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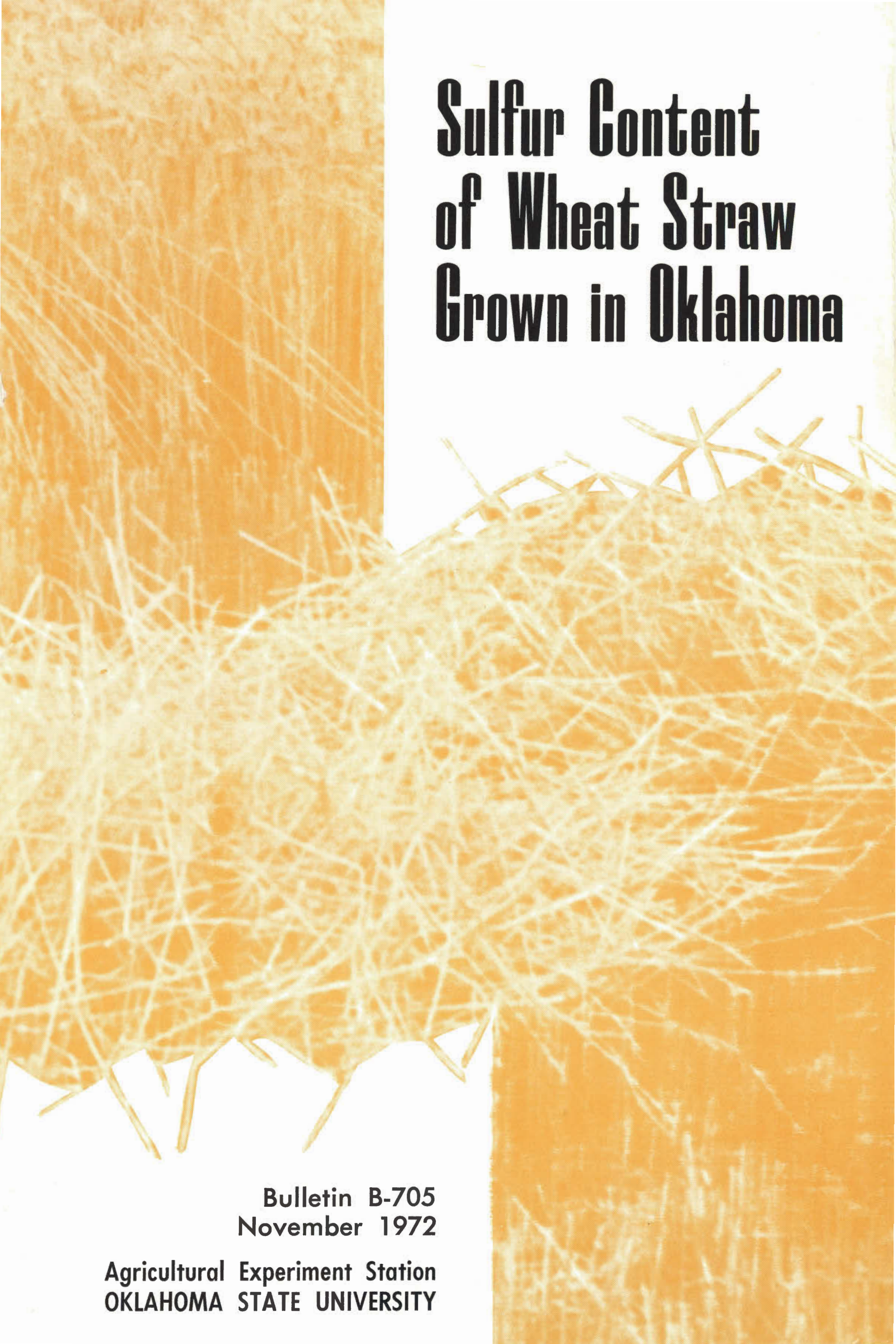

Bulletin B-705
November 1972

Agricultural Experiment Station
OKLAHOMA STATE UNIVERSITY

Sulfur Content of Wheat Straw Grown in Oklahoma

Billy B. Tucker and John M. Baker, Jr.[1]

Sulfur is essential to the growth of plants. It is a constituent of proteins and must be present in rather large quantities in the soil for high crop yields. Plants contain about the same amount of sulfur as phosphorus. A 50 bushel wheat crop will contain from 10 to 14 pounds of elemental sufur.

In most Oklahoma soils, the sulfur needed for crop growth originates from the soil organic matter. It becomes available for plant growth as the soil organic matter oxidizes. High levels of soil organic matter usually means plentiful supplies of sulfur for optimum growth of plants. Some Oklahoma soils contain significant amounts of inorganic sulfur in the form of sulfates.

Soils developed from gypsiferous parent materials tend to contain sulfates in the soil profile. Irrigation water often contains sulfates and supplies considerable amounts of inorganic sulfur to soils.

Many of the fertilizer grades used in the past in Oklahoma contained significant quantities of sulfur, therefore, sulfur was supplied incidental to adding other plant nutrients. However, the use of higher analysis fertilizers in recent years has resulted in smaller amounts of sulfur being applied.

Harper[2] studied the sulfur content of soils, rainfall, and atmosphere in Oklahoma and found the sulfur content of many cultivated soils to be quite low. As would be expected, he also noted that the sulfur content of rainfall in the state was low and much less than industrialized areas of the country.

No widespread sulfur deficiencies have been noted in Oklahoma in the past. In fact, confirmed sulfur deficiencies in the state are rare; but

[1]Appreciation is expressed to the Oklahoma Wheat Research Foundation for providing funds for this study and to Dale Fain, Jim Howell, O. H. Williams, and N. B. Thomas, all area agronomists, for collecting the samples for this study.

[2]Harper, H. J. 1959. Sulfur Content of Oklahoma Soils, Rainfall, and Atmosphere, Okla. Agr. Exp. Sta. Bull. B-536.

Research reported herein was conducted under Oklahoma Station Project Number 1431.

the rapid decline of soil organic matter and the use of high analysis, sulfur-free fertilizers may bring about the need for sulfur application for continued high levels of crop production on some soils.

Fertilizer experiments have been conducted rather frequently in the past in Oklahoma which allowed for the assessment of sulfur needs. These experiments were generally conducted to compare sources of fertilizer elements rather than to ascertain sulfur needs. Many experiments have been conducted comparing ammonium sulfate with other nitrogen sources. Ammonium sulfate contains approximately 24 percent sulfur while the other nitrogen sources contain no sulfur. When comparing phosphorus sources the amount of sulfur applied also varies.

A few studies have been made comparing muriate of potash (0-0-60) with potassium sulfate (0-0-50). Potassium sulfate contains 17.6 percent sulfur while muriate of potash is relatively free from sulfur. With rare exceptions those materials containing sulfur have not increased yields more than those relatively sulfur free. In recent years, in a majority of the fertilizer experiments conducted in Oklahoma, a treatment including a sulfate source was added to ascertain the effects on crop yields of adding sulfur.

A method for assessing sulfur needs was developed by Stewart *et al.*[3] They found that the sulfur content of wheat straw must exceed about 0.15 percent sulfur for straw decomposition to proceed at a maximum rate. Whenever the straw contains less sulfur than about 0.15 percent, immobilization of soil sulfur and a consequent yield reduction is a definite possibility whenever the wheat plants are growing while the straw from the previous crop is being rapidly decomposed.

Whenever wheat straw contains less than 0.04 percent sulfur, it is likely that sulfur was deficient during the growth of the plant and the need for sulfur applications to the field must be considered for continued high levels of production.

Stewart and Whitfield[4] found that whenever wheat straw, low in sulfur, was added to the soil, the decomposition of straw incorporated with the soil immobilized a portion of the available sulfur and caused a reduction in yield. When sulfur was sufficient, the incorporation of straw had no effect on yield. These researchers also found that N/S ratio in green leaf tissue to be a good criterion in assessing the sulfur status of plants. A total nitrogen to total sulfur ratio of about 17 or less suggested that sulfur was not limiting, while a greater ratio limited the formation of protein due to a sulfur deficiency.

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[3]Stewart, B. A., L. K. Porter, and F. G. Viets, Jr. 1966. Effect of Sulfur Content of Straws on Rates of Decomposition and Plant Growth, Soil Science Society of America Proc. Vol. 30:355-358.

[4]Stewart, B. A., and C. J. Whitfield. 1965. Effect of Crop Residue, Soil Temperature, and Sulfur on the Growth of Winter Wheat. Soil Science Soc. of America Proc. Vol. 29:752-755.

A study was initiated in the summer of 1969 utilizing some of the information discussed above in an effort to assess the sulfur needs for wheat production in Oklahoma.

Methods

Wheat straws were collected from 52 locations throughout the wheat belt of Oklahoma. They were collected immediately after harvest and before any post-harvest rainfall had occurred. The straws were free of foreign material and did not include the unthreshed heads.

The samples were collected from fields which had been mapped for standard soil surveys. Locations were chosen to represent "key" wheat-land soils. In addition, samples were taken from selected fertilizer and variety test plots.

The straw samples were dried and prepared for chemical analyses by grinding to pass a 100 mesh sieve. Sulfur contents were determined on a Leco sulfur analyzer. The micro-Kjeldahl was used to determine the total nitrogen in the samples.

Results

The concentrations of nitrogen and sulfur and the nitrogen-sulfur ratios of wheat straw samples grown on selected soil types are presented in Table 1.

The largest nitrogen to sulfur ratio found was 12.2 from a Vernon loam soil in Noble County. This is on eroded soil very low in organic matter. A N/S ratio of 11.3 was obtained from a sample grown on a St. Paul silt loam in Harper County. All sulfur concentrations except one were above the 0.04 percent generally considered as the concentration below which a sulfur deficiency would have been expected for wheat yields. However, only in one case was the sulfur concentration sufficiently high (0.15 percent or above) for rapid decomposition of the wheat straw.

The effects of rates and combinations of the major fertilizer elements on nitrogen and sulfur concentrations, and the N/S ratio of mature wheat straw are reported in Table 2. This study was conducted on Kirkland silt loam on the Agronomy Farm, Stillwater and on a Parsons silt loam at the Eastern Pasture Research Station near Muskogee. The sources of fertilizers used were:

Nitrogen as ammonium nitrate (33-0-0)
Phosphorus as concentrated superphosphate (45-0-0)
Potassium as muriate of potash (0-0-60).

Of the three fertilizer sources used in the experiment, only the concentrated superphosphate contained detectable amounts of sulfur, and that amount was low.

At both Stillwater and Muskogee increasing increments of applied nitrogen increased the nitrogen concentration of the wheat straw. Sulfur

Table 1. Nitrogen and Sulfur Concentrations of Wheat Straw Grown on Some "Key" Wheatland Soils in Oklahoma (1968).

Soil Type	County	%N	%S	N/S Ratio
Abilene Clay loam	Jackson	0.63	0.07	9.7
Bethany silt loam A	Canadian	0.46	0.10	4.6
Bethany silt loam B	Garfield	0.34	0.06	6.2
Bethany silt loam C	Payne	0.46	0.07	7.1
Carey loam	Custer	0.40	0.07	6.2
Carey silt loam A	Dewey	0.88	0.09	10.4
Carey silt loam B	Harmon	0.38	0.10	4.0
Cobb sandy loam	Caddo	0.38	0.06	6.3
Dalhart fine sandy loam	Texas	0.42	0.06	7.6
Dalhart sandy loam	Beaver	0.38	0.08	5.1
Dill fine sandy loam A	Custer	0.44	0.10	4.6
Dill fine sandy loam B	Washita	0.55	0.06	10.0
Enterprise sandy loam	Jackson	0.59	0.09	6.6
Grant silt loam A	Alfalfa	0.86	0.07	10.7
Grant silt loam B	Alfalfa	0.46	0.09	5.4
Hollister clay loam	Jackson	0.59	0.08	7.4
Kirkland silt loam A	Kay	0.23	0.05	5.1
Kirkland silt loam B	Payne	0.25	0.06	4.5
Lawton clay loam	Caddo	0.57	0.07	6.6
Mansker clay loam	Harper	0.48	0.10	4.8
Meno sandy loam A	Greer	0.42	0.06	7.6
Meno sandy loam B	Greer	0.44	0.08	5.5
Miles sandy loam	Beckham	0.50	0.06	9.1
Nash silt loam	Grant	0.38	0.06	6.3
Parsons silt loam	Ottawa	0.57	0.07	8.1
Pondcreek silt loam	Garfield	0.73	0.07	10.4
Port loam	Jackson	0.78	0.09	8.7
Port silt loam	Custer	0.61	0.09	6.8
Pratt fine sandy loam	Harper	0.29	0.03	8.8
Pullman clay loam	Texas	0.53	0.10	5.6
Quinlan sandy loam	Custer	0.38	0.08	5.1
Richfield clay loam A	Harper	0.57	0.11	5.4
Richfield clay loam B	Texas	0.67	0.11	6.1
Runich silt loam	Noble	0.54	0.06	9.0
Springer loam	Greer	0.40	0.06	6.7
Spur loam A	Harper	0.57	0.07	8.1
Spur loam B	Harper	0.29	0.05	5.8
St. Paul silt loam A	Harper	0.96	0.09	11.3
St. Paul silt loam B	Washita	0.42	0.08	5.3
Taloka silt loam	Muskogee	0.38	0.06	6.3
Tipton silt loam A	Harper	0.57	0.07	8.8
Tipton silt loam B	Jackson	0.92	0.16	5.8
Vernon loam	Noble	0.61	0.05	12.2
Woodward clay loam A	Harper	0.90	0.10	9.0
Woodward clay loam B	Harper	0.54	0.07	7.7
Woodward clay loam C	Harper	0.54	0.07	7.7
Yahola sandy loam	Jackson	0.46	0.08	5.8

Table 2. Effects of N, P, and K Fertilization on Nitrogen and Sulfur Status of Wheat Straw (1968).

Fertilizer (lb/A) N	P_2O_5	K_2O	%N Still-water[1]	%N Musko-gee[2]	%S Still-water	%S Musko-gee	N/S Ratio Still water	N/S Ratio Musko-gee
Rates of N								
0	0	0	0.27	0.52	0.06	0.07	4.5	8.0
0	60	40	0.29	0.38	0.06	0.06	4.8	6.3
40	60	40	0.38	0.25	0.06	0.08	6.3	3.3
80	60	40	0.40	0.78	0.06	0.06	6.7	14.2
120	60	40	0.46	0.61	0.07	0.09	7.1	7.2
Rates of P_2O_5								
80	0	40	0.50	0.80	0.07	0.07	7.7	11.4
80	30	40	0.54	0.27	0.08	0.06	7.2	4.9
80	60	40	0.40	0.78	0.06	0.06	6.7	14.2
80	90	40	0.40	0.25	0.06	0.07	6.7	3.8
Rates of K_2O								
80	60	0	0.34	0.34	0.06	0.07	6.2	5.2
80	60	40	0.40	0.78	0.06	0.06	6.7	14.2
80	60	80	0.42	0.29	0.06	0.05	7.6	5.8
120	90	0	0.27	0.90	0.06	0.07	4.5	12.0
120	90	80	0.40	0.38	0.05	0.08	8.0	5.8

[1]Conducted on a Kirkland silt loam soil
[2]Conducted on a Parsons silt loam soil

percentage was not affected by nitrogen fertilization but the N/S ratio increased with increasing nitrogen applications at Stillwater.

Phosphorus fertilization decreased the nitrogen concentration of the wheat straw grown on phosphorus deficient soil but had little effect on the concentration of sulfur, therefore, N/S ratios tended to decrease with increments of applied phosphorus. Potassium additions had no apparent effect on the nitrogen and sulfur status of the straw.

The effects of long-term fertilizer additions on the composition of wheat straw were determined by measuring sulfur and nitrogen concentrations of wheat straw produced on the Magruder Plots which were in their 75th year of continuous wheat in 1968. These data are presented in Table 3.

This study revealed no important effects on the nitrogen and sulfur status as a result of the long-term fertilization procedures except that the nitrogen/sulfur ratio was lower on the plots which had received manure each four years. For many years the source of phosphorus on these plots was ordinary superphosphate (0-20-0) which contained significant amounts of sulfur.

Table 3. Effects of Long-term Fertilizer Applications on the Nitrogen and Sulfur Concentration of Wheat Straw. Magruder Plots, Stillwater (1968).

Treatment	%N	%S	N/S Ratio
Manure	0.25	0.06	4.5
Check	0.40	0.06	7.3
P	0.36	0.06	6.5
N-P	0.38	0.07	5.4
N-P-K	0.38	0.06	6.9
N-P-K, Lime	0.48	0.07	6.9

Straw samples were analyzed from an experiment on Taloka silt loam in Ottawa County in which various sources of phosphate fertilizers containing varying amounts of sulfur were compared.[5] These data are recorded in Table 4. Neither source nor rate of phosphorus influenced the nitrogen and sulfur status of the wheat straw.

Ammonium nitrate was compared with ammonium sulfate at four rates on both clean tilled and stubble mulched plots at the Wheatland Conservation Experiment Station at Cherokee. In general, with stubble mulch tillage residue decomposition is delayed and often coincides with rapid growth of the wheat which may create competition for available nitrogen between soil organisms and the wheat plants. If sulfur should be deficient, ammonium sulfate should supply adequate amounts as it contains 24 percent sulfur. The data from this experiment are reported in Table 5.

Each increment of applied nitrogen regardless of form increased the nitrogen concentration of the straw. Nitrogen contents were essentially doubled by the higher rates of nitrogen as compared to the wheat not receiving nitrogen. Sulfur percentages tended to increase at the higher levels of ammonium sulfate. No apparent differences in nitrogen to sulfur ratios were noted. Tillage methods did not affect the nitrogen nor sulfur status of the wheat straw.

In an effort to ascertain the variability in nitrogen and sulfur concentrations of wheat straw, samples from two replications of a variety test near Cordell in Washita County were collected. The results are recorded in Table 6. Differences between the two replications were nearly as large as differences among varieties. Differences in nitrogen percentages were larger than for sulfur concentrations. It is noteworthy that nitrogen concentrations of the straw were somewhat related to gains in

[5]Appreciation is expressed to the Tennessee Valley Authority for furnishing the phosphate fertilizers used in this experiment.

Table 4. Effect of Phosphate Sources on Sulfur and Nitrogen Concentrations of Wheat Straw. Taloka silt loam, Ottawa County (1968).

Source	Rate (lbs/A)	%N	%S	N/S Ratio
	0	0.57	0.07	8.1
Concentrated Superphosphate (0-45-0)	30	0.63	0.07	9.0
	60	0.48	0.07	6.9
	90	0.50	0.08	6.3
Diammonium Phosphate (21-53-0)	30	0.46	0.08	6.1
	60	0.46	0.06	7.7
	90	0.50	0.07	7.1
Ammonium Phosphate Nitrate (20-20-0)	30	0.44	0.07	6.8
	60	0.48	0.07	6.9
	90	0.46	0.06	7.7
Ammonium Polyphosphate (15-60-0)	30	0.44	0.06	8.0
	60	0.40	0.07	6.2
	90	0.42	0.07	6.0
Urea Ammonium Phosphate (32-24-0)	30	0.48	0.06	8.0
	60	0.40	0.07	6.2
	90	0.36	0.04	9.0

Table 5. Effect of Nitrogen Rates, Nitrogen Source, and Tillage Method on Nitrogen and Sulfur Status of Wheat Straw, Grant silt loam, Alfalfa County (1968).

Tillage	Nitrogen Source	Rate of N (lbs/A)	%N	%S	N/S Ratio
Stubble Mulch		0	0.50	0.07	7.1
	Ammonium Nitrate	20	0.75	0.07	10.7
		40	0.86	0.08	10.8
		80	1.05	0.10	10.5
		160	0.94	0.08	11.8
	Ammonium Sulfate	20	0.57	0.06	10.4
		40	0.80	0.08	10.7
		80	0.96	0.09	10.7
		160	0.82	0.10	8.6
Clean Tilled		0	0.59	0.07	9.1
	Ammonium Nitrate	20	0.63	0.06	10.5
		40	0.80	0.09	9.4
		80	0.80	0.10	8.0
		160	0.94	0.08	11.8
	Ammonium Sulfate	20	0.63	0.06	10.5
		40	0.94	0.07	13.4
		80	0.80	0.07	11.4
		160	0.92	0.10	10.2

yields (data not reported here) but sulfur percentages were not. Nitrogen to sulfur ratios varied from about 5.0 to 10.0. These data do indicate that different varieties will exhibit different nitrogen and sulfur concentrations under similar conditions.

Table 6. Concentrations of Nitrogen and Sulfur in the Straw of Several Varieties of Wheat, Cordell (1968).

Variety	%N Replication 1	%N Replication 2	%S Replication 1	%S Replication 2	N/S Ratio Replication 1	N/S Ratio Replication 2
Agent	0.38	0.46	0.06	0.09	6.3	5.4
Concho	0.63	0.78	0.07	0.10	9.7	8.2
Gage	0.46	0.61	0.08	0.09	6.1	6.8
Improved Triumph	0.54	0.59	0.08	0.10	6.8	6.2
Kaw 61	0.71	0.61	0.09	0.09	7.9	7.2
Parker	0.50	0.63	0.08	0.09	6.3	7.4
Scout	0.69	0.67	0.06	0.07	11.5	9.6
Scout 66	0.52	0.61	0.06	0.08	8.7	8.1
Sturdy	0.54	0.67	0.08	0.09	7.2	7.9
Trader	0.65	0.71	0.06	0.08	10.8	9.2
Erick (1968) Miles sandy loam						
Concho	0.50			0.06	9.1	
Triumph	0.46			0.06	7.7	

Conclusion

The data from this survey did not reveal widespread deficiencies of sulfur for wheat production in Oklahoma.

Nitrogen/sulfur ratios were quite low which would be expected from mature straw. The N/S ratio in mature straw is not suggested as a criterion for assessing sulfur needs for wheat production.

Increasing rates of nitrogen did not materially lower the sulfur content of the wheat straw. If sulfur were deficient, a decrease in sulfur concentration would be expected with increasing increments of applied nitrogen.

Sulfur concentrations of wheat straw were generally lower than that reported to be needed for rapid straw decomposition but were higher than that reported to be the critical level for wheat growth and production.