Influence of adding Pb to soil on the growth of wheat seedlings

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Abstract
Pot experiments were carried out to study the influence of soil Pb pollution on the growth of wheat seedlings. The results are as follows: (1) low concentrations of Pb in the soil stimulate seedling growth; high concentrations, however, inhibit their growth. (2) The Pb taken up by the seedlings is mostly accumulated in the roots, and only a little is transported to the shoots. (3) More Pb was accumulated in the seedlings growing on an acid soil due to the higher level of available Pb.

Key Words
Pb pollution; soil; wheat seedlings.

Introduction
Heavy metals in soils are mostly anthropogenic in origin, which may come from sewage irrigation, solid waste disposal, pesticides and fertilizers application or atmospheric deposition. Soil heavy metal pollution has become a worldwide environmental concern because of its hidden, non-reversible and long-term adverse effects on human health (Chen 1996). With the development of industrial and agricultural production, the problem of soil heavy metal pollution has increasingly become more serious in China. So far, the area of cultivated soils suffered from heavy metal pollution reaches more than 20 million hm^2 nationwide. Due to the large area of soil pollution, China is estimated to produce 12 million ton of heavy metal polluted grain (Li 2005). Soil Pb pollution is one of the most serious problems in agriculture. A high concentration of Pb is harmful to plant growth and development (Wu *et al.* 2004; Wang and Huang 2008; Cao and Huang 2006). Due to its low solubility, Pb is immobile and often retained in topsoil, which does harm to human health through the food chain (Todd *et al.* 1996). The uptake of Pb in the soils from Anhui province, southeastern China, by wheat seedlings and its effects on seedling growth were studied through pot experiments described in this paper.

Methods
Pot experiments
Three soil types in Anhui province, southeastern China, were used in pot experiments, which include a yellow-red soil (Ferralsol) in Xuancheng, a yellow-cinnamon soil (Luvisol) in Hefei and a black soil with lime concretions (Calcisol) in Guoyang county. A wheat variety of No. 19 Yannong was selected for experimental use. A fungicide, $PbSO_4$, was applied to the soils as a supplemental Pb source. A certain amount of $PbSO_4$ was fully mixed with air-dried soils (< 2mm) and then maintained in an incubator within 20 ± 0.2 ^oC for 10 days. Seven soil treatments with different Pb concentrations were presented in Table 1. Disinfected wheat seeds were put into an incubator and maintained within 20 ± 2 ^oC for 12-18 hours to accelerate germination. 100 g treated soil, 50 g quartz and a certain amount of KH_2PO4 and urea were fully mixed and put into a plastic pot (11.5cm x 7cm), with a hollow plastic tube (6mm x 65mm) inserted in the middle and another 50 g quartz evenly covered on the surface. 50.0 mL deionized water was added through the tube in each pot. 100 sprouting seeds with similar size were put into each prepared pot, followed by evenly covering 100 g quartz and adding 20 mL deionized water to make soil water content up to 70%. Each test treatment was triplicate. All the pots were randomly put into the incubator, with the constant temperature of 25 ± 1 ^oC in the day and 20±1 ^oC at night and 12 hour/day illumination (4000 lax). Water was added each day to keep the soil water content stable in the pots. The wheat seedlings were removed after 14 day's cultivation, and then washed, oven-dried and crushed into powder for chemical analyses. The pot experiments were conducted in Anhui Agricultural University from 16 August 16, 2008 to December 23, 2008.

Chemical analyses
Pb concentration in both soil and plant was determined by the atomic absorption spectrophotometer (AAS) method after the soils were digested with mixed acids HF-$HClO_4$ –HNO_3 and the plants with H_2O_2-HNO_3. The physical-chemical properties of soils were measured according to Bao (2000).

Table 1. Seven treatments with different Pb concentrations in the pot experiments.

Soil types	Treatments (Pb concentrations, mg/kg)						
	I	II	III	IV	V	VI	VII
Yellow-red soil	0	25	100	200	400	600	800
Yellow-cinnamon soil	0	25	100	250	500	750	900
Black soil with lime concretions	0	25	100	300	600	900	1200

Results

Relationships between total Pb and chemically extractable Pb in the soils with Pb addition

The contents of HCl- and DTPA-extractable Pb in the three soils are much higher than those of NH_4NO_3- and NH_4AC-extractable Pb; the four chemically extractable Pb contents are significantly correlated with the total Pb (n=7; r^2>0.95). Moreover, the contents of chemically extractable Pb in the yellow-red soil are much higher than those in the other soils, especially in the black soil with lime concretions.

Influence of Pb addition on the growth of wheat seedlings

The dry weights of the shoots and roots of wheat seedlings with the different Pb treatments are shown in Table 2. The treatments of low Pb concentrations, which are < 100mg/kg in the yellow-red soils, <50mg/kg in the yellow-cinnamon soil, and < 100mg/kg in the black soil with lime concretion, stimulate the growth of both shoots and roots of the seedlings; these of the high Pb concentrations, which are >200mg/kg in the yellow-red soil, >100mg/kg in the yellow-cinnamon soil and >300mg/kg in the black soil with lime concretion, on the contrary, inhibit seedlings growth. For example, the dry weights of shoots are only 69.23%, 67.67% and 80.43% of the control when treated with 800mg/kg in the yellow-red soil, and 900mg/kg in the yellow-cinnamon soil and 1200mg/kg in the black soil with lime concretions, respectively; these of roots only 51.54%, 72.89% and 52.77% when treated with the same Pb concentrations. This also suggests that the seedling roots are more severely repressed when treated with the high Pb concentrations.

Table 2. Percentages of plant dry weights with the different treatments compared with the control

Treatments	Percents（%）					
	Yellow-red soil		Yellow-cinnamon soil		Black soil with lime concretions	
	Shoots	Roots	Shoots	Roots	Shoots	Roots
I	100.00	100.00	100.00	100.00	100.00	100.00
II	101.10	106.54	105.17	106.83	105.04	106.93
III	110.38	103.08	90.49	94.96	110.08	104.97
IV	93.41	101.15	76.23	86.350	89.80	79.10
V	88.89	91.15	69.78	67.95	86.01	57.85
VI	77.53	51.54	72.65	72.21	84.03	52.77
VII	69.23	40.38	67.67	72.89	80.43	51.50

Accumulation and distribution of Pb in wheat seedlings

The accumulation of Pb in the wheat seedlings is shown in Table 3. The concentrations of Pb in both the shoots and roots increase with the treated Pb levels increasing. The high transfer factors in the different soils and treatments suggest that the amount of Pb uptaken by the seedlings are mainly retained in the roots rather than quickly transported to the shoots. Pb concentrations in the shoots of seedlings growing on the different test soils with the same Pb treatments are significantly different, so are these in the roots, which follows the sequence of the yellow-red soil > the yellow-cinnamon soil > the black soil with lime concretions. The highest levels of Pb in the seedlings growing on the yellow-red soil are attributed to its highest contents of available Pb due to its low pH and high acidity, which is proved by its highest chemically extractable Pb; likewise, the lowest Pb in the seedlings on the black soil with lime concretions attributed to its lowest contents of available Pb due to its high pH.

Conclusions

The capability of soil Pb extraction by the four chemical solutions are different, which follows the sequence of HCl (0.1mol/l) > DTPA (0.005mol/l) > NH_4NO_3 (1.0mol/l) > NH_4AC (1.0mol/l). There are significant correlations between total Pb and chemical extractable Pb in the soils. Low concentrations of Pb in the soils stimulate the growth of wheat seedlings, while high concentrations of Pb greatly inhibit seedlings growth. The Pb taken up by the seedlings is mainly accumulated in the roots, and only a little is transported to the shoots. An acid soil condition benefits Pb uptake by the seedlings due to the higher levels of available Pb.

Table 3. Transfer and enrichment factors of Pb in wheat seedlings with the different Pb treatments

Treatments	Yellow-red soil		Yellow-cinnamon soil		Black soil with lime concretions	
	Transfer factor*	Enrichment factor**	Transfer factor	Enrichment factor	Transfer factor	Enrichment factor
I	0.195	0. 34	0.0	0. 850	0.0	0.020
II	39.7	0.400	2.5	0. 555	3.5	0.088
III	25.9	0. 656	3.1	0. 323	4.4	0.082
IV	11.1	1.048	1.6	0. 256	3.1	0. 176
V	6.8	1.700	1.3	0. 289	4.4	0. 179
VI	8.4	2.051	2.1	0. 309	7.0	0. 271
VII	11.4	2.254	2.6	0. 368	7.6	0. 274

*Transfer factor: Ratios of Pb concentrations in roots to these in shoots; **Enrichment factor: Ratio of Pb concentrations in wheat seedlings to these in the soils.

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