IMPLICATIONS OF RESIDUE REMOVAL ON SOIL QUALITY IN SOUTHWEST KANSAS

by

NICHOLAS ADAM IHDE

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Major Professor
Dr. DeAnn Presley

Abstract

Through the 2007 Energy Independence and Security Act, the U.S. government has set goals to decrease fossil fuel use and sustainably produce ethanol from biomass, rather than existing corn grain-based ethanol. In southwest Kansas, crop residues are necessary to protect soil from erosion and to contribute to soil organic carbon (SOC) levels, a key factor in most desirable characteristics of soil quality, and are positively related to soil and crop productivity. Our objective was to quantify the effect of different residue management treatments (residue continuously retained, residue continuously removed, and alternating year residue removal) on soil physical properties, chemical properties, and corn yield. For 2.5 years, measurements and samples were collected from a Hugoton loam (L) and Bigbow fine sandy loam (FSL) in southwest Kansas. Residue continuously removed decreased water stable aggregates ≥ 0.25 mm and mean weight diameter of aggregates in contrast to residue continuously retained treatments following two winter seasons at the Bigbow FSL site. In residue continuously removed treatment for the Bigbow FSL, dry aggregate size distribution (ASD) measurements at the soil surface in the fine sandy loam had higher levels of soil % < 0.84 mm (wind erodible fraction) during the winter season of 2008-2009 and 2009-2010 by 6% and 15%, respectively. No significant differences in wet aggregate stability and ASD were measured at the Hugoton L site. Soil temperature and moisture levels monitored during the winter season showed a higher frequency of freeze-thaw cycles, which can be destructive to aggregates, in residue continuously removed plots. During the winter seasons of 2008-2009 and 2009-2010, the residue continuously removed treatments experienced three more freeze-thaw cycles than the residue continuously retained treatments in the Bigbow FSL soil. Bulk density measurements were variable, and no significant differences due to residue treatment were observed in both the loam and fine sandy loam. Total C, N, and exchangeable K were significantly different in residue continuously retained and removed plots due to residue treatment following 1 year of establishment of the study in the FSL. Total C was 14 g kg^{-1} and 8.7 g kg^{-1} in the

residue continuously retained and removed treatments, respectively. Total N was 0.3 g kg^{-1} higher in the residue continuously retained versus the residue continuously removed treatment in the FSL. Irrigated continuous corn in southwest Kansas produces a lot of biomass, and has been reported to create emergence problems in the past. Corn emergence was slightly higher in residue continuously removed treatments in both the spring of 2009 and 2010, but differences were insignificant. No significant treatment effects on corn grain yield were observed in the duration of the study.

Table of Contents

List of Figures

List of Tables

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Chapter 1 - Literature Review

Currently, the United States accounts for 47% of global bio-ethanol production (Balat and Balat, 2009). In 2010, the U.S. produced a record high 50.1 billion liters, up from 18.2 billion liters in 2006. Through the 2007 Energy Independence and Security Act (EISA), the U.S. has set a production goal of 125 billion liters by 2020 (Balat and Balat, 2009). In the past and at present, corn (Zea mays L.) grain is and has been the primary source for ethanol, but as new technology emerges and cost of production decreases, crop residues have been identified as a replacement of grain for ethanol production (Perlack et al., 2005). The EISA of 2007 set production goals in steps to allow for technology and industry growth (Wisner, 2009). With an emphasis of transitioning ethanol production from primarily grain to residue, interest in residue removal implications to the environment have increased. Wilhelm et al. (2004) found the collection of crop residues as a feedstock for biomass ethanol to be an appropriate solution to help solve the United States' over-reliance on imported fuels. However, residue harvest from agricultural lands can induce soil environmental degradation with detrimental effects on soil quality and sustainability of natural resources (Lal, 2005). Multiple studies have reported net losses of soil organic carbon (SOC) by anywhere from 20-60% in the first 50 years on agricultural lands following conversion from native prairie or forest (Huggins et al., 1998; Janzen et al., 1998; Lal et al., 1998; Follett et al., 1997). Crop residues contribute to SOC levels, protect the soil from erosion, and are directly related to desirable soil characteristics and crop productivity (Lal, 2004; Wilhelm et al., 2004; Johnson et al., 2006). Cropping systems that focus on diverse crop rotations and conservation tillage practices that maintain crop residues on the soil surface, have the ability to produce greater biomass and limit or reverse the loss of SOC (Lal et al., 1998; Allmaras et al., 2000; Reicosky and Allmaras, 2003). Graham et al. (2007) recently inventoried potential current and future corn stover supplies throughout the United States. The research examined factors such as the efficiency of harvesting stover, soil moisture, and erosion constraints. The group found that 28% of stover produced in the United States could be sustainably collected. However, if farmers chose to universally switch to no-till corn management, then the amount of sustainably-harvested stover could double. The study did not factor in the need to maintain or enhance soil organic matter or tilth. Sustainable levels of harvestable stover may actually be lower when these two factors are considered. For that reason, the sustainability of removing crop residues for use in energy production has been questioned. Wilhelm et al. (2004) found the collection of crop residues as a feedstock for biofuels to be an appropriate solution to help solve the United States' increasing greenhouse gases in the atmosphere. There is, however, no consensus among researchers on this topic. The following section reviews several papers on the effects of crop residue removal and sustainability.

Residue Removal and Soil Physical Properties

Crop residues protect the soil surface from wind and water erosion, improve soil physical properties, and provide nutrients to the soil (Lindstrom, 1986; Skidmore et al., 1986; Steiner et al., 2000; Dabney et al., 2004; Blanco-Canqui and Lal, 2007). Moebius et al. (2008) found in a study of long–term effects of harvesting corn stover that soil organic matter (SOM) decreases over time when the corn stover is removed. Crop residues replenish and increase SOM concentrations in soils where residue remains on the soil surface following harvest. Oades and Waters (1991), report that the stability of soil aggregates is primarily controlled by SOM in mineral soils. Stability of macroaggregates (>250 μm) is dependent upon roots and fungal hyphae; whereas, microaggregates (<250 μm) stability is a function of organic mineral complexes within the aggregates (Tisdall and Oades, 1982). Enhancing SOC can improve soil physical properties, aggregate stability, microbial activity, and improve water cycling (Kay, 1998; Collins et al., 2000).

In a 2 year study on three different soil series in Ohio, higher rates of residue removal led to weakened soil aggregates, reduced water-stable macroaggregation, and increased microaggregation

(Blanco-Canqui et al. 2006b; Blanco-Canqui and Lal, 2009b). In other research, residue removal has not been found to have any significant effect on wet aggregate stability of soils (Skidmore et al., 1986; Karlen et al., 1994). Karlen et al. (1994) removed residue for 10 consecutive years and did not find any reduction in wet aggregate stability of a no-till silt loam. It has been noted in many studies that effects of residue removal are site-specific and further research is needed to determine residue removal effects on a range of soils in different regions.

Residue also serves as a protective barrier from climatic conditions (e.g., high wind velocity, low precipitation, freeze-thaw cycles, and freeze-drying periods) that work to break down aggregates in the soil (Chepil and Woodruff, 1963; Bullock et al., 1988; Lehrsch et al., 1991; Staricka and Benoit, 1995; Larney et al., 2003). Chepil and Woodruff (1963) explain extensively that unfavorable weather conditions work to destabilize soil aggregates in the soil surface. It has been well noted that residue helps control fluctuations in soil temperature and moisture levels (Bristow et al., 1988; Horton et al., 1994; Larney et al., 2003). Bristow et al. (1988) and Horton et al. (1994) report that in soils with no residue cover, the soil temperature rises faster during the spring season. Soils covered with residue remain cooler longer and dominate the energy exchange at the soil surface. Larney et al. (2003) measured soil temperature during from 1993-1995 in southern Alberta during two winter wheat (*Triticum aestivum* L.) growing seasons in a conventional and no-till system. On average, over the two monitoring periods from late fall to early summer, soil under conventional till was warmer than soil under zero till at 2.5 cm depth for about 70% of the time, while soil under no-till was warmer than soil under conventional till for about 30% of the time (Larney et al., 2003). Their results displayed that no-till promoted cooler soils from late fall to early summer but controlled extreme fluctuations in soil temperature during extremely cold periods. Temperature differences observed in the study may have implications on plant and weed growth, insect pest survival, soil physical, chemical, and microbial processes (Larney et al., 2003).

With the understanding that residue plays an important role in regulating soil temperature and moisture, it is important to look at the effect that frost action may have on soil aggregates during the winter season. Bullock et al. (1988) concluded that seasonal changes in stability of Utah soils were much larger than the difference between soils or differences caused by residue. Decrease in stability was attributed to ice crystals expanding in pores between particles, breaking particle-to-particle bonds, and effectively splitting the larger aggregates into smaller aggregates (Bullock et al., 1988). Lehrsch et al. (1991) performed a study to determine the freezing effects on aggregate stability as affected by texture, mineralogy, and organic matter. They found that in >85% of the cases, aggregate stability decreased as water content increased when subjected to freeze-thaw cycles. In the coarse-textured soils, little energy and few freeze-thaw cycles were needed to effectively weaken the aggregates of the sandy loams (Lehrsch et al., 1991). In addition to freeze-thaw events, freeze-drying can be very detrimental to soil aggregates and has received only limited attention (Staricka and Benoit, 1995). Staricka and Benoit (1995) reported that thawing of moist soils results in more cohesion of aggregates to a degree; however, freeze-drying removes water from the soil by sublimation, thus avoiding any aggregation building cohesion between particles. Freeze-drying effects increased as the water content and aggregate size increased.

Not only does aggregate stability provide a measure of soil quality, but bulk density and cone index can be indicative of compaction, another measure of soil physical properties and soil quality (Blanco-Canqui and Lal, 2009a). Crop residue can lead to a reduction in bulk density in two manners. First, residue left on the soil surface absorbs and dissipates compactive forces. Secondly, decomposition of crop residue adds SOM to the soil, which has a low density, and helps lower the overall bulk density of the mineral fraction. In as little 1 year, Blanco-Canqui et al. (2006a) determined that residue removal can affect soil crust strength properties in a negative manner. Increased bulk density, cone index, and shear strength of soil occurred following residue removal from cropland for all three of the Ohio soils in the study. In a study by Power et al. (1998), when crop residue was returned to the soil surface during the 8 year study, bulk density decreased. Karlen et al. (1994) found no increases in bulk density and cone index during a 10 year residue management study. Skidmore et al. (1986) established different residue treatments on hard red winter wheat and grain sorghum (*Sorghum bicolor* L.) plots in Garden City, KS on a Richfield silty clay loam. Treatments included: incorporation of the residue produced during the immediate past cropping season, incorporation of twice the amount of reside produced by the crop, residue removed by baling and hauling, and residue removed by burning. The study found that most soil physical properties measured (e.g., aggregate size distribution, bulk density, and wet aggregate stability) were influenced minimally by the different residue treatments.

Decreased aggregate stability, increased surface compaction, and increased soil crusts can limit water infiltration, and lead to accelerated erosion (Wilson et al., 2004). Large soil aggregates and clods at the soil surface can increase surface roughness, which in turn can lead to reduced erosion from wind and water (Chepil and Woodruff, 1963; Steiner et al., 2000). According to Trimble and Crosson (2000), soil is eroding at a rate of 2 to 6.8 billion tons per year in the United States. Recent reductions in erosion can be attributed to no-till management practices and the anchored residue left on the surface. Crop residues contribute to erosion control by protecting the soil surface with non-erodible materials (cover) or by changing the surface conformation to alter the flow of water and wind across the surface (roughness or resistance) (Steiner et al., 2000). Returning the residue to the surface can help eliminate and deter erosion. Armburst et al. (1982) conducted a study to investigate the effects of different crop residues on dry soil aggregation. Crops producing greater dry matter were found to protect aggregates, and reduce the wind erodible fraction (WEF) (% <0.84 mm). Type of crop residue affected erodibility of soils, but amount of residue is important as well. Fryear (1985) investigated soil cover and wind erosion and found soil loss was directly related to the percent of soil surface covered by non-erodible elements.

In Fryear's study, residue was measured using a percent coverage method, rather than measuring the mass of residue per amount of area.

Not only does residue provide protection from wind erosion, it also limits water erosion. In arid and semi-arid regions, wind erosion is the primary concern and water erosion in areas that receive adequate rainfall. Lindstrom (1986) studied the effects of residue harvesting on water runoff, soil erosion and nutrient loss in the northwestern Corn Belt (U.S.A.). Residue harvesting increased water runoff and soil erosion for both the reduced tillage and no-till plant systems measured in the study. Soil loss of a loess-derived soil was researched by Dabney et al. (2004) in northern Mississippi. Residue removal treatments resulted in one-third the soil loss in long-term no-till compared to conventional (Dabney et al., 2004).

Residue Removal and Chemical Properties

Removal of crop residues can reduce soil fertility because residues provide essential soil macro- (e.g., K, P, N, Ca, and Mg) and micronutrient (e.g., Fe, Mn, B, Zn, and S) through decomposition (Blanco-Canqui and Lal, 2009a). In decomposition, crop residues are vital in the recycling of SOM and important nutrients in the soil system. Blanco-Canqui and Lal (2009b) reported decreases in total C and N after 4 years of residue removal on three different soil types studied in Ohio. Similar research by Blanco-Canqui and Lal (2007) noted that stover removal rates >25% strongly reduced SOC, and the extent of reduction of total C and N was dependent on residue removal rate and soil type. Recent studies have reported changes in nutrient levels in as little as 1 year (Blanco et al., 2006b), but long-term studies have been established to determine effects of residue removal for corn silage usage (Wilts et al., 2004; Hooker et al., 2005) and can be useful in examining long-term effects. In a long-term (28-yr) tillage and silage removal study, no difference in SOC between silage harvested and stover returned with no-tillage was observed (Hooker et al., 2005); however, silage harvest and moldboard plowing created dramatic SOC losses (Wilts et al., 2004; Hooker et al., 2005). Similar reductions in total C and N have been observed by

Karlen et al. (1994), but little differences in macronutrients were observed due to residue management treatments. When residue was returned to the soil surface, Power et al. (1998) observed slight increases in soil N levels. In other research, Andraski and Bundy (2008) found that cooler soil temperatures in residue retained treatments decreased soil N mineralization, rather than their previously suspected belief that N was immobilized in soil with residue retained at the surface. From the different studies, it was noted that many different factors can affect nutrients pools in the soil based on the different residue management treatments. Rate of removal, rate of residue decomposition, quality of residue, tillage practices, rate of fertilizer application, soil characteristics, and climate all impact the reduction of nutrients with various levels of residue removal (Blanco-Canqui and Lal, 2009a). Blanco-Canqui and Lal (2009b) noted that residue removal on a sloping silt loam reduced the concentrations of macronutrients in the upper 0-10 cm but also the 10-20 cm depth. On nearly levels sites, total C and N and exchangeable K were the only nutrients reduced from residue removal. On sloping sites, erosion of soil particles is the primary mechanism for nutrient removal, particularly N and P, and can be significant when soil erosion tolerance levels are approached (Lindstrom et al., 1986). Lindstrom et al. (1986) also noted that nutrient removal by residue harvest only became significant at high levels of residue harvest, specifically K. Not only have differences in topography been examined, but differences in texture may affect the impact of residue removal on soil nutrient levels. Karlen et al. (1984) conducted a study on a sandy loam to determine any effects that residue removal may have on a coarse-textured soil, and found that harvesting residues increased the annual N, P, and K removal, impact of nutrient depletion was dependent upon season, water management, and rate of corn residue removed. Through these different studies, it is apparent that nutrient reduction in soils is highly variable and dependent on many factors (e.g., rate of removal, rate of residue decomposition, soil characteristics, and climate).

Residue Removal and Corn Yield

Maintaining and building soil quality is important to responsible producers, but often most are concerned with improving their crop yields and profitability for their farming operation. Not only is yield good for a farmer's profitability, but it is also a good indicator of a soil's overall health. In studies that measured the effects of residue removal on corn yield, the results have been unpredictable and dependent on many different factors. Corn yields can be affected in positive and negative ways depending on tillage method, cropping system, soil-specific characteristics (e.g., texture and drainage), topography, and climate during the growing season (Blanco-Canqui and Lal, 2009a). In arid regions, such as the western Great Plains, water shortage is the limiting factor in dryland crop production (Stone et al., 2008). Producers, particularly those who grow corn, are dependent on irrigation from the underlying Ogallala aquifer. Since the beginning of extensive groundwater irrigation ~1950 to 2003, McGuire (2004) has reported declines (>45 m) in some areas of western Kansas, east-central New Mexico, the Oklahoma Panhandle and western Texas where crop productivity is dependent on irrigation.

Production systems that maintain surface residue can affect soil temperature, soil water, and soil chemical and physical properties that also affect grain production (Swanson and Wilhelm, 1996). It is not always possible to control soil moisture, but the soil cover can be manipulated with the use of mulch and mulch tillage (Willis et al., 1957). Karlen et al. (1984), under rain-fed conditions, reported no decrease in yield in 1980, a decrease in yield by 0.88 Mg ha^{-1} in 1981, and an increase of 0.52 Mg ha^{-1} in 1982 where residue was removed at rates up to 90% on a sandy loam in South Carolina. In another study conducted by Karlen et al. (1994), 10 consecutive years of residue removal had no effect on corn yields in 8 out of 10 years on two silt loam soils in Wisconsin. In a study in Iowa on the effects of residue removal on corn yield and yield components, increased soil temperature hastened plant emergence, increased the rate of growth, and increased corn yields to a point as the soil temperature increased under reduced mulch levels (Willis et al., 1957). In Nebraska, residue management rates did not affect yield or yield components (Swanson and Wilhelm, 1996). Power et al. (1998) collected data in a study researching the effects of crop residues on grain production and some selected soil properties. Over a range of 8 years, the group found that increased residues left on the surface increased future yields of corn. Linden et al. (2000) observed that delayed crop establishment by wet and cold soils, resulted in decreased yields. Tillage and residue treatments had insignificant effects on yield, and yield was primarily limited by differences in early season rainfall rather than residue management (Linden et al., 2000).

The importance of soil moisture on corn yield and stand establishment was discussed in the previous paragraph, but moisture is just one of the factors affecting corn yield and yield components. Soil temperature also plays an important role in the establishment and early growth of corn. Beyaert et al. (2002) conducted a tillage effects (e.g., conventional till, zone till, and no-till) on corn production in a coarse-textured soil study in southern Ontario. Initial corn seedling emergence occurred on the same day for all treatments, but the rate of seedling emergence differed slightly among tillage treatments (Beyaert et al., 2002). Even though different emergence rates were observed, it could not be directly attributed to differences in soil temperature at a depth of 4 cm in different tillage treatments. Horton et al. (1994) noted that retaining surface mulch can reduce the springtime soil temperatures, and can have either negative or positive effects, depending on the situation. Blanco-Canqui et al. (2006c) determined that stover removal can negatively impact corn production and soil properties within a short time after removal, depending on the soil. Uneven emergence and plant height was attributed to changes in soil water content and soil temperature dependent on residue management in three Ohio soils (Blanco-Canqui et al., 2006c).

Justification and Objectives

The United States has set a goal to reduce fossil fuel gas consumption by 20% by the year 2017. The EISA (2007) has set biofuel production levels in stages for the allowance of technology and industry to grow as the U.S. works to lower dependence on fossil fuels. Through the EISA (2007), the U.S. government has started a program to decrease fossil fuel use and sustainably produce ethanol from biomass, rather than existing corn grain-based ethanol. Corn stover, and other crop biomass or residue, has been referred to as "trash" or agricultural waste in the past (Lal, 2004). However, crop residues are an important source of SOC, limit soil erosion, and contribute to beneficial characteristics of soil quality which in turn directly affect soil and crop productivity (Lal, 2004; Wilhelm et al., 2004; Johnson et al. 2006).

In southwest Kansas, some producers who irrigate have reported that they have an abundance of crop residue, and would be interested in selling residue for the production of cellulosic ethanol. The U.S. Department of Energy selected a project proposed by Abengoa Bioenergy near the town of Hugoton, KS for funding, and a required Environmental Impact Statement has recently been completed. The facility is expected to process 2,500 short tons of cellulose material per day from sources such as crop residues, dedicated bioenergy crops such as switchgrass, etc. (Tedlock et al, 2011). Studies have been performed across the country researching the sustainability and effects of residue removal on soil quality (Karlen et al., 1984 and 1994; Blanco-Canqui et al., 2006a; Blanco-Canqui and Lal, 2009b). Results from all studies have been highly variable and dependent on many different characteristics inherent to the soil and location of research. Loess and eolian sand-derived soils are common in southwest Kansas (Web Soil Survey, 2009), and since these soils are sensitive to wind erosion, crop residues serve a critical role in soil conservation and farming practices. Further research into residue management and soil quality in southwest Kansas is needed to evaluate if there are any implications of residue removal. Therefore, the objectives of the research project were to:

I. Quantify the effect of residue management on soil quality comparable to common farming practices in southwest Kansas on two soil textures.

   i. Determine the impact of residue removal on soil physical properties (Chapter 2).
   ii. Determine the impact of residue removal on susceptibility to wind erosion of soil (Chapter 2).
   iii. Quantify any measurable changes in corn yield as a result of residue management (Chapter 2).
   iv. Quantify any changes in bulk density (Chapter 3).
   v. Measure impacts of residue removal on soil chemical properties (Chapter 3)
   vi. Determine the effect of residue removal on corn emergence (Chapter 3).

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Chapter 2 - Residue Removal on Sensitive Soil Properties

Abstract

Through the 2007 Energy Independence and Security Act (EISA) of 2007 (Perlack et al., 2005), the U.S. government has outlined goals to decrease fossil fuel use and sustainably produce ethanol from biomass, rather than existing corn grain-based ethanol. In southwest Kansas, irrigated crop residues are both very abundant and vital for protecting soil from erosion. In addition, crop residues contribute to soil organic carbon (SOC) levels, a key factor in most desirable characteristics of soil quality, and positively related to soil and crop productivity. Our objective was to quantify the effect of different residue management treatments (residue continuously retained, residue continuously removed, and alternating year residue removal) on selected soil properties, parameters used to estimate wind erosion potential, and corn (*Zea mays* L.) yield on a fine sandy loam and loam soil between November 2008 and March 2011. Concentration of water-stable aggregates (WSA) ≥ 0.25 mm and mean weight diameter (MWD) of aggregates was greater in residue continuously retained treatments in spring of 2009 and 2010 following the winter season in the fine sandy loam at the 0-5 cm soil depth. In residue continuously removed treatments, dry aggregate size distribution (ASD) measurements at the soil surface in the fine sandy loam textured soil had higher levels of soil %< 0.84 mm (wind erodible fraction) during the winter season of 2008-2009 and 2009-2010 by 6% and 15%, respectively. Soil temperature and moisture levels monitored during the winter season showed higher frequency of freeze-thaw cycles, which can be destructive to aggregates, in residue continuously removed plots. During the winter seasons of 2008-2009 and 2009-2010, the residue continuously removed treatments experienced three more freeze-thaw cycles than the residue continuously retained treatments in the fine sandy loam soil. Corn grain and residue yields showed no significant differences for either 2009 or 2010. Removal of crop residue decreased wet aggregate stability and increased the susceptibility to wind erosion of soils

during the winter season when the soil surface was left exposed to climatic conditions in the fine sandy loam textured soil. Minimal treatment differences on selected soil properties were observed in the loam textured soil during the 30 month duration of the study.

Introduction

The Department of Energy selected a project proposed by Abengoa Bioenergy near the town of Hugoton, KS for funding, and a required Environmental Impact Statement has recently been completed. The facility is expected to process 2,500 short tons of cellulose material per day from sources including crop residues, dedicated bioenergy crops such as switchgrass, etc. (Tedlock et al, 2011). Soils of southwest Kansas, in the area surrounding Hugoton, consist of loess and eolian derived sediments (Web Soil Survey, 2009). In southwest Kansas, crop residues are an integral aspect in cropping systems for the protection they provide to the soil. Maintaining surface crop residues provides benefits to soil directly by reducing erosion by water and wind (Armburst et al., 1982; Steiner et al., 2000). Not only does crop residue serve to reduce erosion, but crop residue is an important aspect of a soil's chemical and physical properties. Blanco-Canqui et al. (2006b) reports that high rates of stover removal weakened soil aggregates, reduced water-stable macroaggregation, and increased microaggregation. Soil aggregation is very important in cropped soils as it controls a range of soil properties which control crop establishment, water infiltration, aeration and drainage, and creates a habitat for soil biota (Oades and Waters, 1991).

Soil aggregate stability is controlled by organic matter (Oades and Waters, 1991). Removing crop residue materials has shown to induce rapid and significant changes in soil crust strength properties, e.g. cone index and bulk density increases, and water content in no-till continuous corn systems across three Ohio soils within a 1 year period (Lal, 2005; Blanco-Canqui et al., 2006a; Moebius et al., 2008). In another study conducted by Blanco-Canqui and Lal (2007), stover removal rates >25% decreased SOC, decreased earthworm population, increased soil strength, reduced plant available water, and decreased crop yields. While significant changes in physical properties have been reported in as little time as 1 year, in a 10 year study of residue removal rates on a no-till soil found no effects of residue treatment on bulk density (Karlen et al., 1994). In a 13 year study of a Richfield silty clay loam, different residue treatments had minimal effects on aggregate size distribution, dry aggregate stability, wet aggregate stability, and bulk density (Skidmore et al., 1986). With variable results reported from different studies, it is important for research to be conducted that will be site specific or applicable to the soils of a specific region (e.g., southwest Kansas).

Crop residues not only serve an important role in building and maintaining aggregate stability, but crop residue also provides protection to the soil from natural erosive forces. With no protective cover, wind erosion can occur when soil grains capable of being moved via saltation are present (Chepil and Woodruff, 1963). Chepil and Woodruff (1963) describe, in great length, wind erosion as a continuous cycle of destabilization and stabilization of soil. Destabilization processes occur when there is a breakdown in the soil structure and when climatic conditions include high wind velocity, low precipitation, and high temperatures (Chepil and Woodruff, 1963). Stabilization of soil can occur through deposition, soil consolidation and aggregation, re-vegetation, and favorable climatic conditions (Chepil and Woodruff, 1963). Under current farming operations in southwest Kansas, year-round vegetative cover is not part of farm crop rotations on irrigate fields. When irrigated, fields are planted to corn during the summer growing season, and crop residues remain on the field during the winter season. Crop residue cover can be used to prevent wind erosion when agricultural operations are focused on maintaining sufficient amounts of residue on the surface during the non-growing season (Chepil and Woodruff, 1963). Soil loss, due to wind erosion, is directly related to the percent of soil surface covered by non-erodible elements (Fryear, 1984). Type of residue cover can also affect wind erosion aggregate size distribution (Armburst et al., 1982).

Destabilization of soil can occur from soil structural breakdown and climatic conditions (Chepil and Woodruff, 1963). During the winter months, soils in southwest Kansas are exposed to temperatures below 0°C (HPRCC, 2011) and higher wind speeds than other areas of Kansas (Kansas Weather Data Library, 2011). In moist soils, frost action during winter can loosen and breakdown soil clods, and thus increase susceptibility to wind erosion (Chepil and Woodruff, 1963). Aggregates frozen when air dry do not decrease in stability, but stability significantly decreases as water contents increase and soil aggregates were exposed to freezing conditions (Bullock et al., 1988; Lehrsch et al. 1991). In coarse-textured soils, little energy and few freeze-thaw cycles were needed to considerably weaken aggregates of the sandy loam soils (Lehrsch et al., 1991). Lehrsch et al. (1991) noted increased clay provides more and stronger clay bridges, thus stronger aggregates. Management of residue through tillage operations also plays a role in soil temperature (Horton et al., 1994; Larney et al. 2003). A zero till treatment promoted cooler soils from late fall to early summer, but controlled extreme fluctuations in soil temperature during extremely cold periods compared to a conventional till treatment (Larney et al., 2003). Leaving crop residues at the surface in a no-till system promotes cooler soil temperature in the spring and warmer soil temperatures during the winter season (Larney et al., 2003). Not only does residue cover provide a buffer between fluctuations in soil temperature, hydraulic properties are also affected by residue cover (Wilson et al. 2004; Blanco-Canqui et al., 2006a; Blanco-Canqui et al., 2007; Blanco-Canqui and Lal, 2007). With no residue cover, bare soils can develop surface seals and crusts (Wilson et al., 2004). Surface crusts decrease hydraulic conductivity and alter air and gas flow (Wilson et al. 2004; Blanco-Canqui et al., 2006a; Blanco-Canqui et al., 2007; Blanco-Canqui and Lal, 2007).

Changes in soil are not the only issue with residue removal; rather, producers are concerned with crop productivity. Some irrigated producers in southwest Kansas feel that they have too much residue and it is hindering crop production. Crop residues are not only necessary to protect soil from erosion and to contribute to SOC levels, but they are also positively related to soil and crop productivity (Wilhelm et al., 2004). Blanco-Canqui and Lal (2007) measured grain and residue yield on three Ohio soils with different residue treatments. Yield reductions were only observed on one soil type, and contributed to a decrease in plant available water and increased ground temperatures from increased levels of stover removal (Blanco-Canqui and Lal, 2007). In a study over an 8 year period in Nebraska on a

Crete-Butler silty clay loam, increased residue left on the surface increased future yields of corn (Powers et al., 1998). Linden et al. (2000) found in years with near average or only a small deficit in the growing season precipitation, yield differences between residue treatments were not significant. It is not always possible to control soil moisture, but the soil cover can be manipulated by the use of mulch and mulch tillage (Willis et al., 1957). When residue is left on the surface, soil temperatures remain cooler longer coming out of winter, whereas, bare soil temperatures increase at a greater rate as air temperature rises (Willis et all, 1957; Bristow et al., 1988; Larney et al., 2003). In a study with residue cover and tillage treatments, increased soil temperature accelerated plant emergence and increased the rate of growth early in the growing season (Willis et al., 1957).

Since a new biomass-to-energy facility is expected to open in southwest Kansas in the near future, and because none of the previous studies featured the unique combination of factors present in southwest Kansas, e.g., large quantities of corn residue produced under irrigation, a warm, dry, windy climate; and fragile eolian soils, our objectives were to:

I. Quantify any changes in wet aggregate stability from residue removal.
II. Determine the impact of residue removal on susceptibility to wind erosion.
III. Quantify any differences in soil moisture and temperature due to residue removal.
IV. Measure the impact of residue removal on corn yield.

Materials and Methods

Field Experiment and Residue Treatments

Experiments were conducted from 2008 to 2011 in southwest Kansas on two producer-owned fields located in Stevens County (37° 21' N, 101° 22' W; 955 m above sea level) (Figure 2.1), a region with a semi-arid, continental climate. From weather data (≈ 106 yr) at Hugoton, KS, mean annual precipitation is 469 mm, the winter mean air temperatures is 1.3°C and summer mean air temperature is 24.7°C (HPRCC, 2011). The study was established in two fields with different soil textures directly following corn harvest in early November, 2008. All field operations were conducted by the producer, and the tillage method was strip-tillage (Table 2.1 and 2.2). Soil types consisted of Hugoton loam (L) (fine-silty, mixed, superactive, mesic Aridic Argiustolls) (Table 2.3) at site 1 and Bigbow fine sandy loam (FSL) (fine-loamy, mixed, superactive, mesic Aridic Haplustalfs) (Table 2.4) at site 2. Following the mechanical corn harvest, residue was raked using a wheel rake and then round baled and removed from designated plots, for an average removal by mass of 70%. Residue removal on plots included: 0, 1, and 2 years of removal. Plots were setup in a randomized complete block design on both locations. Plot size was 15.24 m long x 18.28 m wide. The Hugoton L site was continuous corn for the growing seasons of 2008, 2009 and 2010. At the Bigbow FSL site, corn was planted for the growing seasons of 2008 and 2009, and then sorghum (*Sorghum bicolor* L.) for the 2010 growing season. Sorghum was selected for 2010 due to a limited amount of irrigation water that was available to that field during the 2010 growing season, as determined by the farmer-cooperator.

Residue removal treatments were established following corn harvest in 2008. The methods selected represent current available technology that would likely be utilized by producers in the study area. Corn was harvested with a John Deere 9870 (Deere & Company, Moline, Illinois) combine with a Stalkmaster chopping corn head, which is a type of corn head that cuts the stalks (rather than snapping), and the resultant stalk height was 24 cm. Once harvest was completed, residue was raked with a John Deere 4430 tractor and a H&S HD II (H&S Manufacturing Company, Inc., Marshfield, Wisconsin) wheel rake (Figure 2.4a). A John Deere 6430 tractor and John Deere 568 round baler was used for baling corn residue material on the residue removal plots. At both the Hugoton L and Bigbow FSL site, two residue treatments were split between the 16 plots (2008 and 2010). In half (eight) of the plots, residue was retained on the soil surface and the other half (eight) plots were raked and baled to establish the residue continuously retained (Figure 2.2 & 2.4c). Following harvest in the fall of 2009, a new treatment was added to bring the total to three residue treatments. Producers may be inclined to remove crop residue less frequently than every year, so a residue alternating removal was added to simulate every other year removal. Therefore, the eight plots which residue was removed from in the fall of 2008 year were split into two sets of four plots. On four plots, residue was raked and baled to keep a residue continuously removed treatment. On the other four plots (where residue had been removed the previous year) the residue was retained in the plots to establish an alternating removal treatment (Figure 2.3). Alternating removal treatment was established to simulate residue removal every other year. The remaining eight plots were left alone to continue the residue continuously retained treatment. Finally, for residue removal following harvest in 2010, residue was raked and baled at both sites in both the residue alternating removal and residue continuously removed treatments.

Wet Aggregate Stability

Samples were collected periodically (Table 2.5) from each plot following the methods recently published by Stone and Schlegel (2010). Soil samples, 1.5 kg in mass, were collected from 0-5 and 5-15 cm depths. Samples were obtained from three random locations within each plot and placed into bags where they were allowed to air dry. The air-dried soil was then sieved to collect aggregates 2.00 to 1.00 mm in size. Size distribution of water stable aggregates (WSA) was determined by wet sieving (Kemper and Chepil, 1965) with a machine that moved four nests of sieves, in separate compartments, through a vertical displacement of 37 mm at 30 cycles min $^{-1}$. Each nest had three sieves of 127 mm diameter and 40 mm depth with screen openings of 1.00, 0.50, and 0.25 mm. A 30-g mass of aggregates 2.00 to1.00 mm was placed on the top sieve of a nest, rapidly immersed in tap water, soaked for 10 min, and sieved in water for 10 min. After sieving, the material in the bottom of each bucket was passed through a 0.053 mm sieve to collect aggregates. The mass of the oven-dry material (aggregates plus fragments) that remained on each sieve after sieving was determined. Material from each sieve and the aggregates in the bottom of the bucket (< 0.053 mm) was then dispersed with sodium hexametaphosphate solution (13.9 g/l). Oven-dried sand particles that were retained on the same sieve after dispersion were determined. Concentration of WSA retained on each of the three sieve-opening sizes, independent of material retained on other sieves, was calculated as:

$$\text{WSA} = (m_m - m_f)/(m_t - m_f)$$

Where m_m is dry mass of material on a sieve after sieving, m_f is dry mass of fragments on the same sieve after dispersion, and m_t is the total sample dry mass. The mean weight diameter (MWD) of WSA was calculated as:

$$\text{MWD} = \quad (w_i/m_a)x_i$$

Where w_i represents the dry mass of aggregates (w_1 through w_4) determined for each of the four sieve sizes (aggregates and fragments after sieving [m_m] minus fragments on the same sieve after dispersion [m_f] and dry mass (w_5) passing through the sieve with 0.053 mm opening during sieving (Kemper and Rosenau, 1986),where x_i represents mean diameter of each of the five size fractions (size of smallest fraction [x_5] was calculated as 0.053 mm/2), and m_a is total dry mass of aggregates (sum of w_1 through w_5).

Aggregate Size Distribution

Aggregate size distribution (ASD) was determined on dry soil samples following the modified rotary sieving procedure (Lyles et al., 1970). Approximately 5 kg of soil was sampled at three locations within each plot at the surface to a depth of 2.5 cm using a flat shovel and then placed into separate pans. Pans of soil were oven-dried at 105°C for 2 days. Once dry, the samples were passed through the modified rotary sieve apparatus. After all the soil material passed through the rotary sieve, soil was weighed for the following size fractions: < 0.42, 0.42-0.84, 0.84-2.0, 2.0-6.35, 6.35-14.05, 14.05-44.45, and > 44.45 mm. From the different size fractions, %< 0.84 mm (wind erodible fraction, WEF), geometric mean diameter (GMD), and geometric standard deviation (GSD) were calculated using the computation method in Wagner and Ding (1994). Wagner and Ding's (1994) direct computation method for GMD (x'_g) and GSD (σ'_g) are:

$$x'_g = e^a \quad \text{and} \quad \sigma'_g = e^b$$

where

i = sieve cut

$X'_{g(i)}$ = = geometric mean within sieve cut i

n = total number of sieve cuts

m_i = mass fraction of sieve cut i

Soil Temperature and Moisture

Temperature and moisture measurements were collected hourly *in-situ* using Stevens Hydra probes (Stevens Water Monitoring Systems, Inc., Portland, OR). Sensors were placed at a depth of 5 cm below the soil surface once residue treatments were implemented. Temperature and moisture measurements were logged throughout the winter season when freeze-thaw cycles can affect soil aggregates. Temperature and moisture sensors were installed following harvest and collected data throughout the critical winter season, and then removed from the field in April before planting. To determine differences in the soil temperature and moisture, data from 12:00 pm was selected every day during the winter season. Daily 12:00 pm values were used for statistical analysis and data display.

Residue Coverage

Residue measurements were conducted throughout the winter and spring months following harvest in 2008 and 2009 until planting in 2009 and 2010, using the line-transect procedure based from Laflen et al. (1981). A 15.24 m tape, with markings every 15.24 cm, was stretched across the plots and residue at the markings was counted. Two counts were taken in each plot following implementation of residue treatment and throughout the winter season until the time of planting (Table 2.3).

Grain and Residue Yield

Entire corn plants were hand harvested from 2.67 m of the two center rows of each plot, ears were removed from the stalk, and then the ears were dried until grain moisture was approximately 15%. Once dried, corn was processed through an automated corn shelling machine (ALMACO, Nevada, IA) and corn kernels were weighed to obtain grain yield. Corn cobs were retained, dried, and weighed for use in residue yield data. Grain samples from each plot were then taken to measure moisture using a GAC 2000 by DICKEY-john (DICKEY-john, Minneapolis, MN).

After corn was hand-harvested, the rest of the corn plant (stalks and leaves) were weighed in the field and returned to the plots. From each plot, a sub-sample of plant material was brought back and dried to determine plant moisture.

Statistical Analysis

Statistical analysis of residue treatment effects on wet aggregate stability, aggregate size distribution, soil temperature and moisture, residue coverage, and grain yield was conducted using analysis of variance (ANOVA). All measurements were analyzed using a randomized complete block design, with residue treatment as the factor and block as a random variable. The F-Test was used for treatment factor main effects, and F-protected t-test was used on pairwise comparisons to follow up any significant differences due to treatment. The Proc Glimmix procedure of the SAS version 9.2 (SAS Institute Inc, 2008) was used for ANOVA and mean separation differences. All results were considered significantly different at P=0.10 unless noted otherwise.

Results and Discussion

Wet Aggregate Stability

Aggregates were sampled at least twice per winter period at each site and in the results section data will be presented by sampling time. Within each sampling time, Hugoton L results will be explained first, followed by the results for the Bigbow FSL.

In fall 2008, concentration of sand-free WSA was significantly affected by residue treatment at the Hugoton L site in the size fraction of aggregates (0.53 to 0.25, 0.25 to 0.50, and 0.50 to 1.00 mm) at the depth of 0-5 and in the 0.50 to 1.00 mm size fraction for the 5-15 cm depth (Table 2.6). MWD of the soils with residue continuously retained treatment was also significantly greater than the residue continuously removed treatment for both depths (Table 2.7). At the time of the fall 2008 sampling, the project was newly initiated, as treatments had only been established for 1 month (Table 2.5). Therefore, one reason for the decreased aggregate stability in the 0-5 cm depth, in the residue continuously removed soil samples, may be an effect of aggregate destruction due to the raking and baling of residue (Figure 2.4b). At the Bigbow FSL site and for the fall 2008 sampling time, there were only significant treatment effects on the aggregates <0.053 mm in size and on in the 0-5 cm depth (Table 2.6). Mean weight diameter of aggregates in the residue continuously retained was 0.444 versus 0.310 mm for the residue continuously removed treatment (Table 2.7). Differences in soil MWD may be attributed to disturbance from the raking and baling operation (Figure 2.4b). No differences were observed for any size classes or in MWD in the 5-15 cm soil depth at the Bigbow site in fall 2008.

Sand-free WSA and MWD were not significantly affected by residue treatments in the spring of 2009 in the Hugoton L (Table 2.9). Although there were no significant treatment effects, the soil in the residue continuously retained plots had a larger MWD and a slightly higher concentration of aggregates in the larger size ranges. The only significant differences for the spring 2009 Bigbow FSL sand-free WSA were in the 0.053-0.25 and 0.50 -1.00 mm size classes in the 0-5 cm depth (Table 2.9). Soils in the residue continuously removed treatments had more 0.053 – 0.25 mm sized aggregates than the retained treatment, while the soil in the residue continuously retained treatment had significantly more of the larger aggregates in the 0.5 – 1.00 mm fraction. No significant differences were observed in the MWD of soil due to treatment at 0-5 cm. At 5-15 cm, MWD was significantly larger for the Bigbow FSL retained treatment; samples in the residue retained treatment had a MWD of 0.308 mm compared to 0.184 mm in the soil in the residue continuously removed treatment. Also, soil in the residue retained plots had a larger concentration of macroaggregates (for the size ranges of >1.00 and down to >0.25 mm) while the residue removed contained greater concentrations of microaggregates (0.053-0.25 and <0.053 mm) (Tisdall and Oades, 1982).

As explained in the methods section, the treatment structure changed following the fall 2009 corn harvest. An additional treatment was added, to simulate the effect of residue removal in alternating years. Producers in the region may not be interested in removing residue from the same fields each year, but rather, might be more apt to remove residue every other year, or in some other rotation. Therefore, in the fall 2009 results, there were three treatments: residue continuously retained, e.g., residue was not removed in fall 2008 or fall 2009; residue alternating removal, where residue was removed in fall 2008 but retained in fall 2009; and residue continuously removal, where residue was removed in both fall 2008 and fall 2009. Fall of 2009 soil samples (collected on 18 Nov. 2009, Table 2.3) did not have significant differences in the top 0-5 cm at either site (Table 2.12). Residue alternating removal and residue continuously removed soil had similar and smaller MWD as well as sand-free WSA distribution (Table 2.13). For the Hugoton L site, the soil at the depth of 5-15 cm displayed a treatment difference in both sand-free WSA and MWD. Soil in the residue alternating removal treatment, had the largest and the highest concentration of macroaggregates in comparison to the residue continuously retained and removed treatments (Table 2.13). At the Bigbow FSL site (Table 2.14), no significant differences were observed at any depth.

Following the winter season, no significant differences among sand-free WSA and MWD were observed in the Hugoton L (Table 2.15) in the spring 2010. Soil in the residue continuously removed had the highest concentration of microaggregates and the lowest MWD in 0-5 cm depth. At 5-15 cm, sand-free WSA and MWD were all very similar. The spring 2010 samples from the Bigbow FSL site had differences in four out the five sand-free WSA size fractions, and MWD in the 0-5 cm depth (Table 2.15). After 2 years of differing residue treatments, differences in soil wet aggregates stability were observed amongst the treatments between the residue continuously retained and the other treatments of residue continuously removed and alternating removal. Residue continuously retained had the largest MWD and highest concentration of macroaggregates (Table 2.17). Alternating and continuously removed residue soil samples had the highest concentration of microaggregates (Table 2.17). The differences observed in the depth of 0-5 cm at the Bigbow FSL site are a good display of the importance residue has on soil quality. The residue cover played a crucial role in protecting the aggregates in the soil surface from natural destructive forces (Larney *et al*., 2003).

Samples were collected one final time in the fall of 2010 following harvest. At both the Hugoton L and Bigbow FSL sites, there were no significant differences due to treatment observed at either depth of 0-5 and 5-15 cm (Table 2.18). Although differences were not significant, the residue continuously retained treatment generally had better aggregate stability at the Hugoton L site (Table 2.19). The Hugoton L site had a higher concentration of macroaggregates in the residue continuously retained treatment plots than the other treatments of residue continuously removed and alternating removal. The Bigbow FSL site had similar numbers for all treatments, and no differences were observed at both depths of 0-5 and 5-15 cm (Table 2.20).

Wet aggregate stability at both sites appeared to be very dependent on the winter weather forces. Differences due to treatment were mainly observed at spring sampling dates, rather than fall sampling dates. Most fall sampling differences were most likely due to disturbance from raking and baling operations. Depending on the setting of the wheel rake, (e.g., if set too low) the rake can be very destructive to aggregates at the surface. Spring differences were attributed to the difference in weather conditions that the soil surface was exposed to (Bullock *et al*., 1988). Crop residue provides great advantages in the protection role to soil (Dabney et al., 2004; Wilson et al., 2004; Blanco-Canqui et al., 2006b)

Aggregate Size Distribution

Dry aggregate size distribution samples (henceforth referred to as wind erosion samples) were collected in December 2008 for Hugoton L and showed no differences between treatments at sampling (Table 2.21). Wind erosion information collected from ASD include %< 0.84 mm WEF, GMD, and GSD. The amount of soil that is %< 0.84 mm allows us to determine the fraction of the surface 2.5 cm that is actually susceptible to wind erosion (Chepil and Woodruff, 1963). GMD and GSD are measurements from ASD that give an estimate of erodible aggregates in the soil, and allow for comparisons between treatments (Nimmo and Perkins, 2002). Following the winter season, when soils are most susceptible to wind erosion, the Hugoton L did not have any significant differences in wind erosion parameters between treatments (Figure 2.5). Although there was no significant difference due to treatment, the %< 0.84 mm WEF, GMD, and GSD all underwent changes between December 2008 and April 2009 caused by the winter climatic conditions. The WEF for both treatments increased while GMD and GSD decreased. Bigbow FSL measurements in December 2008 were significantly different for the WEF and GSD (Table 2.21) due to residue treatment; the continuously removed treatment had a significantly larger WEF and smaller GMD and GSD. All wind erosion parameters showed a difference between the treatments between December 2008 and April 2009. Similar to Hugoton L site, the WEF increased, GMD decreased, and GSD increased during the winter season (Figure 2.5). A visual comparison between the two sites in Figure 2.5 shows the general effect of soil texture on the wind erosion parameters too, as the coarser-textured Bigbow FSL has a greater WEF and smaller GMD and GSD compared to the finer-textured Hugoton L.

Wind erosion samples taken in February of 2010 showed no treatment differences at either the Hugoton L or Bigbow FSL sites (Table 2.21). The WEF, GMD, and GSD were all very similar for all three treatments. May 2010 samples showed differences for wind erosion parameters at both Hugoton L and Bigbow FSL. Only GSD was of significance at the Hugoton L site. Bigbow FSL had significant treatment differences at P=0.10 in the %< 0.84 mm WEF and P=0.05 in the GSD parameter. All parameters displayed differences amongst treatments at both sites in May 2010 (Figure 2.6). Wind erodible fraction of soil changed during the winter season at both Hugoton L and Bigbow FSL sites. At the Bigbow FSL site, residue continuously retained had the lowest WEF (53.8%) while the residue continuously removed treatment had the highest WEF (74.4%). Geometric mean diameter for both sites increased during the winter season. Residue continuously retained aggregates were largest compared to alternating and continuous removal at the Hugoton L and Bigbow FSL site. Showing a significant difference due to treatment between residues continuously removed and retained, GSD was higher at both sites. Residue alternating removal treatment soil was not significantly different from either the residue continuously retained and removed plots.

Following the fall harvest and residue removal of 2010, samples for wind erosion were collected in January of 2011. No significant differences were observed at either the Hugoton L or Bigbow FSL site (Table 2.23). It is of interest to compare the two different sites and differences in wind erosion parameters for two varying soil textures. The Bigbow FSL site had approximately double the amount of fraction of soil susceptible to erosion by wind (%< 0.84 mm) than the Hugoton L site (Figure 2.6). Also, the GMD and GSD are smaller in diameter for the Bigbow FSL site (Figure 2.7). The GMD in the Hugoton

L residue continuously retained was 2.1 mm and the Bigbow FSL continuous retained GMD 0.19 mm, e.g., a difference of 10 times because of the difference in the two soil textures.

In all seasons when wind erosion samples were first taken following harvest, the measurements were similar amongst all treatments. The main changes occurred during the winter season when the soil surface was exposed to the natural elements in the residue treatments where corn residue was removed. Over the past 1.5 years, Hugoton has had higher monthly average wind speeds and maximum wind speeds (Table 2.24) than Parson, KS (southeast Kansas) and Manhattan, KS (northeast Kansas). Residue retained on the soil surface protected the soil from freeze-thaw and freeze-drying events which can be destructive to soil clods (Bullock et al., 1988; Lehrsch et al., 1991; Staricka and Benoit, 1995). The textural difference between the two sites was very apparent at each sampling date in the WEF, GMD, and GSD. Bigbow FSL had higher WEF of soil and lower GMD and GSD measurements at each time each year.

Soil Temperature and Moisture

Soil temperature and moisture probes placed in the soil during the winter season provided crucial information about fluxes in surface soil temperature and moisture, which yielded data on the number of freeze-thaw periods destructive to soil aggregates (Bullock et al., 1988; Larney et al., 2003). Soil aggregates provide many benefits to soil quality and improve the overall soil health (Skidmore et al., 1986; Power et al., 1998; Blanco-Canqui et al. 2006). During the first winter season of 2008-2009, the Hugoton L site had many fluctuations in soil temperature (Figure 2.8) between both treatments. During the winter measurement period, 43 out of 54 days were significantly different in soil temperatures due to residue treatment. Although soil temperature fluctuated with the corresponding air temperature, soil in residue continuously removed plots experienced higher magnitudes of fluctuations. In the residue continuously retained, soil temperature didn't fluctuate as greatly with the air temperature as residue continuously removed. Also, during the winter period, soil temperature in residue continuously removed plots fell below 0°C 5 times as compared to three times in the residue continuously retained treatments. More freeze-thaw cycles allowed for a higher chance of breakdown of aggregates in the residue continuously removed plots (Lehrsch et al., 1991). Along with soil temperature measurements, soil moisture was observed during the same period. Soil moisture levels stayed relatively constant during the winter season in the residue continuously retained treatment at the Hugoton L site (Figure 2.9). Soil moisture fluctuated during the season, and was significantly different due to treatment for 8 days out of 54 days that soil moisture was measured. Many of these variations occurred when the air temperature fell below freezing, and then the soil moisture fell as well. These drops in soil moisture were directly related to the air temperature and reflect times when the soil water froze in the soil. The periods of freeze-thaw aid in the destruction of aggregates, but also display the ability of the residue to buffer the soil temperature and limit crucial freeze-thaw cycles frequency (Larney et al., 2003).

At the Bigbow FSL site, soil temperature (Figure 2.10) behaved in a very similar fashion to the Hugoton L site during the winter season of 2008-2009. At the Bigbow FSL site, soil temperature dropped below 0°C seven times in the residue continuously removed compared to four times in the residue continuously retained treatment. Surface temperature at the Bigbow FSL site had significant differences between treatments for 24 out of 53 days. Soil moisture readings in the FSL soil (Figure 2.11) follow the same trend as well. In the residue continuously retained, the soil moisture level stayed relatively constant throughout the winter season, whereas, the residue continuously removed had multiple fluctuations in moisture. Although fluctuations in moisture were observed, only 1 day out of 54 had a significant difference in soil moisture due to residue treatment. Again, fluctuations of soil moisture directly correspond with the air temperature and indicate periods of freeze-thaw within the soil.

During the winter season of 2009-2010, the Hugoton L soil temperatures for both treatments, residue continuously removed and retained, did not fluctuate as greatly as the previous year (Figure 2.12). For 18 days out of 50 days, residue treatment had a significant effect on soil temperature.

Residue continuously removed plot's soil temperature dropped below freezing five times, compared to two times in the residue continuously retained. Air temperature throughout the 2009-2010 winter didn't fluctuate in a magnitude as great as the previous winter of 2008-2009. Soil temperatures under the residue continuously removed dropped more quickly and rose again faster following the shifts in air temperature during the winter season. Soil moisture levels at the Hugoton L site (Figure 2.13) were not very similar during the winter season. Residue continuously retained moisture levels were constantly higher throughout the winter season from the time the moisture probes were installed. The residue continuously removed likely lost some moisture to evaporation during the period between residue removal and probe installation. Even though there was a difference in initial moisture levels between the two residue treatments, there were still observable trends. Water content in the residue continuously removed was quicker to drop following decreases in air temperature, whereas, the residue continuously retained moisture levels did not drop at high rates when the soil water froze. At the Bigbow FSL site (Figure 2.14), soil temperatures stayed relatively close, with residue continuously removed treatment plots experiencing greater fluctuations in soil temperature. Soil temperature was significantly different due to treatment for 19 out of 56 days during the 2009-2010 winter months. Soil in continuous residue removal plots experienced six periods where soil temperature dropped below 0°C, and soil under residue continuously retained only fell below 0°C three times. In the Bigbow FSL, freeze-thaw cycles were very important to breakdown of aggregates. The fine sandy loam texture didn't have as much clay; clay helps bind soil particles in aggregates, to aid in resisting crucial freeze-thaw cycles (Lehrsch et al., 1991). The Bigbow FSL site (Figure 2.15) showed greater fluctuations in water content in the residue continuously removed plots. Soil moisture in residue continuously removed plots displayed more rapid decreases, indicative of soil water freezing, than the residue continuously retained plots. The residue treatments had a significant effect on water content for 7 out of 56 days during the winter season that water content was measured.

Residue Coverage

Retaining crop residues on the soil, versus removal, provides many benefits to soil in the form of nutrient cycling, protection from erosive forces, and soil temperature and moisture (Linden et al., 2000; Wilhelm et al., 2004; Lal, 2005). During the winter seasons of 2008-2009 and 2009-2010, residue transects were counted to determine the ground coverage. The line-transect method used only determines the amount of coverage on a percentage base, and not on a percentage by mass base. In the winter of 2008-2009 two residue treatments had been established, residue continuously removed and residue continuously retained. Starting in November 2008 (Table 2.25), residue counts were conducted on transects in each plot following residue harvest. At both sites, residue counts were high the first time with 90 and 95% coverage in the Hugoton L and Bigbow FSL residue continuously retained treatments. The residue continuously removed treatment had 70 and 73% ground coverage. While this number may seem high for a count immediately following raking and baling operation, it should be noted that the starting residue quantities were very large, and the raking and baling or residue harvested the larger, bulkier components of the residue. Finer materials were still present and measured using the line-transect method. During the winter season, the residue continuously retained coverage decreased by 40% (Figure 2.16) and residue continuously removed coverage declined by 56% (Figure 2.16) at the Hugoton L site.

At the Bigbow FSL site, residue coverage increased in the continuous retained treatment from November to December by a small amount (Figure 2.17). This slight increase can be attributed to blowing of some larger pieces of residue such as husks, leaves, and some stalks onto the removed plots from the surrounding residue returned plots and the rest of the field (residue was not baled off of the remainder of the field). During the winter season, the same trend was observed at the Bigbow FSL site as was observed at the Hugoton L site during the winter 2008-2009 season. Residue continuously retained coverage decreased by 27% and continuous removed by 49% (Figure 2.17) at the Bigbow FSL site. Residue coverage declined more on the continuously removed plots, which is most likely a direct effect of the raking and baling operation. The raking and baling removed the larger, bulkier residue material leaving behind smaller, lighter material. This smaller, lighter material most likely was blown to neighboring plots or completely off all plots. Residue coverage counts were significantly different during the first season (Table 2.25), which would be expected following the residue removal operation.

Residue coverage was again tracked during the winter 2009-2010. Following harvest in the fall of 2009, residue was either raked and baled or retained on select plots. With another treatment added, there were three treatments for residue observation during the winter season. In the Hugoton L, all residue treatments were at a higher level after harvest (Figure 2.18). At all dates of residue measurement, surface coverage was significantly different due to treatment (Table 2.26). Residue continuously removed treatment had a ground coverage of 76% directly following raking and baling. Then, by the following May, the average ground coverage was down 75% to only 19%. Such a decline was due to the wind blowing the finer residue material off the plots during the windy winter season. Also, residue had been removed for two consecutive years and the finer residue from the year before may have decomposed by this time. In January 2010, when the second ground cover count was taken, there was an increase in the residue coverage in the residue continuously removed treatment. The increase can be observed in the Bigbow FSL as well from December to January. Wind blowing residue on and off plots during this time period accounts for the fluctuations. Another thing to note, the raking and baling operation can be very destructive to the standing stalks. Stalks and root masses were pulled from the soil surface and knocked over, particularly during the raking operation, and some stalks were driven upon during both operations. Corn stalks can help protect the surface residue and also stay anchored, further protecting the soil from the wind. Surface cover in the other two residue treatments, continuously retained and alternating removal, which residue was not removed the winter of 2009-

2010, remained at a constant level of residue coverage during the remainder of the winter season (Figure 2.18). They dropped only slightly throughout the season.

At the Bigbow FSL site (Figure 2.19), residue continuously removed plots experienced the same trend in residue levels as the Hugoton loam site. All dates, except those measured in January were significantly different (Table 2.26) during the winter 2009-2010 season due to treatment effects. Residue continuously removed and alternating removal treatments started high and dropped slightly by 9 and 16%, respectively. Residue continuously removed coverage increased by 39% from December to January from residue materials blowing onto plots. Then, from January to May the residue continuously removed plot's coverage decreased 44% to residue coverage of 50%, respectively, at the Bigbow FSL site.

The common trend of residue coverage decreasing during the winter seasons in the residue continuously removed plots is of great importance. Coverage was fairly high following harvest, but this was attributed to the method of measurement for residue. Measurements were not based upon mass, but percent of ground covered. Residue provides protection to the soil aggregates and structure in the surface layer of soil from wind erosion and freeze-thaw cycles (Bullock et al., 1988). As discussed earlier in the soil temperature and soil moisture section, the residue provided a buffer from the weather. Freeze-thaw cycles can be extremely destructive to aggregates. Breakdown in aggregates allows for increased susceptibility to wind erosion, decreased porosity or aeration, and decreased soil quality (Armburst *et al*., 1982; Skidmore et al.*;* 1986; Blanco-Canqui et al., 2006).

Grain and Residue Yield

Grain and residue yield data were collected through hand sampling in the fall of 2009 and 2010. Corn was harvested in both 2009 and 2010 at the Hugoton L site. At the Bigbow FSL site, corn was harvested in 2009 and sorghum was harvested in 2010. No significant differences were observed between treatments for either year, at either site (Table 2.27). In 2009, grain yield for continuous retained and removed were similar at 13.55 and 13.21 Mg ha^{-1} for the Hugoton L site (Table 2.28). Grain yield at the Bigbow FSL site were 13.56 and 12.81 Mg ha^{-1} for continuous retained and removed, respectively (Table 2.28). The fall 2010 yield samples showed no differences due to treatment at either the Hugoton L site or the Bigbow FSL site (Table 2.27). The Hugoton L yields were similar for all treatments, and no significant differences due to treatment could be observed (Table 2.27). At the Bigbow FSL site, yield data was extremely low due to intense, unintended weed pressure in sorghum during the growing season (Table 2.29).

Conclusions

Over the course of the 30-month time period of the study, significant differences due to residue treatments were observed at both the Hugoton L and Bigbow FSL site in wet aggregate stability. Wet aggregate stability decreased when residue was removed and the soil was exposed during winter months at the Bigbow FSL site. Other research has indicated coarser-textured soils are more sensitive to residue removal (Karlen et al., 1984; Lehrsch et al., 1991). From establishment of residue treatments in fall to the spring sampling date, climatic conditions appeared to have the greatest effect on the concentration of WSA and MWD. During the warmer growing season, aggregate stability appeared to return to nearly the same level that it was at the previous fall. Bullock et al. (1988) reported minimal bonding between aggregates during spring, but that bonds that were broken during winter can reform between bordering aggregates during the warmer season. At the finer-textured Hugoton L site, very few significant differences were observed resulting from residue treatments. Due to the relatively short time period of the study, if any changes were occurring in the Hugoton L soil, they were at a rate slower than could be measured. Lehrsch et al., (1991) reported stronger aggregates in samples containing high amounts of clay, and that the higher clay contents provided more and stronger clay bridges. Organic matter improves aggregate stability (Lehrsch et al., 1991; Oades and Waters, 1991), but the experiment was too short to measure any observable changes in organic matter. It is apparent the coarser-textured Bigbow FSL soil was more sensitive to residue removal than the finer-textured Hugoton L soil.

Changes in wind erosion measurements were also observed during the winter seasons while the study was conducted. Significant differences due to residue treatment were not observed in the Hugoton loam during winter months, but there were increases in the WEF and decreases in GMD and GSD in residue removal treatments. The Bigbow FSL did experience significant differences due to residue treatment following the winter seasons of 2008-2009 and 2009-2010. April 2009 measurements, following one winter of residue treatments, WEF increased and GMD and GSD decreased. GMD and GSD are measurements that express the amount of erodible sized aggregates present in a soil. Directly following winter of 2009-2010, WEF and GSD displayed significant differences. Residue continuously retained soil had the lowest amount of WEF and residue continuously removed samples had the highest level WEF. These results are similar to a lab simulation by Fryear (1985) where higher amounts of wind erosion were measured in soils with less residue cover. At final sampling in the fall of 2010, samples displayed no differences in wind erosion measurements affected by residue treatments.

Increased erodibility and decreased aggregate stability was attributed to the climatic conditions that the soils were exposed to with the implementation of differing residue treatments. Plots with residue removal treatments experienced more freeze-thaw cycles in the winter months than those where residue was retained. Bullock et al. (1998) report that freeze-thaw cycles breakdown macro- and microaggregates into smaller aggregates from expansion of water crystals in pores, which breakdown particle to particle bonding between aggregates. Fewer freeze-thaw events are necessary in coarse textured soils to substantially decrease aggregate stability (Lehrsch et al., 1991). Not only are freeze-thaw events important, but also are freeze-drying events. Freeze-drying events can be more detrimental in soils with larger particle sizes and increased water contents (Staricka and Benoit, 1995). When residue is removed or incorporated into the soil, the soil surface is exposed directly to the climatic conditions and can experience greater fluctuations in temperature directly related to air temperature (Bristow et al., 1988; Larney et al., 2003). Use of the Stevens Hydraprobes displayed the differences in fluctuations in temperature that occurred during the winter season between different residue treatments. Soil temperature warmed faster in spring and cooled quicker in the residue removed treatment with higher incidences of freeze-thaw events. Soil in the residue continuously retained treatments had slow rates of change in soil temperature following the air temperature, and limited freeze-thaw events occurred during winter months.

Directly related to the quality of the soil, productivity of crops were a very important measure of any influence residue treatments may have had on the soil itself. Yields in the fall of 2009 and 2010 were not significantly different due to treatment for either site. The 2010 yield measurements from the Bigbow FSL were extremely variable and low due to extreme weed pressure experienced in the plots. No conclusion could be made from the yield data collected. In the Hugoton L, both years had no significant treatment differences in corn grain and residue yield. In a similar study by Blanco-Canqui and Lal (2007) grain and stover yields were reduced on a silt loam soil, but not at two other locations of a silt loam and clay loam. Karlen et al. (1994) reported no significant yield differences between residue treatments; rather yield differences from year to year due to season differences in rainfall. Both locations were fertilized annually and irrigated weekly during the growing according to soil testing and decisions made by the landowner. Due to the adequate supply of nutrients and moisture that was supplied to the sites, any benefits of water conservation and nutrient cycling which might have been attributed to residue retention were not observed.

Residue removal affected different soil properties during the 30 month study. Future work is needed to continue to investigate long-term effects of residue removal. Soil organic matter plays an integral role in the stability of soil aggregates (Oades and Waters, 1991), and changes in SOM may not have been detectable in the relatively short time period of the study. Long-term studies have been established that examine the effects on soil properties when residue is completely removed for corn silage usage (Wilts et al., 2004; Hooker et al., 2005). However, there is the necessity for investigation in to long-term effects of various rates of removal and frequency of residue removal. In some situations, depending on location and soil characteristics, it may not be sustainable to remove residue every year, but it may be acceptable for removal every 2 or 3 years.

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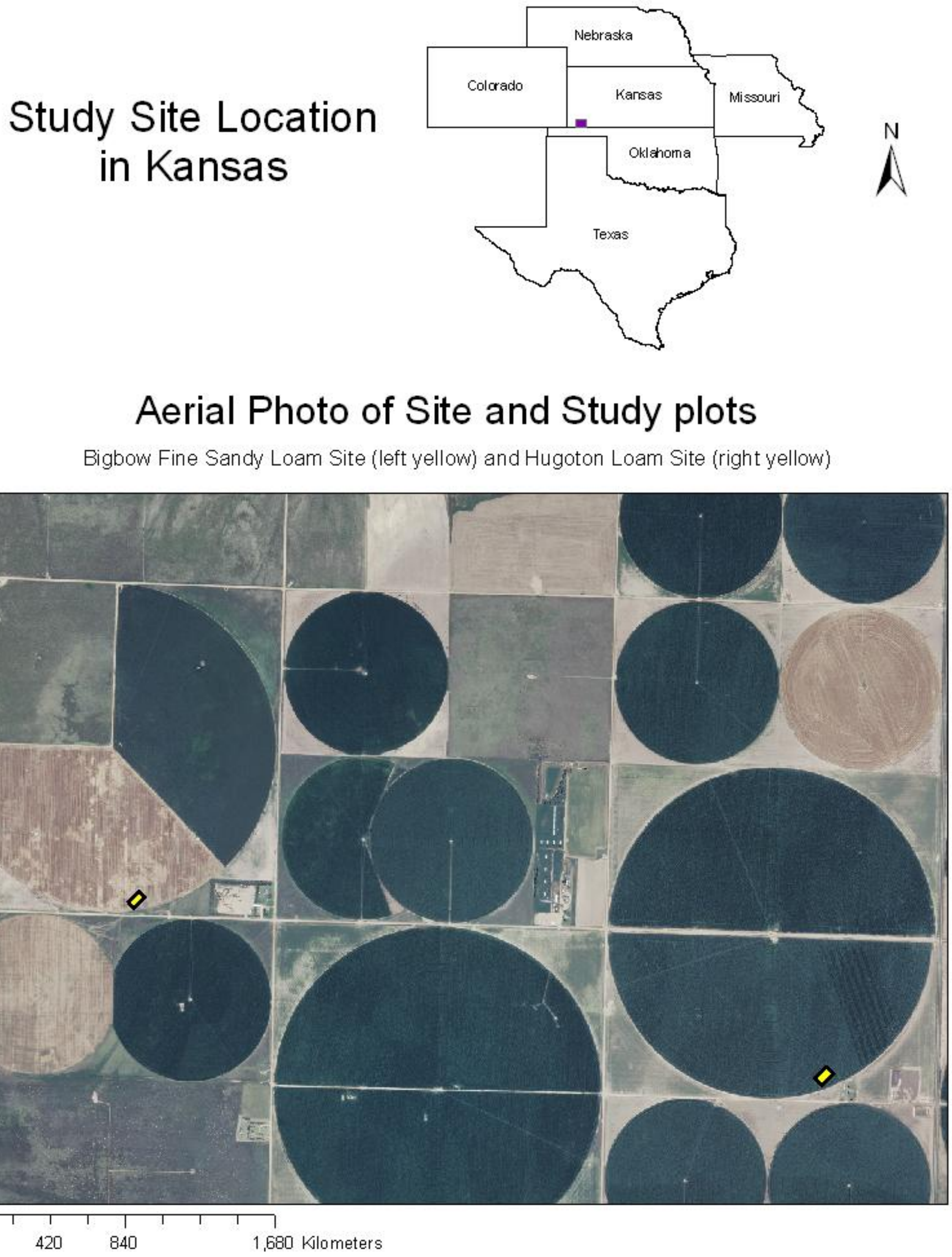

Figure 2.1 Study site location in Kansas and aerial photo of plot location.

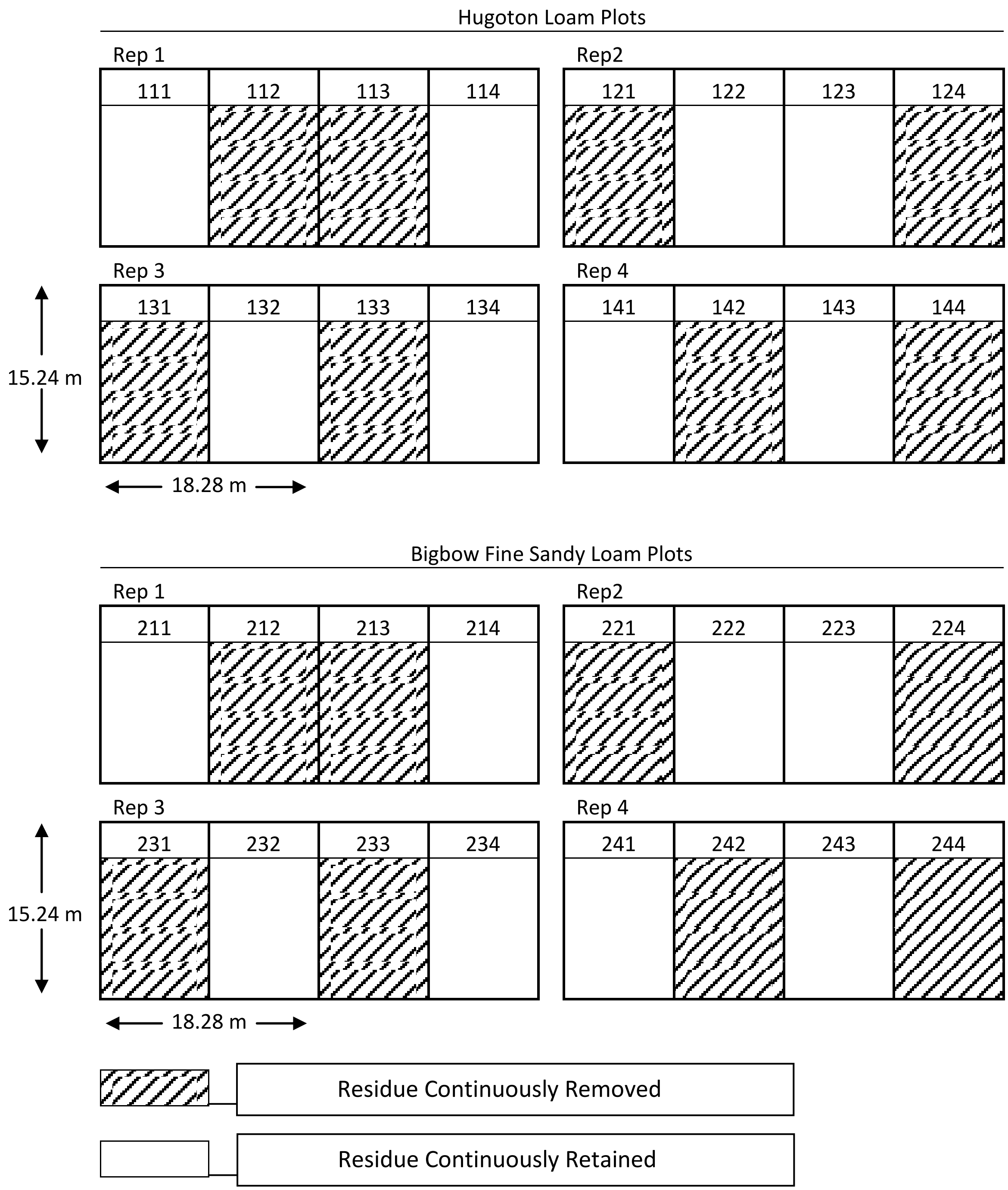

Figure 2.2 Plot layout for Hugoton L and Bigbow FSL fall 2008-2009 with residue treatments.

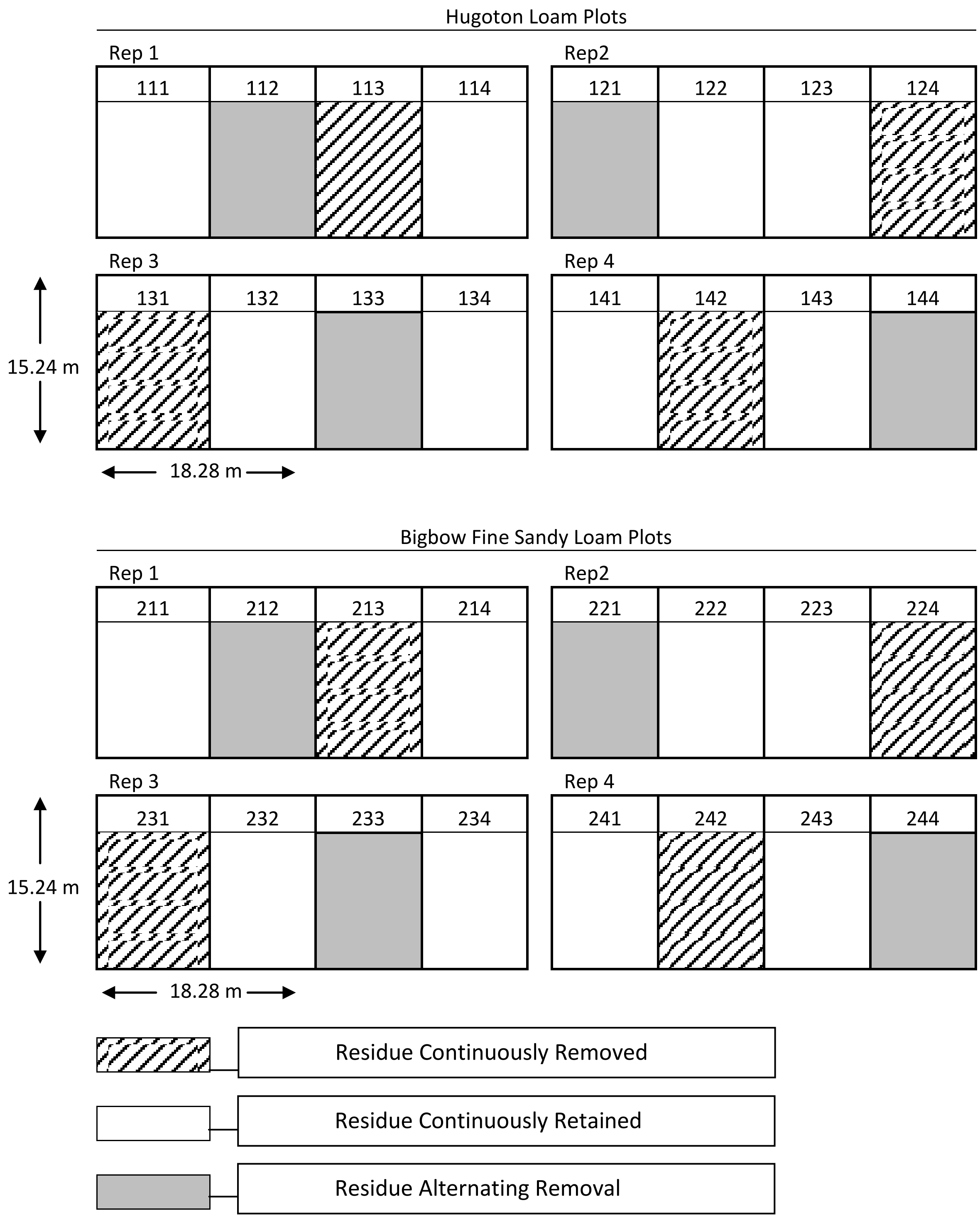

Figure 2.3 Plot layout for Hugoton L and Bigbow FSL fall 2009-2010 with residue treatments.

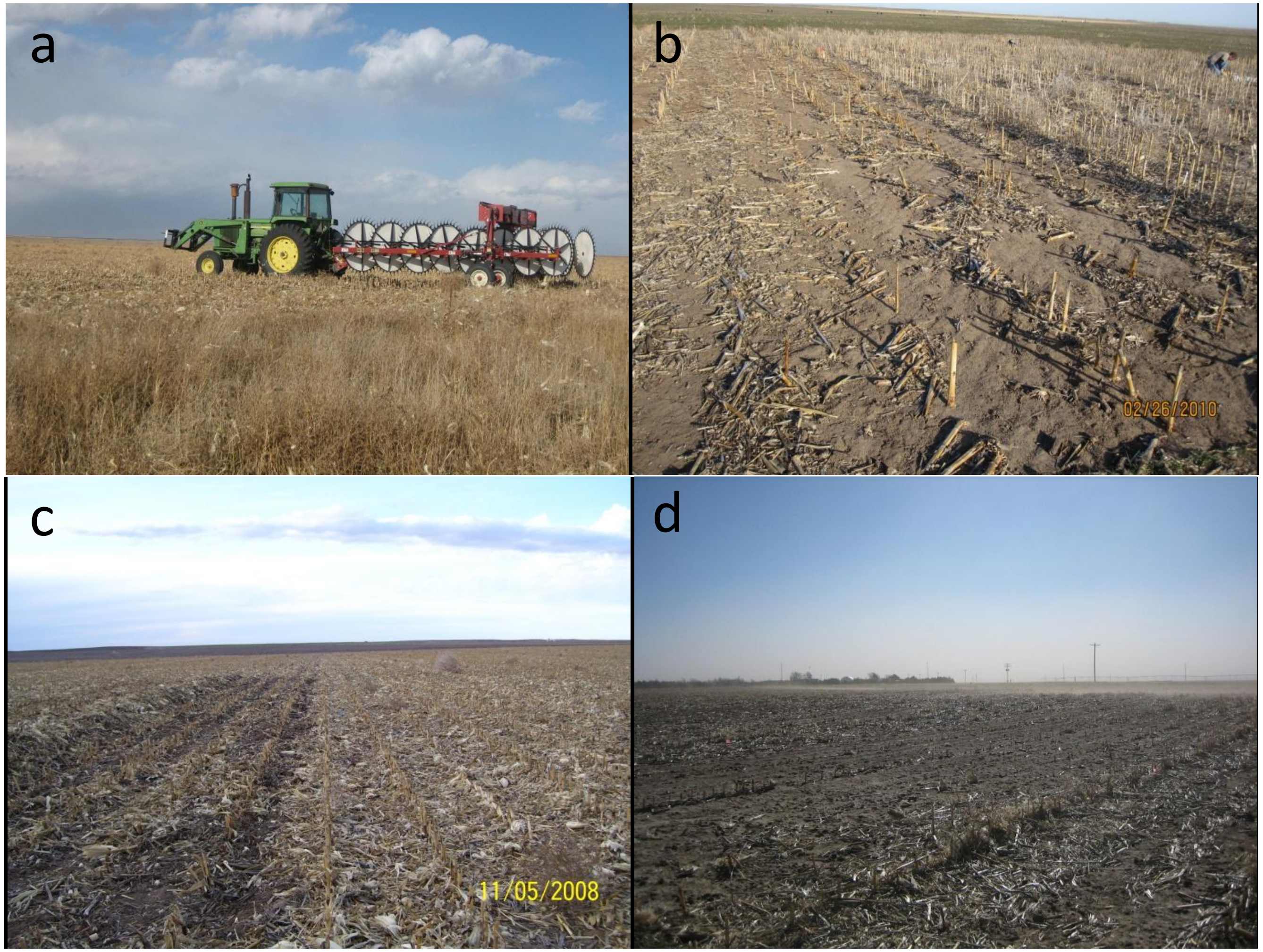

Figure 2.4 Photos from study site: a.) Tractor and wheel rake b.) Soil surface of Bigbow FSL following raking and baling (note the disturbed soil surface from the rake) c.) Residue removed (left side of photo) versus residue retained (right side of photo) d.) Wind erosion at sampling in April 2009.

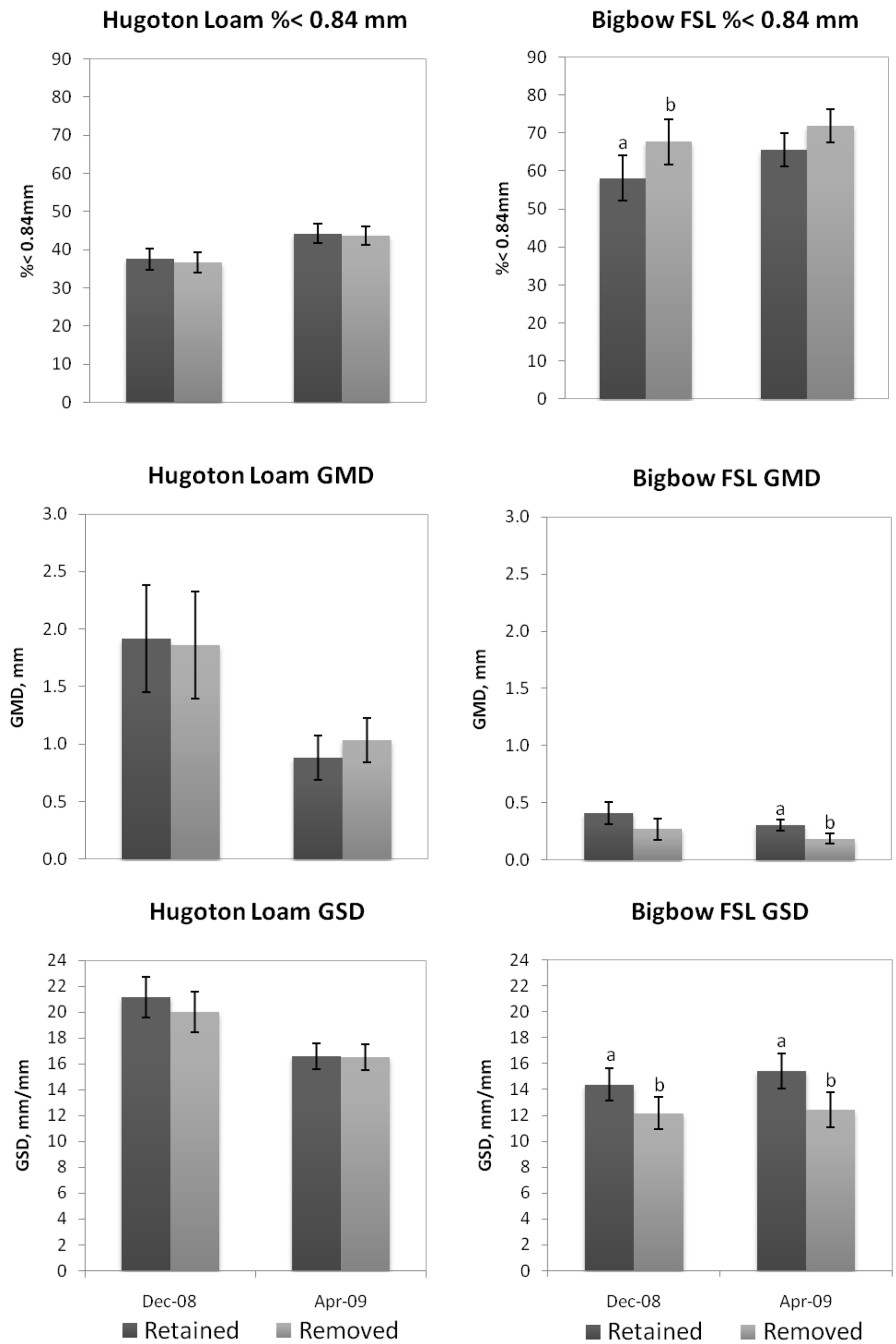

Figure 2.5 Fall 2008 and spring 2009 wind erosion parameters: %< 0.84 mm, geometric mean diameter (GMD), and geometric standard deviation (GSD). Error bars represent ± standard error. Different lowercase letters indicate a significant difference between treatments within the same season (P=0.10).

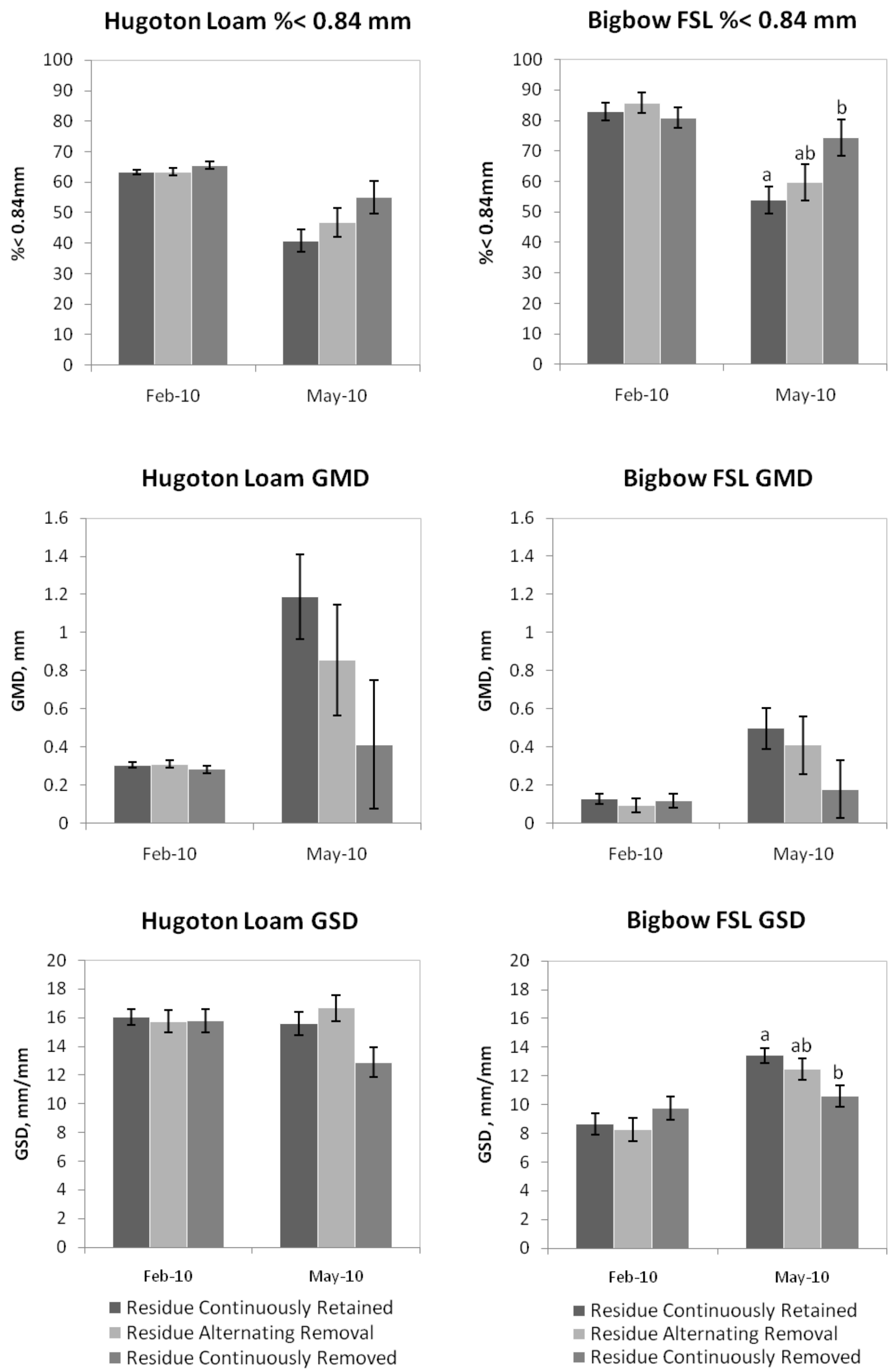

Figure 2.6 February 2010 and May 2010 wind erosion parameters: %< 0.84 mm, geometric mean diameter (GMD), and geometric standard deviation (GSD). Error bars represent ± standard error. Different lowercase letters indicate a significant difference between treatments within the same season (P=0.10).

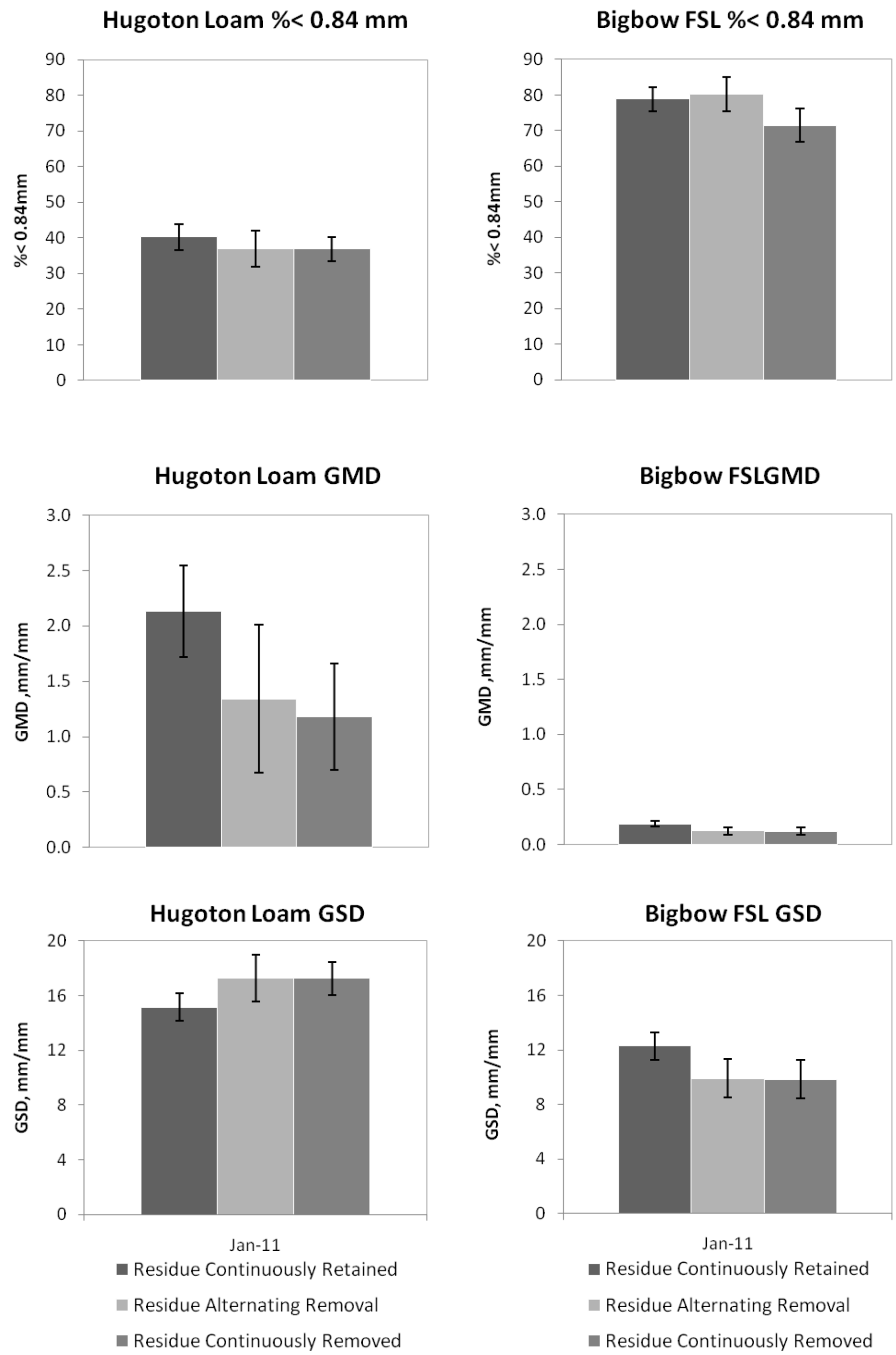

Figure 2.7 February 2010 and May 2010 wind erosion parameters: %< 0.84 mm, geometric mean diameter (GMD), and geometric standard deviation (GSD). Error bars represent ± standard error. No significant differences due to treatment observed between means (P=0.10).

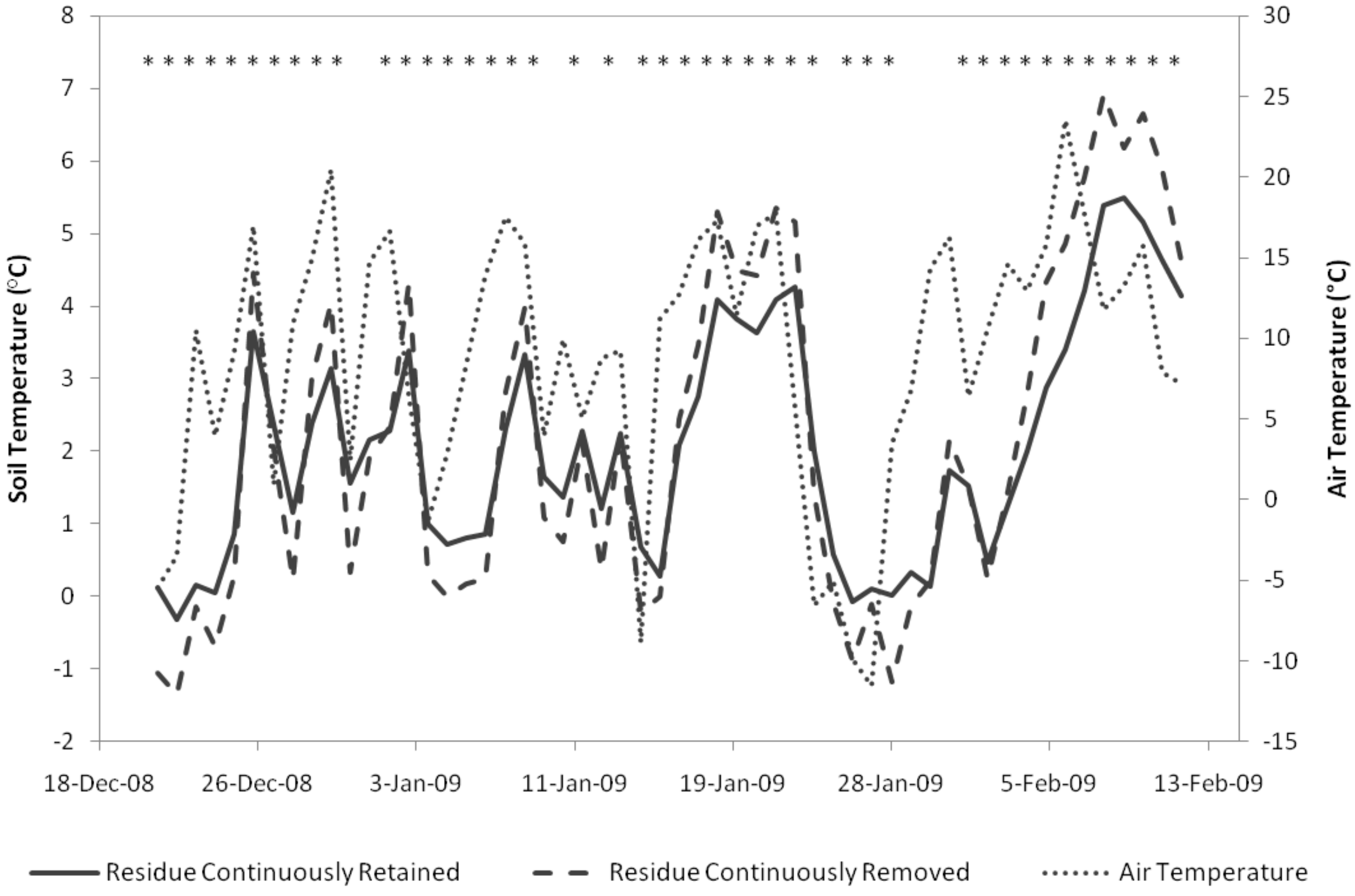

Figure 2.8 Hugoton L soil temperature during winter 2008-2009. *= significant difference between treatments (P=0.10).

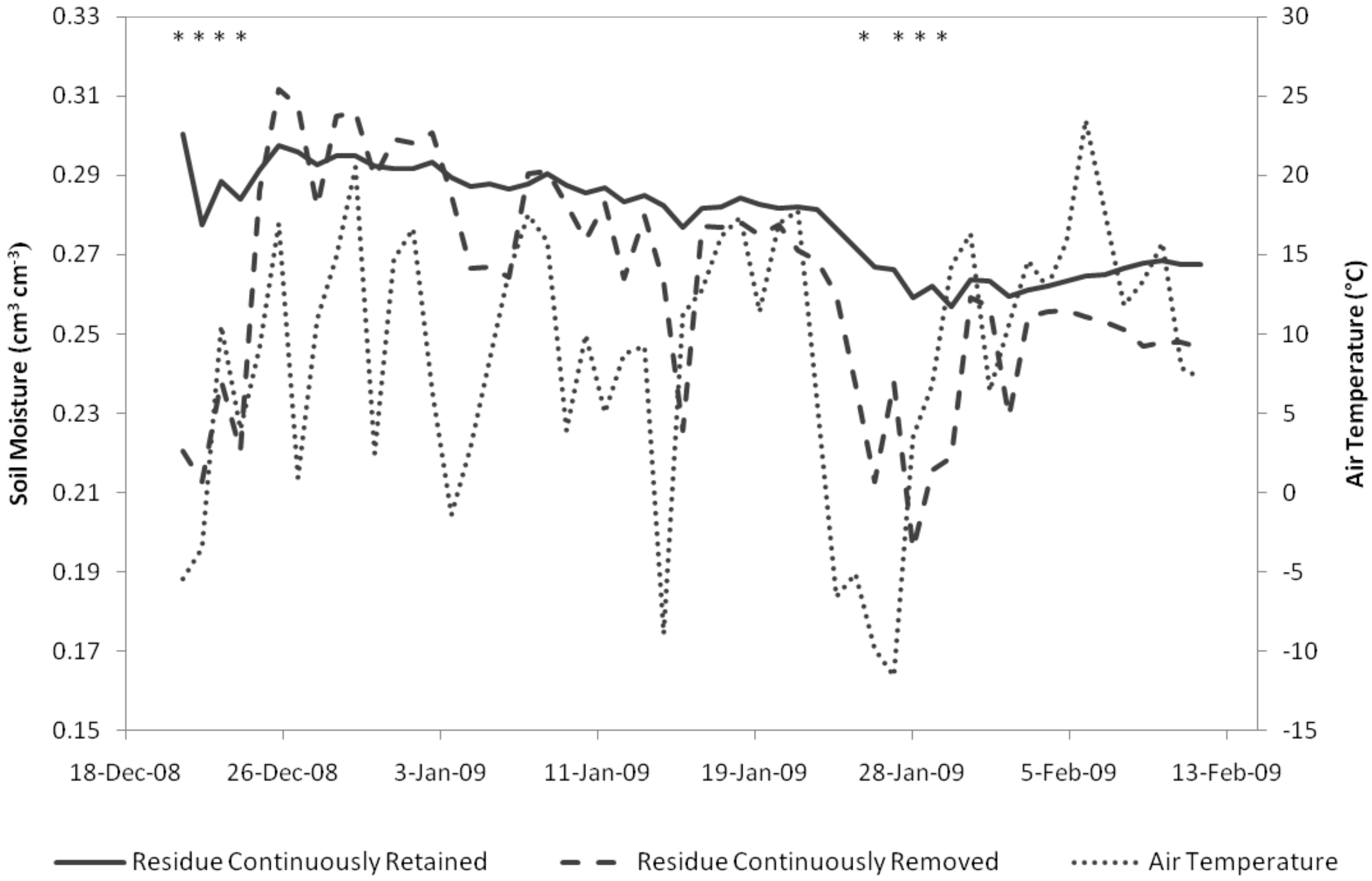

Figure 2.9 Hugoton L soil moisture during winter 2008-2009. *= significant difference between treatments (P=0.10).

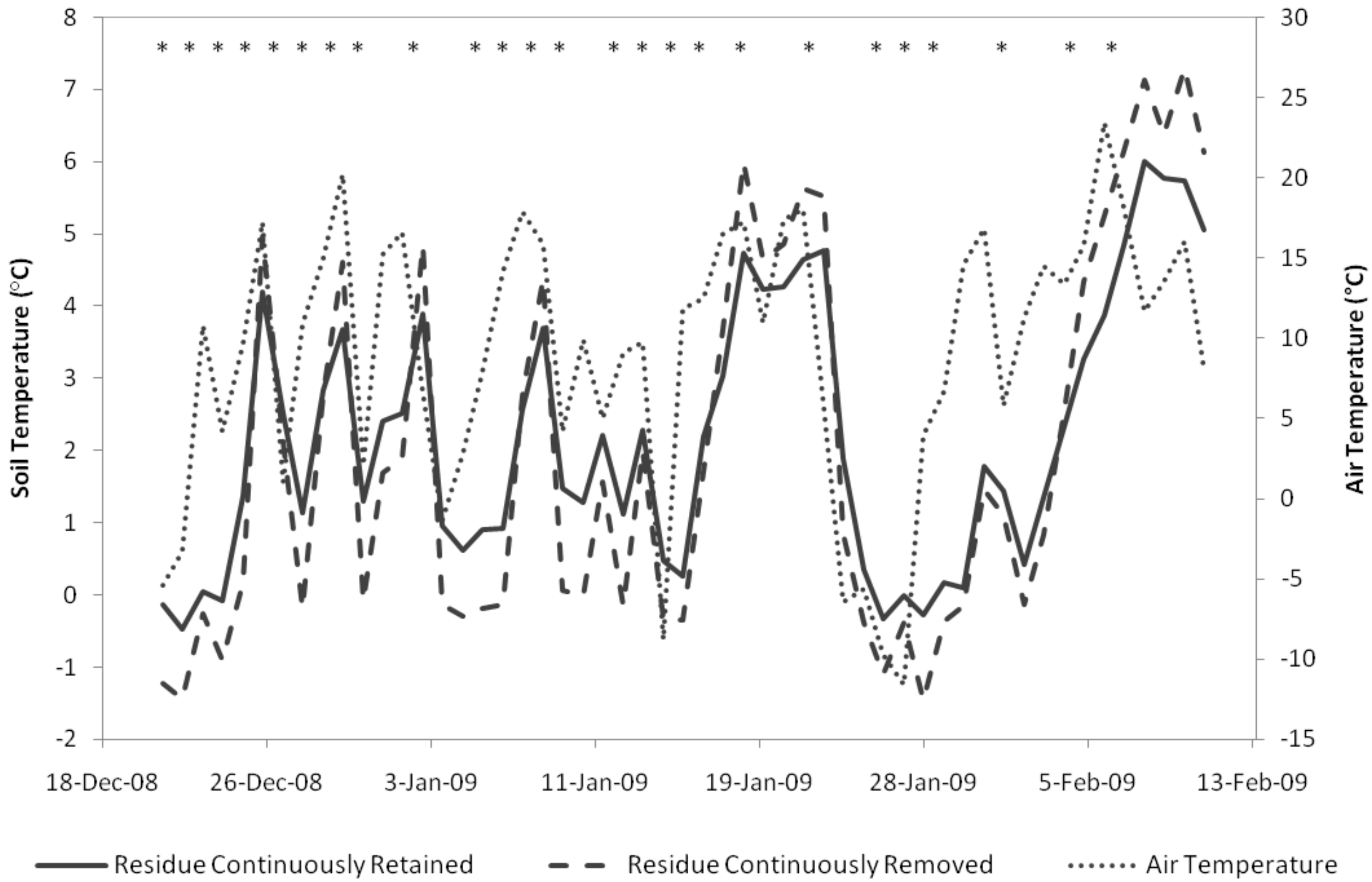

Figure 2.10 Bigbow FSL soil temperature winter 2008-2009. *= significant difference between treatments (P=0.10).

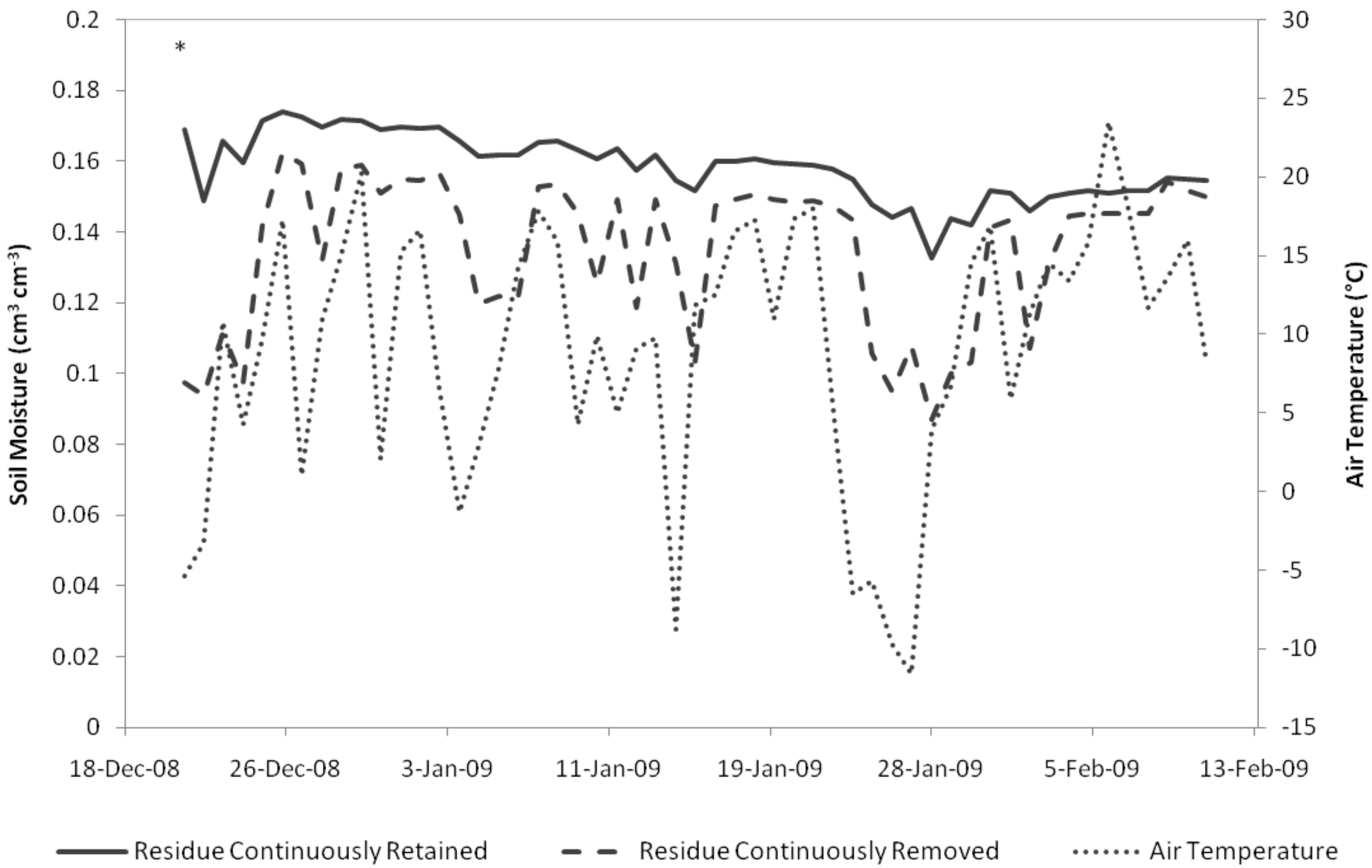

Figure 2.11 Bigbow FSL soil moisture winter 2008-2009. *= significant difference between treatments (P=0.10).

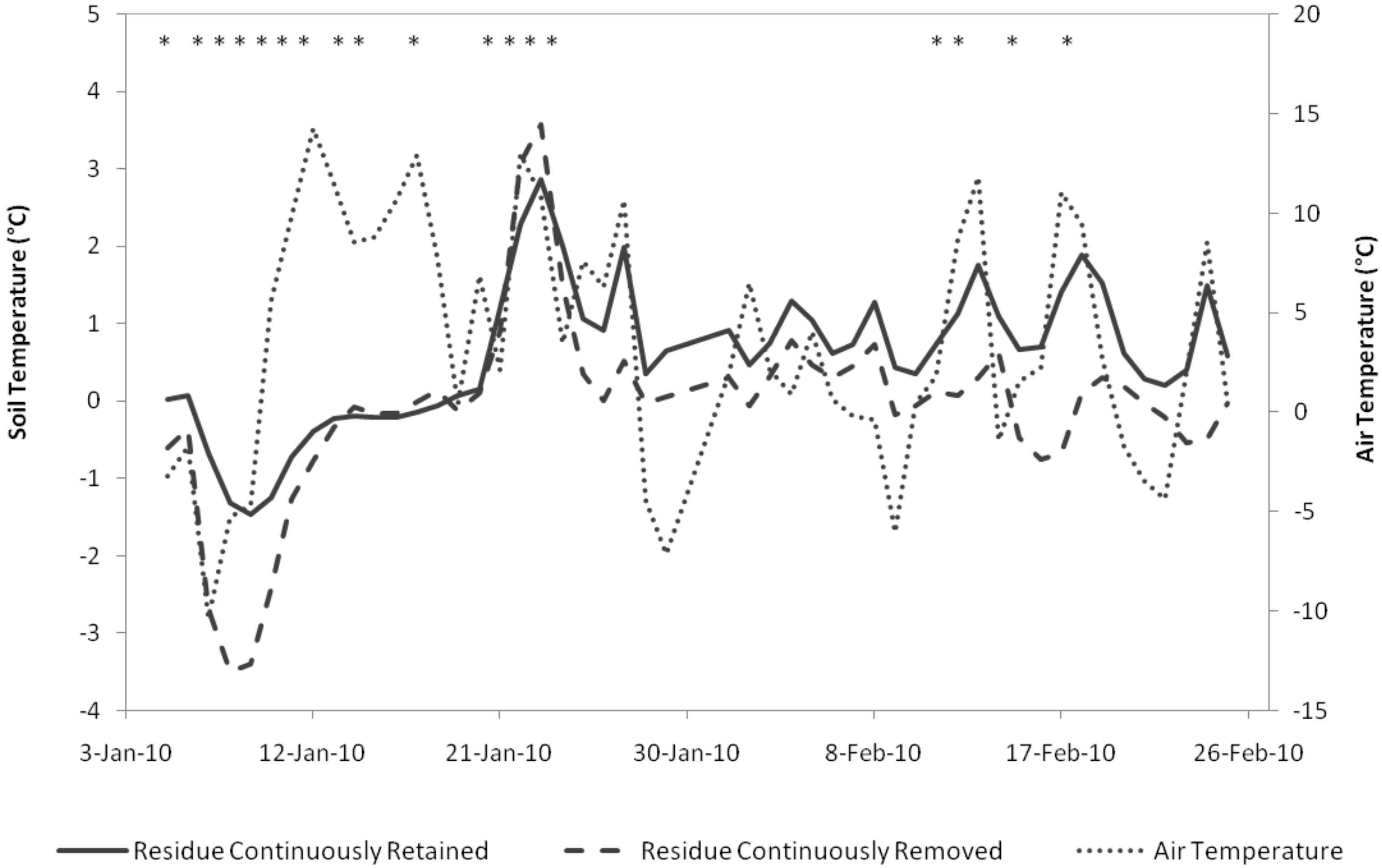

Figure 2.12 Hugoton L soil temperature during winter 2009-2010. *= significant difference between treatments (P=0.10).

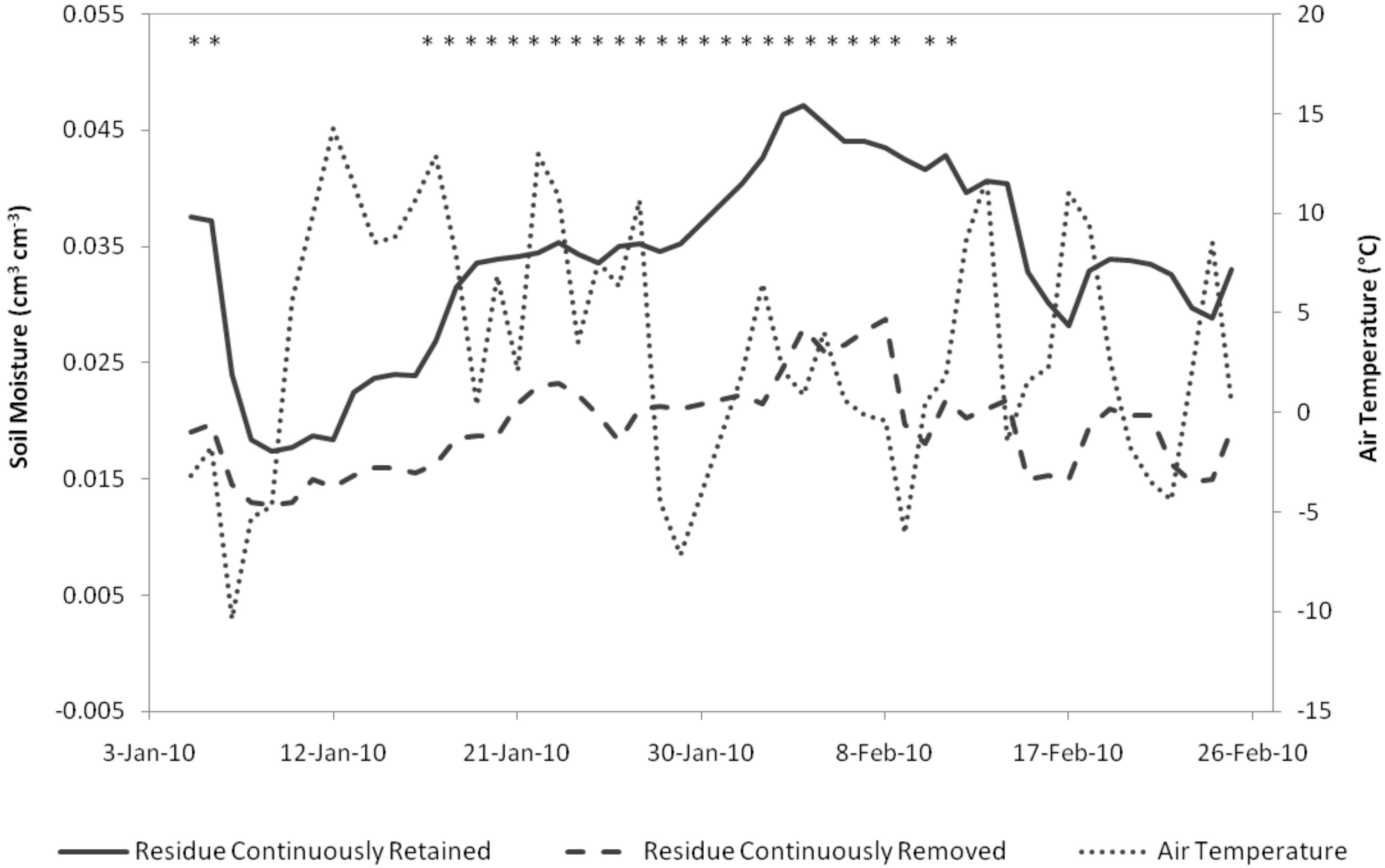

Figure 2.13 Hugoton L soil moisture during winter 2009-2010. *= significant difference between treatments (P=0.10).

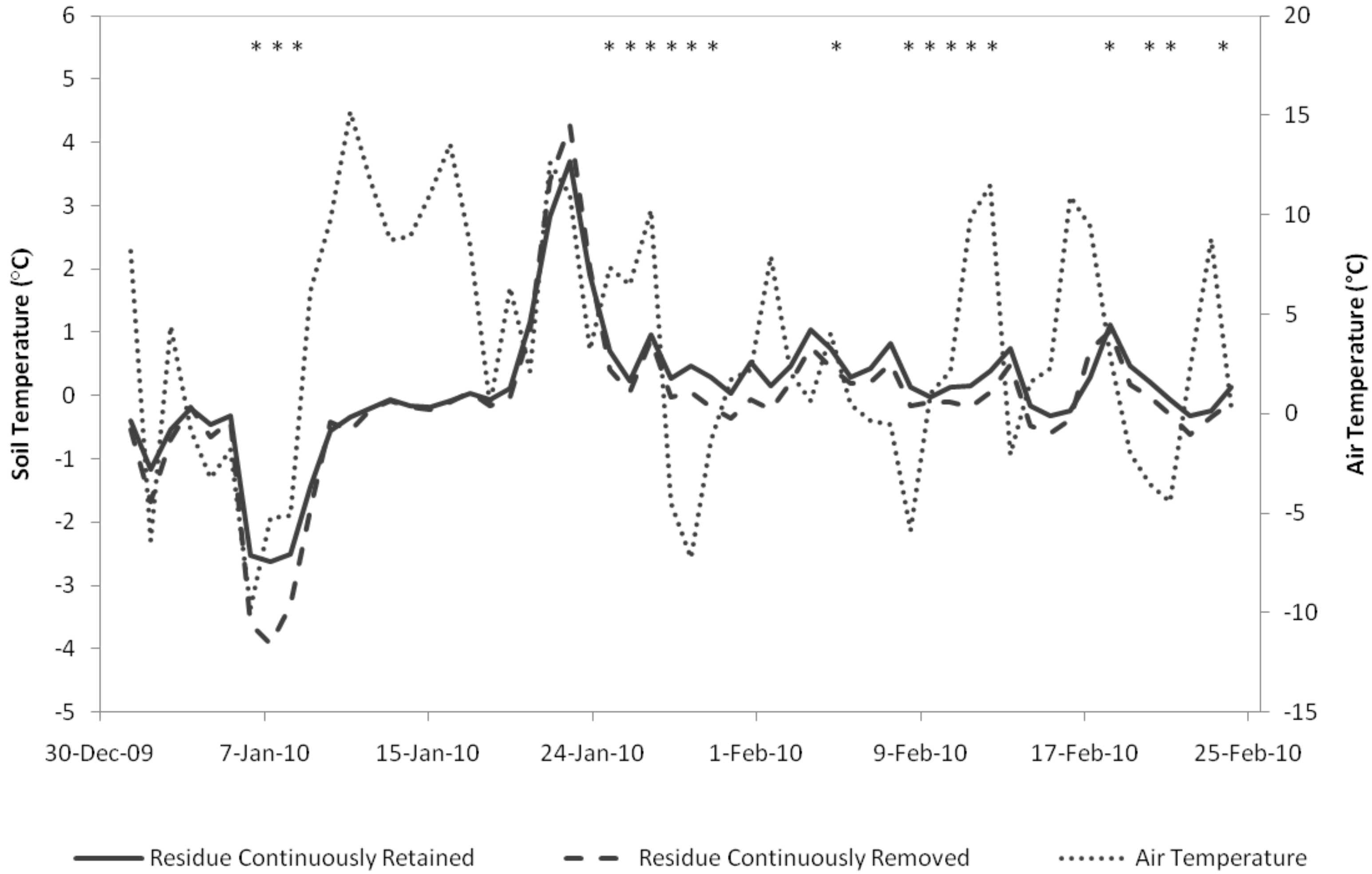

Figure 2.14 Bigbow FSL soil temperature during winter 2009-2010. *= significant difference between treatments (P=0.10).

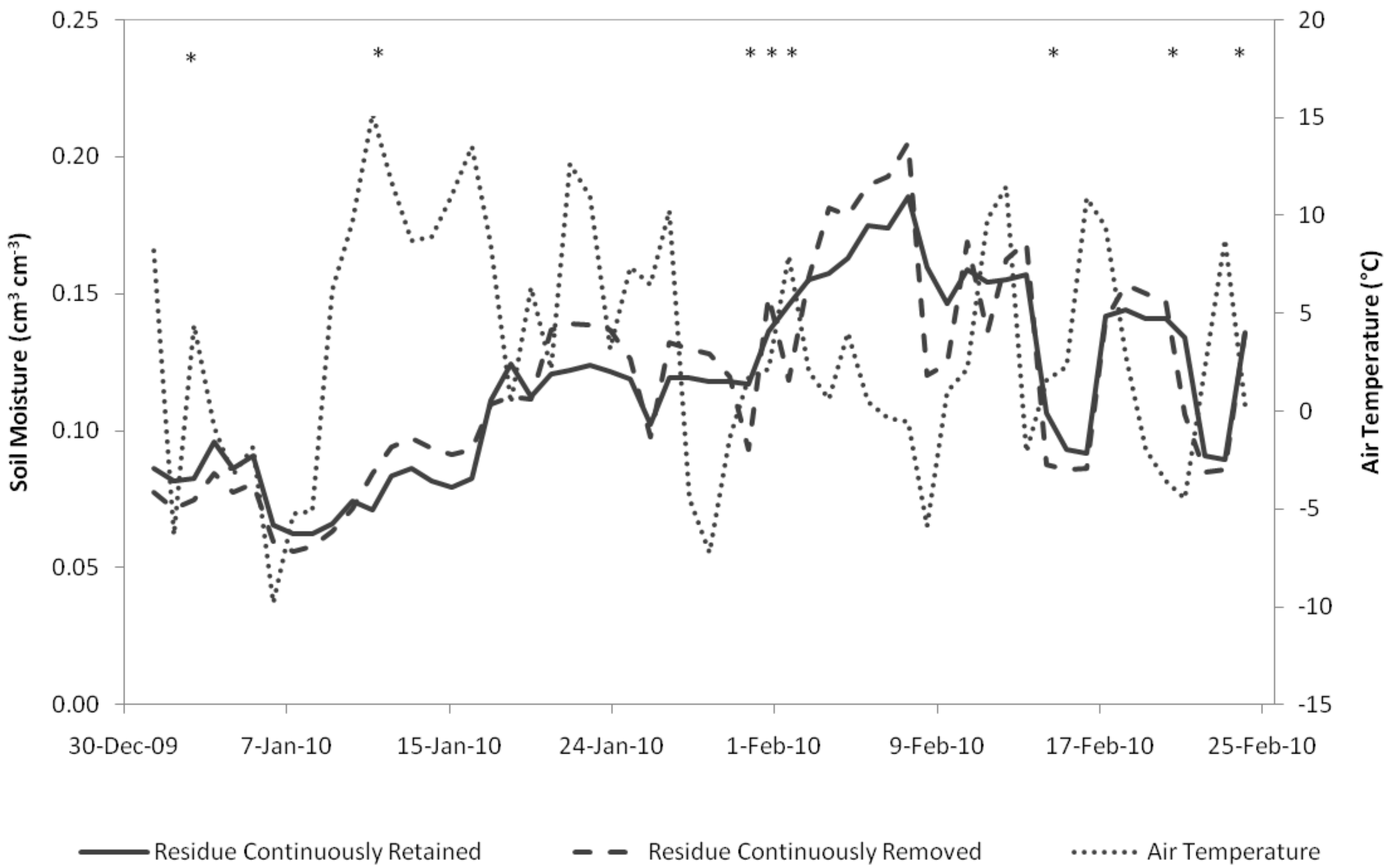

Figure 2.15 Bigbow FSL soil moisture during winter 2009-2010. *= significant difference between treatments (P=0.10).

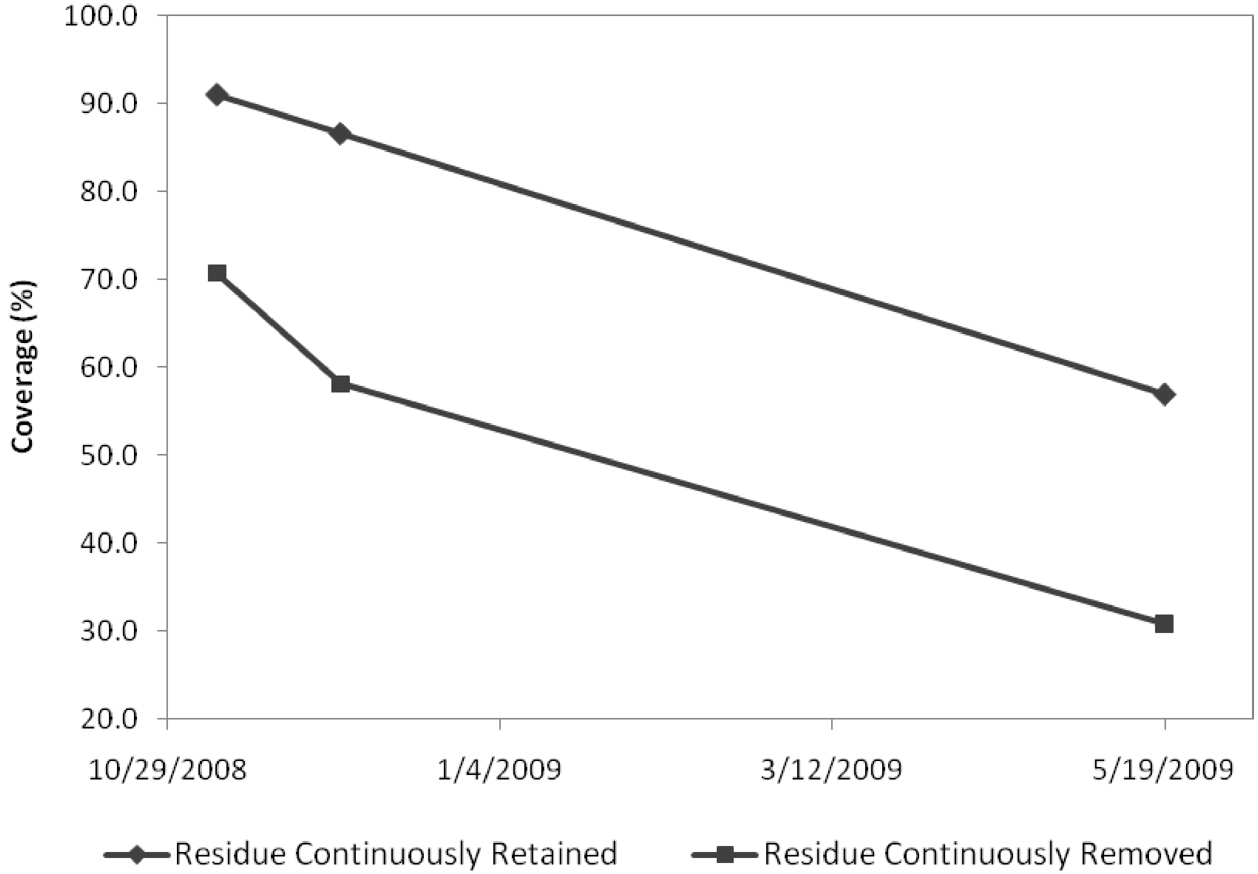

Figure 2.16 Hugoton L residue coverage for winter 2008-2009 treatments residue continuously retained and residue continuously removed. Residue counts were significantly different for all dates (P=0.05).

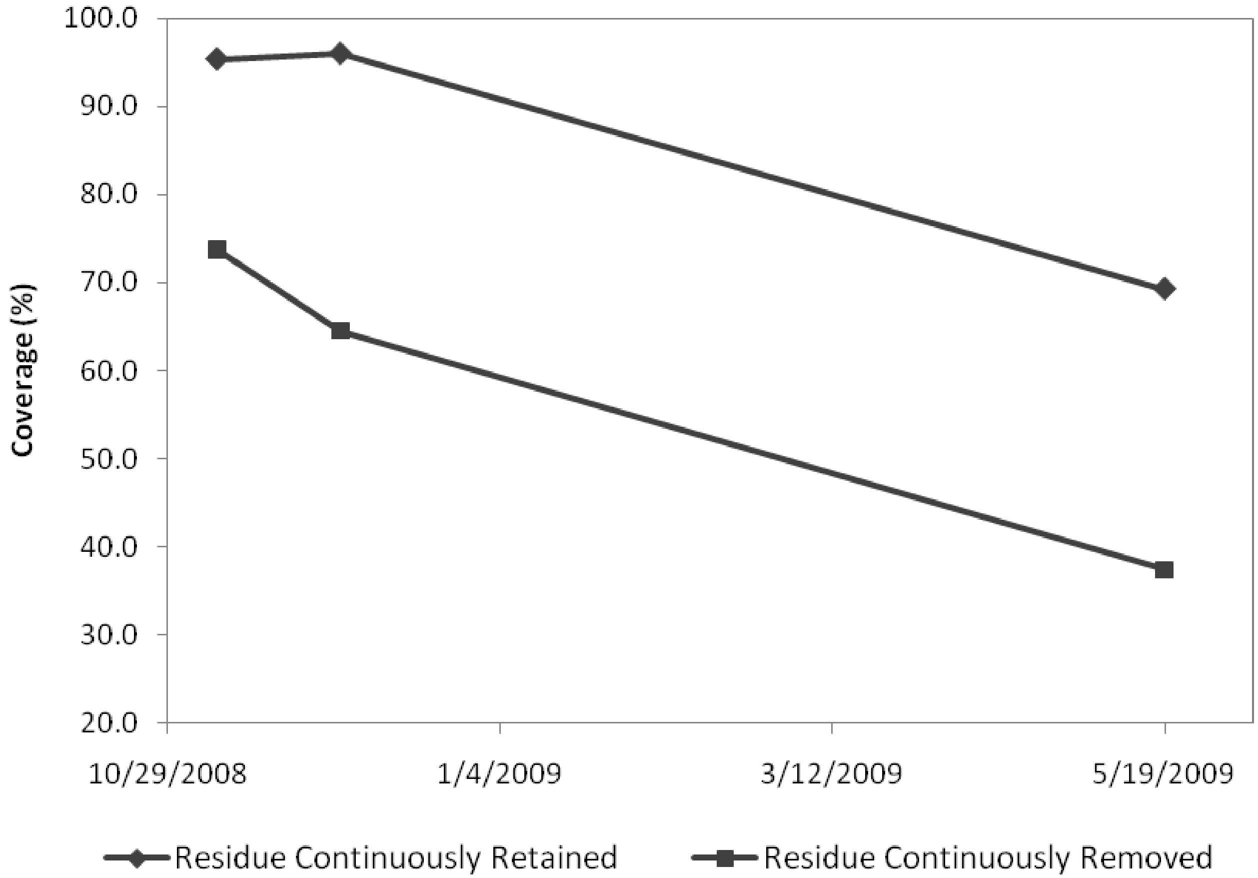

Figure 2.17 Bigbow FSL residue coverage for winter 2008-2009 of treatments residue continuously retained and residue continuously removed. Residue counts were significantly different for all dates (P=0.05).

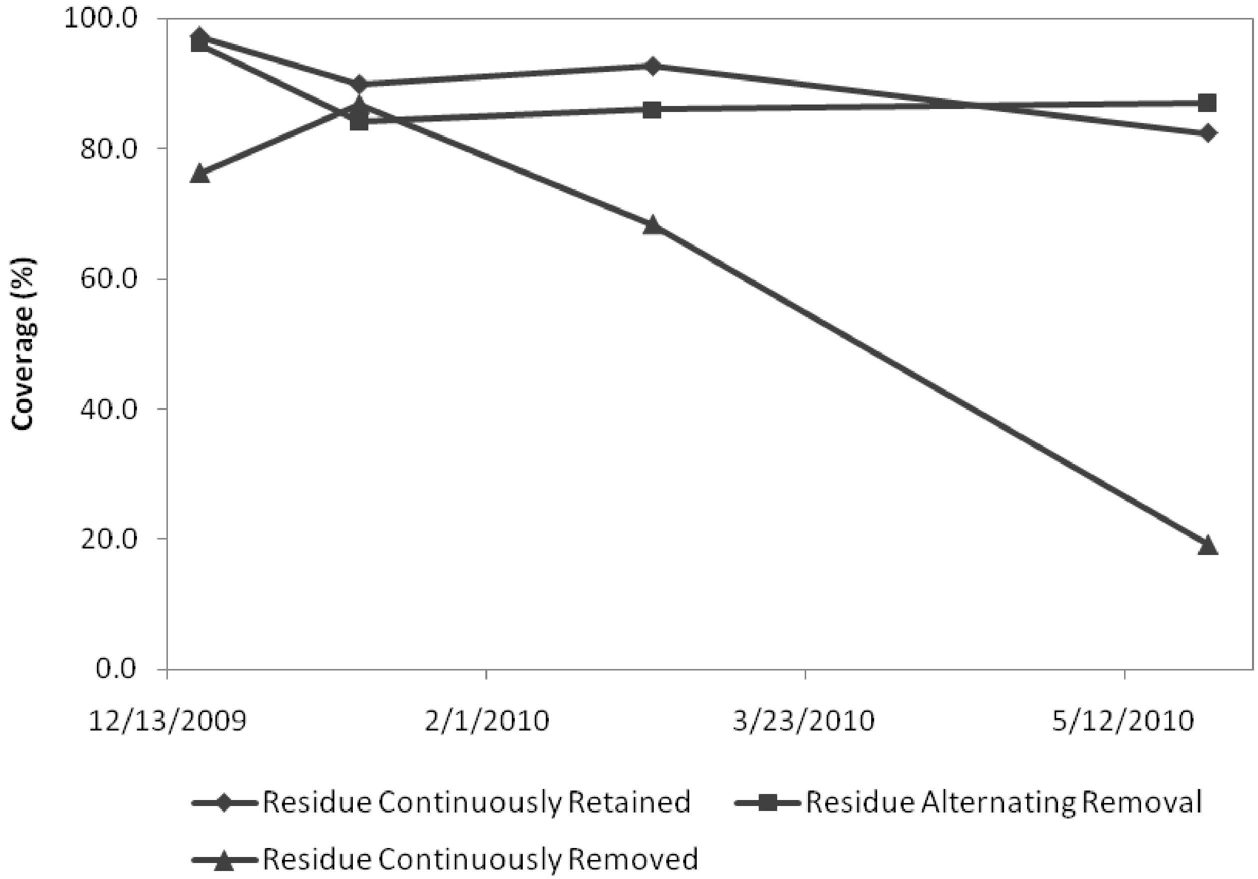

Figure 2.18 Hugoton L residue coverage for winter 2009-2010 of residue continuously retained, residue alternating removal, and residue continuously removed treatments. Residue counts were significantly different for all dates (P=0.05).

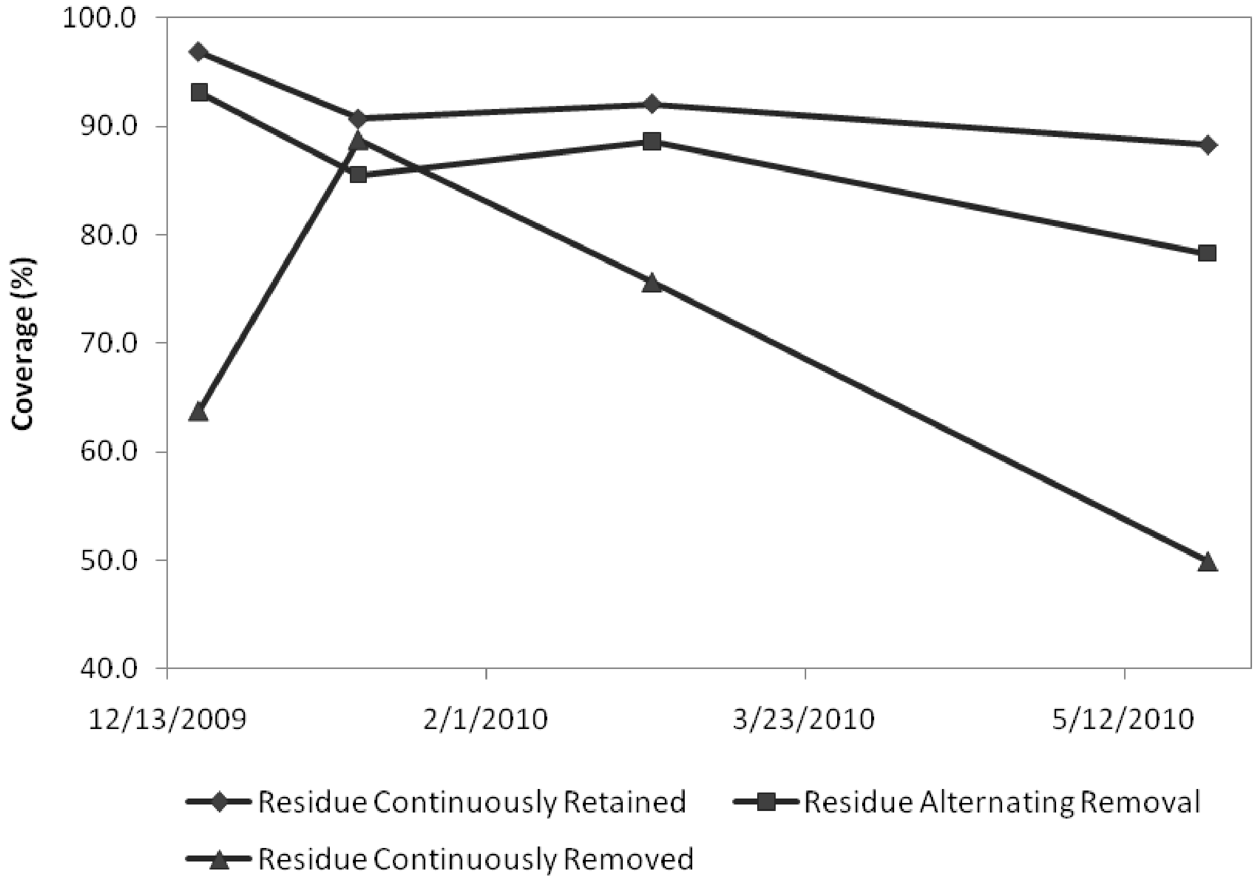

Figure 2.19 Bigbow FSL residue coverage for winter 2009-2010 of residue continuously retained, residue alternating removal, and residue continuously removed treatments. Residue counts were significantly different for all dates (P=0.05) except 12 Jan. 2010.

Table 2.1 Schedule of fertilizer, herbicide, planting, and irrigation dates with rates of application and method of application at Hugoton L site.

Hugoton Loam Field Operations 2008-2010			
Date	Operation	Rate	Equipment
March	Fertilizer Application	164 kg ha^{-1} -N (NH3) 12 kg ha^{-1} -N 41 kg ha^{-1}-P	JD 8530 and Orthman 1-Tripper
Early May	Planting	Pioneer 32T82 at 85,185 pop ha^{-1}	JD 8530 and JD 1770 Planter
Mid - May	Herbicide Application	Ammonium Sulfate at 1.82 kg ha^{-1} Dicamba at 0.28 kg ai ha^{-1} Glyphosate at 0.84 kg ae ha^{-1} S-metolachlor at 1.03 kg ai ha^{-1} and atrazine at 0.82 kg ai ha^{-1}	JD 4830 Sprayer
June	Herbicide Application	Ammonium Sulfate at 2.52 kg ha^{-1} Glyphosate at 1.34 kg ae ha^{-1}	JD 4830 Sprayer
May - August	Irrigation	54 cm	Center Pivot Irrigator

Table 2.2 Schedule of fertilizer, herbicide, planting, and irrigation dates with rates of application and method of application at Bigbow FSL site.

Bigbow Fine Sandy Loam Field Operations 2008 and 2009			
Date	Operation	Rate	Equipment
March	Fertilizer Application	164 kg ha^{-1} -N (NH3) 12 kg ha^{-1} -N 41 kg ha^{-1}-P	JD 8530 and Orthman 1-Tripper
Early May	Planting	Pioneer 33D47 at 76, 500 pop ha^{-1}	JD 8530 and JD 1770 Planter
Mid - May	Herbicide Application	Ammonium Sulfate at 1.82 kg ha^{-1} 2,4-D at 0.19 kg ai ha^{-1} S-metolachlor at 0.1.03 kg ai ha^{-1} and atrazine at 0.82 kg ai ha^{-1} Glyphosate at 0.84 kg ae ha^{-1}	JD 4830 Sprayer
June	Herbicide Application	Ammonium Sulfate at 1.82 kg ha^{-1} Glyphosate at 084 kg ae ha^{-1} Diflufenzopyr at 0.0.06 kg ai ha^{-1} and Dicamba at 0.15 kg ai ha^{-1}	JD 4830 Sprayer
May - August	Irrigation	54 cm	Center Pivot Irrigator

Table 2.3 Table of Hugoton L soil pedon properties.

Hugoton Loam Soil Pedon Properties										
		Particle Size Distribution				Structure			Matrix Color	
Horizon	Depth	Sand	Silt	Clay	Texture†	Grade‡	Size	Type§	Dry¶	Moist
	cm	---------------%---------------								
Ap	12	37	44	19	L	1	Medium	SBK	10 YR 4 2	10 YR 3 2
Bt	37	33	41	26	L	2	Medium	SBK	10 YR 4 3	10 YR 3 3
Btk1	56	36	34	30	CL	2	Medium	SBK	7.5 YR 5 4	7.5 YR 5 4
Btk2	81	33	42	25	L	1	Medium	SBK	7.5 YR 4 4	7.5 YR 4 4
Bk	98+	31	40	29	CL	1	Medium	SBK	7.5 YR 5 4	7.5 YR 5 4

Notes: † L =loam, CL= clay loam

‡ 1 = weak, 2= moderate

§ SBK = Sub Angular Blocky

¶ Dry and moist colors described in Munsell © notation (Hue, Value, Chroma)

Table 2.4 Table of Bigbow FSL soil pedon properties.

Bigbow Fine Sandy Loam Soil Pedon Properties										
		Particle Size Distribution				Structure			Matrix Color	
Horizon	Depth	Sand	Silt	Clay	Texture†	Grade‡	Size	Type§	Dry¶	Moist
	cm	---------------%---------------								
Ap1	10	76	16	8	FSL	1	Fine	SBK	10 YR 4 2	10 YR 3 2
Ap2	19	84	10	6	LFS	1	Fine	SBK	10 YR 5 4	10 YR 4 4
C	34	88	8	4	S	0	--	SGR	11 YR 5 4	11 YR 4 4
Bwb	63	52	32	16	FSL	2	Medium	SBK	12 YR 3 3	12 YR 3 3
Btb	84	50	28	22	L	2	Medium	SBK	13 YR 4 3	13 YR 4 3
Bkb	104+	60	22	18	FSL	1	Medium	SBK	7.5 YR 5 4	7.5 YR 4 4

Notes: † FSL = fine sandy loam, LFS = loamy fine sand, S = Sand, L = loam

‡ 0 = structureless, 1 = weak, 2= moderate

§ SBK = subangular blocky

¶ Dry and moist colors described in Munsell © notation (Hue, Value, Chroma)

Table 2.5 Schedule of soil sampling and other measurements.

History of Sampling and Measurement Dates	
Field Sample	Date
Wet Aggregate Stability	
Fall 2008	8 Nov. 2008
Spring 2009	4 April 2009
Fall 2009	18 Nov. 2009
Spring 2010	5 April 2009
Fall 2010	9 Nov. 2010
Wind Erosion	
Winter 2008-2009	19 Dec. 2008
Winter 2008-2009	18 April 2009
Winter 2009-2010	26 Feb. 2010
Winter 2009-2010	12 May 2010
Winter 2010-2011	29 Jan. 2011
Residue Measurements	
Winter 2008-2009	8 Nov. 2008
Winter 2008-2009	3 Dec. 2008
Winter 2008-2009	19 May 2009
Winter 2009-2010	18 Dec. 2009
Winter 2009-2010	12 Jan. 2010
Winter 2009-2010	27 Feb. 2010
Winter 2009-2010	25 May 2010
Grain and Residue Harvest	
Fall 2009	18 Sept. 2009
Fall 2010	5 Oct. 2010
Soil Fertility	
Fall 2008	8 Nov. 2008
Fall 2009	18 Nov. 2009
Fall 2010	9 Nov. 2010
Bulk Density	
Fall 2008	8 Nov. 2008
Fall 2009	18 Nov. 2009
Fall 2010	5 Oct. 2010

Table 2.6 ANOVA tables of Hugoton L and Bigbow FSL Mean Weight Diameter (MWD) and Water Stable Aggregate (WSA) size classes from fall 2008. Results from contrasts are shown as *, **, and NS, indicating significance at P=0.10, P=0.05, or not significant at P=0.10.

Hugoton Loam Fall 2008		
Property	Residue Treatment	
	Depth	
	0-5cm	5-15cm
MWD	**	*
WSA Size Class		
<0.053	NS	NS
0.053 to 0.25	**	NS
0.25 to 0.5	*	NS
0.5 to 1.00	**	**
1.00 to 2.00	NS	NS

Bigbow FSL Fall 2008		
Property	Residue Treatment	
	Depth	
	0-5cm	5-15cm
MWD	**	NS
WSA Size Class		
<0.053	**	NS
0.053 to 0.25	NS	NS
0.25 to 0.5	NS	NS
0.5 to 1.00	NS	NS
1.00 to 2.00	NS	NS

Table 2.7 Concentration of water-stable aggregates and mean weight diameter (MWD) as affected by residue removed and residue retained in the Hugoton L fall 2008.

	Hugoton Loam Fall 2008					
	Concentration of water-stable aggregates on each size or sieve opening					Mean Weight Diameter
	<0.053	0.053 to 0.25	0.25 to 0.5	0.5 to 1.00	1.00 to 2.00	
	g sand-free 100 g^{-1} soil					mm
Treatment	0--5 cm					
1 Year Residue Retained	43.63 †	25.50 a	14.13 a	13.25 a	3.88 a	0.259 a
1 Year Residue Removed	47.88	35.50 b	10.25 b	5.75 b	0.63 b	0.158 b
	5--15 cm					
1 Year Residue Retained	45.37	33.38	12.38	8.25 a	0.25	0.148 a
1 Year Residue Removed	46.00	37.50	12.38	3.75 b	0.13	0.175 b

Note: † Within columns for each depth, means followed by different letters are significantly different (P=0.10).

Table 2.8 Concentration of water-stable aggregates and mean weight diameter (MWD) as affected by residue removed and residue retained in the Bigbow FSL fall 2008.

Bigbow FSL Fall 2008						
	Concentration of water-stable aggregates on each size or sieve opening					Mean Weight Diameter
	<0.053	0.053 to 0.25	0.25 to 0.5	0.5 to 1.00	1.00 to 2.00	
	g sand-free 100 g^{-1} soil					mm
Treatment	0--5 cm					
1 Year Residue Retained	48.50 a†	5.25	10.75	20.88	15.12	0.444 a
1 Year Residue Removed	57.50 b	5.5	12.00	17.25	7.38	0.310 b
	5--15 cm					
1 Year Residue Retained	63.88	7.13	10.50	15.00	3.63	0.234
1 Year Residue Removed	64.25	7.25	12.25	11.50	4.50	0.228

Note: † Within columns for each depth, means followed by different letters are significantly different (P=0.10).

Table 2.9 ANOVA tables of Hugoton L and Bigbow FSL Mean Weight Diameter (MWD) and Water Stable Aggregate (WSA) size classes from spring 2009. Results from contrasts are shown as *, **, and NS, indicating significance at P=0.10, P=0.05, or not significant at P=0.10.

Hugoton Loam Spring 2009		
Property	Residue Treatment	
	Depth	
	0-5cm	5-15cm
MWD	NS	NS
WSA Size Class		
<0.053	NS	NS
0.053 to 0.25	NS	NS
0.25 to 0.5	NS	NS
0.5 to 1.00	NS	NS
1.00 to 2.00	NS	NS

Bigbow FSL Spring 2009		
Property	Residue Treatment	
	Depth	
	0-5cm	5-15cm
MWD	NS	**
WSA Size Class		
<0.053	NS	**
0.053 to 0.25	*	NS
0.25 to 0.5	NS	NS
0.5 to 1.00	*	NS
1.00 to 2.00	NS	*

Table 2.10 Concentration of water-stable aggregates and mean weight diameter (MWD) as affected by residue removed and residue retained in the Hugoton L spring 2009.

	Hugoton Loam Spring 2009					
	Concentration of water-stable aggregates on each size or sieve opening					Mean Weight Diameter
	<0.053	0.053 to 0.25	0.25 to 0.5	0.5 to 1.00	1.00 to 2.00	
	g sand-free 100 g^{-1} soil					mm
Treatment	0--5 cm					
1 Year Residue Retained	39.62†	17.38	21.38	17.88	3.25	0.301
1 Year Residue Removed	43.62	21.38	18.13	12.75	4.25	0.269
	5--15 cm					
1 Year Residue Retained	32.50	14.63	16.63	24.50	11.63	0.453
1 Year Residue Removed	40.62	16.38	15.88	20.50	6.63	0.349

Note: † Within columns for each depth, means are not significantly different due to treatment (P=0.10).

Table 2.11 Concentration of water-stable aggregates and mean weight diameter (MWD) as affected by residue removed and residue retained in the Bigbow FSL spring 2009.

Bigbow FSL Spring 2009						
	Concentration of water-stable aggregates on each size or sieve opening					Mean Weight Diameter
	<0.053	0.053 to 0.25	0.25 to 0.5	0.5 to 1.00	1.00 to 2.00	
	g sand-free 100 g^{-1} soil					mm
Treatment	0--5 cm					
1 Year Residue Retained	60.00†	5.75 a	13.88	13.25 a	7.00	0.283
1 Year Residue Removed	63.50	10.38 b	14.63	7.50 b	4.13	0.203
	5--15 cm					
1 Year Residue Retained	56.00 a	7.63	15.25	12.50	8.63 a	0.308 a
1 Year Residue Removed	67.38 b	7.50	13.25	9.63	2.25 b	0.184 b

Note: † Within columns for each depth, means followed by different letters are significantly different (P=0.10).

Table 2.12 ANOVA tables of Hugoton L and Bigbow FSL Mean Weight Diameter (MWD) and Water Stable Aggregate (WSA) size classes from fall 2009. Results from contrasts are shown as *, **, and NS, indicating significance at P=0.10, P=0.05, or not significant at P=0.10.

Hugoton Loam Fall 2009		
Property	Residue Treatment	
	Depth	
	0-5cm	5-15cm
MWD	NS	*
WSA Size Class		
<0.053	NS	**
0.053 to 0.25	NS	NS
0.25 to 0.5	NS	**
0.5 to 1.00	NS	**
1.00 to 2.00	NS	NS

Bigbow FSL Fall 2009		
Property	Residue Treatment	
	Depth	
	0-5cm	5-15cm
MWD	NS	NS
WSA Size Class		
<.053	NS	NS
0.053 to 0.25	NS	NS
0.25 to 0.5	NS	NS
0.5 to 1.00	NS	NS
1.00 to 2.00	NS	**

Table 2.13 Concentration of water-stable aggregates and mean weight diameter (MWD) as affected by residue removed and residue retained in the Hugoton L fall 2009.

	Hugoton Loam Fall 2009					
	Concentration of water-stable aggregates on each size or sieve opening					Mean Weight Diameter
	<0.053	0.053 to 0.25	0.25 to 0.5	0.5 to 1.00	1.00 to 2.00	
	g sand-free 100 g^{-1} soil					mm
Treatment	0--5 cm					
Residue Continuously Retained	38.00†	26.50	18.50	14.38	2.75	0.268
Residue Alternating Removal	38.75	31.50	16.75	11.50	1.50	0.233
Residue Continuously Removed	40.25	28.25	18.50	11.50	1.75	0.233
	5--15 cm					
Residue Continuously Retained	43.88 a	39.88	11.00 a	5.00 a	0.00	0.155 a
Residue Alternating Removal	36.00 b	32.50	16.50 b	13.25 b	1.75	0.248 b
Residue Continuously Removed	44.25 a	37.50	12.25 a	6.00 a	0.00	0.165 a

Note: † Within columns for each depth, means followed by different letters are significantly different (P=0.10).

Table 2.14 Concentration of water-stable aggregates and mean weight diameter (MWD) as affected by residue removed and residue retained in the Bigbow FSL fall 2009.

Bigbow FSL Fall 2009						
	Concentration of water-stable aggregates on each size or sieve opening					Mean Weight Diameter
	<0.053	0.053 to 0.25	0.25 to 0.5	0.5 to 1.00	1.00 to 2.00	
	g sand-free 100 g^{-1} soil					mm
Treatment	0--5 cm					
Residue Continuously Retained	47.88†	5.25	16.00	18.50	12.00	0.400
Residue Alternating Removal	52.75	6.25	16.50	17.50	7.25	0.325
Residue Continuously Removed	55.50	6.75	15.75	16.00	6.00	0.298
	5--15 cm					
Residue Continuously Retained	63.88	7.13	16.50	10.38	1.50 a	0.191
Residue Alternating Removal	67.50	7.50	15.50	9.25	0.25 a	0.163
Residue Continuously Removed	63.25	8.25	15.25	9.00	4.75 b	0.223

Note: † Within columns for each depth, means followed by different letters are significantly different (P=0.10).

Table 2.15 ANOVA tables of Hugoton L and Bigbow FSL Mean Weight Diameter (MWD) and Water Stable Aggregate (WSA) size classes from spring 2010. Results from contrasts are shown as *, **, and NS, indicating significance at P=0.10, P=0.05, or not significant at P=0.10.

Hugoton Loam Spring 2010		
Property	Residue Treatment	
	Depth	
	0-5cm	5-15cm
MWD	NS	NS
WSA Size Class		
<0.053	NS	NS
0.053 to 0.25	NS	NS
0.25 to 0.5	NS	NS
0.5 to 1.00	NS	NS
1.00 to 2.00	NS	NS

Bigbow FSL Spring 2010		
Property	Residue Treatment	
	Depth	
	0-5cm	5-15cm
MWD	**	NS
WSA Size Class		
<0.053	**	NS
0.053 to 0.25	**	NS
0.25 to 0.5	**	NS
0.5 to 1.00	NS	NS
1.00 to 2.00	*	NS

Table 2.16 Concentration of water-stable aggregates and mean weight diameter (MWD) as affected by residue removed and residue retained in the Hugoton L spring 2010.

Hugoton Loam Spring 2010						
	Concentration of water-stable aggregates on each size or sieve opening					Mean Weight Diameter
	<0.053	0.053 to 0.25	0.25 to 0.5	0.5 to 1.00	1.00 to 2.00	
	g sand-free 100 g^{-1} soil					mm
Treatment	0--5 cm					
Residue Continuously Retained	34.13†	16.00	24.00	21.38	4.13	0.348
Residue Alternating Removal	30.50	17.75	23.50	23.50	4.50	0.370
Residue Continuously Removed	34.50	20.75	22.25	20.75	1.50	0.305
	5--15 cm					
Residue Continuously Retained	43.88	32.00	14.63	9.25	0.25	0.190
Residue Alternating Removal	39.00	29.75	17.50	13.25	0.50	0.228
Residue Continuously Removed	41.75	30.00	19.75	8.25	0.25	0.198

Note: † Within columns for each depth, means not significantly different due to treatment (P=0.10).

Table 2.17 Concentration of water-stable aggregates and mean weight diameter (MWD) as affected by residue removed and residue retained in the Bigbow FSL spring 2010.

	Bigbow FSL Spring 2010					
	Concentration of water-stable aggregates on each size or sieve opening					Mean Weight Diameter
	<0.053	0.053 to 0.25	0.25 to 0.5	0.5 to 1.00	1.00 to 2.00	
	g sand-free 100 g^{-1} soil					mm
Treatment	0--5 cm					
Residue Continuously Retained	45.75 a†	5.63 a	14.62 a	21.75	12.88 a	0.430 a
Residue Alternating Removal	52.00 b	6.00 a	17.00 b	19.25	5.25 b	0.310 b
Residue Continuously Removed	50.00 b	7.75 b	18.00 b	17.50	6.50 b	0.323 b
	5--15 cm					
Residue Continuously Retained	63.75	7.63	13.13	12.00	3.50	0.223
Residue Alternating Removal	67.00	7.50	13.75	10.50	1.50	0.183
Residue Continuously Removed	65.25	9.00	13.25	11.00	1.75	0.185

Note: † Within columns for each depth, means followed by different letters are significantly different (P=0.10).

Table 2.18 ANOVA tables of Hugoton L and Bigbow FSL Mean Weight Diameter (MWD) and Water Stable Aggregate (WSA) size classes from fall 2010. Results from contrasts are NS, indicating not significant at P=0.10.

Hugoton Loam Fall 2010		
Property	Residue Treatment	
	Depth	
	0-5cm	5-15cm
MWD	NS	NS
WSA Size Class		
<0.053	NS	NS
0.053 to 0.25	NS	NS
0.25 to 0.5	NS	NS
0.5 to 1.00	NS	NS
1.00 to 2.00	NS	NS

Bigbow FSL Fall 2010		
Property	Residue Treatment	
	Depth	
	0-5cm	5-15cm
MWD	NS	NS
WSA Size Class		
<0.053	NS	NS
0.053 to 0.25	NS	NS
0.25 to 0.5	NS	NS
0.5 to 1.00	NS	NS
1.00 to 2.00	NS	NS

Table 2.19 Concentration of water-stable aggregates and mean weight diameter (MWD) as affected by residue removed and residue retained in the Hugoton L fall 2010.

Hugoton Loam Fall 2010						
	Concentration of water-stable aggregates on each size or sieve opening					Mean Weight Diameter
	<0.053	0.053 to 0.25	0.25 to 0.5	0.5 to 1.00	1.00 to 2.00	
	g sand-free 100 g^{-1} soil					mm
Treatment	0--5 cm					
Residue Continuously Retained	39.31†	24.83	15.27	14.54	6.06	0.304
Residue Alternating Removal	43.08	30.19	13.14	10.01	3.58	0.235
Residue Continuously Removed	46.14	28.86	13.39	9.71	1.91	0.208
	5--15 cm					
Residue Continuously Retained	47.75	31.08	11.98	7.77	1.42	0.185
Residue Alternating Removal	44.51	29.89	11.95	9.36	4.30	0.238
Residue Continuously Removed	48.97	32.63	10.63	6.27	1.50	0.173

Note: † Within columns for each depth, means not significantly different due to treatment (P=0.10).

Table 2.20 Concentration of water-stable aggregates and mean weight diameter (MWD) as affected by residue removed and residue retained in the Bigbow FSL fall 2010.

Bigbow FSL Fall 2010						
	Concentration of water-stable aggregates on each size or sieve opening					Mean Weight Diameter
	<0.053	0.053 to 0.25	0.25 to 0.5	0.5 to 1.00	1.00 to 2.00	
	g sand-free 100 g^{-1} soil					mm
Treatment	0--5 cm					
Residue Continuously Retained	42.91†	5.14	14.88	20.69	16.38	0.476
Residue Alternating Removal	44.57	4.24	14.08	19.97	17.15	0.478
Residue Continuously Removed	44.31	6.01	16.95	20.34	12.40	0.420
	5--15 cm					
Residue Continuously Retained	54.56	8.05	12.20	12.90	12.30	0.353
Residue Alternating Removal	55.90	6.51	11.86	14.96	10.78	0.343
Residue Continuously Removed	54.83	7.55	12.03	15.58	10.01	0.340

Note: † Within columns for each depth, means not significantly different due to treatment (P=0.10).

Table 2.21 ANOVA tables for fall 2008 and spring 2009 of wind erosion parameters: %< 0.84 mm, geometric mean diameter (GMD), and geometric standard deviation (GSD). Results from contrasts are shown as *, **, and NS, indicating significance at P=0.10, P=0.05, or not significant at P=0.10.

December 2008		
Property	Residue Treatment	
	Hugoton L	Bigbow FSL
%< 0.84 mm	NS	**
GMD	NS	NS
GSD	NS	*

April 2009		
Property	Residue Treatment	
	Hugoton L	Bigbow FSL
%< 0.84 mm	NS	NS
GMD	NS	**
GSD	NS	**

Table 2.22 ANOVA tables for February 2010 and May 2010 of wind erosion parameters: %< 0.84 mm, geometric mean diameter (GMD), and geometric standard deviation (GSD). Results from contrasts are shown as *, **, and NS, indicating significance at P=0.10, P=0.05, or not significant at P=0.10.

February 2010		
Property	Residue Treatment	
	Hugoton L	Bigbow FSL
%< 0.84 mm	NS	NS
GMD	NS	NS
GSD	NS	NS

May 2010		
Property	Residue Treatment	
	Hugoton L	Bigbow FSL
%< 0.84 mm	NS	*
GMD	NS	NS
GSD	*	**

Table 2.23 ANOVA tables for January 2011 of wind erosion parameters: %< 0.84 mm, geometric mean diameter (GMD), and geometric standard deviation (GSD). NS, indicating not significant at P=0.10.

January 2011		
Property	Residue Treatment	
	Hugoton L	Bigbow FSL
%< 0.84 mm	NS	NS
GMD	NS	NS
GSD	NS	NS

Table 2.24 Average monthly wind speeds and maximum wind speeds at three different locations in Kansas from October 2009 to April 2011.

Wind Measurements at Hugoton, Manhattan, and Parsons, Kansas						
	Hugoton, KS		Manhattan, KS		Parsons, KS	
Month and Year	Avg. Wind Speed	Max Wind Speed	Avg. Wind Speed	Max Wind Speed	Avg. Wind Speed	Max Wind Speed
	----------m s^{-1}----------		----------m s^{-1}----------		----------m s^{-1}----------	
Oct. 2009	4.19	11.69	2.31	7.75	3.32	6.87
Nov. 2009	4.65	10.07	2.82	8.23	2.71	6.27
Dec. 2009	5.18	11.04	3.06	8.92	3.16	6.91
Jan. 2010	4.29	9.78	2.85	7.46	2.68	5.88
Feb. 2010	4.42	9.71	3.09	7.82	2.82	6.06
Mar. 2010	5.49	11.62	3.12	8.73	3.29	6.88
Apr. 2010	6.70	14.36	3.73	10.13	3.17	7.27
May 2010	6.65	14.83	3.31	9.75	2.95	7.11
Jun. 2010	4.74	10.86	2.97	10.10	2.59	6.42
Jul. 2010	3.02	8.40	2.65	7.19	2.34	6.31
Aug. 2010	2.86	7.59	2.45	7.20	2.30	5.94
Sep. 2010	2.93	9.10	2.59	6.79	2.69	7.23
Oct. 2010	2.85	8.66	2.05	5.84	2.28	6.53
Nov. 2010	4.78	10.27	2.69	6.65	3.03	7.14
Dec. 2010	5.18	11.04	2.56	6.34	2.55	6.01
Jan. 2011	3.20	7.99	2.50	6.28	2.55	6.42
Feb. 2011	2.69	6.68	3.11	6.89	2.89	6.66
Mar. 2011	3.97	10.02	3.11	7.16	3.30	7.18

Notes: Data summary collected from Kansas Weather Data Library.

Table 2.25 ANOVA table for Hugoton L and Bigbow FSL residue coverage winter 2008-2009. Results from contrasts are shown as * and ** indicating significance at P=0.10 and P=0.05.

Residue Coverage Winter 2008-2009		
	Residue Treatment	
Date	Hugoton L	Bigbow FSL
11/8/2008	**	**
12/3/2008	**	**
5/19/2009	*	**

Table 2.26 ANOVA table for Hugoton L and Bigbow FSL residue coverage for winter 2009-2010. Results from contrasts are shown as *, **, and NS, indicating significance at P=0.10, P=0.05, or not significant at P=0.10.

Residue Coverage Winter 2009-2010		
	Residue Treatment	
Date	Hugoton L	Bigbow FSL
12/18/2009	**	**
1/12/2010	*	NS
2/27/2010	**	**
5/25/2010	**	*

Table 2.27 ANOVA table for grain and residue yields at Hugoton L and Bigbow FSL sites in 2009 and 2010. Results were not significant (NS) in any year.

2009 & 2010 Grain and Residue Yield		
Residue Treatment		
	Hugoton L	Bigbow FSL
	-------2009-------	
Grain	NS	NS
Residue	NS	NS
	-------2010-------	
Grain	NS	NS
Residue	NS	NS

Table 2.28 Grain and Residue yield for Hugoton L and Bigbow FSL for 2009.

2009 Grain and Residue Yield				
	Grain Yield		Residue Yield	
	Hugoton Loam	Bigbow Fine Sandy Loam	Hugoton Loam	Bigbow Fine Sandy Loam
Treatment	-----------Mg ha^{-1}-----------		-----------Mg ha^{-1}-----------	
Residue Continuously Retained	13.55†	13.56	10.30	9.69
Residue Continuously Removed	13.21	12.81	10.13	9.79

Note: † Within columns, means not significantly different (P=0.10).

Table 2.29 Grain and Residue yield for Hugoton L and Bigbow FSL for 2010.

2010 Grain and Residue Yield				
	Grain Yield		Residue Yield	
	Hugoton Loam	Bigbow Fine Sandy Loam	Hugoton Loam	Bigbow Fine Sandy Loam
Treatment	-----------Mg ha^{-1}-----------		-----------Mg ha^{-1}-----------	
Residue Continuously Retained	12.99†	0.39	8.85	0.63
Residue Alternating Removal	12.43	0.25	7.64	0.58
Residue Continuously Removed	13.00	0.41	8.07	0.63

Note: † Within columns, means not significantly different (P=0.10).

Chapter 3 - Residue Removal Effects on Soil Properties and Corn Emergence

Abstract

Crop residues protect the soil surface wind and water erosion, improve soil physical properties, and provide nutrients to the soil. Crop residue can provide reduction in bulk density in two manners. One, residue left on the soil surface absorbs and dissipates compactive forces. Secondly, decomposition of crop residue adds soil organic matter (SOM) to the soil, which has a low density, and helps lower the overall bulk density of the mineral fraction. Removal of crop residues can reduce soil fertility because residues are an important reservoir of essential macro- (e.g., K, P, N, Ca, and Mg) and micronutrient (e.g., Fe, Mn, B, Zn, and S) pools. Three different corn (*Zea mays* L.) residue management treatments (residue continuously retained, residue continuously removed, and alternating year residue removal) were established in a fine sandy loam (FSL) and loam (L) soil in southwest Kansas. During the 2.5 year duration of the study, physical properties, chemical properties and yield components were measured. Bulk density measurements in the L textured soil showed higher bulk density in the residue continuously retained treatments in the top 0-5 cm in 2008 and 2009 following harvest. At depths of 5-10 and 10-15 cm, the residue continuously removed treatments had significantly higher bulk density measurements. The FSL textured soil displayed no significant differences in bulk density at any depth during at any of the sampling dates. Total C, N, and exchangeable K were significantly different in residue continuously retained and removed plots due to residue treatment following 1 year of establishment of the study in the FSL soil. Total C was 14 g kg^{-1} and 8.7 g kg^{-1} in the residue continuously retained and removed treatments, respectively. Total N was 0.3 g kg^{-1} higher in the residue continuously retained versus the residue continuously removed treatment in the FSL. After 2 years of residue treatments, the fall 2010 samples displayed no significant differences in soil nutrient levels. Lastly, corn emergence in different

residue treatment plots were examined following planting in the spring of 2009 and 2010. Irrigated continuous corn in southwest Kansas produces a lot of biomass, and has been reported to create emergence problems in the past for some producers. No significant differences in both spring seasons were observed in corn emergence at both soils.

Introduction

Bulk density is a critical indicator of soil compaction, and crop residue removal can increase bulk density because crop residue is capable of absorbing and dissipating compactive forces from wheel traffic (Blanco-Canqui and Lal, 2009a). Measuring bulk density may indicate any changes that occur during the field study. Increases in bulk density in as little as 1 year were observed in a study by Blanco-Canqui et al., (2006a, 2006b) in residue removal studies in Ohio. Karlen et al. (1994) observed no significant changes in bulk density in the 0-5 cm depth of soil following 10 consecutive years of residue removal in a no-till system. Blanco-Canqui and Lal (2009a) report decomposed crop residues can lower bulk density because SOM has a lower density than the mineral fraction, and in a no-till system, the reduction in soil bulk density is concentrated near the surface where residue is usually concentrated. Moebius et al. (2008) observed declines in SOM over time when corn stover was removed in a long-term study established in 1973 on a Raynham silt loam in New York. Not only does SOM decrease, but removal of corn stover decreases the available water holding capacity and increases the bulk density of the soil (Lal, 2005). After multiple residue removal studies, research has indicated that residue removal can impact soil quality and more studies are needed to determine site specific impacts over long term periods (Blanco-Canqui and Lal, 2007). Crop residues are necessary to protect soil from erosion and contribute to SOC levels, a factor important to soil properties and productivity (Wilhelm et al., 2004).

Removal of crop residues can reduce soil fertility because residues provide essential soil macro- (e.g., K, P, N, Ca, and Mg) and micronutrient (e.g., Fe, Mn, B, Zn, and S) through decomposition (Blanco-Canqui and Lal, 2009a). Blanco-Canqui and Lal (2009b) reported decreases in total C and N after 4 years of residue removal on three different soil types in Ohio. Available P was significantly reduced at one site and significant impacts on K were observed at all sites due to residue treatments (Blanco-Canqui and Lal, 2009b). Karlen et al. (1994) also noted reductions in total C and N after 10 consecutive years of residue removal in silt loams in a no till operation, but no reductions in P, K, Ca, and Mg concentrations were observed. In a similar study on a sandy loam, harvesting crop residues significantly increased annual N, P, and K removal, but the impact was dependent upon season, water management, and rate of corn residue removed (Karlen et al., 1984; Lindstrom, 1986). In an 8 year study of the effects of crop residues on selected soil properties, when residue was returned to the soil surface, Power et al. (1998) observed slight increases in soil N levels. Blanco-Canqui and Lal (2009b) report that topographical and textural differences can affect the impact of residue removal on soil nutrient loss. High stover removal from the sloping silt loam not only reduced the concentration of all macronutrients, but the effects were measureable in both soil depths (0-10 and 10-20 cm), unlike in the other soils where reductions were primarily confined to the 0-10 cm depth (Blanco-Canqui and Lal, 2009b). Through these different studies, it is evident nutrient reduction in soils is highly variable and dependent on many factors (e.g., rate of removal, rate of residue decomposition, soil characteristics, and climate), and site specific research is needed to determine sustainable rates of residue removal.

Production systems that maintain surface residue can affect soil temperature, soil water, and soil chemical and physical properties that also affect grain production (Swanson and Wilhelm, 1996). It is not always possible to control soil moisture, but the soil cover can be manipulated by the use of mulch and mulch tillage (Willis et al., 1957). Studies have been conducted to determine the effects of different residue management treatments on yield and yield components (Willis et al., 1957; Swanson and Wilhelm, 1996; Beyaert et al., 2002; Blanco-Canqui et al., 2006c). Residue management studies have recently focused on residue removal rates (Blanco-Canqui et al., 2006 a, b, c); whereas previous research was conducted on different tillage treatments and resulting effects (Willis et al., 1957; Beyaert et al., 2002). Willis et al. (1957) concluded increased in soil temperature accelerated plant emergence and increased the rate of growth in a central Iowa soil. In Nebraska, residue rate on the soil surface did not affect yield or yield components across multiple planting dates (Swanson and Wilhelm, 1996). Blanco-Canqui et al. (2006c) performed a study on corn growth and yield under different rates of residue removal in a long-term no-till system, concluding residue removal can have a negative effect on both soil properties and corn production in a very short time, but the magnitude of the effects likely depends on soil type. Blanco-Canqui et al. (2006c) reported that differences in corn seedling emergence and plant height was a direct effect of different residue management effects on soil water content and soil temperature.

Research reviewed has shown contrasting results of residue removal on bulk density and soil chemical properties occurring in as little as 1 year and up to 10 years (Blanco-Canqui et al, 2006a; Karlen et al., 1994). The study location in southwest Kansas contains soils derived from loess and eolian sediments (Web Soil Survey, 2009) that may be sensitive to residue removal. Producers have reported concerns about thick residue and resulting effects impact corn emergence, and ultimately yield. Through our residue removal study, it was our objective to:

I. Quantify any changes in bulk density due to residue removal.

II. Measure the impact of residue removal on soil nutrients

III. Determine any differences in corn emergence due to residue management treatments.

Materials and Methods

Bulk Density

Bulk density samples were obtained using the core method (Blake and Hartge, 1986) at depths of 0-5, 5-10, and 10-15 cm with a 5 cm diameter using a slide hammer sampler (AMS, Inc., American Falls, ID). Samples were collected from three random spots within each plot in fall 2008, spring and fall 2009, spring and fall 2010. Soil cores were placed in tin cans, and then oven-dried for 2 days at 105°C. Once samples reached a constant mass, the water content and bulk density were calculated.

Soil Chemical Properties

Soil samples were collected in the fall of 2008, 2009, and 2010 following harvest for determination of chemical properties. Three samples of approximately 1 kg were collected from three random locations in the plot, and then soil was mixed for submission to the Kansas State University Soil Testing Laboratory in Manhattan, KS. Soil was analyzed for available phosphorus (P), exchangeable potassium (K), and total carbon (C) and nitrogen (N). The Mehlich 3 extraction procedure (Frank et al., 2011) was used to determine available P. Plant available K was measured using the 1 mol L^{-1} NH_4OAc soil extraction method (Warncke and Brown, 2011). Potassium analysis was done using a model 3110 Flame Atomic Absorption (AA) Spectrometer (Perkin Elmer Corp., Norwalk, CT). Total C and N were determined using a LECO TruSpec CN (LECO Corporation, St Joseph, MI) combustion analyzer at Kansas State Soil Testing laboratory (Kansas State University, Manhattan, KS).

Spring Stand Emergence

Population counts were taken at approximately V5, and were conducted in two locations within the plots. A tape measure was stretched to 5.3 m and the plants in one row along the tape were counted and expressed in number of plants per hectare.

Results and Discussion

Bulk Density

Fall 2008 bulk density samples collected after harvest showed no significant differences in at the Hugoton L site (Table 3.1). Bulk density was very similar between treatments at all three depths (0-5, 5-10, and 10-15 cm) at the Hugoton L site (Figure 3.1). At the Bigbow FSL site, there were differences at all depths between treatments (Table 3.1). In the residue continuously retained treatment, bulk density was greater in the top 0-5 cm and lower in the 5-10 and 10-15 cm increments than the residue continuously removed (Figure 3.1). Differences may have been due to spatial or sampling variability, or they might be attributed to disturbance during the raking operation, e.g., the soil in the residue continuously removed treatment may have been loosened by the rake, creating a zone of lower density. Measurements for both treatments would otherwise have been expected to be very similar since the study was just initiated.

In fall 2009, after the experiment had been conducted for 1 year, at the Hugoton L site, no differences were observed between treatments in bulk density (Table 3.1). The bulk density measurements were consistently high for all samples in the fall of 2009. Karlen et al. (1994) did not observe any changes in bulk density following a 10 year no-till residue management study. At the Bigbow FSL site, the 0-5 cm depth bulk density of the residue continuously retained was approximately 20% higher than that of residue continuously removed (Figure 3.2). For the depths of 5-10 and 10-15 cm, the bulk density values were less in the residue continuously retained than those of residue continuously removed (Figure 3.2). Differences between these two treatments were very difficult to explain due to their variability. Most likely, differences were due to sampling inconsistencies during the collection period with the slide-hammer sampler.

In fall of 2010, at the last collection of bulk density for both sites, no differences due to treatment were observed in both the Hugoton L and Bigbow FSL bulk densities at any depth (Table 3.1). Bulk density values were similar at each depth for the Hugoton L site. Hillel (1998) reports that well aggregated loam soils may have bulk density values of 1.2 g cm^{-3}, and sandy soils with may have up to 1.6 g cm^{-3} bulk density values when volume of pore space is minimum. The bulk density from 0-5 cm at the Hugoton L site following harvest were: 1.24 and 1.27 g cm^{-3}; 1.13 and 1.22 g cm^{-3}; and 1.27, 1.28, and 1.33 g cm^{-3} in the residue continuously retained, residue continuously removed, and residue alternating removal treatments in 2008, 2009, and 2010, respectively (Figure 3.1, 3.2, and 3.3). At the Bigbow FSL site, no significant differences were observed due to treatment at any depth. Surface bulk density values at 0-5 cm were: 1.72 and 1.45 g cm^{-3}, 1.78 and 1.41 g cm^{-3}, and 1.43, 1.44, and 1.45 g cm^{-3} in the residue continuously retained, residue continuously removed, and residue alternating removal treatments in 2008, 2009, and 2010, respectively (Figure 3.1, 3.2, and 3.3).

Due to the variability in bulk density measured from year to year, it was difficult to determine if there was a direct residue effect on bulk density of the soil. Karlen et al. (1994) found residue treatments had no significant effect on bulk density of two silt loam soils. In more recent work, Blanco-Canqui et al. (2006a) found after 1 year of residue removal, bulk densities increased in three different Ohio soils.

Soil Chemical Properties

Soil chemical properties were measured each fall following harvest in the 2008, 2009, and 2010. Soil P, K, total N, and total C values were determined at each site for each treatment. In the fall of 2008, the only significant differences were observed in K levels at 0-5, 10-15, and 15-30 cm depths (Table 3.2) at the Hugoton L site. Continuous residue removal plot's soil samples contained lower levels of K at depths to 30 cm (Table 3.3). In a previous study, Karlen et al. (1984) reported increases in K removal as residue removal rates increased, but only in soil sampled near the surface. Any differences observed at lower depths may have been due to spatial variability. No other differences were observed among the other soil properties. The Bigbow FSL site displayed no differences in chemical property levels.

In the fall of 2009, there were no significant differences in soil chemical properties due to treatment. Differences were observed in the top 0-5 cm depth at the Bigbow FSL site for K, total N, and total C (Table 3.4). Residue continuously retained soil had higher values in the top 0-5 cm for K, total N, and total C (Table 3.5). For K, residue continuously retained samples had a value of 470 mg kg^{-1} compared to 414 mg kg^{-1} in the residue continuously removed plots (Table 3.5). Total N was 1.6 g kg^{-1} in residue continuously retained and 1.3 g kg^{-1} in residue continuously removed plots (Table 3.5). Finally, total C was 14.0 and 8.7 g kg^{-1} for residue continuously retained and residue continuously removed, respectively. Similar results have been reported by Karlen et al. (1984), where decreases in total N and C were observed after 10 years of residue removal in a sandy loam soil.

Chemical properties measured in fall 2010 showed no significant differences at the Hugoton L site (Table 3.6). Only one significant difference in P at a depth of 0-5 cm (Table 3.6) was observed at the Bigbow FSL site. In the fall of 2009, the residue alternating removal treatment was added to the study. This addition was made by splitting the number of residue continuously removed plots in half, and then retaining residue on them for the second year. The residue alternating removal treatment had the highest level of P in 2010 (Table 3.7).

While there were only a small number of differences observed in fall of 2009, residue removal did not significantly affect soil chemical properties. Differences were more likely to be observed under longer periods of residue removal. When residue is removed, soil nutrients derived from corn residue will begin to become depleted from the soil (Blanco-Canqui and Lal, 2009b). However, in the short-term, it appeared residue removal did not have any significant effects on soil fertility levels of the Hugoton L. For coarser-textured soils, such as the Bigbow FSL, soil nutrient levels decreased in the surface 0-5 cm in a short time period (Karlen et al. 1984; Blanco-Canqui and Lal, 2009b). From this study, we observed a decline from 2008 to 2009 at the Bigbow FSL site in K, total N, and total C in the residue continuously removed treatment.

Spring Corn Emergence

One of the biggest problems associated with irrigated continuous corn production in southwest Kansas is managing the abundant corn residue, as reported by producers. Irrigated corn can produce high-yielding harvests many years in a row, which in turn produce a lot of residue that remains on the soil surface. Combine the high levels of residue with the windy conditions of southwestern Kansas, and there can be problems with residue bunching up and getting deep in spots across the field. Due to these issues, producers have been looking for residue management options. When residue is blown around and collects in piles, emergence and ultimately yield can be affected in a negative manner. Each spring following planting, stand counts were conducted to determine any affects residue treatment may have had on the corn stand. In both the spring of 2009 and 2010, no significant differences were observed between treatments (Table 3.8). Even though differences were not significant, the residue continuously removed treatment had a slightly higher plant population in both years (Table 3.9).

Conclusions

Bulk density measurements made during the course of the study varied in value from year to year indicating variability in sampling from year to year. Results from residue management treatments were mixed and it was difficult to determine any direct effect of residue treatment, especially in the coarser-textured Bigbow FSL. In the fall of 2008 and 2009 surface bulk density densities were greater in the residue continuously retained versus the residue continuously removed at the Bigbow FSL site, while at depths of 5-10 and 10-15 cm the residue continuously removed densities were highest. The Hugoton L experienced no significant changes at any depth during the study. Karlen et al. (1994) also found no significant changes in bulk density during 10 years of consecutive removal on a no-till soil. In other research, increases in bulk density have been measured in as little as 1-3 years of residue removal (Blanco-Canqui et al., 2006a, and b).

Soil fertility measurements taken each fall directly following harvest, showed very few differences in nutrient levels. The Bigbow FSL in fall 2009 experienced a decrease in total C and N following 1 year of residue removal at a depth of 0-5 cm. There was also a significant difference due to treatment with exchangeable K in the surface depth of 0-5 cm. In a study conducted on a similar soil type, a Norfolk sandy loam, harvesting crop residues significantly decreased soil N, P, and K levels, but the impact of nutrient removal was dependent upon season, water management, and rate of stover removed (Karlen et al., 1984). Blanco-Canqui and Lal (2009b) have reported significant differences in total C and N, and only significant differences due to residue treatments with available P when soils were located on a sloping landform position. Both study sites (Hugoton L and Bigbow FSL), where the research was conducted, were fertilized annually according to soil testing recommendations, and one may not have expected to see many differences under such a fertilization program. Rate of removal, rate of residue decomposition, rate of fertilizer application, soil characteristics, and climate all factor into the amount of soil nutrient depletion from residue removal treatments (Blanco-Canqui and Lal, 2009a).

Emergence is an important component to yield, and farmers have expressed concern about residue limiting emergence in southwest Kansas. In the spring of 2009 and 2010, no significant differences were measured at the Hugoton L site or the Bigbow FSL site in 2009. Residue continuously retained treatments had slightly lower plant populations, but not of any significance. Similar research studies on yield and yield components have reported results very similar to those at the Hugoton L and Bigbow FSL site (Willis et al., 1957; Swanson and Wilhelm, 1996; Beyaert et al., 2002; Blanco-Canqui et al., 2006c). Residue removal resulted in warmer soils earlier in the spring, which created more suitable germination and growing conditions in the early growing season (Beyaert et al., 2002; Blanco-Canqui et al., 2006c). Yield was not affected by the differences in rate of emergence (Swanson and Wilhelm, 1996; Beyaert et al., 2002; Blanco-Canqui et al., 2006c).

Bulk density measurements were variable from year to year and also varied within each year. Variability may have been associated with sampling error or differences in machinery traffic within plots. From these measurements, it was difficult to conclude if there were any residue treatment affects on soil bulk density. Karlen et al. (1994) reported no differences in bulk density in two Wisconsin silt loams after 10 consecutive years of residue removal. Other research by Blanco-Canqui et al. (2006a) has indicated that changes in bulk density can occur in as little as 1 year of residue removal.

As reported in other studies, the impact of residue removal on bulk density has been variable from location to location (Karlen et al., 1994, Blanco-Canqui et al., 2006a). Soil chemical properties measured showed significant differences in the Bigbow FSL following 1 year of removal, but no differences in the Hugoton L were observed in the duration of the study. Karlen et al., (1984) reported similar results where residue removal decreased total N, total C, and K on a Norfolk sandy loam, and no residue removal effects on two Wisconsin silt loam soil (Karlen et al., 1994). Though nutrient removal occurred on the Norfolk sandy loam, depletion of soil nutrients was amended through an annual fertilization program.

Corn emergence measured following planting in 2008 and 2009 showed minimal differences due to residue removal. Continuous residue removal plots had a slightly higher plant population after emergence, but were not of significance due to residue treatment. Other research at different locations, have reported uneven and delayed emergence of corn where residue is returned at a normal or higher rate with no significant impact on corn grain yield (Swanson and Wilhelm, 1996; Blanco-Canqui et al., 2006c). Uneven emergence in the spring was attributed to differences in soil temperature among the different residue management treatments (Blanco-Canqui et al., 2006c).

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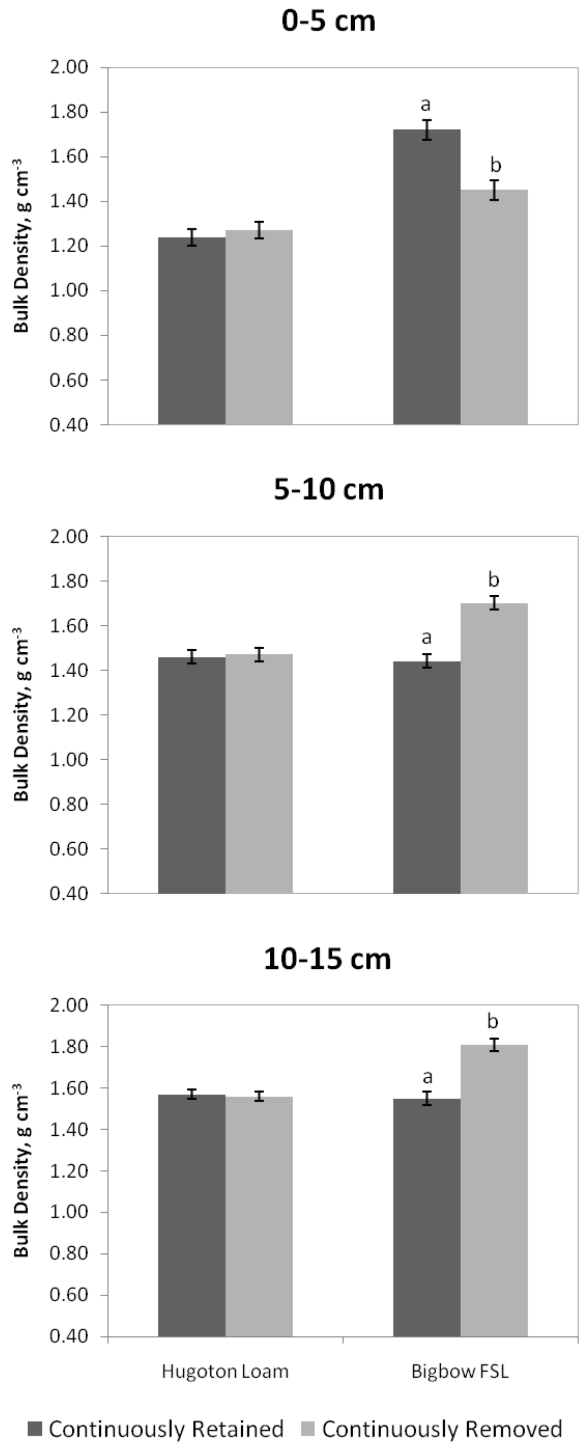

Figure 3.1 Bulk density in fall 2008 at initiation of study at Hugoton L and Bigbow FSL sites at depths of 0-5, 5-10, and 10-15 cm. Error bars represent ± standard error. For each location and depth, columns with different lowercase letters are significantly different due to treatment (P=0.10).

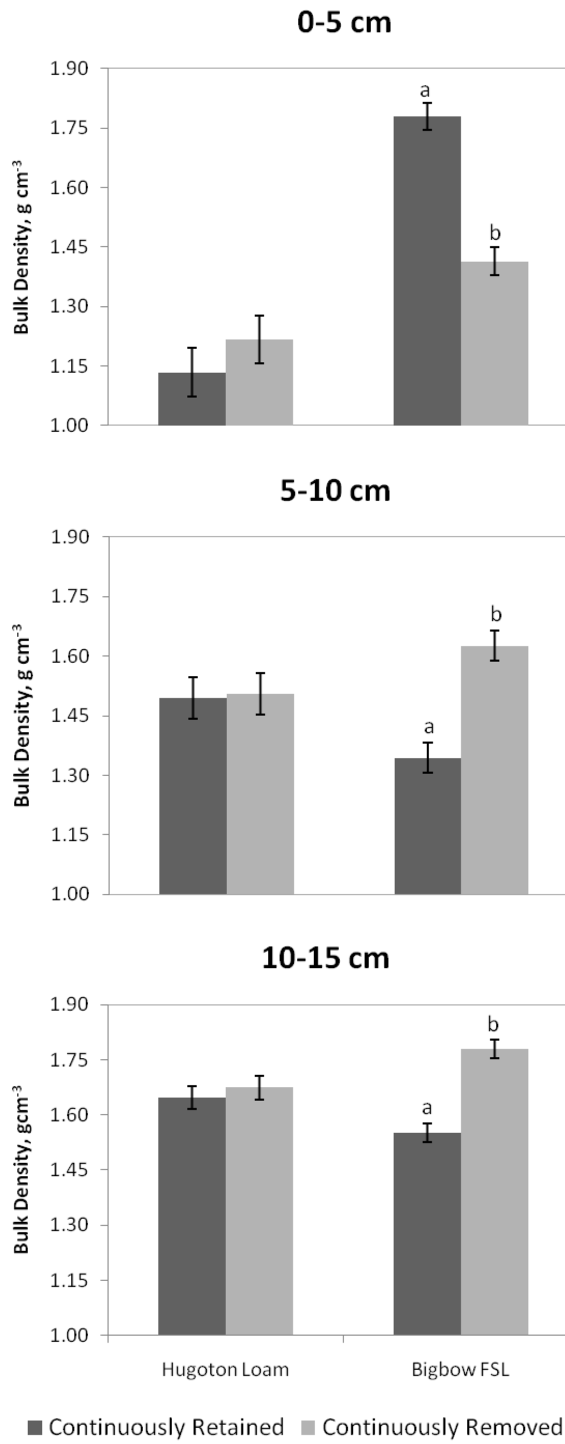

Figure 3.2 Bulk density fall of 2009 at Hugoton L and Bigbow FSL sites at depths of 0-5, 5-10, and 10-15 cm. Error bars represent ± standard error. For each location and depth, columns with different lowercase letters are significantly different due to treatment (P=0.10).

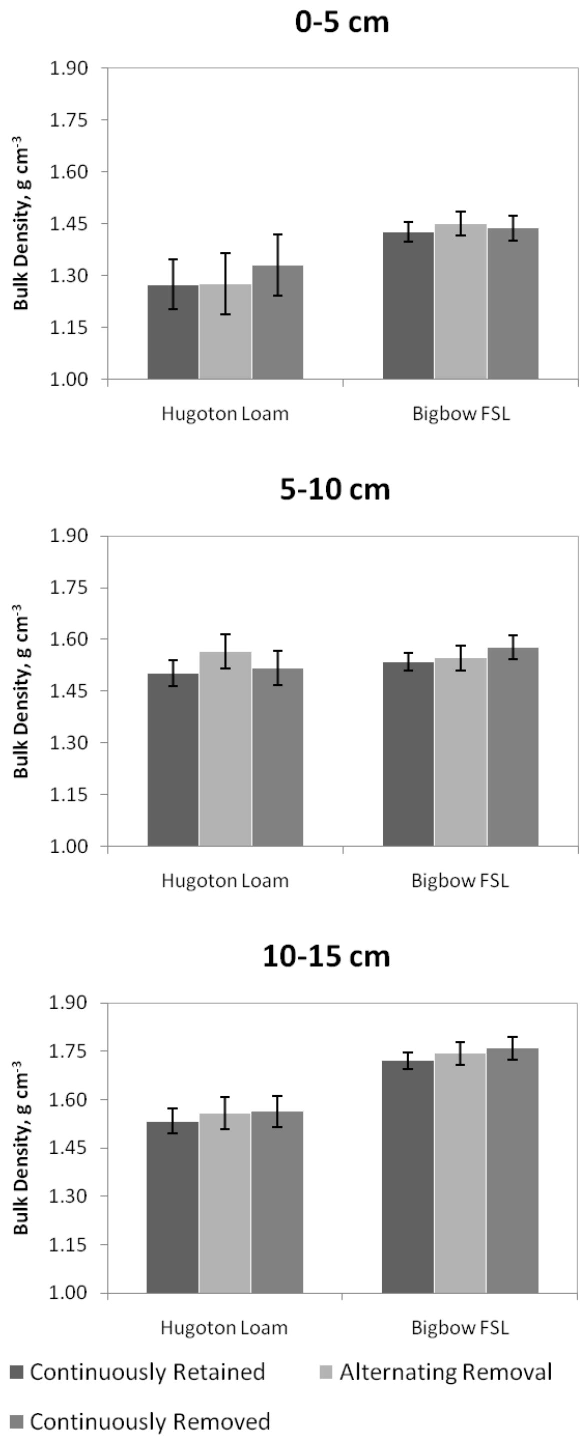

Figure 3.3 Bulk density fall of 2010 at Hugoton L and Bigbow FSL sites at depths of 0-5, 5-10, and 10-15 cm. Error bars represent ± standard error. No significant difference between treatments (P=0.10) at any location or depth.

Table 3.1 ANOVA tables for bulk density at the Hugoton L and Bigbow FSL sites for fall 2008, 2009, and 2010. Results from contrasts are shown as ** and NS, indicating significance at P=0.05 or not significant at P=0.10.

Bulk Density Fall 2008		
Residue Treatment		
Depth	Hugoton L	Bigbow FSL
0-5 cm	NS	**
5-10 cm	NS	**
10-15 cm	NS	**

Bulk Density Fall 2009		
Residue Treatment		
Depth	Hugoton L	Bigbow FSL
0-5 cm	NS	**
5-10 cm	NS	**
10-15 cm	NS	**

Bulk Density Fall 2010		
Residue Treatment		
Depth	Hugoton L	Bigbow FSL
0-5 cm	NS	NS
5-10 cm	NS	NS
10-15 cm	NS	NS

Table 3.2 ANOVA table of treatment effect for soil chemical properties at the Hugoton L and Bigbow FSL sites for depths of 0-5, 5-10, 10-15, 15-30 cm in the fall of 2008. Results from contrasts are shown as *, **, and NS, indicating significance at P=0.10, P=0.05, or not significant at P=0.10.

ANOVA Treatment effects on soil chemical properties for Fall 2008								
Depth	Mehlich3 soil test P		K		Total N		Total C	
-----cm-----	Hugoton L	Bigbow FSL	Hugoton L	Bigbow FSL	Hugoton L	Bigbow FSL	Hugoton L	Bigbow FSL
0-5	NS	NS	**	NS	NS	NS	NS	NS
5-10	NS	NS	NS	NS	NS	NS	NS	NS
10-15	NS	NS	**	NS	NS	NS	NS	NS
15-30	NS	NS	*	NS	NS	NS	NS	NS

Table 3.3 Soil chemical properties at the Hugoton L and Bigbow FSL sites in the fall 2008.

Soil Chemical Properties at Hugoton Loam and Bigbow Fine Sandy Loam Sites								
	Mehlich3 soil test P		K		Total N		Total C	
Treatment	Hugoton L	Bigbow FSL	Hugoton L	Bigbow FSL	Hugoton L	Bigbow FSL	Hugoton L	Bigbow FSL
	------mg kg^{-1}------		------mg kg^{-1}------		------g kg^{-1}------		------g kg^{-1}------	
------ 0-5 cm -----								
Continuously Retained	46†	65	850 a	416	1.5	1.5	17.3	13.6
Continuously Removed	54	57	718 b	417	1.5	1.4	16.6	12.8
------ 5-10 cm -----								
Continuously Retained	42	62	632	327	1.3	1.1	13.4	9.1
Continuously Removed	45	43	617	323	1.3	1.0	13.0	9.0
------ 10-15 cm -----								
Continuously Retained	27	43	497 a	274	1.0	0.5	10.4	3.7
Continuously Removed	49	37	445 b	276	1.0	0.4	9.7	3.6
------ 15-30 cm -----								
Continuously Retained	12	28	391 a	245	0.9	0.3	12.2	1.9
Continuously Removed	11	24	361 b	274	0.9	0.3	12.0	2.1

Note: † Within columns for each variable, location, and depth, means followed by different letters are significantly different (P=0.10).

Table 3.4 ANOVA table of treatment effect for soil chemical properties at the Hugoton L and Bigbow FSL sites for depths of 0-5, 5-10, 10-15, 15-30 cm in the fall of 2009. Results from contrasts are shown as *, **, and NS, indicating significance at P=0.10, P=0.05, or not significant at P=0.10.

ANOVA Table Treatment effects on soil nutrient levels -Fall 2009								
Depth	Mehlich3 soil test P		K		Total N		Total C	
-----cm-----	Hugoton L	Bigbow FSL	Hugoton L	Bigbow FSL	Hugoton L	Bigbow FSL	Hugoton L	Bigbow FSL
0-5	NS	NS	NS	**	NS	**	NS	**
5-10	NS	NS	NS	NS	NS	NS	NS	NS
10-15	NS	NS	NS	NS	NS	NS	NS	NS
15-30	NS	*	NS	**	NS	NS	NS	

Table 3.5 Soil chemical properties at the Hugoton L and Bigbow FSL sites in the fall 2009.

Soil Chemical Properties at Hugoton Loam and Bigbow Fine Sandy Loam Sites								
	Mehlich3 soil test P		K		Total N		Total C	
Treatment	Hugoton L	Bigbow FSL	Hugoton L	Bigbow FSL	Hugoton L	Bigbow FSL	Hugoton L	Bigbow FSL
	------mg kg^{-1}------		------mg kg^{-1}------		------g kg^{-1}------		------g kg^{-1}------	
------ 0-5 cm -----								
Continuously Retained	50†	63	654	470 a	1.8	1.6 a	19.3	14.0 a
Continuously Removed	47	65	668	414 b	1.7	1.3 b	16.9	8.7 b
------ 5-10 cm -----								
Continuously Retained	48	59	645	336	1.6	1.3	15.7	8.7
Continuously Removed	48	64	653	358	1.6	1.3	13.9	8.0
------ 10-15 cm -----								
Continuously Retained	39	54	584	297	1.4	1.0	12.1	3.8
Continuously Removed	34	52	560	295	1.4	0.9	11.1	3.0
------ 15-30 cm -----								
Continuously Retained	18	32 a	467	245 a	1.3	0.6	12.2	
Continuously Removed	20	25 b	437	331 b	1.2	0.7	11.0	

Note: † Within columns for each variable, location, and depth, means followed by different letters are significantly different (P=0.10).

Table 3.6 ANOVA table of treatment effect for soil chemical properties at the Hugoton L and Bigbow FSL sites for depths of 0-5, 5-10, 10-15, 15-30 cm in the fall of 2010. Results from contrasts are shown as ** and NS, indicating significance at P=0.05 or not significant at P=0.10.

ANOVA Table Treatment effects on soil nutrient levels -Fall 2010								
Depth	Mehlich3 soil test P		K		Total N		Total C	
-----cm-----	Hugoton L	Bigbow FSL	Hugoton L	Bigbow FSL	Hugoton L	Bigbow FSL	Hugoton L	Bigbow FSL
0-5	NS	**	NS	NS	NS	NS	NS	NS
5-10	NS	NS	NS	NS	NS	NS	NS	NS
10-15	NS	NS	NS	NS	NS	NS	NS	NS
15-30	NS	--	NS	--	NS	--	NS	--

Table 3.7 Soil chemical properties at the Hugoton L and Bigbow FSL sites in the fall 2010.

	Soil Chemical Properties at Hugoton Loam and Bigbow Fine Sandy Loam Sites							
	Mehlich3 soil test P		K		Total N		Total C	
Treatment	Hugoton L	Bigbow FSL	Hugoton L	Bigbow FSL	Hugoton L	Bigbow FSL	Hugoton L	Bigbow FSL
	------mg kg^{-1}------		------mg kg^{-1}------		------g kg^{-1}------		------g kg^{-1}------	
				------ 0-5 cm -----				
Continuously Retained	47†	42 a	790	420	1.7	1.6	19.2	14.3
Alternating Removal	28	81 b	733	370	1.7	1.3	18.7	11.8
Continuously Removed	49	40 a	768	436	1.6	1.4	18.0	13.1
				------ 5-10 cm -----				
Continuously Retained	49	43	669	320	1.4	1.4	15.1	13.2
Alternating Removal	20	56	673	352	1.3	1.1	13.2	10.7
Continuously Removed	35	34	679	367	1.4	1.1	14.2	10.2
				------ 10-15 cm -----				
Continuously Retained	60	36	629	290	1.2	0.8	11.7	6.6
Alternating Removal	15	45	509	297	1.0	0.8	10.7	6.3
Continuously Removed	34	29	518	311	1.1	0.7	11.3	5.1
				------ 15-30 cm -----				
Continuously Retained	12		401		0.9		12.5	
Alternating Removal	5		333		0.9		11.4	
Continuously Removed	9		330		0.9		12.8	

Note: † Within columns for each variable, location, and depth, means followed by different letters are significantly different (P=0.10).

Table 3.8 ANOVA table of corn emergence in 2009 and 2010 due to residue treatment. Results from contrasts were not significant (NS) at P=0.10.

ANOVA - Corn Emergence		
	Hugoton L	Bigbow FSL
2009	NS	NS
2010	NS	--

Table 3.9 Plant population directly following emergence at Hugoton L and Bigbow FSL sites for 2009 and 2010 growing season.

Corn Emergence		
	Hugoton L	Bigbow FSL
----2009----		
	------ plants ha^{-1}------	
Continuously Retained	77033†	78731
Continuously Removed	78731	80738
----2010----		
	------ plants ha^{-1}------	
Continuously Retained	64374	--
Alternating Removal	63603	--
Continuously Removed	70704	--

Note: † No significant difference for any location or year between treatments (P=0.10).

Chapter 4 - Impact of Residue Removal

As a new biomass to bioethanol plant is set to break ground in southwest Kansas, sustainability of residue removal has been questioned. Southwest Kansas has a unique combination of factors present (e.g., dry and windy climate, fragile eolian soils, and high amounts of corn residue produced under irrigation) where residue serves an integral role in soil and crop productivity. In the past and at present, corn (Zea mays L.) grain is and has been the primary source for ethanol, but as new technology emerges and cost of production decreases, crop residues have been identified as a replacement of grain for ethanol production (Perlack et al., 2005). Wilhelm et al. (2004) found the collection of crop residues as a feedstock for biomass ethanol to be an appropriate solution to help solve the United States overreliance on imported fuels. However, residue harvest from agricultural lands can induce soil and environmental degradation with detrimental effects on soil quality and sustainability of natural resources (Lal, 2005).

Crop residues protect the soil surface from wind and water erosion, improve soil physical properties, and provide nutrients to the soil (Lindstrom, 1986; Skidmore et al., 1986; Steiner et al., 2000; Dabney et al., 2004; Blanco-Canqui and Lal, 2007). In a 2 year study on three different soil series in Ohio, higher rates of residue removal led to weakened soil aggregates, reduced water-stable macroaggregation, and increased microaggregation (Blanco-Canqui et al. 2006; Blanco-Canqui and Lal, 2009). In other research, residue removal has not been found to have any significant effect on wet aggregate stability of soils (Skidmore et al., 1986; Karlen et al., 1994). Previous research has reported inconsistent results that appeared to be highly dependent on characteristics of the soil and site location. Skidmore et al. (1986) conducted a study on residue removal in southwest Kansas in a finer textured Richfield silty clay loam soil, and found minimal effects of residue removal on soil physical properties. None of the previous work has focused on coarse-textured soils of eolian origin under the unique set of factors present in southwest Kansas.

From this study, we have determined the impact of residue removal is dependent on characteristics of the soil present. Significant differences in wet aggregate stability, susceptibility to wind erosion, and soil chemical properties were observed at the Bigbow FSL site due to residue removal, while minimal changes were observed at the finer-textured Hugoton L site. Texture was an integral aspect of the stability of aggregates and their resistance to breakdown during winter seasons. When residue was continuously retained at the surface of the Bigbow FSL site, aggregates were protected from the climatic conditions and destruction of aggregates was decreased. Soil aggregates at the Hugoton L site were able to resist breakdown, due to increased clay content as well as increased organic matter levels, even when residue was continuously removed. Residue with alternating year removal decreased the magnitude of aggregate destruction at the Bigbow FSL site, but not to equivalent levels of aggregates in the residue continuously retained. In the 2.5 years of the study, grain yield was not significantly affected by residue treatment.

Going forward in the future, as producers look to research to make decisions in regards to residue removal, they will need to consider the soils and site locations. Based on our research, residue removal on soils with increased clay contents can be accomplished sustainably in the short-term. Following 2 years of residue continuously removed, the loam texture at the Hugoton site had minimal changes in soil chemical and physical properties. At the Bigbow FSL site, residue continuously removed negatively affected soil chemical and physical properties in the short duration of the study. If residue is to be removed from coarser-textured soils, removal should be done in alternating years or at reduced levels of removal in the field. Residue can be removed at reduced rates in strips across the field or any other method that retains a moderate to substantial amount of residue. Also, producers should plant perpendicular to prevailing wind direction where wind speeds at the soil surface are reduced from standing corn residue. Taller stalks compared to shorter stalks will help to decrease the wind speed at the soil surface, and ultimately limit wind erosion.

Residue removal decisions will need to be made by the individual producer based on profitability and sustainability of their farming operation. Producers have been concerned they have an abundance of residue that may be limiting the corn yield potential. Through the study, residue treatment did not have any significant effect on grain yield or corn emergence. Residue removal may be accomplished sustainably depending on inherent soil characteristics and will need to be considered at each potential removal site. This research focused on two soils common to Stevens County, Kansas in a short time period (2.5 years). More research should be conducted on local soils to determine the effects on soil quality and productivity from: long-term removal, different residue removal rates, irrigated vs. dryland, contrasting topography, and combine cutting heights.

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Appendix A - Volumetric Water Content

Table A.1 Equivalent water depth in the top 150 cm of soil at Hugoton L and Bigbow FSL sites in spring of 2009 and 2010.

Equivalent Water Depth in the Top 150 cm				
	-----2009-----		-----2010-----	
Treatment	Hugoton L	Bigbow FSL	Hugoton L	Bigbow FSL
	----------------- cm -----------------			
Residue Continuously Retained	6.05†	6.91	6.71	6.86
Residue Continuously Removed	6.09	7.31	6.37	6.52

Note: † Within columns for location and year, means not significantly different due to treatment (P=0.10).

Equivalent water depth was not significantly different due to treatment at both sites in the spring of 2009 and 2010. Volumetric water content was determined in depth increments of 5 cm, and then summed to a depth of 150 cm for equivalent water depth.

Appendix B - SAS Code

Table B.1 Sample SAS code used for determination of water stable aggregates and mean weight diameter. Similar code used in statistical analysis of all other data collected.

```
input field$ month$ plot block treatment$ percent< gmd gsd;
            title1 'February 2010 GMD';
datalines;

;

run;
proc sort data=soilASD; by field; run;
ods html;
ods graphics on;

proc glimmix data=soilASD;
By field;
class block treatment;
      model  percent< = treatment/ddfm=satterth;
      **model  gmd = treatment/ddfm=satterth;
      **model  gsd =  treatment/ddfm=satterth;
      random block (treatment block);
      lsmeans  treatment  / pdiff ;
      lsmeans  treatment / alpha=0.10 plot=meanplot(sliceby=treatment join cl);
      run;
```

Appendix C - Soil Pedon Descriptions of Hugoton L and Bigbow FSL.

Hugoton Loam

TAXONOMIC CLASS: Fine-silty, mixed, superactive, mesic Aridic Argiustolls

TYPICAL PEDON: Hugoton loam--on a 0.5 percent convex slope in cropland. (Colors are for dry soil unless otherwise stated.)

Ap--0 to 12 cm; dark grayish brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) moist; weak medium subangular structure; hard, friable; abrupt smooth boundary.

Bt--12 to 37 cm; brown (10YR 4/3) loam, dark brown (10YR 3/3) moist; moderate medium and coarse subangular blocky structure; hard, friable; few fine rounded masses of calcium carbonate; strongly effervescent; clear smooth boundary.

Btk--37 to 56 cm; brown (7.5YR 5/4) clay loam, brown (7.5YR 5/4) moist; moderate medium and coarse subangular blocky structure; hard, friable; common medium rounded masses of calcium carbonate; violently effervescent; clear smooth boundary.

Btk2--56 to 81 cm; brown (7.5YR 5/3) loam, brown (7.5YR 4/4) moist; weak medium subangular blocky structure; very hard, friable; common medium rounded masses of calcium carbonate; violently effervescent;; clear smooth boundary. (Combined thickness of Bt horizons is 0 to 69 cm)

Bk--81 to 98+ cm; light brown (7.5YR 6/4) clay loam, brown (7.5YR 5/4) moist; weak medium subangular blocky structure; hard, friable; many medium rounded masses of calcium carbonate; violently effervescent.

Bigbow Fine Sandy Loam

TAXONOMIC CLASS: Fine-loamy, mixed, superactive, mesic Aridic Haplustalfs

TYPICAL PEDON: Bigbow fine sandy loam--cropland. (Colors are for dry soil unless otherwise stated.)

Ap1--0 to 10 cm; dark grayish brown (10YR 4/2) fine sandy loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to weak fine granular structure; slightly hard, very friable; noneffervescent; clear smooth boundary.

Ap2--10 to 19 cm; yellowish brown (10YR 5/4) loamy fine sand and dark yellowish brown (10YR 4/4) moist; weak medium subangular blocky structure; moderately hard, very friable; noneffervescent; clear smooth boundary. (Combined thickness of the A horizons is 0 to 19 cm)

C--19 to 34 cm; yellowish brown (10YR 5/4) sand, dark yellowish brown (10YR 4/4) moist; loose single grain; loose and loose; noneffervescent; abrupt smooth boundary.

Bwb--34 to 63 cm; dark brown (10YR 3/3) fine sandy loam and dark brown (10YR 3/3) clay loam; moderate medium subangular blocky; moderately hard, friable; strong effervescence; abrupt smooth boundary.

Btb--63 to84 cm; brown (10YR 4/3) loam and brown (10YR 4/3) moist; moderate medium subangular blocky; moderately hard, very friable; common medium rounded masses of calcium carbonate; violently effervescent; clear smooth boundary.

Bkb--84 to 104+ cm; brown (7.5YR 5/4) fine sandy loam, brown (7.5YR 4/4) moist; weak medium subangular blocky; hard, friable; common medium rounded masses of calcium carbonate; violently effervescent.

Appendix D - Chapter 2 Raw Data

Table D.1 Wet aggregate stability raw data.

Wet Aggregate Stability Data for Hugoton L and Bigbow FSL											
Field	Date	Plot	Block	Treatment	Depth	MWD	1.00 WSA	0.5 WSA	0.25 WSA	0.053 WSA	<.053 WSA
					---cm---	--mm--	-------------g sand-free 100 g^{-1} soil-------------				
Hugoton	11-8-2008	111	1	ret	0--5	0.53	0.20	0.24	0.08	0.08	0.40
Hugoton	11-8-2008	123	2	ret	0--5	0.19	0.02	0.07	0.15	0.33	0.44
Hugoton	11-8-2008	141	4	ret	0--5	0.16	0.00	0.06	0.12	0.36	0.46
Hugoton	11-8-2008	143	4	ret	0--5	0.21	0.02	0.09	0.13	0.35	0.41
Hugoton	11-8-2008	114	1	ret	0--5	0.22	0.01	0.12	0.16	0.31	0.41
Hugoton	11-8-2008	122	2	ret	0--5	0.34	0.04	0.25	0.19	0.14	0.39
Hugoton	11-8-2008	132	3	ret	0--5	0.14	0.00	0.05	0.09	0.31	0.55
Hugoton	11-8-2008	134	3	ret	0--5	0.28	0.02	0.18	0.21	0.16	0.43
Hugoton	11-8-2008	113	1	rem	0--5	0.18	0.00	0.08	0.14	0.36	0.41
Hugoton	11-8-2008	121	2	rem	0--5	0.20	0.01	0.09	0.15	0.35	0.40
Hugoton	11-8-2008	131	3	rem	0--5	0.15	0.01	0.05	0.08	0.39	0.47
Hugoton	11-8-2008	133	3	rem	0--5	0.16	0.01	0.05	0.11	0.31	0.52
Hugoton	11-8-2008	112	1	rem	0--5	0.09	0.00	0.02	0.04	0.25	0.69
Hugoton	11-8-2008	124	2	rem	0--5	0.14	0.00	0.04	0.07	0.41	0.47
Hugoton	11-8-2008	142	4	rem	0--5	0.17	0.01	0.06	0.12	0.36	0.46
Hugoton	11-8-2008	144	4	rem	0--5	0.18	0.01	0.07	0.11	0.41	0.41
Hugoton	11-8-2008	111	1	ret	5--15	0.22	0.01	0.14	0.16	0.19	0.49
Hugoton	11-8-2008	123	2	ret	5--15	0.13	0.00	0.04	0.08	0.43	0.45
Hugoton	11-8-2008	141	4	ret	5--15	0.14	0.00	0.05	0.11	0.36	0.48
Hugoton	11-8-2008	143	4	ret	5--15	0.17	0.00	0.06	0.12	0.39	0.42

Hugoton	11-8-2008	114	1	ret	5--15	0.21	0.00	0.10	0.18	0.38	0.34
Hugoton	11-8-2008	122	2	ret	5--15	0.21	0.01	0.11	0.13	0.30	0.44
Hugoton	11-8-2008	132	3	ret	5--15	0.19	0.00	0.12	0.12	0.30	0.46
Hugoton	11-8-2008	134	3	ret	5--15	0.13	0.00	0.04	0.09	0.32	0.55
Hugoton	11-8-2008	113	1	rem	5--15	0.16	0.00	0.04	0.15	0.44	0.36
Hugoton	11-8-2008	121	2	rem	5--15	0.16	0.00	0.05	0.14	0.33	0.48
Hugoton	11-8-2008	131	3	rem	5--15	0.12	0.00	0.03	0.07	0.39	0.51
Hugoton	11-8-2008	133	3	rem	5--15	0.12	0.00	0.03	0.08	0.34	0.54
Hugoton	11-8-2008	112	1	rem	5--15	0.18	0.00	0.04	0.26	0.24	0.46
Hugoton	11-8-2008	124	2	rem	5--15	0.13	0.00	0.02	0.09	0.42	0.47
Hugoton	11-8-2008	142	4	rem	5--15	0.14	0.01	0.03	0.09	0.41	0.47
Hugoton	11-8-2008	144	4	rem	5--15	0.17	0.00	0.06	0.11	0.43	0.39
Bigbow	11-8-2008	211	1	ret	0--5	0.65	0.32	0.18	0.08	0.04	0.39
Bigbow	11-8-2008	222	2	ret	0--5	0.29	0.06	0.17	0.11	0.08	0.58
Bigbow	11-8-2008	223	2	ret	0--5	0.30	0.07	0.16	0.11	0.08	0.58
Bigbow	11-8-2008	232	3	ret	0--5	0.37	0.09	0.20	0.16	0.05	0.50
Bigbow	11-8-2008	234	3	ret	0--5	0.39	0.08	0.29	0.09	0.07	0.47
Bigbow	11-8-2008	241	4	ret	0--5	0.38	0.09	0.26	0.09	0.04	0.53
Bigbow	11-8-2008	214	1	ret	0--5	0.84	0.45	0.18	0.06	0.02	0.30
Bigbow	11-8-2008	243	4	ret	0--5	0.33	0.05	0.23	0.16	0.04	0.53
Bigbow	11-8-2008	212	1	rem	0--5	0.48	0.16	0.24	0.08	0.05	0.46
Bigbow	11-8-2008	221	2	rem	0--5	0.22	0.02	0.15	0.12	0.08	0.62
Bigbow	11-8-2008	224	2	rem	0--5	0.28	0.06	0.16	0.12	0.07	0.59
Bigbow	11-8-2008	231	3	rem	0--5	0.31	0.05	0.23	0.10	0.06	0.56
Bigbow	11-8-2008	233	3	rem	0--5	0.42	0.13	0.17	0.19	0.02	0.48
Bigbow	11-8-2008	242	4	rem	0--5	0.20	0.01	0.15	0.14	0.07	0.63
Bigbow	11-8-2008	213	1	rem	0--5	0.23	0.03	0.15	0.12	0.05	0.65
Bigbow	11-8-2008	244	4	rem	0--5	0.34	0.13	0.13	0.09	0.04	0.61
Bigbow	11-8-2008	211	1	ret	5--15	0.26	0.04	0.18	0.12	0.07	0.60
Bigbow	11-8-2008	222	2	ret	5--15	0.27	0.07	0.12	0.10	0.08	0.62

Bigbow	11-8-2008	223	2	ret	5--15	0.30	0.05	0.20	0.14	0.05	0.56
Bigbow	11-8-2008	232	3	ret	5--15	0.23	0.04	0.14	0.11	0.07	0.65
Bigbow	11-8-2008	234	3	ret	5--15	0.21	0.04	0.10	0.10	0.09	0.66
Bigbow	11-8-2008	241	4	ret	5--15	0.21	0.03	0.13	0.10	0.07	0.67
Bigbow	11-8-2008	214	1	ret	5--15	0.16	0.01	0.11	0.09	0.07	0.72
Bigbow	11-8-2008	243	4	ret	5--15	0.23	0.01	0.22	0.08	0.07	0.63
Bigbow	11-8-2008	212	1	rem	5--15	0.22	0.02	0.14	0.14	0.12	0.59
Bigbow	11-8-2008	221	2	rem	5--15	0.21	0.04	0.11	0.09	0.08	0.67
Bigbow	11-8-2008	224	2	rem	5--15	0.24	0.09	0.06	0.10	0.07	0.68
Bigbow	11-8-2008	231	3	rem	5--15	0.12	0.00	0.06	0.09	0.09	0.75
Bigbow	11-8-2008	233	3	rem	5--15	0.41	0.14	0.19	0.09	0.04	0.54
Bigbow	11-8-2008	242	4	rem	5--15	0.24	0.04	0.15	0.14	0.06	0.61
Bigbow	11-8-2008	213	1	rem	5--15	0.17	0.00	0.09	0.18	0.07	0.66
Bigbow	11-8-2008	244	4	rem	5--15	0.21	0.03	0.12	0.15	0.05	0.64
Hugoton	4-4-2009	111	1	ret	0--5	0.23	0.01	0.08	0.24	0.31	0.35
Hugoton	4-4-2009	114	1	ret	0--5	0.18	0.02	0.10	0.10	0.16	0.63
Hugoton	4-4-2009	122	2	ret	0--5	0.38	0.04	0.27	0.22	0.14	0.32
Hugoton	4-4-2009	123	2	ret	0--5	0.38	0.06	0.22	0.24	0.17	0.31
Hugoton	4-4-2009	132	3	ret	0--5	0.25	0.02	0.13	0.25	0.13	0.46
Hugoton	4-4-2009	134	3	ret	0--5	0.30	0.03	0.18	0.22	0.15	0.41
Hugoton	4-4-2009	141	4	ret	0--5	0.40	0.05	0.30	0.20	0.13	0.32
Hugoton	4-4-2009	143	4	ret	0--5	0.29	0.03	0.15	0.24	0.20	0.37
Hugoton	4-4-2009	112	1	rem	0--5	0.25	0.01	0.12	0.26	0.22	0.39
Hugoton	4-4-2009	113	1	rem	0--5	0.14	0.01	0.05	0.12	0.18	0.64
Hugoton	4-4-2009	121	2	rem	0--5	0.18	0.01	0.08	0.17	0.23	0.52
Hugoton	4-4-2009	124	2	rem	0--5	0.19	0.01	0.08	0.17	0.27	0.47
Hugoton	4-4-2009	131	3	rem	0--5	0.16	0.01	0.06	0.15	0.22	0.56
Hugoton	4-4-2009	133	3	rem	0--5	0.20	0.01	0.10	0.19	0.20	0.50
Hugoton	4-4-2009	142	4	rem	0--5	0.40	0.05	0.29	0.21	0.14	0.31
Hugoton	4-4-2009	144	4	rem	0--5	0.63	0.23	0.24	0.18	0.25	0.10

Hugoton	4-4-2009	111	1	ret	5--15	0.54	0.14	0.33	0.16	0.11	0.25
Hugoton	4-4-2009	114	1	ret	5--15	0.12	0.01	0.04	0.09	0.19	0.68
Hugoton	4-4-2009	122	2	ret	5--15	0.44	0.10	0.25	0.20	0.19	0.27
Hugoton	4-4-2009	123	2	ret	5--15	0.50	0.12	0.29	0.19	0.15	0.25
Hugoton	4-4-2009	132	3	ret	5--15	0.66	0.27	0.24	0.12	0.08	0.28
Hugoton	4-4-2009	134	3	ret	5--15	0.55	0.16	0.29	0.17	0.11	0.26
Hugoton	4-4-2009	141	4	ret	5--15	0.43	0.08	0.28	0.18	0.14	0.32
Hugoton	4-4-2009	143	4	ret	5--15	0.38	0.05	0.24	0.22	0.20	0.29
Hugoton	4-4-2009	112	1	rem	5--15	0.19	0.01	0.09	0.14	0.30	0.46
Hugoton	4-4-2009	113	1	rem	5--15	0.26	0.01	0.18	0.17	0.13	0.51
Hugoton	4-4-2009	121	2	rem	5--15	0.46	0.09	0.30	0.19	0.12	0.29
Hugoton	4-4-2009	124	2	rem	5--15	0.62	0.22	0.27	0.16	0.13	0.22
Hugoton	4-4-2009	131	3	rem	5--15	0.34	0.06	0.26	0.11	0.06	0.52
Hugoton	4-4-2009	133	3	rem	5--15	0.26	0.01	0.18	0.18	0.18	0.45
Hugoton	4-4-2009	142	4	rem	5--15	0.45	0.10	0.27	0.17	0.17	0.29
Hugoton	4-4-2009	144	4	rem	5--15	0.21	0.03	0.09	0.15	0.22	0.51
Bigbow	4-4-2009	211	1	ret	0--5	0.26	0.06	0.12	0.14	0.08	0.60
Bigbow	4-4-2009	214	1	ret	0--5	0.26	0.07	0.10	0.14	0.09	0.60
Bigbow	4-4-2009	222	2	ret	0--5	0.16	0.02	0.06	0.12	0.07	0.72
Bigbow	4-4-2009	223	2	ret	0--5	0.29	0.07	0.13	0.17	0.04	0.59
Bigbow	4-4-2009	232	3	ret	0--5	0.68	0.27	0.32	0.08	0.03	0.31
Bigbow	4-4-2009	234	3	ret	0--5	0.25	0.05	0.12	0.14	0.05	0.63
Bigbow	4-4-2009	241	4	ret	0--5	0.21	0.01	0.13	0.18	0.04	0.64
Bigbow	4-4-2009	243	4	ret	0--5	0.15	0.01	0.08	0.14	0.06	0.71
Bigbow	4-4-2009	212	1	rem	0--5	0.22	0.01	0.08	0.22	0.29	0.39
Bigbow	4-4-2009	213	1	rem	0--5	0.22	0.04	0.13	0.11	0.09	0.64
Bigbow	4-4-2009	221	2	rem	0--5	0.14	0.01	0.07	0.14	0.08	0.71
Bigbow	4-4-2009	224	2	rem	0--5	0.41	0.21	0.05	0.11	0.07	0.56
Bigbow	4-4-2009	231	3	rem	0--5	0.14	0.01	0.07	0.12	0.08	0.72
Bigbow	4-4-2009	233	3	rem	0--5	0.21	0.04	0.11	0.11	0.07	0.68

Bigbow	4-4-2009	242	4	rem	0--5	0.14	0.01	0.06	0.13	0.09	0.71
Bigbow	4-4-2009	244	4	rem	0--5	0.14	0.00	0.03	0.23	0.06	0.67
Bigbow	4-4-2009	211	1	ret	5--15	0.36	0.15	0.09	0.11	0.09	0.56
Bigbow	4-4-2009	214	1	ret	5--15	0.53	0.21	0.20	0.12	0.05	0.42
Bigbow	4-4-2009	222	2	ret	5--15	0.19	0.01	0.11	0.15	0.08	0.64
Bigbow	4-4-2009	223	2	ret	5--15	0.44	0.20	0.08	0.14	0.03	0.54
Bigbow	4-4-2009	232	3	ret	5--15	0.34	0.08	0.19	0.14	0.08	0.52
Bigbow	4-4-2009	234	3	ret	5--15	0.26	0.02	0.16	0.24	0.14	0.45
Bigbow	4-4-2009	241	4	ret	5--15	0.20	0.02	0.10	0.16	0.08	0.64
Bigbow	4-4-2009	243	4	ret	5--15	0.14	0.00	0.07	0.16	0.06	0.71
Bigbow	4-4-2009	212	1	rem	5--15	0.15	0.03	0.05	0.09	0.09	0.74
Bigbow	4-4-2009	213	1	rem	5--15	0.22	0.03	0.10	0.22	0.08	0.58
Bigbow	4-4-2009	221	2	rem	5--15	0.14	0.01	0.07	0.12	0.07	0.73
Bigbow	4-4-2009	224	2	rem	5--15	0.17	0.01	0.10	0.14	0.07	0.68
Bigbow	4-4-2009	231	3	rem	5--15	0.14	0.00	0.08	0.12	0.09	0.71
Bigbow	4-4-2009	233	3	rem	5--15	0.28	0.07	0.14	0.11	0.07	0.60
Bigbow	4-4-2009	242	4	rem	5--15	0.25	0.03	0.18	0.13	0.07	0.59
Bigbow	4-4-2009	244	4	rem	5--15	0.12	0.00	0.05	0.13	0.06	0.76
Hugoton	11-18-2009	111	1	cont_ret	0--5	0.30	0.03	0.18	0.21	0.24	0.34
Hugoton	11-18-2009	114	1	cont_ret	0--5	0.19	0.01	0.08	0.16	0.32	0.43
Hugoton	11-18-2009	122	2	cont_ret	0--5	0.26	0.02	0.15	0.18	0.28	0.38
Hugoton	11-18-2009	123	2	cont_ret	0--5	0.19	0.01	0.08	0.12	0.38	0.41
Hugoton	11-18-2009	132	3	cont_ret	0--5	0.30	0.02	0.19	0.25	0.21	0.34
Hugoton	11-18-2009	134	3	cont_ret	0--5	0.29	0.03	0.18	0.20	0.20	0.39
Hugoton	11-18-2009	141	4	cont_ret	0--5	0.28	0.03	0.16	0.18	0.24	0.39
Hugoton	11-18-2009	143	4	cont_ret	0--5	0.33	0.07	0.13	0.18	0.25	0.36
Hugoton	11-18-2009	112	1	alt_rem	0--5	0.16	0.00	0.05	0.11	0.43	0.41
Hugoton	11-18-2009	124	2	alt_rem	0--5	0.28	0.02	0.17	0.19	0.25	0.37
Hugoton	11-18-2009	133	3	alt_rem	0--5	0.28	0.02	0.15	0.23	0.21	0.39
Hugoton	11-18-2009	144	4	alt_rem	0--5	0.21	0.02	0.09	0.14	0.37	0.38

Hugoton	11-18-2009	113	1	cont_rem	0--5	0.23	0.02	0.12	0.16	0.28	0.43
Hugoton	11-18-2009	121	2	cont_rem	0--5	0.24	0.02	0.12	0.19	0.28	0.39
Hugoton	11-18-2009	131	3	cont_rem	0--5	0.20	0.02	0.08	0.13	0.32	0.45
Hugoton	11-18-2009	142	4	cont_rem	0--5	0.26	0.01	0.14	0.26	0.25	0.34
Hugoton	11-18-2009	111	1	cont_ret	5--15	0.16	0.00	0.05	0.11	0.43	0.41
Hugoton	11-18-2009	114	1	cont_ret	5--15	0.16	0.00	0.05	0.12	0.40	0.43
Hugoton	11-18-2009	122	2	cont_ret	5--15	0.16	0.00	0.06	0.11	0.37	0.45
Hugoton	11-18-2009	123	2	cont_ret	5--15	0.15	0.00	0.04	0.10	0.43	0.43
Hugoton	11-18-2009	132	3	cont_ret	5--15	0.15	0.00	0.05	0.12	0.38	0.45
Hugoton	11-18-2009	134	3	cont_ret	5--15	0.15	0.00	0.05	0.11	0.37	0.47
Hugoton	11-18-2009	141	4	cont_ret	5--15	0.15	0.00	0.05	0.10	0.38	0.47
Hugoton	11-18-2009	143	4	cont_ret	5--15	0.16	0.00	0.05	0.11	0.43	0.40
Hugoton	11-18-2009	112	1	alt_rem	5--15	0.43	0.07	0.28	0.24	0.15	0.26
Hugoton	11-18-2009	124	2	alt_rem	5--15	0.21	0.00	0.11	0.16	0.37	0.36
Hugoton	11-18-2009	133	3	alt_rem	5--15	0.17	0.00	0.07	0.14	0.34	0.45
Hugoton	11-18-2009	144	4	alt_rem	5--15	0.18	0.00	0.07	0.12	0.44	0.37
Hugoton	11-18-2009	113	1	cont_rem	5--15	0.17	0.00	0.07	0.12	0.35	0.46
Hugoton	11-18-2009	121	2	cont_rem	5--15	0.19	0.00	0.08	0.16	0.36	0.40
Hugoton	11-18-2009	131	3	cont_rem	5--15	0.14	0.00	0.04	0.10	0.37	0.48
Hugoton	11-18-2009	142	4	cont_rem	5--15	0.16	0.00	0.05	0.11	0.42	0.43
Bigbow	11-18-2009	211	1	cont_ret	0--5	0.31	0.05	0.19	0.19	0.07	0.50
Bigbow	11-18-2009	214	1	cont_ret	0--5	0.35	0.08	0.19	0.17	0.05	0.51
Bigbow	11-18-2009	222	2	cont_ret	0--5	0.60	0.25	0.20	0.14	0.04	0.36
Bigbow	11-18-2009	223	2	cont_ret	0--5	0.44	0.14	0.20	0.16	0.04	0.45
Bigbow	11-18-2009	232	3	cont_ret	0--5	0.28	0.02	0.20	0.18	0.07	0.52
Bigbow	11-18-2009	234	3	cont_ret	0--5	0.27	0.05	0.15	0.17	0.06	0.57
Bigbow	11-18-2009	241	4	cont_ret	0--5	0.69	0.33	0.19	0.11	0.03	0.34
Bigbow	11-18-2009	243	4	cont_ret	0--5	0.26	0.04	0.16	0.16	0.06	0.58
Bigbow	11-18-2009	212	1	alt_rem	0--5	0.50	0.19	0.18	0.15	0.05	0.42
Bigbow	11-18-2009	224	2	alt_rem	0--5	0.24	0.02	0.16	0.18	0.07	0.58

Bigbow	11-18-2009	233	3	alt_rem	0--5	0.23	0.02	0.14	0.18	0.08	0.58
Bigbow	11-18-2009	244	4	alt_rem	0--5	0.33	0.06	0.22	0.15	0.05	0.53
Bigbow	11-18-2009	213	1	cont_rem	0--5	0.36	0.11	0.13	0.16	0.07	0.53
Bigbow	11-18-2009	221	2	cont_rem	0--5	0.34	0.09	0.19	0.11	0.05	0.56
Bigbow	11-18-2009	231	3	cont_rem	0--5	0.28	0.02	0.20	0.20	0.08	0.50
Bigbow	11-18-2009	242	4	cont_rem	0--5	0.21	0.02	0.12	0.16	0.07	0.63
Bigbow	11-18-2009	211	1	cont_ret	5--15	0.18	0.01	0.09	0.17	0.09	0.63
Bigbow	11-18-2009	214	1	cont_ret	5--15	0.15	0.00	0.08	0.15	0.08	0.68
Bigbow	11-18-2009	222	2	cont_ret	5--15	0.25	0.03	0.16	0.19	0.06	0.56
Bigbow	11-18-2009	223	2	cont_ret	5--15	0.17	0.01	0.09	0.15	0.07	0.67
Bigbow	11-18-2009	232	3	cont_ret	5--15	0.26	0.04	0.14	0.18	0.06	0.58
Bigbow	11-18-2009	234	3	cont_ret	5--15	0.15	0.00	0.08	0.14	0.08	0.69
Bigbow	11-18-2009	241	4	cont_ret	5--15	0.20	0.02	0.09	0.18	0.06	0.64
Bigbow	11-18-2009	243	4	cont_ret	5--15	0.17	0.01	0.10	0.16	0.07	0.66
Bigbow	11-18-2009	212	1	alt_rem	5--15	0.19	0.01	0.12	0.17	0.07	0.63
Bigbow	11-18-2009	224	2	alt_rem	5--15	0.17	0.00	0.10	0.16	0.07	0.67
Bigbow	11-18-2009	233	3	alt_rem	5--15	0.14	0.00	0.07	0.15	0.09	0.70
Bigbow	11-18-2009	244	4	alt_rem	5--15	0.15	0.00	0.08	0.14	0.07	0.70
Bigbow	11-18-2009	213	1	cont_rem	5--15	0.32	0.02	0.15	0.18	0.07	0.58
Bigbow	11-18-2009	221	2	cont_rem	5--15	0.18	0.02	0.09	0.15	0.08	0.67
Bigbow	11-18-2009	231	3	cont_rem	5--15	0.25	0.00	0.07	0.12	0.12	0.68
Bigbow	11-18-2009	242	4	cont_rem	5--15	0.14	0.01	0.07	0.12	0.08	0.72
Hugoton	4-5-2010	111	1	cont_ret	0--5	0.36	0.02	0.25	0.30	0.16	0.27
Hugoton	4-5-2010	114	1	cont_ret	0--5	0.31	0.02	0.17	0.29	0.22	0.30
Hugoton	4-5-2010	122	2	cont_ret	0--5	0.37	0.03	0.26	0.26	0.16	0.28
Hugoton	4-5-2010	123	2	cont_ret	0--5	0.57	0.18	0.24	0.23	0.13	0.22
Hugoton	4-5-2010	132	3	cont_ret	0--5	0.31	0.02	0.21	0.25	0.19	0.33
Hugoton	4-5-2010	134	3	cont_ret	0--5	0.23	0.03	0.15	0.12	0.08	0.62
Hugoton	4-5-2010	141	4	cont_ret	0--5	0.35	0.02	0.25	0.25	0.14	0.33
Hugoton	4-5-2010	143	4	cont_ret	0--5	0.28	0.01	0.18	0.22	0.20	0.38

Hugoton	4-5-2010	112	1	alt_rem	0--5	0.30	0.02	0.18	0.24	0.21	0.35
Hugoton	4-5-2010	124	2	alt_rem	0--5	0.30	0.01	0.19	0.26	0.25	0.29
Hugoton	4-5-2010	133	3	alt_rem	0--5	0.48	0.10	0.31	0.20	0.12	0.27
Hugoton	4-5-2010	144	4	alt_rem	0--5	0.40	0.05	0.26	0.24	0.13	0.31
Hugoton	4-5-2010	113	1	cont_rem	0--5	0.18	0.01	0.06	0.15	0.31	0.47
Hugoton	4-5-2010	121	2	cont_rem	0--5	0.39	0.01	0.29	0.32	0.14	0.24
Hugoton	4-5-2010	131	3	cont_rem	0--5	0.21	0.02	0.09	0.18	0.27	0.44
Hugoton	4-5-2010	142	4	cont_rem	0--5	0.44	0.02	0.39	0.24	0.11	0.23
Hugoton	4-5-2010	111	1	cont_ret	5--15	0.22	0.01	0.12	0.18	0.30	0.40
Hugoton	4-5-2010	114	1	cont_ret	5--15	0.15	0.00	0.04	0.12	0.41	0.43
Hugoton	4-5-2010	122	2	cont_ret	5--15	0.17	0.00	0.10	0.08	0.32	0.50
Hugoton	4-5-2010	123	2	cont_ret	5--15	0.24	0.01	0.13	0.20	0.33	0.34
Hugoton	4-5-2010	132	3	cont_ret	5--15	0.22	0.00	0.12	0.18	0.28	0.42
Hugoton	4-5-2010	134	3	cont_ret	5--15	0.15	0.00	0.05	0.12	0.32	0.50
Hugoton	4-5-2010	141	4	cont_ret	5--15	0.15	0.00	0.05	0.12	0.33	0.49
Hugoton	4-5-2010	143	4	cont_ret	5--15	0.22	0.00	0.13	0.17	0.27	0.43
Hugoton	4-5-2010	112	1	alt_rem	5--15	0.26	0.01	0.17	0.19	0.24	0.38
Hugoton	4-5-2010	124	2	alt_rem	5--15	0.24	0.00	0.14	0.19	0.35	0.32
Hugoton	4-5-2010	133	3	alt_rem	5--15	0.15	0.00	0.05	0.12	0.34	0.49
Hugoton	4-5-2010	144	4	alt_rem	5--15	0.26	0.01	0.17	0.20	0.26	0.37
Hugoton	4-5-2010	113	1	cont_rem	5--15	0.17	0.00	0.07	0.14	0.34	0.45
Hugoton	4-5-2010	121	2	cont_rem	5--15	0.21	0.00	0.10	0.19	0.32	0.40
Hugoton	4-5-2010	131	3	cont_rem	5--15	0.17	0.01	0.07	0.12	0.33	0.47
Hugoton	4-5-2010	142	4	cont_rem	5--15	0.24	0.00	0.09	0.34	0.21	0.35
Bigbow	4-5-2010	211	1	cont_ret	0--5	0.40	0.09	0.25	0.15	0.06	0.45
Bigbow	4-5-2010	214	1	cont_ret	0--5	0.68	0.31	0.20	0.13	0.04	0.33
Bigbow	4-5-2010	222	2	cont_ret	0--5	0.38	0.07	0.25	0.16	0.05	0.47
Bigbow	4-5-2010	223	2	cont_ret	0--5	0.37	0.10	0.19	0.16	0.06	0.50
Bigbow	4-5-2010	232	3	cont_ret	0--5	0.48	0.17	0.22	0.12	0.06	0.44
Bigbow	4-5-2010	234	3	cont_ret	0--5	0.36	0.11	0.17	0.15	0.07	0.51

Bigbow	4-5-2010	241	4	cont_ret	0--5	0.37	0.09	0.21	0.15	0.06	0.49
Bigbow	4-5-2010	243	4	cont_ret	0--5	0.40	0.09	0.25	0.15	0.05	0.47
Bigbow	4-5-2010	212	1	alt_rem	0--5	0.42	0.11	0.25	0.15	0.05	0.44
Bigbow	4-5-2010	224	2	alt_rem	0--5	0.24	0.02	0.16	0.17	0.06	0.58
Bigbow	4-5-2010	233	3	alt_rem	0--5	0.32	0.05	0.20	0.18	0.07	0.50
Bigbow	4-5-2010	244	4	alt_rem	0--5	0.26	0.03	0.16	0.18	0.06	0.56
Bigbow	4-5-2010	213	1	cont_rem	0--5	0.43	0.12	0.21	0.17	0.06	0.44
Bigbow	4-5-2010	221	2	cont_rem	0--5	0.27	0.03	0.17	0.18	0.07	0.54
Bigbow	4-5-2010	231	3	cont_rem	0--5	0.33	0.08	0.16	0.17	0.08	0.51
Bigbow	4-5-2010	242	4	cont_rem	0--5	0.26	0.03	0.16	0.20	0.10	0.51
Bigbow	4-5-2010	211	1	cont_ret	5--15	0.39	0.12	0.19	0.13	0.07	0.50
Bigbow	4-5-2010	214	1	cont_ret	5--15	0.18	0.01	0.12	0.11	0.08	0.67
Bigbow	4-5-2010	222	2	cont_ret	5--15	0.27	0.05	0.14	0.14	0.07	0.59
Bigbow	4-5-2010	223	2	cont_ret	5--15	0.21	0.04	0.10	0.13	0.07	0.66
Bigbow	4-5-2010	232	3	cont_ret	5--15	0.23	0.03	0.15	0.12	0.08	0.63
Bigbow	4-5-2010	234	3	cont_ret	5--15	0.17	0.01	0.09	0.15	0.08	0.67
Bigbow	4-5-2010	241	4	cont_ret	5--15	0.19	0.01	0.10	0.15	0.08	0.65
Bigbow	4-5-2010	243	4	cont_ret	5--15	0.14	0.01	0.07	0.12	0.08	0.73
Bigbow	4-5-2010	212	1	alt_rem	5--15	0.25	0.03	0.17	0.15	0.06	0.59
Bigbow	4-5-2010	224	2	alt_rem	5--15	0.18	0.02	0.10	0.12	0.06	0.70
Bigbow	4-5-2010	233	3	alt_rem	5--15	0.17	0.01	0.09	0.14	0.10	0.66
Bigbow	4-5-2010	244	4	alt_rem	5--15	0.13	0.00	0.06	0.14	0.08	0.73
Bigbow	4-5-2010	213	1	cont_rem	5--15	0.21	0.02	0.13	0.14	0.07	0.64
Bigbow	4-5-2010	221	2	cont_rem	5--15	0.17	0.01	0.11	0.14	0.08	0.66
Bigbow	4-5-2010	231	3	cont_rem	5--15	0.15	0.01	0.07	0.11	0.13	0.68
Bigbow	4-5-2010	242	4	cont_rem	5--15	0.21	0.03	0.13	0.14	0.08	0.63
Hugoton	11-9-2010	111	1	cont_ret	0--5	21.82	27.20	18.98	10.09	21.91	0.62
Hugoton	11-9-2010	114	1	cont_ret	0--5	3.21	12.42	15.83	38.11	30.44	0.27
Hugoton	11-9-2010	122	2	cont_ret	0--5	0.80	6.23	12.40	33.76	46.81	0.17
Hugoton	11-9-2010	123	2	cont_ret	0--5	1.94	10.87	12.98	36.70	37.50	0.22

Hugoton	11-9-2010	132	3	cont_ret	0--5	2.54	13.10	18.37	14.20	51.79	0.24
Hugoton	11-9-2010	134	3	cont_ret	0--5	8.55	14.48	12.53	17.22	47.22	0.32
Hugoton	11-9-2010	141	4	cont_ret	0--5	3.34	15.28	15.44	24.38	41.56	0.27
Hugoton	11-9-2010	143	4	cont_ret	0--5	6.28	16.74	15.60	24.15	37.23	0.32
Hugoton	11-9-2010	112	1	alt_rem	0--5	4.62	9.24	15.91	22.19	48.04	0.24
Hugoton	11-9-2010	124	2	alt_rem	0--5	2.66	12.91	13.61	35.09	35.72	0.25
Hugoton	11-9-2010	133	3	alt_rem	0--5	2.07	8.59	10.02	26.94	52.37	0.19
Hugoton	11-9-2010	144	4	alt_rem	0--5	4.95	9.30	13.01	36.54	36.20	0.26
Hugoton	11-9-2010	113	1	cont_rem	0--5	1.46	10.14	16.33	32.35	39.72	0.22
Hugoton	11-9-2010	121	2	cont_rem	0--5	1.16	10.13	14.39	35.06	39.25	0.21
Hugoton	11-9-2010	131	3	cont_rem	0--5	2.14	8.74	10.63	20.52	57.96	0.18
Hugoton	11-9-2010	142	4	cont_rem	0--5	2.87	9.81	12.19	27.50	47.63	0.22
Hugoton	11-9-2010	111	1	cont_ret	5--15	1.31	10.79	15.97	19.38	52.54	0.20
Hugoton	11-9-2010	114	1	cont_ret	5--15	1.53	15.59	19.11	25.29	38.48	0.26
Hugoton	11-9-2010	122	2	cont_ret	5--15	0.29	4.02	11.05	40.44	44.21	0.15
Hugoton	11-9-2010	123	2	cont_ret	5--15	0.55	7.03	6.92	36.47	49.03	0.16
Hugoton	11-9-2010	132	3	cont_ret	5--15	0.34	3.95	12.08	29.01	54.63	0.14
Hugoton	11-9-2010	134	3	cont_ret	5--15	0.34	4.85	7.15	29.49	58.17	0.13
Hugoton	11-9-2010	141	4	cont_ret	5--15	2.11	6.63	10.53	32.05	48.67	0.18
Hugoton	11-9-2010	143	4	cont_ret	5--15	4.87	9.30	13.01	36.54	36.29	0.26
Hugoton	11-9-2010	112	1	alt_rem	5--15	1.59	10.42	13.43	25.95	48.61	0.20
Hugoton	11-9-2010	124	2	alt_rem	5--15	0.20	8.08	9.92	43.10	38.70	0.18
Hugoton	11-9-2010	133	3	alt_rem	5--15	0.28	3.11	7.83	28.22	60.57	0.12
Hugoton	11-9-2010	144	4	alt_rem	5--15	15.12	15.81	16.60	22.30	30.16	0.45
Hugoton	11-9-2010	113	1	cont_rem	5--15	0.07	3.91	9.00	42.89	44.13	0.14
Hugoton	11-9-2010	121	2	cont_rem	5--15	0.49	6.58	12.05	37.56	43.32	0.17
Hugoton	11-9-2010	131	3	cont_rem	5--15	0.32	7.06	9.81	19.02	63.79	0.14
Hugoton	11-9-2010	142	4	cont_rem	5--15	5.12	7.53	11.66	31.05	44.64	0.24
Bigbow	11-9-2010	211	1	cont_ret	0--5	19.35	23.52	12.28	5.68	39.16	0.53
Bigbow	11-9-2010	214	1	cont_ret	0--5	7.25	21.12	18.24	6.24	47.15	0.36

Bigbow	11-9-2010	222	2	cont_ret	0--5	11.70	21.09	14.26	5.45	47.50	0.41
Bigbow	11-9-2010	223	2	cont_ret	0--5	24.95	16.49	13.05	4.11	41.39	0.56
Bigbow	11-9-2010	232	3	cont_ret	0--5	21.06	23.90	13.06	4.32	37.66	0.56
Bigbow	11-9-2010	234	3	cont_ret	0--5	16.50	21.57	17.02	4.73	40.17	0.49
Bigbow	11-9-2010	241	4	cont_ret	0--5	5.42	19.59	17.79	6.58	50.62	0.32
Bigbow	11-9-2010	243	4	cont_ret	0--5	24.78	18.27	13.36	4.00	39.59	0.58
Bigbow	11-9-2010	212	1	alt_rem	0--5	21.77	24.89	11.61	4.29	37.45	0.57
Bigbow	11-9-2010	224	2	alt_rem	0--5	8.73	17.46	15.25	5.12	53.43	0.34
Bigbow	11-9-2010	233	3	alt_rem	0--5	31.47	22.36	12.90	4.28	28.99	0.70
Bigbow	11-9-2010	244	4	alt_rem	0--5	6.64	15.15	16.55	3.27	58.40	0.30
Bigbow	11-9-2010	213	1	cont_rem	0--5	9.49	21.85	18.19	5.68	44.79	0.39
Bigbow	11-9-2010	221	2	cont_rem	0--5	20.76	22.68	12.33	4.33	39.90	0.54
Bigbow	11-9-2010	231	3	cont_rem	0--5	9.69	19.69	17.58	8.05	44.98	0.38
Bigbow	11-9-2010	242	4	cont_rem	0--5	9.65	17.12	19.69	5.96	47.58	0.37
Bigbow	11-9-2010	211	1	cont_ret	5--15	26.18	9.99	11.43	7.24	45.15	0.53
Bigbow	11-9-2010	214	1	cont_ret	5--15	3.25	13.19	11.96	8.45	63.15	0.22
Bigbow	11-9-2010	222	2	cont_ret	5--15	15.71	15.35	12.20	7.16	49.59	0.42
Bigbow	11-9-2010	223	2	cont_ret	5--15	12.61	11.29	11.95	7.04	57.12	0.34
Bigbow	11-9-2010	232	3	cont_ret	5--15	15.30	13.83	9.03	11.48	50.36	0.40
Bigbow	11-9-2010	234	3	cont_ret	5--15	14.24	15.50	9.54	6.56	54.16	0.39
Bigbow	11-9-2010	241	4	cont_ret	5--15	1.42	11.91	14.07	8.40	64.20	0.19
Bigbow	11-9-2010	243	4	cont_ret	5--15	9.66	12.13	17.39	8.05	52.78	0.33
Bigbow	11-9-2010	212	1	alt_rem	5--15	12.33	21.44	11.99	6.40	47.84	0.41
Bigbow	11-9-2010	224	2	alt_rem	5--15	16.93	12.82	12.07	4.86	53.31	0.42
Bigbow	11-9-2010	233	3	alt_rem	5--15	12.30	15.11	10.30	7.52	54.76	0.36
Bigbow	11-9-2010	244	4	alt_rem	5--15	1.55	10.45	13.06	7.27	67.67	0.18
Bigbow	11-9-2010	213	1	cont_rem	5--15	11.18	13.25	13.06	6.79	55.73	0.34
Bigbow	11-9-2010	221	2	cont_rem	5--15	9.42	18.51	11.09	6.74	54.24	0.35
Bigbow	11-9-2010	231	3	cont_rem	5--15	8.41	12.91	11.00	10.33	57.34	0.30
Bigbow	11-9-2010	242	4	cont_rem	5--15	11.04	17.64	12.96	6.34	52.01	0.37

Table D.2 Raw data of wind erosion measurements from aggregate size distribution and surface roughness.

Wind Erosion Measurement Raw Data								
Site	Sample Date	Plot	Block	Treatment	% < 0.84 mm	GMD	GSD	STDEV
					$g\ g^{-1}$	mm	$mm\ mm^{-1}$	
Hugoton	Dec. 2008	111	1	Retained	39.95	1.44	24.44	6.44
Hugoton	Dec. 2008	112	1	Removed	42.21	0.88	16.58	5.97
Hugoton	Dec. 2008	113	1	Removed	31.59	2.07	19.05	5.08
Hugoton	Dec. 2008	114	1	Retained	38.55	1.27	18.30	5.71
Hugoton	Dec. 2008	121	2	Removed	26.83	3.92	21.91	6.19
Hugoton	Dec. 2008	122	2	Retained	26.28	3.63	19.98	7.70
Hugoton	Dec. 2008	123	2	Retained	40.95	1.04	19.60	5.20
Hugoton	Dec. 2008	124	2	Removed	42.99	0.95	15.55	7.20
Hugoton	Dec. 2008	131	3	Removed	41.18	0.97	17.63	3.21
Hugoton	Dec. 2008	132	3	Retained	48.63	0.58	16.80	7.42
Hugoton	Dec. 2008	133	3	Removed	33.30	2.35	26.68	6.26
Hugoton	Dec. 2008	134	3	Retained	45.26	0.75	18.35	4.76
Hugoton	Dec. 2008	141	4	Retained	23.73	4.40	20.41	2.57
Hugoton	Dec. 2008	142	4	Removed	31.58	2.78	24.85	3.62
Hugoton	Dec. 2008	143	4	Retained	36.75	2.22	31.48	5.24
Hugoton	Dec. 2008	144	4	Removed	43.77	0.96	17.98	3.08
Bigbow	Dec. 2008	211	1	Retained	49.63	0.55	15.85	8.43
Bigbow	Dec. 2008	212	1	Removed	64.88	0.24	11.63	5.44
Bigbow	Dec. 2008	213	1	Removed	59.94	0.30	12.97	6.41
Bigbow	Dec. 2008	214	1	Retained	49.37	0.41	13.11	6.14
Bigbow	Dec. 2008	221	2	Removed	70.91	0.16	10.88	8.75
Bigbow	Dec. 2008	222	2	Retained	71.65	0.31	11.12	7.39
Bigbow	Dec. 2008	223	2	Retained	48.18	0.59	16.61	8.26
Bigbow	Dec. 2008	224	2	Removed	80.03	0.10	9.47	5.15
Bigbow	Dec. 2008	231	3	Removed	43.75	0.77	15.70	5.28
Bigbow	Dec. 2008	232	3	Retained	44.75	0.73	16.81	8.90
Bigbow	Dec. 2008	233	3	Removed	58.13	0.36	17.60	6.96
Bigbow	Dec. 2008	234	3	Retained	59.65	0.32	15.63	10.41
Bigbow	Dec. 2008	241	4	Retained	71.41	0.18	12.98	6.17
Bigbow	Dec. 2008	242	4	Removed	78.62	0.12	9.88	5.68
Bigbow	Dec. 2008	243	4	Retained	69.98	0.19	12.91	8.29
Bigbow	Dec. 2008	244	4	Removed	85.3	0.08	9.23	6.03
Hugoton	Apr. 2009	111	1	Retained	46.69	0.60	16.87	6.20
Hugoton	Apr. 2009	112	1	Removed	48.37	0.63	13.57	9.48
Hugoton	Apr. 2009	113	1	Removed	33.37	1.74	17.10	10.31

Hugoton	Apr. 2009	114	1	Retained	35.19	1.59	18.13	14.99
Hugoton	Apr. 2009	121	2	Removed	42.79	0.90	17.19	14.58
Hugoton	Apr. 2009	122	2	Retained	49.36	0.58	15.64	9.34
Hugoton	Apr. 2009	123	2	Retained	36.95	1.28	16.40	7.16
Hugoton	Apr. 2009	124	2	Removed	34.84	2.18	11.67	10.04
Hugoton	Apr. 2009	131	3	Removed	46	0.80	20.10	9.91
Hugoton	Apr. 2009	132	3	Retained	39.26	1.19	19.83	8.16
Hugoton	Apr. 2009	133	3	Removed	41.44	0.99	20.10	12.79
Hugoton	Apr. 2009	134	3	Retained	54.94	0.39	15.70	8.87
Hugoton	Apr. 2009	141	4	Retained	49.19	0.54	15.15	6.00
Hugoton	Apr. 2009	142	4	Removed	51.44	0.52	16.66	8.01
Hugoton	Apr. 2009	143	4	Retained	42.32	0.87	15.00	5.98
Hugoton	Apr. 2009	144	4	Removed	50.52	0.52	15.55	6.60
Bigbow	Apr. 2009	211	1	Retained	58.56	0.33	15.27	10.86
Bigbow	Apr. 2009	212	1	Removed	69.55	0.20	12.48	6.76
Bigbow	Apr. 2009	213	1	Removed	57.77	0.36	17.41	10.06
Bigbow	Apr. 2009	214	1	Retained	57.35	0.37	16.75	8.38
Bigbow	Apr. 2009	221	2	Removed	69.35	0.18	13.84	8.21
Bigbow	Apr. 2009	222	2	Retained	71.19	0.18	13.00	7.69
Bigbow	Apr. 2009	223	2	Retained	55.43	0.49	19.42	8.10
Bigbow	Apr. 2009	224	2	Removed	78.39	0.11	10.22	4.76
Bigbow	Apr. 2009	231	3	Removed	63.74	0.26	14.29	7.53
Bigbow	Apr. 2009	232	3	Retained	54.01	0.45	19.31	6.12
Bigbow	Apr. 2009	233	3	Removed	71.67	0.16	12.48	7.36
Bigbow	Apr. 2009	234	3	Retained	74.7	0.28	15.96	5.89
Bigbow	Apr. 2009	241	4	Retained	68.3	0.22	15.20	7.34
Bigbow	Apr. 2009	242	4	Removed	82.03	0.11	8.74	8.12
Bigbow	Apr. 2009	243	4	Retained	85.58	0.08	8.53	6.18
Bigbow	Apr. 2009	244	4	Removed	82.57	0.11	9.94	6.80
Hugoton	Feb. 2010	111	1	Cont. Ret.	63.02	0.31	15.54	4.93
Hugoton	Feb. 2010	112	1	Alt. Rem.	61.32	0.33	14.45	8.85
Hugoton	Feb. 2010	113	1	Removed	68.07	0.24	14.67	3.07
Hugoton	Feb. 2010	114	1	Cont. Ret.	63.46	0.28	16.17	4.80
Hugoton	Feb. 2010	121	2	Removed	62.87	0.34	16.39	8.57
Hugoton	Feb. 2010	122	2	Cont. Ret.	63.98	0.35	17.49	8.34
Hugoton	Feb. 2010	123	2	Cont. Ret.	64.37	0.31	14.27	5.90
Hugoton	Feb. 2010	124	2	Alt. Rem.	66.87	0.28	15.33	5.54
Hugoton	Feb. 2010	131	3	Removed	65.21	0.28	17.52	5.03
Hugoton	Feb. 2010	132	3	Cont. Ret.	61.65	0.33	18.79	6.32
Hugoton	Feb. 2010	133	3	Alt. Rem.	65.60	0.27	17.00	4.20
Hugoton	Feb. 2010	134	3	Cont. Ret.	66.50	0.23	15.61	7.71
Hugoton	Feb. 2010	141	4	Cont. Ret.	60.44	0.35	17.41	5.21

Hugoton	Feb. 2010	142	4	Removed	65.92	0.27	14.65	6.73
Hugoton	Feb. 2010	143	4	Cont. Ret.	64.22	0.28	13.04	7.00
Hugoton	Feb. 2010	144	4	Alt. Rem.	59.83	0.36	16.22	6.44
Bigbow	Feb. 2010	211	1	Cont. Ret.	83.04	0.10	8.56	6.49
Bigbow	Feb. 2010	212	1	Alt. Rem.	84.35	0.10	8.23	4.84
Bigbow	Feb. 2010	213	1	Removed	82.60	0.10	8.94	6.41
Bigbow	Feb. 2010	214	1	Cont. Ret.	81.68	0.11	9.07	3.22
Bigbow	Feb. 2010	221	2	Removed	84.50	0.08	9.31	6.05
Bigbow	Feb. 2010	222	2	Cont. Ret.	84.82	0.11	8.21	7.89
Bigbow	Feb. 2010	223	2	Cont. Ret.	90.30	0.06	6.78	5.71
Bigbow	Feb. 2010	224	2	Alt. Rem.	87.10	0.08	7.54	8.06
Bigbow	Feb. 2010	231	3	Removed	68.79	0.19	12.42	4.76
Bigbow	Feb. 2010	232	3	Cont. Ret.	69.58	0.35	10.17	5.26
Bigbow	Feb. 2010	233	3	Alt. Rem.	78.62	0.12	10.84	5.64
Bigbow	Feb. 2010	234	3	Cont. Ret.	82.23	0.11	9.65	4.48
Bigbow	Feb. 2010	241	4	Cont. Ret.	83.00	0.09	9.19	6.39
Bigbow	Feb. 2010	242	4	Removed	87.36	0.08	8.25	5.21
Bigbow	Feb. 2010	243	4	Cont. Ret.	88.43	0.09	7.67	3.89
Bigbow	Feb. 2010	244	4	Alt. Rem.	92.65	0.06	6.46	5.94
Hugoton	May 2010	111	1	Cont. Ret.	61.86	0.31	13.42	7.06
Hugoton	May 2010	112	1	Alt. Rem.	62.58	0.26	14.86	7.71
Hugoton	May 2010	113	1	Removed	55.57	0.38	12.17	5.46
Hugoton	May 2010	114	1	Cont. Ret.	39.07	1.01	14.60	9.22
Hugoton	May 2010	121	2	Removed	57.66	0.35	12.79	9.52
Hugoton	May 2010	122	2	Cont. Ret.	43.67	0.83	16.33	4.46
Hugoton	May 2010	123	2	Cont. Ret.	45.39	0.76	14.67	6.94
Hugoton	May 2010	124	2	Alt. Rem.	40.34	0.94	13.86	9.75
Hugoton	May 2010	131	3	Removed	51.86	0.50	13.68	8.47
Hugoton	May 2010	132	3	Cont. Ret.	59.34	0.31	14.09	6.25
Hugoton	May 2010	133	3	Alt. Rem.	44.08	0.85	18.36	4.89
Hugoton	May 2010	134	3	Cont. Ret.	26.90	2.55	16.20	6.46
Hugoton	May 2010	141	4	Cont. Ret.	34.80	1.47	17.52	4.91
Hugoton	May 2010	142	4	Removed	--	--	--	6.99
Hugoton	May 2010	143	4	Cont. Ret.	36.48	1.38	16.40	4.08
Hugoton	May 2010	144	4	Alt. Rem.	39.73	1.38	19.67	4.58
Bigbow	May 2010	211	1	Cont. Ret.	33.47	1.29	11.88	2.69
Bigbow	May 2010	212	1	Alt. Rem.	40.94	0.86	13.59	3.66
Bigbow	May 2010	213	1	Removed	77.05	0.13	10.31	8.74
Bigbow	May 2010	214	1	Cont. Ret.	52.76	0.44	14.32	3.07
Bigbow	May 2010	221	2	Removed	73.59	0.14	11.46	5.45
Bigbow	May 2010	222	2	Cont. Ret.	54.11	0.42	13.62	4.07
Bigbow	May 2010	223	2	Cont. Ret.	63.33	0.23	12.29	4.61

Bigbow	May 2010	224	2	Alt. Rem.	71.37	0.17	11.23	4.58
Bigbow	May 2010	231	3	Removed	65.54	0.23	12.02	4.70
Bigbow	May 2010	232	3	Cont. Ret.	45.33	0.64	12.24	4.88
Bigbow	May 2010	233	3	Alt. Rem.	50.23	0.48	14.13	3.29
Bigbow	May 2010	234	3	Cont. Ret.	59.62	0.32	14.34	6.68
Bigbow	May 2010	241	4	Cont. Ret.	53.93	0.44	15.79	9.36
Bigbow	May 2010	242	4	Removed	81.61	0.20	8.54	7.46
Bigbow	May 2010	243	4	Cont. Ret.	68.34	0.18	12.86	6.70
Bigbow	May 2010	244	4	Alt. Rem.	76.00	0.13	10.96	6.29
Hugoton	Jan 2011	111	1	Cont. Ret.	37.34	0.97	12.92	5.77
Hugoton	Jan 2011	112	1	Alt. Rem.	36.46	1.40	17.28	7.88
Hugoton	Jan 2011	113	1	Removed	45.51	0.71	17.63	6.58
Hugoton	Jan 2011	114	1	Cont. Ret.	27.35	3.03	18.39	7.62
Hugoton	Jan 2011	121	2	Removed	34.48	1.93	20.44	3.67
Hugoton	Jan 2011	122	2	Cont. Ret.	23.17	2.97	12.96	5.88
Hugoton	Jan 2011	123	2	Cont. Ret.	--	--	--	5.12
Hugoton	Jan 2011	124	2	Alt. Rem.	--	--	--	3.75
Hugoton	Jan 2011	131	3	Removed	38.64	1.21	16.29	1.78
Hugoton	Jan 2011	132	3	Cont. Ret.	43.51	0.82	17.97	12.42
Hugoton	Jan 2011	133	3	Alt. Rem.	41.91	0.89	17.31	4.97
Hugoton	Jan 2011	134	3	Cont. Ret.	36.63	1.20	16.02	4.36
Hugoton	Jan 2011	141	4	Cont. Ret.	21.35	3.41	12.71	4.77
Hugoton	Jan 2011	142	4	Removed	42.20	0.87	14.63	3.4
Hugoton	Jan 2011	143	4	Cont. Ret.	--	--	--	7.16
Hugoton	Jan 2011	144	4	Alt. Rem.	--	--	--	3.78
Bigbow	Jan 2011	211	1	Cont. Ret.	66.78	0.20	12.62	7.53
Bigbow	Jan 2011	212	1	Alt. Rem.	70.74	0.21	13.02	5.03
Bigbow	Jan 2011	213	1	Removed	84.89	0.08	8.25	7.61
Bigbow	Jan 2011	214	1	Cont. Ret.	85.92	0.09	7.98	12.54
Bigbow	Jan 2011	221	2	Removed	82.86	0.09	8.60	3.72
Bigbow	Jan 2011	222	2	Cont. Ret.	88.18	0.08	7.41	8.28
Bigbow	Jan 2011	223	2	Cont. Ret.	58.67	0.32	16.07	4.97
Bigbow	Jan 2011	224	2	Alt. Rem.	83.66	0.10	9.27	3.93
Bigbow	Jan 2011	231	3	Removed	65.14	0.22	13.45	6.42
Bigbow	Jan 2011	232	3	Cont. Ret.	69.67	0.16	11.43	4.86
Bigbow	Jan 2011	233	3	Alt. Rem.	81.67	0.09	8.69	5.63
Bigbow	Jan 2011	234	3	Cont. Ret.	71.95	0.18	12.90	3.82
Bigbow	Jan 2011	241	4	Cont. Ret.	63.51	0.24	14.42	3.89
Bigbow	Jan 2011	242	4	Removed	82.64	0.09	9.09	15.15
Bigbow	Jan 2011	243	4	Cont. Ret.	66.74	0.22	15.41	5.09
Bigbow	Jan 2011	244	4	Alt. Rem.	84.87	0.09	8.65	6.63

Table D.3 Soil sensor raw data. Soil temperature, soil moisture, and air temperature measurements recorded at 12:00 pm during the winter seasons of 2008-2009 and 2009-2010.

Hugoton and Bigbow Daily 12:00 pm Sensor Data					
Date	Field	Treatment	Air Temp. (°C)	Temp. (°C)	Moist. ($cm^3 cm^{-3}$)
21-Dec-08	Hugoton	Retained	-5.45	0.12	0.300
22-Dec-08	Hugoton	Retained	-3.48	-0.32	0.278
23-Dec-08	Hugoton	Retained	10.50	0.15	0.289
24-Dec-08	Hugoton	Retained	3.96	0.04	0.284
25-Dec-08	Hugoton	Retained	9.16	0.87	0.291
26-Dec-08	Hugoton	Retained	16.99	3.66	0.298
27-Dec-08	Hugoton	Retained	0.91	2.37	0.296
28-Dec-08	Hugoton	Retained	10.89	1.15	0.293
29-Dec-08	Hugoton	Retained	14.89	2.39	0.295
30-Dec-08	Hugoton	Retained	20.49	3.14	0.295
31-Dec-08	Hugoton	Retained	2.44	1.56	0.292
1-Jan-09	Hugoton	Retained	14.67	2.16	0.292
2-Jan-09	Hugoton	Retained	16.66	2.27	0.292
3-Jan-09	Hugoton	Retained	6.38	3.39	0.293
4-Jan-09	Hugoton	Retained	-1.38	1.01	0.290
5-Jan-09	Hugoton	Retained	2.84	0.72	0.287
6-Jan-09	Hugoton	Retained	8.40	0.80	0.288
7-Jan-09	Hugoton	Retained	13.87	0.86	0.287
8-Jan-09	Hugoton	Retained	17.49	2.32	0.288
9-Jan-09	Hugoton	Retained	15.86	3.33	0.290
10-Jan-09	Hugoton	Retained	3.95	1.65	0.288
11-Jan-09	Hugoton	Retained	9.92	1.36	0.286
12-Jan-09	Hugoton	Retained	5.05	2.29	0.287
13-Jan-09	Hugoton	Retained	8.77	1.21	0.283
14-Jan-09	Hugoton	Retained	9.20	2.25	0.285
15-Jan-09	Hugoton	Retained	-8.88	0.68	0.282
16-Jan-09	Hugoton	Retained	11.23	0.28	0.277
17-Jan-09	Hugoton	Retained	12.73	2.08	0.282
18-Jan-09	Hugoton	Retained	16.13	2.75	0.282
19-Jan-09	Hugoton	Retained	17.33	4.09	0.284
20-Jan-09	Hugoton	Retained	11.42	3.83	0.283
21-Jan-09	Hugoton	Retained	16.98	3.63	0.282
22-Jan-09	Hugoton	Retained	17.74	4.08	0.282
23-Jan-09	Hugoton	Retained	5.69	4.25	0.282
24-Jan-09	Hugoton	Retained	-6.59	2.01	0.277

25-Jan-09	Hugoton	Retained	-5.10	0.58	0.272
26-Jan-09	Hugoton	Retained	-9.86	-0.08	0.267
27-Jan-09	Hugoton	Retained	-11.53	0.11	0.266
28-Jan-09	Hugoton	Retained	3.49	0.01	0.259
29-Jan-09	Hugoton	Retained	6.81	0.34	0.262
30-Jan-09	Hugoton	Retained	14.26	0.13	0.257
31-Jan-09	Hugoton	Retained	16.30	1.73	0.264
1-Feb-09	Hugoton	Retained	6.38	1.52	0.263
2-Feb-09	Hugoton	Retained	10.61	0.48	0.260
3-Feb-09	Hugoton	Retained	14.59	1.27	0.261
4-Feb-09	Hugoton	Retained	12.94	1.99	0.262
5-Feb-09	Hugoton	Retained	15.79	2.87	0.263
6-Feb-09	Hugoton	Retained	23.52	3.40	0.265
7-Feb-09	Hugoton	Retained	17.67	4.22	0.265
8-Feb-09	Hugoton	Retained	11.78	5.38	0.267
9-Feb-09	Hugoton	Retained	13.30	5.49	0.268
10-Feb-09	Hugoton	Retained	15.72	5.17	0.269
11-Feb-09	Hugoton	Retained	7.87	4.63	0.268
12-Feb-09	Hugoton	Retained	7.21	4.13	0.268
21-Dec-08	Hugoton	Removed	-5.45	-1.05	0.221
22-Dec-08	Hugoton	Removed	-3.48	-1.36	0.213
23-Dec-08	Hugoton	Removed	10.50	-0.13	0.238
24-Dec-08	Hugoton	Removed	3.96	-0.69	0.221
25-Dec-08	Hugoton	Removed	9.16	0.27	0.286
26-Dec-08	Hugoton	Removed	16.99	4.45	0.312
27-Dec-08	Hugoton	Removed	0.91	2.03	0.308
28-Dec-08	Hugoton	Removed	10.89	0.23	0.282
29-Dec-08	Hugoton	Removed	14.89	3.01	0.305
30-Dec-08	Hugoton	Removed	20.49	4.04	0.306
31-Dec-08	Hugoton	Removed	2.44	0.33	0.290
1-Jan-09	Hugoton	Removed	14.67	1.91	0.299
2-Jan-09	Hugoton	Removed	16.66	2.32	0.298
3-Jan-09	Hugoton	Removed	6.38	4.31	0.301
4-Jan-09	Hugoton	Removed	-1.38	0.29	0.285
5-Jan-09	Hugoton	Removed	2.84	0.00	0.267
6-Jan-09	Hugoton	Removed	8.40	0.17	0.267
7-Jan-09	Hugoton	Removed	13.87	0.25	0.264
8-Jan-09	Hugoton	Removed	17.49	2.83	0.291
9-Jan-09	Hugoton	Removed	15.86	3.99	0.291
10-Jan-09	Hugoton	Removed	3.95	1.08	0.283
11-Jan-09	Hugoton	Removed	9.92	0.75	0.274
12-Jan-09	Hugoton	Removed	5.05	2.12	0.283

13-Jan-09	Hugoton	Removed	8.77	0.36	0.264
14-Jan-09	Hugoton	Removed	9.20	2.23	0.280
15-Jan-09	Hugoton	Removed	-8.88	-0.21	0.263
16-Jan-09	Hugoton	Removed	11.23	-0.01	0.226
17-Jan-09	Hugoton	Removed	12.73	2.43	0.277
18-Jan-09	Hugoton	Removed	16.13	3.45	0.277
19-Jan-09	Hugoton	Removed	17.33	5.30	0.278
20-Jan-09	Hugoton	Removed	11.42	4.50	0.275
21-Jan-09	Hugoton	Removed	16.98	4.42	0.277
22-Jan-09	Hugoton	Removed	17.74	5.34	0.271
23-Jan-09	Hugoton	Removed	5.69	5.15	0.269
24-Jan-09	Hugoton	Removed	-6.59	1.41	0.260
25-Jan-09	Hugoton	Removed	-5.10	-0.09	0.237
26-Jan-09	Hugoton	Removed	-9.86	-0.87	0.213
27-Jan-09	Hugoton	Removed	-11.53	-0.11	0.238
28-Jan-09	Hugoton	Removed	3.49	-1.18	0.196
29-Jan-09	Hugoton	Removed	6.81	-0.12	0.216
30-Jan-09	Hugoton	Removed	14.26	0.22	0.219
31-Jan-09	Hugoton	Removed	16.30	2.16	0.259
1-Feb-09	Hugoton	Removed	6.38	1.52	0.257
2-Feb-09	Hugoton	Removed	10.61	0.24	0.229
3-Feb-09	Hugoton	Removed	14.59	1.46	0.254
4-Feb-09	Hugoton	Removed	12.94	2.78	0.256
5-Feb-09	Hugoton	Removed	15.79	4.33	0.256
6-Feb-09	Hugoton	Removed	23.52	4.87	0.254
7-Feb-09	Hugoton	Removed	17.67	5.78	0.253
8-Feb-09	Hugoton	Removed	11.78	6.91	0.251
9-Feb-09	Hugoton	Removed	13.30	6.18	0.247
10-Feb-09	Hugoton	Removed	15.72	6.65	0.248
11-Feb-09	Hugoton	Removed	7.87	5.88	0.248
12-Feb-09	Hugoton	Removed	7.21	4.62	0.247
21-Dec-08	Bigbow	Retained	-5.39	-0.14	0.169
22-Dec-08	Bigbow	Retained	-3.27	-0.48	0.149
23-Dec-08	Bigbow	Retained	10.81	0.04	0.166
24-Dec-08	Bigbow	Retained	4.22	-0.08	0.160
25-Dec-08	Bigbow	Retained	9.63	1.37	0.171
26-Dec-08	Bigbow	Retained	17.25	4.20	0.174
27-Dec-08	Bigbow	Retained	1.02	2.52	0.173
28-Dec-08	Bigbow	Retained	10.86	1.13	0.170
29-Dec-08	Bigbow	Retained	15.00	2.83	0.172
30-Dec-08	Bigbow	Retained	20.23	3.68	0.172
31-Dec-08	Bigbow	Retained	2.09	1.30	0.169

1-Jan-09	Bigbow	Retained	15.25	2.41	0.170
2-Jan-09	Bigbow	Retained	16.62	2.52	0.169
3-Jan-09	Bigbow	Retained	6.63	3.90	0.170
4-Jan-09	Bigbow	Retained	-1.34	0.95	0.166
5-Jan-09	Bigbow	Retained	2.85	0.63	0.161
6-Jan-09	Bigbow	Retained	7.90	0.90	0.162
7-Jan-09	Bigbow	Retained	14.19	0.93	0.162
8-Jan-09	Bigbow	Retained	17.86	2.57	0.165
9-Jan-09	Bigbow	Retained	15.90	3.69	0.166
10-Jan-09	Bigbow	Retained	4.22	1.48	0.163
11-Jan-09	Bigbow	Retained	9.90	1.27	0.161
12-Jan-09	Bigbow	Retained	5.01	2.22	0.164
13-Jan-09	Bigbow	Retained	9.07	1.12	0.158
14-Jan-09	Bigbow	Retained	9.73	2.29	0.162
15-Jan-09	Bigbow	Retained	-8.77	0.48	0.155
16-Jan-09	Bigbow	Retained	11.83	0.27	0.152
17-Jan-09	Bigbow	Retained	12.47	2.19	0.160
18-Jan-09	Bigbow	Retained	16.53	3.04	0.160
19-Jan-09	Bigbow	Retained	17.25	4.74	0.161
20-Jan-09	Bigbow	Retained	10.95	4.23	0.160
21-Jan-09	Bigbow	Retained	17.37	4.27	0.159
22-Jan-09	Bigbow	Retained	18.02	4.64	0.159
23-Jan-09	Bigbow	Retained	5.70	4.76	0.158
24-Jan-09	Bigbow	Retained	-6.47	1.89	0.155
25-Jan-09	Bigbow	Retained	-5.67	0.36	0.148
26-Jan-09	Bigbow	Retained	-9.72	-0.34	0.144
27-Jan-09	Bigbow	Retained	-11.63	-0.01	0.147
28-Jan-09	Bigbow	Retained	3.96	-0.28	0.133
29-Jan-09	Bigbow	Retained	6.70	0.16	0.144
30-Jan-09	Bigbow	Retained	14.54	0.11	0.142
31-Jan-09	Bigbow	Retained	16.83	1.79	0.152
1-Feb-09	Bigbow	Retained	5.84	1.44	0.151
2-Feb-09	Bigbow	Retained	11.31	0.41	0.146
3-Feb-09	Bigbow	Retained	14.50	1.35	0.150
4-Feb-09	Bigbow	Retained	13.38	2.34	0.151
5-Feb-09	Bigbow	Retained	15.80	3.26	0.152
6-Feb-09	Bigbow	Retained	23.46	3.88	0.151
7-Feb-09	Bigbow	Retained	18.12	4.85	0.152
8-Feb-09	Bigbow	Retained	11.67	6.00	0.152
9-Feb-09	Bigbow	Retained	13.54	5.77	0.155
10-Feb-09	Bigbow	Retained	16.00	5.74	0.155
11-Feb-09	Bigbow	Retained	8.09	5.05	0.155

21-Dec-08	Bigbow	Removed	-5.39	-1.22	0.098
22-Dec-08	Bigbow	Removed	-3.27	-1.43	0.094
23-Dec-08	Bigbow	Removed	10.81	-0.26	0.112
24-Dec-08	Bigbow	Removed	4.22	-0.90	0.097
25-Dec-08	Bigbow	Removed	9.63	0.17	0.142
26-Dec-08	Bigbow	Removed	17.25	4.97	0.163
27-Dec-08	Bigbow	Removed	1.02	2.12	0.159
28-Dec-08	Bigbow	Removed	10.86	-0.19	0.132
29-Dec-08	Bigbow	Removed	15.00	2.78	0.158
30-Dec-08	Bigbow	Removed	20.23	4.61	0.159
31-Dec-08	Bigbow	Removed	2.09	-0.07	0.151
1-Jan-09	Bigbow	Removed	15.25	1.68	0.155
2-Jan-09	Bigbow	Removed	16.62	1.90	0.155
3-Jan-09	Bigbow	Removed	6.63	4.84	0.157
4-Jan-09	Bigbow	Removed	-1.34	-0.13	0.145
5-Jan-09	Bigbow	Removed	2.85	-0.29	0.120
6-Jan-09	Bigbow	Removed	7.90	-0.19	0.122
7-Jan-09	Bigbow	Removed	14.19	-0.13	0.122
8-Jan-09	Bigbow	Removed	17.86	2.77	0.153
9-Jan-09	Bigbow	Removed	15.90	4.37	0.154
10-Jan-09	Bigbow	Removed	4.22	0.07	0.145
11-Jan-09	Bigbow	Removed	9.90	0.00	0.125
12-Jan-09	Bigbow	Removed	5.01	1.57	0.149
13-Jan-09	Bigbow	Removed	9.07	-0.16	0.119
14-Jan-09	Bigbow	Removed	9.73	2.00	0.149
15-Jan-09	Bigbow	Removed	-8.77	-0.34	0.131
16-Jan-09	Bigbow	Removed	11.83	-0.36	0.103
17-Jan-09	Bigbow	Removed	12.47	1.70	0.147
18-Jan-09	Bigbow	Removed	16.53	3.69	0.149
19-Jan-09	Bigbow	Removed	17.25	5.98	0.151
20-Jan-09	Bigbow	Removed	10.95	4.65	0.149
21-Jan-09	Bigbow	Removed	17.37	4.85	0.149
22-Jan-09	Bigbow	Removed	18.02	5.62	0.149
23-Jan-09	Bigbow	Removed	5.70	5.52	0.148
24-Jan-09	Bigbow	Removed	-6.47	0.86	0.144
25-Jan-09	Bigbow	Removed	-5.67	-0.39	0.106
26-Jan-09	Bigbow	Removed	-9.72	-1.11	0.095
27-Jan-09	Bigbow	Removed	-11.63	-0.39	0.108
28-Jan-09	Bigbow	Removed	3.96	-1.45	0.087
29-Jan-09	Bigbow	Removed	6.70	-0.38	0.100
30-Jan-09	Bigbow	Removed	14.54	-0.16	0.103
31-Jan-09	Bigbow	Removed	16.83	1.46	0.141

1-Feb-09	Bigbow	Removed	5.84	1.09	0.144
2-Feb-09	Bigbow	Removed	11.31	-0.14	0.107
3-Feb-09	Bigbow	Removed	14.50	0.84	0.131
4-Feb-09	Bigbow	Removed	13.38	2.56	0.144
5-Feb-09	Bigbow	Removed	15.80	4.35	0.145
6-Feb-09	Bigbow	Removed	23.46	5.25	0.145
7-Feb-09	Bigbow	Removed	18.12	6.14	0.145
8-Feb-09	Bigbow	Removed	11.67	7.14	0.145
9-Feb-09	Bigbow	Removed	13.54	6.37	0.154
10-Feb-09	Bigbow	Removed	16.00	7.29	0.152
11-Feb-09	Bigbow	Removed	8.09	6.14	0.150
5-Jan-10	Hugoton	Retained	-3.20	0.03	0.038
6-Jan-10	Hugoton	Retained	-1.75	0.07	0.037
7-Jan-10	Hugoton	Retained	-10.36	-0.67	0.024
8-Jan-10	Hugoton	Retained	-5.28	-1.32	0.018
9-Jan-10	Hugoton	Retained	-4.71	-1.46	0.017
10-Jan-10	Hugoton	Retained	5.62	-1.25	0.018
11-Jan-10	Hugoton	Retained	9.86	-0.72	0.019
12-Jan-10	Hugoton	Retained	14.24	-0.39	0.018
13-Jan-10	Hugoton	Retained	11.48	-0.22	0.022
14-Jan-10	Hugoton	Retained	8.56	-0.20	0.024
15-Jan-10	Hugoton	Retained	8.78	-0.20	0.024
16-Jan-10	Hugoton	Retained	10.68	-0.21	0.024
17-Jan-10	Hugoton	Retained	12.90	-0.14	0.027
18-Jan-10	Hugoton	Retained	7.80	-0.07	0.032
19-Jan-10	Hugoton	Retained	0.38	0.07	0.034
20-Jan-10	Hugoton	Retained	6.86	0.16	0.034
21-Jan-10	Hugoton	Retained	2.09	1.20	0.034
22-Jan-10	Hugoton	Retained	12.98	2.29	0.034
23-Jan-10	Hugoton	Retained	10.86	2.87	0.035
24-Jan-10	Hugoton	Retained	3.49	2.01	0.034
25-Jan-10	Hugoton	Retained	7.60	1.07	0.034
26-Jan-10	Hugoton	Retained	6.32	0.91	0.035
27-Jan-10	Hugoton	Retained	10.67	1.99	0.035
28-Jan-10	Hugoton	Retained	-4.45	0.35	0.035
29-Jan-10	Hugoton	Retained	-7.15	0.65	0.035
1-Feb-10	Hugoton	Retained	1.93	0.91	0.040
2-Feb-10	Hugoton	Retained	6.49	0.47	0.043
3-Feb-10	Hugoton	Retained	2.13	0.74	0.046
4-Feb-10	Hugoton	Retained	0.88	1.30	0.047
5-Feb-10	Hugoton	Retained	4.04	1.05	0.046
6-Feb-10	Hugoton	Retained	0.61	0.62	0.044

7-Feb-10	Hugoton	Retained	-0.17	0.73	0.044
8-Feb-10	Hugoton	Retained	-0.37	1.28	0.044
9-Feb-10	Hugoton	Retained	-6.04	0.44	0.043
10-Feb-10	Hugoton	Retained	0.48	0.35	0.042
11-Feb-10	Hugoton	Retained	1.79	0.73	0.043
12-Feb-10	Hugoton	Retained	8.68	1.12	0.040
13-Feb-10	Hugoton	Retained	11.81	1.76	0.041
14-Feb-10	Hugoton	Retained	-1.44	1.09	0.040
15-Feb-10	Hugoton	Retained	1.56	0.66	0.033
16-Feb-10	Hugoton	Retained	2.24	0.70	0.030
17-Feb-10	Hugoton	Retained	11.05	1.41	0.028
18-Feb-10	Hugoton	Retained	9.44	1.89	0.033
19-Feb-10	Hugoton	Retained	2.71	1.53	0.034
20-Feb-10	Hugoton	Retained	-1.75	0.62	0.034
21-Feb-10	Hugoton	Retained	-3.50	0.29	0.033
22-Feb-10	Hugoton	Retained	-4.38	0.20	0.033
23-Feb-10	Hugoton	Retained	2.03	0.41	0.030
24-Feb-10	Hugoton	Retained	8.54	1.50	0.029
25-Feb-10	Hugoton	Retained	0.44	0.59	0.033
5-Jan-10	Hugoton	Removed	-3.20	-0.60	0.019
6-Jan-10	Hugoton	Removed	-1.75	-0.36	0.020
7-Jan-10	Hugoton	Removed	-10.36	-2.68	0.015
8-Jan-10	Hugoton	Removed	-5.28	-3.49	0.013
9-Jan-10	Hugoton	Removed	-4.71	-3.40	0.013
10-Jan-10	Hugoton	Removed	5.62	-2.42	0.013
11-Jan-10	Hugoton	Removed	9.86	-1.27	0.015
12-Jan-10	Hugoton	Removed	14.24	-0.77	0.014
13-Jan-10	Hugoton	Removed	11.48	-0.34	0.015
14-Jan-10	Hugoton	Removed	8.56	-0.07	0.016
15-Jan-10	Hugoton	Removed	8.78	-0.16	0.016
16-Jan-10	Hugoton	Removed	10.68	-0.16	0.016
17-Jan-10	Hugoton	Removed	12.90	-0.01	0.016
18-Jan-10	Hugoton	Removed	7.80	0.13	0.019
19-Jan-10	Hugoton	Removed	0.38	-0.12	0.019
20-Jan-10	Hugoton	Removed	6.86	0.10	0.019
21-Jan-10	Hugoton	Removed	2.09	0.89	0.022
22-Jan-10	Hugoton	Removed	12.98	3.08	0.023
23-Jan-10	Hugoton	Removed	10.86	3.57	0.023
24-Jan-10	Hugoton	Removed	3.49	1.49	0.022
25-Jan-10	Hugoton	Removed	7.60	0.36	0.021
26-Jan-10	Hugoton	Removed	6.32	0.01	0.018
27-Jan-10	Hugoton	Removed	10.67	0.52	0.021

28-Jan-10	Hugoton	Removed	-4.45	-0.03	0.021
29-Jan-10	Hugoton	Removed	-7.15	0.06	0.021
1-Feb-10	Hugoton	Removed	1.93	0.30	0.022
2-Feb-10	Hugoton	Removed	6.49	-0.05	0.022
3-Feb-10	Hugoton	Removed	2.13	0.31	0.025
4-Feb-10	Hugoton	Removed	0.88	0.78	0.028
5-Feb-10	Hugoton	Removed	4.04	0.46	0.026
6-Feb-10	Hugoton	Removed	0.61	0.31	0.027
7-Feb-10	Hugoton	Removed	-0.17	0.45	0.028
8-Feb-10	Hugoton	Removed	-0.37	0.74	0.029
9-Feb-10	Hugoton	Removed	-6.04	-0.18	0.020
10-Feb-10	Hugoton	Removed	0.48	-0.07	0.018
11-Feb-10	Hugoton	Removed	1.79	0.12	0.022
12-Feb-10	Hugoton	Removed	8.68	0.06	0.020
13-Feb-10	Hugoton	Removed	11.81	0.30	0.021
14-Feb-10	Hugoton	Removed	-1.44	0.61	0.022
15-Feb-10	Hugoton	Removed	1.56	-0.47	0.015
16-Feb-10	Hugoton	Removed	2.24	-0.75	0.015
17-Feb-10	Hugoton	Removed	11.05	-0.68	0.015
18-Feb-10	Hugoton	Removed	9.44	0.11	0.020
19-Feb-10	Hugoton	Removed	2.71	0.30	0.021
20-Feb-10	Hugoton	Removed	-1.75	0.18	0.021
21-Feb-10	Hugoton	Removed	-3.50	-0.03	0.021
22-Feb-10	Hugoton	Removed	-4.38	-0.21	0.016
23-Feb-10	Hugoton	Removed	2.03	-0.54	0.015
24-Feb-10	Hugoton	Removed	8.54	-0.48	0.015
25-Feb-10	Hugoton	Removed	0.44	-0.03	0.019
1-Jan-10	Bigbow	Retained	8.18	-0.39	0.086
2-Jan-10	Bigbow	Retained	-6.36	-1.17	0.082
3-Jan-10	Bigbow	Retained	4.43	-0.53	0.083
4-Jan-10	Bigbow	Retained	-0.77	-0.20	0.096
5-Jan-10	Bigbow	Retained	-3.27	-0.46	0.086
6-Jan-10	Bigbow	Retained	-1.80	-0.31	0.091
7-Jan-10	Bigbow	Retained	-9.79	-2.53	0.066
8-Jan-10	Bigbow	Retained	-5.23	-2.61	0.062
9-Jan-10	Bigbow	Retained	-5.13	-2.50	0.062
10-Jan-10	Bigbow	Retained	6.18	-1.44	0.066
11-Jan-10	Bigbow	Retained	9.70	-0.55	0.074
12-Jan-10	Bigbow	Retained	15.18	-0.34	0.071
13-Jan-10	Bigbow	Retained	11.76	-0.19	0.084
14-Jan-10	Bigbow	Retained	8.70	-0.06	0.086
15-Jan-10	Bigbow	Retained	8.90	-0.16	0.082

16-Jan-10	Bigbow	Retained	11.04	-0.19	0.079
17-Jan-10	Bigbow	Retained	13.52	-0.09	0.083
18-Jan-10	Bigbow	Retained	8.50	0.04	0.111
19-Jan-10	Bigbow	Retained	0.42	-0.07	0.125
20-Jan-10	Bigbow	Retained	6.35	0.12	0.113
21-Jan-10	Bigbow	Retained	2.18	1.16	0.121
22-Jan-10	Bigbow	Retained	12.62	2.84	0.122
23-Jan-10	Bigbow	Retained	10.96	3.69	0.124
24-Jan-10	Bigbow	Retained	3.21	1.92	0.122
25-Jan-10	Bigbow	Retained	7.33	0.70	0.119
26-Jan-10	Bigbow	Retained	6.48	0.23	0.103
27-Jan-10	Bigbow	Retained	10.26	0.96	0.119
28-Jan-10	Bigbow	Retained	-4.47	0.26	0.119
29-Jan-10	Bigbow	Retained	-7.23	0.47	0.118
30-Jan-10	Bigbow	Retained	-1.37	0.30	0.118
31-Jan-10	Bigbow	Retained	1.69	0.03	0.117
1-Feb-10	Bigbow	Retained	2.18	0.52	0.136
2-Feb-10	Bigbow	Retained	7.94	0.16	0.146
3-Feb-10	Bigbow	Retained	2.05	0.46	0.155
4-Feb-10	Bigbow	Retained	0.62	1.04	0.157
5-Feb-10	Bigbow	Retained	4.04	0.75	0.163
6-Feb-10	Bigbow	Retained	0.45	0.29	0.175
7-Feb-10	Bigbow	Retained	-0.35	0.43	0.174
8-Feb-10	Bigbow	Retained	-0.55	0.83	0.186
9-Feb-10	Bigbow	Retained	-5.90	0.13	0.160
10-Feb-10	Bigbow	Retained	0.99	-0.02	0.147
11-Feb-10	Bigbow	Retained	2.12	0.13	0.159
12-Feb-10	Bigbow	Retained	9.83	0.14	0.154
13-Feb-10	Bigbow	Retained	11.50	0.39	0.155
14-Feb-10	Bigbow	Retained	-2.07	0.75	0.157
15-Feb-10	Bigbow	Retained	1.59	-0.16	0.106
16-Feb-10	Bigbow	Retained	2.25	-0.31	0.093
17-Feb-10	Bigbow	Retained	10.90	-0.25	0.092
18-Feb-10	Bigbow	Retained	9.39	0.29	0.142
19-Feb-10	Bigbow	Retained	2.88	1.12	0.144
20-Feb-10	Bigbow	Retained	-1.97	0.47	0.141
21-Feb-10	Bigbow	Retained	-3.57	0.20	0.141
22-Feb-10	Bigbow	Retained	-4.43	-0.07	0.134
23-Feb-10	Bigbow	Retained	2.19	-0.32	0.091
24-Feb-10	Bigbow	Retained	8.80	-0.25	0.089
25-Feb-10	Bigbow	Retained	0.32	0.13	0.136
1-Jan-10	Bigbow	Removed	8.18	-0.53	0.078

2-Jan-10	Bigbow	Removed	-6.36	-1.68	0.072
3-Jan-10	Bigbow	Removed	4.43	-0.69	0.075
4-Jan-10	Bigbow	Removed	-0.77	-0.19	0.085
5-Jan-10	Bigbow	Removed	-3.27	-0.65	0.078
6-Jan-10	Bigbow	Removed	-1.80	-0.41	0.081
7-Jan-10	Bigbow	Removed	-9.79	-3.60	0.060
8-Jan-10	Bigbow	Removed	-5.23	-3.92	0.056
9-Jan-10	Bigbow	Removed	-5.13	-3.32	0.058
10-Jan-10	Bigbow	Removed	6.18	-1.79	0.063
11-Jan-10	Bigbow	Removed	9.70	-0.42	0.072
12-Jan-10	Bigbow	Removed	15.18	-0.55	0.084
13-Jan-10	Bigbow	Removed	11.76	-0.23	0.094
14-Jan-10	Bigbow	Removed	8.70	-0.09	0.097
15-Jan-10	Bigbow	Removed	8.90	-0.18	0.094
16-Jan-10	Bigbow	Removed	11.04	-0.22	0.091
17-Jan-10	Bigbow	Removed	13.52	-0.11	0.093
18-Jan-10	Bigbow	Removed	8.50	0.05	0.110
19-Jan-10	Bigbow	Removed	0.42	-0.17	0.112
20-Jan-10	Bigbow	Removed	6.35	-0.02	0.111
21-Jan-10	Bigbow	Removed	2.18	1.02	0.137
22-Jan-10	Bigbow	Removed	12.62	3.40	0.139
23-Jan-10	Bigbow	Removed	10.96	4.28	0.139
24-Jan-10	Bigbow	Removed	3.21	2.03	0.137
25-Jan-10	Bigbow	Removed	7.33	0.41	0.126
26-Jan-10	Bigbow	Removed	6.48	0.05	0.098
27-Jan-10	Bigbow	Removed	10.26	0.87	0.132
28-Jan-10	Bigbow	Removed	-4.47	-0.02	0.130
29-Jan-10	Bigbow	Removed	-7.23	0.05	0.128
30-Jan-10	Bigbow	Removed	-1.37	-0.17	0.120
31-Jan-10	Bigbow	Removed	1.69	-0.36	0.093
1-Feb-10	Bigbow	Removed	2.18	-0.05	0.149
2-Feb-10	Bigbow	Removed	7.94	-0.23	0.119
3-Feb-10	Bigbow	Removed	2.05	0.21	0.156
4-Feb-10	Bigbow	Removed	0.62	0.77	0.181
5-Feb-10	Bigbow	Removed	4.04	0.46	0.179
6-Feb-10	Bigbow	Removed	0.45	0.20	0.190
7-Feb-10	Bigbow	Removed	-0.35	0.22	0.193
8-Feb-10	Bigbow	Removed	-0.55	0.51	0.205
9-Feb-10	Bigbow	Removed	-5.90	-0.17	0.120
10-Feb-10	Bigbow	Removed	0.99	-0.10	0.124
11-Feb-10	Bigbow	Removed	2.12	-0.10	0.169
12-Feb-10	Bigbow	Removed	9.83	-0.19	0.136

13-Feb-10	Bigbow	Removed	11.50	0.05	0.162
14-Feb-10	Bigbow	Removed	-2.07	0.49	0.169
15-Feb-10	Bigbow	Removed	1.59	-0.47	0.088
16-Feb-10	Bigbow	Removed	2.25	-0.60	0.086
17-Feb-10	Bigbow	Removed	10.90	-0.38	0.086
18-Feb-10	Bigbow	Removed	9.39	0.72	0.140
19-Feb-10	Bigbow	Removed	2.88	1.03	0.153
20-Feb-10	Bigbow	Removed	-1.97	0.18	0.150
21-Feb-10	Bigbow	Removed	-3.57	-0.03	0.147
22-Feb-10	Bigbow	Removed	-4.43	-0.30	0.106
23-Feb-10	Bigbow	Removed	2.19	-0.62	0.085
24-Feb-10	Bigbow	Removed	8.80	-0.33	0.086
25-Feb-10	Bigbow	Removed	0.32	-0.10	0.136

Table D.4 Residue measurements at Hugoton L and Bigbow FSL sites during 2008-2009 and 2009-2010 winter seasons.

Residue Coverage Winter 2008-2009						
Field	Plot	Block	Treatment	11-8-08	12-3-08	5-19-09
				---%---	---%---	---%---
Hugoton	111	1	Retained	93	87	63
Hugoton	114	1	Retained	92	83	71
Hugoton	122	2	Retained	83	81	37
Hugoton	123	2	Retained	93	84	72
Hugoton	132	3	Retained	92	88	57
Hugoton	134	3	Retained	94	90	57
Hugoton	141	4	Retained	92	87	41
Hugoton	143	4	Removed	90	92	60
Hugoton	112	1	Removed	65	63	26
Hugoton	113	1	Removed	69	50	17
Hugoton	121	2	Removed	64	63	25
Hugoton	124	2	Removed	72	56	45
Hugoton	131	3	Removed	70	57	30
Hugoton	133	3	Removed	65	48	17
Hugoton	142	4	Removed	84	53	47
Hugoton	144	4	Removed	78	75	41
Bigbow	211	1	Retained	97	95	75
Bigbow	214	1	Retained	96	98	66
Bigbow	222	2	Retained	95	96	73
Bigbow	223	2	Retained	99	99	79
Bigbow	232	3	Retained	94	98	75
Bigbow	234	3	Retained	93	94	56
Bigbow	241	4	Retained	96	94	66
Bigbow	243	4	Removed	94	94	67
Bigbow	212	1	Removed	80	63	52
Bigbow	213	1	Removed	71	61	42
Bigbow	221	2	Removed	71	63	49
Bigbow	224	2	Removed	69	68	41
Bigbow	231	3	Removed	86	76	40
Bigbow	233	3	Removed	78	77	44
Bigbow	242	4	Removed	65	58	24
Bigbow	244	4	Removed	71	50	8

Residue Coverage Winter 2009-2010							
Field	Plot	Block	Treatment	12-18-09	1-12-10	2-27-10	5-25-10
				---%---	---%---	---%---	---%---
Hugoton	1	111	Cont Ret	98	91	93	82
Hugoton	1	114	Cont Ret	96	90	95	85
Hugoton	2	122	Cont Ret	97	89	94	87
Hugoton	2	123	Cont Ret	97	93	94	83
Hugoton	3	132	Cont Ret	98	95	94	66
Hugoton	3	134	Cont Ret	98	89	89	83
Hugoton	4	141	Cont Ret	97	83	89	84
Hugoton	4	143	Cont Ret	100	90	96	91
Hugoton	1	112	Alt Rem	96	85	82	81
Hugoton	2	124	Alt Rem	98	80	90	94
Hugoton	3	133	Alt Rem	95	87	82	79
Hugoton	4	144	Alt Rem	97	85	91	95
Hugoton	1	112	Cont Rem	74	86	67	15
Hugoton	2	124	Cont Rem	81	86	71	22
Hugoton	3	133	Cont Rem	69	86	66	17
Hugoton	4	144	Cont Rem	81	90	70	24
Bigbow	1	211	Cont Ret	99	96	97	97
Bigbow	1	214	Cont Ret	97	96	90	89
Bigbow	2	222	Cont Ret	95	88	95	83
Bigbow	2	223	Cont Ret	98	88	96	87
Bigbow	3	232	Cont Ret	98	87	89	93
Bigbow	3	234	Cont Ret	96	85	90	85
Bigbow	4	241	Cont Ret	97	95	90	91
Bigbow	4	243	Cont Ret	97	94	91	85
Bigbow	1	212	Alt Rem	99	96	96	92
Bigbow	2	224	Alt Rem	91	83	86	69
Bigbow	3	233	Alt Rem	94	85	84	76
Bigbow	4	244	Alt Rem	90	79	89	76
Bigbow	1	212	Cont Rem	61	91	70	50
Bigbow	2	224	Cont Rem	63	91	77	66
Bigbow	3	233	Cont Rem	67	92	75	52
Bigbow	4	244	Cont Rem	64	83	81	32

Table D.5 Grain and residue yield data collected 18 Sep. 2009 and 5 Oct. 2010 at Hugoton L and Bigbow FSL sites.

Grain and Residue Yield 2009 and 2010 at Hugoton L and Bigbow FSL						
Field	Date	Plot	Block	Treatment	Grain Yield	Residue Yield
					--Mg ha^{-1}--	--Mg ha^{-1}--
hugoton	9-18-2009	112	1	rem	7.91	6.90
hugoton	9-18-2009	113	1	rem	15.16	13.76
hugoton	9-18-2009	121	2	rem	14.18	7.11
hugoton	9-18-2009	124	2	rem	13.18	8.91
hugoton	9-18-2009	131	3	rem	11.26	9.45
hugoton	9-18-2009	133	3	rem	13.76	17.17
hugoton	9-18-2009	142	4	rem	16.98	6.87
hugoton	9-18-2009	144	4	rem	13.21	10.85
hugoton	9-18-2009	111	1	ret	13.53	6.73
hugoton	9-18-2009	114	1	ret	15.65	9.07
hugoton	9-18-2009	122	2	ret	14.20	13.47
hugoton	9-18-2009	123	2	ret	11.30	6.64
hugoton	9-18-2009	132	3	ret	15.68	7.44
hugoton	9-18-2009	134	3	ret	13.27	10.83
hugoton	9-18-2009	141	4	ret	12.51	12.65
hugoton	9-18-2009	143	4	ret	12.24	15.61
bigbow	9-18-2009	212	1	rem	12.91	8.44
bigbow	9-18-2009	213	1	rem	12.57	9.76
bigbow	9-18-2009	221	2	rem	9.80	13.02
bigbow	9-18-2009	224	2	rem	13.64	11.47
bigbow	9-18-2009	231	3	rem	13.30	8.28
bigbow	9-18-2009	233	3	rem	14.58	12.05
bigbow	9-18-2009	242	4	rem	11.51	7.93
bigbow	9-18-2009	244	4	rem	14.20	7.37
bigbow	9-18-2009	211	1	ret	14.15	11.37
bigbow	9-18-2009	214	1	ret	14.05	10.69
bigbow	9-18-2009	222	2	ret	13.02	6.96
bigbow	9-18-2009	223	2	ret	14.30	9.14
bigbow	9-18-2009	232	3	ret	15.43	11.46
bigbow	9-18-2009	234	3	ret	13.64	10.02
bigbow	9-18-2009	241	4	ret	13.07	9.24
bigbow	9-18-2009	243	4	ret	10.63	8.61
hugoton	10-5-2010	112	1	alt_rem	12.58	7.16
hugoton	10-5-2010	124	2	alt_rem	12.71	9.68
hugoton	10-5-2010	133	3	alt_rem	12.17	6.51

hugoton	10-5-2010	144	4	alt_rem	12.15	7.22
hugoton	10-5-2010	111	1	cont_ret	14.50	9.12
hugoton	10-5-2010	114	1	cont_ret	11.77	8.56
hugoton	10-5-2010	122	2	cont_ret	11.75	8.45
hugoton	10-5-2010	123	2	cont_ret	13.81	8.56
hugoton	10-5-2010	132	3	cont_ret	13.96	10.32
hugoton	10-5-2010	134	3	cont_ret	12.99	8.39
hugoton	10-5-2010	141	4	cont_ret	11.80	8.97
hugoton	10-5-2010	143	4	cont_ret	13.23	8.40
hugoton	10-5-2010	113	1	cont_rem	14.12	9.37
hugoton	10-5-2010	121	2	cont_rem	13.58	8.45
hugoton	10-5-2010	131	3	cont_rem	11.07	6.50
hugoton	10-5-2010	142	4	cont_rem	13.22	7.96
bigbow	10-5-2010	212	1	alt_rem	0.20	0.60
bigbow	10-5-2010	224	2	alt_rem	0.34	0.66
bigbow	10-5-2010	233	3	alt_rem	0.25	0.46
bigbow	10-5-2010	244	4	alt_rem	0.21	0.60
bigbow	10-5-2010	211	1	cont_ret	0.62	0.77
bigbow	10-5-2010	214	1	cont_ret	0.28	0.54
bigbow	10-5-2010	222	2	cont_ret	0.57	0.65
bigbow	10-5-2010	223	2	cont_ret	0.45	0.67
bigbow	10-5-2010	232	3	cont_ret	0.19	0.58
bigbow	10-5-2010	234	3	cont_ret	0.01	0.48
bigbow	10-5-2010	241	4	cont_ret	0.58	0.70
bigbow	10-5-2010	243	4	cont_ret	0.43	0.64
bigbow	10-5-2010	213	1	cont_rem	0.35	0.67
bigbow	10-5-2010	221	2	cont_rem	0.56	0.61
bigbow	10-5-2010	231	3	cont_rem	--	--
bigbow	10-5-2010	242	4	cont_rem	0.44	0.68

Appendix E - Chapter 3 Raw Data

Table E.1 Bulk density, gravimetric water content and volumetric water content data from depth increments of 0-5, 5-10, and 10-15 cm. Samples collected 8 Nov. 2008; 18 Nov. 2009; and 9 Nov. 2010.

Bulk Density, Gravimetric, and Volumetric Water Data

					2008			2009			2010		
Field	Plot	Block	Treatment 2008-2009 (2010)	Depth (cm)	Bulk Density	Gravimetric Water Content	Volumetric Water Content	Bulk Density	Gravimetric Water Content	Volumetric Water Content	Bulk Density	Gravimetric Water Content	Volumetric Water Content
					(g/cm^3)	(g/g)	(cm^3/cm^3)	(g/cm^3)	(g/g)	(cm^3/cm^3)	(g/cm^3)	(g/g)	(cm^3/cm^3)
Hugoton	111	1	Retained	0--5	1.35	0.22	0.30	1.03	0.34	0.36	1.29	0.11	0.14
Hugoton	111	1	Retained	5--10	1.52	0.23	0.34	1.42	0.27	0.39	1.54	0.17	0.26
Hugoton	111	1	Retained	10--15	1.46	0.20	0.29	1.59	0.24	0.38	1.52	0.17	0.25
Hugoton	112	1	Removed (Alt Rem)	0--5	1.13	0.18	0.20	1.24	0.29	0.36	1.23	0.07	0.08
Hugoton	112	1	Removed (Alt Rem)	5--10	1.37	0.22	0.30	1.38	0.26	0.35	1.53	0.14	0.21
Hugoton	112	1	Removed (Alt Rem)	10--15	1.54	0.22	0.34	1.58	0.24	0.37	1.51	0.15	0.23
Hugoton	113	1	Removed	0--5	1.34	0.16	0.22	1.21	0.29	0.35	1.42	0.06	0.09
Hugoton	113	1	Removed	5--10	1.40	0.22	0.30	1.57	0.24	0.38	1.36	0.11	0.15
Hugoton	113	1	Removed	10--15	1.57	0.22	0.35	1.67	0.22	0.37	1.54	0.13	0.21
Hugoton	114	1	Retained	0--5	1.17	0.21	0.24	1.34	0.30	0.40	1.46	0.08	0.11
Hugoton	114	1	Retained	5--10	1.53	0.22	0.34	1.60	0.25	0.40	1.44	0.14	0.20
Hugoton	114	1	Retained	10--15	1.57	0.23	0.36	1.66	0.26	0.44	1.51	0.17	0.25
Hugoton	121	2	Removed	0--5	1.27	0.19	0.24	1.33	0.19	0.26	1.22	0.07	0.08
Hugoton	121	2	Removed	5--10	1.45	0.22	0.31	1.41	0.27	0.39	1.50	0.14	0.20

Hugoton	121	2	Removed	10--15	1.49	0.23	0.35	1.64	0.24	0.39	1.46	0.18	0.26
Hugoton	122	2	Retained	0--5	1.16	0.18	0.21	1.09	0.32	0.35	0.82	0.09	0.11
Hugoton	122	2	Retained	5--10	1.32	0.23	0.30	1.48	0.26	0.38	1.47	0.14	0.21
Hugoton	122	2	Retained	10--15	1.57	0.22	0.35	1.64	0.23	0.38	1.49	0.16	0.24
Hugoton	123	2	Retained	0--5	1.16	0.20	0.23	1.11	0.34	0.38	1.27	0.07	0.09
Hugoton	123	2	Retained	5--10	1.48	0.23	0.33	1.44	0.27	0.39	1.54	0.14	0.21
Hugoton	123	2	Retained	10--15	1.63	0.23	0.37	1.69	0.24	0.40	1.59	0.16	0.25
Hugoton	124	2	Removed (Alt Rem)	0--5	1.18	0.16	0.19	0.94	0.31	0.29	1.12	0.11	0.13
Hugoton	124	2	Removed (Alt Rem)	5--10	1.49	0.23	0.34	1.32	0.29	0.39	1.56	0.15	0.24
Hugoton	124	2	Removed (Alt Rem)	10--15	1.59	0.23	0.37	1.62	0.25	0.41	1.56	0.18	0.27
Hugoton	131	3	Removed	0--5	1.41	0.17	0.24	1.22	0.30	0.37	1.38	0.05	0.07
Hugoton	131	3	Removed	5--10	1.60	0.20	0.32	1.52	0.24	0.36	1.59	0.11	0.17
Hugoton	131	3	Removed	10--15	1.63	0.19	0.31	1.64	0.23	0.37	1.52	0.14	0.21
Hugoton	132	3	Retained	0--5	1.11	0.20	0.23	1.22	0.30	0.37	1.26	0.07	0.09
Hugoton	132	3	Retained	5--10	1.43	0.22	0.31	1.50	0.24	0.37	1.52	0.13	0.19
Hugoton	132	3	Retained	10--15	1.43	0.22	0.31	1.64	0.21	0.35	1.55	0.15	0.23
Hugoton	133	3	Removed (Alt Rem)	0--5	1.29	0.13	0.17	1.49	0.26	0.31	1.45	0.08	0.10
Hugoton	133	3	Removed (Alt Rem)	5--10	1.52	0.20	0.30	1.87	0.23	0.34	1.73	0.12	0.18
Hugoton	133	3	Removed (Alt Rem)	10--15	1.58	0.20	0.32	1.97	0.21	0.34	1.79	0.13	0.21
Hugoton	134	3	Retained	0--5	1.21	0.18	0.22	1.29	0.28	0.36	1.36	0.06	0.08
Hugoton	134	3	Retained	5--10	1.50	0.20	0.30	1.60	0.23	0.37	1.59	0.04	0.06
Hugoton	134	3	Retained	10--15	1.68	0.20	0.34	1.63	0.22	0.36	1.60	0.13	0.20
Hugoton	141	4	Retained	0--5	1.27	0.16	0.20	1.00	0.35	0.35	1.53	0.13	0.20
Hugoton	141	4	Retained	5--10	1.30	0.20	0.26	1.49	0.26	0.39	1.37	0.11	0.15

Hugoton	141	4	Retained	10--15	1.63	0.21	0.34	1.67	0.23	0.39	1.42	0.13	0.18
Hugoton	142	4	Removed	0--5	1.31	0.18	0.24	1.21	0.31	0.37	1.30	0.07	0.09
Hugoton	142	4	Removed	5--10	1.38	0.22	0.30	1.56	0.25	0.39	1.62	0.13	0.21
Hugoton	142	4	Removed	10--15	1.54	0.22	0.34	1.67	0.24	0.39	1.73	0.15	0.26
Hugoton	143	4	Retained	0--5	1.46	0.20	0.29	0.99	0.32	0.31	1.20	0.09	0.11
Hugoton	143	4	Retained	5--10	1.56	0.21	0.33	1.42	0.28	0.40	1.55	0.15	0.23
Hugoton	143	4	Retained	10--15	1.61	0.21	0.33	1.66	0.24	0.40	1.58	0.16	0.26
Hugoton	144	4	Removed (Alt Rem)	0--5	1.25	0.16	0.20	1.09	0.34	0.37	1.31	0.11	0.15
Hugoton	144	4	Removed (Alt Rem)	5--10	1.51	0.23	0.35	1.41	0.29	0.40	1.43	0.14	0.20
Hugoton	144	4	Removed (Alt Rem)	10--15	1.53	0.23	0.35	1.60	0.26	0.41	1.37	0.13	0.18
Bigbow	211	1	Retained	0--5	1.73	0.12	0.21	1.69	0.16	0.27	1.41	0.03	0.04
Bigbow	211	1	Retained	5--10	1.64	0.13	0.21	1.14	0.23	0.27	1.55	0.05	0.07
Bigbow	211	1	Retained	10--15	1.82	0.13	0.24	1.44	0.19	0.27	1.66	0.05	0.08
Bigbow	212	1	Removed (Alt Rem)	0--5	1.38	0.12	0.17	1.59	0.19	0.31	1.46	0.02	0.03
Bigbow	212	1	Removed (Alt Rem)	5--10	1.71	0.13	0.22	1.66	0.15	0.25	1.51	0.03	0.05
Bigbow	212	1	Removed (Alt Rem)	10--15	1.81	0.09	0.17	1.77	0.12	0.22	1.67	0.04	0.07
Bigbow	213	1	Removed	0--5	1.36	0.10	0.13	1.33	0.19	0.25	1.62	0.02	0.04
Bigbow	213	1	Removed	5--10	1.74	0.12	0.21	1.55	0.15	0.24	1.59	0.03	0.05
Bigbow	213	1	Removed	10--15	1.78	0.10	0.18	1.77	0.12	0.21	1.88	0.04	0.07
Bigbow	214	1	Retained	0--5	1.78	0.10	0.18	1.85	0.12	0.21	1.45	0.03	0.04
Bigbow	214	1	Retained	5--10	1.47	0.17	0.24	1.42	0.24	0.34	1.50	0.04	0.06
Bigbow	214	1	Retained	10--15	1.31	0.35	0.46	1.73	0.15	0.26	1.73	0.04	0.07
Bigbow	221	2	Removed	0--5	1.30	0.13	0.17	1.41	0.27	0.39	1.39	0.02	0.03
Bigbow	221	2	Removed	5--10	1.68	0.13	0.22	1.53	0.10	0.16	1.54	0.03	0.05

Bigbow	221	2	Removed	10--15	1.87	0.10	0.19	1.79	0.02	0.04	1.65	0.03	0.06
Bigbow	222	2	Retained	0--5	1.41	0.45	0.63	1.81	0.11	0.19	1.42	0.02	0.03
Bigbow	222	2	Retained	5--10	1.25	0.46	0.58	1.32	0.15	0.19	1.62	0.03	0.05
Bigbow	222	2	Retained	10--15	1.36	0.39	0.53	1.52	0.14	0.21	1.62	0.03	0.06
Bigbow	223	2	Retained	0--5	1.75	0.12	0.21	1.84	0.11	0.20	1.37	0.02	0.03
Bigbow	223	2	Retained	5--10	1.39	0.17	0.24	1.40	0.19	0.26	1.62	0.03	0.05
Bigbow	223	2	Retained	10--15	1.57	0.14	0.22	1.50	0.19	0.29	1.76	0.04	0.06
Bigbow	224	2	Removed (Alt Rem)	0--5	1.56	0.09	0.14	1.23	0.15	0.19	1.44	0.02	0.02
Bigbow	224	2	Removed (Alt Rem)	5--10	1.78	0.09	0.16	1.61	0.14	0.22	1.64	0.02	0.03
Bigbow	224	2	Removed (Alt Rem)	10--15	1.78	0.08	0.14	1.79	0.10	0.18	1.65	0.03	0.04
Bigbow	231	3	Removed	0--5	1.53	0.11	0.18	1.43	0.23	0.33	1.32	0.03	0.04
Bigbow	231	3	Removed	5--10	1.61	0.12	0.19	1.66	0.17	0.29	1.64	0.04	0.07
Bigbow	231	3	Removed	10--15	1.88	0.10	0.19	1.80	0.13	0.23	1.74	0.04	0.08
Bigbow	232	3	Retained	0--5	1.67	0.13	0.21	1.84	0.13	0.24	1.40	0.03	0.04
Bigbow	232	3	Retained	5--10	1.31	0.18	0.24	1.31	0.28	0.37	1.60	0.04	0.07
Bigbow	232	3	Retained	10--15	1.50	0.16	0.25	1.44	0.19	0.27	1.80	0.04	0.08
Bigbow	233	3	Removed (Alt Rem)	0--5	1.46	0.12	0.18	1.30	0.18	0.23	1.43	0.02	0.03
Bigbow	233	3	Removed (Alt Rem)	5--10	1.58	0.13	0.21	1.54	0.20	0.31	1.49	0.03	0.05
Bigbow	233	3	Removed (Alt Rem)	10--15	1.83	0.10	0.18	1.75	0.12	0.21	1.93	0.03	0.06
Bigbow	234	3	Retained	0--5	1.86	0.09	0.16	1.69	0.12	0.20	1.41	0.02	0.03
Bigbow	234	3	Retained	5--10	1.44	0.10	0.14	1.33	0.18	0.24	1.40	0.04	0.05
Bigbow	234	3	Retained	10--15	1.53	0.11	0.17	1.55	0.17	0.26	1.80	0.04	0.07
Bigbow	241	4	Retained	0--5	1.76	0.10	0.18	1.76	0.11	0.19	1.45	0.02	0.03
Bigbow	241	4	Retained	5--10	1.55	0.12	0.19	1.53	0.18	0.27	1.47	0.03	0.04

Bigbow	241	4	Retained	10--15	1.66	0.14	0.23	1.60	0.15	0.24	1.61	0.03	0.06
Bigbow	242	4	Removed	0--5	1.48	0.14	0.20	1.50	0.17	0.25	1.42	0.02	0.03
Bigbow	242	4	Removed	5--10	1.73	0.13	0.22	1.67	0.13	0.22	1.53	0.03	0.04
Bigbow	242	4	Removed	10--15	1.76	0.10	0.18	1.76	0.11	0.19	1.77	0.03	0.05
Bigbow	243	4	Retained	0--5	1.83	0.08	0.15	1.76	0.11	0.20	1.51	0.02	0.03
Bigbow	243	4	Retained	5--10	1.49	0.10	0.15	1.31	0.17	0.22	1.52	0.03	0.05
Bigbow	243	4	Retained	10--15	1.67	0.11	0.19	1.64	0.13	0.22	1.80	0.03	0.06
Bigbow	244	4	Removed (Alt Rem)	0--5	1.56	0.12	0.19	1.52	0.12	0.18	1.47	0.02	0.02
Bigbow	244	4	Removed (Alt Rem)	5--10	1.75	0.12	0.21	1.79	0.10	0.19	1.54	0.02	0.03
Bigbow	244	4	Removed (Alt Rem)	10--15	1.80	0.10	0.17	1.81	0.10	0.18	1.73	0.03	0.05

Table E.2 Soil chemical properties data from Hugoton L and Bigbow FSL sites. Samples collected on 8 Nov. 2008; 18 Nov. 2009; and 9 Nov. 2010.

Soil Chemical Properties Data from Hugoton L and Bigbow FSL										
Field	Year	Plot	Block	Depth	Treatment	pH	Mehlich3-P	K	Total N %	Total C %
						(1:1)	p-ppm	k-ppm	$g\ g^{-1}$	$g\ g^{-1}$
Hugoton	2008	111	1	0--5	ret	7.7	52	938	0.17	1.56
Hugoton	2008	112	1	0--5	rem	7.9	66	852	0.18	1.77
Hugoton	2008	113	1	0--5	rem	7.9	24	790	0.15	1.59
Hugoton	2008	114	1	0--5	ret	8.1	74	898	0.14	1.57
Hugoton	2008	121	2	0--5	rem	8.1	66	744	0.16	1.90
Hugoton	2008	122	2	0--5	ret	8.2	25	793	0.16	1.91
Hugoton	2008	123	2	0--5	ret	7.8	19	668	0.16	1.67
Hugoton	2008	124	2	0--5	rem	8.0	39	705	0.15	1.74
Hugoton	2008	131	3	0--5	rem	7.9	52	560	0.13	1.46
Hugoton	2008	132	3	0--5	ret	8.1	49	735	0.12	1.46
Hugoton	2008	133	3	0--5	rem	8.1	58	673	0.18	1.64
Hugoton	2008	134	3	0--5	ret	7.8	49	965	0.14	1.77
Hugoton	2008	141	4	0--5	ret	8.0	67	979	0.13	1.76
Hugoton	2008	142	4	0--5	rem	8.2	102	570	0.07	1.36
Hugoton	2008	143	4	0--5	ret	7.9	35	820	0.18	2.11
Hugoton	2008	144	4	0--5	rem	8.2	28	853	0.14	1.78
Hugoton	2008	111	1	5--10	ret	7.9	62	629	0.13	0.99
Hugoton	2008	112	1	5--10	rem	7.8	66	571	0.11	0.99
Hugoton	2008	113	1	5--10	rem	7.8	28	600	0.13	1.21
Hugoton	2008	114	1	5--10	ret	8.1	66	620	0.13	1.34
Hugoton	2008	121	2	5--10	rem	8.0	55	578	0.12	1.29
Hugoton	2008	122	2	5--10	ret	7.9	21	575	0.14	1.52
Hugoton	2008	123	2	5--10	ret	8.2	31	692	0.12	1.39

Hugoton	2008	124	2	5--10	rem	8.3	26	575	0.12	1.33
Hugoton	2008	131	3	5--10	rem	8.0	24	560	0.10	1.13
Hugoton	2008	132	3	5--10	ret	7.9	46	679	0.12	1.28
Hugoton	2008	133	3	5--10	rem	7.9	54	665	0.18	1.27
Hugoton	2008	134	3	5--10	ret	7.7	34	697	0.08	1.22
Hugoton	2008	141	4	5--10	ret	8.1	52	608	0.20	1.52
Hugoton	2008	142	4	5--10	rem	8.1	85	850	0.13	1.87
Hugoton	2008	143	4	5--10	ret	8.1	24	556	0.08	1.47
Hugoton	2008	144	4	5--10	rem	8.1	24	540	0.18	1.32
Hugoton	2008	111	1	10--15	ret	7.5	11	448	0.09	0.73
Hugoton	2008	112	1	10--15	rem	7.1	15	401	0.09	0.76
Hugoton	2008	113	1	10--15	rem	7.2	24	418	0.08	0.76
Hugoton	2008	114	1	10--15	ret	8.1	32	470	0.10	1.09
Hugoton	2008	121	2	10--15	rem	8.1	38	444	0.10	1.11
Hugoton	2008	122	2	10--15	ret	7.9	16	462	0.09	1.12
Hugoton	2008	123	2	10--15	ret	7.9	15	497	0.10	0.97
Hugoton	2008	124	2	10--15	rem	7.9	11	510	0.09	0.92
Hugoton	2008	131	3	10--15	rem	8.1	190	409	0.07	0.79
Hugoton	2008	132	3	10--15	ret	8.0	24	562	0.10	0.96
Hugoton	2008	133	3	10--15	rem	8.0	49	540	0.11	1.00
Hugoton	2008	134	3	10--15	ret	8.1	23	558	0.07	1.14
Hugoton	2008	141	4	10--15	ret	8.1	47	506	0.19	1.05
Hugoton	2008	142	4	10--15	rem	8.1	53	467	0.11	1.14
Hugoton	2008	143	4	10--15	ret	8.1	21	474	0.06	1.23
Hugoton	2008	144	4	10--15	rem	8.2	9	407	0.12	1.26
Hugoton	2008	111	1	15--30	ret	7.9	10	364	0.10	0.69
Hugoton	2008	112	1	15--30	rem	8.1	6	340	0.09	1.01
Hugoton	2008	113	1	15--30	rem	8.0	6	362	0.08	0.83
Hugoton	2008	114	1	15--30	ret	8.0	27	419	0.08	1.31
Hugoton	2008	121	2	15--30	rem	8.1	15	327	0.08	1.55

Hugoton	2008	122	2	15--30	ret	8.2	7	311	0.08	1.30
Hugoton	2008	123	2	15--30	ret	8.2	4	336	0.06	0.95
Hugoton	2008	124	2	15--30	rem	8.3	6	349	0.06	1.32
Hugoton	2008	131	3	15--30	rem	7.9	9	376	0.06	0.70
Hugoton	2008	132	3	15--30	ret	7.9	8	480	0.07	1.13
Hugoton	2008	133	3	15--30	rem	7.7	12	450	0.11	1.48
Hugoton	2008	134	3	15--30	ret	8.1	8	411	0.14	1.60
Hugoton	2008	141	4	15--30	ret	8.0	20	390	0.04	1.72
Hugoton	2008	142	4	15--30	rem	8.1	24	348	0.10	1.35
Hugoton	2008	143	4	15--30	ret	8.2	13	418	0.14	1.06
Hugoton	2008	144	4	15--30	rem	7.7	6	338	0.10	1.35
Bigbow	2008	211	1	0--5	ret	7.4	50	410	0.15	1.54
Bigbow	2008	212	1	0--5	rem	7.7	72	451	0.13	1.23
Bigbow	2008	213	1	0--5	rem	7.5	43	477	0.14	1.53
Bigbow	2008	214	1	0--5	ret	7.1	35	451	0.19	2.01
Bigbow	2008	221	2	0--5	rem	7.5	56	424	0.15	1.49
Bigbow	2008	222	2	0--5	ret	7.7	64	556	0.12	1.16
Bigbow	2008	223	2	0--5	ret	7.7	93	316	0.12	0.86
Bigbow	2008	224	2	0--5	rem	7.7	95	313	0.12	0.94
Bigbow	2008	231	3	0--5	rem	7.6	49	474	0.18	1.42
Bigbow	2008	232	3	0--5	ret	7.5	49	486	0.16	1.38
Bigbow	2008	233	3	0--5	rem	7.4	46	406	0.14	1.05
Bigbow	2008	234	3	0--5	ret	7.5	39	365	0.15	1.40
Bigbow	2008	241	4	0--5	ret	7.3	66	425	0.15	1.34
Bigbow	2008	242	4	0--5	rem	7.4	49	399	0.13	1.17
Bigbow	2008	243	4	0--5	ret	7.4	120	319	0.13	1.16
Bigbow	2008	244	4	0--5	rem	7.3	47	392	0.12	1.43
Bigbow	2008	211	1	5--10	ret	7.6	40	357	0.14	1.20
Bigbow	2008	212	1	5--10	rem	7.4	42	322	0.09	0.73
Bigbow	2008	213	1	5--10	rem	7.2	27	346	0.15	1.48

Bigbow	2008	214	1	5--10	ret	7.7	27	332	0.06	0.60
Bigbow	2008	221	2	5--10	rem	7.8	35	400	0.09	0.95
Bigbow	2008	222	2	5--10	ret	7.8	55	400	0.13	0.93
Bigbow	2008	223	2	5--10	ret	7.4	142	312	0.15	1.11
Bigbow	2008	224	2	5--10	rem	7.8	76	261	0.08	0.62
Bigbow	2008	231	3	5--10	rem	7.7	41	347	0.10	0.74
Bigbow	2008	232	3	5--10	ret	7.6	41	309	0.12	1.00
Bigbow	2008	233	3	5--10	rem	7.4	44	316	0.12	0.94
Bigbow	2008	234	3	5--10	ret	7.3	41	315	0.12	0.93
Bigbow	2008	241	4	5--10	ret	7.2	81	360	0.13	1.07
Bigbow	2008	242	4	5--10	rem	7.5	47	308	0.08	0.65
Bigbow	2008	243	4	5--10	ret	7.8	68	229	0.06	0.45
Bigbow	2008	244	4	5--10	rem	7.4	35	284	0.12	1.12
Bigbow	2008	211	1	10--15	ret	8.0	32	311	0.06	0.47
Bigbow	2008	212	1	10--15	rem	8.0	33	275	0.02	0.31
Bigbow	2008	213	1	10--15	rem	7.8	23	279	0.05	0.46
Bigbow	2008	214	1	10--15	ret	7.6	27	307	0.02	0.24
Bigbow	2008	221	2	10--15	rem	8.0	33	294	0.04	0.45
Bigbow	2008	222	2	10--15	ret	8.0	36	316	0.06	0.44
Bigbow	2008	223	2	10--15	ret	8.0	69	222	0.04	0.37
Bigbow	2008	224	2	10--15	rem	8.2	57	258	0.05	0.26
Bigbow	2008	231	3	10--15	rem	7.7	36	341	0.08	0.58
Bigbow	2008	232	3	10--15	ret	7.8	30	252	0.05	0.31
Bigbow	2008	233	3	10--15	rem	7.8	37	274	0.05	0.37
Bigbow	2008	234	3	10--15	ret	8.1	39	264	0.06	0.39
Bigbow	2008	241	4	10--15	ret	7.6	57	311	0.07	0.52
Bigbow	2008	242	4	10--15	rem	8.2	31	291	0.03	0.23
Bigbow	2008	243	4	10--15	ret	7.8	56	209	0.04	0.25
Bigbow	2008	244	4	10--15	rem	7.9	45	193	0.03	0.25
Bigbow	2008	211	1	15--30	ret	8.1	21	240	0.03	0.26

Bigbow	2008	212	1	15--30	rem	8.2	11	299	0.03	0.30
Bigbow	2008	213	1	15--30	rem	8.3	14	276	0.03	0.28
Bigbow	2008	214	1	15--30	ret	8.4	17	344	0.02	0.27
Bigbow	2008	221	2	15--30	rem	8.4	18	245	0.01	0.18
Bigbow	2008	222	2	15--30	ret	8.2	30	233	0.03	0.20
Bigbow	2008	223	2	15--30	ret	8.2	35	175	0.03	0.13
Bigbow	2008	224	2	15--30	rem	8.3	46	245	0.03	0.17
Bigbow	2008	231	3	15--30	rem	8.4	13	433	0.04	0.28
Bigbow	2008	232	3	15--30	ret	8.3	22	300	0.04	0.22
Bigbow	2008	233	3	15--30	rem	8.1	35	268	0.04	0.19
Bigbow	2008	234	3	15--30	ret	8.2	29	205	0.02	0.12
Bigbow	2008	241	4	15--30	ret	8.1	27	241	0.02	0.19
Bigbow	2008	242	4	15--30	rem	8.3	22	212	0.02	0.12
Bigbow	2008	243	4	15--30	ret	8.1	44	225	0.02	0.15
Bigbow	2008	244	4	15--30	rem	8.2	33	217	0.03	0.15
Hugoton	2009	111	1	0--5	ret	7.6	65.8	800	0.21	2.12
Hugoton	2009	112	1	0--5	rem	7.8	25.1	720	0.16	1.25
Hugoton	2009	113	1	0--5	rem	8.1	24.9	755	0.20	1.76
Hugoton	2009	114	1	0--5	ret	8.0	67	745	0.19	2.04
Hugoton	2009	121	2	0--5	rem	8.4	71.7	638	0.20	2.18
Hugoton	2009	122	2	0--5	ret	8.5	30.2	675	0.19	2.03
Hugoton	2009	123	2	0--5	ret	8.1	4.68	379	0.11	0.83
Hugoton	2009	124	2	0--5	rem	8.1	5.07	430	0.10	0.90
Hugoton	2009	131	3	0--5	rem	8.3	49	780	0.18	1.74
Hugoton	2009	132	3	0--5	ret	8.2	68.3	754	0.20	2.32
Hugoton	2009	133	3	0--5	rem	8.4	80.9	685	0.17	1.62
Hugoton	2009	134	3	0--5	ret	8.1	61.5	619	0.17	1.74
Hugoton	2009	141	4	0--5	ret	8.2	57.5	643	0.19	2.22
Hugoton	2009	142	4	0--5	rem	8.1	72.2	675	0.18	2.25
Hugoton	2009	143	4	0--5	ret	8.0	46.6	614	0.17	2.11

Hugoton	2009	144	4	0--5	rem	8.3	47.7	660	0.17	1.83
Hugoton	2009	111	1	5--10	ret	7.7	60.9	590	0.18	1.35
Hugoton	2009	112	1	5--10	rem	8.1	54.4	672	0.16	1.26
Hugoton	2009	113	1	5--10	rem	8.3	51.1	634	0.15	1.22
Hugoton	2009	114	1	5--10	ret	8.2	55.5	679	0.16	1.55
Hugoton	2009	121	2	5--10	rem	8.2	58.3	671	0.18	2.02
Hugoton	2009	122	2	5--10	ret	8.3	27.5	608	0.17	1.60
Hugoton	2009	123	2	5--10	ret	8.3	13.5	504	0.14	1.09
Hugoton	2009	124	2	5--10	rem	8.3	14	600	0.13	1.02
Hugoton	2009	131	3	5--10	rem	8.5	41.2	745	0.18	1.18
Hugoton	2009	132	3	5--10	ret	8.2	67.7	669	0.19	1.96
Hugoton	2009	133	3	5--10	rem	8.3	62.5	651	0.15	1.20
Hugoton	2009	134	3	5--10	ret	7.7	57.3	718	0.16	1.51
Hugoton	2009	141	4	5--10	ret	8.2	63.2	735	0.15	1.62
Hugoton	2009	142	4	5--10	rem	8.3	66.4	653	0.17	1.83
Hugoton	2009	143	4	5--10	ret	8.2	36	659	0.16	1.85
Hugoton	2009	144	4	5--10	rem	8.2	34.1	598	0.15	1.36
Hugoton	2009	111	1	10--15	ret	7.3	17.3	478	0.14	0.79
Hugoton	2009	112	1	10--15	rem	7.8	26.1	551	0.12	0.69
Hugoton	2009	113	1	10--15	rem	7.9	19.3	523	0.15	0.99
Hugoton	2009	114	1	10--15	ret	8.2	56.5	610	0.14	1.24
Hugoton	2009	121	2	10--15	rem	8.5	49.4	492	0.14	1.22
Hugoton	2009	122	2	10--15	ret	8.2	22.5	559	0.15	1.19
Hugoton	2009	123	2	10--15	ret	8.3	23.5	634	0.17	1.54
Hugoton	2009	124	2	10--15	rem	8.2	25.9	619	0.16	1.45
Hugoton	2009	131	3	10--15	rem	8.2	33.2	633	0.14	0.93
Hugoton	2009	132	3	10--15	ret	8.3	77.8	621	0.15	1.19
Hugoton	2009	133	3	10--15	rem	8.4	52.5	590	0.14	1.04
Hugoton	2009	134	3	10--15	ret	8.2	43.9	597	0.13	1.10
Hugoton	2009	141	4	10--15	ret	8.2	44.1	622	0.13	1.23

Hugoton	2009	142	4	10--15	rem	8.2	41.8	576	0.13	1.27
Hugoton	2009	143	4	10--15	ret	8.2	29.7	554	0.13	1.40
Hugoton	2009	144	4	10--15	rem	8.3	20	493	0.14	1.26
Hugoton	2009	111	1	15--30	ret	8.2	7.36	341	0.11	0.74
Hugoton	2009	112	1	15--30	rem	8.2	5.16	361	0.11	0.69
Hugoton	2009	113	1	15--30	rem	7.9	37.1	416	0.12	0.62
Hugoton	2009	114	1	15--30	ret	8.2	29.5	468	0.12	1.12
Hugoton	2009	121	2	15--30	rem	8.2	21	388	0.11	1.03
Hugoton	2009	122	2	15--30	ret	8.2	8.01	405	0.12	1.05
Hugoton	2009	123	2	15--30	ret	8.4	29.7	705	0.20	2.17
Hugoton	2009	124	2	15--30	rem	8.4	30.7	691	0.17	1.71
Hugoton	2009	131	3	15--30	rem	8.1	10.4	455	0.11	1.33
Hugoton	2009	132	3	15--30	ret	8.2	14.8	511	0.16	1.18
Hugoton	2009	133	3	15--30	rem	8.3	29.2	497	0.11	1.09
Hugoton	2009	134	3	15--30	ret	8.2	21.8	457	0.11	1.13
Hugoton	2009	141	4	15--30	ret	8.2	18.9	462	0.11	1.19
Hugoton	2009	142	4	15--30	rem	8.2	21.4	368	0.11	1.25
Hugoton	2009	143	4	15--30	ret	8.2	15.8	390	0.11	1.18
Hugoton	2009	144	4	15--30	rem	8.1	5.76	318	0.11	1.09
Bigbow	2009	211	1	0--5	ret	8.2	54.5	450	0.15	1.12
Bigbow	2009	212	1	0--5	rem	8.0	61.2	459	0.15	1.25
Bigbow	2009	213	1	0--5	rem	8.2	35.7	411	0.12	0.81
Bigbow	2009	214	1	0--5	ret	8.0	48.1	483	0.14	1.20
Bigbow	2009	221	2	0--5	rem	7.7	35.5	359	0.09	0.35
Bigbow	2009	222	2	0--5	ret	7.9	70.0	477	0.19	1.74
Bigbow	2009	223	2	0--5	ret	8.0	91.6	451	0.15	1.49
Bigbow	2009	224	2	0--5	rem	8.1	105.0	368	0.13	0.93
Bigbow	2009	231	3	0--5	rem	8.0	57.5	393	0.10	0.32
Bigbow	2009	232	3	0--5	ret	7.8	59.7	471	0.15	1.15
Bigbow	2009	233	3	0--5	rem	7.9	42.0	451	0.14	0.94

Bigbow	2009	234	3	0--5	ret	8.0	36.1	542	0.13	0.86
Bigbow	2009	241	4	0--5	ret	7.6	82.7	449	0.19	1.71
Bigbow	2009	242	4	0--5	rem	8.0	67.3	462	0.15	1.18
Bigbow	2009	243	4	0--5	ret	7.8	62.3	433	0.19	1.91
Bigbow	2009	244	4	0--5	rem	7.8	114.0	408	0.16	1.14
Bigbow	2009	211	1	5--10	ret	8.0	66.6	376	0.14	0.85
Bigbow	2009	212	1	5--10	rem	7.9	46.4	360	0.12	0.60
Bigbow	2009	213	1	5--10	rem	7.9	59.6	414	0.12	0.86
Bigbow	2009	214	1	5--10	ret	7.8	43.9	403	0.11	0.47
Bigbow	2009	221	2	5--10	rem	8.1	48.1	519	0.11	0.61
Bigbow	2009	222	2	5--10	ret	7.9	98.1	330	0.17	1.31
Bigbow	2009	223	2	5--10	ret	7.7	41.5	300	0.09	0.38
Bigbow	2009	224	2	5--10	rem	7.7	99.9	235	0.14	0.86
Bigbow	2009	231	3	5--10	rem	8.1	70.6	466	0.14	0.96
Bigbow	2009	232	3	5--10	ret	8.0	48.7	343	0.14	0.99
Bigbow	2009	233	3	5--10	rem	7.9	34.3	316	0.13	0.79
Bigbow	2009	234	3	5--10	ret	7.9	57.4	347	0.11	0.54
Bigbow	2009	241	4	5--10	ret	7.5	70.1	291	0.14	1.05
Bigbow	2009	242	4	5--10	rem	7.8	54.5	291	0.15	0.99
Bigbow	2009	243	4	5--10	ret	7.7	46.2	297	0.17	1.38
Bigbow	2009	244	4	5--10	rem	7.9	100.0	265	0.13	0.73
Bigbow	2009	211	1	10--15	ret	8.2	55.8	329	0.10	0.27
Bigbow	2009	212	1	10--15	rem	8.1	45.4	331	0.07	0.03
Bigbow	2009	213	1	10--15	rem	7.9	59.1	314	0.14	0.86
Bigbow	2009	214	1	10--15	ret	7.4	47.6	332	0.06	ND
Bigbow	2009	221	2	10--15	rem	7.8	30.6	284	0.07	0.18
Bigbow	2009	222	2	10--15	ret	7.9	79.4	283	0.10	0.46
Bigbow	2009	223	2	10--15	ret	8.2	40.7	275	0.09	0.07
Bigbow	2009	224	2	10--15	rem	7.7	93.0	234	0.12	0.64
Bigbow	2009	231	3	10--15	rem	8.3	49.6	345	0.07	0.01

Bigbow	2009	232	3	10--15	ret	7.9	59.1	323	0.07	0.05
Bigbow	2009	233	3	10--15	rem	7.8	38.3	341	0.08	0.28
Bigbow	2009	234	3	10--15	ret	7.9	53.5	318	0.11	0.66
Bigbow	2009	241	4	10--15	ret	7.8	52.5	247	0.09	0.28
Bigbow	2009	242	4	10--15	rem	7.8	45.5	294	0.10	0.42
Bigbow	2009	243	4	10--15	ret	7.0	45.8	265	0.14	0.90
Bigbow	2009	244	4	10--15	rem	8.2	53.0	220	0.07	0.00
Bigbow	2009	211	1	15--30	ret	8.2	28.9	240	0.07	--
Bigbow	2009	212	1	15--30	rem	8.3	31.0	350	0.06	--
Bigbow	2009	213	1	15--30	rem	8.2	32.2	320	0.09	--
Bigbow	2009	214	1	15--30	ret	8.5	19.5	364	0.06	--
Bigbow	2009	221	2	15--30	rem	8.4	20.3	299	0.05	--
Bigbow	2009	222	2	15--30	ret	8.3	45.0	273	0.06	--
Bigbow	2009	223	2	15--30	ret	8.2	32.0	250	0.06	--
Bigbow	2009	224	2	15--30	rem	8.4	45.6	201	0.06	--
Bigbow	2009	231	3	15--30	rem	8.6	23.1	413	0.06	--
Bigbow	2009	232	3	15--30	ret	8.4	22.0	276	0.06	--
Bigbow	2009	233	3	15--30	rem	8.4	24.6	293	0.06	--
Bigbow	2009	234	3	15--30	ret	8.0	40.2	219	0.06	--
Bigbow	2009	241	4	15--30	ret	8.1	29.8	221	0.06	--
Bigbow	2009	242	4	15--30	rem	8.4	25.5	208	0.06	--
Bigbow	2009	243	4	15--30	ret	8.2	39.2	269	0.06	--
Bigbow	2009	244	4	15--30	rem	8.3	47.8	183	0.04	--
hugoton	2010	111	1	0-5	cont_ret	7.8	62.6	919	0.19	1.99
hugoton	2010	112	1	0-5	alt_rem	7.9	30.3	670	0.18	1.82
hugoton	2010	113	1	0-5	cont_rem	8.2	72.5	810	0.17	1.70
hugoton	2010	114	1	0-5	cont_ret	8.2	70.1	670	0.20	2.30
hugoton	2010	121	2	0-5	cont_rem	8.3	45.7	710	0.17	1.99
hugoton	2010	122	2	0-5	cont_ret	8.3	19.7	750	0.18	2.25
hugoton	2010	123	2	0-5	cont_ret	8.4	30.0	630	0.16	1.75

hugoton	2010	124	2	0-5	alt_rem	8.4	24.8	640	0.15	1.81
hugoton	2010	131	3	0-5	cont_rem	8.5	21.0	710	0.11	1.28
hugoton	2010	132	3	0-5	cont_ret	8.2	58.3	920	0.20	2.04
hugoton	2010	133	3	0-5	alt_rem	8.4	28.1	900	0.16	1.69
hugoton	2010	134	3	0-5	cont_ret	8.4	30.5	740	0.13	1.28
hugoton	2010	141	4	0-5	cont_ret	8.3	67.7	930	0.15	1.82
hugoton	2010	142	4	0-5	cont_rem	8.2	58.2	840	0.20	2.24
hugoton	2010	143	4	0-5	cont_ret	8.3	33.5	760	0.16	1.94
hugoton	2010	144	4	0-5	alt_rem	8.3	26.9	720	0.17	2.14
hugoton	2010	111	1	5-10	cont_ret	7.8	46.7	590	0.13	1.20
hugoton	2010	112	1	5-10	alt_rem	7.8	12.3	590	0.12	1.00
hugoton	2010	113	1	5-10	cont_rem	8.2	58.0	630	0.13	1.22
hugoton	2010	114	1	5-10	cont_ret	8.4	63.7	650	0.16	1.68
hugoton	2010	121	2	5-10	cont_rem	8.5	30.8	660	0.14	1.57
hugoton	2010	122	2	5-10	cont_ret	8.5	106.0	275	0.13	1.42
hugoton	2010	123	2	5-10	cont_ret	8.5	19.6	630	0.15	1.61
hugoton	2010	124	2	5-10	alt_rem	8.5	21.2	680	0.12	1.29
hugoton	2010	131	3	5-10	cont_rem	8.5	20.0	686	0.11	1.12
hugoton	2010	132	3	5-10	cont_ret	8.5	38.3	890	0.14	1.42
hugoton	2010	133	3	5-10	alt_rem	8.5	25.5	810	0.14	1.47
hugoton	2010	134	3	5-10	cont_ret	8.2	36.3	890	0.16	1.94
hugoton	2010	141	4	5-10	cont_ret	8.3	52.9	800	0.14	1.31
hugoton	2010	142	4	5-10	cont_rem	8.4	33.0	740	0.16	1.75
hugoton	2010	143	4	5-10	cont_ret	8.4	24.6	630	0.12	1.49
hugoton	2010	144	4	5-10	alt_rem	8.5	20.4	610	0.12	1.53
hugoton	2010	111	1	10-15	cont_ret	7.9	28.5	600	0.13	1.05
hugoton	2010	112	1	10-15	alt_rem	7.8	18.6	516	0.11	0.89
hugoton	2010	113	1	10-15	cont_rem	8.3	75.9	560	0.12	1.04
hugoton	2010	114	1	10-15	cont_ret	8.4	61.3	700	0.12	1.28
hugoton	2010	121	2	10-15	cont_rem	8.5	24.4	509	0.11	1.39

hugoton	2010	122	2	10-15	cont_ret	8.5	49.4	459	0.10	1.14
hugoton	2010	123	2	10-15	cont_ret	8.4	11.4	494	0.11	1.14
hugoton	2010	124	2	10-15	alt_rem	8.5	14.8	312	0.10	1.12
hugoton	2010	131	3	10-15	cont_rem	8.3	11.3	458	0.09	0.80
hugoton	2010	132	3	10-15	cont_ret	8.5	34.4	810	0.13	1.19
hugoton	2010	133	3	10-15	alt_rem	8.6	11.8	740	0.10	0.98
hugoton	2010	134	3	10-15	cont_ret	8.5	20.2	730	0.11	1.17
hugoton	2010	141	4	10-15	cont_ret	8.3	254.0	760	0.12	1.14
hugoton	2010	142	4	10-15	cont_rem	8.5	23.7	543	0.11	1.30
hugoton	2010	143	4	10-15	cont_ret	8.4	17.5	481	0.10	1.27
hugoton	2010	144	4	10-15	alt_rem	8.5	16.1	469	0.10	1.30
hugoton	2010	111	1	15-30	cont_ret	8.5	5.4	315	0.09	0.93
hugoton	2010	112	1	15-30	alt_rem	8.3	4.6	260	0.09	0.70
hugoton	2010	113	1	15-30	cont_rem	8.3	13.4	362	0.08	1.85
hugoton	2010	114	1	15-30	cont_ret	8.6	11.2	376	0.09	1.40
hugoton	2010	121	2	15-30	cont_rem	8.6	7.0	303	0.08	1.33
hugoton	2010	122	2	15-30	cont_ret	8.6	3.6	284	0.07	0.93
hugoton	2010	123	2	15-30	cont_ret	8.6	4.9	301	0.08	1.10
hugoton	2010	124	2	15-30	alt_rem	8.6	4.5	310	0.07	1.23
hugoton	2010	131	3	15-30	cont_rem	8.4	3.7	320	0.08	0.70
hugoton	2010	132	3	15-30	cont_ret	8.6	10.2	710	0.10	1.44
hugoton	2010	133	3	15-30	alt_rem	8.7	6.1	432	0.11	1.41
hugoton	2010	134	3	15-30	cont_ret	8.7	6.8	417	0.10	1.63
hugoton	2010	141	4	15-30	cont_ret	8.5	49.6	469	0.09	1.29
hugoton	2010	142	4	15-30	cont_rem	8.4	13.1	334	0.10	1.25
hugoton	2010	143	4	15-30	cont_ret	8.5	8.1	339	0.09	1.28
hugoton	2010	144	4	15-30	alt_rem	8.5	6.2	331	0.08	1.21
bigbow	2010	211	1	0-5	cont_ret	8.0	28.0	342	0.16	1.61
bigbow	2010	212	1	0-5	alt_rem	7.3	63.8	444	0.17	1.64
bigbow	2010	213	1	0-5	cont_rem	7.6	39.9	405	0.11	1.05

bigbow	2010	214	1	0-5	cont_ret	7.1	33.0	351	0.16	1.39
bigbow	2010	221	2	0-5	cont_rem	7.4	54.2	406	0.17	1.55
bigbow	2010	222	2	0-5	cont_ret	7.5	45.8	335	0.13	1.09
bigbow	2010	223	2	0-5	cont_ret	7.8	40.0	690	0.16	1.54
bigbow	2010	224	2	0-5	alt_rem	7.8	94.7	303	0.10	0.93
bigbow	2010	231	3	0-5	cont_rem	7.9	38.7	670	0.16	1.56
bigbow	2010	232	3	0-5	cont_ret	7.4	40.0	475	0.18	1.75
bigbow	2010	233	3	0-5	alt_rem	7.6	106.0	389	0.15	1.39
bigbow	2010	234	3	0-5	cont_ret	7.3	49.7	424	0.14	1.28
bigbow	2010	241	4	0-5	cont_ret	7.0	62.1	338	0.18	1.56
bigbow	2010	242	4	0-5	cont_rem	7.2	29.0	261	0.12	1.07
bigbow	2010	243	4	0-5	cont_ret	7.4	36.0	404	0.13	1.22
bigbow	2010	244	4	0-5	alt_rem	7.7	60.1	344	0.09	0.77
bigbow	2010	211	1	5-10	cont_ret	8.3	15.3	342	0.11	1.24
bigbow	2010	212	1	5-10	alt_rem	7.5	55.2	423	0.15	1.51
bigbow	2010	213	1	5-10	cont_rem	8.0	32.6	322	0.08	0.68
bigbow	2010	214	1	5-10	cont_ret	7.1	22.0	299	0.12	0.86
bigbow	2010	221	2	5-10	cont_rem	7.2	38.4	321	0.13	1.19
bigbow	2010	222	2	5-10	cont_ret	7.4	35.3	291	0.12	0.95
bigbow	2010	223	2	5-10	cont_ret	7.6	88.5	239	0.17	1.68
bigbow	2010	224	2	5-10	alt_rem	7.8	78.0	266	0.10	0.80
bigbow	2010	231	3	5-10	cont_rem	8.2	26.4	448	0.12	1.06
bigbow	2010	232	3	5-10	cont_ret	7.5	31.2	362	0.14	1.30
bigbow	2010	233	3	5-10	alt_rem	7.5	30.7	420	0.16	1.60
bigbow	2010	234	3	5-10	cont_ret	6.9	56.1	278	0.15	1.49
bigbow	2010	241	4	5-10	cont_ret	7.0	60.4	310	0.22	2.08
bigbow	2010	242	4	5-10	cont_rem	7.3	38.1	377	0.12	1.14
bigbow	2010	243	4	5-10	cont_ret	7.6	33.0	438	0.11	0.98
bigbow	2010	244	4	5-10	alt_rem	7.8	61.0	300	0.04	0.35
bigbow	2010	211	1	10-15	cont_ret	8.2	23.5	341	0.06	0.63

bigbow	2010	212	1	10-15	alt_rem	7.6	42.9	363	0.07	0.69
bigbow	2010	213	1	10-15	cont_rem	8.3	30.8	313	0.07	0.44
bigbow	2010	214	1	10-15	cont_ret	7.3	19.4	295	0.06	0.36
bigbow	2010	221	2	10-15	cont_rem	8.0	36.9	299	0.07	0.55
bigbow	2010	222	2	10-15	cont_ret	7.9	35.2	285	0.09	0.60
bigbow	2010	223	2	10-15	cont_ret	8.3	43.3	206	0.06	0.42
bigbow	2010	224	2	10-15	alt_rem	8.2	54.3	241	0.04	0.34
bigbow	2010	231	3	10-15	cont_rem	8.5	26.3	395	0.05	0.43
bigbow	2010	232	3	10-15	cont_ret	8.1	30.1	307	0.06	0.50
bigbow	2010	233	3	10-15	alt_rem	7.4	23.4	297	0.15	1.21
bigbow	2010	234	3	10-15	cont_ret	7.4	48.3	235	0.08	0.71
bigbow	2010	241	4	10-15	cont_ret	6.9	64.2	300	0.18	1.61
bigbow	2010	242	4	10-15	cont_rem	7.6	23.4	237	0.08	0.63
bigbow	2010	243	4	10-15	cont_ret	7.9	25.1	351	0.06	0.47
bigbow	2010	244	4	10-15	alt_rem	8.2	58.0	287	0.04	0.26

Table E.3 Raw data of corn emergence at Hugoton L and Bigbow FSL sites. Stand counts collected on 16 June 2009 and 25 May 2010.

Corn Emergence Data Hugoton L and Bigbow FSL					
Field	Date	Plot	Block	Treatment	Count
					plants/acre
hugoton	6-16-2009	111	1	cont_ret	29000
hugoton	6-16-2009	112	1	cont_rem	32000
hugoton	6-16-2009	113	1	cont_rem	30000
hugoton	6-16-2009	114	1	cont_ret	32000
hugoton	6-16-2009	121	2	cont_rem	33500
hugoton	6-16-2009	122	2	cont_ret	32000
hugoton	6-16-2009	123	2	cont_ret	31500
hugoton	6-16-2009	124	2	cont_rem	31500
hugoton	6-16-2009	131	3	cont_rem	32000
hugoton	6-16-2009	132	3	cont_ret	29000
hugoton	6-16-2009	133	3	cont_rem	31500
hugoton	6-16-2009	134	3	cont_ret	32000
hugoton	6-16-2009	141	4	cont_ret	33000
hugoton	6-16-2009	142	4	cont_rem	32000
hugoton	6-16-2009	143	4	cont_ret	31000
hugoton	6-16-2009	144	4	cont_rem	32500
bigbow	6-16-2009	211	1	cont_ret	31500
bigbow	6-16-2009	212	1	cont_rem	34500
bigbow	6-16-2009	213	1	cont_rem	30500
bigbow	6-16-2009	214	1	cont_ret	32500
bigbow	6-16-2009	221	2	cont_rem	34000
bigbow	6-16-2009	222	2	cont_ret	33000
bigbow	6-16-2009	223	2	cont_ret	28500
bigbow	6-16-2009	224	2	cont_rem	34000
bigbow	6-16-2009	231	3	cont_rem	29500
bigbow	6-16-2009	232	3	cont_ret	31000
bigbow	6-16-2009	233	3	cont_rem	33500
bigbow	6-16-2009	234	3	cont_ret	33000
bigbow	6-16-2009	241	4	cont_ret	32000
bigbow	6-16-2009	242	4	cont_rem	32500
bigbow	6-16-2009	243	4	cont_ret	33500
bigbow	6-16-2009	244	4	cont_rem	33000
hugoton	5-25-2010	111	1	cont_ret	26000
hugoton	5-25-2010	112	1	alt_rem	29500
hugoton	5-25-2010	113	1	cont_rem	30500

hugoton	5-25-2010	114	1	cont_ret	26000
hugoton	5-25-2010	121	2	cont_rem	27000
hugoton	5-25-2010	122	2	cont_ret	27500
hugoton	5-25-2010	123	2	cont_ret	26500
hugoton	5-25-2010	124	2	alt_rem	27000
hugoton	5-25-2010	131	3	cont_rem	26500
hugoton	5-25-2010	132	3	cont_ret	27000
hugoton	5-25-2010	133	3	alt_rem	27000
hugoton	5-25-2010	134	3	cont_ret	25500
hugoton	5-25-2010	141	4	cont_ret	27500
hugoton	5-25-2010	142	4	cont_rem	30500
hugoton	5-25-2010	143	4	cont_ret	22500
hugoton	5-25-2010	144	4	alt_rem	19500

Appendix F - Additional Data Collected

Table F.1 Bulk density, gravimetric water content, and volumetric water content data from soil cores (diameter 3.76 cm) to a depth of 1.8 m collected in the spring of 2009 and 2010.

Bulk Density, Gravimetric Water Content, and Volumetric Water Content of Deep Cores										
					4 April 2009			5 April 2010		
Field	Plot	Depth (inches)	Block	Treatment	Gravimetric Water Content	Bulk Density	Volumetric Water Content	Gravimetric Water Content	Bulk Density	Volumetric Water Content
					(g/g)	(g/cm^3)	(cm^3/cm^3)	(g/g)	(g/cm^3)	(cm^3/cm^3)
Hugoton	113	0-2	1	Removed	0.081	1.21	0.098	0.211	1.17	0.246
Hugoton	113	2--4	1	Removed	0.151	1.24	0.187	0.221	1.39	0.306
Hugoton	113	4--6	1	Removed	0.194	1.35	0.261	0.205	1.38	0.282
Hugoton	113	6--8	1	Removed	0.188	1.20	0.226	0.197	1.39	0.274
Hugoton	113	8--10	1	Removed	0.184	1.29	0.236	0.186	1.58	0.294
Hugoton	113	10--12	1	Removed	0.178	1.30	0.231	0.183	1.34	0.245
Hugoton	113	12--14	1	Removed	0.172	1.31	0.224	0.175	1.51	0.263
Hugoton	113	14--16	1	Removed	0.161	1.20	0.193	0.173	1.51	0.262
Hugoton	113	16--18	1	Removed	0.160	0.94	0.151	0.183	1.35	0.247
Hugoton	113	18--20	1	Removed	0.164	0.90	0.148	0.200	1.46	0.291
Hugoton	113	20--22	1	Removed	0.170	1.02	0.173	0.187	1.39	0.260
Hugoton	113	22--24	1	Removed	0.164	1.11	0.182	0.180	1.39	0.250
Hugoton	113	24--26	1	Removed	0.163	0.90	0.146	0.172	1.04	0.179
Hugoton	113	26--28	1	Removed	0.161	1.30	0.209	0.180	1.32	0.237
Hugoton	113	28--30	1	Removed	0.179	1.09	0.195	0.181	0.92	0.167
Hugoton	113	30--32	1	Removed	0.177	1.04	0.184	0.190	1.14	0.216
Hugoton	113	32--34	1	Removed	0.172	1.09	0.187	0.183	1.02	0.186
Hugoton	113	34--36	1	Removed	0.175	0.75	0.132	0.176	1.38	0.243
Hugoton	113	36--38	1	Removed	0.155	1.23	0.191	0.141	1.11	0.156
Hugoton	113	38--40	1	Removed	0.160	1.12	0.179	0.150	1.30	0.196
Hugoton	113	40--42	1	Removed	0.166	1.08	0.180	0.140	1.20	0.168
Hugoton	113	42--44	1	Removed	0.166	0.98	0.162	0.137	0.95	0.131
Hugoton	113	44--46	1	Removed	0.174	0.86	0.150	0.121	1.22	0.148
Hugoton	113	46--48	1	Removed	0.149	1.11	0.165	0.126	1.44	0.181
Hugoton	113	48--50	1	Removed	0.154	1.34	0.206	0.126	1.10	0.138
Hugoton	113	50--52	1	Removed	0.165	1.21	0.198	0.124	1.19	0.148
Hugoton	113	52--54	1	Removed	0.147	1.33	0.195	0.120	1.34	0.161
Hugoton	113	54--56	1	Removed	0.146	0.89	0.130	0.130	1.24	0.161
Hugoton	113	56--58	1	Removed	0.149	1.26	0.188	0.134	1.20	0.160
Hugoton	113	58--60	1	Removed	0.154	1.13	0.173	0.138	1.35	0.186

Hugoton	113	60--62	1	Removed	0.147	1.45	0.214	0.130	1.24	0.162
Hugoton	113	62--64	1	Removed	0.153	1.40	0.214	0.107	1.26	0.135
Hugoton	113	64--66	1	Removed	0.184	1.30	0.239	0.114	1.27	0.145
Hugoton	113	66--68	1	Removed	0.166	1.34	0.222	0.125	1.15	0.143
Hugoton	113	68--70	1	Removed	0.178	1.40	0.248	0.135	1.23	0.165
Hugoton	113	70--72	1	Removed	0.179	1.43	0.255	0.131	1.18	0.154
Hugoton	114	0-2	1	Retained	0.177	0.80	0.141	0.239	1.39	0.333
Hugoton	114	2--4	1	Retained	0.213	1.30	0.278	0.228	1.26	0.288
Hugoton	114	4--6	1	Retained	0.211	1.39	0.292	0.225	1.22	0.273
Hugoton	114	6--8	1	Retained	0.206	1.35	0.277	0.235	1.38	0.324
Hugoton	114	8--10	1	Retained	0.202	1.48	0.300	0.224	1.49	0.334
Hugoton	114	10--12	1	Retained	0.197	1.40	0.276	0.207	1.42	0.293
Hugoton	114	12--14	1	Retained	0.195	1.58	0.308	0.208	1.32	0.274
Hugoton	114	14--16	1	Retained	0.186	1.31	0.244	0.176	1.52	0.267
Hugoton	114	16--18	1	Retained	0.182	1.41	0.257	0.187	1.47	0.275
Hugoton	114	18--20	1	Retained	0.179	1.24	0.221	0.179	1.43	0.255
Hugoton	114	20--22	1	Retained	0.170	1.49	0.252	0.184	1.37	0.251
Hugoton	114	22--24	1	Retained	0.165	1.46	0.241	0.173	1.29	0.223
Hugoton	114	24--26	1	Retained	0.169	1.32	0.224	0.196	1.28	0.251
Hugoton	114	26--28	1	Retained	0.163	1.55	0.253	0.184	1.47	0.271
Hugoton	114	28--30	1	Retained	0.165	1.11	0.182	0.186	1.36	0.252
Hugoton	114	30--32	1	Retained	0.164	1.23	0.202	0.182	1.27	0.231
Hugoton	114	32--34	1	Retained	0.169	1.18	0.199	0.171	1.25	0.214
Hugoton	114	34--36	1	Retained	0.149	1.23	0.184	0.169	1.44	0.244
Hugoton	114	36--38	1	Retained	0.151	1.22	0.185	0.165	1.40	0.231
Hugoton	114	38--40	1	Retained	0.145	1.37	0.199	0.172	1.50	0.258
Hugoton	114	40--42	1	Retained	0.148	1.20	0.179	0.178	1.28	0.228
Hugoton	114	42--44	1	Retained	0.146	1.63	0.238	0.172	1.73	0.298
Hugoton	114	44--46	1	Retained	0.151	0.98	0.148	0.175	1.41	0.247
Hugoton	114	46--48	1	Retained	0.154	1.42	0.218	0.185	1.52	0.281
Hugoton	114	48--50	1	Retained	0.148	1.48	0.218	0.158	1.38	0.218
Hugoton	114	50--52	1	Retained	0.122	1.66	0.204	0.150	1.39	0.209
Hugoton	114	52--54	1	Retained	0.108	1.34	0.145	0.150	1.41	0.213
Hugoton	114	54--56	1	Retained	0.164	1.42	0.233	0.149	1.44	0.215
Hugoton	114	56--58	1	Retained	0.164	1.20	0.196	0.144	1.40	0.201
Hugoton	114	58--60	1	Retained	0.165	1.35	0.222	0.153	1.41	0.215
Hugoton	114	60--62	1	Retained	0.160	1.41	0.226	0.150	1.27	0.190
Hugoton	114	62--64	1	Retained	0.163	1.27	0.207	0.153	1.44	0.220
Hugoton	114	64--66	1	Retained	0.154	1.41	0.217	0.147	1.39	0.205
Hugoton	114	66--68	1	Retained	0.154	1.44	0.222	0.141	1.29	0.182
Hugoton	114	68--70	1	Retained	0.186	1.22	0.228	0.138	1.34	0.184
Hugoton	114	70--72	1	Retained	0.171	1.24	0.212	0.144	1.27	0.183

Hugoton	121	0-2	2	Removed	0.136	1.12	0.153	0.180	1.15	0.207
Hugoton	121	2--4	2	Removed	0.211	1.15	0.243	0.141	1.55	0.219
Hugoton	121	4--6	2	Removed	0.202	1.50	0.303	0.158	1.44	0.228
Hugoton	121	6--8	2	Removed	0.197	1.11	0.219	0.182	1.61	0.293
Hugoton	121	8--10	2	Removed	0.197	1.52	0.298	0.200	1.27	0.255
Hugoton	121	10--12	2	Removed	0.197	1.47	0.290	0.209	1.34	0.280
Hugoton	121	12--14	2	Removed	0.185	1.32	0.244	0.129	1.58	0.203
Hugoton	121	14--16	2	Removed	0.183	1.28	0.234	0.160	1.47	0.236
Hugoton	121	16--18	2	Removed	0.185	1.52	0.282	0.102	1.64	0.167
Hugoton	121	18--20	2	Removed	0.181	1.16	0.209	0.168	1.46	0.246
Hugoton	121	20--22	2	Removed	0.172	1.16	0.200	0.141	1.52	0.215
Hugoton	121	22--24	2	Removed	0.164	1.36	0.223	0.113	1.48	0.167
Hugoton	121	24--26	2	Removed	0.155	1.28	0.198	0.168	1.48	0.249
Hugoton	121	26--28	2	Removed	0.162	1.49	0.242	0.160	1.29	0.206
Hugoton	121	28--30	2	Removed	0.159	1.06	0.169	0.158	1.55	0.244
Hugoton	121	30--32	2	Removed	0.153	1.17	0.179	0.163	1.42	0.232
Hugoton	121	32--34	2	Removed	0.147	1.24	0.182	0.151	1.46	0.221
Hugoton	121	34--36	2	Removed	0.144	1.44	0.209	0.145	1.54	0.222
Hugoton	121	36--38	2	Removed	0.145	1.38	0.200	0.140	1.33	0.185
Hugoton	121	38--40	2	Removed	0.143	1.41	0.202	0.144	1.10	0.158
Hugoton	121	40--42	2	Removed	0.141	1.33	0.188	0.130	1.20	0.155
Hugoton	121	42--44	2	Removed	0.136	1.30	0.177	0.144	1.48	0.213
Hugoton	121	44--46	2	Removed	0.141	1.61	0.228	0.131	1.29	0.169
Hugoton	121	46--48	2	Removed	0.138	1.36	0.188	0.135	1.58	0.214
Hugoton	121	48--50	2	Removed	0.145	1.52	0.221	0.140	1.63	0.228
Hugoton	121	50--52	2	Removed	0.133	1.05	0.140	0.120	1.19	0.143
Hugoton	121	52--54	2	Removed	0.125	1.61	0.201	0.124	1.53	0.189
Hugoton	121	54--56	2	Removed	0.126	1.12	0.141	0.127	1.53	0.195
Hugoton	121	56--58	2	Removed	0.131	1.54	0.201	0.133	1.13	0.151
Hugoton	121	58--60	2	Removed	0.139	1.74	0.241	0.139	1.36	0.188
Hugoton	121	60--62	2	Removed	0.137	1.57	0.214	0.141	1.73	0.243
Hugoton	121	62--64	2	Removed	0.156	1.66	0.260	0.142	1.40	0.199
Hugoton	121	64--66	2	Removed	0.143	1.82	0.262	0.126	1.48	0.186
Hugoton	121	66--68	2	Removed	0.129	1.68	0.217	0.077	1.56	0.120
Hugoton	121	68--70	2	Removed	0.125	1.81	0.226	0.112	1.60	0.179
Hugoton	121	70--72	2	Removed	0.143	1.74	0.249	0.107	1.31	0.140
Hugoton	122	0-2	2	Retained	0.139	1.32	0.184	0.157	1.33	0.208
Hugoton	122	2--4	2	Retained	0.177	1.51	0.267	0.197	1.16	0.229
Hugoton	122	4--6	2	Retained	0.177	1.36	0.240	0.198	1.26	0.249
Hugoton	122	6--8	2	Retained	0.177	1.52	0.269	0.156	1.73	0.270
Hugoton	122	8--10	2	Retained	0.177	1.48	0.262	0.112	1.58	0.177
Hugoton	122	10--12	2	Retained	0.168	1.19	0.199	0.167	1.44	0.241

Hugoton	122	12--14	2	Retained	0.163	1.28	0.209	0.155	1.44	0.224
Hugoton	122	14--16	2	Retained	0.194	0.89	0.174	0.170	1.30	0.221
Hugoton	122	16--18	2	Retained	0.161	1.37	0.221	0.175	1.40	0.245
Hugoton	122	18--20	2	Retained	0.151	1.22	0.183	0.168	1.29	0.218
Hugoton	122	20--22	2	Retained	0.158	1.20	0.191	0.175	1.27	0.222
Hugoton	122	22--24	2	Retained	0.160	1.29	0.206	0.171	1.28	0.220
Hugoton	122	24--26	2	Retained	0.159	1.12	0.178	0.174	1.45	0.253
Hugoton	122	26--28	2	Retained	0.163	1.22	0.198	0.171	1.23	0.211
Hugoton	122	28--30	2	Retained	0.168	1.20	0.202	0.147	1.21	0.178
Hugoton	122	30--32	2	Retained	0.168	1.14	0.192	0.082	1.45	0.119
Hugoton	122	32--34	2	Retained	0.163	1.19	0.194	0.129	1.42	0.184
Hugoton	122	34--36	2	Retained	0.151	1.14	0.173	0.153	1.33	0.203
Hugoton	122	36--38	2	Retained	0.143	0.84	0.121	0.169	1.17	0.197
Hugoton	122	38--40	2	Retained	0.138	1.47	0.203	0.160	1.36	0.217
Hugoton	122	40--42	2	Retained	0.133	1.19	0.158	0.155	1.31	0.204
Hugoton	122	42--44	2	Retained	0.141	1.16	0.164	0.104	1.46	0.151
Hugoton	122	44--46	2	Retained	0.141	1.58	0.222	0.131	0.98	0.128
Hugoton	122	46--48	2	Retained	0.135	1.51	0.205	0.137	1.62	0.222
Hugoton	122	48--50	2	Retained	0.113	1.39	0.158	0.126	1.40	0.176
Hugoton	122	50--52	2	Retained	0.109	1.62	0.175	0.105	1.68	0.176
Hugoton	122	52--54	2	Retained	0.105	1.68	0.177	0.083	2.28	0.190
Hugoton	122	54--56	2	Retained	0.097	1.72	0.166	0.075	1.74	0.130
Hugoton	122	56--58	2	Retained	0.095	1.51	0.144	0.071	1.40	0.099
Hugoton	122	58--60	2	Retained	0.089	1.50	0.134	0.072	1.62	0.117
Hugoton	122	60--62	2	Retained	0.112	1.37	0.153	0.086	1.55	0.133
Hugoton	122	62--64	2	Retained	0.120	1.63	0.195	--	--	--
Hugoton	122	64--66	2	Retained	0.136	1.67	0.227	--	--	--
Hugoton	122	66--68	2	Retained	0.118	1.50	0.178	0.111	1.59	0.177
Hugoton	122	68--70	2	Retained	0.135	1.49	0.200	0.116	1.21	0.141
Hugoton	122	70--72	2	Retained	0.118	1.30	0.153	0.097	1.58	0.152
Hugoton	131	0-2	3	Removed	0.086	0.89	0.076	0.197	0.97	0.192
Hugoton	131	2--4	3	Removed	0.179	1.29	0.231	0.199	1.29	0.257
Hugoton	131	4--6	3	Removed	0.189	1.52	0.286	0.215	1.43	0.307
Hugoton	131	6--8	3	Removed	0.205	1.70	0.347	0.227	1.36	0.307
Hugoton	131	8--10	3	Removed	0.205	1.56	0.319	0.227	1.43	0.326
Hugoton	131	10--12	3	Removed	0.192	1.51	0.291	0.201	1.43	0.287
Hugoton	131	12--14	3	Removed	0.179	1.51	0.270	0.188	1.66	0.312
Hugoton	131	14--16	3	Removed	0.158	1.24	0.196	0.171	1.19	0.204
Hugoton	131	16--18	3	Removed	0.160	1.47	0.234	0.178	1.34	0.237
Hugoton	131	18--20	3	Removed	0.162	1.45	0.235	0.175	1.61	0.282
Hugoton	131	20--22	3	Removed	0.164	1.15	0.189	0.172	1.32	0.227
Hugoton	131	22--24	3	Removed	0.162	1.34	0.217	0.178	1.41	0.251

Hugoton	131	24--26	3	Removed	0.170	1.39	0.235	0.180	1.33	0.239
Hugoton	131	26--28	3	Removed	0.175	1.54	0.270	0.181	1.31	0.238
Hugoton	131	28--30	3	Removed	0.190	1.16	0.221	0.179	1.61	0.289
Hugoton	131	30--32	3	Removed	0.197	1.48	0.292	0.167	1.53	0.256
Hugoton	131	32--34	3	Removed	0.187	1.35	0.253	0.149	1.41	0.211
Hugoton	131	34--36	3	Removed	0.181	1.12	0.203	0.138	1.48	0.205
Hugoton	131	36--38	3	Removed	0.181	1.54	0.278	0.130	1.33	0.173
Hugoton	131	38--40	3	Removed	0.155	1.09	0.169	0.133	1.43	0.190
Hugoton	131	40--42	3	Removed	0.144	1.31	0.188	0.133	1.95	0.259
Hugoton	131	42--44	3	Removed	0.151	1.17	0.177	0.126	1.44	0.181
Hugoton	131	44--46	3	Removed	0.137	1.60	0.218	0.126	1.24	0.156
Hugoton	131	46--48	3	Removed	0.171	1.36	0.233	0.120	1.22	0.146
Hugoton	131	48--50	3	Removed	0.140	1.57	0.219	0.117	1.38	0.161
Hugoton	131	50--52	3	Removed	0.136	1.32	0.180	0.117	1.61	0.188
Hugoton	131	52--54	3	Removed	0.123	1.21	0.148	0.129	1.42	0.183
Hugoton	131	54--56	3	Removed	0.123	1.30	0.160	0.138	1.39	0.191
Hugoton	131	56--58	3	Removed	0.126	1.56	0.195	0.139	1.61	0.225
Hugoton	131	58--60	3	Removed	0.125	1.33	0.166	0.151	1.37	0.208
Hugoton	131	60--62	3	Removed	0.137	1.56	0.214	0.156	1.48	0.231
Hugoton	131	62--64	3	Removed	0.136	1.58	0.215	0.121	1.33	0.161
Hugoton	131	64--66	3	Removed	0.146	1.41	0.206	0.126	1.53	0.192
Hugoton	131	66--68	3	Removed	0.172	1.57	0.271	0.118	1.30	0.152
Hugoton	131	68--70	3	Removed	0.186	0.69	0.129	0.118	1.46	0.172
Hugoton	131	70--72	3	Removed	--	--	--	--	--	--
Hugoton	132	0-2	3	Retained	0.138	1.42	0.195	0.207	1.24	0.256
Hugoton	132	2--4	3	Retained	0.170	1.11	0.189	0.202	1.42	0.287
Hugoton	132	4--6	3	Retained	0.184	1.33	0.245	0.194	1.31	0.255
Hugoton	132	6--8	3	Retained	0.182	1.24	0.225	0.199	1.70	0.339
Hugoton	132	8--10	3	Retained	0.184	1.28	0.235	0.198	1.29	0.256
Hugoton	132	10--12	3	Retained	0.179	1.30	0.234	0.202	1.70	0.344
Hugoton	132	12--14	3	Retained	0.176	1.26	0.222	0.193	0.81	0.155
Hugoton	132	14--16	3	Retained	0.164	1.06	0.174	0.196	1.38	0.270
Hugoton	132	16--18	3	Retained	0.152	1.13	0.172	0.187	1.42	0.266
Hugoton	132	18--20	3	Retained	0.150	1.08	0.161	0.188	1.23	0.231
Hugoton	132	20--22	3	Retained	0.147	1.10	0.161	0.174	1.31	0.227
Hugoton	132	22--24	3	Retained	0.166	1.20	0.200	0.167	1.39	0.232
Hugoton	132	24--26	3	Retained	0.175	1.42	0.249	0.171	1.30	0.223
Hugoton	132	26--28	3	Retained	0.186	1.22	0.227	0.170	1.34	0.227
Hugoton	132	28--30	3	Retained	0.173	1.18	0.205	0.172	1.38	0.237
Hugoton	132	30--32	3	Retained	0.177	1.37	0.244	0.169	1.30	0.220
Hugoton	132	32--34	3	Retained	0.172	1.21	0.209	0.164	1.32	0.217
Hugoton	132	34--36	3	Retained	0.157	1.46	0.230	0.160	1.32	0.212

Hugoton	132	36--38	3	Retained	0.141	1.05	0.148	0.157	1.50	0.236
Hugoton	132	38--40	3	Retained	0.142	1.45	0.206	0.156	1.37	0.214
Hugoton	132	40--42	3	Retained	0.135	1.47	0.198	0.158	1.42	0.224
Hugoton	132	42--44	3	Retained	0.135	1.05	0.142	0.154	1.43	0.221
Hugoton	132	44--46	3	Retained	0.141	1.33	0.187	0.144	1.61	0.232
Hugoton	132	46--48	3	Retained	0.120	1.43	0.171	0.151	1.35	0.204
Hugoton	132	48--50	3	Retained	0.125	1.56	0.196	0.141	1.47	0.207
Hugoton	132	50--52	3	Retained	0.114	1.33	0.152	0.127	1.57	0.200
Hugoton	132	52--54	3	Retained	0.127	1.73	0.220	0.135	1.60	0.215
Hugoton	132	54--56	3	Retained	0.130	1.32	0.172	0.146	1.41	0.205
Hugoton	132	56--58	3	Retained	0.135	1.49	0.201	0.146	1.46	0.214
Hugoton	132	58--60	3	Retained	0.136	1.44	0.196	0.165	1.32	0.217
Hugoton	132	60--62	3	Retained	0.138	1.34	0.185	0.207	1.72	0.354
Hugoton	132	62--64	3	Retained	0.140	1.43	0.200	0.159	1.33	0.212
Hugoton	132	64--66	3	Retained	0.139	1.53	0.212	0.124	1.47	0.183
Hugoton	132	66--68	3	Retained	0.150	1.40	0.210	0.136	1.67	0.228
Hugoton	132	68--70	3	Retained	0.172	1.01	0.174	0.141	1.66	0.235
Hugoton	132	70--72	3	Retained	0.222	1.17	0.261	0.112	1.58	0.176
Hugoton	141	0-2	4	Retained	0.109	1.43	0.155	0.192	1.03	0.197
Hugoton	141	2--4	4	Retained	0.163	1.12	0.183	0.196	1.13	0.222
Hugoton	141	4--6	4	Retained	0.171	1.37	0.234	0.187	1.28	0.239
Hugoton	141	6--8	4	Retained	0.179	1.34	0.241	0.191	1.33	0.254
Hugoton	141	8--10	4	Retained	0.176	1.15	0.203	0.189	1.13	0.214
Hugoton	141	10--12	4	Retained	0.176	1.17	0.206	0.099	1.58	0.157
Hugoton	141	12--14	4	Retained	0.168	1.15	0.194	0.184	1.37	0.253
Hugoton	141	14--16	4	Retained	0.173	1.26	0.218	0.209	1.47	0.308
Hugoton	141	16--18	4	Retained	0.175	1.26	0.220	0.177	1.40	0.248
Hugoton	141	18--20	4	Retained	0.168	1.32	0.221	0.173	1.36	0.235
Hugoton	141	20--22	4	Retained	0.160	1.43	0.230	0.160	1.43	0.229
Hugoton	141	22--24	4	Retained	0.157	1.48	0.232	0.161	1.05	0.169
Hugoton	141	24--26	4	Retained	0.152	1.31	0.200	0.164	1.28	0.209
Hugoton	141	26--28	4	Retained	0.145	1.29	0.187	0.140	1.16	0.163
Hugoton	141	28--30	4	Retained	0.142	1.37	0.195	0.148	1.40	0.208
Hugoton	141	30--32	4	Retained	0.146	1.28	0.187	0.153	1.33	0.203
Hugoton	141	32--34	4	Retained	0.143	1.35	0.193	0.154	1.27	0.195
Hugoton	141	34--36	4	Retained	0.150	1.21	0.182	0.149	1.24	0.184
Hugoton	141	36--38	4	Retained	0.147	1.13	0.166	0.152	1.28	0.195
Hugoton	141	38--40	4	Retained	0.138	1.30	0.179	0.154	1.43	0.220
Hugoton	141	40--42	4	Retained	0.140	0.95	0.134	0.151	1.32	0.200
Hugoton	141	42--44	4	Retained	0.147	1.13	0.167	0.138	1.54	0.213
Hugoton	141	44--46	4	Retained	0.132	0.68	0.089	0.146	1.11	0.162
Hugoton	141	46--48	4	Retained	0.144	1.14	0.164	0.159	1.38	0.220

Hugoton	141	48--50	4	Retained	0.143	1.37	0.195	0.157	1.23	0.193
Hugoton	141	50--52	4	Retained	0.145	1.46	0.212	0.161	1.37	0.220
Hugoton	141	52--54	4	Retained	0.152	1.33	0.202	0.152	1.12	0.170
Hugoton	141	54--56	4	Retained	0.154	1.26	0.193	0.158	1.16	0.183
Hugoton	141	56--58	4	Retained	0.156	1.08	0.168	0.156	1.35	0.210
Hugoton	141	58--60	4	Retained	0.155	1.23	0.190	0.125	1.56	0.196
Hugoton	141	60--62	4	Retained	0.155	1.23	0.192	0.130	1.60	0.208
Hugoton	141	62--64	4	Retained	0.155	1.32	0.204	0.127	1.27	0.161
Hugoton	141	64--66	4	Retained	0.160	1.08	0.173	0.137	1.37	0.187
Hugoton	141	66--68	4	Retained	0.166	1.30	0.215	0.124	1.54	0.190
Hugoton	141	68--70	4	Retained	0.161	0.74	0.119	0.127	1.32	0.168
Hugoton	141	70--72	4	Retained	0.160	1.24	0.198	0.122	1.51	0.184
Hugoton	142	0-2	4	Retained	0.096	1.49	0.142	0.181	1.31	0.237
Hugoton	142	2--4	4	Retained	0.146	1.17	0.172	0.193	1.21	0.233
Hugoton	142	4--6	4	Removed	0.183	1.33	0.243	0.186	1.33	0.247
Hugoton	142	6--8	4	Removed	0.185	1.62	0.301	0.130	1.59	0.206
Hugoton	142	8--10	4	Removed	0.187	1.53	0.287	0.155	1.54	0.238
Hugoton	142	10--12	4	Removed	0.183	1.35	0.247	0.144	1.47	0.211
Hugoton	142	12--14	4	Removed	0.170	1.47	0.250	0.174	1.27	0.221
Hugoton	142	14--16	4	Removed	0.165	1.10	0.182	0.169	1.41	0.238
Hugoton	142	16--18	4	Removed	0.167	1.23	0.206	0.146	1.48	0.216
Hugoton	142	18--20	4	Removed	0.208	1.35	0.280	0.156	1.26	0.197
Hugoton	142	20--22	4	Removed	0.149	1.27	0.188	0.166	1.27	0.210
Hugoton	142	22--24	4	Removed	0.147	1.24	0.182	0.135	1.45	0.195
Hugoton	142	24--26	4	Removed	0.149	1.39	0.208	0.155	1.43	0.221
Hugoton	142	26--28	4	Removed	0.141	1.22	0.172	0.140	1.24	0.174
Hugoton	142	28--30	4	Removed	0.136	1.21	0.165	0.124	1.50	0.186
Hugoton	142	30--32	4	Removed	0.139	1.34	0.186	0.146	1.50	0.219
Hugoton	142	32--34	4	Removed	0.162	1.29	0.209	0.142	1.33	0.189
Hugoton	142	34--36	4	Removed	0.135	1.20	0.162	0.141	1.43	0.201
Hugoton	142	36--38	4	Removed	0.132	1.26	0.167	0.073	1.59	0.116
Hugoton	142	38--40	4	Removed	0.134	1.36	0.183	0.106	1.43	0.152
Hugoton	142	40--42	4	Removed	0.150	1.11	0.166	0.129	1.33	0.172
Hugoton	142	42--44	4	Removed	0.127	1.67	0.212	0.143	1.48	0.212
Hugoton	142	44--46	4	Removed	0.132	0.73	0.096	0.134	1.38	0.185
Hugoton	142	46--48	4	Removed	0.123	1.35	0.166	0.135	1.33	0.180
Hugoton	142	48--50	4	Removed	0.115	1.61	0.184	0.142	1.25	0.178
Hugoton	142	50--52	4	Removed	0.113	1.23	0.139	0.140	1.38	0.193
Hugoton	142	52--54	4	Removed	0.128	1.29	0.165	0.132	1.50	0.199
Hugoton	142	54--56	4	Removed	0.132	1.35	0.179	0.124	1.19	0.147
Hugoton	142	56--58	4	Removed	0.126	1.37	0.172	0.122	1.45	0.178
Hugoton	142	58--60	4	Removed	0.123	1.26	0.155	0.119	1.58	0.187

Hugoton	142	60--62	4	Removed	0.135	1.19	0.160	0.116	1.36	0.157
Hugoton	142	62--64	4	Removed	0.136	1.33	0.180	0.113	1.16	0.131
Hugoton	142	64--66	4	Removed	0.133	1.15	0.153	0.109	1.38	0.151
Hugoton	142	66--68	4	Removed	0.140	1.05	0.147	--	--	--
Hugoton	142	68--70	4	Removed	0.139	1.21	0.168	--	--	--
Hugoton	142	70--72	4	Removed	0.116	1.30	0.151	--	--	--
Bigbow	213	0-2	1	Removed	0.145	1.21	0.176	0.109	1.27	0.139
Bigbow	213	2--4	1	Removed	0.116	1.36	0.158	0.077	2.39	0.184
Bigbow	213	4--6	1	Removed	0.104	1.44	0.149	0.115	1.45	0.167
Bigbow	213	6--8	1	Removed	0.110	1.70	0.186	0.120	1.56	0.188
Bigbow	213	8--10	1	Removed	0.127	1.60	0.203	0.106	1.53	0.161
Bigbow	213	10--12	1	Removed	0.100	1.61	0.160	0.105	1.43	0.151
Bigbow	213	12--14	1	Removed	0.115	1.55	0.179	0.100	1.43	0.143
Bigbow	213	14--16	1	Removed	0.144	1.65	0.237	0.114	1.48	0.169
Bigbow	213	16--18	1	Removed	0.166	1.59	0.265	0.085	1.62	0.138
Bigbow	213	18--20	1	Removed	0.179	1.52	0.272	0.159	1.63	0.259
Bigbow	213	20--22	1	Removed	0.173	1.48	0.256	0.159	1.42	0.227
Bigbow	213	22--24	1	Removed	0.217	1.61	0.350	0.179	1.46	0.262
Bigbow	213	24--26	1	Removed	0.239	1.32	0.316	0.196	1.33	0.261
Bigbow	213	26--28	1	Removed	0.243	1.37	0.334	0.210	1.31	0.275
Bigbow	213	28--30	1	Removed	0.252	1.31	0.331	0.218	1.19	0.258
Bigbow	213	30--32	1	Removed	0.258	1.20	0.310	0.222	1.15	0.254
Bigbow	213	32--34	1	Removed	0.255	1.21	0.310	0.218	1.28	0.279
Bigbow	213	34--36	1	Removed	0.265	1.06	0.281	0.218	1.14	0.249
Bigbow	213	36--38	1	Removed	0.262	1.24	0.326	0.235	1.23	0.288
Bigbow	213	38--40	1	Removed	0.250	1.05	0.262	0.247	1.15	0.283
Bigbow	213	40--42	1	Removed	0.263	1.23	0.325	0.250	1.14	0.284
Bigbow	213	42--44	1	Removed	0.276	1.00	0.275	0.249	1.15	0.285
Bigbow	213	44--46	1	Removed	0.274	0.99	0.271	0.231	1.12	0.259
Bigbow	213	46--48	1	Removed	0.266	0.47	0.126	0.243	1.20	0.292
Bigbow	213	48--50	1	Removed	0.261	0.55	0.143	0.245	1.16	0.284
Bigbow	213	50--52	1	Removed	0.260	0.55	0.142	0.250	1.13	0.282
Bigbow	213	52--54	1	Removed	0.261	0.65	0.169	0.254	1.06	0.270
Bigbow	213	54--56	1	Removed	0.255	0.83	0.212	0.260	1.07	0.279
Bigbow	213	56--58	1	Removed	0.247	0.91	0.225	0.273	1.09	0.298
Bigbow	213	58--60	1	Removed	0.236	0.87	0.207	0.273	1.06	0.288
Bigbow	213	60--62	1	Removed	0.222	0.95	0.210	0.271	1.08	0.293
Bigbow	213	62--64	1	Removed	0.217	0.87	0.189	0.277	1.04	0.289
Bigbow	213	64--66	1	Removed	--	--	--	--	--	--
Bigbow	213	66--68	1	Removed	--	--	--	--	--	--
Bigbow	213	68--70	1	Removed	--	--	--	--	--	--
Bigbow	213	70--72	1	Removed	--	--	--	--	--	--

Bigbow	214	0-2	1	Retained	0.164	1.02	0.168	0.139	1.37	0.191
Bigbow	214	2--4	1	Retained	0.144	1.38	0.199	0.123	1.60	0.196
Bigbow	214	4--6	1	Retained	0.128	1.47	0.188	0.098	1.51	0.147
Bigbow	214	6--8	1	Retained	0.108	1.47	0.158	0.102	1.82	0.186
Bigbow	214	8--10	1	Retained	0.101	1.59	0.160	0.099	1.51	0.149
Bigbow	214	10--12	1	Retained	0.131	1.65	0.217	0.100	1.44	0.144
Bigbow	214	12--14	1	Retained	0.115	1.58	0.182	0.100	1.59	0.159
Bigbow	214	14--16	1	Retained	0.097	1.50	0.145	0.109	1.54	0.168
Bigbow	214	16--18	1	Retained	0.131	1.52	0.199	0.104	1.64	0.170
Bigbow	214	18--20	1	Retained	0.178	1.47	0.261	0.117	1.37	0.161
Bigbow	214	20--22	1	Retained	0.179	1.63	0.291	0.152	1.34	0.204
Bigbow	214	22--24	1	Retained	0.187	1.16	0.218	0.173	1.38	0.239
Bigbow	214	24--26	1	Retained	0.199	1.27	0.252	0.184	1.33	0.245
Bigbow	214	26--28	1	Retained	0.204	1.40	0.286	0.195	1.31	0.256
Bigbow	214	28--30	1	Retained	0.214	1.16	0.249	0.200	1.27	0.254
Bigbow	214	30--32	1	Retained	0.214	1.33	0.286	0.205	1.35	0.275
Bigbow	214	32--34	1	Retained	0.224	1.30	0.292	0.208	1.34	0.279
Bigbow	214	34--36	1	Retained	0.221	1.21	0.268	0.216	1.07	0.230
Bigbow	214	36--38	1	Retained	0.216	1.21	0.262	0.226	1.18	0.267
Bigbow	214	38--40	1	Retained	0.216	1.36	0.295	0.218	1.02	0.223
Bigbow	214	40--42	1	Retained	0.217	1.12	0.242	0.190	1.15	0.218
Bigbow	214	42--44	1	Retained	0.233	1.14	0.267	0.191	1.17	0.223
Bigbow	214	44--46	1	Retained	0.235	1.13	0.266	0.202	1.20	0.242
Bigbow	214	46--48	1	Retained	0.221	1.12	0.249	0.217	1.13	0.245
Bigbow	214	48--50	1	Retained	0.227	1.01	0.230	0.221	1.11	0.244
Bigbow	214	50--52	1	Retained	0.238	0.80	0.189	0.222	1.16	0.258
Bigbow	214	52--54	1	Retained	0.240	0.97	0.233	0.219	1.36	0.298
Bigbow	214	54--56	1	Retained	0.247	1.11	0.275	0.215	1.04	0.223
Bigbow	214	56--58	1	Retained	0.233	0.79	0.183	0.222	0.97	0.216
Bigbow	214	58--60	1	Retained	0.250	1.12	0.280	0.207	1.14	0.236
Bigbow	214	60--62	1	Retained	0.256	0.78	0.200	0.219	1.03	0.226
Bigbow	214	62--64	1	Retained	0.260	1.10	0.285	0.235	1.18	0.278
Bigbow	214	64--66	1	Retained	0.261	1.03	0.269	0.232	1.06	0.247
Bigbow	214	66--68	1	Retained	0.235	0.99	0.232	0.204	1.07	0.220
Bigbow	214	68--70	1	Retained	0.224	1.20	0.269	0.177	1.38	0.243
Bigbow	214	70--72	1	Retained	0.195	1.15	0.224	0.191	1.28	0.246
Bigbow	221	0-2	2	Removed	0.137	1.07	0.146	0.076	1.16	0.088
Bigbow	221	2--4	2	Removed	0.153	1.31	0.200	0.100	1.38	0.138
Bigbow	221	4--6	2	Removed	0.119	1.44	0.171	0.100	1.55	0.156
Bigbow	221	6--8	2	Removed	0.104	1.41	0.146	0.075	1.59	0.120
Bigbow	221	8--10	2	Removed	0.089	1.62	0.145	0.087	1.58	0.137
Bigbow	221	10--12	2	Removed	0.108	1.61	0.174	0.069	1.14	0.078

Bigbow	221	12--14	2	Removed	0.076	1.51	0.114	0.067	1.44	0.096
Bigbow	221	14--16	2	Removed	0.174	1.43	0.249	0.065	1.54	0.101
Bigbow	221	16--18	2	Removed	0.151	1.67	0.252	0.072	1.49	0.107
Bigbow	221	18--20	2	Removed	0.147	1.56	0.230	0.079	1.78	0.140
Bigbow	221	20--22	2	Removed	0.156	1.51	0.235	0.163	1.47	0.239
Bigbow	221	22--24	2	Removed	0.188	1.52	0.287	0.163	1.30	0.212
Bigbow	221	24--26	2	Removed	0.222	1.32	0.293	0.165	1.42	0.234
Bigbow	221	26--28	2	Removed	0.228	1.25	0.286	0.167	1.35	0.226
Bigbow	221	28--30	2	Removed	0.229	1.44	0.329	0.176	1.19	0.210
Bigbow	221	30--32	2	Removed	0.200	1.29	0.258	0.186	1.24	0.231
Bigbow	221	32--34	2	Removed	0.225	1.32	0.298	0.191	1.25	0.239
Bigbow	221	34--36	2	Removed	0.244	1.07	0.262	0.187	1.43	0.268
Bigbow	221	36--38	2	Removed	0.258	1.21	0.313	0.188	1.24	0.234
Bigbow	221	38--40	2	Removed	0.255	1.15	0.294	0.191	1.36	0.259
Bigbow	221	40--42	2	Removed	0.228	1.31	0.298	0.194	1.13	0.218
Bigbow	221	42--44	2	Removed	0.223	1.13	0.252	0.203	1.28	0.260
Bigbow	221	44--46	2	Removed	0.171	1.11	0.189	0.202	1.23	0.249
Bigbow	221	46--48	2	Removed	0.240	0.87	0.208	0.204	1.37	0.280
Bigbow	221	48--50	2	Removed	0.252	0.68	0.172	0.203	1.29	0.262
Bigbow	221	50--52	2	Removed	0.239	1.09	0.259	0.197	1.18	0.234
Bigbow	221	52--54	2	Removed	0.221	1.29	0.286	0.191	1.05	0.200
Bigbow	221	54--56	2	Removed	0.221	1.34	0.296	0.203	1.36	0.276
Bigbow	221	56--58	2	Removed	0.230	1.20	0.276	0.199	1.17	0.233
Bigbow	221	58--60	2	Removed	0.235	1.16	0.274	0.195	1.15	0.224
Bigbow	221	60--62	2	Removed	0.257	1.12	0.288	0.190	1.24	0.236
Bigbow	221	62--64	2	Removed	0.230	1.06	0.244	0.164	1.21	0.199
Bigbow	221	64--66	2	Removed	0.167	0.98	0.163	0.189	1.25	0.235
Bigbow	221	66--68	2	Removed	0.197	0.97	0.192	0.195	1.15	0.224
Bigbow	221	68--70	2	Removed	0.214	1.06	0.228	0.186	1.23	0.229
Bigbow	221	70--72	2	Removed	0.204	0.92	0.188	0.181	1.15	0.208
Bigbow	222	0-2	2	Retained	0.117	1.41	0.164	0.106	1.19	0.126
Bigbow	222	2--4	2	Retained	0.117	1.39	0.162	0.110	1.39	0.153
Bigbow	222	4--6	2	Retained	0.105	1.36	0.143	0.175	1.35	0.236
Bigbow	222	6--8	2	Retained	0.113	1.55	0.174	0.086	1.66	0.143
Bigbow	222	8--10	2	Retained	0.095	1.47	0.139	0.125	1.65	0.206
Bigbow	222	10--12	2	Retained	0.105	1.60	0.168	0.103	1.29	0.133
Bigbow	222	12--14	2	Retained	0.118	1.72	0.203	0.107	1.41	0.151
Bigbow	222	14--16	2	Retained	0.149	1.72	0.257	0.092	1.64	0.152
Bigbow	222	16--18	2	Retained	0.166	1.57	0.260	0.134	1.51	0.202
Bigbow	222	18--20	2	Retained	0.167	1.51	0.252	0.161	1.53	0.246
Bigbow	222	20--22	2	Retained	0.176	1.25	0.221	0.169	1.48	0.250
Bigbow	222	22--24	2	Retained	0.193	1.63	0.315	0.170	1.48	0.252

Bigbow	222	24--26	2	Retained	0.216	1.50	0.323	0.187	1.37	0.255
Bigbow	222	26--28	2	Retained	0.220	1.13	0.249	0.202	1.35	0.273
Bigbow	222	28--30	2	Retained	0.226	1.17	0.263	0.123	1.44	0.177
Bigbow	222	30--32	2	Retained	0.225	1.02	0.229	0.211	1.10	0.233
Bigbow	222	32--34	2	Retained	0.234	0.77	0.179	0.221	1.26	0.278
Bigbow	222	34--36	2	Retained	0.237	1.21	0.287	0.219	1.16	0.254
Bigbow	222	36--38	2	Retained	0.240	1.24	0.298	0.210	1.29	0.272
Bigbow	222	38--40	2	Retained	0.224	1.36	0.304	0.211	1.19	0.252
Bigbow	222	40--42	2	Retained	0.230	1.19	0.273	0.227	1.18	0.267
Bigbow	222	42--44	2	Retained	0.224	1.06	0.237	0.243	0.95	0.232
Bigbow	222	44--46	2	Retained	0.214	1.25	0.268	0.218	1.23	0.268
Bigbow	222	46--48	2	Retained	0.241	1.04	0.251	0.215	1.31	0.281
Bigbow	222	48--50	2	Retained	0.225	1.04	0.234	0.218	1.11	0.241
Bigbow	222	50--52	2	Retained	0.225	1.10	0.247	0.226	1.39	0.314
Bigbow	222	52--54	2	Retained	0.219	1.22	0.268	0.238	1.22	0.291
Bigbow	222	54--56	2	Retained	0.212	1.19	0.252	0.235	1.19	0.279
Bigbow	222	56--58	2	Retained	0.216	1.15	0.249	0.238	1.09	0.260
Bigbow	222	58--60	2	Retained	0.163	1.23	0.200	0.236	1.17	0.275
Bigbow	222	60--62	2	Retained	0.158	1.49	0.236	0.238	1.34	0.318
Bigbow	222	62--64	2	Retained	0.173	1.46	0.253	0.223	1.11	0.247
Bigbow	222	64--66	2	Retained	0.162	1.43	0.233	0.207	1.23	0.255
Bigbow	222	66--68	2	Retained	0.158	1.25	0.198	0.201	1.25	0.251
Bigbow	222	68--70	2	Retained	0.109	1.22	0.134	0.211	1.33	0.280
Bigbow	222	70--72	2	Retained	0.114	1.49	0.170	0.177	1.23	0.217
Bigbow	231	0-2	3	Removed	0.152	0.82	0.125	0.077	1.13	0.087
Bigbow	231	2--4	3	Removed	0.120	1.46	0.175	0.102	1.33	0.136
Bigbow	231	4--6	3	Removed	0.139	1.29	0.180	0.098	1.57	0.153
Bigbow	231	6--8	3	Removed	0.124	1.45	0.180	0.104	1.64	0.170
Bigbow	231	8--10	3	Removed	0.140	1.84	0.258	0.109	1.80	0.195
Bigbow	231	10--12	3	Removed	0.113	1.65	0.186	0.148	1.47	0.217
Bigbow	231	12--14	3	Removed	0.136	1.58	0.214	0.105	1.56	0.164
Bigbow	231	14--16	3	Removed	0.144	1.47	0.212	0.124	1.56	0.193
Bigbow	231	16--18	3	Removed	0.173	1.52	0.263	0.121	1.57	0.190
Bigbow	231	18--20	3	Removed	0.189	1.51	0.286	0.115	1.28	0.147
Bigbow	231	20--22	3	Removed	0.241	1.22	0.295	0.121	1.54	0.186
Bigbow	231	22--24	3	Removed	0.247	1.32	0.327	0.160	1.47	0.236
Bigbow	231	24--26	3	Removed	0.241	1.43	0.345	0.207	1.39	0.287
Bigbow	231	26--28	3	Removed	0.237	1.32	0.313	0.238	1.29	0.307
Bigbow	231	28--30	3	Removed	0.241	1.24	0.300	0.230	1.40	0.323
Bigbow	231	30--32	3	Removed	0.256	1.32	0.338	0.221	1.41	0.312
Bigbow	231	32--34	3	Removed	0.255	1.35	0.345	0.221	1.31	0.289
Bigbow	231	34--36	3	Removed	0.249	1.45	0.362	0.236	1.61	0.380

Bigbow	231	36--38	3	Removed	0.251	1.39	0.348	0.239	1.13	0.271
Bigbow	231	38--40	3	Removed	0.250	1.46	0.365	0.252	1.34	0.336
Bigbow	231	40--42	3	Removed	0.238	0.92	0.220	0.249	1.39	0.347
Bigbow	231	42--44	3	Removed	0.249	1.42	0.354	0.243	1.05	0.255
Bigbow	231	44--46	3	Removed	0.248	1.28	0.318	0.243	1.23	0.299
Bigbow	231	46--48	3	Removed	0.261	1.29	0.337	0.191	1.14	0.218
Bigbow	231	48--50	3	Removed	0.261	1.26	0.329	0.241	1.46	0.352
Bigbow	231	50--52	3	Removed	0.259	1.00	0.259	0.245	1.38	0.339
Bigbow	231	52--54	3	Removed	0.257	0.90	0.231	0.248	1.34	0.333
Bigbow	231	54--56	3	Removed	0.273	1.28	0.350	0.249	1.23	0.307
Bigbow	231	56--58	3	Removed	0.273	0.96	0.263	0.258	1.20	0.310
Bigbow	231	58--60	3	Removed	0.273	1.22	0.332	0.262	1.20	0.314
Bigbow	231	60--62	3	Removed	0.267	1.07	0.286	0.261	1.07	0.278
Bigbow	231	62--64	3	Removed	0.268	1.09	0.293	0.257	1.09	0.280
Bigbow	231	64--66	3	Removed	0.261	1.12	0.292	0.253	1.06	0.269
Bigbow	231	66--68	3	Removed	0.253	1.27	0.323	0.262	1.20	0.315
Bigbow	231	68--70	3	Removed	0.240	1.07	0.257	0.258	1.17	0.302
Bigbow	231	70--72	3	Removed	0.240	1.23	0.295	0.254	1.10	0.280
Bigbow	232	0-2	3	Retained	0.160	0.98	0.157	0.153	1.27	0.195
Bigbow	232	2--4	3	Retained	0.136	1.26	0.171	0.132	1.51	0.200
Bigbow	232	4--6	3	Retained	0.118	1.44	0.171	0.107	1.70	0.181
Bigbow	232	6--8	3	Retained	0.115	1.55	0.178	0.106	1.55	0.165
Bigbow	232	8--10	3	Retained	0.113	1.57	0.177	0.116	1.52	0.177
Bigbow	232	10--12	3	Retained	0.114	1.57	0.179	0.143	1.63	0.234
Bigbow	232	12--14	3	Retained	0.157	1.57	0.246	0.145	1.60	0.232
Bigbow	232	14--16	3	Retained	0.128	1.57	0.201	0.126	1.56	0.197
Bigbow	232	16--18	3	Retained	0.135	1.45	0.196	0.129	1.51	0.194
Bigbow	232	18--20	3	Retained	0.124	1.65	0.205	0.141	1.50	0.212
Bigbow	232	20--22	3	Retained	0.137	1.48	0.203	0.136	1.55	0.211
Bigbow	232	22--24	3	Retained	0.155	1.56	0.242	0.174	1.58	0.275
Bigbow	232	24--26	3	Retained	0.207	1.59	0.330	0.249	1.28	0.320
Bigbow	232	26--28	3	Retained	0.240	1.32	0.318	0.237	1.16	0.274
Bigbow	232	28--30	3	Retained	0.240	1.12	0.268	0.250	1.42	0.355
Bigbow	232	30--32	3	Retained	0.255	1.24	0.318	0.246	1.40	0.345
Bigbow	232	32--34	3	Retained	0.250	1.24	0.309	0.236	1.19	0.281
Bigbow	232	34--36	3	Retained	0.249	1.42	0.354	0.230	1.30	0.299
Bigbow	232	36--38	3	Retained	0.247	1.23	0.303	0.225	1.29	0.291
Bigbow	232	38--40	3	Retained	0.240	1.23	0.295	0.236	1.36	0.321
Bigbow	232	40--42	3	Retained	0.254	1.32	0.336	0.239	1.15	0.275
Bigbow	232	42--44	3	Retained	0.257	1.19	0.307	0.245	1.31	0.322
Bigbow	232	44--46	3	Retained	0.262	1.20	0.313	0.239	1.17	0.280
Bigbow	232	46--48	3	Retained	0.269	1.28	0.343	0.257	1.24	0.318

Bigbow	232	48--50	3	Retained	0.274	1.21	0.331	0.249	1.15	0.287
Bigbow	232	50--52	3	Retained	0.278	1.20	0.334	0.248	1.05	0.259
Bigbow	232	52--54	3	Retained	0.278	1.35	0.375	0.258	1.25	0.321
Bigbow	232	54--56	3	Retained	0.276	0.91	0.252	0.260	1.00	0.260
Bigbow	232	56--58	3	Retained	0.282	1.00	0.283	0.265	1.13	0.299
Bigbow	232	58--60	3	Retained	0.273	1.20	0.329	0.271	1.09	0.296
Bigbow	232	60--62	3	Retained	0.273	1.08	0.294	0.266	1.08	0.289
Bigbow	232	62--64	3	Retained	0.259	1.14	0.296	0.263	1.07	0.283
Bigbow	232	64--66	3	Retained	0.256	0.94	0.241	0.184	1.25	0.231
Bigbow	232	66--68	3	Retained	0.263	1.20	0.316	0.259	1.25	0.324
Bigbow	232	68--70	3	Retained	0.240	1.13	0.272	0.247	1.11	0.273
Bigbow	232	70--72	3	Retained	0.225	1.36	0.306	0.227	1.25	0.284
Bigbow	241	0-2	4	Retained	0.148	1.20	0.178	0.147	0.81	0.118
Bigbow	241	2--4	4	Retained	0.101	1.39	0.140	0.133	1.11	0.148
Bigbow	241	4--6	4	Retained	0.080	1.37	0.109	0.108	1.55	0.168
Bigbow	241	6--8	4	Retained	0.090	1.51	0.135	0.097	1.69	0.163
Bigbow	241	8--10	4	Retained	0.087	1.53	0.133	0.091	1.57	0.142
Bigbow	241	10--12	4	Retained	0.128	1.39	0.177	0.097	1.61	0.157
Bigbow	241	12--14	4	Retained	0.154	1.40	0.216	0.122	1.53	0.187
Bigbow	241	14--16	4	Retained	0.171	1.50	0.255	0.120	1.60	0.193
Bigbow	241	16--18	4	Retained	0.166	1.31	0.217	0.145	1.49	0.217
Bigbow	241	18--20	4	Retained	0.163	1.36	0.221	0.160	1.68	0.269
Bigbow	241	20--22	4	Retained	0.191	1.70	0.324	0.192	1.36	0.262
Bigbow	241	22--24	4	Retained	0.182	1.37	0.250	0.222	1.28	0.284
Bigbow	241	24--26	4	Retained	0.170	1.34	0.229	0.211	1.25	0.263
Bigbow	241	26--28	4	Retained	0.163	1.44	0.235	0.188	1.16	0.218
Bigbow	241	28--30	4	Retained	0.149	1.22	0.182	0.185	1.32	0.243
Bigbow	241	30--32	4	Retained	0.163	1.68	0.275	0.175	1.33	0.233
Bigbow	241	32--34	4	Retained	0.133	1.76	0.233	0.171	1.31	0.223
Bigbow	241	34--36	4	Retained	0.135	1.52	0.204	0.161	1.20	0.194
Bigbow	241	36--38	4	Retained	0.136	1.50	0.204	0.164	1.29	0.211
Bigbow	241	38--40	4	Retained	0.132	0.82	0.109	0.156	1.42	0.221
Bigbow	241	40--42	4	Retained	0.121	1.04	0.126	0.167	1.40	0.234
Bigbow	241	42--44	4	Retained	0.134	1.27	0.171	0.137	1.48	0.202
Bigbow	241	44--46	4	Retained	0.132	1.53	0.202	0.128	1.45	0.185
Bigbow	241	46--48	4	Retained	0.113	0.67	0.076	0.123	1.33	0.164
Bigbow	241	48--50	4	Retained	0.110	1.47	0.163	0.133	1.51	0.202
Bigbow	241	50--52	4	Retained	0.095	1.00	0.094	0.178	1.27	0.227
Bigbow	241	52--54	4	Retained	0.157	1.56	0.245	0.142	1.37	0.195
Bigbow	241	54--56	4	Retained	0.113	1.02	0.115	0.125	1.34	0.167
Bigbow	241	56--58	4	Retained	0.123	1.61	0.197	0.126	1.47	0.186
Bigbow	241	58--60	4	Retained	0.109	1.20	0.131	0.138	1.37	0.188

Bigbow	241	60--62	4	Retained	0.108	1.05	0.113	0.111	1.31	0.146
Bigbow	241	62--64	4	Retained	0.116	1.03	0.119	0.123	1.43	0.176
Bigbow	241	64--66	4	Retained	0.100	1.12	0.112	0.131	1.35	0.176
Bigbow	241	66--68	4	Retained	0.103	1.43	0.147	0.124	1.25	0.156
Bigbow	241	68--70	4	Retained	0.089	0.63	0.056	0.125	1.04	0.130
Bigbow	241	70--72	4	Retained	0.170	1.70	0.289	0.122	1.36	0.167
Bigbow	242	0-2	4	Removed	0.153	1.08	0.166	0.055	1.22	0.067
Bigbow	242	2--4	4	Removed	0.106	1.36	0.144	0.079	1.48	0.116
Bigbow	242	4--6	4	Removed	0.095	1.30	0.124	0.085	1.52	0.129
Bigbow	242	6--8	4	Removed	0.096	1.51	0.145	0.076	1.64	0.124
Bigbow	242	8--10	4	Removed	0.094	1.57	0.148	0.068	1.35	0.091
Bigbow	242	10--12	4	Removed	0.111	1.97	0.218	0.074	1.68	0.124
Bigbow	242	12--14	4	Removed	0.167	1.51	0.252	0.092	1.54	0.142
Bigbow	242	14--16	4	Removed	0.182	1.61	0.293	0.154	1.47	0.226
Bigbow	242	16--18	4	Removed	0.190	1.58	0.301	0.163	1.58	0.258
Bigbow	242	18--20	4	Removed	0.193	1.48	0.286	0.167	1.66	0.278
Bigbow	242	20--22	4	Removed	0.194	1.55	0.300	0.164	1.35	0.220
Bigbow	242	22--24	4	Removed	0.206	1.47	0.303	0.165	1.38	0.229
Bigbow	242	24--26	4	Removed	0.203	1.07	0.217	0.170	1.47	0.250
Bigbow	242	26--28	4	Removed	0.192	1.38	0.264	0.163	1.34	0.220
Bigbow	242	28--30	4	Removed	0.177	1.50	0.266	0.153	1.42	0.216
Bigbow	242	30--32	4	Removed	0.165	1.38	0.228	0.140	1.32	0.186
Bigbow	242	32--34	4	Removed	0.160	1.56	0.248	0.133	1.34	0.179
Bigbow	242	34--36	4	Removed	0.141	1.15	0.162	0.129	1.41	0.182
Bigbow	242	36--38	4	Removed	0.139	1.47	0.204	0.128	1.29	0.164
Bigbow	242	38--40	4	Removed	0.144	1.42	0.204	0.134	1.26	0.168
Bigbow	242	40--42	4	Removed	0.150	1.00	0.149	0.137	1.39	0.190
Bigbow	242	42--44	4	Removed	0.144	1.06	0.153	0.127	1.49	0.189
Bigbow	242	44--46	4	Removed	0.139	1.33	0.185	0.132	1.50	0.198
Bigbow	242	46--48	4	Removed	0.141	1.54	0.217	0.122	1.34	0.164
Bigbow	242	48--50	4	Removed	0.170	1.35	0.228	0.119	1.43	0.170
Bigbow	242	50--52	4	Removed	0.165	1.54	0.253	0.104	1.67	0.174
Bigbow	242	52--54	4	Removed	0.163	1.58	0.257	0.101	1.54	0.156
Bigbow	242	54--56	4	Removed	0.129	1.55	0.200	0.107	1.49	0.159
Bigbow	242	56--58	4	Removed	0.121	1.58	0.190	0.125	1.37	0.171
Bigbow	242	58--60	4	Removed	0.116	1.44	0.167	0.118	1.41	0.166
Bigbow	242	60--62	4	Removed	0.104	1.39	0.143	0.110	1.33	0.147
Bigbow	242	62--64	4	Removed	0.113	1.45	0.164	0.120	1.30	0.157
Bigbow	242	64--66	4	Removed	0.137	1.38	0.189	0.121	1.46	0.178
Bigbow	242	66--68	4	Removed	0.176	1.44	0.254	0.107	1.36	0.146
Bigbow	242	68--70	4	Removed	0.177	1.04	0.183	0.104	1.44	0.150
Bigbow	242	70--72	4	Removed	0.177	1.20	0.212	0.100	1.52	0.153

Table F.2 Penetrometer and vane shear strength measurements collected 19 May 2009 at Hugoton L and Bigbow FSL site.

Penetrometer and Vane Shear Strength Measurements					
Field	Plot	Block	Treatment	Pocket Penetrometer	Vane Shear Strength
				kg/cm^2	kg/cm^2
Hugoton	111	1	Retained	3.2	0.7
Hugoton	112	1	Removed	3.1	0.9
Hugoton	113	1	Removed	3.8	0.7
Hugoton	114	1	Retained	3.0	0.7
Hugoton	121	2	Removed	2.9	0.9
Hugoton	122	2	Retained	2.6	0.8
Hugoton	123	2	Retained	3.1	0.7
Hugoton	124	2	Removed	1.9	1.2
Hugoton	131	3	Removed	2.7	0.7
Hugoton	132	3	Retained	2.7	0.8
Hugoton	133	3	Removed	3.2	0.7
Hugoton	134	3	Retained	2.7	0.7
Hugoton	141	4	Retained	2.9	0.9
Hugoton	142	4	Removed	3.0	0.9
Hugoton	143	4	Retained	2.6	1.1
Hugoton	144	4	Removed	2.1	1.1
Bigbow	211	1	Retained	2.2	1.4
Bigbow	212	1	Removed	1.3	1.3
Bigbow	213	1	Removed	1.6	1.4
Bigbow	214	1	Retained	1.7	1.3
Bigbow	221	2	Removed	1.3	1.0
Bigbow	222	2	Retained	1.6	1.0
Bigbow	223	2	Retained	1.5	0.9
Bigbow	224	2	Removed	1.3	1.0
Bigbow	231	3	Removed	1.7	1.0
Bigbow	232	3	Retained	1.4	1.1
Bigbow	233	3	Removed	1.5	1.1
Bigbow	234	3	Retained	1.1	0.9
Bigbow	241	4	Retained	1.1	0.7
Bigbow	242	4	Removed	1.5	0.8
Bigbow	243	4	Retained	1.2	1.1
Bigbow	244	4	Removed	1.7	0.8