Effect of UAN and ATS Solutions on the Decomposition of Wheat Residue in No-Till Systems

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Introduction

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. Lack of residue protection, surface soil is vulnerable to negative environmental and anthropogenic influences, such as wind blow, precipitation strike, dramatic temperature change due to the solar radiation, animal traffic, and 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 at certain areas (Presley and Tatarko 2009).

Producers adopt no-till farming system more and more today due to the fewer disturbances of soil and better retention of crop residue on the ground. Blanco-Canqui and Lal (2009) stated that indiscriminate removal of crop residue could drastically reduce the erosion benefit from no-till farming. Therefore, crop residue has been largely remained in the field after harvest for lowering the possibility of wind erosion in some regions today.

On the other hand, by having such large amount 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 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 sacrifice many benefits gained from no-till system.

In 2013, global wheat production was expected a 4.3% increase to 690 million tons (FAO, 2013). Unlike other crop residues, wheat straw is usually not considered as animal husbandry or other use (i.e. mushroom composting mixture) (Butler et al., 2013). Therefore, wheat straw, more likely, would be remained in the filed after harvest.

One recommendation extension specialists make is to apply nitrogen (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, sulfur (S) can be a limiting factor, especially after cultivation of high S demand plants such as alfalfa, to higher microbial activity. Therefore, ammonium thiosulfate (ATS) is also considered to fasten crop residue decomposition.

The objectives of this research are to conduct on-farm study to evaluate the effect of different UAN and ATS application rates on the decomposition of wheat straw and study the timing of UAN application and the effects on decomposition of residue.

Materials and Methods

Three research sites were establish in western Kansas in 2011 and 2012 right after the wheat harvest. They were in Hays, Colby, and Garden City respectively. A randomized complete block design with four replications was conducted in the experiment. The plots at each site were made in 6.1 meter by 6.1 meter size and were placed directly over the center of the where the combine traveled. 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. The UAN/ATS were applied at two different timings to separate plots, making a total of 13 treatments (table 1): the first timing occurred September after wheat harvest and the second timing took place in February second year before temperatures increase to favor microbial decomposition.

Residue samples were collected from every research plot in a 0.61 meter by 0.61 meter area in summer 2012, June 2013, and October 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 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.

A double shear using shear box was applied to test the shear stress and specific energy required to cut wheat straw. Figure 1 shows the design of the shear box. Shear box is consisted with two parallel aluminum plates (channel) 6 mm apart. Between them, the third plate (blade) can move up and down along the central axis freely. Five holes with diameters range from 2 mm to 6 mm were drilled on all three plates to accommodate different wheat straw sizes. Shear box was attached to the load cell of a tension/compression testing machine (figure 2). The blade plate 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:

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

Where

τ_s is the shear stress (MPa)

F is the shear force at failure (N)

A is the wheat straw wall area at failure cross-section (mm^2)

<table>
<tr><th></th><th>Treatment</th><th>N rate (kg/ha)</th><th>S rate (kg/ha)</th><th colspan="2">Fertilizer application timing</th></tr>
<tr><td>1</td><td>Control</td><td>0</td><td>0</td><td rowspan="7">Sept. 2011</td><td rowspan="7">Sept. 2012</td></tr>
<tr><td>2</td><td>Urea20</td><td>11.2</td><td>0</td></tr>
<tr><td>3</td><td>Urea40</td><td>22.4</td><td>0</td></tr>
<tr><td>4</td><td>Urea60</td><td>33.6</td><td>0</td></tr>
<tr><td>5</td><td>ATS15</td><td>7.7</td><td>16.8</td></tr>
<tr><td>6</td><td>ATS30</td><td>15.5</td><td>33.6</td></tr>
<tr><td>7</td><td>Mixed</td><td>49.1</td><td>33.6</td></tr>
<tr><td>8</td><td>Urea20</td><td>11.2</td><td>0</td><td rowspan="3">Feb. 2012</td><td rowspan="3">Feb. 2013</td></tr>
<tr><td>9</td><td>Urea40</td><td>22.4</td><td>0</td></tr>
<tr><td>10</td><td>Urea60</td><td>33.6</td><td>0</td></tr>
</table>

11	ATS15	7.7	16.8		
12	ATS30	15.5	33.6		
13	Mixed	49.1	33.6		

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

The specific energy was then calculated as:

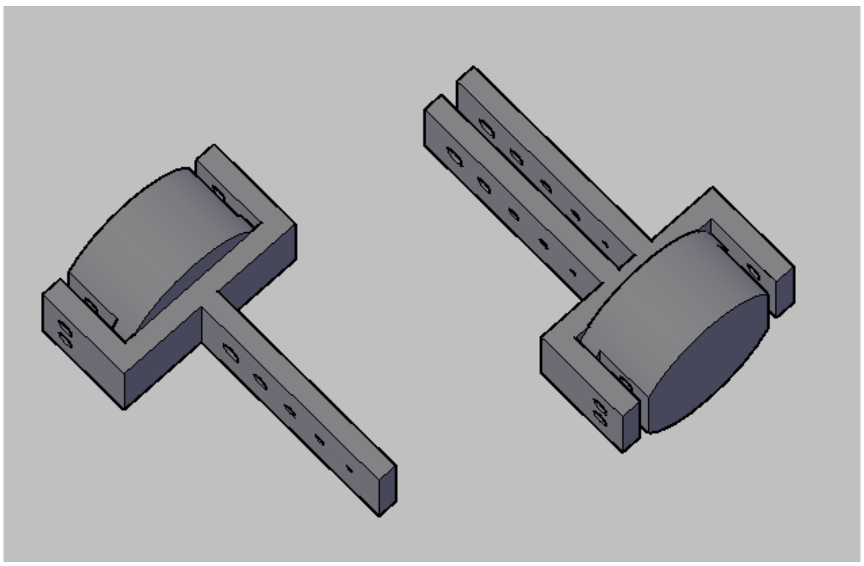
$$SE = \frac{TE}{A}$$

Where

SE is the specific energy (J/mm^2)

TE is the total energy (J)

A is the wheat straw wall area at failure cross-section (mm^2)



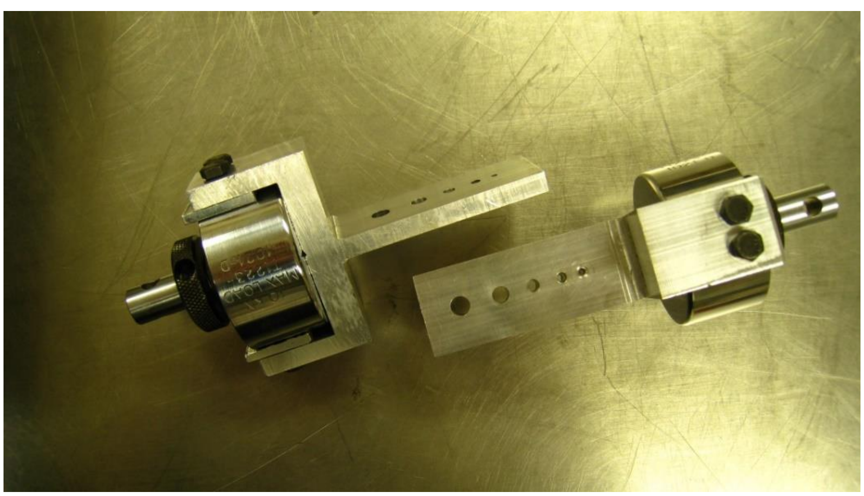


Figure 1. Design of shear box in AutoCAD 2010 and manufactured shear box.

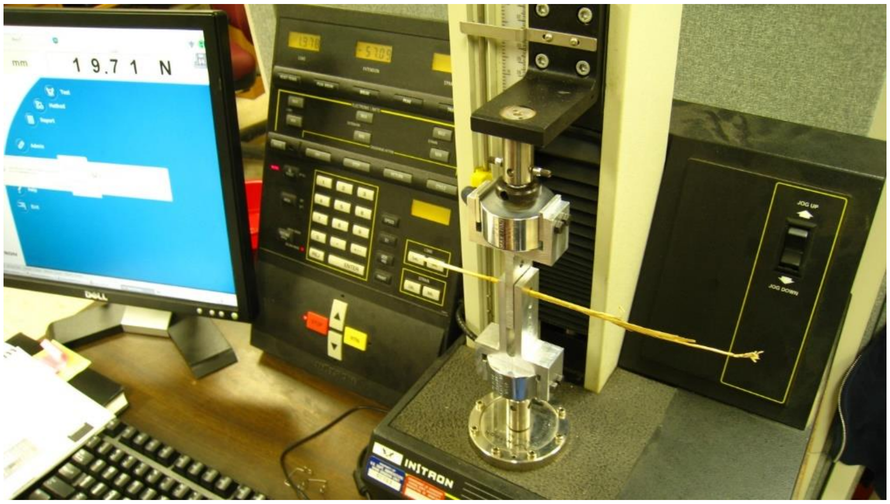


Figure 2. Shear box attached with load cell that hooked with a computer.

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 verses center blade movement was then graphed (figure 3).

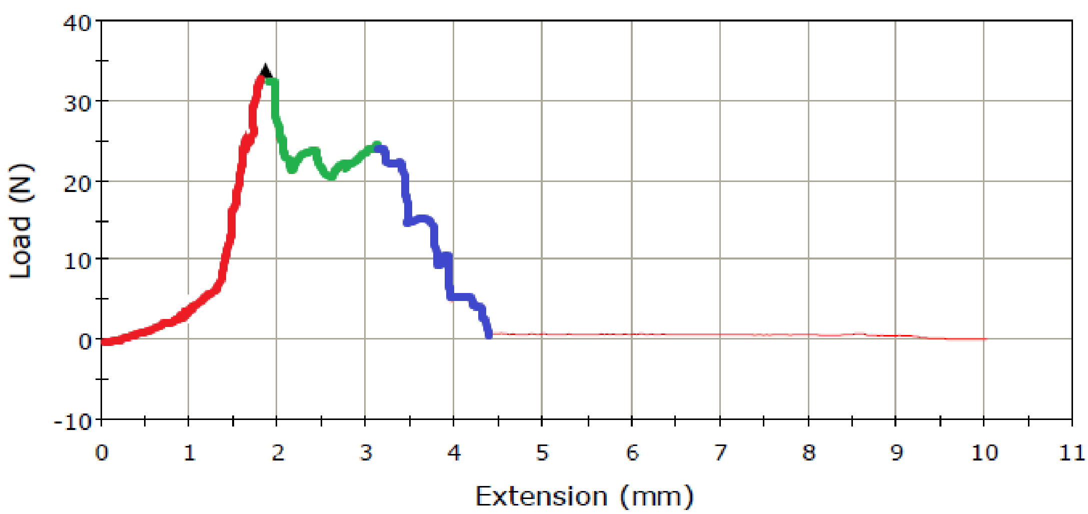


Figure 3. Shear force verses blade extension recorded by computer with different colors showing different shearing stages.

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-sectional area at the breaking point of wheat straw, a microscope and camera was utilized 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).

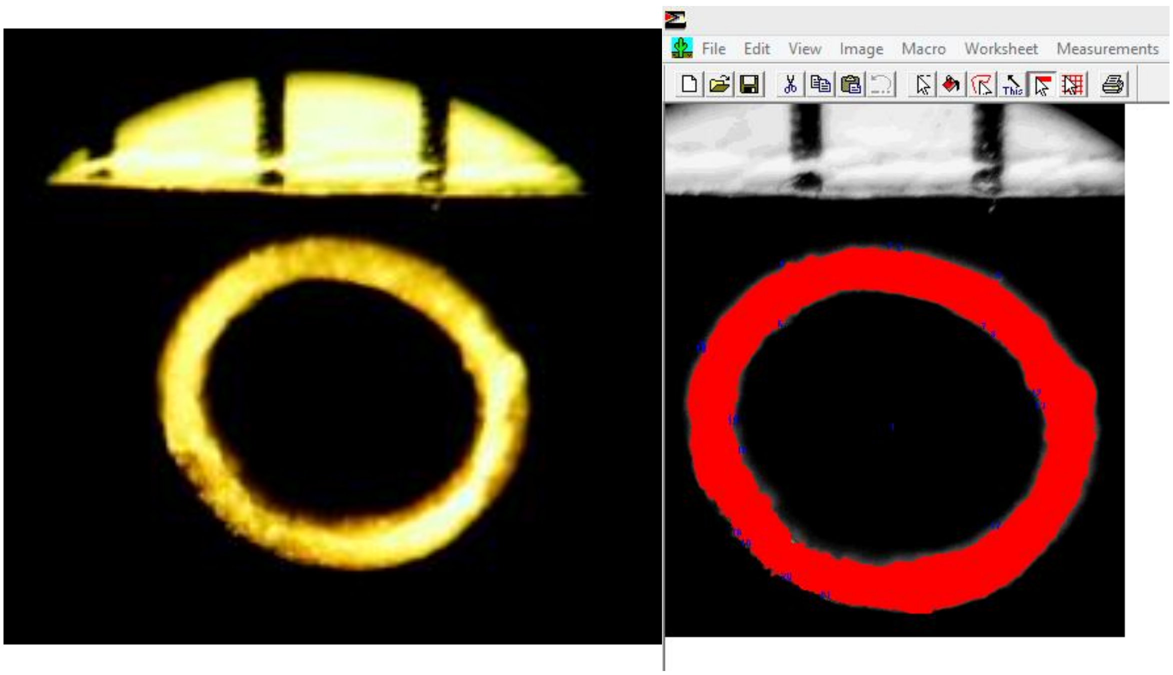


Figure 4. Image of wheat straw under microscope and being analyzed with SigmaScan 5 software.

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

Milestones and Current Results

Three sample periods were conducted in this experiment. In 2012, sample was collected from all three sites in summer time. In 2013, to better simulate the cultivation season, two sampling periods were conducted. They were in June and October 2013, respectively. For sample from Garden City of June 2013, we only collected the biomass data. Due to the severe wind blow weather situation in Garden City, all residue left on ground were blown away. We were not able to collect any standing residue during the fieldwork. In October 2013, we skipped Garden City site due to the consideration of weather.

Till January 2014, all fieldwork and lab work were completed. Data analysis is in process. In this report, we will focus on summer 2012 sample. We report the physical parameters including aboveground biomass, shear stress and specific energy.

In the experiment design, we considered two factors. They are treatment and timing. Using GLM and MIXED procedures in SAS 9.3, we conducted two-way ANOVA analysis.

2012 summer							
		Biomass		Specific Energy		Shear Stress	
		F-value	P-value	F-value	P-value	F-value	P-value
Colby	Trt*	0.26	0.9329	0.66	0.655	1.14	0.3613
	time	2.85	0.1022	0.21	0.6519	0.24	0.6295
	trt*time	1.41	0.2513	0.34	0.8828	0.74	0.6021
Hays	trt	0.62	0.686	4.6	0.0025	2.3	0.0662
	time	0.05	0.8253	5.96	0.0199	1.82	0.1862
	trt*time	0.5	0.7724	2.09	0.0896	1.51	0.2112
Garden City	trt	1.51	0.2115	3.81	0.0071	0.97	0.4496
	time	0.37	0.5484	0.54	0.4659	1.6	0.2136
	trt*time	1.27	0.2979	1.38	0.2561	2.56	0.044

* Treatment

Table 2. Two-way ANOVA statistical analysis results of summer 2012 sample.

In table 2, the data in red indicate there is a significant difference level exist in the data. We only report the data that has significant difference level (in red).

Figure 5 shows the aboveground biomass different between 2011 fall application treatment and 2012 spring application treatment. According to the graph, 2011 fall application plots have less biomass. Longer fertilizer application period seems decompose more wheat straw. Theoretically, longer reaction time could make the wheat straw weaker than short application period. Also, wind blow can take wheat straw with lower resistant ability away from plots. Therefore, fall application plots may have less residue remained compared to the spring application plots. However, through table 2, this phenomena was only observed at Hays site. Also, treatment does not make any difference on aboveground biomass among all three sites.

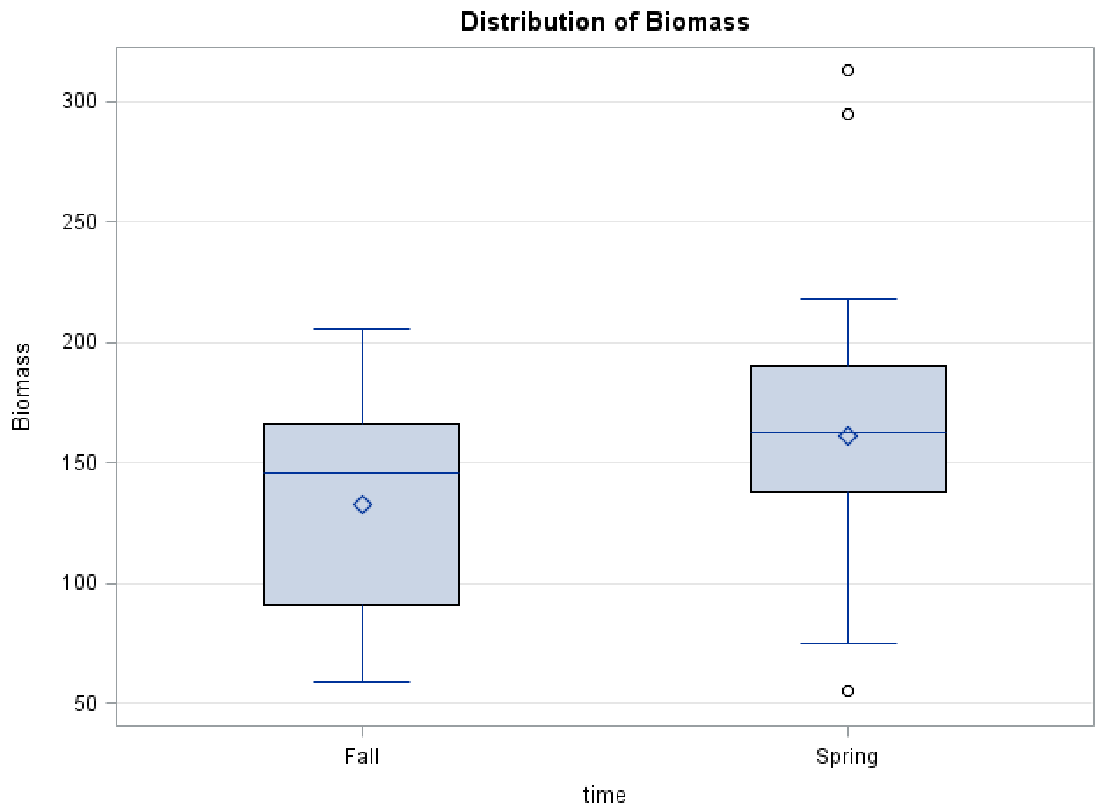


Figure 5. Aboveground biomass at Hays, summer 2012.

Figure 6 shows the specific energy required by the shearing test for the samples from fall fertilizer application treatment plots at Hays. Specific energy decreased significantly with increasing amount of UAN usage. However, there is no significant difference between Urea40 and Urea 60 on specific energy measured. Furthermore, ATS seems have no effect on specific energy.

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

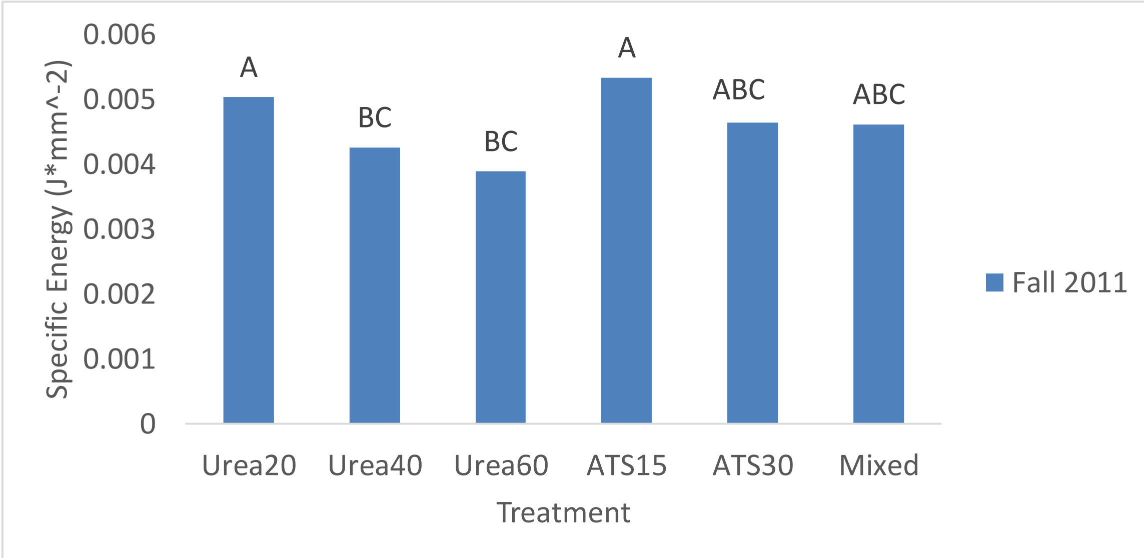


Figure 6. Effects of different treatments on specific energy of samples from Hays with fall 2011 fertilizer application.

Since there is timing and treatment interaction, we need to look at the timing effect individually. Figure 8 shows the effects of timing on specific energy of samples from Hays.

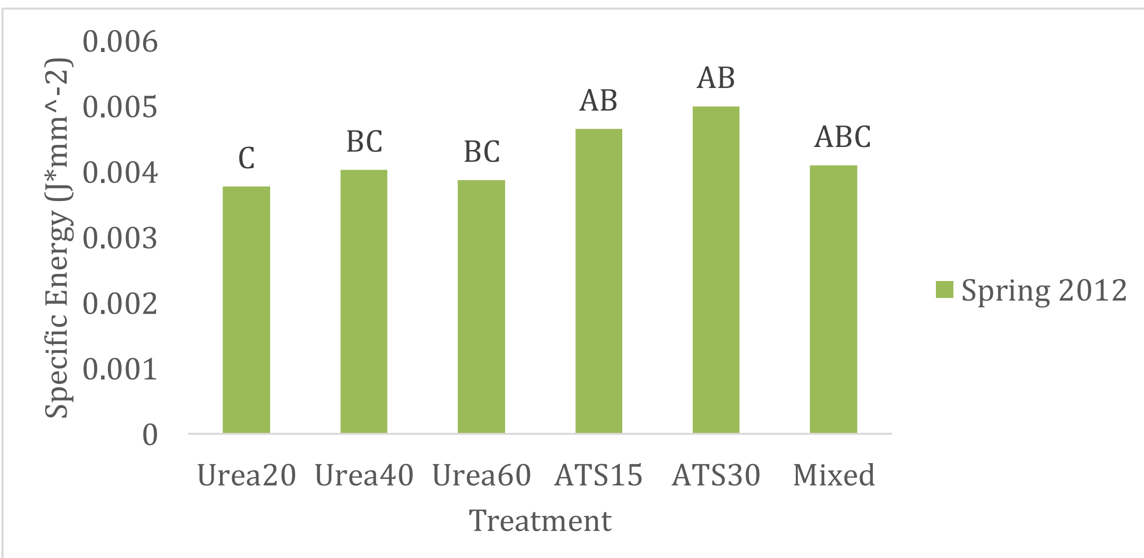


Figure 7. Effects of different treatments on specific energy of samples from Hays with spring 2012 fertilizer application.

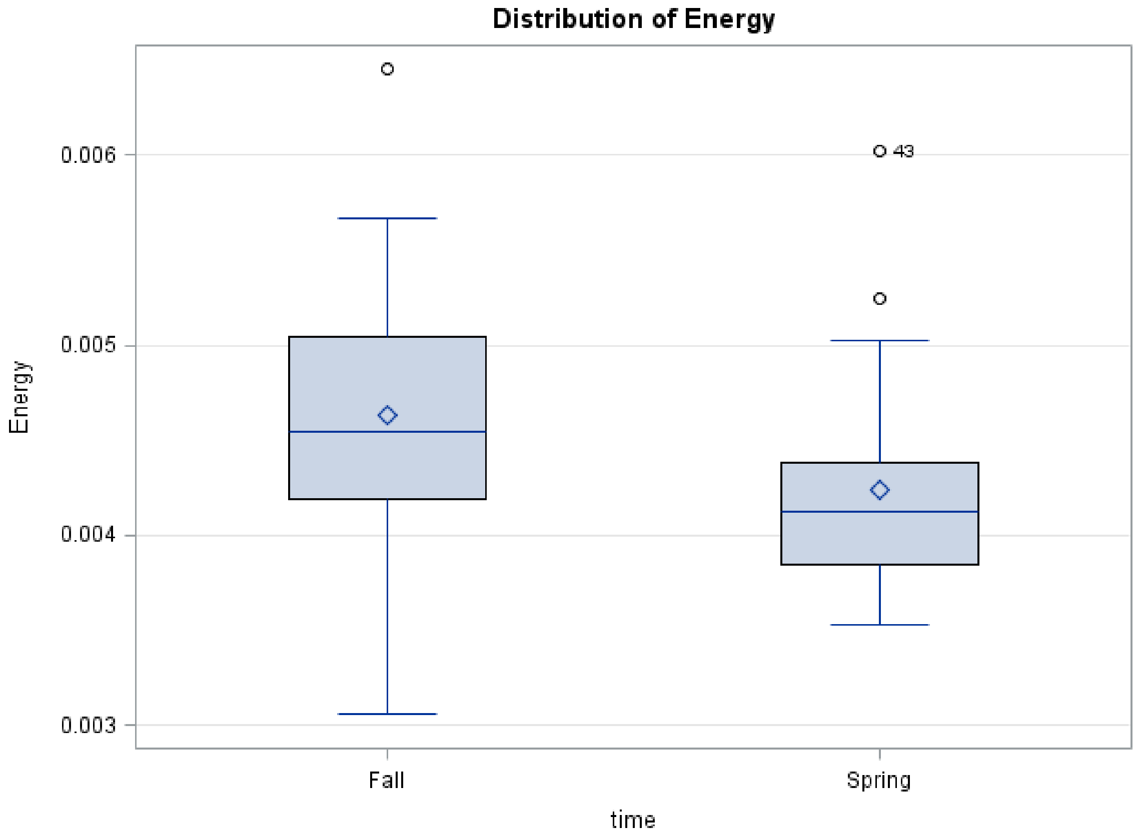


Figure 8. Timing effect on specific energy of samples from summer 2012, Hays.

From figure 8, the specific energy of wheat straw from spring application plots are significantly lower than from fall application plots. One reason to cause this may be attributed to the wind blow. Apparently, highly decomposed residues are easier to be blown away from plots than the others due to the weaker structure and lighter mass. Therefore, less decomposed residue may have higher chance to be remained in the field. Thus, there was high possibility to collect less decomposed sample from the field that gave higher specific energy.

For the shear stress of summer 2012 Hays sample, urea60 with fall 2011 application treatment had significantly low shear stress (figure 9). It indicates longer reaction period and higher amount of N rate can increase the decomposition speed. Similar to the specific energy, ATS seems have no effect on decomposition rate of wheat straw.

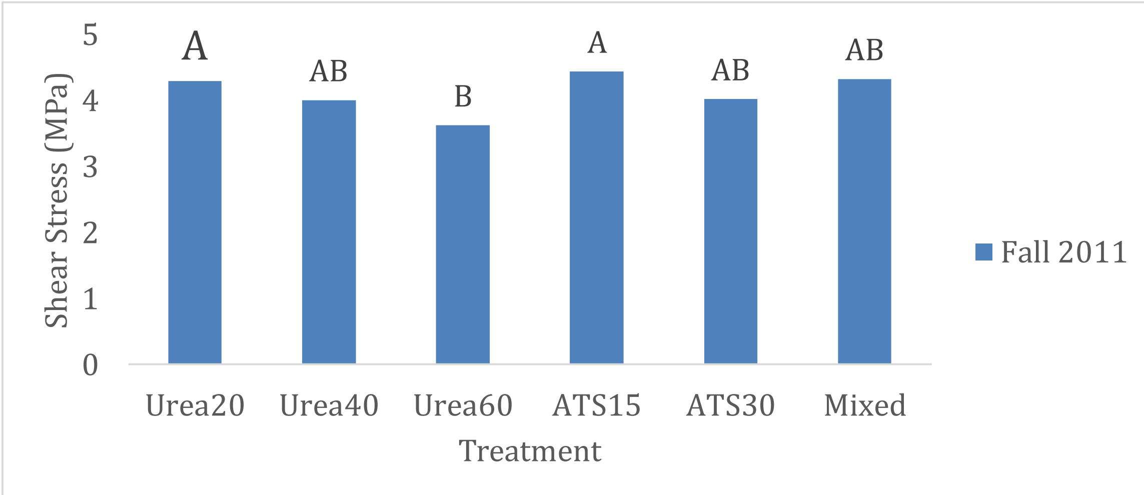


Figure 9. Effects of different treatments on shear stress of samples from Hays with fall 2011 fertilizer application.

Conclusions

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

Future Work

We are going to conduct more detailed statistical analysis for better understanding the effect of different N rates and S rates on wheat straw decomposition. Meanwhile, chemical analysis is in process. Total carbon and total N will be reported. We strongly suggest chamber study for better control of environmental variables such as wind blow, moisture content, soil type, temperature, and solar radiation. Final report of this study will be submitted in middle of 2014 and a paper related to this study will be published in peer-reviewed journal in 2014.

Reference:

Blanco-Canqui, H., and Lal, R. 2009. Crop residue removal impacts on soil productivity and environmental quality. *Critical Reviews in Plant Science.* **28**: 139-163.

Butler E., Devlin G., Meier D., McDonnell K., 2013. Characterisation of spruce, salix, mischanthus and wheat straw for pyrolysis applications. Bioresource Thechnology. 131: 202-209

Presley, D and Tatarko, J. 2009 Principles of wind erosion and its control. Kansas State University, MF-2860