SULFUR AND MICRONUTRIENT CHANGES AS A FUNCTION OF DRYLAND CROPPING INTENSITY

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ABSTRACT

With low levels of soil organic matter (SOM) in the central Great Plains, and a general lack of fertilizer application other than N and P, a need exists to evaluate and monitor sulfur (S) and micronutrient (Zn, Fe, Cu, Mn) and other changes that may be occurring because of greater cropping intensities and subsequent nutrient uptake. We evaluated in a Weld loam at three different depths (0-2 , 0-6, 6-12 inches), the effects of increasing cropping intensity (wheat-fallow to continuous cropping) on extractable levels of soil sulfate-S, micronutrients, exchangeable K, and Ca. Soil reaction (pH), cation exchange capacity (CEC), and texture, along with grain yield, and nutrient concentration in the leaves of corn and sunflower were also evaluated. Data showed significant responses of cropping intensity to pH, exchangeable Ca and K, and extractable Zn, Fe and Mn at the 0-2 inch depth, to pH and extractable Mn at the 0-6 inch depth, and no differences at the 6-12 inch depth. Soil sulfate did not show any significant differences and leaf nutrient concentration differences were a function of plant species and not of cropping intensity. In general, differences were due to soil changes created by continuous cropping systems, which received greater fertilization and produced more biomass per unit time than fallowed systems.

INTRODUCTION

As cropping intensity increases and no-tillage systems become more prevalent in the Great Plains, a greater demand for nutrients is exacted upon the soil resources than existed with the traditional clean-till winter wheat summer fallow system. Nitrogen and sometimes P fertilizers are no longer used once in two years as with the traditional system, but twice in a 3-yr rotation with fallow, three times in a 4-yr rotation with fallow, and continuously, as in the case of rotations without fallow. Invariably these longer rotations produce more biomass per unit time, and exact a greater export of nutrients in grain or forage. In the central Great Plains where SOM levels are usually below 2%, and where secondary and micronutrients are rarely applied as fertilizer, a need exists to monitor and evaluate changes that may be occurring in these intensively cropped systems with respect to soil nutrients that may become depleted over the long term, and soil chemical properties that may be adversely changing.

Fertility research data other than N and P are available, but sparse, and usually not done with no-till and long rotations. Follett et al. (1988), found erratic but generally positive responses of wheat *(Triticum aestivum* L.) to S fertilization in Colorado, but this response was not correlated with soil sulfate levels. Rasmussen and Allmaras (1986) working in Oregon, found similar results. Canadian researchers have reported increased yield in oilcrops, especially Canola (*Brassica napus* L.), with S (Jacobsen et al., 1992). Could S be necessary for sunflower (*Helianthus annuus* L.) in the central Great Plains? Are micronutrients other than Zn which is sometimes applied for corn becoming necessary as was found in Alberta for Cu and yield suppression due to disease (Evans et al., 1994)?

The primary objectives of the research, therefore, were to assess the effects of increasing cropping intensities at three different depths on soil changes in: 1) levels of soil sulfate and available Zn, Fe, Mn, and Cu, 2) levels of exchangeable K, and Ca, and 3) pH and CEC. Secondary objectives were to estimate levels of these nutrients exported through grain removal for the last four years, and to determine nutrient concentrations in the leaves of corn (*Zea mays* L.) and sunflower.

MATERIALS AND METHODS

Field test plots were selected from rotation plots established in Washington County near Akron, CO in 1990 on a Weld loam (fine, smectitic, mesic, Aridic Paleustolls). Selected chemical and physical properties are given in Table 1 for 0-2, 0-6, and 6-12 inch depths. Plots were 30 x 100 feet, and all received adequate N and P fertilization. Rotation plots were selected to equally represent four different cropping intensity levels: 0.5, 0.67. 0.75, and 1.0 where 0.5 represents one crop in a 2-yr rotation (example, Wheat (W)-Fallow (F)), 0.67, two crops in a 3-yr rotation (example, W-Corn-F or W-Sunflower-F), 0.75, three crops in a 4-yr rotation (example, W-C-proso Millet (M) (*Panicum miliaceum* L.-F or W-C-Sun-F), and 1.0, continuous cropping (example, W-C-M or W-M). Wheat fallow plots were the only ones farmed with all three tillage practices (conventional (sweep plow) , reduced and no-till), while the others were predominantly no-tilled. Ten plots for each cropping intensity entry were selected from the same replication blocks so as to minimize spatial variability. For more detailed information relative to experimental design and cultural practices, see Bowman et al., 1999 and Anderson et al., 1999.

Soil samples were taken in the summer of 1999 at the 0-2, 0-6, and 6-12 inch depths. After air-drying and passing through a 2-mm screen, soil was sent to a commercial laboratory for the following analyses: texture (hydrometer method), CEC (calculated by cation summation method) and pH with a 1:1 (water) extraction. Sulfate was determined with 0.01 M monobasic calcium phosphate, and micronutrients by the DTPA extraction method (Lindsey and Norvell, (1978). Exchangeable Ca and K were determined with pH 7 ammonium acetate (Simard, 1993). Cations in plant digests were determined by atomic absorption spectrophotometry. Nutrients from grain export were estimated from our yield values and average nutrient concentrations from the literature (Bennett, 1993).

Data were analyzed with cropping intensity as the main effect using analysis of variance and Tukey's mean difference (0.1 level).

RESULTS AND DISCUSSIONS

The research plots were all situated on the same soil series and contained essentially the same proportions of silt and clay (Table 1). For SOM and pH, there were no differences for cropping intensities with fallow, but the continuous cropping system was higher in SOM and lower in pH at the 0-2 inch only. The SOM changes have been previously reported by Bowman et al (1999). Nitrogen fertilization (NH_4 sources) over the years created the significant drop in surface pH (Bowman and Halvorson, 1998). Cation exchange capacity increased with depth, but was not affected by cropping intensities.

Tables 2, 3, and 4 showed the levels of the seven extractable nutrients and % Ca saturation for the three different depths at the four different cropping intensities. As before with SOM and pH, differences were only found in the surface soil and with five of the seven nutrients: Zn, Fe, Mn, K, and Ca. While available K, Zn, and Fe were significantly greater with continuous cropping, Ca and Mn were lower. The effects on the latter nutrients is pH related and were described in a previous work (Bowman and Halvorson, 1998). Also Fe is more available at the lower pH values found with continuous cropping. This lowering of Ca levels was also reflected in the lower % Ca saturation. In many of the comparisons true differences only existed between the W-F system (cropping intensity, 0.5) and the continuous cropping system (cropping intensity, 1.0).

The levels of sulfate were essentially the same for all cropping intensities. As stated earlier, Follett et al. (1988) did not find this soil parameter to be very useful in predicting yield increases. Separating the soils from sunflower rotations from that of wheat, corn and proso millet did not show any inordinate reduction in soil sulfate levels for sunflower. Since insignificant inputs of sulfate arise from water and air in our system, nutrient recycling and the possibility of gypsum source contributions must be investigated in the future. Sulfate-S levels in the native sod (data not shown) was only slightly greater (23 mg/kg, 0-2 inch depth) than those in the cultivated rotations.

Table 5 showed the nutrient concentrations found in corn and sunflower leaves in our research plots with a comparison from the literature of values representing sufficiency range for those nutrients. Generally our values fell within the acceptable ranges except for Zn. There were no significant concentration differences because of increasing cropping intensity, just differences due to species uptake.

For an approximation of nutrient uptake, average yields (75 bushel corn, 45 bushel wheat) were used adjusted for fallow (W-C-F rotation), and for a 10-year period. Since we have no grain nutrient concentration data (this will be obtained next year for wheat, corn, millet and sunflower), we used data from Bennett (1993). Total uptake (removal in grain) was only relatively high for K and SO_4-S, (99 lb and 15 lb/acre, respectively). Calcium removal was about 2 lb, Zn, 0.4 lb, and Fe, 0.2 lb. Putting this into perspective with the major nutrients, N was about 300 lb, and P, about 60 lb.

Present data seem to indicate that these nutrients exported in the grain are not yet limiting production because of recycling through crop residues from 4-yr rotations, or continuous cropping, and because of the sufficiency of the cation-exchange capacity and nutrients in the original soil. However, this needs to be verified next year through more soils data and nutrient budgets for aboveground biomass. Additionally, research on the use of additional S on low organic matter soils, and in oil crops should be initiated.

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Table 1. Selected physical and chemical characteristics of test plots with increasing cropping intensity.

Soil Parameter	Soil Depth (Inches)	Cropping intensity† 0.50	0.67	0.75	1.00
pH (1:1)	0-2*	5.7	5.6	5.6	5.3
	0-6	6.0	6.1	6.2	5.8
	6-12	7.0	7.0	7.0	6.9
SOM (%)	0-2*	1.66	1.70	1.74	1.93
	0-6	1.20	1.20	1.20	1.20
	6-12	1.09	1.00	0.97	1.05
CEC (cmol/kg)	0-2	14.5	13.8	14.3	13.6
	0-6	15.7	15.8	14.6	15.3
	6-12	20.1	18.8	20.1	18.3
% Fines	0-2	61	60	62	62
	0-6	62	63	64	64
	6-12	69	65	67	67

† Cropping intensity is the ratio of crops to crops and fallow in a rotation.
* Cropping intensity significant at $P \leq 0.1$.

Table 2. Effects of cropping intensity on selected soil chemical properties at the 0-2 inch depth.

Soil Parameter	0.5	Cropping 0.67	Intensity† 0.75	1.0	Tukey‡ (0.1)	Std. Error
Exch-K, mg/kg	709	759	784	801	66	27
Exch-Ca, mg/kg	1340	1200	1200	1100	181	75
SO_4-S, mg/kg	21	20	20	20	8	3
Zn, mg/kg	0.56	0.57	0.58	0.72	0.03	0.06
Mn, mg/kg	42	46	48	52	6	3
Fe, mg/kg	27	29	30	37	7	3
Cu, mg/kg	1.0	1.0	1.0	1.1	0.11	0.04
% Ca Saturation	46	44	42	40	5	2

†Cropping intensity is the ratio of crops to crops and fallow in a rotation.
‡Critical value for mean difference at $P \leq 0.1$ (Tukey).

Table 3. Effects of increasing cropping intensity on seven selected available nutrients (0-6 inch depth).

Soil Parameter	0.5	Cropping 0.67	intensity 0.75	1.0	Tukey†	Std. Error
Exch. K, mg/kg	594	654	698	670	130	54
Exch. Ca, mg/kg	1615	1658	1670	1475	278	115
SO_4-S, mg/kg	8.5	11	9.0	7.9	7.5	3.1
Zn, mg/kg	0.51	0.44	0.61	0.46	0.2	0.1
Mn, mg/kg	33	33	35	48	14	5
Fe, mg/kg	22	22	25	28	9	4
Cu, mg/kg	1.0	1.0	1.0	1.1	0.2	0.04

† Critical value for mean difference at $P \leq 0.1$ (Tukey).

Table 4. Effects of increasing cropping intensity on seven selected available nutrients (6-12 inch depth).

Soil Parameter	Cropping intensity 0.5	0.67	0.75	1.0	Tukey†	Std. Error
Exch. K, mg/kg	674	599	689	621	126	53
Exch. Ca, mg/kg	2780	2500	2640	2400	510	212
SO_4-S, mg/kg	5	5	5	6	2	1
Zn, mg/kg	0.36	0.32	0.32	0.36	0.06	0.03
Mn, mg/kg	14	14	14	17	5	2
Fe, mg/kg	10	10	9	12	4	2
Cu, mg/kg	0.8	0.8	0.8	0.7	0.1	0.1

† Critical value for mean difference at $P \leq 0.1$ (Tukey).

Table 5. Corn and sunflower leaf concentration of selected nutrients and sufficiency ranges.

Nutrient	Corn	Sunflower	Sufficiency range Corn	Sufficiency range Sunflower
Sulfur (%)	0.12	0.58	0.1-0.3	0.30-0.55
Ca (%)	0.53	4.81	0.2-1.0	1.5-3.0
Zn, mg/kg	11	21	20-70	25-100
Mn, mg/kg	102	255	20-150	50-1000
Cu, mg/kg	16	10	6-20	4-25