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Leaf Chlorosis and Seed Yield of Dry Beans Grown on High-pH Calcareous Soil following Foliar Iron Sprays

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Abstract. Iron deficiency chlorosis (FeDC) causes extensive reduction in yields of edible dry beans (Phaseolus vulgaris L.) grown on high-pH calcareous soils. Fifteen bean cultivars/lines differing in response to FeDC were grown 2 years (1988 and 1989) on a high-pH (8.0), calcareous (2.3% calcium carbonate equivalent in surface 20 cm), and low-Fe (2.2 mg Fe/kg) Typic Haplustolls silt loam in the field (central Nebraska) to determine the effects of FeDC on seed yield of cultivars/lines sprayed with Fe. A significant interaction (P < 0.05) between cultivars/lines × Fe spray treatment was noted for visual FeDC ratings in 1988 only, and no significant interactions were noted for seed yield either year. Sprayed cultivars/lines generally produced higher yields than unsprayed ones. Overall increases were 47% in 1988 and 41% in 1989. Even though only slight FeDC was noted on some cultivars/lines receiving no Fe spray, seed yields were significantly increased when sprayed with Fe. Some cultivars/lines with moderate or moderately severe FeDC ratings did not show a significant increase in yield when sprayed with Fe, while other cultivars/lines did. Seed yield reductions for the cultivars/lines per unit of FeDC rating (1 = green to 5 = severe chlorosis) were 915 kg·ha−1 for unsprayed and 1518 kg·ha−1 for sprayed plants in 1988 and 344 kg·ha−1 for unsprayed and 608 kg·ha−1 for sprayed plants in 1989.

Iron deficiency chlorosis (FeDC) is a major constraint for production of many crops, such as edible dry beans, when grown on high-pH calcareous soils of the Great Plains (Clark, 1982; Coyne et al., 1973). Seed yield losses in bean cultivars/lines would likely occur due to this disorder, but these have not been documented. Soybean [Glycine max (L.) Merr.] and sorghum [Sorghum bicolor (L.) Moench] are sensitive to FeDC when grown on calcareous soils. Soybean seed yields decreased by 20% per unit of visual leaf FeDC rating (1 = no chlorosis to 5 = severe chlorosis) (Froehlich and Fehr, 1981) and by 740 to 940 kg·ha−1 per unit of visual leaf FeDC rating (1 = no chlorosis to 5 = severe chlorosis and 6 = dead plants) (Kinkaid, 1986). Grain yield losses of sorghum varied with year, site, source and timing of foliar spray or soil amendment, and genotype (Clark et al., 1990). Yield losses occurred when visual leaf FeDC ratings in sorghum were between slight and moderate (Clark et al., 1988; Williams et al., 1986). Predicted yield losses were 1090 kg·ha−1 per unit of visual FeDC rating (Clark et al., 1988). The objectives of our study were to determine: 1) yield losses due to Fe deficiency as expressed by visual leaf FeDC symptoms in edible dry bean cultivars/lines grown on a high-pH calcareous soil and 2) the effects of Fe spray on cultivar/line seed yields grown on the same soil.

Fifteen bean cultivars/lines (Table 1) with different responses to FeDC (Zaiter et al., 1987; H.Z. Zaiter and D.P. Coyne, 1984-87, personal observations) were grown 2 years (1988 and 1989) on a high-pH calcareous C oral soil loam (saline and alkaline, very slightly, mixed, mesic Typic Haplustolls) located near North Platte in central Nebraska. No fertilizer was applied to the plots in either year. The chemical properties of the soils were: pH 8.0 (1 : soil : water) ; 1.9% organic matter; 2.2% calcium carbonate equivalent in surface 20 cm; 35.2 Ca, 5.7 Mg, 3.5 K, and 0.86 Na in cmol (+) grams soil; 1.4 dS·m−1 electrical conductivity; and 222 nitrate, 32.6 P (extracted with 0.50 m sodium bicarbonate; pH 8.5). 5.0 Mn, 2.2 Zn, 2.2 Fe, 1.1 Zn, and 0.22 Cu [Mn, Fe, Zn, and Cu were extracted with 0.005 M diethylenetriaminediacetate (DTPA)] in milligrams per kilogram of soil.

Seeds of each cultivar were planted on 27 May 1988 and 24 May 1989 in 3-m-long single rows, 0.6 m between rows, and three to four plants per 0.3 m of row. The experiment was conducted as a split-plot. The whole-plot treatments were Fe sprayed and not sprayed, arranged in a complete block (six replications in 1988 and four in 1989). The split-plot treatments were cultivars/lines. Plots were sprayed to runoff with a hand-held sprayer three times each year 29 June, 14 July, and 1 Aug. in 1988 and 29 June, 18 July, and 15 Aug. in 1989) with Fe at 0.5 kg·ha−1 + FeEDDHA: [Fe(III)ethylendiaminedi(2-hydroxyphenyl)acetate, “Sequestrene-138 Fe”]; CIBA-Geigy, Greensboro, N.C.] with Tween-80 added as a surfactant (Trifluoroethyl-N,N,N-diethyl-4-(trifluoromethyl)benzenamine] at 1.2 liters·ha−1 was soil-incorporated before planting each year for weed control. Plots were irrigated by furrow about every 10 days throughout the growing season.

Visual leaf FeDC ratings were rated each year, before the first (second trifoliate leaves fully expanded) and second (flowering and late vegetative stage) Fe spray treatments applied. On a scale where 1 = normal green leaves, 2 = trace of FeDC symptoms on an occasional leaf, 3 = moderate FeDC symptoms on several leaves, 4 = moderately severe FeDC symptoms on most leaves, and 5 = severe FeDC symptoms on all leaves. The FeDC scores each year were combined to give one mean for the cultivars/lines per treatment each year since the FeDC ratings appeared similar. Seed yields (13% moisture) were determined after harvest.

Data were tested using a split-plot analysis of variance (Milkilen and Johnson, 1984). Calculations were performed using the SAS-General Linear Model procedures as the calculating tool (SAS Institute, 1989).

A significant interaction (P < 0.05) between cultivars/lines and Fe spray treatment was noted for visual FeDC ratings in 1988 only, and no significant interactions for these
Table 1. Visual leaf FeDC ratings and seed yields (estimated uncertainty ±5 kg) of dry bean cultivars/lines grown on high-pH calcareous soil.

<table>
<thead>
<tr>
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<tr>
<td>1</td>
<td>WMI-83-10</td>
<td>2.2</td>
<td>1.4</td>
<td>1.1</td>
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<td>3607</td>
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<td>2</td>
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<td>2.2</td>
<td>1.2</td>
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<td>2596</td>
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<td>3</td>
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</tr>
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<td>4</td>
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<td>1.9</td>
<td>3.2</td>
<td>1.7</td>
<td>2175</td>
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<td>3438</td>
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<td>1.2</td>
<td>2.6</td>
<td>1.2</td>
<td>1741</td>
<td>2559</td>
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<td>2.0</td>
<td>2.3</td>
<td>1.4</td>
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<td>2416</td>
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<td>10</td>
<td>White Kidney</td>
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<td>2252</td>
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<td>11</td>
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<td>2.5</td>
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FeDC (chlorosis) ratings were 1 = normal green leaves, 2 = trace of FeDC symptoms on an occasional leaf, 3 = moderate FeDC symptoms on several leaves, 4 = moderately severe FeDC symptoms on most leaves, and 5 = severe FeDC symptoms on all leaves. The FeDC ratings were compared with the LSD-2 for the spray treatment means within or between cultivars/lines. The FeDC ratings were compared with the LSD-2 for the spray treatment means within or between cultivars/lines. The FeDC ratings were compared with the LSD-2 for the spray treatment means within or between cultivars/lines.

Fig. 1. Linear regressions of seed yield on visual leaf FeDC ratings (1 = normal green leaves, 2 = trace of FeDC symptoms on an occasional leaf, 3 = moderate FeDC symptoms on several leaves, 4 = moderately severe FeDC symptoms on most leaves, and 5 = severe FeDC symptoms on all leaves) of unsprayed (US) and sprayed (S) dry bean cultivars/lines grown on high-pH calcareous soil in 1988. Linear regression equations and R² values were: US = 4431 - 915x with R² = 0.83 for unsprayed; and y = 4850 - 1518x with R² = 0.60 for sprayed cultivars/lines.
Fig. 2. Linear regressions of seed yield on visual leaf FeDC ratings (1 = normal green leaves, 2 = trace of FeDC symptoms on an occasional leaf, 3 = moderate FeDC symptoms on several leaves, 4 = moderately severe FeDC symptoms on most leaves, and 5 = severe FeDC symptoms on all leaves) of unsprayed (US) and sprayed (S) dry bean cultivars/lines grown on high-pH calcareous soil in 1989. Linear regression equations and $R^2$ values were: $y = 2015 - 344x$ with $R^2 = 0.41$ for unsprayed; and $y = 2637 - 608x$ with $R^2 = 0.56$ for sprayed cultivars/lines.

D.P. Coyne and D.S. Nuland, 1983-89, unpublished data. Even though these sensitive cultivars/lines responded to the Fe spray with reduced visual leaf FeDC symptoms, they still did not produce economic seed yields, perhaps because the soils used in this study induced such severe abiotic stresses on these unadapted cultivars/lines that they could not be alleviated, even with Fe sprays.

Seed yield and visual leaf FeDC ratings were negatively related (Figs. 1 and 2). Decreases in seed yield per unit of visual leaf FeDC rating were 915 kg·ha$^{-1}$ in 1988 and 344 kg·ha$^{-1}$ in 1989 for unsprayed cultivars/lines and 1518 kg·ha$^{-1}$ in 1988 and 608 kg·ha$^{-1}$ in 1989 for sprayed cultivars/lines. Decreases in seed yield were larger for sprayed than for unsprayed cultivars/lines per unit of visual leaf FeDC rating. The decreases in seed yield most likely were larger for sprayed compared to unsprayed cultivars/lines because Fe-sprayed plants had higher yields than unsprayed plants and ranges of visual leaf FeDC ratings for sprayed plants were narrower than for unsprayed plants.

These results clearly indicate that considerable losses in seed yield of edible dry bean cultivars/lines can occur when plants are grown on high-pH calcareous soils that induce visual FeDC symptoms on leaves. Spraying with Fe could produce improved economic seed yields in some cultivars/lines when grown on these kind of soils. Additional field trials should be conducted slightly less severe soil conditions to determine the value of Fe sprays on these cultivars/lines.

Literature Cited


