Potential of Managing Iron and Zinc Deficiency in Dry Beans With Interplantings of Annual Ryegrass

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Abstract
Beans (Phaseolus spp. L.) are extensively grown throughout the western Great Plains. However, high pH soils prevalent in this region limit the availability of many micronutrients, especially iron and zinc. Iron deficiency in high pH soils results in interveinal chlorosis in beans, and a higher susceptibility to insect and disease damage thereby sacrificing yield and quality. A Wyoming farmer observed that dry beans grown with an intercrop of annual ryegrass (Lolium perenne L. sp., multiflorum (Lam.) Huds.) did not exhibit any iron-deficiency chlorosis and produced better than beans grown without the ryegrass intercrop. We conducted field studies in Goshen County, Wyoming in 2006 to test the hypothesis that an annual ryegrass intercrop may result in increased iron availability in a pinto bean field. Treatments included beans planted in annual ryegrass intercropped in the soil, bean-animal-ray intercropped, and beans planted alone as a control. There was significantly higher soil iron and zinc availability in the bean-animal-ray intercropping compared to beans alone. Iron concentration in bean leaves declined in all treatments but at a lower rate in the bean-animal ray intercropping and bean-animal-ray intercropping when compared to the control, though this difference was not significant.

Introduction
Over the last five years, the value of dry beans in Wyoming has averaged $127,900/mmt, making it the fourth most valuable crop in the state after hay, sugarbeets, and barley. Nationally, Wyoming ranks fourth in Pinto bean production (USDAA NSAS, 2006). Micronutrient availability can be a critical limitation on bean production and health (Joneo and Jacobson, 2003). In Wyoming, pH, low organic matter, and calcareous soils limit the availability of many micronutrients, especially iron (Stevens and Belden, 2005). Iron deficiency under these conditions is not a result of absolute iron deficiency in the soil but rather low iron availability (Moore and Gunatilaka, 1986). Conventional management of iron deficiency in beans is achieved by multiple foliar applications of 1% iron solution applied at 20-30 gallons per acre, or intraspecific applications of more expensive iron chelates at approximately half the rate of iron sulfate (Stevens and Belden, 2005). A non-chemical cultural practice that may help alleviate iron deficiency for organic and commercial bean producers and would also provide a more sustainable and potentially more affordable solution for conventional and organic farmers. Studies have shown that some grasses have the ability to extract micronutrients from the soil through exudates of phytochelator (Mzala et al., 1998) and have been extensively studied in maize (Szafran et al.), wheat (Triticum aestivum L.), barley (Hordeum vulgare L.), and oats (Avena sativa L.) (Singh et al., 2005). Annual ryegrass has not been reported in the literature as a known phytochelator-releasing plant. We hypothesize that phytochelator-releasing iron chelate introduced to the soil by annual ryegrass may explain the observation that dry beans grown with an intercrop of annual ryegrass did not exhibit iron-deficiency chlorosis and yielded better than beans grown without the ryegrass intercrop. The objectives of the study was therefore to determine the effectiveness of intercropping annual ryegrass with pinto beans in mitigating iron deficiency in calcareous soils.

Materials and Methods
We established a field experiment at Mike and Cindy Ridenour’s farm in Goshen County, WY at 47°55′N, 108°23′W and an elevation of 1300 ft. The selected field had not been previously plowed with annual ryegrass. Field preparation and planting was done between May and June 2006.

Results and Discussion
1. Beans on plots in which annual ryegrass failed to germinate and had interveinal chlorosis (Fig. 1A) recovered one month after re-seeding and establishment of ryegrass (Fig. 1B).
2. ANOVA of the Fe availability showed no significant differences between the three treatments. The results however showed a general trend in favor of bean-ryegrass intercrop (Fig. 2).
3. Soil organic matter (SOM) in the treatments with ryegrass were significantly higher than the control plots (p=0.05). This suggests that the organic matter can be increased by addition of organic matter to the soil to improve the availability of iron and zinc for the plants in the soil (Fig. 3).
4. The pLH of the control plots was marginally higher (p=0.05) than the other treatments suggesting that the higher S0M in the ryegrass plots may have helped to slightly reduce the pH on those plots (Table 1). However, there was no significant correlation between soil Fe and soil Zn with SOM.
5. There was a significant negative correlation between pH and the concentration of Fe and Zn in the soil suggesting that as the soil pH decreased, Fe and Zn availability (r=0.65, p=0.001).
6. A two-group T-TEST procedure to compare the intercropped plots with the control treatment showed that soil Fe and Zn in the bean-annual ryegrass intercropped treatment was significantly higher (p=0.063) than in the control (Table 2). These results suggest that intercropping annual ryegrass with beans has the potential to increase deficient micronutrients in the soil.

Conclusions
1. Strong negative correlation between pH and the concentration of Fe and Zn in the soil suggest that something else, other than the increased organic matter in the intercropped plots contributed toward increased iron and zinc availability. There is therefore a need to investigate the possibility of that mechanism since the increased organic matter in the intercropped plots may play an increasing micronutrient availability in the soil.

References

Table 1: Effect of treatments; beans-only, beans-ryegrass intercrop, and beans-annual ryegrass incorporated on soil organic matter and pH.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Organic Matter (%)</th>
<th>pH</th>
</tr>
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<tbody>
<tr>
<td>Bean-annual ryegrass Intercropped</td>
<td>5.88a</td>
<td>7.08a</td>
</tr>
<tr>
<td>Bean-annual ryegrass Inoculated</td>
<td>8.88b</td>
<td>7.56b</td>
</tr>
<tr>
<td>Beans Only</td>
<td>4.43c</td>
<td>7.47c</td>
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Means within a column followed by the same letter are not significantly different (p=0.05).

Table 2: A two-group T-TEST procedure to compare the intercropped plots with the control treatment showed that there was significantly higher (p=0.05) higher soil Fe and Zn availability in the bean-annual ryegrass incorporated compared to the control.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean Soil Fe ppm</th>
<th>Mean Soil Zn ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bean-annual ryegrass Intercropped</td>
<td>4.10</td>
<td>5.07</td>
</tr>
<tr>
<td>Beans Only</td>
<td>4.32</td>
<td>4.32</td>
</tr>
</tbody>
</table>

Means within a column followed by the same letter are not significantly different (p=0.05).

Figure 1A: Bean-animal-ryegrass plots on July 17, 2006 before annual ryegrass germination. The ryegrass on this plot failed to germinate and had to be re-seeded.

Figure 1B: The same bean-animal-ryegrass plot on August 24, 2006 after ryegrass germination.

Figure 2: Effect of three treatments on soil available iron over time. Iron availability increased for all treatments with the greatest increase in pinto-animal ryegrass companion planting.

Figure 3: Effect of three treatments on soil available zinc over time. The results showed a trend in favor of bean-animal-ryegrass intercrop with regard to zinc availability in the soil.

Figure 4: Effect of three treatments on the concentration of Fe in the tissues over time. A similar trend as Table 3 was observed in the Fe concentration in bean leaves, where there was a more step-decline over time in the control treatment compared to these plots with annual ryegrass.

Figure 5: The effect of these treatments on soil organic matter. Soil organic matter was significantly higher in the bean-ryegrass intercrop than in the other treatments.