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Antonio P. Mallarino
Iowa State University, apmallar@iastate.edu

Joshua T. Enderson
Iowa State University

Mazhar U. Haq
Iowa State University, mazhar@iastate.edu

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Corn and soybean yield responses to micronutrients fertilization

Antonio P. Mallarino, professor, Agronomy, Iowa State University; Joshua T. Enderson, graduate assistant, Agronomy, Iowa State University; Mazhar U. Haq, assistant scientist, Agronomy, Iowa State University

Introduction

Micronutrients such as boron (B), chloride (Cl), copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn) are essential plant nutrients taken up by crops in very small amounts, but a deficiency can have profound effects on yield because they perform important physiological functions. Deficiencies seldom are observed or are widespread in Iowa and neighboring states. Farmers and crop consultants have been asking questions, however, concerning possible yield loss due to deficiency of micronutrients in corn and soybean. Questions arise because of observed Fe deficiency in soybean in calcareous soils, word from Indiana of Mn deficiencies in soybean interacting with glyphosate herbicide, and increasing yield that may increase micronutrients uptake. The soil parent material and soil formation process over time along with the effects of soil moisture, aeration, and temperature can significantly impact the amount of plant-available micronutrients. All these factors make much more difficult the calibration and use of diagnostic tools such as soil and plant-tissue testing than for P or K, for example, and are less reliable to assess the degree of deficiency for crops. Table 1 indicates the usually accepted conditions and crops in which micronutrient deficiencies are more likely.

Table 1. Traditional view concerning likelihood of micronutrients deficiency.

Micronutrient	Soil Conditions	Most Sensitive Crop
Boron (B)	Sandy or highly weathered soils low in organic matter, drought	Alfalfa, clovers
Copper (Cu)	Acid organic or very sandy soils	Wheat, oats, corn
Iron (Fe)	Very high pH (> 7.0)	Soybean
Manganese (Mn)	Organic soils with pH (> 5.8), mineral soils with high pH (> 7.0)	Soybean, wheat, oats, sugar beets
Zinc (Zn)	Sandy or organic, low organic matter due to erosion, high pH (> 7.0)	Corn
Molybdenum (Mo)	Sandy or very acid soils (< 5.5)	Soybean, legumes

Research during the 1960s and 1970s showed isolated instances of Zn deficiency in corn, and the results were used to develop the Iowa interpretations in Extension publication PM 1688. The old research showed no corn or soybean response to other micronutrients, except for soybean response to Mo in extremely acid soils, but needed liming eliminates the deficiency. There has been scarce recent research. Studies in Iowa and Minnesota have shown that fertilization with Fe seldom alleviates soybean Fe deficiency in calcareous soils or is not cost effective. Isolated trials have shown no corn or soybean yield response to chloride (Cl), and also no soybean yield response to Mn application and no interaction with glyphosate.

Therefore, a large study looking at the corn and soybean response to the micronutrients B, Cu, Mn, and Zn was conducted in Iowa from 2012 until 2014. Three distinct projects were (1) foliar fertilization with the micronutrients B, Cu, Mn, and/or Zn sprayed separately or in mixture, (2) fertilization to the soil with B, Mn, and Zn applied separately or in mixture banded with the planter or broadcast, and (3) strip trials demonstrations in coordination with ISU field agronomists of foliar fertilization with a mixture of B, Mn, and Zn. Most trials were conducted in 2012 and 2013, and the trials conducted in 2014 had not been summarized at the time this article was written. This article summarizes results from projects 1 and 2 observed in 2012 and 2013. Results of the strip trials were summarized before by the field agronomists.

Micronutrients fertilization effects on corn and soybean yield

Foliar Fertilization Trials

This project's objective was to evaluate the corn and soybean grain yield responses to foliar application of B, Cu, Mn, and/or Zn sprayed separately or in mixture. There was more funding available to work on soybean than in corn. Forty-two soybean trials were conducted from 2012 to 2013 mostly on farmers' fields, which were established across 20 counties and included 25 soil series. Seven corn trials were conducted from 2012 to 2013 at fields of ISU research farms, which encompassed six counties and six soil series. Tillage involved no-till or chisel-plowing of cornstalks in the fall and field cultivating or disking both cornstalks and soybean residue in the spring. Table 2 shows summarized information of the soil properties of the trial sites.

Table 2. Summary of initial soil-test values for the corn and soybean foliar fertilization trials.†

					Micronutrients Soil Test Results						
						DTPA Method			Mehlich-3 Method		
Stats	**pH**	**Clay**	**OM**	**CEC**	**B**	**Cu**	**Mn**	**Zn**	**Cu**	**Mn**	**Zn**
		----- % ----		*meq/100g*	------------------------- *ppm* -------------------------						
Min	4.9	15	3.1	13.6	0.2	0.3	4.0	0.5	1.6	32	1.2
Max	7.5	33	8.0	36.4	1.7	1.8	42	15	5.5	128	32
Avg.	6.1	27	5.0	24.3	0.7	1.2	19	2.4	3.0	74	4.5

† 49 trials with corn or soybean during 20012 and 2013; 6-inch depth; OM, organic matter; CEC, cation exchange capacity; B was analyzed by the hot water method.

Treatments applied to both crops replicated four times were a control, each micronutrient applied separately, and a mixture of all four of them (six treatments). The treatments were sprayed twice to the same plots at the V6 growth stage of both crops and at soybean R2/R3 stage or corn R1 (silking) stage. Commercially available fluid fertilizers based on boric acid for B and EDTA for the other nutrients were sprayed using a hand-held CO_2 sprayer with a 5-foot spraying width and 15 gal/acre of water. The total amount applied of B, Cu, Mn, and Zn (element basis) were 0.16, 0.08, 0.33, and 0.50 lb element/acre, respectively.

Drought in 2012 or excessive rainfall in 2013 limited yield at five soybean trials (25 to 37 bu/acre site average) and corn yield at two trials (144 and 156 bu/acre). However, yields were moderate to high at other trials (40 to 73 bu/acre for soybean and 201 to 255 bu/acre of corn). There were no statistically significant grain yield increases from the micronutrients application at any corn or soybean trial. At one soybean trial, which was the highest yielding field, there were decreases from applying Cu alone and the mixture. Figure 1 shows average yield results across all soybean trials for each year. Statistical analyses showed a small yield decrease from the mixture in 2012 and 2013 (2.1 and 1.9 bu/acre decrease, respectively). In corn there were no increases or decreases at any site, and Figure 2 shows average yield results across the seven trials.

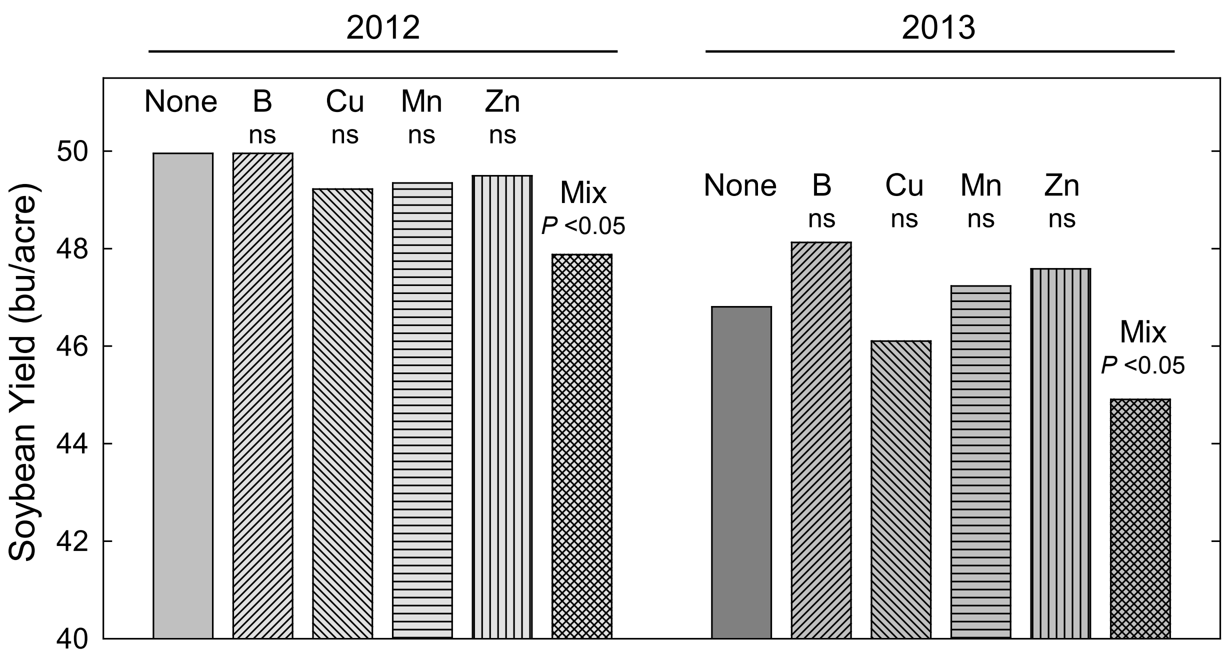

Figure 1. Soybean yield as affected by foliar fertilization with boron (B), copper (Cu), manganese (Mn), zinc (Zn) or their mixture (averages of 22 trials in 2012 and 20 in 2013).

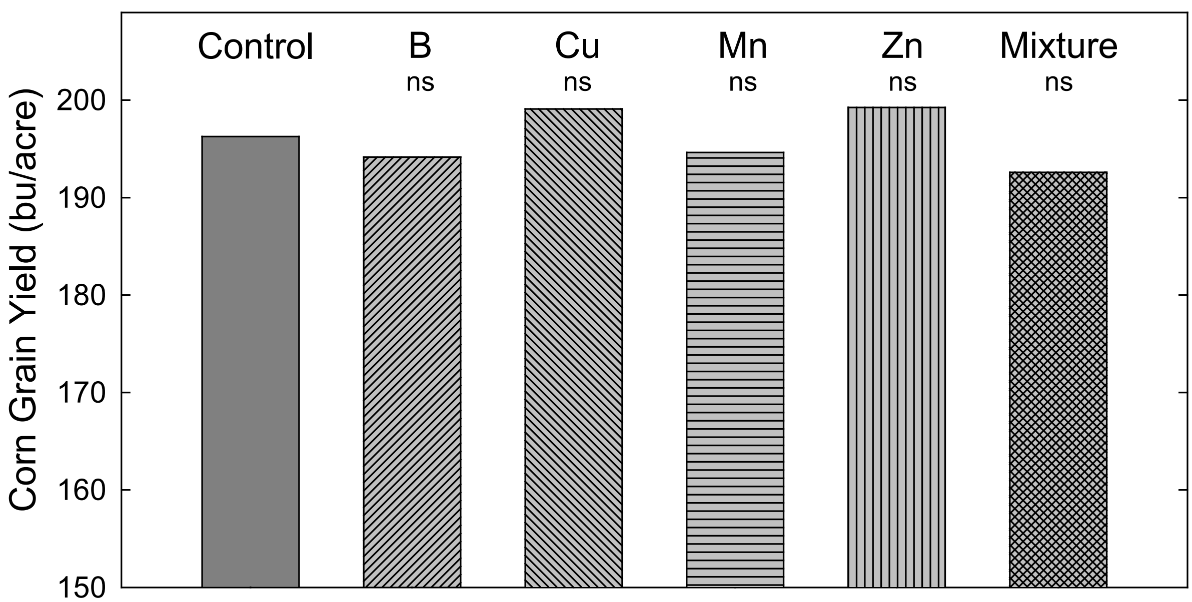

Figure 2. Corn yield as affected by foliar fertilization with boron (B), copper (Cu), manganese (Mn), zinc (Zn) or their mixture (averages of seven trials from 2012 to 2013).

Trials with fertilization to the soil

Another project's objective was to evaluate application to the soil of B, Mn, and/or Zn separately or in mixture for corn-soybean rotations. Eight trials were established in spring 2012 at fields of eight research farms, which were evaluated until 2014. The farms were near Ames, Atlantic, Chariton, Crawfordsville, Kanawha, Muscatine, Nashua, and Sutherland. Four trials began with corn and four with soybean, and the crops were switched in other years to continue corn-soybean rotations at each site. Therefore, a two-year corn soybean rotation was completed during 2012 and 2013. Tillage in all trials involved chisel-plowing of cornstalks in the fall and field cultivating or disking both cornstalks and soybean residue in the spring. Both crops were planted at a 30-inch row spacing. Table 3 shows the research farm locations, soils, and the most relevant initial soil-test values before the study began in spring 2012.

Table 3. Locations and soil-test values for eight trials with micronutrients applied to the soil

Research farm	Soil Type †	Organic matter	pH	Micronutrients Soil Test Results				
					Soil DTPA		Soil Mehlich-3	
				B	Mn	Zn	Mn	Zn
		%		ppm				
Central	Clarion L	4.0	5.8	0.39	12	3.0	33	4.2
East	Toolesboro SaL	3.6	6.2	0.18	2.1	1.2	6.6	1.7
Northeast	Floyd L	4.0	5.8	0.50	22	3.2	50	4.6
North	Nicollet L	5.7	5.5	0.77	19	1.4	36	1.8
Northwest	Marcus SCL	7.9	5.6	1.16	40	0.9	70	1.4
Southeast	Mahaska SCL	5.0	6.0	0.52	18	1.4	53	2.1
South	Grundy SiL	4.8	5.8	0.34	20	2.3	46	2.4
Southwest	Marshall SCL	3.7	5.6	0.25	35	0.7	75	1.1

† L, loam; SaL, sandy loam; SiL, silty loam, SCL, silty clay loam.

Each trial included six treatments replicated three times that were a control (no micronutrients applied), separate treatments of B, Mn, or Zn applied banded with the planters, a mixture of these three micronutrients banded with the planter, and a mixture broadcast and incorporated into the soil by field cultivation or light disking. All planter-band micronutrient fertilizers were mixed with MAP fertilizer at a rate of 4 lb N/acre and 21 lb P_2O_5/acre. The same planter-band MAP rate was applied for the control and the broadcast micronutrients mixture. Uniform, non-limiting rates of P, K, and S were applied across all plots. For corn, a uniform rate of 200 lb N/acre was applied. Solid and granulated fertilizers were used, and the nutrient sources and application rates were for B NuBor 10, 10% B, at 0.5 lb B/acre for planter-band and at 2 lb B/acre for broadcast application; for Mn Broadman20, 20% Mn, at 5 lb Mn/acre both for planter-banded and broadcast placement methods; and for Zn EZ20, 20% Zn, at 5 lb Zn/acre both for planter-banded and broadcast placement methods.

Drought in 2012 or excess rainfall in 2013 limited corn or soybean grain yield in some trials, but yields were moderate to high in others. The average site yield ranged from 155 to 242 bu/acre for corn and from 37 to 72 bu/acre for soybean. There were no statistically significant corn or soybean grain yield increases or decreases at any site from application of the micronutrients B, Mn, and Zn or their mixture banded or broadcast. Figures 3 and 4 show the average corn and soybean yield results across all sites and years.

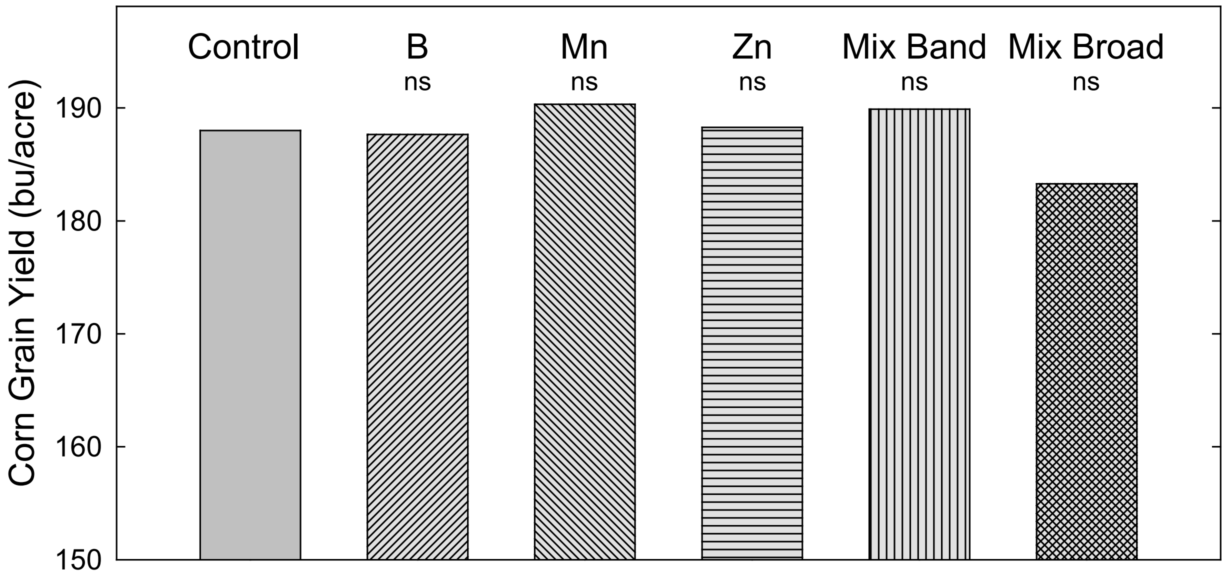

Figure 3. Corn yield as affected by application of boron (B), manganese (Mn), zinc (Zn) banded with the planter and application of their mixture banded or broadcast (averages of eight trials from 2012 to 2013).

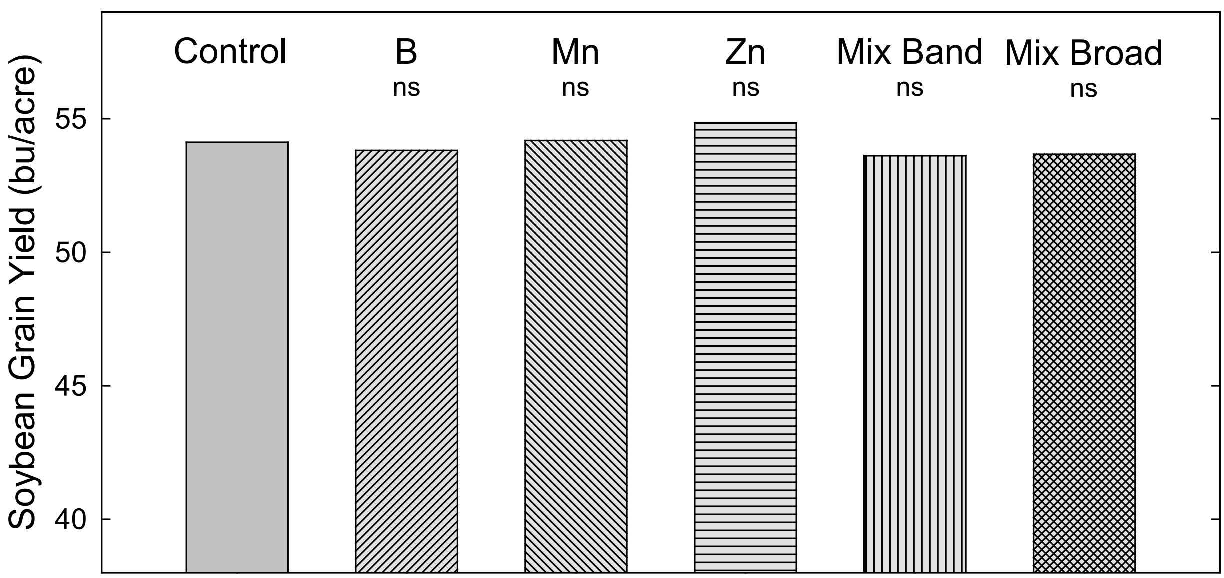

Figure 4. Soybean yield as affected by application of boron (B), manganese (Mn), zinc (Zn) banded with the planter and application of their mixture banded or broadcast (averages of eight trials from 2012 to 2013).

Fertilization effects on plant micronutrient concentrations

Fertilization to the foliage at the V6 growth stage sometimes increased the micronutrient concentration in leaves sampled at the early plant reproductive stages, but increases were small inconsistent across crops, trials, and micronutrients (not shown). This result has been reported for previous research in other states. Fertilization to the soil increased the concentrations in plant tissue at the V6 growth stage more and more frequently than in leaves at mid-season, perhaps because application rates were higher and earlier (not shown).

In contrast to results for grain yield or vegetative plant tissue, fertilization often increased the concentrations of micronutrients in corn and soybean grain (not shown). The increases were greater for B, Cu, and Zn than for Mn.

These grain concentration increases, together with no yield increases at any site, suggest that the micronutrients sprayed or applied to the soils did get into the plant but did not increase yield because soil supply was sufficient.

Soil-test values and yield response

Soil B was measured by the hot-water method whereas soil Cu, Mn, and Zn and were measured with the DTPA, which are recommended methods by the north-central region committee for soil and plant analysis (NCERA-13). We also extracted soil Cu, Mn, and Zn with the Mehlich-3 method because it is being used by many laboratories although it is not recommended by the NCERA-13 yet due to lack of field calibration with yield response.

Soil-test interpretations for micronutrients are not currently available in Iowa except for Zn measured with the DTPA test for corn and sorghum, in which levels < 0.5, 0.5 to 0.8 and ≥ 0.9 ppm are considered deficient, marginal, and adequate, respectively. These ranges for Zn approximately coincide with levels suggested in other states of the region. However, few states have established sufficiency values for other micronutrients, and often are not specific for corn, soybean, or other grain crops. The values deemed sufficient across the north-central states range from 0.51 to 2 ppm for B by the hot water method and 0.21 or greater for Cu, 1.0 to 2.0 for Mn, and 0.76 to 1.0 ppm for Zn by the DTPA method. There are no field-response based interpretations in the region for micronutrients measured with the Mehlich-3 method.

Tables 1 and 2 show the measured ranges of soil-test values. A lack of corn or soybean yield response did not allow for the identification of sufficiency values for soil test results. Use of the lowest or highest value of the published soil-test interpretations predicted corn or soybean grain yield responses from B application at five sites (using the lowest suggested value) or all sites (using the highest suggested value), from Cu and Mn at none of the sites, and from Zn at six sites (using the lowest suggested value) or 40 sites (using the highest suggested value). However, there were no grain yield increases at any site.

Plant-tissue test values and yield response

Plant tissue samples were collected and analyzed for their total micronutrient concentrations to study the relationships with soil-test values and grain yield response. The aboveground portions of corn and soybean plants were sampled at the V6 growth stage, mature soybean leaves were sampled at the R2-R3 stage, and corn ear-leaf blades were sampled at the R1 stage (silking).

Interpretations for micronutrients plant-tissue tests are not available in Iowa and most states of the north-central region. Sufficiency values are suggested for the tri-state region of Indiana, Michigan, and Ohio for mature soybean leaves at midseason and for corn ear-leaf blades at silking. In soybean, deficiencies are deemed possible if concentrations in leaves are for B < 21 ppm, Cu < 10 ppm, Mn < 21 ppm, and Zn < 21 ppm. In corn, deficiencies are deemed possible if concentrations in leaves are for B < 4 ppm, Cu < 6 ppm, Mn < 20 ppm, and Zn < 20 ppm.

Use of these tri-state tissue-test interpretations predicted soybean yield responses from B at no site, from Cu at 39 sites, from Mn at no site, and from Zn at two sites. The lowest observed concentrations in soybean leaves at the R2-R3 stage were 27.0, 3.8, 26.0, and 17.8 ppm for B, Cu, Mn, and Zn, respectively. Use of these interpretations for corn would have predicted yield responses from B at one site, from Cu and Mn at no site, and from Zn at one site. The lowest observed concentrations in corn leaves at silking were 3.3, 7.0, 23, and 14 ppm for B, Cu, Mn, and Zn, respectively. There are no published sufficiency levels in the region for corn or soybean tissue tests at earlier growth stages.

We could not determine which one of the several soil and plant-tissue tests used was better because there were no grain yield increases at any site. However, the results implied large differences among these diagnostic tools at evaluating plant availability of micronutrients. Except for a good relationships between soil Zn by the DTPA and Mehlich-3 methods other relationships among micronutrients in soil, plants at the V5-V6 stage, and leaves at early reproductive stages were poor and seldom statistically significant. Moreover, relationships between micronutrient concentrations in tissue at the V5-V6 and R2-R3 growth stages were statistically significant but very poor.

Study summary and conclusions

1. The results of 65 harvested field trials with corn or soybean summarized here showed that foliar fertilization with B, Cu, Mn, and Zn or fertilization to the soil with B, Mn, and Zn did not increase grain yield at any field with yield levels ranging from low to very high. Results of 25 foliar fertilization strip-trials with a mixture of B, Mn, and Zn not summarized here that were conducted with ISU field agronomists showed a yield increase in one soybean field and a yield decrease in one cornfield.
2. In contrast to a lack of grain yield response, fertilization sometimes increased the micronutrient concentrations in vegetative plant tissue and most often in grain, which show that application to the soil or foliage did not increase yield because the soil supply was sufficient.
3. Use of published soil or plant-tissue test interpretations from other states, which are old or developed for conditions very different from those in Iowa, would have called for unneeded micronutrient fertilization in many fields, with the only exception of soil tests for Cu and Mn because the observed values were higher than the published sufficiency ranges. Unfortunately, the general lack of grain yield increases did not allow for establishing reliable soil or tissue tests interpretations for Iowa at this time.

So what should Iowa farmers do about micronutrients?

1. Deciding about fertilization of corn and soybean with micronutrients based on yield levels or soil and tissue tests interpretations from other states is risky because the likelihood of even offsetting product and application costs is very small.
2. Temporarily could continue basing Zn fertilization for corn on current suggestions in Iowa Extension publication PM 1688. Improved interpretations for Zn and for other micronutrients may be developed once ongoing projects that will provide additional information are completed.
3. Decisions about micronutrients fertilization could be better made by targeting fields with more likelihood of yield response by following traditional knowledge about the conditions in which a micronutrient deficiency is more likely, which were summarized in Table 1.