SPATIAL RESPONSE OF CORN TO BANDED ZINC SULFATE FERTILIZER IN IOWA

A. Bickel and R. Killorn
Department of Agronomy
Iowa State University
Ames, Iowa

Abstract

The solubility of zinc (Zn) decreases as pH increases. There are soil associations that contain high pH spots within fields where the surrounding soils' pHs are slightly acid. It is reasonable to expect that Zn availability, due to a difference in solubility, is different in the two areas. The objectives of this study were to find corn (*Zea mays* L.) grain yield responses to Zn fertilizers within fields and to define the soil characteristics in responsive areas. The study was conducted at twelve sites, two in 1998, five in 1999 and five in 2000. Treatments were 0 and 5 lb Zn/a applied to field-length strips of corn and replicated four times. Zinc was applied 2 in. to the side and 2 in. below the seeds during planting. Multiple soil series were identified at each site and treatment pairs were located within them. Soil samples were analyzed for Zn, phosphorus, potassium, organic matter and pH. Grain yields were measured along with whole plant (V6 to V10 growth stage) and grain Zn content and uptake. In this study, significant yield decreases occurred on some soils due to Zn application. Negative yield responses occurred on soils in one of two situations; on soils with high soil test Zn (Zn > 0.8 ppm) or on soils with low soil test Zn (Zn <= 0.8 ppm) and high pH (pH>= 7). Based on these results this type of Zn application would have little agronomic benefit in Iowa. Finally, corn yield responses to variable Zn application throughout a field were not unpredictable.

Introduction

Field studies have been conducted to define corn response to Zn fertilization (Mallarino and Webb, 1995; Carsky and Reid, 1990; Viteri-Arriola, 1984; Boawn, 1973; Marens et al., 1973; Brown and Krantz, 1966; Langin, et al., 1962). In most of this research Zn was applied by broadcasting followed by incorporation. However, banding is an efficient way to uniformly apply the small amounts of Zn required per acre. Furthermore, banding is regaining popularity especially in conservation tillage systems.

The solubility of zinc (Zn) decreases as soil pH increases (Lindsay, 1978). In the western portion of the corn belt there are several soil associations that contain high pH spots within fields where the surrounding soils' pHs are slightly acid. It is reasonable to expect that Zn availability, due to a difference in solubility, is different in the two areas. Today, Global Positioning Systems (GPS) and variable rate fertilizer application systems allow producers to apply fertilizers at different rates throughout a field. This would be economical if producers could save money by applying less fertilizer. Little, if any, research has been completed to look at differential responses of corn to Zn across different soil series within a field.

The objectives of this study were to find grain yield responses to Zn fertilizers within fields, and to define the soil characteristics in responsive areas thereby providing a basis for differential Zn applications.

Materials and Methods

The experiment was conducted from 1998 through 2000. There were two sites in 1998 (1 & 2), five (3 - 7) in 1999, and five (8-12) in 2000 (Figure 1). The sites were located in crop producers' fields or on outlying research farms operated by Iowa State University. Treatments, paired with and without Zn, were applied to the corn in long strips (10 ft. or 15 ft. wide and 500 ft to 1000 ft. long) with four to six replications. The widths and lengths of strips and number of replications varied due to the producer's equipment and the allotted experiment area.

Zn was applied as zinc sulfate (36% Zn) at a rate of 5 lb Zn/a in a band 2 in. below and 2 in. to the side of the seed. The banding attachment was also pulled through the soil on the control strips even though no fertilizer was applied. Approximately 30% of the Zn in the fertilizer material was water-soluble. Zinc sulfate was broadcast without incorporation after planting at site one in 1998. The tillage practices and hybrids used at each site were those use by the cooperators (Table 1).

All of the experimental sites were located in North Central and Western Iowa (Figure 1). Cultural information for each site is listed in Table 1.

Soil Series

Soil series were identified using county soil surveys (Braham, 1989; Dankert et al., 1981; Dideriksen, 1992; Koppen, 1975; Lensch, 1989), followed by field verification to distinguish calcareous from non- calcareous soils. This was accomplished by dropping 1 N HCl on bare soil at 3-ft. intervals and watching for effervescence. If effervescence was not different at a site, the strips were divided into 50 ft. sections.

Next, the sections and/or soil series were divided into paired treatment strips. One strip from each pair was then randomly selected to receive Zn fertilizer. Each treatment strip was then divided into plots that aligned with the corresponding treatment pair (Figures 2a and 2b). When the paired plots did not contain the same soil series they were considered "blank areas" and were not sampled (Figure 2b). The plot length was kept constant at each site but varied among sites due to the space available within soil series (Figure 2a and 2b). Some soil series had a larger area than others so the number of plots per soil series was unbalanced. No more than four plots per soil series were chosen within each set of paired strips. These four plots were randomly selected.

Soil Samples

Soil samples were taken every 25 ft. to a depth of 6 in. in the strips where no Zn was applied immediately after planting. Samples were ground using a stainless steel grinder to avoid Zn contamination, and analyzed for organic matter (Walkley, and Black, 1934), pH (1:1 slurry), Olsen phosphorus (Olsen, et al., 1954), potassium (Carson, 1980), and DTPA extractable Zn(Kahn, 1979; Kahn, and Soltanpour, 1978; Lindsay, and Norvell, 1978). The DTPA extracts were analyzed for Zn using an atomic absorption spectrometer.

Plants

Whole, above ground plant samples of the corn were taken when the plants reached the V6-V10 growth stage (Hanway, 1982). Two plant samples were taken from each plot within each treatment strip. The plant samples were ground in a stainless steel grinder, digested in sulfuric acid and 50% hydrogen peroxide (Hach, 1989), and analyzed for Zn using an atomic absorption spectrometer. Zinc uptake was also calculated.

Grain

Grain was harvested from the two middle rows of each plot. Yields were adjusted to 15.5% moisture content. The grain samples were ground in a stainless steel mill, digested in sulfuric acid and 50% hydrogen peroxide (Hach, 1989), and analyzed for Zn concentration using an atomic absorption spectrometer. Zn uptake was also calculated.

Soil Test Interpretation

The P, K, and Zn soil test interpretations (Table 2) are those of Iowa State University (ISU) Extension (Voss et al., 1999). The pH and organic matter (OM) interpretations were more subjective. A high pH was considered 7.0 and above. The following scale was used to define high, medium, and low organic matter: < 1% is low, 1-4% is medium/adequate, > 5 % is high.

Statistical Analysis

Statistical analyses were done using SAS (SAS, 1996). The model at each site was an unbalanced, split plot. A probability level of 0.05 or less was used to declare significance.

Results and Discussion

Responses to Zn differed among sites (P>F=<0.01) so each site was analyzed separately. The data were sorted by site and soil series and then divided into groups of different pH and Zn concentrations (Table 3). The soil series at the sites and their classifications are shown in Table 4. The soil analysis results sorted by site and soil series are in Table 5.

Soil test Zn varied among locations and among soils within locations (Table 5). At some sites there were soil series that were both low and high in Zn. Sixtyone comparisons are included in the data and 30 were high in Zn while 31 were low.

The most common result was that Zn application had no effect on grain yield (Table 6). There were six sites where grain yield was significantly affected on one or more soils. However there were only nine significant grain yield responses to Zn application in the 61 comparisons. Grain yield decreased in seven of these instances. The magnitude of the decreases ranged from about 4 bu/a to 35 bu/a. This is somewhat surprising because soils tests (Table 5) for Zn were low (less than 0.8 ppm DTPA-extractable Zn) about half of the time, 31 of 61 comparisons. The two positive responses were 35 bu/a on a Webster soil at site 5 and 9 bu/a on a Nicollet soil at site 12. The negative responses occurred in soils testing both low and high in Zn while the positive responses both occurred on soils testing high in Zn.

Conclusions

Several conclusions can be stated based upon the data presented here. First, Iowa soils vary in the amount of soil test Zn that they contain. Second, there seems to be little predictable chance of a corn grain yield response to addition of Zn fertilizer. The method of application used in this study may have affected this result. Unfortunately the study does not provide data that will allow a definite conclusion based upon the method of application. Third, there are times when application of Zn may result in a decrease in corn grain yield. This suggests that application of zinc to soils that test high (greater than 0.8 ppm DTPA extractable Zn) as "insurance" carries a risk. Fourth, the results from this study suggest that the soil test currently used for Zn in Iowa is not a good predictor of the probability of a positive corn grain yield response to addition of Zn fertilizer. Fifth, there was no strong relationship between yield response to applied Zn and soil pH. These data strongly suggest that Zn fertilizer should not be applied to Iowa soils that have high pH.

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Table. 1 Zinc site information.

Site	Producer	Year	County	Strip length	Hybrid	Plant Date	Harvest Date
				ft			
1	Producer	1998	Wright	900	P 3730	5/4/1998	10/10/1998
2	Producer	1998	Hancock	1260	P 3489	5/5/1998	10/22/1998
3	ISU Research Farm	1999	Pottawattamie	525	GH9230BT	5/14/1999	9/28/1999
4	ISU Research Farm	1999	O'Brien	600	DK 477	5/11/1999	11/25/1999
5	Producer	1999	Webster	650	G 8704	5/5/1999	11/26/1999
6	ISU Research Farm	1999	Hancock	490	P 3563	5/4/1999	10/12/1999
7	Producer	1999	Hancock	1000	P 3489	5/4/1999	10/14/1999
8	ISU Research Farm	2000	O'Brien	600	DK 537	4/28/2000	10/12/2000
9	ISU Research Farm	2000	Hancock	500	P3563	4/25/2000	9/29/2000
10	Producer	2000	Grundy	600	DK C57-72	4/14/2000	NA
11	Producer	2000	Grundy	600	M2767	4/14/2000	NA
12	Producer	2000	Hancock	1200	P3489	4/25/2000	10/6/2000

DK = DeKalb, G = Garst, GH = Golden Harvest, M= Mycogen, P = Pioneer

Table 2. Iowa State University Extension Soil Interpretations.

soil test	low	marginal	adequate	high
	mg kg^{-1}			
Olsen P	< 8	na	8 to 14	> 14
K	< 81	na	81 to 120	> 120
Zn	0 to 0.4	0.5 to 0.8	na	> 0.8

na = not available

Table 3. Soil Zn content and pH parameters used in statistical analysis.

Soil charactersitic	Parameter	
	1	2
Zn mg kg^{-1}	<=0.8	>0.8
pH	<7	>=7

Table 4. Classification of soil series found in this study.

Series Name	Classification
Canisteo	fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquoll
Clarion	fine-loamy, mixed, superactive, mesic Typic Hapludoll
Exira	fine-silty, mixed, superactive, mesic, Typic Hapludoll
Galva	fine-silty, mixed, superactive, mesic Typic Hapludoll
Harps	fine-loamy, mixed, superactive, mesic Typic Calciaquoll
Marshall	fine-silty, mixed, superactive, mesic Typic Hapludoll
Muscatine	fine-silty, mixed, mesic Aquic Hapludoll
Nicollet	fine-loamy, mixed, superactive, mesic Aquic Hapludoll
Okoboji	fine, smectitic, superactive, mesic Cumulic Vertic Endoaquoll
Primghar	fine-silty, mixed, superactive, mesic Aquic Hapludoll
Ransom	fine-silty, mixed, superactive, mesic Aquic Hapludoll
Sac	fine-silty, mixed, superactive, mesic Typic Hapludoll
Tama	fine-silty, mixed, superactive, mesic Typic Agriudoll
Webster	fine-loamy, mixed, superactive, mesic, Typic Endoaquoll

Table 5. Soil Characteristics sorted by site, soil series, soil test Zn, and pH.

Site	Year	Soil	Zn	P	K	pH	OM
				----------$mg\ kg^{-1}$----------			%
1	1998	Nicollet	high	26.7	239	low	5.1
		Webster	high	21.5	214	high	7.6
2		Canisteo	high	17.0	248	high	6.1
3	1999	Exira	high	40.3	312	low	3.6
			high	60.6	350	high	3.9
		Marshall	low	28.0	201	low	2.5
			low	29.0	198	high	3.0
			high	66.0	290	high	3.5
4		Primghar	low	24.7	176	low	4.9
			low	26.8	180	high	4.9
			high	30.1	173	low	4.9
		Ransom	low	19.6	155	low	4.7
			low	28.5	183	high	4.8
		Sac	low	16.4	154	low	4.4
			low	27.4	166	high	3.7
			low	16.4	162	low	4.5
5		Canisteo	high	23.8	168	high	7.8
			high	13.0	176	high	8.5
		Clarion	high	35.1	145	low	5.9
			high	27.8	159	high	6.8

		Nicollet	high	43.2	157	high	6.4
		Webster	high	39.2	212	low	6.8
			high	33.0	182	high	7.2
6		Canisteo	low	13.0	178	high	8.0
		Nicollet	low	11.7	157	low	4.7
			low	10.5	178	high	5.4
		Webster	low	14.9	206	high	6.8
			high	29.0	245	low	7.0
7		Canisteo	low	10.2	189	high	7.9
			high	12.3	221	high	7.6
		Harps	low	23.3	192	high	5.2
		Nicollet	low	32.0	162	low	5.3
			low	37.0	191	high	5.7
			high	52.0	254	high	7.7
		Okoboji	low	2.3	173	high	9.2
			high	9.5	185	high	8.7
8	2000	Galva	low	10.4	155	low	4.8
		Primghar	low	7.0	142	low	4.8
			high	8.0	139	low	4.8
			low	14.3	143	high	4.9
		Sac	low	3.0	135	low	4.0
9		Canisteo	low	14.0	140	low	6.8
			high	29.7	171	low	6.6
		Clarion	low	14.5	131	low	3.8
			high	17.9	139	low	4.2
10		Muscatine	low	22.9	295	low	3.6
			low	19.7	289	high	3.6
			high	21.5	294	low	4.4
			high	47.0	226	high	3.7
		Tama	low	19.0	239	low	2.8
			high	35.6	322	low	2.8
11		Muscatine	low	16.9	218	low	8.3
			low	19.7	263	high	5.6
			high	12.2	202	low	12.2
			high	15.5	217	high	4.4
		Tama	low	12.9	207	low	2.9
			high	21.0	230	low	13.0
12		Canisteo	low	8.5	183	high	7.2
			high	11.0	245	high	7.8
		Harps	low	8.3	121	high	9.8
		Nicollet	low	15.0	161	low	5.3
			high	13.0	141	low	5.3
			low	8.0	157	high	8.7

high Zn = > 0.8 ppm, low Zn = < = 0.8 ppm, high pH = > = 7, low pH = <7

Table 6. Responses in yield, plant Zn concentration and uptake and grain Zn concentration and uptake due to Zn application.

		Indices		Yield	Plant Zn	Plant Zn	Grain Zn	Grain Zn
		Soil test	Soil	response	conc.	uptake	conc.	uptake
Site	Soil	Zinc	pH	--------	--------	w/Zn-no Zn	--------	--------
				bu/a	ppm	g Zn/g	ppm	lb/a
1	Nicollet	high	low	-4.3	-2	ns	ns	ns
	Webster	high	high	ns	ns	ns	ns	ns
2	Canisteo	high	high	ns	3	ns	ns	ns
3	Exira	high	low	ns	ns	ns	ns	ns
		high	high	ns	ns	ns	ns	ns
	Marshall	low	low	ns	11	ns	ns	ns
		high	low	ns	ns	ns	0.06	ns
		high	high	-32	8	0.04	ns	-4.5
4	Primghar	low	low	ns	ns	ns	ns	ns
		low	high	ns	ns	ns	ns	ns
		high	low	ns	15	ns	ns	ns
	Ransom	low	low	ns	ns	ns	ns	ns
	Sac	low	low	ns	12	0.01	2	ns
		high	low	ns	ns	ns	ns	ns
		low	high	ns	ns	ns	ns	ns
5	Canisteo	high	high	ns	3	0.01	ns	ns
	Clarion	high	low	ns	ns	ns	ns	ns
		high	high	ns	ns	ns	ns	ns
	Nicollet	high	low	ns	ns	ns	1	4
	Webster	high	low	ns	ns	ns	ns	ns
		high	high	35	ns	ns	ns	ns
6	Canisteo	low	high	ns	ns	ns	ns	ns
	Nicollet	low	low	ns	ns	ns	0.03	0.03
		low	high	ns	ns	0.01	4	4
	Webster	high	low	ns	ns	ns	ns	ns
		low	high	ns	ns	ns	ns	ns
7	Canisteo	low	high	ns	4	ns	ns	ns
		high	high	ns	0.05	ns	ns	ns
	Harps	low	high	-22.5	ns	0.02	-4	ns
	Nicollet	low	low	ns	ns	ns	ns	ns
		low	high	ns	ns	ns	ns	ns
		high	high	ns	6	ns	ns	ns
	Okoboji	low	high	-15	-5	-0.02	-4	-5
		high	high	ns	ns	ns	-5	-4
8	Galva	low	low	ns	ns	ns	ns	ns
	Primghar	low	low	ns	-11	-0.0086	-7	ns
		high	low	ns	ns	ns	ns	ns

		low	high	ns	ns	ns	ns	ns
	Sac	low	low	ns	ns	ns	ns	ns
9	Canisteo	low	low	ns	ns	ns	ns	ns
		high	low	-11	ns	ns	ns	ns
	Clarion	low	low	ns	ns	ns	ns	ns
		high	low	ns	-17	-0.009	ns	ns
10	Muscatine	low	low	ns	ns	ns	ns	ns
		low	high	ns	ns	ns	ns	ns
		high	low	ns	ns	ns	13	9
		high	high	ns	ns	ns	ns	ns
	Tama	low	low	ns	ns	ns	ns	ns
		high	low	ns	ns	ns	ns	ns
11	Muscatine	low	low	ns	ns	ns	ns	ns
		low	high	ns	ns	ns	ns	ns
		high	low	ns	ns	ns	ns	ns
		high	high	ns	ns	ns	ns	ns
	Tama	low	low	ns	-24	ns	ns	ns
		high	low	ns	-16	ns	ns	ns
12	Canisteo	low	high	ns	ns	-0.003	ns	ns
		high	high	ns	ns	ns	ns	ns
	Harps	low	high	-26	ns	-0.002	ns	ns
	Nicollet	low	low	-12	-19	-0.029	18	15
		high	low	9	-10	0.003	ns	ns
		low	high	ns	ns	ns	ns	ns

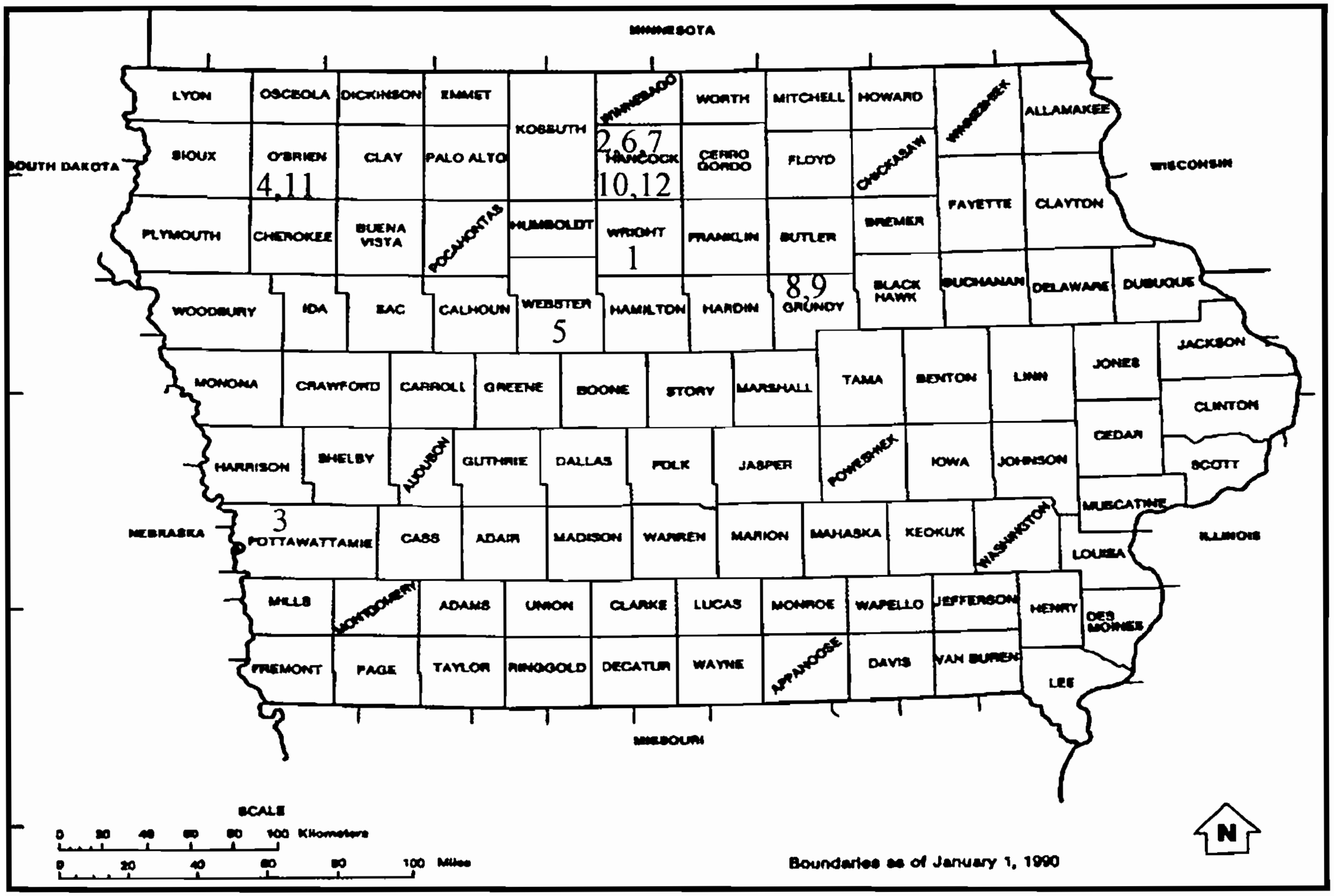
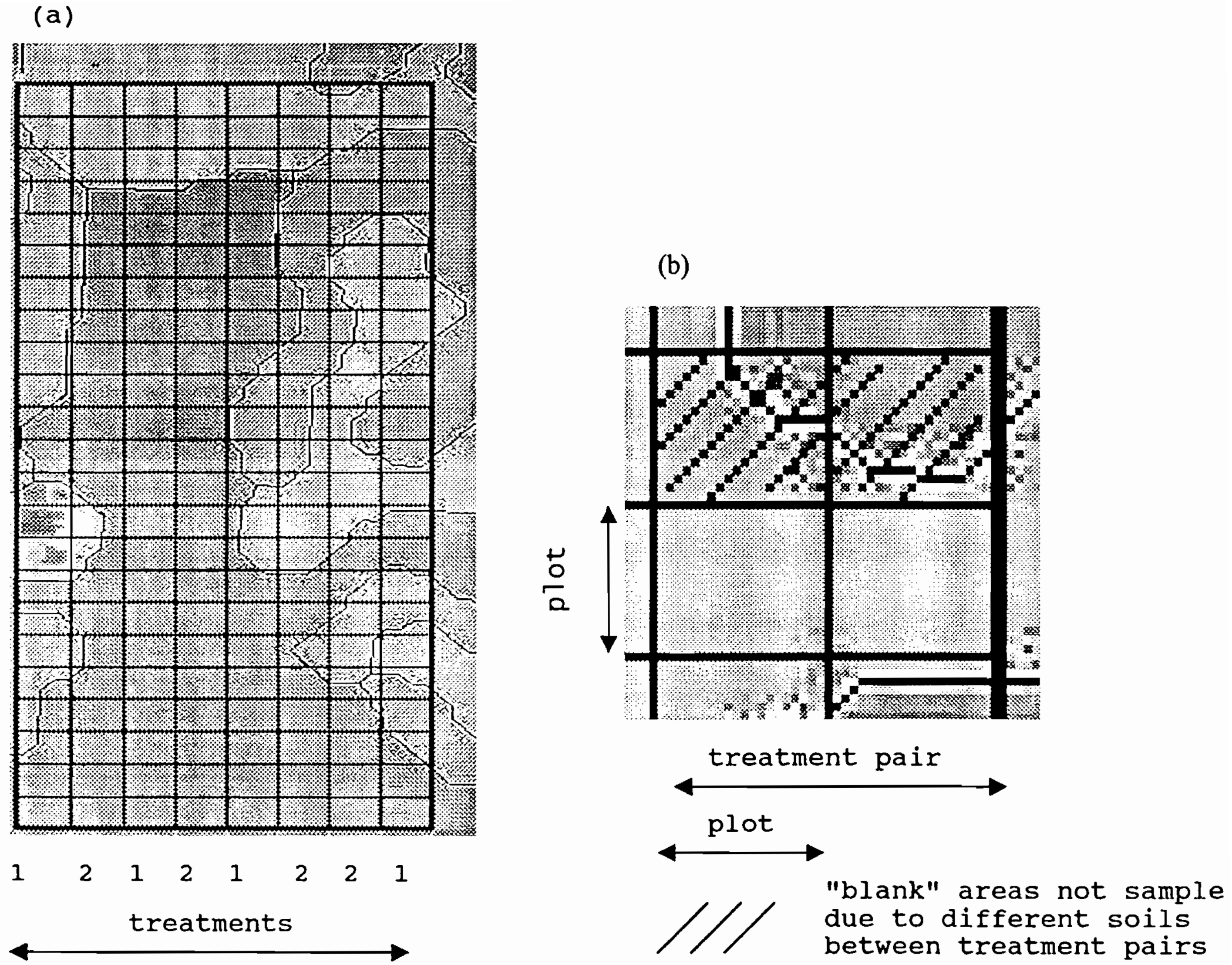


Figure 1. County Locations of Zn response sites in Iowa ; sites 1 - 3 are from 1998, sites 4 - 8 are from 1999, and sites 9 – 12 are from 2000 .



;ure 2. Soil map with experimental layout (a) including treatments (1 = no Zn, 2 = Zn) and
atment strips (b) close up of treatment pairs and plots.

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