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Iron toxicity in leafy spurge (*Euphorbia esula* L.)

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Many heavy metals are toxic to plants, but iron is usually regarded as having little direct effect on plants. Most problems with iron occur in acid soils and are related to changes in soil pH. In calcareous soils, commonly found in much of Montana, most of the iron is precipitated and unavailable to plants.

During the course of growing *Euphorbia esula* in the greenhouse as food for a biological control insect, the plants developed chlorosis, which led us to suspect iron deficiency. When chelated iron was applied to the plants in an attempt to alleviate the chlorosis, all plants that received the application either died or were severely injured within two weeks. As a consequence, a study was initiated to test whether *Euphorbia esula* was sensitive to iron.

Euphorbia esula was grown in sand culture with four treatments employed: 1) Control - a standard Hoagland's nutrient solution, 2) Fe-EDTA - a Hoagland's solution with 100 times the normal iron in the chelated form, 3) $FeCl_3$ - a Hoagland's solution with 100 times the normal iron in the form of iron chloride, and 4) EDTA - a Hoagland's solution with the normal level of iron but 100 times the level of chelating agent (the EDTA). For each treatment, 50 root crowns were planted in 4-inch square pots filled with sand and placed in a 10 by 15 by 1 dm galvanized tray on the greenhouse bench. Each pot was numbered and each tray was randomly assigned to a treatment. Trays and pots within trays were systematically rotated weekly to reduce variance due to location. Watering was applied thrice weekly by pouring 20 liters of nutrient solution into each tray and letting the pots stand in the solution for 4-6 hours after which time the solution was drained from each tray. The height of each plant was recorded weekly.

High levels of iron in either the chloride or chelated form significantly depressed growth within 21 days ($P < 0.01$). Fe-EDTA reduced growth greater than $FeCl_3$, but not significantly ($P > 0.50$). This may have resulted from some precipitation of iron in the $FeCl_3$ treatment, effectively reducing the dosage received. In both treatments, bronzing (typical of iron toxicity) was abundantly evident, particularly in the older leaves. Plants in the Fe-EDTA treatment also had a very pale yellow chlorosis that was most pronounced in the youngest leaves and diminished with leaf age. Inflorescences were not produced in either iron treatment.

The EDTA treatment was included to eliminate the possibility that the chelating agent was the cause of the necrosis and death of *E. esula* plants we originally observed. EDTA did indeed reduce growth, but took longer to show an effect (28-31 days). EDTA treated plants had the pale yellow chlorosis observed in the Fe-EDTA treatment, but had no bronzing.

The results demonstrated that *E. esula* was indeed sensitive to the concentration of available iron. A second experiment was conducted to determine a general threshold level of iron that would elicit major injury and/or death to *E. esula*. The experimental design was as before, except that the four treatments were: 1) 1X - Control - a standard Hoagland's nutrient solution, 2) 3X Fe - Hoagland's solution with 10 times the normal iron in the unchelated form ($FeCl_3$), 3) 10X Fe - Hoagland's solution with 10 times the normal iron in the unchelated form, 4) 100X Fe - Hoagland's solution with 10 times the normal iron in the unchelated form. The height of the tallest plant in each pot and any evidence of plant injury were recorded weekly. Six categories were recognized as evidence of injury to plants: death, general chlorosis, chlorosis of apical leaves, leaf bronzing, leaf drop, and leaf curling.

High levels of iron (10X and 100X) significantly depressed growth within 21 days ($P < 0.01$), and in the case of the 100X treatment, arrested growth within 14 days. However the 3X treatment actually stimulated growth as compared to the control treatment.

Death of root crowns did not occur in either the control or the 3X treatment, occurred rarely in the 10X treatment, and in more than half the pots in the 100X treatment. The control plants rarely had generalized chlorosis or leaf abscission, occasionally had leaf bronzing or leaf curling, and a few times had apical leaf chlorosis. In the 3X treatment, apical leaf chlorosis and leaf bronzing occurred more often than in the controls, but there was less leaf curling and no leaf abscission. In the 10X treatment leaf curling was uncommon, general and apical chlorosis occurred frequently, and leaf bronzing and abscission occurred in more than half the pots. In the 100X treatment apical leaf chlorosis was impossible to assess because leaf abscission was so prevalent that only apical leaves were present on the plant. The leaves that remained were generally chlorotic and had bronzing as well. Leaf curling was rare.

Since a single root crown has several stems that arise from separate crown buds, in those pots that had live plants we also counted the total number of stems that had grown from the root crown and the number of living stems at the end of the seven-week experiment. The total number of stems that were initiated by root crowns were not significantly different for any treatment, although the two lower iron concentrations had more stems than the two higher iron treatments. Only in the high iron treatment was the number of live stems significantly lower.

A third experiment was conducted to determine the effect of these same concentrations of iron on range grasses. The experimental design was as in the previous experiment, except that ten pots each of five grass species were grown in the four iron concentrations. The five grasses were *Agrogyron smithii* Rydb., *A. spicatum* (Pursh) Scibn. & Smith, *Bromus inermis* L., *Festuca idahoensis* Elmer, and *Poa pratensis* L.

The pattern of grass growth in the same iron concentrations was similar to *E. esula*, except that the growth reduction (as compared to the control) in the 10X treatment was proportionally less than for *E. esula* in all five grasses. All grasses in the 100X treatment died within five weeks.

Injury symptoms for grasses were not evident in the control or 3X treatments. Occasional bronzing and chlorosis of leaf tips occurred in the 10X treatment although grasses in most pots appeared quite healthy looking. *P. pratensis* had more injury symptoms than any of the other grasses.

The results demonstrate that *E. esula* is indeed sensitive to the dosage of available iron. Low levels of iron may even increase the growth of *E. esula*. Grasses seem less sensitive to iron at medium concentrations, and in particular grasses grown in the 10X treatment appeared to be less damaged than did *E. esula*. This presents the possibility that application of iron in the field may significantly stress *E. esula* while at the same time allowing significant grass growth.