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Exploring the Value of Plant Analysis to Enhance Water Use Efficiency in Southwest Kansas

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Exploring the Value of Plant Analysis to Enhance Water Use Efficiency in Southwest Kansas

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Summary
Nutrient deficiency is identified by use of visual symptoms. However, the application of the proposed deficient nutrient often does not result in the correction of the observed visual symptoms. This is because essential nutrients do not operate independently of each other or independently of the overall plant health and growing conditions. A study was initiated in 2016 at the Kansas State University Southwest Research-Extension Center Finnup Farm near Garden City, KS, to use both soil and plant analyses to identify toxicities or hidden deficiencies that could be limiting corn yield at various irrigation capacities. Soil samples prior to planting and plant samples at tasseling were collected from corn grown under five irrigation capacities and dryland conditions. Irrigation capacities were 0.25, 0.17, 0.13, 0.10, and 0.08 in./d. Relationships among plant nutrients and corn yield were developed to identify possible nutrients that could be limiting corn yield. Soil analysis showed soil pH of around 8 and organic matter of around 2%. In general, as expected, soil pH did increase with reduction in irrigation capacity. Sulfur (S) was the only nutrient found to be of concern within the soil analysis. Sulfur was also found to be of concern in the plant analysis. The S concentration was right at the lower limit of the sufficiency level. All other nutrients were within the required sufficiency level. However, manganese (Mn) (110 ppm) concentration was found to be higher than that of iron (Fe) (94 ppm). Whenever Mn concentration in a plant is higher than that of Fe regardless of concentration, it is an indication of Fe deficiency. Moreover, a significant relationship ($P = 0.05$) was observed for plant Fe concentration and corn grain yield at the 10% significance level. Likewise, an even stronger significant relationship ($P = 0.035$) was observed for Fe/Mn ratio and corn grain yield at the 5% significance level. These results suggest that Fe deficiency could be the hidden deficiency limiting corn yield.

Introduction
Irrigated corn production is an important part of the agricultural systems in southwest Kansas. Deep, well-drained soils coupled with abundant sunlight enables farmers to produce high yielding crops when using irrigation. However, good fertility and balanced nutrient inputs are critical to producing optimum yields that lead to profitability.

Soil testing has always been the cornerstone of any well-designed fertility program. However, plant analysis can provide a good evaluation of the micronutrient status. In fact, when developing a good fertility program that maximizes profitability, soil and plant analyses are recommended to be used together to obtain the best result, particularly to detect shortages in micronutrients. Plant analysis was used to discover that ions present in high concentration could depress the adsorption of other ions of like charge and influence optimum plant growth (Pierre and Bower, 1943).

Most soils in southwest Kansas have a high pH (7-8.5). The chemistry of high pH soils makes them susceptible to deficiencies of most micronutrients. Nutrient interactions affect the availability of other nutrients, which are predominantly micronutrients. For example, a high potassium (K) level, which is common to soils of southwest Kansas, could cause a reduction in both calcium (Ca) and magnesium (Mg) uptake (Barber, 1995; Mengel et al., 2001). Sulfur uptake can also be influenced by nitrates (Rehm and Caldwell, 1968). Sulfate levels can also depress molybdenum uptake by the roots (Olsen and Watanabe, 1979). Cations K, Mg, and Ca and the anion phosphate at high levels can reduce zinc uptake (Barber, 1995). High nitrate levels can also inhibit copper uptake (Kinsey and Walters, 1999). Clearly, the nutrient dynamics in a growing plant are very complex. Plant analysis provides a nutritional profile of the growing plant that can reveal a hidden need for specific nutrients or imbalanced plant nutrition. This hidden need is not often expressed in visible symptoms, but can often be the missing link limiting crop yield. Plant analysis is an important research tool to study the interaction among nutrients and to identify hidden deficiencies or toxicities.

Experimental Procedures

Treatments

This experiment was conducted under 5 irrigation capacities (0.25, 0.17, 0.13, 0.10, and 0.08 in./d) and dryland. Irrigation was triggered based on an evapotranspiration (ET) water budget limited by irrigation capacity. Soil water measurements were taken weekly using a neutron attenuation technique (CPN 503DR, CPN International, Concord, CA) at 12-in. increments up to 8 ft, to monitor the adequacy of the irrigation schedule.

Design

Treatments were replicated four times in a randomized complete block design. Individual plots were 45- × 90-ft.

Cultural Practice

Fertilizer application and weed control were based on Kansas State University's recommendations for high-yielding corn production.

Measurements

Soil nutrient analysis: Soil samples were collected from each plot pre-plant at a 0-6-inch depth and analyzed for nitrogen (N), phosphorus (P), K, Ca, Mg, Fe, zinc (Zn), Mn, and S.

Plant nutrient analysis: 15 of the uppermost, fully expanded leaves were collected at random from each plot at tasseling (VT) and analyzed to determine the levels of primary nutrients (N, P, and K), secondary nutrients (Ca, Mg, S, and chlorine), and for micronutrients (Zn, Cu, Fe, Mn, boron (B), molybdenum (Mo), and aluminum (Al)).

Plant health and N status: Sensor readings were collected within each plot using a GreenSeeker (Ntech Industries, Inc, Ukiah, CA) handheld at different growth stages and at the time of leaf sampling.

Grain yield: Yield was collected by hand harvesting two center rows of 10 feet each.

Data Analysis

Analysis of variance were counducted using the SAS 9.4 (SAS Institute Inc., Cary, NC) statistical software. Regression and correlation analyses were used to establish a relationship between sensor readings, nutrient content, and irrigation level. Plant analysis data was compared to published sufficiency ranges. Comparative economic analysis was conducted to determine the value of plant analysis to the producers.

Results and Discussion

Soil analysis revealed all nutrients with the exception of S to be sufficient for maximizing corn yield (Table 1). Plant analysis also showed all nutrients to be sufficient for optimal yield (Table 2). However, nutrient levels of S and Fe could impact yield. The concentration of S was a concern because some studies report sufficiency levels between 0.20 - 0.50%. Regression analysis reported a significant (*P* value = 0.05) relationship at the 10% significance level between plant Fe concentration and grain yield (Figure 1). The Fe and Mn ratio also showed a significant (*P* value = 0.035) relationship with grain yield at the 5% significance level (Figure 2). Iron deficiency is a severe problem in high pH (calcareous and/or alkaline) soils in western Kansas. This limitation is not easily overcome with Fe fertilizer, because it is not a problem of lack of Fe but rather of solubility. The ability of some plant species to extract Fe from high pH soils suggests that the cause of this problem must reside in the internal plant metabolism; the pH and redox reactions near the root. Earlier studies have reported that excessive Mn can cause chlorosis curable by treatment with Fe, and plants susceptible to lime-induced chlorosis common in high pH soils are also susceptible to Mn chlorosis (Chapman, 1931; McGeorge, 1923). Iron and Mn are intimately interdependent in their effects upon the plant chlorosis (Shive, 1941). Plants absorb Fe in the active ferrous state under the influence of strong reducing systems of the living cell (Hell and Stephan, 2003; Kobayashi and Nishizawa, 2012; Somers and Shive, 1942). However, if a counter reactant in the form of a strong oxidizing agent such as Mn is present in adequate concentration the active Fe may be oxidized to the ferric state, rendering the Fe biologically inactive, producing the pathological symptom of chlorosis (Somers and Shive, 1942). Therefore, both oxidizing and reducing ions of both Fe and Mn must be maintained within a plant. Researchers have recommended that the Fe/Mn in the plant tissue should be between 1 and 2.5 irrespective of concentration in the plant tissue (Shive, 1941; Somers and Shive, 1942; Twyman, 1951). In our study, Fe/Mn ratio was less than 1, indicating that Fe could be the hidden deficiency limiting yield (Table 3, figure 3). These results suggest that increasing the Fe concentration in the plant could maximize grain yield.

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Table 1. Soil analysis for corn grown under five different irrigation capacities and dryland conditions in 2016 growing season at the Kansas State University Southwest Research-Extension Center Finnup Farm near Garden City, KS

	Irrigation capacity					
Soil component	0.25	0.17	0.13	0.1	0.08	Dryland
	----------------------- inches per day -----------------------					
Depth	0-6"	0-6"	0-6"	0-6"	0-6"	0-6"
pH	8.03	8.08	7.98	8.03	8.10	8.13
Cation exchange capacity	29	29	30	30	31	31
Organic matter (%)	2.0	2.1	2.1	2.1	2.2	2.0
Calcium (ppm)	4588	4629	4656	4911	5093	5232
Magnesium (ppm)	604	627	598	574	525	499
Sodium (ppm)	48	51	38	50	37	31
Potassium (ppm)	615	644	690	651	675	726
Nitrogen (ppm)	50	46	54	54	54	48
Phosphorus (ppm)	47	45	57	69	63	66
Sulfur (ppm)	18	21	13	27	16	12
Zinc (ppm)	3.2	2.8	3.1	4.0	2.9	2.8
Iron (ppm)	4.8	5.3	5.3	4.8	3.8	4.0
Manganese (ppm)	2.8	3.3	3.0	3.3	3.0	2.5
Copper (ppm)	1.2	1.2	1.2	1.5	1.2	1.3

Table 2. Plant analysis for corn grown under five different irrigation capacities and dryland conditions in 2016 growing season at the Kansas State University Southwest Research–Extension Center Finnup Farm near Garden City, KS

	Irrigation capacity					
Plant component	0.25	0.17	0.13	0.1	0.08	Dryland
	----------------------- inches per day -----------------------					
Calcium (%)	0.44	0.43	0.46	0.42	0.44	0.48
Magnesium (%)	0.17	0.16	0.17	0.16	0.16	0.17
Sodium (%)	0.01	0.01	0.01	0.01	0.01	0.01
Potassium (%)	2.53	2.56	2.52	2.58	2.53	2.54
Nitrogen (%)	3.23	3.33	3.31	3.25	3.38	3.25
Phosphorus (%)	0.30	0.30	0.31	0.29	0.29	0.30
Sulfur (%)	0.20	0.20	0.20	0.19	0.19	0.19
Zinc (ppm)	31.25	30.50	32.50	29.50	31.25	30.25
Iron (ppm)	96.00	96.75	92.75	93.75	93.00	89.50
Manganese (ppm)	105.00	105.75	115.50	105.50	115.50	113.25
Copper (ppm)	12.75	12.50	13.25	12.25	13.00	12.50
Boron (ppm)	24.75	25.00	26.00	23.75	24.25	24.50

Table 3. Effect of irrigation capacity on five nutrient ratios in the soil and two plant nutrient ratios in 2016 growing season at the Kansas State University Southwest Research–Extension Center Finnup Farm near Garden City, KS

Irrigation capacity	Soil					Plant	
Inches per day	Ca/Mg	K/Mg	P/S	P/Zn	Fe/Mn	N/S	Fe/Mn
0.25	7.6	1.0	2.7	16.5	1.7	16	0.92
0.17	7.4	1.0	2.1	16.2	1.7	17	0.92
0.13	7.9	1.2	4.9	18.2	1.7	17	0.81
0.10	8.6	1.1	4.3	17.0	1.4	17	0.89
0.08	9.7	1.3	4.2	21.5	1.3	18	0.81
Dryland	10.5	1.5	6.2	23.9	1.7	17	0.79

In soil, calcium/magnesium (Ca/Mg) (7:1 for a high clay and 3:1 for a sandy soil) ratio determines gas exchange in the soil; potassium/magnesium (K/Mg) (1:1) affects Mg, K and P uptake; phosphorus/sulfur (P/S) (1:1) affects P uptake; P/Zn (10:1 Mehlich 3 extraction) affects P and /zinc (Zn) uptake; and Fe/Mn (2:1) affects plant resilience and ability to fight off pests and diseases. In the plant, N/S (15:1) affects protein synthesis; and Fe/Mn (between 1.5:1 and 2.5:1) affects Fe and manganese (Mn) availability in the plant; greater than 2.5 results in Mn deficiency and lower than 1 results in Fe deficiency.

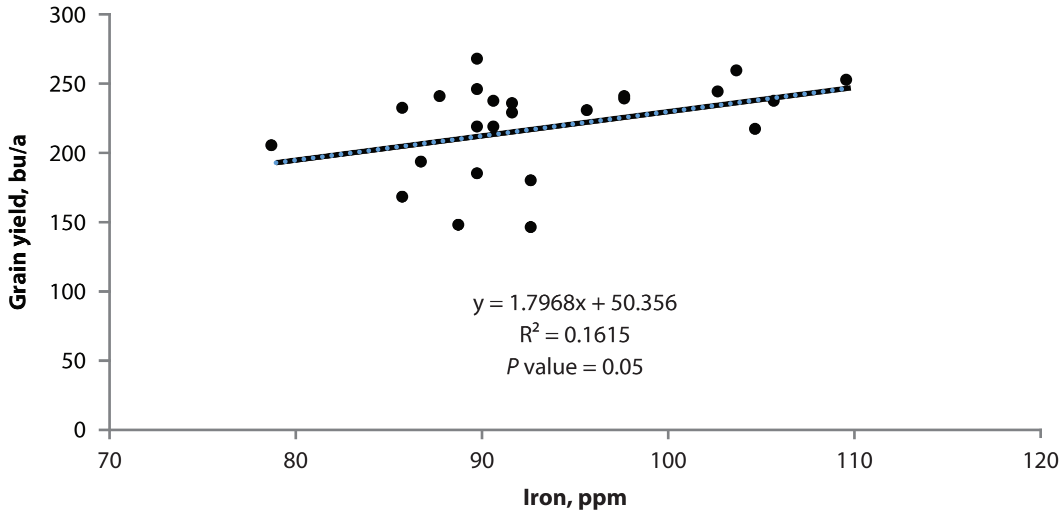

Figure 1. Relationship between grain yield and plant iron concentration for corn grown under five irrigation capacities (0.25, 0.17, 0.13, 0.10, and 0.08 in./d) and dryland at the Kansas State University Southwest Research–Extension Center Finnup Farm near Garden City, KS.

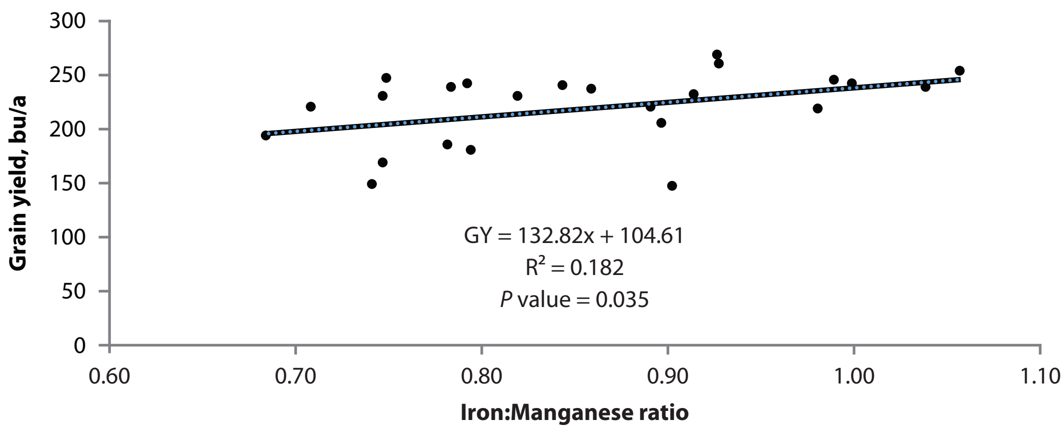

Figure 2. Relationship between grain yield and plant Fe/Mn ratio for corn grown under five irrigation capacities (0.25, 0.17, 0.13, 0.10, and 0.08 in./d) and dryland at the Kansas State University Southwest Research–Extension Center Finnup Farm near Garden City, KS.