb, and Cu contents in plants were evaluated. The toxicities of these metal oxides to both plants were compared with each other.

MATERIALS AND METHODS

Cadmium oxide, zinc oxide and lead oxide were used in these experiments and the nominal concentrations of metals mixed with soil are shown in Table 1. Tap water was added to the containers as required to maintain good plants growth. Wheat, *Triticum estiva* C.V., rice plants, *Oryza sativa* L., were planted in pots of size 1/5,000 a containing 10 kg of dry soil. Alluvial soil was used for the experiment with a pH value of 5.95 and heavy metal concentrations as follows: Cd 0.2 μ/g , Zn 144 μg/g, Pb 33 μg/g and Cu 40 μg/g in dry matter. Two plants per pot were planted from December to June for 23 weeks for wheat, and from July to November for 15 weeks for rice plants.

The pots were divided into the following groups according to the treatment received : (1) Control, (2) CdO, (3) ZnO, (4) PbO, (5) CdO+ZnO. Four replicates were used in every group. Every pot received as a basal fertilizer 5g of ammoniumsulfate 4.3g of superphosphate calcium and 1.4g of potassium, and tap water containing <0.01 ppm Cd.

The wheat grains and the brown rice (unpolsihed rice) after dry-treatment at 60 °C for 48 h in hot-air drier underwent wet digestion with HNO_3-$HClO_4$ (2 : 1) solution and were made up to a fixed volume by the addition of 1N-HCl. These solution were used for the determination of Cd, Zn, Pb, and Cu with atomic absorption spectrophotometer after application of the DDTC-MIBK method.

RESULTS AND DISCUSSIONS

The realation ships between the concentration of Cd, Zn, Pb in soil treated with CdO, ZnO, PbO and the respective

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METHODS

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TABLE 1
Relationship between the growth of wheat and rice plants and the metal concentrations in soil.

Metal treatment (ppm)		Length of stem (cm)		Weight of stem (cm)		Weight of roots (g)		Weight of grain (g)		Yield ratio (%)	
		A	B	A	B	A	B	A	B	A	B
Cd	10	85	101	53	88	1.6	29	34.0	154	97.1	101
	30	82	98	52	82	1.1	26	23.0	141	69.7	92.2
	100	79	97	47	69	1.3	19	5.0	140	15.2	91.5
	300	76	97	45	68	1.4	20	1.0	130	12.1	84.9
	1000	61	84	21	65	0.2	20	1.0	106	3.0	69.3
	3000	57	67	7	41	0.2	18	1.0	49	3.0	32.2
	6000	49	65	7	35	0.2	9	0.5	29	1.5	19.1
	10000	24	40	3	21	0.1	6	0.3	1.9	0.8	1.2
Zn	1000	77	99	39	101	0.9	20	12.0	165	36.4	108
	3000	80	98	29	101	1.0	22	17.0	150	51.5	98.0
	10000	62	98	20	100	0.8	18	6.0	148	18.2	76.7
	30000	47	99	5	98	0.3	18	0.3	145	0.9	74.8
	60000	50	99	3	96	0.2	21	0.01	145	0.03	74.8
Pb	300	74	97	46	86	1.8	27	35.0	144	106	94.1
	1000	83	97	50	89	1.4	24	34.0	155	103	101
	3000	84	94	41	92	1.0	22	35.0	146	103	95.4
	10000	82	100	37	106	0.9	27	25.0	177	75.7	116
	30000	78	102	29	118	0.6	26	18.0	193	54.6	126
Cd 100 + Zn	500	41	98	8	87	0.2	20	0.6	159	1.82	104
Cd 1000+ Zn	5000	40	90	6	71	0.1	22	0.3	112	0.91	73.2
Control		89	99	54	87	1.6	28	35.0	153	100	100

A: Wheat, B: Rice plant

concentrations in grains are presented in Figs. 1a-1c, for wheat, and in Figs. 2a-2c for rice plants.

Table 1 shows the growth indices of wheat and rice plants at various nominal concentrations of metals in soil. Also, the correlation coefficients between the concentrations of Cd, Zn, Pb in soil and the Cd, Zn, Pb and Cu concentrations in every part of wheat and rice plants are shown in Table 2.

CdO treatment group

A significant correlation between the concentration of cadmium as CdO in soil and the yields of wheat was recognized

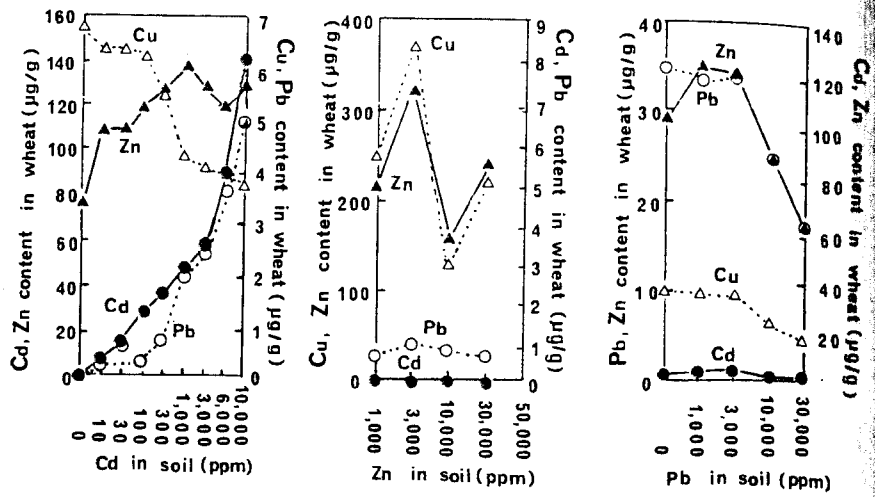


Figure 1a-1c. Relatioship between the concentrations of Cd, Zn, Pb, in soil and the Cd, Zn, Pb and Cu concentrations in wheat grain.

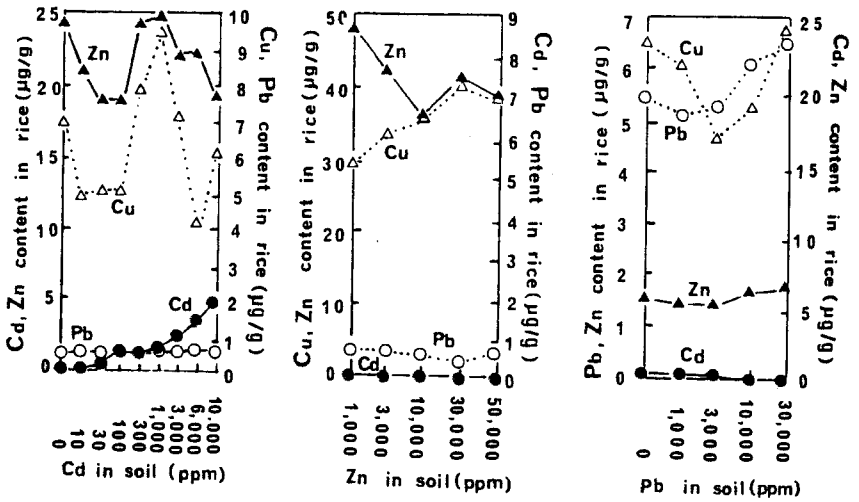
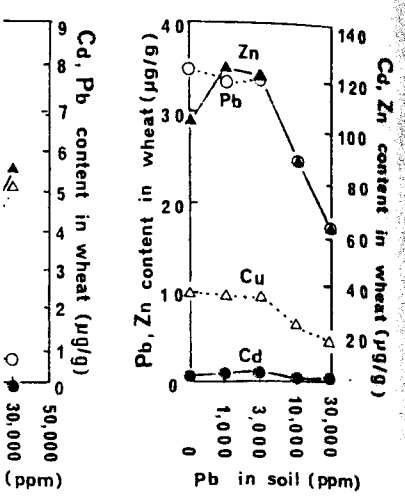


Figure 2a-2c. Relatioship between the concentrations of Cd, Zn, Pb in soil and the Cd, Zn, Pb and Cu concentrations in rice grain(brown rice).



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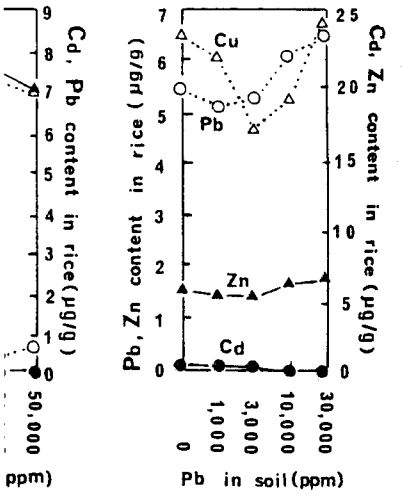

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TABLE 2

Correlation coefficients between the concentrations of Cd, Zn, Pb in soil and the yields of plants, and the Cd, Zn, Pb and Cu concentrations in every part of plants.

Metal treatment group	(Metal in grain) -(Metal in soil)	Correlation coefficient A	Correlation coefficient B	Correlation equation (y = alogx + b) A a	A b	B a	B b
CdO	(grain Cd)-(soil Cd)	0.91**	0.88**	0.05	3.26	-0.53	0.446
	(grain Zn)-(soil Cd)	0.24	-0.605	0.01	3.36	24.0	-0.85
	(grain Pb)-(soil Cd)	0.89**	0.89**	1.27	3.60	0.41	0.02
	(grain Cu)-(soil Cd)	-0.95**	0.614	-2.07	16.7	5.41	0.349
	(Yield) - (soil Cd)	-0.86**	-0.863**	-0.17	7.57	181.3	-15.16
ZnO	(grain Cd)-(soil Zn)	-0.70*	-0.796**	-1.09	8.84	0.157	0.005
	(grain Zn)-(soil Zn)	0.48	0.97**	160.9	8.89	10.79	2.78
	(grain Pb)-(soil Zn)	-0.88**	0.145	0.44	0.048	0.509	0.006
	(grain Cu)-(soil Zn)	-0.32	-0.234	7.01	-0.164	8.07	-0.08
	(Yield) - (soil Zn)	-0.99**	-0.943**	-0.21	10.6	58.89	-5.63
PbO	(grain Cd)-(soil Pb)	0.40	-0.964**	3.36	4.43	0.202	-0.015
	(grain Zn)-(soil Pb)	-0.64*	-0.368	-0.06	15.3	24.89	-0.468
	(grain Pb)-(soil Pb)	0.96**	0.906**	0.49	6.07	0.108	0.08
	(grain Cu)-(soil Pb)	-0.60	-0.104	-0.78	13.8	6.19	-0.03
	(Yield) - (soil Pb)	-0.89**	0.700*	-0.21	14.3	125	5.24

*: $p<0.05$, **: $p<0.01$, A: Wheat, B: rice plant, Yield: grain yield

($p<0.010$). Wheat yield decreased by 30 %, 85 %, and 97 % in the presence of 30 ppm Cd, 100 ppm Cd, and 1,000 ppm Cd, respectively. In the wheat plants that were treated with more than 1,000 ppm Cd, the yield percentage was less than 3 % of the control yield, and was very low comparison with that of rice plants (69 %) at the same Cd levels in soil.

Therefore cadmium is much more toxic to wheat than to rice plants. Cadmium concentration of wheat of wheat seed increased with Cd concentration in soil (Fig. 1a).

The highest concentration obtained for wheat was 141 μg/g Cd at the Cd 10,000 ppm group. This value is the critical levels of wheat to CdO, and is 28 times that of rice plants at the same CdO levels in soil.

The zinc concentration of wheat tended to increase with Cd concentration in soil and the same results was observed for rice bran. However, antagonism between Cd and Zn was not observed in contrast with the results for polished rice (Muramoto 1989).

The Pb content of wheat tended to increase and was about 12 times that of control in the 10,000 ppm Cd group.

ZnO treatment group

At Zn concentrations in soil from 10,000 ppm up to 50,000 ppm, a yield decrease of around 25 % in comparison with control was observed. In 10,000 ppm Zn group, wheat did not grow at all(0 %) because of Zn toxicity.

Wheat and rice though they belong to the same family of plants, they have a different sensitivity towards ZnO toxicity.

The Zn concentration in wheat grains did not increase consistently with the Zn concentration in soil though the toxicity increased a lot. Therefore, the effect of Zn toxicity on wheat growth was very strong almost equal to that of Cd, but was not observed in rice plants at 50,000 ppm Zn in soil.

PbO treatment group

The growth of both wheat and rice plants was much more satisfactory in the group treated with PbO than in the groups treated either with CdO or with ZnO. The wheat yield decreased to 55 % of control at 30,000 ppm Pb, but rice yield increased to 126 % of control at the same concentration level. The Pb content increased with the amount of PbO in soil, and was about 22 times that of control at 30,000 ppm Pb. Pb concentration of wheat and Pb concentration in soil, but a positive one between Pb in wheat and PbO in soil.

Mixed metal groups

In both the mixed metal groups (Cd 100ppm + Zn 500 ppm, Cd 1,000ppm + Zn 5,000 ppm), the yields of wheat decreased compared with those of cadmium alone. However, in rice plants, the addition of Zn did not make the yield lower than what it was when Cd was used alone. Also, the contents of Cd in the Cd 100 ppm + Zn 500 ppm group and the Cd 1,000 ppm + Zn 5,000 ppm group were about 55 % and 33 % respectively lower than those at the same concentrations of Cd used alone. These results were similar to those of polished rice and unpolished rice except for the results concerning rice bran.

There was not much variation of Cu concentration in wheat even of high concentrations of metals in soil except for a slightly increase with CdO concentration in soil. Also, in the mixed metal group (Cd + Zn), the Cu concentration of wheat was slightly higher than that in the group treated only with Cd.

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CONCLUSIONS

The metal uptake by wheat and rice plants was determined at the critical levels of metal oxides.

1. The highest concentration obtained for wheat(seeds) was 141 μg/g Cd at the Cd 10,000 ppm group. This value is higher than the value of 4.97 μg/g for unpolished rice and higher than any other we have seen in the reports for treatment with CdO.

2. Wheat is more sensitive to CdO compared with rice plant. The yield of wheat decreased by 30 % in the presence of 30 ppm Cd, but that of rice plants by only 8 %. Also, as concentration of more than 1.0 μg/g Cd in wheat was observed at 5 ppm Cd, while similar concentrations for rice plants were observed at 300 ppm Cd in soil.

3. The toxicity of ZnO to wheat is higher than that to rice plants. The yield of wheat decreased by 50 % at Zn 10,000 ppm in soil. However, even at high concentrations of PbO in soil there was not severe damage in growth of wheat or rice. The percentage of wheat yield decrease in comparison with control was 25 % at 10,000 Pb in soil.

4. In the mixed metal groups, the growth damage is higher than the one when Cd is used alone. Combined toxicity to wheat was observed when applying CdO and ZnO together. The addition of Zn in soil decreased the toxicity of Cd to rice plants by a small amounts.

5. The concentration of the metals in seeds of plants at similar concentration in soil was found to be higher in wheat than in rice. The Cu concentration in seds under with the exception of the group treated with PbO.

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