Journal of the Minnesota Academy of Science

Volume 43 | Number 3 Article 2

1977

Response of Setaria faberii to High Lime Soils

Nancy Huang
University of Minnesota

Russell S. Adams Jr.
University of Minnesota

Response of Setaria Faberii to High Lime Soils

NANCY HUANG,* R.S.ADAMS, JR.**

ABSTRACT - *Setaria faberii* (giant foxtail) was observed to grow poorly in some calcareous soils or upon the addition of calcium carbonate to some acid soils. The data suggest that liming might be a feasible and practical tool in the control of this major weed pest.

EDITOR'S NOTE: Figures 2, 3, and 4 relating to this paper appear on the cover of this issue of the *Journal* of the Minnesota Academy of Science.

Setaria faberii Herrm. (giant foxtail) is known as one of the most prevalent weed problems in cultivated field crops in the central United States (Santlemann et al. 1963). One *S. faberii* plant per foot of row has been shown to reduce yields of maize (*Zea mays L.)* by 7 to 10% (Meggitt, 1970).

In spite of its relative importance little is known about the physiology of giant foxtail. In its early stages of growth it is not competitive for light, moisture or nutrients (Schreiber and Williams, 1967). Dry weight production decreases linearly with increases in shade intensity (Knake, 1972; Santelmann et al. 1963). Reduction in maize yields by giant foxtail occurs early in the season. Any factor that reduces giant foxtail growth early in the season will increase the competitive advantage of the cultivated crop.

In unreported work of the second author *S. faberii had* been observed to be less vigorous and productive in the field with high lime treatments. This study was initiated in the greenhouse to evaluate that phenomenon. Retarded growth of the giant foxtail by lime might be due to increased growth and competition by the maize or some physiological or metabolic effect.

Liming of acid soils is known to increase the yield of maize and other crops (Fisher, 1969; Pearson and Adams, 1967). Corbin *et al.* (1971) noted that liming up to a pH of 6.5 appeared to enhance the phytotoxicity of herbicides. Thorup (1969) proposed that where reduced growth or yields are observed with liming the effect may be due to curtailed water uptake by the plant. Meyer and Anderson (1956) suggested that the hydrogen ion concentration in soil might directly affect enzyme activators or inhibitors. Trace element availability may also be influenced by soil pH.

This study was initiated to determine the growth of *S. faberii* in several different soils types and in acid soils receiving calcium carbonate treatments. Attempts were made to examine the mechanisms of these responses.

For this study 14 Minnesota soils were selected from the collection described by Pluth *et al.* (1970). These soils varied widely in several properties. Pertinent soil data are given in Table 1.

*NANCY HUANG, a junior scientist in the Soil Science Department at the University of Minnesota when this paper was presented, received the B.S. degree from Boston University and M.S. from Lehigh University, both in biology.

**RUSSELL S. ADAMS, Jr., is a professor of Soil Science at the University of Minnesota. He holds degrees in soil science and soil chemistry from Kansas State University and the Ph.D. in Soil Biochemistry from the University of Illinois.

Procedure in the greenhouse

In the initial screen 400 g of air dry soil were placed in 1.06 liter wax coated cardboard containers and then 40 *S. faberii* seeds were planted one cm deep. The seeds were pretreated for 3 minutes with 2.5 percent perchlorate bleach just prior to planting. Pots were watered daily to approximately field capacity. Seedlings were thinned to 20 plants after two weeks. After five to six weeks the plants were harvested at the soil surface, oven dried at 50° C, weighed, and the plant material saved for further analyses. Treatments were prepared in duplicate and the experiment was conducted twice. In one set, the treatments were grown in the greenhouse with natural lighting and in the other with supplemental lighting. In the latter case the treatments received natural daylight supplemented with fluorescent lighting for a 16 hour day. The intensity varied between 350 to 700 quantum microeinsteins m^{-2}/sec. Temperatures in the greenhouse varied between 25 and 28°C.

Six soils were selected for the liming experiments. They were Blue Earth sil, Brainerd fsl, Lester fsl, Milaca fsl, Ontanagon c, Svea sil. These soils were modified by adding 0.5, 1.0, 2.0 or 4.0 percent Reagent Grade calcium carbonate powder by weight. The modified soils were tumbled on an end over end shaker for 15 minutes to increase mixing. As above, 400 g of air-dried soil were weighed into wax coated cardboard containers. Treatments were planted in duplicate. The soil was brought to approximately field capacity and incubated at 25° C for 10 days to allow equilibration of the lime with the soil. Planting, watering and harvesting were conducted as above. For emission spectrograph analysis 1 g of dry plant materials were ashed in a muffle furnace at 550° C for 8 hours. The ash was dissolved in 10 ml 0.5% $LiCL_2$and 1.5% HC1 solution and analyzed by emission spectrography using a Jarrell-Ash Model 66-000.

In a similar experiment the lower limits of $CaCO_3$ effectiveness was determined by mixing with soil as above $CaCO_3$ at rates of 0, 0.1, 0.25, and one percent by weight. Procedures followed those above, except that plants were

harvested after four weeks and Nicollet 1 and Zimmerman fs were substituted for Blue Earth sil and Brianerd fsl.

After treatments containing $CaCO_3$ were harvested soils were analyzed to determine soil pH, 1/3 and 15 bar moisture and rate of water loss according to procedures described by Pluth, *et. al.* (1970).

Living *S. faberii* plants were carefully extracted from the control Fayette sil treatment, the roots thoroughly washed and the plants transferred to, and grown in, Erlenmeyer flasks in full Hoaglund's solution (Hoaglund and Arnon, 1938) buffered from 3 to 10 pH in unit increments using 1N HC1 or 1 N KOH. The plants were grown for two weeks. The Hoaglund's solution which was continuously aerated was changed after one week, its pH being adjusted every second day. The roots were examined under microscope.

Prediction equation developed

Data from the screening of several Minnesota soils are shown in Figure 1 and statistical analysis in Table 2. While soil pH had a significant effect on the growth of *S. faberii*, the variability was high and a contribution from other factors was apparent. A linear regression equation using pH and 1/3 bar moisture accounted for only 30 percent of the variability. As other properties were introduced into the equation 1/3 bar moisture became less significant as indicated by the partial correlation coefficient.

The best fit prediction equation was determined to be as follows:

$DW_c = 12.001 - 2.957\ pH + .195\ pH^2 - .013\ Fe + .001\ FexpH$

where DW_c = estimated dry weight of *S. faberii*

pH = soil pH

Fe = acid (0.1N HCL) extractable iron

N = 47

$R^2 = 0.663$

Calculated F = 21.185

Standard error of estimate = 0.279

All partial correlation coefficients included in the equation were significant at the 5% level.

Precisely what is measured by acid extractable iron is not known. Presumably it represents in part colloidal and amorphous iron serving as cementing materials in the soil matrix or associated with soil organic matter. Statistically it is related to sand and silt contents, exchangeable calcium, potassium, and sodium, and moisture capacities.

Because of their lack of independence these soil properties give no clear indication of the mechanism of the response. Differences in these properties cannot be considered as causing the growth differences of *S. faberii;* only that they are predictive of the response.

Data from the experiments studying the influence of the addition of $CaCO_3$ are given in Figures 2 and 3. Figure 4

Table 1. Pertinent properties of soils used in this study.

Soil Type	Subgroup Classification	Organic Carbon %	Carbonate Carbon %	Clay %	pH	1/3 Bar moisture capacity %	Cation exchange capacity meq/100g	Acid extractable iron ppm	Acid extractable aluminum ppm
Blue Earth sil	Cumulic Haplaquolls	11.0	2.2	34.5	7.7	62.5	36.4	4	⩽30
Brainerd fsl	Aquic Fragiochrepts	2.6	0	12.4	5.4	23.7	15.2	70	275
Canisteo l	Typic Haplaquolls	7.3	1.0	30.4	7.8	37.3	43.5	8	⩽30
Fayette sil	Typic Hapludalfs	2.3	0	17.0	5.4	28.7	15.1	65	280
Hegne sic	Typic Calciaquolls	4.3	1.7	46.3	8.0	42.9	37.8	8	⩽30
Hubbard ls	Udic Haplaborolls	1.2	0	6.8	5.8	8.9	6.4	155	190
Kranzburg sicl	Udic Haplaborolls	2.9	0	32.1	6.6	17.9	26.8	185	338
Lester fsl	Mollic Hapludalfs	2.3	0	13.7	6.3	17.7	16.4	14	170
Milaca fsl	Typic Fragiochrepts	1.7	0	6.8	5.7	16.8	6.2	32	160
Nicollet l	Aquic Hapludolls	2.8	0	21.9	6.0	24.1	20.4	206	250
Ontonagon c	Typic Eutroboralfs	3.5	0	59.4	5.2	36.3	40.2	130	540
Svea sil	Pachic Udic Haploborolls	3.1	0	26.6	6.6	33.1	23.1	8	100
Ulen Vfsl	Aquic Haploborolls	2.9	1.2	12.4	8.3	15.1	11.7	194	⩽30
Zimmerman fs	Alfic Udipsamments	0.7	0	3.1	5.5	5.5	3.8	195	120

Table 2. Simple correlation coefficient relating *S. faberii* growth to soil properties.

	Organic Carbon	Clay	pH	Moisture 1/3 bar	Cation Exchange Capacity	Acid Extractable Iron	Acid Extractable Aluminum	Sand	Coarse Silt	Exchangeable Calcium	Dry Weight
Organic Carbon	1.00										
Clay	0.561	1.000									
pH	0.663	0.215	1.000								
Moisture 15 bar	0.946	0.759	0.551	1.000							
Cation Exchange Capacity	0.776	0.903	0.439	0.896	1.000						
Acid Extractable Iron	-0.549	-0.251	-0.251	-0.573	-0.437	1.000					
Acid Extractable Aluminum	-0.391	-0.357	-0.717	-0.205	0.068	0.364	1.000				
Sand	-0.549	-0.808	-0.144	-0.747	-0.757	0.427	-0.296	1.000			
Coarse Silt	0.152	0.179	-0.007	0.272	0.181	-0.320	0.125	-0.709	1.000		
Exchangeable Calcium	0.927	0.450	0.849	0.851	0.707	-0.495	-0.536	-0.451	0.159	1.000	
Moisture 1/3 bar	0.912	0.715	0.441	0.962	0.815	-0.653	-0.161	-0.758	0.333	0.792	0.339
Medium Fine[3] Silt	0.606	0.678	0.113	0.758	0.672	-0.534	0.198	0.957	0.731	0.481	0.379
Dry Weight *S. faberii*	0.126	0.169	-0.292	0.187	0.245	-0.559	0.235	-0.356	0.383	0.044	1.000

r = 0.282 significant at the 5% level; r = 0.365 significant at the 1% level.

shows the response of *S. faberii* to Ontonagon c. Adding large quantities of calcium carbonate to acid soils significantly reduced the growth of giant foxtail. At levels of $CaCO_3$ normally applied in the field to modify soil acidity significant reduction in giant foxtail growth was also obtained. Table 3 shows soil pH at the conclusion of the latter experiment and plant heights at two time periods as compared to the untreated check. As early as two weeks after seeding slight retardations in plant heights could be observed. According to Knake and Slife (1969) as soon as corn or soybeans are tall enough to produce shade, competition from giant foxtail is substantially reduced. Thus, any delay in development in the early stages of growth due to liming would give the crop a more competitive advantage.

However, the responses obtained in this study may not be a direct effect of the addition of $CaCO_3$. This treatment with the Blue Earth sil, a calcareous lacustrine soil, resulted in improved *S. faberii* growth. Furthermore, giant foxtail appeared to do well on some calcareous soils in the initial screen. The strong correlation between growth and acid extractable iron in the first experiment suggest that the response may be due to an effect on iron availability.

Efforts to identify other factors that might be affected by liming and provide a mechanism for growth retardation were inconclusive. No obvious effects of the $CaCO_3$ were observed on 1/3 or 15 bar moisture retention by the treated soils. The rate of evaporation of water from the soil also was unaffected by the $CaCO_3$. These data are not reported. Other than an increase in uptake of calcium the $CaCO_3$ did not appear to significantly affect mineral nutrition. There was some evidence of borderline zinc deficiency, but these differences were neither consistent nor significant. There was no consistent response of iron uptake with treatment.

However, when *S. faberii* plants were transferred to Hoaglund's solution buffered over a range of pH, differences in treatment did occur. After two weeks in Hoaglund's solution marked differences in growth occurred. Plants grown at pH 3 and pH 4 advanced to maturity, setting seeds. The roots of the giant foxtail in these treatments were turgid with well developed primary and secondary systems. Plants in pH 6, 7, 8, 9, and 10 treatments showed little development and flower heads did not form. A general browning and discoloration of the roots were observed.

Upon microscopic examination (Cover), roots from pH 3 and pH 4 treatments were clean and free from fungal and bacterial infection. Roots from the other treatments were heavily infected with fungi and bacteria. At this point one must question whether the *S. faberii* root growth was poor because the roots were infected by fungi and bacteria or whether the roots became infected because the plant was weak and susceptible. This aspect needs to be evaluated. Also, this study needs to be extended to the soil treatments to determine if root development is affected by the $CaCO_3$ treatments in soil. These observations were consistent with qualitative field observations. In the field giant foxtail appeared to be smaller and less mature in the high lime treatments.

Table 3. The effect of calcium carbonate addition.

$CaCO_3$ added %	Plant height % of control, after 2 wks	4 wks	Soil pH	Element in Plant Tissue % Ca	ppm Zn	ppm Fe
			Ontonagon c			
0			5.1a*	0.16 a	63 ab	107 a
0.1	98 a	92 ab	5.4 b	0.18 a	58 a	132 a
0.25	95 a	95 a	5.8 c	0.20 a	71 b	122 a
0.5	84 b	77 b	6.4 d	0.21 a	99 c	137 a
1.0	74 c	45 c	6.9 e	0.45 b	59 ab	164 a
			Milaca fsl			
0			6.3 a	0.40 a	81 a	141 a
0.1	99 a	104 a	6.4 a	0.44 a	91 a	133 a
0.25	75 c	97 b	7.0 b	0.47 a	93 a	146 a
0.5	73 c	92 bc	7.3 c	0.47 a	87 a	137 a
1.0	81 b	99 c	7.4 c	0.53 a	105 a	165 a
			Svea sil			
0	–	–	6.5 a	0.34 a	31 a	177 a
0.1	102 a	106 a	6.9 b	0.42 ab	37 a	138 a
0.25	82 b	94 a	7.4 c	0.50 b	32 a	126 a
0.5	79 b	94 a	7.5 d	0.54 b	32 a	130 a
1.0	85 b	76 a	7.5 d	0.56 b	30 a	177 a
			Zimmerman fs			
0	–	–	5.2 a	0.27 a	44 e	67 a
0.1	95 a	82 a	6.4 b	0.54 a	41 d	82 ab
0.25	83 b	71 ab	7.0 c	0.55 a	27 a	114 bc
0.5	75 bc	70 ab	7.2 d	0.57 a	28 b	110 bc
1.0	70 c	59 b	7.4 e	0.58 a	30 c	143 c
			Lestor fsl			
0	–	–	6.2 a	0.32 a	66 a	42 a
0.1	95 a	101 a	6.5 b	0.37 b	83 a	133 a
0.25	74 c	98 a	7.0 c	0.44 c	85 a	114 a
0.5	69 c	96 a	7.2 d	0.47 d	71 a	120 a
1	79 b	91 a	7.3 e	0.46 cd	93 a	121 a

* Within any one soil type, numbers followed by the same letter are not significantly different according to Bayes LSD test.

Negative response observed

There seems to be a significant, but inconsistent negative response of *S. faberii* to the addition of $CaCO_3$ to soils. This response appeared not to be a direct effect and may be due to an effect on the availability of some other nutrient. This response occurs at rates well within those normally used in soil acidity modification. and were effective with some acid soils. Consequently, the practice would be consistent with conventional systems of good soil management. The data suggests that liming could become an effective cultural tool in controlling a major weed pest, reducing the need for herbicide applications. Soil pH may also be a factor in restricting the spread of giant foxtail into western Minnesota. Efforts to determine the mechanism of this effect need further study.

REFERENCES

CORBIN, F.T., R. P. UPCHURCH and F. L. SELMAN. 1971. Influence of pH on the phytotoxicity. Weed Sci. 19.

FISHER, T.R. 1969. Crop yields in relation to soil pH. Missouri Agri. Sta. Res. Bull. No. 947, Columbia, Mo.

HOAGLUND, D.R. and D.E. ARNON. 1938. The water culture method of growing plants without soil. Rep. California Agric. Exptl. Sta. Ca. No. 347.

KNAKE, E.L. 1972. Effect of shade on Giant Foxtail. Weed Sci.20.

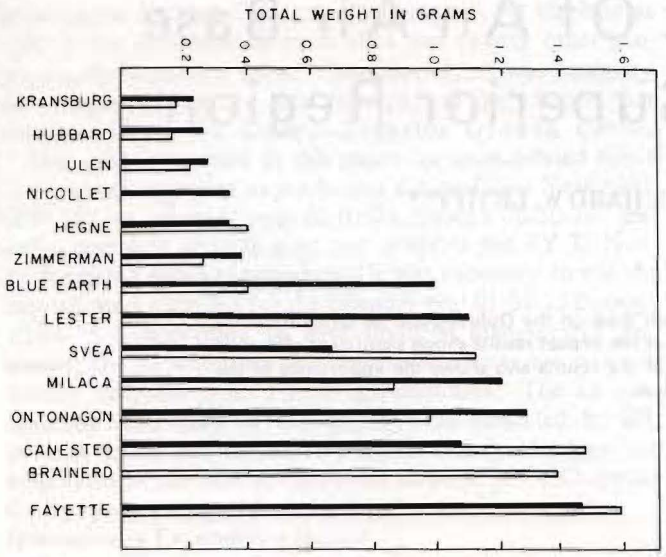

FIGURE 1. Dry matter production of *S. faberii* in two experiments, one (open bar), under natural lighting and two (solid bar), under supplemental lighting on 14 soil types. There were no significant differences due to time and/or lighting.

KNAKE, E.L., F. SLIFE. 1969. Effect of time of giant foxtail removal from corn and soybeans. Weed Sci. 17.

MEGGITT, W.F. 1970. Weed control methods. Proc., 1st FAO Int. Conf. on Weed Control. Univ. Cal., Davis, Weed Science Society of America.

MEYER, B.S. and D.B. ANDERSON. 1956. *Plant Physiology*. D. Van Norstrand Co. New Jersey.

PEARSON, R.W., F. ADAMS. 1967. Soil Acidity and Liming. R.C. Dinauer, Ed., American Society of Agronomy. Madison, Wisconsin.

PLUTH, D.J., R.S. ADAMS, Jr., R. H. RUST, and J.R. PETERSON. 1970. Characteristics of sixteen selected soil series in Minnesota. Minn. Agr. Exp. Sta. Tech. Bull. No. 272.

SANTELMANN, P.W., J.A. MEADE and R.A. PETERS. 1963. Growth and development of yellow foxtail and giant foxtail. Weed Sci. 11.

SCHREIBER, M.M. and J.L. Williams, Jr. 1967. Toxicity of root residues of grass species. Weed Sci. 15.

THORUP, J.T. 1969. pH effect on root growth and water uptake by plants. Agron. J. 61.