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 reducing yield and quality. A Wyoming farmer observed that dry beans grown with an intercrop of annual ryegrass (*Lolium perenne* L. ssp. *multiflorum* (Lam.) Husnot) 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 rye intercrop may result in increased iron availability in a pinto bean field. Treatments included beans planted in annual rye residue incorporated in the soil, bean-annual rye intercrop, and beans planted alone as a control. There was significantly higher soil iron and zinc availability in the bean-annual rye intercrop compared to beans alone. Iron concentration in bean leaves declined in all treatments but at a lower rate in the bean-annual rye intercrop and beans-annual rye residue 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 $12,700,000 making it the fourth most valuable crop in the state after hay, sugarbeets, and barley. Nationally, Wyoming ranks fourth in Pinto bean production (USDA NASS, 2006). Micronutrient availability can be a critical limitation on bean production and health (Jones and Jacobsen, 2003). In Wyoming, high 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 of low iron availability (Mengel and Geurtzen, 1986). Conventional management of iron deficiency in beans is achieved by multiple foliar applications of 1% iron sulfate solution applied at 20-30 gallons per acre, or similar applications of the more expensive iron chelates at approximately half the rate of iron sulfate (Stevens and Belden, 2005). A non-chemical cultural practice would therefore be a welcome alternative for organic and natural bean producers and would also provide a more sustainable and potentially more affordable solution for conventional bean growers. Studies have shown that some grasses have the ability to extract micronutrients from the soil through exudates of phytosiderophores. This mechanism has been extensively studied in maize (*Zea mays* L.), 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 phytosiderophore releasing plant. We hypothesize that phytosiderophore-derived 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 objective 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 42°05′ N, 104°23′ W and an elevation of 1,390m asl. The selected field had not been previously planted with annual ryegrass. Field preparation and planting was done between May and June 2006.

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

Materials and Methods cont.

The study consisted of 0.6 x 6 meter plots in a randomized complete block design with six replications. Treatments included 1)'Nodak' pinto beans planted with 'Gulf' annual ryegrass residue incorporated in the soil; 2) 'Nodak' pinto beans intercropped with 'Gulf' annual ryegrass; and 3) Monoculture of 'Nodak' pinto beans as the control treatment. Pinto bean planted into incorporated annual ryegrass residue was included to determine if the same effect as intercropping would be observed. This would be convenient for machine harvesting as rapid growth and establishment of annual ryegrass could make it difficult to machine harvest beans. Irrigation was provided by means of drip tape and weeding was performed manually.

Bean leaf and soil samples were randomly collected from each plot for tissue analysis at plant establishment, mid-season, and maturity. In each case, 2 to 3 of the youngest fully matured leaves were collected from an average of 15 plants per plot, in accordance with Hue et al. (2000). Leaf samples were oven-dried, finely ground, and analyzed for Fe, Zn, Mo, P, Mn, and Cu. Soil samples were air dried, ground and sieved through a 2-mm screen in accordance with Hue et al. (2000) and tested for P, K, pH, Organic Matter, Fe, Zn, Mn, Cu, Mo, and EC. Beans were harvested by hand, air-dried, threshed, winnowed and weighed between August 7 and October 28, 2006, and yield data recorded.

Analysis of variance (ANOVA) of the Fe and Zn availability was done using the MIXED and GLM procedures in SAS (SAS Institute, 1999-2000). Treatment differences determined using Fisher's protected LSD (α= 0.10). A two-group TTEST procedure in SAS (SAS Institute, 1999-2000) done without the bean-ryegrass incorporated treatment (included in this study for machine harvesting convenience).

Results and Discussion

1. Beans on one plot 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, and 4).

3. Soil organic matter (SOM) in the treatments with ryegrass was significantly higher than the control plots (α=0.10; p=0.086) suggesting that the extensive rooting system of the annual ryegrass may have contributed to higher below ground biomass (Fig. 5).

4. The pH of the control plots was marginally higher (α=0.10; p=0.01) than the other treatments suggesting that the higher SOM 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 increased (r^2 = 0.65, p<0.0001).

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 = 0.0631) than in the control (Table 2).

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

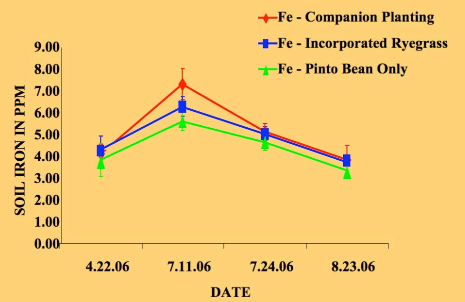

Figure 2: Effect of three treatments on soil available iron over time. Iron availability increased for all treatments with the greatest increase in pinto-annual ryegrass companion planting.

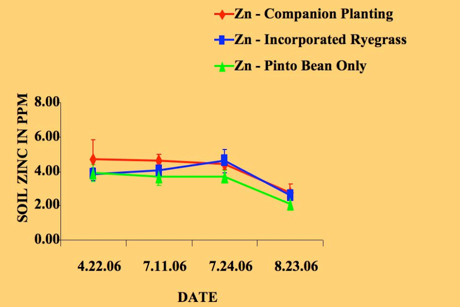

Figure 3: Effect of three treatments on soil available zinc over time. The results showed a general trend in favor of bean-annual ryegrass intercrop with regard to zinc availability in the soil.

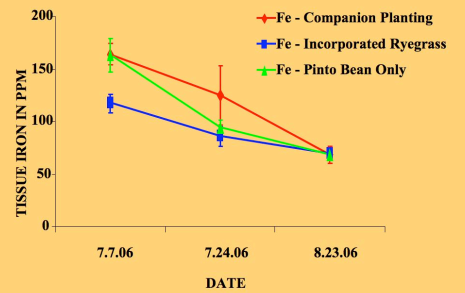

Figure 4: Effect of three treatments on the concentration of Fe in the tissues over time. A similar trend as Table 3 was observed in the Fe concentration in bean leaves, where there was a more steep decline over time in the control treatment compared to those plots with annual ryegrass.

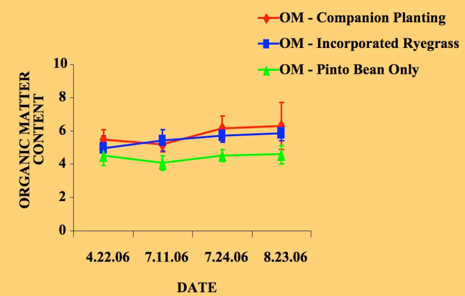

Figure 5: The effect of three treatments on soil organic matter. Soil organic matter was significantly higher in the bean-ryegrass intercrop than in the other treatments

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

Treatment	Organic Matter (%)	pH
Bean-annual ryegrass Intercropped	5.80a	7.68a
Bean-annual ryegrass Incorporated	5.49ab	7.56ab
Beans Only	4.43b	7.47b
	LSD 1.278 (p = 0.086)	LSD 0.196 (p = 0.01)

Means within a column followed by the same letter are not significantly different (α=0.10)

Table 2: A two-group T-TEST procedure to compare the intercropped plots with the control treatment showed that there was significantly (α=0.10) higher soil Fe and Zn availability in the bean-annual ryegrass intercrop compared to the control.

Treatment	Mean Soil Zn (ppm)	Mean Soil Fe (ppm)
Bean-annual ryegrass Intercropped	4.10	5.07
Beans Only	4.32	4.33
Alpha = 0.10	(p = 0.0631)	(p = 0.015)

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 further the possibility that root exudates from annual ryegrass may play in increasing micronutrient availability in the soil.

2. These results suggest that intercropping annual ryegrass with beans has the potential to increase deficient micronutrients in the soil

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