Interactive effect of sulphur and lead on the growth of muskmelon (*Cucumis melo* L.) seedling

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EL-B. Ragab, A.

Department of Soil Science, Faculty of Agriculture,
Tanta University, Egypt

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Summary: The effect of sulphur and lead on growth of muskmelon (*Cucmis melo* L.) sweet ananas was measured under plastic tunnel. Lead (Pb) was applied at the rate of 0, 75, 300, 600 and 1200 µg/g of soil in factorial combination with treatments of 0, 48, 80, 112 and 224 mg S/kg soils. Muskmelon growth was reduced by increasing Pb concentration and/or by removing S from the growth medium. Lead concentration in plant tissues increased linearly with increasing Pb concentration in the growth medium. Increasing S concentration in solution reduced the effects of the 75–1200 µg Pb /g soil treatments. Increasing S concentration in soil increased shoot and root growth at high levels of Pb. Increased levels of S in the growth medium decreased Pb concentration in shoot and root tissues and increased growth of muskmelon. The reduction in Pb toxicity at high S supply may be due to reduced root absorption of Pb.

Introduction

Sulphur (S) deficiency is becoming an important problem for European agriculture. Now consumers are extremely health conscious. As a result they want vegetables rich in vitamins and minerals. Vegetables containing toxic compounds, such as nitrate or heavy metals will not be highly marketable to consumers. Thus, it is of utmost importance that an optimum nutrient solution supplied to vegetables seedlings affects growth in the greenhouse and has a carry-over in the field after transplanting. Sulphur fertilization is a feasible technique for lowering the plant uptake of undesired or toxic elements in polluted soils. This is due to the antagonistic relationship between S and anionic trace elements, including arsenic (As), antimony (Sb) and Mo, which, despite their essential function, can be toxic to plants. Excess S fertilization can also increase the concentrations of cationic trace elements such as copper, zinc and cadmium levels in shoot (Schnug 1990).

Fertilizers and pesticides applied for cultivation purposes as well as municipal and industrial waste application to cultivated soils deposit heavy metals in the soil. From these contaminated soils, plants absorb substantial amounts of heavy metals (Rappaport et al 1988). The continuous introduction of heavy metals by plants into food chain presents a health hazard to man and animals.

Lead is nonessential to plants that is present in the environment in soil and rock dusts and as a combustion product of gasoline (Lagerwerff, 1971). Freshly precipitated Pb from burned gasoline is relatively soluble, but is converted to less soluble forms in soil.

Lead uptake by young corn shoots has been found to depend upon the level of Pb in the soil, as well as the capacity of soil to sorb Pb (Miller et. al., 1975). The applied element concentration also provides a poor toxicity index as its concentration in the soil and absorption by plants can be affected by series of factors (Batsa and Tabatabai, 1992). It has been shown that the effect on yield for potentially harmful element might depend mainly, if not entirely, on its concentration in the tissue, and this plant tissue concentration can be relatively independent of other factors (Beckett and Davis, 1977).

Lead is a normal soil constituent with widely varying concentration (John, and Laerhoven, 1972). Baumhardt and Welch (1972) found neither decrease nor enhanced yield of corn with application of 3200 mg Pb/kg soil. Dang et al. (1990) observed affects of Pb at lower concentration of Pb slightly decreased the fresh and dry matter yield of fenugreek, the difference between levels being significant only at 400 mg Pb/kg soil. While the significant decreased in dry matter yield of onion was observed at 50 mg Pb/kg soil.

John and Laerhoven (1972) observed that PbCl2 lowered the amount of P and S in lettuce and oats, but had no significant effect on other elements studied.

The objectives of this study were to examine the interactive effects of Pb and S concentration in the growth medium on muskmelon growth, and heavy metal uptake by an easily grown test plant as muskmelon (*Cucmis melo* L,).

Materials and methods

Pot experiments were carried out under plastic tunnel at the experimental station farm of the university of Horticulture and Food Industry in Soroksár (near Budapest), during July, Aug. and Sept. 1997. Plants were grown in 2.8 -liter black plastic pots filled soil. The soil was a sandy loam with pH 7.85 and 0.46% organic matter content. Lead was applied separately at 0, 75, 300, 600 or 1200 mg/g of air-dried soil as lead nitrate [Pb $(NO_3)_2$] in factorial combination with treatments of 0, 48, 80, 112 and 224 mg S/kg soils. Pots without any addition of lead (Pb) or sulphur (S) constituted the control. The experiment was replicated five times in completely randomized block design. A basal dressing of macronutrient at 400 N, 200 Ca, 390 K, 48 Mg and 62 P mg/kg soils. Micronutrients were applied (in mg/liter) as 49 Fe as FeHEDTA (ferric hydroxyl ethylene diamine tetra acetate), and salts- H_3BO_3 (2.86), Mn SO_4, H_2O (6.16), 4.6 $ZnSO_4.7H_2O$ (0.22), $CuSO_4.5H_2O$ (0.08), and $H_2MoO_4.H_2O$ (0.02). Fertilizers and treatment solutions were manually mixed in the soil. The soil in the pots was brought to field capacity four times and allowed to air-dry 3-4 days each time at 25 °C under the plastic tunnel to permit soil metal interactions prior to planting. Seeds of muskmelon were germinated in 2.8 -liter black plastic pots filled with treated soil. The pots were watered with distilled water daily to maintain 50 percent water holding capacity of the soil. Immediately after germination seedlings were thinned to one seedling per pot. Plants were harvested 42 days after germination. Harvested plants were washed with distilled water. The plants were divided into shoots and roots as separate samples, shoot fresh weight was recorded Tissue samples were dried in a forced–air oven at 70 °C, and shoot and root dry weights were determined. Ground tissue samples (200 mg) were digested in an acid mixture of HNO3 -$HClO_4$, oxidized with H_2O_2. Digested dry matter for shoot and root was analyzed for Pb, by atomic adsorption spectrometry and for S by turbidimetrically method (Jones 1995).

After cropping, soil samples from each treatment were collected and analyzed for their DTPA (diethylenetriamine-pentacetic acid)-extractable Pb contents.

Analysis of variance (ANOVA) was performed on the results of the experiments. Least significant difference values were calculated at 1% level and 5% level.

Results and discussion

Growth

The trait was effected by S, Pb and S-Pb interaction. The application of 75 mg Pb /g soil slightly increased the shoot fresh weight, total dry weight, root and shoot dry weights over the control *(Table 1)*. All the other treatment concentrations were resulted decreases in growth. A drastic reduction

Table 1 Fresh and dry weight of muskmelon seedling exposed to various concentrations of lead and sulphur

Added element	Conc. (ppm)	Shoot fresh wt.	Dry matter production g / plant					
			Total dry wt.		Shoot		Root	
Pb	0	45.94 A	4.62 B	(100.0)@	3.68 B	(100.0)	0.94 B	(100.0)
	75	46.05 A	5.67 A	(122.7)	4.42 A	(120.1)	1.09 A	(117.9)
	300	38.95 B	3.78 C	(81.2)	3.04 C	(82.6)	0.73 C	(77.6)
	600	29.88 C	2.70 D	(58.4)	2.36 D	(64.1)	0.33 D	(35.1)
	1200	18.97 D	1.67 E	(36.1)	1.50 E	(40.8)	0.17 E	(18.1)
S	0	19.39 E	1.76 E	(100.0)@	1.46 e	(100.0)	0.29 E	(100.0)
	48	27.36 D	2.77 D	(157.4)	2.27 d	(155.5)	0.50 D	(210.1)
	80	39.24 C	3.96 C	(225.0)	3.27 c	(223.4)	0.69 C	(237.9)
	112	43.37 B	4.38 B	(248.9)	3.62 b	(247.9)	0.76 B	(264.1)
	224	50.44 A	5.40 A	(306.8)	4.38 a	(300.0)	1.03 A	(344.8)

Means followed by different letters in each column are significantly different at P 0.05 (small letters) and at P 0.01 (capital letters).
@ = Figures in parenthesis are the percent yield of control.

Table 2 Sulphur and Pb composition of muskmelon seedling, and on DTPA-extractable Pb in soil exposed to various concentrations of lead and sulphur.

Added element	Conc. (ppm)	S % dry wt.		mg Pb /g soil		DTPA-Pb in soil
		Shoot	Root	Shoot	Root	
Pb	0	0.87 a	0.27 a	1.00 E	2.02 E	22.89 E
	75	0.88 a	0.26 a	4.61 D	13.53 D	31.53 D
	300	0.86 a	0.27 a	21.62 V	42.18 C	48.78 C
	600	0.81 a	0.21 b	48.59 B	101.41 B	64.84 B
	1200	0.65 b	0.20 b	80.18 A	302.17 A	114.4 A
S	0	0.26 E	0.14 E	35.21 a	101.93 a	65.51 A
	48	0.61 D	0.17 D	33.61 b	97.40 b	61.22 B
	80	0.90 C	0.25 C	32.60 b	90.86 c	57.18 C
	112	1.10 B	0.31 B	31.25 c	92.04 c	53.00 D
	224	1.20 A	0.34 A	23.80 d	79.07 d	46.10 E

Means followed by different letters in each column are significantly different at P 0.05(small letters) and at P 0.01 (capital letters).

in the yield of shoot fresh weight and dry weight of shoot and root was observed at 300 mg Pb /g soil and above. The results are in agreement with the findings of earlier workers Rolfe (1973); Khan and Khan (1983) and Dang et al (1990) who showed a similar view that the heavy-metal toxicity depends upon one or more nutrient(s) concentration within the plants. However, the results seemed to be in contrast to other work reported in literature Baumhardt and Welch (1972). The considerable variation between species, metal concentration and other environmental factors may be a plausible explanation for the difference.

Table 3 Interactions effect of sulphur and lead on fresh and dry weight of muskmelon seedling

Added element	Conc. (ppm)	Shoot fresh wt.	Dry matter production g / plant					
			Total dry wt.		Shoot		Root	
0	0	23.2	2.21	(100.0) @	1.80	(100.0)	0.41	(100.0)
	48	34.7	3.61	(166.1)	2.88	(164.8)	0.74	(182.0)
	80	50.2	5.15	(233.1)	4.07	(226.6)	1.1	(261.2)
	112	58.3	5.63	(258.3)	4.43	(253.2)	1.2	(293.2)
	224	63.3	6.51	(296.8)	5.20	(293.2)	1.3	(323.6)
75	0	23.4	1.98	(89.5)	1.57	(87.2)	0.41	(101.0)
	48	34.9	4.26	(195.7)	3.38	(194.1)	0.87	(214.8)
	80	50.7	6.06	(274.6)	4.81	(267.5)	1.25	(304.2)
	112	55.1	6.62	(303.9)	5.24	(299.3)	1.38	(340.5)
	224	66.2	8.63	(393.6)	7.10	(400.4)	1.53	(378.4)
300	0	19.5	1.85	(83.6)	1.52	(84.4)	0.33	(79.7)
	48	30.4	2.85	(131.1)	2.33	(133.6)	0.52	(128.4)
	80	43.9	4.17	(189.1)	3.44	(191.0)	0.74	(179.8)
	112	46.4	4.54	(208.6)	3.74	(213.6)	0.80	(197.9)
	224	54.7	5.46	(248.9)	4.20	(236.8)	1.26	(311.2)
600	0	17.4	1.55	(69.9)	1.35	(75.2)	0.19	(46.8)
	48	21.7	1.86	(85.9)	1.64	(94.1)	0.22	(55.0)
	80	32.3	2.78	(125.6)	2.54	(140.9)	0.24	(59.1)
	112	36.5	3.26	(149.7)	2.99	(170.8)	0.27	(65.7)
	224	41.6	4.03	(165.6)	3.30	(186.1)	0.74	(82.1)
1200	0	13.5	1.19	(53.7)	1.06	(58.9)	0.13	(31.2)
	48	15.1	1.29	(59.2)	1.15	(66.0)	0.14	(33.3)
	80	19.2	1.65	(74.7)	1.51	(83.9)	0.14	(34.3)
	112	20.7	1.84	(84.5)	1.69	(96.6)	0.15	(36.2)
	224	26.4	2.37	(108.2)	2.10	(118..4)	0.27	(67.2)
LSD 5%	5.5		0.51		0.53		0.08	

@ = Figures in parenthesis are the percent yield of control (0 Pb and 0 S mg/g soil)

An increasing trend in yield of shoot fresh weight, total dry weight and dry weight of root was observed and indicate a highly significant (at the 1% level) with increasing S concentration in soil. While the increasing trend in yield of dry weight of shoot was observed and indicate significant (at the 5% level) with increasing S concentration in soil *(Table 2).*

Muskmelon growth was reduced by increasing Pb concentration and/or by removing S from the growth medium *(Table 3).* When both S deficiency *(Table 2)* and Pb toxicity *(Table 3)* affected plant growth, both shoot and root growth was greatly reduced. Total dry weight *(Table 3)* was smaller under S absence than in the presence of different S concentrations. Increasing S concentration in solution reduced the effects of the 75–1200 μg Pb /g soil treatments. Increasing S concentration from 48 ppm to 224 ppm in soil increased shoot and root growth at high levels of Pb. The response of relative yield to both S and Pb concentration in the growth medium followed essentially similar trends as those of dry matter yield *(Table 3).* S-Pb interaction effect was significant (at the 5% level) on the growth of muskmelon *(Table 3).*

Lead (Pb) and sulphur (S) composition

Lead (Pb) concentration in plant tissues increased linearly with increasing Pb concentration in the growth medium. Plants had higher concentration of Pb in root tissues than shoot tissues at all Pb concentration in the growth medium *(Table 2).* The Pb content in plants grown in growth medium without S was higher than that in plants grown with the addition of S. Increasing S concentration in growth medium markedly decreased Pb concentration in plant tissues. An increase in S concentration in growth medium decreased the Pb concentration of shoots and roots *(Table 2).* These show that the maximum amount of Pb accumulation in the roots. Lead accumulation in tissue is found to be directly to proportional to that applied in the soil and in a similar way, indicating an inhibiting effect of S on Pb absorption. Sulfur (S) concentration of plant tissues increased with increasing S concentration in the growth medium, as shown in *Table 2,* indicate a highly significant correlation (at the 1% level) exists between that S applied to soil and the S concentration found in the tissue of muskmelon. Shoot portions showed higher S concentration than roots. The effect of Pb concentration in the growth medium was significant (at the 5% level) on S concentration of plant tissues *(Table 2).* The interaction effect of S-Pb was

Table 4 Interactions effect of sulphur and lead on S and Pb composition of muskmelon seedling, and on DTPA-extractable Pb in soil.

Conc. of added element µg/g soil)		S % dry wt.		mg Pb /g soil		DTPA-Pb µg Pb g^{-1} soil
Pb	S	Shoot	Root	Shoot	Root	
	0	0.22	0.14	0.99	1.87	30.13
	48	0.61	0.19	1.06	2.01	26.90
	80	0.94	0.28	1.03	2.30	24.36
	112	1.26	0.34	1.00	1.91	18.43
	224	1.36	0.39	0.92	2.04	14.60
	0	0.26	0.13	5.15	15.45	36.80
	48	0.68	0.18	5.00	15.00	34.90
	80	0.94	0.27	4.98	14.50	32.40
	112	1.21	0.33	4.72	14.16	29.66
	224	1.34	0.36	3.20	8.50	23.96
	0	0.31	0.16	26.8	53.60	61.80
	48	0.65	0.19	25.00	50.00	53.30
	80	0.95	0.27	24.12	45.00	47.63
	112	1.15	0.34	19.90	39.80	43.50
	224	1.24	0.36	12.30	22.50	37.70
	0	0.29	0.14	54.27	114.80	75.20
	48	0.59	0.15	52.00	110.00	70.63
	80	0.89	0.22	48.90	99.11	66.70
	112	1.06	0.27	47.10	99.63	62.60
	224	1.21	0.29	40.70	83.50	49.10
	0	0.25	0.13	88.46	323.90	123.60
	48	0.53	0.14	85.00	310.00	120.50
	80	0.80	0.21	84.06	293.40	114.76
	112	0.84	0.26	83.56	304.75	110.93
	224	0.84	0.29	61.90	278.80	105.00
LSD 5%		0.15	ns	2.30	7.25	2.64

ns = not significan

significant (at the 5% level) on concentration of Pb in plant tissues and on concentration of S in shoot, but there was not interaction effect on concentration of S in root *(Table 4).*

DTPA-Extractable Pb in soil

DTPA-extractable Pb increased significantly with each level of Pb applied to soil. Increasing S concentration in growth medium markedly decreased Pb DTPA-extractable Pb concentration in soil *(Table 2).* S-Pb interaction effect was significant (at the 5% level) on DTPA-extractable Pb in soil *(Table 4).*

The main results indicate a promontory effect of lower additions of Pb. The lower addition of Pb is a 'ballast' element, which also invariably induced an increase in growth. Allinson and Dzialo (1981) and Lagerwerff (1971) have also reported enhanced growth due to application of Pb. The reasons for this growth enhancement remain largely unexplained. The higher additions of Pb resulted in a significant inhibition of growth, which also has been observed by others (Dang et. al., 1990; Aery and Sarkar, 1991).

Muskmelon growth was reduced by increasing Pb concentration and /or by removing S from the growth medium. When both S deficiency and Pb toxicity affected plant growth, both shoot and root growth was greatly reduced. The growth inhibition at the higher loading rates of heavy metal might be due to an inhibition of mitotic activity in meristematic zone (Powell et al., 1986) and/or to an inhibition of cell enlargement in the elongation zone as a consequence of decreased cellular turgor (Gabbrielli et al., 1990). Higher reduction in root growth than shoot growth seems to be due to Pb higher concentration in root tissues than in the shoots (Barcelo and poschenrieder, 1990; Aery and Jagetiya, 1997).

Conclusions

Previous results predicated that must give attention to the lead supplies and the design of strategies for essential plant nutrients fertilization will be an important part of future plant nutrition programs. The fertilization in practical cropping systems might therefore be more difficult and complicated. A need will exist for reliable diagnostic systems as well as for new fertilizer products. Plant analysis is the most successful tool for the inhibition of the Pb status of agricultural crops. Results clearly demonstrate that sulphur fertilization as $MgSO_4.7H_2O$ and (NH_4) 2 SO_4 is a feasible technique to lower plant uptake of undesired or toxic elements on polluted soils. The application of these finding to field conditions further work, as the high rate of sulphur demand under glasshouse conditions combined with a limited of sulphur supply than in the field.

References

Aery, N. C. & Jagetiya, B. L. (1997): Relative toxicity of cadmium, lead and zinc on barley. Commum. Soil Sci. Plant Anal., 28: 949-960.

Aery, N. C. & Sarkar, S. (1991): Studies on the effect of heavy metal stress on growth parameters of soybean. J. Environ. Biol. 12: 15-24.

Allinson, D. W. & Dzialo, C. (1981): The influence of lead, cadmium and nickel on the growth of ryegrass and oats. Plant and Soil 62: 81-89.

Barcelo, J. & Poschhenrieder, C. (1990): Plant water relations as affected by heavy metal stress: A review. J. Plant Nutr. 13: 1-37.

Basta, N. T. & Tabatabai, M. A. (1992): Effect of cropping systems on adsorption of metals by soils. I. Single-metal adsorption. Soil Sci. 153: 108-114.

Baumhardt, G. R. & Welch, L. F. (1972): Lead uptake and corn growth with soil applied lead. J. Environ. Qual. 1: 92-94.

Beckett, P. H. T. & Davis, R. D. (1977): Upper critical levels of toxic elements in plants. New Phytol. 79: 95-106.

Dang, Y. P., Chhabra, R. & Verma, K. S. (1990): Effect of Cd, Ni, Pb and Zn on growth and chemical composition of onion and fenugreek. Commun. Soil Sci. Plant Anal., 21: 717-735.

Gabbrielli, R., Pandofini, T.\, Vergnano, O. & Palandri, M. R. (1990): Comparison of two serpentine species with different nickel tolerance strategies. Plant and Soil 122: 271-277.

John, M. K., & Laerhoven, C. Van (1972): Lead uptake by lettuce and oats as affected by lime, nitrogen and sources of lead. J. Environ. Qual. 1: 169-171.

Jones, Jr., J. B. (1995): Determining total sulphur in plant tissue using the HACH kit Spectrophotometer technique. Sulphur in Agrc. 19: 58-62.

Khan, S. & Khan, N. N. (1983): Influence of lead and cadmium on the growth and nutrient concentration of tomato *(Lycopersicum esculentum)* and egg plant *(Solanum melongena)*. Plant and Soil 74: 387-394.

Lagerwerff, J. V. (1971): Uptakes of cadmium lead and zinc by radish from soil and air. Soil Sci. 111: 129-133.

Miller, J. E., Hassett, J. J. & Koeppe, D. E. (1975): The effect of lead sorption capacity on the uptake of lead by corn. Commun. Soil Sci. Plant Anal., 6: 349-358.

Powell, M. J., Davies, M. S. & Francis, D. (1986): The influence of Zinc on cell cycle in root meristem of a zinc tolerant and non-tolerant cultivar of *Festuca rubra* L. New Phytol. 102: 419-428.

Rappaport, B. D., Martens, D. C., Reneau, R. B. & Simpson, T. W. (1988): Metal availability in sludge-amended soils with elevated metal levels. J. Environ. Qual. 17: 42-47.

Rolfe, G. L. (1973): Lead uptake by selected tree seedlings. J. Environ. Qual. 2: 153-157.

Schnug, E. (1990): Sulphur nutrition and quality of vegetables. Sulphur in Agrc 14: 3-7.

Walker, W. M., Miller, J. E. & Hassett, J. J. (1977): Effect of lead and cadmium upon the calcium, magnesium, potassium, and phosphorus concentration in young corn plants. Soil Sci. 124: 14515