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Field and Greenhouse Screening of Oat Seedlings for Iron Chlorosis

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Summary

Susceptible oat (*Avena sativa* L.) genotypes may express iron-deficiency chlorosis when grown on calcareous soils. Known resistant ('Coker 227') and susceptible ('TAM O-312') cultivars were compared with 28 cultivars and breeding lines of oat in greenhouse and field plots. The soil used for both field and greenhouse studies was a Parrita sandy clay loam with pH near 8.0. Field plots were irrigated three times per week, while greenhouse seedlings were maintained in saturated soils after the 1.5- to 2-leaf stage. Chlorosis scores were related to shoot height and shoot mass ($P < 0.001$), but the correlation coefficients were low ($r = 0.27$ and 0.17, respectively). Half of each field plot was defoliated periodically with a mower. Defoliation tended to enhance the chlorosis expression and improve the correlation between greenhouse and field chlorosis scores. Correlations between greenhouse chlorosis scores and several chlorosis scores taken over a 3-month period in the field ranged from 0.38 to 0.71. The best correlation ($r = 0.71$) was between greenhouse chlorosis scores taken after 7 days of water saturation and the field chlorosis score taken about 10 days after the first field defoliation treatment.

Introduction

Oats are primarily used in South Texas for grazing. Much of the soil in this semiarid area is calcareous, and iron (Fe)-deficiency chlorosis is common (Anderson, 1982). Enhanced chlorosis is often observed in oat forage tests following clipping. Defoliation has also been shown to enhance expression of chlorosis in soybean (*Glycine max* (L.) Merr.) (Piper et al., 1986). Several studies attempted to distinguish Fe-efficient and Fe-inefficient lines, and some progress has been recorded. The oat cultivar Coker 227 has been classified as Fe-efficient, while TAM O-312 is considered Fe-inefficient (McDaniel and Dunphy, 1978; Brown and McDaniel, 1978; Olsen and Brown, 1980; McDaniel and Brown, 1982). McDaniel and Brown (1982) reviewed the literature on iron chlorosis in oat and listed the relative susceptibility of 10 cultivars. Fehr (1984) suggested that producers and scientists alike should be aware of the relative Fe-deficiency chlorosis susceptibility of alternative cultivars (genotypes) of crops. Currently, there is no published list for oat, except the short list given by McDaniel and Brown (1982).

In a recent review, Marschner et al. (1986) characterized grasses as "Strategy II" plants. Strategy II plants are characterized by an Fe-deficiency-induced enhancement of release of phytosiderophores (non-proteinogenic amino acids), which sparingly mobilize soluble inorganic Fe-III compounds by complexation of Fe-III and formation of Fe phytosiderophores. Fe-inefficient TAM O-312 and Fe-efficient Coker 227 oat differ in their release of phytosiderophores in response to iron-deficiency stress. Coker 227 releases a phytosiderophore, whereas TAM O-312 does not (Jolley and Brown, 1989). These researchers also observed that Coker 227 may be able to take up Fe-III in chelated form, while TAM O-312 could not, and they suggested that Coker 227 may have a complementary system of Fe uptake.

A rapid, simple soil-based screening system for use in classifying oat cultivars and breeding lines has eluded researchers. Gildersleeve and Ocumpaugh (1989a,b) developed a soil-based greenhouse procedure to characterize clover (*Trifolium* spp.) seedlings for relative susceptibility to Fe-deficiency chlorosis. Individual clover seedlings were grown in Super-Cell Cone-tainers® filled with calcareous soils. Bowen and Rodgers (1987) also used Cone-tainers® for screening sorghum (*Sorghum bicolor* (L) Moench). Our objective was to determine whether Fe-deficiency chlorosis could be quantified with oat seedlings grown in calcareous soil in the greenhouse and whether it could be related to chlorosis expression on the same cultivars grown on a similar calcareous soil in the field.

Procedures

Seed of 30 genotypes (19 cultivars and 11 breeding lines) were assembled (Table 1). The soil in both the greenhouse and field was a Parrita sandy clay loam (clayey, mixed, hyperthermic, shallow Petrocalcic Paleustoll); the greenhouse soil was taken from a site within a few yards of the field planting. The soil test results for the two soils are given in Table 2.

Keywords: *Avena sativa* L. / calcareous soils.

Table 1. Mean chlorosis score taken on three dates in the greenhouse and other data on February 26, 1991, from greenhouse-grown oat seedling.

Line	Mean chlorosis score			Height	Root length	Root score	Shoot weight	Root weight	Shoot-to-root ratio
	Feb. 7	Feb. 15	Feb. 25						
				..... inches			..... g		
Mesquite II	1.43†	2.00	2.64	9	15	5.86‡	0.152	0.139	1.11
Blizzard	1.71	1.79	2.29	9	18	4.93	0.123	0.115	1.09
TAM O-301	1.64	2.14	2.86	9	17	5.86	0.142	0.157	0.91
TAM O-312	2.00	3.79	4.00	11	13	4.07	0.129	0.143	1.03
Nora	1.29	1.93	2.50	10	17	5.14	0.137	0.138	1.02
Bob	1.50	1.93	2.36	10	14	5.14	0.128	0.139	0.96
Cimmarron	1.64	2.00	2.57	9	19	5.50	0.129	0.141	0.93
Okay	1.93	1.93	2.43	10	16	4.71	0.112	0.105	1.11
TAMO 386	2.36	3.00	3.21	10	17	5.57	0.147	0.151	1.01
FLA 501	2.00	2.50	3.00	10	19	5.14	0.147	0.162	0.94
Coronado	1.57	2.50	3.00	10	19	4.79	0.124	0.136	0.96
Ozark	1.71	2.00	3.00	8	16	4.86	0.112	0.136	0.86
H833	1.29	2.07	2.93	9	15	4.86	0.127	0.148	0.94
Mesquite	2.07	2.50	3.43	9	18	5.21	0.123	0.148	0.87
Big Mac	1.36	2.43	2.57	7	17	6.00	0.134	0.147	0.93
Coker 227	1.50	2.00	2.36	9	20	6.00	0.140	0.149	0.98
Coker 234	1.93	2.57	2.93	9	14	4.93	0.123	0.124	1.03
H422	1.50	2.07	3.00	8	15	4.79	0.126	0.124	1.04
TX89B1847	2.14	2.93	3.50	9	22	5.93	0.121	0.146	0.83
TX87B748	2.14	3.07	3.36	9	17	4.86	0.138	0.129	1.07
TX87M1521	1.79	2.07	2.93	9	18	5.07	0.140	0.138	1.03
TX89B1590	2.29	2.71	3.14	10	18	4.93	0.130	0.129	1.05
TX83AB2923	2.00	2.21	2.57	9	22	5.36	0.126	0.130	0.98
TX82M4964	2.07	2.79	3.93	10	18	3.50	0.138	0.130	1.12
TX82M4350	1.86	2.29	2.93	9	13	3.50	0.108	0.101	1.07
TX89B1755	2.00	2.93	3.50	10	20	5.43	0.128	0.157	0.86
Coker 87-11	1.21	1.43	1.79	7	12	4.21	0.088	0.095	0.94
TX86B336	1.36	1.57	2.21	9	13	5.14	0.118	0.130	0.94
TX86B1117	1.79	2.14	2.57	8	13	5.50	0.128	0.134	0.99
TX86B1207	2.00	2.43	2.79	9	18	5.21	0.118	0.131	0.93
Mean	1.77	2.32	2.88	9	17	5.07	0.128	0.136	0.98
LSD (0.05)	0.31	0.36	0.35	1	2	0.63	0.015	0.024	0.16

†Chlorosis score: 1 = green, 5 = severe chlorosis.
‡Root score = root fibrousness: 1 = poor, 9 = very fibrous.

Table 2. Analysis of Parrita sandy clay loam soil used for greenhouse and field study.

	Greenhouse pH 8.2	Field pH 8.4
Element	..... ppm	
Nitrogen	15	3
Phosphorus	114	89
Potassium	209	163
Calcium	12,586	11,547
Magnesium	282	276
Zinc	0.81	0.41
Iron	3.02	10.38
Manganese	3.13	3.47
Copper	0.13	0.19

For the greenhouse study, one seed of each oat genotype was placed in each of 21 Super-Cell Cone-tainers®. After emergence, seven uniform seedlings were selected for each of two replications. Seedlings were at the 1.5- to 2-leaf stage when the racks of Cone-tainers® were placed into tubs of distilled water to induce a saturated soil condition. The specifics of this Cone-tainer® procedure were published by Gildersleeve and Ocumpaugh (1989a). Chlorosis scores were taken (on a scale of 1 to 5; 1 = green, 5 = severe chlorosis) on February 7, 15, and 25 following saturation. On February 26, all seedling were washed free of soil, and root and shoot length were determined. In addition, a root fibrousness score (1 = poor, 9 = very fibrous) was assigned to each seedling. Roots were then separated from the shoots and both were dried. Oven-dry weights were determined individually for each

seedling. Shoot-to-root dry-weight ratios were calculated.

The field study was seeded in single-row plots with rows spaced 25 in. apart. Field plots were replicated four times in a randomized block design. Plots were seeded January 28, 1991, and were irrigated two or three times per week from February 11 to April 5 unless sufficient rainfall occurred. Irrigation was imposed in an attempt to enhance the expression of Fe-deficiency chlorosis. Chlorosis scores were taken on February 14 and 28; March 11, 19, and 28; and April 2 and 9. After the February 28 chlorosis scoring, half of each plot was clipped to 3-in. stubble to further enhance chlorosis expression. This treatment was repeated at about 2-week intervals. Chlorosis ratings in March and April were taken separately for the clipped and non-clipped portion of each plot.

The General Linear Models and Means procedure of PC-SAS (SAS Institute, 1985) were used to determine genotype effects in both greenhouse and field data. Coefficients of correlations were calculated with data from all individual seedlings in the greenhouse and all chlorosis scores in the field. Coefficients of correlation between field and greenhouse chlorosis scores for various dates were calculated on the basis of mean values. The Pearson correlation procedure of PC-SAS was used for all correlations.

Results and Discussions

Genotypes differed in the greenhouse for all traits measured (Table 1). Mean chlorosis scores increased with length of soil saturation time from 1.77 on February 7 to 2.88 on February 25. Extended shoot growth averaged 9 in., and root length averaged 17 in. Oat seedling shoot dry matter weight and root weight both averaged 0.13 g, but genotypes ranged in shoot-to-root ratios from 0.83 to 1.12. Root fibrousness score averaged about 5 but ranged from 2 to 7 for individual seedlings, and genotype means ranged from 3.5 to 6.0. TAM O-312 and two experimental lines had the poorest root scores.

When correlations were calculated among all the traits in the greenhouse, a number of correlations were significant, but r-values were generally low. The best correlation in the greenhouse was between chlorosis scores taken on February 7 and February 15 (r = 0.67).

Chlorosis scores were taken on seven separate dates from February 14 until April 9 in the field; the last five dates included a score for clipped and unclipped portion of each plot. Clipping increased the overall mean chlorosis score by 0.3 to 0.7 units. Coefficients of correlation between chlorosis scores taken on different successive dates without clipping ranged from 0.12 (March 19 vs. March 28) to 0.72 (February 28 vs. March 11). Correlations generally were higher when clipped plots were compared on successive dates (range of r = 0.45 to 0.57).

When coefficients of correlation were calculated between means of greenhouse and field chlorosis scores, r-values generally were higher for clipped field plots than for non-clipped field plots. The best correlation (r = 0.71) was between the February 15 greenhouse scores and the March 11 field scores on clipped plots (Table 3). The March 11 field chlorosis score on clipped plots had the highest mean value (3.05) of all scores taken in the field. However, the February 15 scores were not the highest observed chlorosis ratings in the greenhouse. Correlations between the February 15 greenhouse chlorosis scores and all field chlorosis scores taken between February 28 and April 2 exceeded r = 0.61 and exceeded r = 0.51 for all field dates. When scores taken on other dates in the greenhouse are compared with field chlorosis scores, the r-values generally are lower and range from r = 0.38 to r = 0.65.

When genotypes were ranked according to the February 15 greenhouse chlorosis scores, 'Nora', 'Cimmarron', and 'Mesquite II' were green in the greenhouse but chlorotic in the field (Table 4). Notable reversals that were chlorotic in the greenhouse but green in the field were 'FLA 501', 'Coronado', and 'Big Mac'.

Table 3. Pearson correlation coefficient between 3 chlorosis scores taken in the greenhouse and 12 chlorosis scores taken on 7 dates in the field.

Field chlorosis score date	Greenhouse chlorosis score date		
	Feb. 7	Feb. 15	Feb. 25
	r-value		
Feb. 14	0.43*	0.51	0.57
Feb. 28	0.46	0.61	0.56
Mar. 11	0.50	0.68	0.62
Mar. 11 (c)†	0.50	0.71	0.64
Mar. 19	0.54	0.64	0.55
Mar. 19 (c)	0.61	0.65	0.65
Mar. 28	0.55	0.68	0.58
Mar. 28 (c)	0.60	0.67	0.60
Apr. 2	0.42	0.62	0.47
Apr. 2 (c)	0.50	0.63	0.56
Apr. 9	0.38	0.53	0.40
Apr. 9 (c)	0.49	0.55	0.41

*All correlation coefficients significant, $P < 0.05$; all coefficients > 0.55 are significant at $P < 0.001$.

†(c) = Score taken on portion of plot clipped to 3-in. stubble height to enhance chlorosis expression.

Table 4. Rank of mean chlorosis scores for 30 oat genotypes on 2 dates in the greenhouse and 4 dates in the field. Field scores were from the portion of each plot that was defoliated.

Line	Greenhouse		Field			
	Feb. 15	Feb. 25	Mar. 11	Mar. 19	Mar. 28	Apr. 2
	Chlorosis ranking†					
Coker 87-11	1	1	1	5	1	2
TX86B336	2	2	7	17	6	14
Blizzard	3	2	7	23	11	14
Bob	4	4	7	9	6	11
Nora	4	6	18	9	16	19
Okay	4	5	4	23	19	19
Cimmarron	7	7	22	13	11	8
Coker 227	7	4	7	5	3	8
Mesquite II	7	12	7	17	25	24
Ozark	7	19	2	3	4	2
H422	10	19	3	5	4	1
H833	10	15	7	9	11	2
TX87M1521	10	15	4	17	16	11
TAM O-301	13	14	7	1	1	2
TX86B1117	13	7	22	9	6	19
TX83AB2923	16	7	4	13	16	2
TX82M4350	17	15	7	17	22	19
Big Mac	18	7	7	2	6	11
TX86B1207	18	13	7	28	25	24
Coronado	20	19	18	3	6	8
FLA 501	20	19	27	5	11	2
Mesquite	20	26	22	13	19	14
Coker 234	23	15	7	17	11	14
TX89B1590	24	23	22	17	22	27
TX82M4964	25	29	27	27	22	29
TX89B1755	25	27	18	28	29	24
TX89B1847	25	27	27	13	25	14
TAMO 386	28	24	18	23	19	19
TX87B748	29	25	22	23	28	27
TAM O-312	30	30	30	30	29	30

† Chlorosis ranking is from most green (number 1) to most chlorotic (number 30). Oat lines with the same chlorosis score were given the same rank.

This study indicates that Fe-deficiency chlorosis of oat seedlings in the greenhouse after about 7 days of growth in water-saturated calcareous soil relates well to field-grown oat. The greenhouse system is simple and can be done with a minimum amount of seed, soil, greenhouse space, and labor.

The root fibrousness scores seemed to be well related to chlorosis expression in some genotypes (highly fibrous root = green seedlings), but over all genotypes the relationship does not hold. This suggests that the type of root system may be one mechanism or trait oat breeders need to be aware of when developing oat cultivars for use in calcareous soils.

Although determining which system is the most correct in ranking Fe-efficient and Fe-inefficient genotypes is difficult, this greenhouse system appears to have merit. This system consistently ranked the Fe-inefficient genotypes such as TAM O-312 and 'TAMO 386' and a number of experimental lines as being chlorosis susceptible (Fe-inefficient).

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