Chromium-Zinc Interaction in Accumulation of Minerals by Bush Beans

HEIDI A. SCHMITT and CONNIE M. WEAVER
Foods and Nutrition Department
Purdue University, West Lafayette, Indiana 47907

Introduction

Zinc is necessary for human metabolism. It is a necessary trace element in plants for the synthesis of tryptophan and anxin and also functions in metaloenzyme systems. Chromium has been implicated as being necessary for efficient carbohydrate metabolism and has been shown to be effective in treating other dietry related diseases. Chromium is not considered to be an essential element for plants, but no study has been able to completely eliminate the element from the plant. Huffman and Allaway (4) attempted to eliminate chromium from plants (romaine lettuce, tomato, wheat, and bush bean) by growing successive generations in "chromium-free" solution ($3.8x10^{-4}$ μM Cr) and reduced the chromium levels to an average of 22 ng Cr/g dry wt. Chromium may be necessary in very minute quantities, and it has been shown that small quantities of chromium in the nutrient solution enhance growth of avacodo and citrus plants compared to a "chromium-free" solution (2).

Hahn and Evans (3) reported an antagonism between zinc and chromium in the absorption of these metals by rats. A chromium and zinc interaction in accumulation of these minerals in plants has not been reported. In this work, bush beans were choosen as a model for investigation of a possible chromium-zinc interaction.

Methods

Bush beans (*Phaseolus vulgaris* L. 'Blue Lake') were germinated in a circulating hydroponic system using BR-8 cellulose grow blocks as supports. Seven days after germination each group of 15 plants was exposed to a nutrient solution (1) containing the following: $2.2x10^5$ cpm ^{51}Cr/liter, $8.8x10^5$ cpm ^{65}Zn/liter, or both nuclides dosed at the same concentration as in the single labeled solutions. All solutions contained 1.5 ppm stable Zn and no added stable chromium. In the radioactive solutions, $2.2x10^5$ cpm^{51} Cr/liter represents less than $3x10^{-2}$ ppb and $8.8x10^5$ cpm ^{65}Zn/liter represents less than 1.02 ppb.

The beans were harvested at maturity (2 months after germination), washed with deionized water, and chopped to a very fine mesh in a food processor. Samples (approx. 9g. wet wt.) were taken from each group and dried in a vacuum over at 70°C for 12 hours. Samples were then counted using a Harshaw 3″ x 3″ NaI(T1) integral line detector. Overlapping of the energy spectrum of chromium and zinc in the dual-labeled plants was accounted for by solving simultaneous equations. Counts were adjusted for fluctuations in counting efficiency and for decay occuring after harvest.

Results and Discussion

Accumulation of ^{51} Cr by bush beans in the presence and absence of ^{65}Zn is shown in Figure 1. Bush beans exposed only to radioactive chromium contained 303 ± 17 cpm/g dry wt. which was 76.9% of the count rate (398 ± 20 cpm ^{51}Cr/g dry wt.) accumulated by the dual-labeled plants.

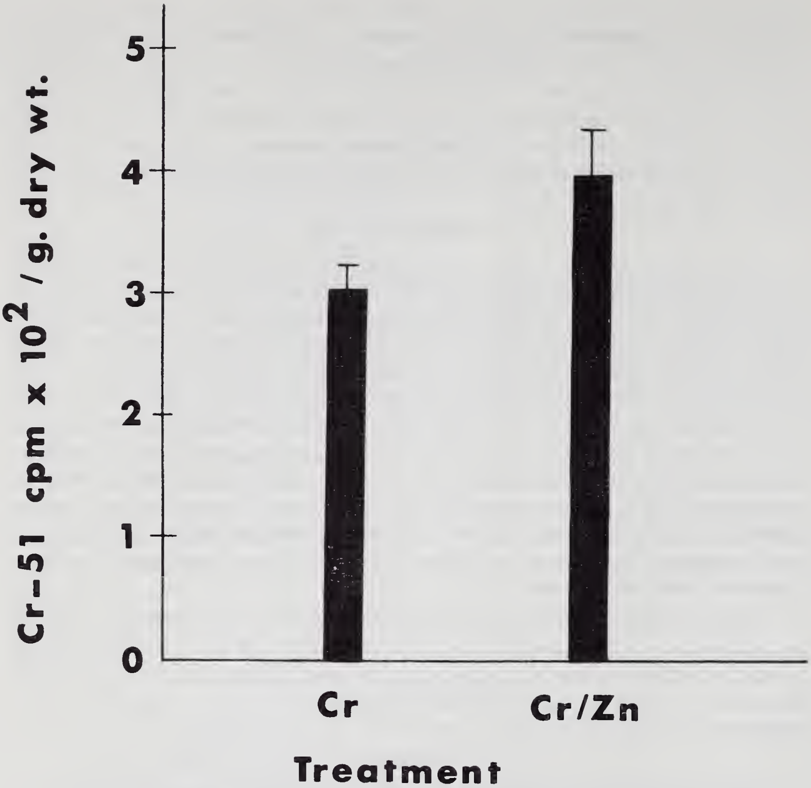

FIGURE 1. *^{51}Cr accumulation in the absence and presence of ^{65}Zn in bush beans.*

The influence of ^{51}Cr in the nutrient solution on accumulation of ^{65}Zn by bush beans is shown in Figure 2. Beans exposed to radioactive zinc alone accumulated 8025 ± 90 cpm ^{65}Zn/g dry wt. while those grown in nutrient solutions containing both radionuclides accumulated 1358 ± 37 cpm ^{65}Zn/g dry wt. This represents an accumulation by dual-labeled plants of only 16.9% as much ^{65}Zn as single-labeled plants.

These results show that the accumulation of chromium by plants is somewhat increased by zinc, the accumulation of zinc is greatly suppressed by chromium at least for the levels used in this study. Two possible explanations of these observations can be offered. Competition between chromium and zinc at the site of uptake of these elements or for translocation into the bean may exist. This explanation is unlikely since the presence of radioactive zinc did not suppress the uptake of radioactive chromium. Alternatively, the level of chromium used in this study may have been toxic to the uptake or translocation mechanisms for zinc which could influence zinc accumulation by the plants. Toxicity due to chromium has been noted at levels of >1.0 ppm in soybeans (8) and these authors suggested that chromium may exert its toxic effects on the roots. Zinc is known to be readily translocated in plants and its concentration in the shoots varies linearly with the

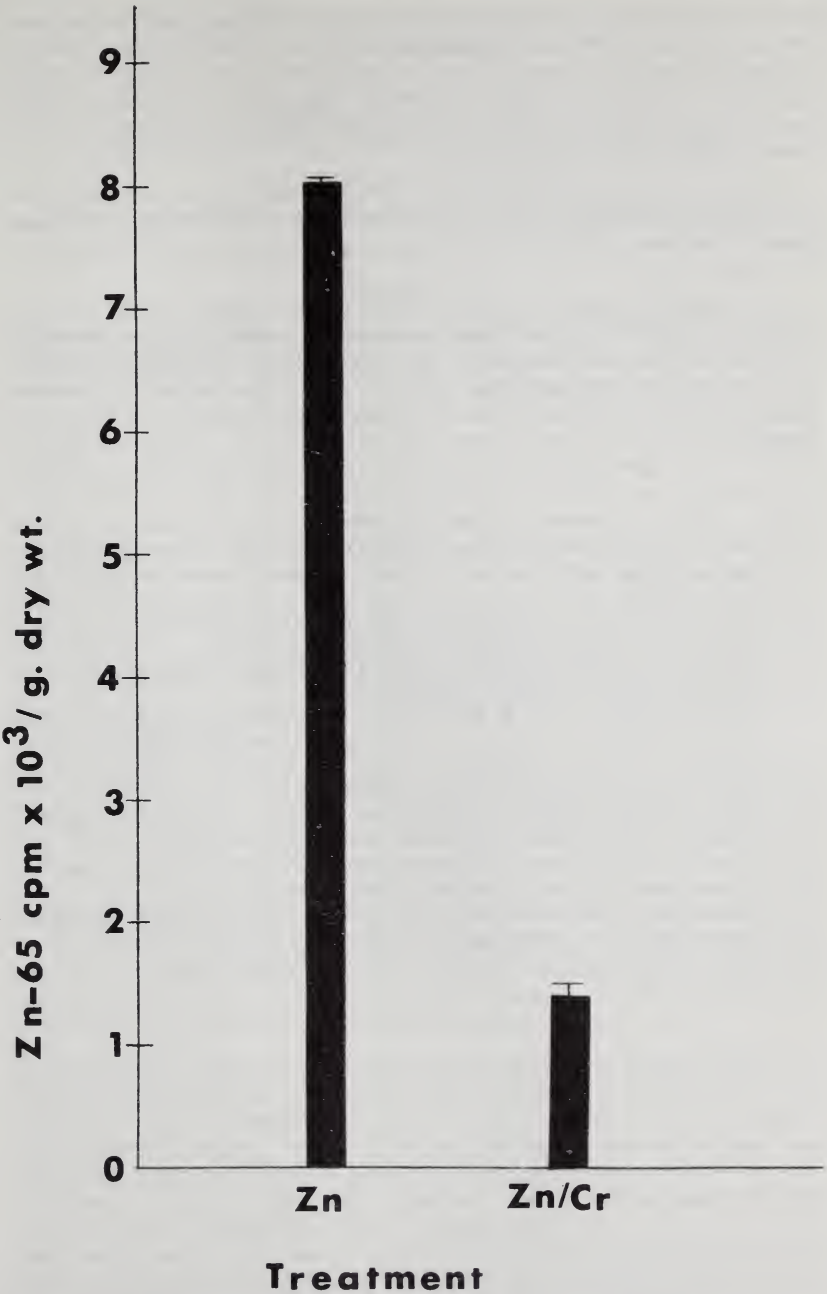

FIGURE 2. *^{65}Zn accumulation in the absence and presence of ^{51}Cr in bush beans.*

dose (9), chromium is poorly translocated and most chromium resides in the roots. An increase in the chromium concentration in the nutrient solution does not necessarily mean an increase in chromium concentration in the plant (7). Others have shown the beneficial effects of chromium to be within a very narrow concentration range (2) which may vary with the concentration of other macrominerals in plants (6) and between plant species.

Plants treated with ^{51}Cr showed a decreased yield. The plants also exhibited signs of early senescence and wilting and browning of roots compared to plants grown in the absence of ^{51}Cr. Similar symptoms have been noted in chromium toxicity studies (5).

Although the yields were not recorded in this experiment, as part of another study in which bush bean plants were exposed to ^{65}Zn and to the dual label of ^{65}Zn and ^{51}Cr, the yield was calculated for three plants from each treatment. The bean yield from the dual-labeled plants was only 41% of the yield of single-labeled plants. A similar suppression of zinc accumulation by chromium was observed in these plants.

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