Physically Evaluating Wheat Straw Decomposition Via Different Fertilizer Treatments

Study samples indicate longer fertilizer application periods can decompose more crop residue.

Yuxin He, Drs. DeAnn Presley and John Tatarko

The Fluid Journal • Official Journal of the Fluid Fertilizer Foundation • Fall 2014 • Vol. 22, No. 4, Issue #86

▼ DOWNLOAD

Summary: *Summer samples from our Colby site fall treatment plots had less aboveground biomass than spring treatment plots, indicating a longer fertilizer application period can decompose crop residue. Specific energy also seems more sensitive to fertilizer application timing and shear stress is more affected by fertilizer rates. Meanwhile, more detailed analyses on the effect of different nitrogen (N) and sulfur (S) rates on wheat- straw decomposition will be conducted.*

The importance of crop residue to soil quality has been gradually learned and recognized by researchers and farmers, particularly in the semi-arid area, where precipitation is limited. Lacking residue protection, surface soil is vulnerable to negative environmental and anthropogenic influences, such as:

- Wind blow
- Precipitation strike
- Dramatic temperature change due to solar radiation
- Animal traffic
- Agricultural equipment compaction.

In western Kansas, wind erosion might be the most significant soil degradation process due to the local climate characteristics. By removing the most fertile layer of soil, lowering water holding capacity, degrading soil structure, and increasing soil variability, wind erosion can reduce soil productivity significantly in certain areas.

Producers adopt no-till farming more and more today owing to fewer disturbances of the soil and better retention of crop residue on the ground. Research has demonstrated that indiscriminate removal of crop residue can drastically reduce the erosion benefit from no-till farming. Therefore, crop residue has largely remained in the field after harvest in order to lower the possibility of wind erosion in some regions today.

On the other hand, by having such large amounts of crop residue on the field, farmers usually report problems about establishing a good plant stand in high residue situations. Dry regions have a climate that is not as conducive to residue decomposition as the more humid regions. As a result, some producers resort to tillage as a means for decreasing residue to allow them to get a better stand, which sacrifices the many benefits gained from the no-till system.

In 2013, global wheat production was expecting a 4.3 percent increase to 690 million tons (FAO, 2013). Unlike other crop residues, wheat-straw is usually not considered for animal husbandry or other use (i.e., mushroom composing mixture). Therefore, wheat-straw more likely would remain in the field after harvest.

One recommendation extension specialists make is to apply N fertilizer as urea ammonium nitrate (UAN) in a fine mist on the residue to stimulate microbial activity and subsequent decomposition of the residue. Meanwhile, as a secondary nutrient, S can be a limiting factor to higher microbial activity, especially after cultivation of high S demand plants such as alfalfa. Therefore, ammonium thiosulfate (ATS) is also considered to stimulate crop residue decomposition.

The objectives of this research are to:

- Conduct on-farm research to evaluate the effect of different UAN and ATS application rates on the decomposition of wheat- straw
- Study the timing of UAN application and the effects of decomposition of residue.

Methodology

Sites. The research sites were established in Western Kansas in 2011 and 2012, right after the wheat harvest. They were in Hays, Colby, and Garden City, respectively.

Block design. A randomized, complete block design with four replications was conducted in the experiment.

Plots at each site were made in 6.1 meter by 6.1 meter size and were placed directly over the center of where the combine traveled.

Application rates. The plots had UAN applied at rates of 0, 11.2, 22.4, and 33.6 kg N/ha and ATS applied at rates of 16.8 and 33.6 kg S/ha, which also contained 7.7 and 15.5 kg/ha N with a flat fan spray tip.

Timing. UAN/ATS were applied at two different timings to separate plots, making a total of 13 treatments (Table 1). The first timing occurred in September after wheat harvest. The second timing took place in February, the second year before temperatures increased to favor microbial decomposition.

Residue samples were collected from every research plot in a 0.61 by 0.61 meter area in the summer of 2012, in June and October of 2013 from all three sites. We tried to conduct the sampling at these times when cultivation is commonly in process to simulate the situation cultivator experiences. The residue was sieved to remove any soil and material that may have been collected from the field. It was dried and weighed to calculate total surface residue. A subsample was then ground and sent to the laboratory for total N and total carbon analysis.

Shear box

A double shear-using shear box was applied to test the shear stress and specific energy required to cut wheat-straw. The shear box consists of two parallel aluminum plates (channel) 6 mm apart (Figure 1). Between them, the third plate (blade) can move up and down along the central axis freely. Five holes with diameters ranging from 2 mm to 6 mm were drilled on all three plates to accommodate different wheat straw sizes. The shear box was then attached to the load cell of a tension/compression testing machine (Figure 2). The blade was set to move at 10 mm/min velocity and the applied force was recorded by a strain-gauge load cell. The shear stress was then calculated as:

$$rs = \frac{F}{2A}$$

where r2 is the shear stress (MPa), F is the shear force at failure (N), and A is the wheat straw wall area at failure cross section (mm2). The specific energy was then calculated as:

Table 1. Treatments of decomposition experiment and their application time.

	Treatment	N rate (kg/ha)	S rate (kg/ha)	Fertilizer application timing	
1	Control	0	0	Sept. 2011	Sept. 2012
2	Urea20	11.2	0		
3	Urea40	22.4	0		
4	Urea60	33.6	0		
5	ATS15	7.7	16.8		
6	ATS30	15.5	33.6		
7	Mixed	49.1	33.6		
8	Urea20	11.2	0	Feb. 2012	Feb. 2013
9	Urea40	22.4	0		
10	Urea60	33.6	0		
11	ATS15	7.7	16.8		
12	ATS30	15.5	33.6		
13	Mixed	49.1	33.6		

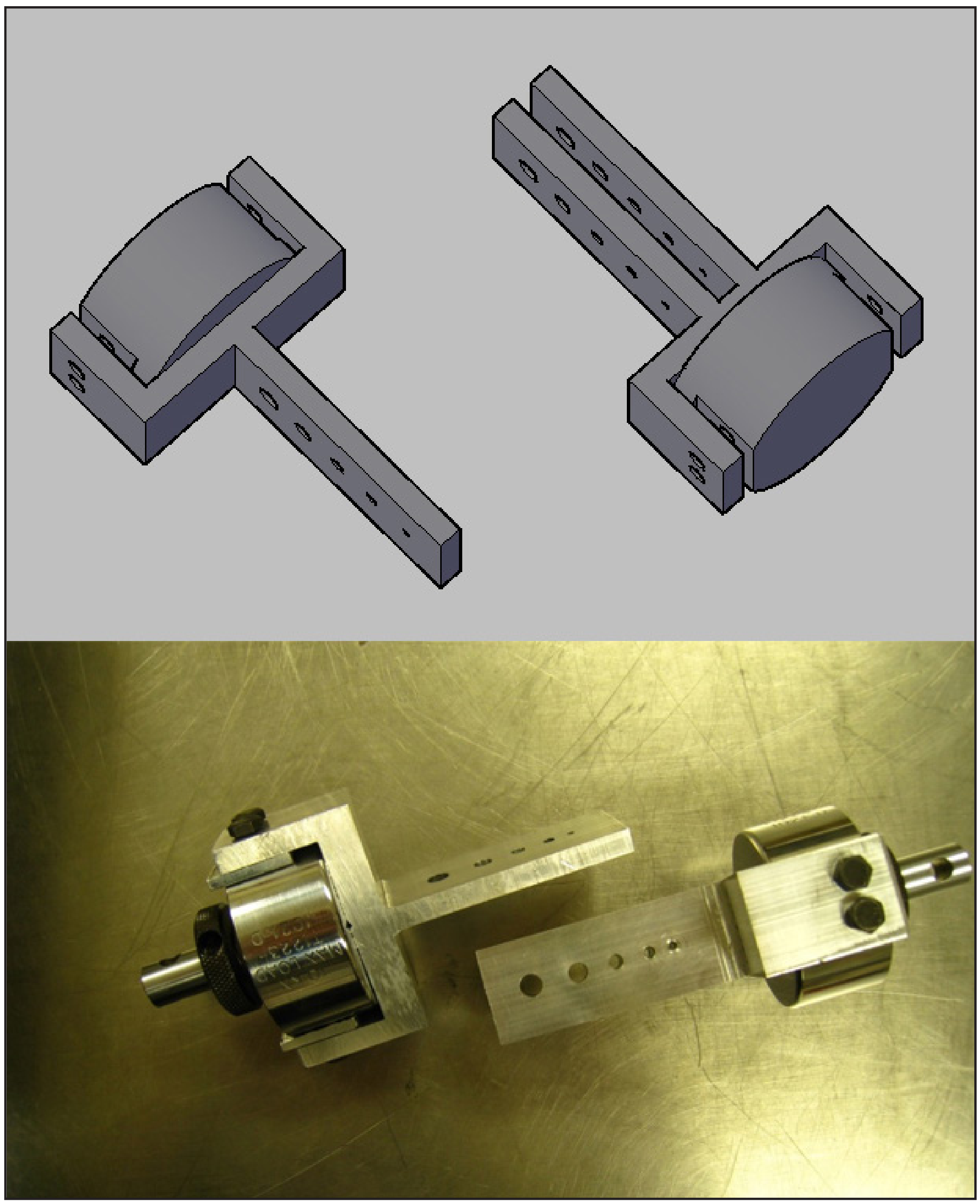

Figure 1. Design of shear box through AutoCAD2010 and manufactured shear box.

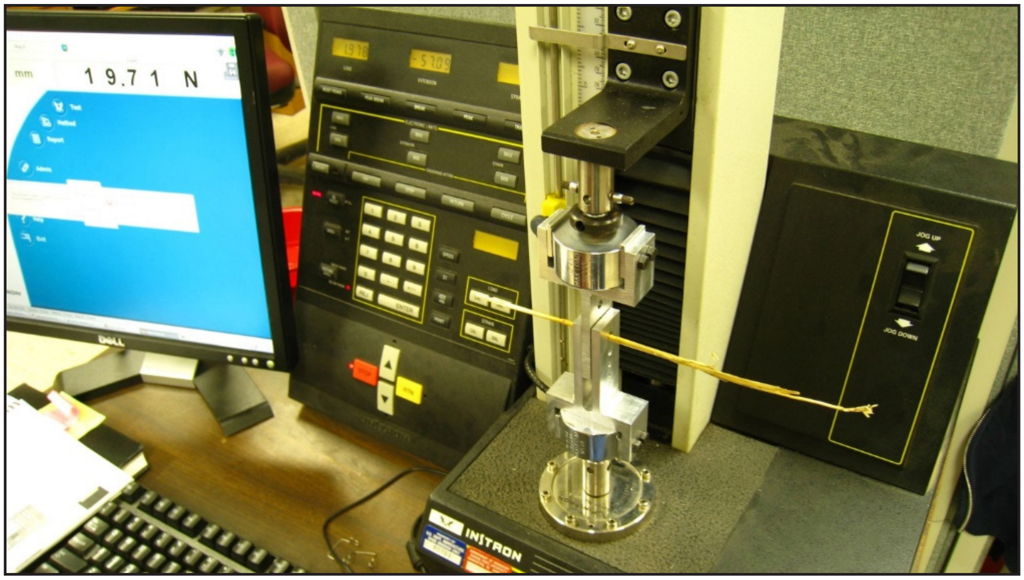

Figure 2. Testing wheat straw physical strength using a shear box attached with load cell that connected with a computer.

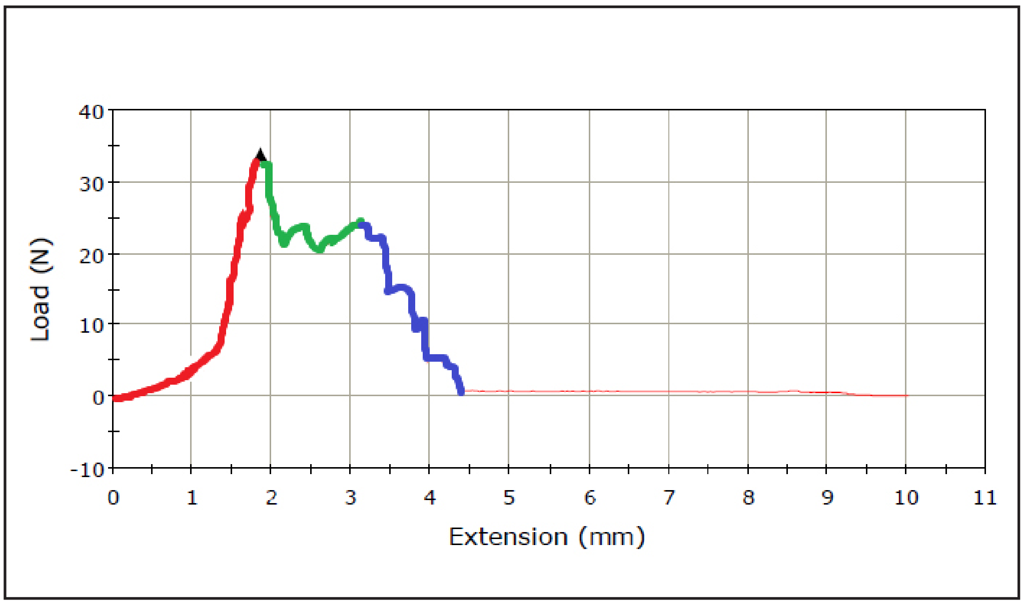

Figure 3. Shear force along blade movement recorded by computer with different colors showing different shearing stages.

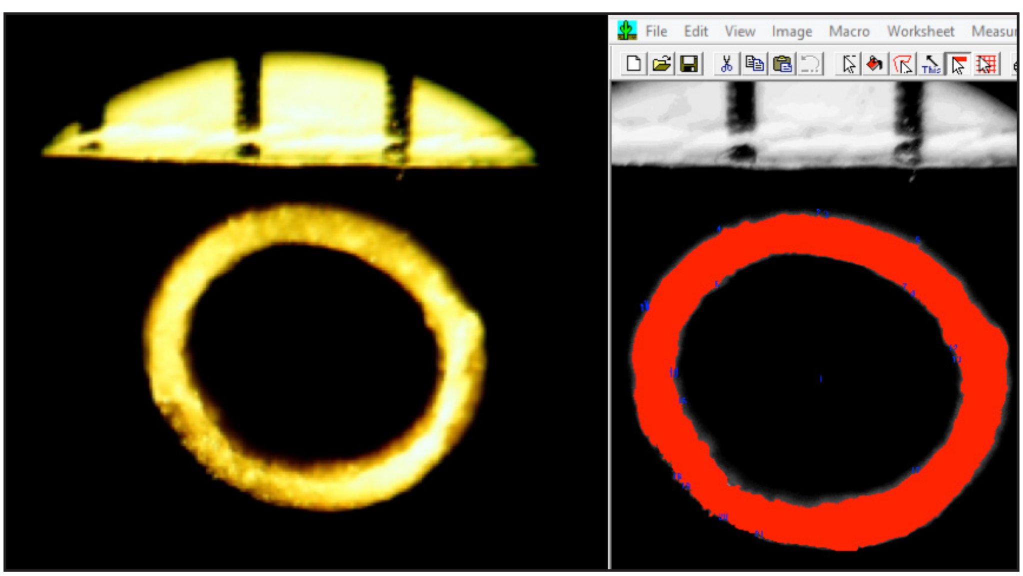

Figure 4. Image of cross section of wheat straw at breaking point under microscope and being analyzed by SigmaScan 5 software.

$$SE = \frac{TE}{A}$$

where SE is the specific energy (J/mm2), TE is the total energy (J), and A is the wheat straw wall area at failure cross-section (mm2).

Twenty-five wheat straws from each plot were tested for shear stress and specific energy. During the shearing test, shear force was recorded by the computer. Shear force versus center movement was then graphed (Figure 3).

From Figure 3 the highest load was reported by the computer, which was also the shearing force (F) of the wheat straw where it breaks. Integration, the area between load and extension from zero to breaking point, is the total energy (TE) demanded by cutting through the wheat straw.

To accurately measure the cross-sectioned area at the breaking point of wheat straw, a microscope and camera were used to capture images of the cross-sectional area of wheat straw. The pictures were then analyzed with the software SigmaScan 5. Figure 4 shows the wheat straw captured by a microscope (left) and then analyzed with the software for area (right).

Data were statistically analyzed through SAS 9.3 software and summarized. MIXED and GLM procedures were applied to analyze the data.

Data analysis

Three sample periods were conducted in this experiment. In 2012, samples were collected from all three sites during summer months. In 2013, to better stimulate cultivation season, two sampling periods were conducted. They were in June and October 2013, respectively.

By January of 2014, all field work and lab work were completed. Data analysis is in process. In this report we will focus on the summer of 2012 sampling. It will include physical parameters, as well as:

- Aboveground biomass
- Shear stress
- Specific energy.

In the experimental design we considered two factors. They were treatment and timing. Using GMS and

MIXed procedures in SAS 9.3, we conducted two-way ANOVA analysis. In Table 2, the data in red indicate there is a significant difference level. We only report the data that has significant difference levels (in red).

Garden City. For the sample from Garden city of June 2013, we only collected biomass data. Owing to the severe windy weather situation, all residue left on the ground was blown away. We were not able to collect any standing residue during our fieldwork. In October 2013, we skipped the Garden City site owing to the weather.

Hays. Figure 5 shows the aboveground biomass difference between 2011 fall application treatment and 2012 spring application treatment. According to the graph, 2011 fall application plots have less biomass. Longer fertilizer application periods seem to decompose more wheat straw. Theoretically, longer reaction time could make the wheat-straw weaker than shorter application periods. Also, strong winds can take wheat straw with lower resistant ability away from plots. Therefore, fall application plots may have less residue remaining compared to the spring application plots. However, this phenomenon was only observed at the Hays site (Table 2). Also, treatment did not make any difference on aboveground biomass in any of the three sites.

Figure 6 shows the specific energy required by the shearing test for the samples from fall fertilizer applications in treatment plots at Hays. Specific energy decreased significantly with increasing amounts of UAN usage. However, there was no significant difference between Urea 40 and Urea 60 on specific energy measured. Furthermore, ATS seems to have no effect on specific energy.

For spring 2012, in fertilizer application samples at Hays--similar to fall application--UAN decreased the specific energy requirement significantly compared to ATS treatments (Figure 7). However, there was no difference between treatments with different UAN application rates.

Since there was timing and treatment interaction, we needed to look at the timing effects individually. Figure 8 shows the effects of timing on specific

Table 2. Analysis of variance results of summer 2012 sample

2012 summer							
		Biomass		Specific Energy		Shear Stress	
		F-value	P-value	F-value	P-value	F-value	P-value
Colby	Trt*	0.26	0.933	0.66	0.655	1.14	0.361
	time	2.85	0.102	0.21	0.652	0.24	0.630
	trt*time	1.41	0.251	0.34	0.883	0.74	0.602
Hays	trt	0.62	0.686	4.6	0.003	2.3	0.066
	time	0.05	0.825	5.96	0.020	1.82	0.186
	trt*time	0.5	0.772	2.09	0.090	1.51	0.211
Garden City	trt	1.51	0.212	3.81	0.007	0.97	0.450
	time	0.37	0.548	0.54	0.466	1.6	0.214
	trt*time	1.27	0.298	1.38	0.256	2.56	0.044

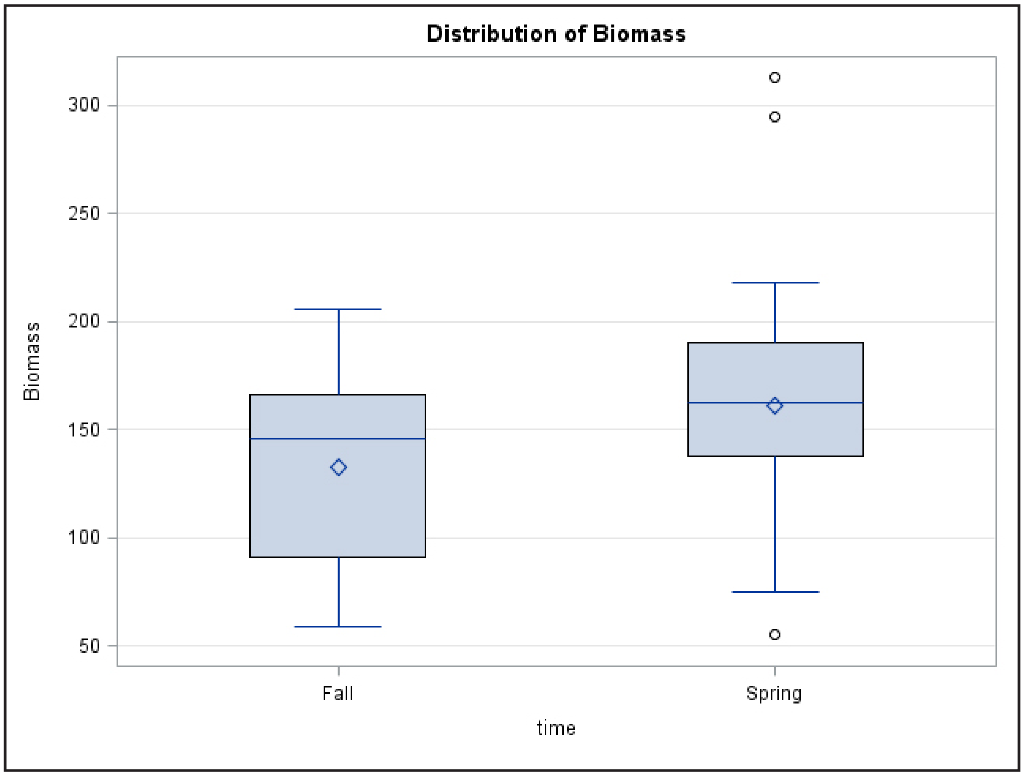

Figure 5. Aboveground biomass at Hays, summer 2012.

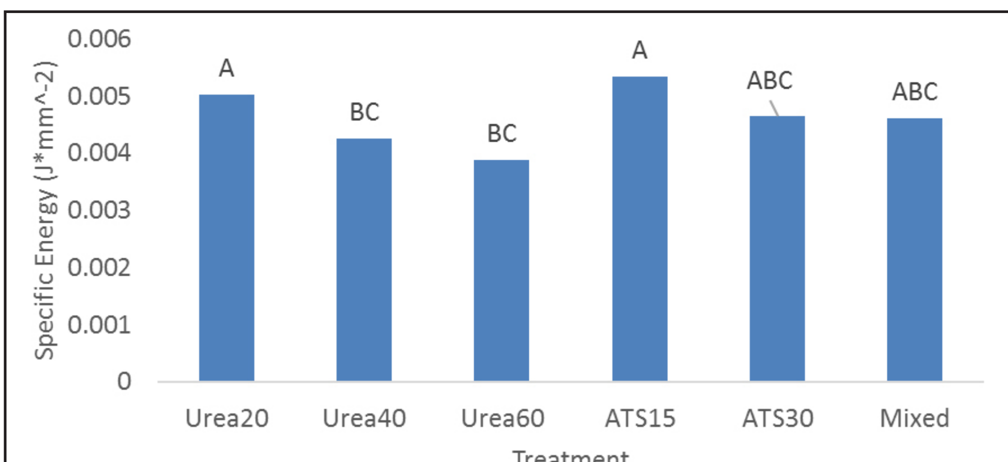

Figure 6. Effects of different treatments on specific energy of samples from Hays with fall 2011 fertilizer application.

energy from the samples taken in Hays. The specific energy of wheat straw from spring application plots is significantly lower than from fall application plots. One reason to cause this may be attributed to the strong winds. Apparently, highly decomposed residues are more easily blown away from some plots than others due to the weaker structure and lighter mass. Therefore, less decomposed residue may have a higher chance of remaining in the field. Thus, there was a higher possibility of collecting less decomposed samples from the field that gave higher specific energy.

For the shear stress of summer 2012, the Hays sample Urea60, with a fall 2011 application treatment, had significantly lower shear stress (Figure 9). It indicates a longer reaction period and a higher N rate can increase the decomposition speed. Similar to the specific energy, ATS seems to have no effect on the decomposition rate of wheat straw.

Colby. For samples from the Colby site in the summer of 2012, fall treatment plots had less aboveground biomass than spring treatment plots, indicating that a longer fertilizer application period can decompose more crop residue. Also, from the current results, specific energy seems more sensitive to fertilizer application timing and shear stress is more affected by fertilizer rates.

Looking ahead

We are going to conduct more detailed statistical analyses for better understanding of the effect of different N rates and S rates on wheat-straw decomposition.

Meanwhile, chemical analyses are also in process. Total carbon and total N will be reported.

We strongly favor chamber studies for better control on environmental variables such as wind, moisture, soil type, temperature, and solar radiation.

Mr. He and Dr. Presley are in the Department of Agronomy, Kansas State University, Manhattan, KS and Dr.Tatarko is in USDA-ARS, Manhattan, KS

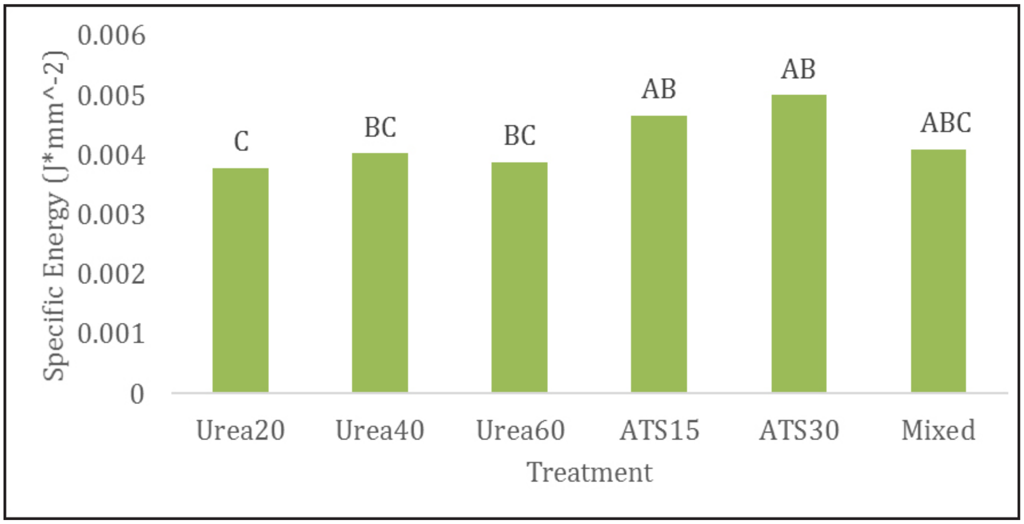

Figure 7. Effects of different treatments on specific energy of samples from Hays with spring 2012 fertilizer application.

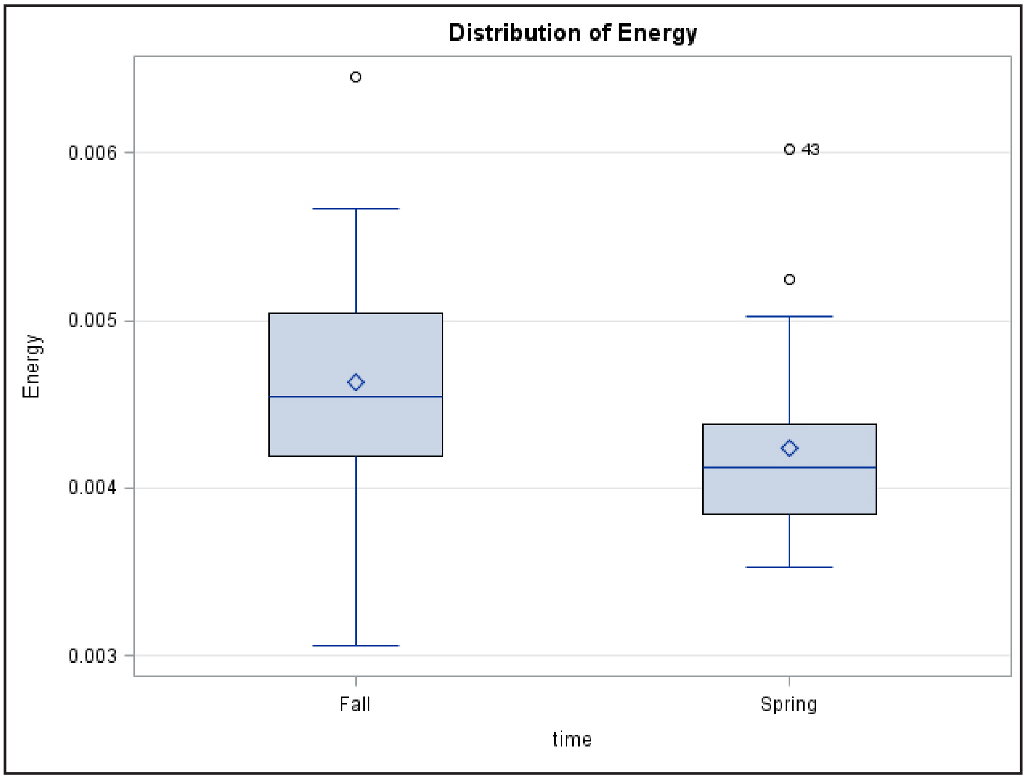

Figure 8. Timing effect on specific energy of samples from summer 2012, Hays.

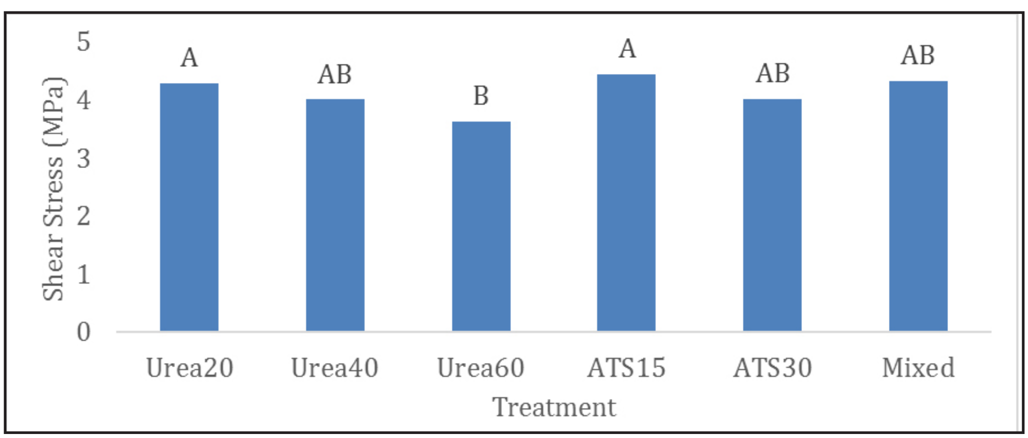

Figure 9. Effects of different treatments on shear stress of samples from Hays with fall 2011 fertilizer application..