Survey of corn response to fertilizer sulfur in Missouri[1]

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Abstract

Fertilizer sulfur (S) rate studies were conducted during 1991 and 1992 at 53 sites located throughout Missouri on soils that were primarily silt loam or heavier. Sites were selected on the basis of a high yield potential since a common belief among farmers and fertilizer dealers is that the greater crop S requirement of high yields exceeds the S supply from the soil and incidental sources. Either ammonium sulfate or ammonium thiosulfate were applied at planting or within four weeks following planting at rates of 0, 15, 30 and 60 lb. S/acre. Grain yields exceeded 175 bu./acre in 29 of 47 site-years. Significant grain yield increases from fertilizer S were observed at three of 47 harvested sites, and significant decreases at five sites. Leaf S concentrations were increased by fertilizer S at 46% of the sites during early vegetative growth (V5-V8) and at 38% of the sites at anthesis. Grain S concentrations were significantly increased by fertilizer S at 20% of the sites. There were no apparent trends between relative yield and soil sulfate, leaf tissue S concentration, or site yield. Consequently, this research indicates that corn response to fertilizer S is infrequent and unpredictable on Missouri's silt loam or heavier textured soils.

Introduction

The sufficiency of S for today's high yielding corn crops in the Midwest is a concern often raised by farmers, and fertilizer dealers. The present concern is based on the belief that today's high yields require more S than is supplied by the soil and incidental sources. Although S is required in amounts similar to that of phosphorus, widespread crop S deficiencies have not been observed with only limited use of fertilizer S. This has been due to the supply of S through many incidental sources such as low analysis multi-nutrient fertilizers, S-containing pesticides, farmyard manure, irrigation water, and S emissions from burning high-S fossil fuels which are deposited in rainfall (Tisdale et al. 1986). Due to changing farming practices and pollution control measures, incidental S supply has decreased. A decrease in the S supply from incidental sources puts a greater demand on the soil to supply S to a crop. Greenhouse evaluations have shown many Midwestern

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soils to be inadequate in meeting a corn crop's S needs (Hanson et al., 1979; Hoeft et al., 1985).

Most documented S deficiencies of corn have been reported on coarse textured, low organic matter soils (Fox et al., 1964; Rabuffetti, and Kamprath, 1977; Hanson, 1979; Rehm, 1982; Reneau, 1983; O'Leary and Rehm, 1990). However, the present concern for new S deficiencies is primarily in regard to heavier textured soils. To date only a few crop responses to fertilizer S have been observed on heavier textured soils in the Midwest, and they are relatively recent (Lamond, 1990; O'Leary and Rehm, 1990). Also, few studies have examined a broad spectrum of soils across a large geographic area. In an Illinois field study conducted during the late 1970's, corn grain yield response to fertilizer S was observed at only 5 of 82 sites (Hoeft et al., 1985). More recently, with studies conducted on silt loam soils in Illinois, Sawyer and Ebelhar (1992) observed no grain yield increase of wheat with 30 lb. S/acre in six site-years during 1989-92.

The objective of this study was to survey corn response to fertilizer S on heavier-textured Missouri soils not previously considered S deficient.

Materials and Methods

During 1991 and 1992 fertilizer S rate studies were conducted at 53 sites (22 in 1991 and 31 in 1992), located throughout Missouri. When conducted on farmers' fields, studies were superimposed on farmers' normal farming operations. Twenty five soil series were represented. Most sites had topsoil textures that were silt loam or heavier. Soil samples (0 to 12 inches in 1991, and 0 to 18 inches in 1992 by six inch increments) were taken at or near planting time. Of the sites sampled, only one (B55) would have received a fertilizer S recommendation based on University of Missouri soil test recommendations (i.e. CEC less than 6.5 and sulfate less than 7.5 ppm). Cation exchange capacity varied from 5.9 to 21.3, and organic matter content varied from 0.8 to 4.2%. Twenty two sites were irrigated. Seven sites were farmed no-till.

Experiment design was a randomized complete block with six replications. Study treatments were fertilizer S applied at rates of 0, 15, 30 and 60 lb. S/acre. Plot size was 10 feet (four rows) by 40 feet. In 1991 ammonium sulfate (21-0-0-24S) was the S source at all sites except C43 and N45 in which ammonium thiosulfate (12-0-0-26S) was used. In 1992 the S source was ammonium sulfate. All ammonium sulfate treatments were hand broadcast. Ammonium thiosulfate treatments were knifed into the soil with urea ammonium nitrate solution (UAN) (32-0-0). All S applications were made between planting and the 4-5 leaf stage. Nitrogen supplied by the S source was balanced with either ammonium nitrate (34-0-0) or UAN.

Leaf samples were taken during vegetative growth (V5 to V8) and at anthesis, and were analyzed for S and N concentration. No vegetative samples were taken from sites in which the S was applied more than two weeks following planting. Grain samples were also analyzed for S and N concentration. Plots were harvested either by hand (40 feet of row) or by combine (68 feet of row).

The significance of any fertilizer S effect was determined by analysis of variance of all treatments, analysis of variance with pooled S rates, and regression of corn response to S rate. A significance level of $\alpha = 0.10$ was used for all analyses.

In order to compare treatment differences between sites on a relative basis, relative yields were calculated for each measured parameter by dividing the zero S treatment value by the mean value of the three S treatments.

Results

Grain Yield

Corn yields were well above the state average at most sites (Table 1), and generally represented the high yield-high S demand scenario for which a S fertilizer response might be expected. Of the 53 sites that were established, 47 were harvested for grain yield; 19 in 1991 and 28 in 1992. In 1991 eight sites had plot yields ≥ 175 bu./acre and four sites had yields ≥ 200 bu./acre. In 1992 grain yields were much above average, as 21 sites had yields ≥ 175 bu./acre and 10 sites had yields ≥ 200 bu./acre.

Significant yield differences between individual treatments were observed at six sites (indicated in Table 1 by a LSD value). Of those, only at site E36 was yield increased by fertilizer S (7 bu./acre with 60 lb. S/acre). Yield decreases were observed at two sites, N57 and E72. Site N57 had a coefficient of variation of 26.7% and is considered an outlier. At three other sites (S81, B92 and E68), the significant treatment differences were between individual S treatments.

The zero S treatment yield was greater than the average of the three S rates at three sites (B94, C65, and E78) and less at one site (C43). Site C43 is considered an outlier as it had a coefficient of variation of 22.6%.

Linear regression indicated a significant yield response from fertilizer S at two sites (N57 and B90). As indicated above, the yield response to fertilizer S at site N57 was negative. At site B90, a yield increase (17 bu./acre with 60 lb. S/acre) was observed.

Table 2. Grain yields averaged across sites for 1991 and 1992.

	Sulfur Rate (lb./acre)			
Year	0	15	30	60
	---------------------- bu./acre --------------------			
1991	159	160	160	158
1992	184	184	181	184
1991-92	174	174	172	174

The across-site average grain yields indicated no effect of fertilizer S. Treatment yields were essentially identical in both 1991 and 1992 (Table 2).

Relative yields were also averaged for the different geographic areas in the study (not shown) and they varied only from 0.98 to 1.00. Thus no particular geographic area appeared to be S deficient.

Even with the wide range of yields (94 to 234 bu./acre of the zero S treatment), there was no relationship between relative yield and site yield (Fig. 1). Therefore, the data do not support the premise that fertilizer S is needed with higher yields and subsequent greater S demand.

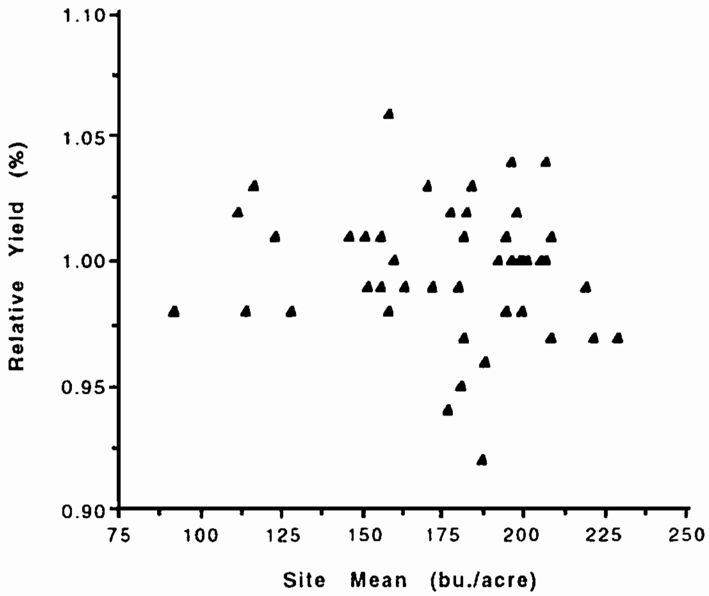

Figure 1. Relative yield vs. site mean

Tissue and Grain Sulfur Concentration

As a percentage of the sites sampled, significant increases in tissue S concentrations were observed most frequently with the vegetative (V6) sampling. Four of eight sites (50%) in 1991 and 9 of 20 sites (45%) in 1992 resulted in increased leaf S concentration due to fertilizer S. At anthesis three of 17 sites (18%) in 1991 and 15 of 31 sites (48%) in 1992 resulted in significantly increased leaf S. Reneau (1983) suggested a critical value of 0.17% for anthesis leaf S concentration. Ten sites had zero S treatment leaf S concentrations at or below 0.17%. Of these ten sites, the relative grain yield varied from 0.92 to 1.06 with four sites having a relative yield greater than 1.00 and four sites less than 1.00. Only two of 19 sites (11%) in 1991 and six of 22 sites (27%) in 1992 had significantly increased grain S concentrations from fertilizer S.

Of the 12 S sites that had increased leaf S concentrations due to fertilizer S at the V6 stage, only four had increased leaf S concentrations at anthesis (C42, N77, C83, and N87). Of these four, only N77 had increased grain S concentration. Site E36 was the only grain yield responsive site to have increased leaf or grain S concentration. For both tissue and grain samplings, the S concentrations of the zero S treatment correlated very poorly with relative yield.

Soil Sulfate and Crop Response to S

Soil sulfate in the surface six inches varied from 0.8 to 11.7 ppm. All but five sites had surface soil sulfate concentrations less than 7.5 ppm which is the critical value used by the University of Missouri for soil S recommendations. A CEC < 6.5 is another factor for S recommendations, and all sites but B55 had higher values. However, the correlation between relative grain yield and surface soil sulfate was very low ($R^2 < 0.01$). Surface soil sulfate was also a poor predictor of leaf S concentrations.

Sulfate concentrations in the 6-12 inch layer were often higher than the surface soil and ranged from 1.1 to 21.5. Although subsoil sulfate correlated better with relative yield than the surface soil, it was still not a good predictor of crop performance.

Frequency Distributions of Crop Responses to Fertilizer S

Despite the infrequency of significant grain yield responses to fertilizer S, there is a concern that grain yield responses may be too small to be detected statistically. Frequency distributions of the relative yield or concentration (relative value of the zero S treatment to the three S treatments) show trends of the response to fertilizer S. These are shown in Figure 2. Those sites that had significant fertilizer S effects are identified on the top of the bar that they represent.

The frequency distributions shifted to the left (smaller relative value) with increased crop maturity, suggesting that S sources other than fertilizer S eventually became available. For the V6 leaf sampling, the distribution skewed to the right of one (a value greater than one represents an increase in leaf S due to fertilizer S). At anthesis, with the exception of two sites, the distribution approximates a normal distribution, suggesting random variation around the mean. Like the V6 distribution, it is centered near 1.02. For grain S and grain yield, the distributions are centered on 1.00 and also approximate a normal distribution. Both parameters had sites with significant effects greater and less than one. The apparent normal distributions centered on 1.00 with few significant responses suggest that the observed results were indeed random and that yield was not increased by amounts undetectable by statistical analysis.

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Table 1. Grain yield response to fertililzer sulfur.

Area of state	Study site	Sulfur Rate (lb./acre) 0	15	30	60	$LSD_{(.10)}$	CV
Southeast		---------- bu./acre ----------					(%)
1991	B53	164	167	160	158	NS	7.5
	B54	144	150	140	147	NS	10.9
	B55	195	199	204	194	NS	10.8
	B56	192	199	189	190	NS	8.4
1992	B90	200	193	215	217	NS#	10.3
	B91	149	142	159	153	NS	12.7
	B92	185	195	155	191	24	13.1
	B93	213	210	197	214	NS	10.2
	B94	188	178	179	177	NS‡	6.1
Central							
1991	C33	175	179	176	181	NS	5.4
	C34	129	126	129	127	NS	8.7
	C39	114	115	118	117	NS	15.5
	C40	234	224	229	228	NS	6.8
	C41	94	84	97	94	NS	14.1
	C42	166	172	174	166	NS	7.0
	C43	104	115	125	124	NS‡	22.6
1992	C64	190	198	194	204	NS	6.6
	C65	227	220	220	219	NS‡	3.3
	C66	195	196	196	195	NS	3.8
	C67	199	201	204	192	NS	6.6
	C82	181	176	180	183	NS	4.0
	C84	198	200	195	201	NS	3.0
	C88	184	174	171	176	NS	9.9
East and Northeast							
1991	E35	221	219	212	225	NS	5.3
	E36	122	120	118	129	7	5.9
	E50	202	195	205	198	NS	11.8
	E51	157	155	159	153	NS	9.1
1992	E68	206	201	201	214	10	4.9
	E69	201	204	198	201	NS	3.0
	E70	193	186	189	184	NS	3.6
	E71	159	156	158	163	NS	7.9
	E72	161	165	157	150	10	5.9
	E73	180	181	179	186	NS	6.0
	E78	199	180	186	186	NS‡	6.6
Northwest							
1991	N45	180	178	186	184	NS	6.0
	N57	138	135	110	95	32#	26.7
	N58	180	187	188	182	NS	7.0
1992	N74	198	188	198	197	NS	5.4
	N75	207	215	206	207	NS	4.4
	N76	207	212	206	205	NS	5.4
	N77	151	162	161	159	NS	10.2
	N85	-	-	-	-	-	-
	N86	152	148	150	155	NS	4.8
	N87	110	121	106	110	NS	11.7
Southwest							
1991	S37	116	114	115	112	NS	8.0
1992	S79	193	198	193	194	NS	5.2
	S80	153	163	152	152	NS	7.1
	S81	172	177	166	171	6	3.4

‡ Significant difference ($Pr > F = 0.10$) between no sulfur check and average of sulfur rates.

Significant linear regression.

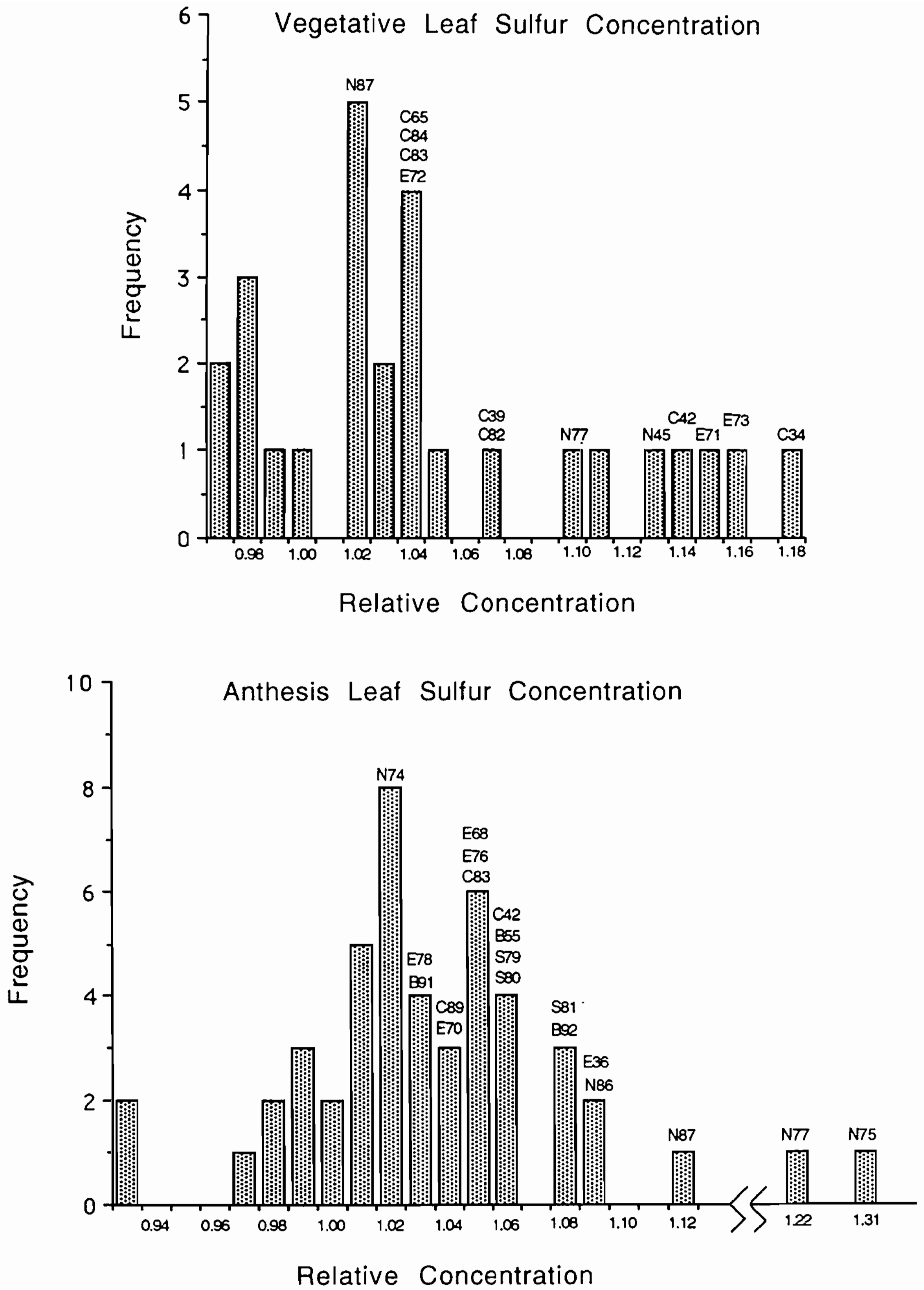

Figure 2. Frequency distributions of relative vegetative and leaf S concentrations.

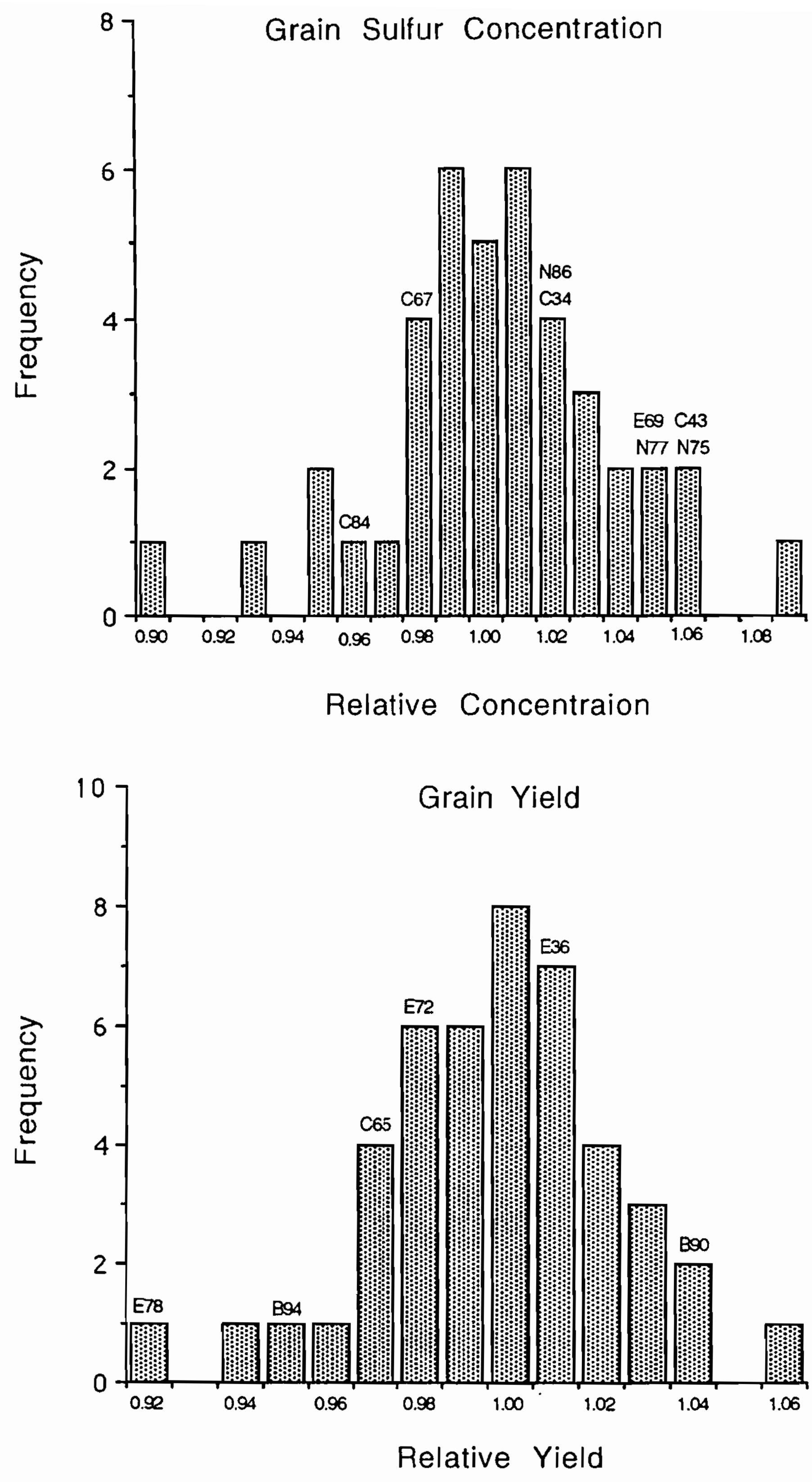

Figure 2. Frequency distributions of relative grain concentration and grain yield.

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