Cover crops for soil health and forage

by

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Abstract

Cover crops have numerous benefits and while cover crops have been used for centuries, currently there are few producers in Kansas growing them and so there is a need for additional research on how cover crops affect soil properties, and on the potential for utilizing cover crops as forage. Two studies are presented in this thesis. The first study evaluated the use of cover crops in a vegetable production system as compared to a fully tilled control. This study evaluated soil physical properties in the form of wet aggregate stability and infiltration, and microbial properties by soil microbial biomass carbon (MBC). Over the three year study, the most pronounced differences observed were in the wet aggregate stability between the cover crop and control treatments where the cover crop treatments had better soil aggregation compared to the control. At the conclusion of the study, there was not a difference between fall and spring planted cover crop treatments. The second study evaluates species composition and forage quality of various combinations of multi-species cover crop mixtures. This study evaluated sixteen treatments, each consisting of a three-way mixture of a brassica (turnip or radish), grass (rye, wheat, barley, oat), and a legume (berseem clover or Austrian winter pea). Species composition analysis found that the brassica species dominated the mixtures (60-80% by mass on a dry weight basis) in 2014 while the grass species were dominant (62 – 67%) in 2015. Overall all treatments produced prime quality forage (as compared to hay values), however some treatments cost significantly more to plant than others. Therefore an economic analysis compared the treatments and found that the treatments containing turnips and oats generally provided the best return on investment given that both of these species were among the cheapest to plant and produced moderate to high biomass compared to the other treatments. The results of

these projects point to the potential benefits that cover crops can have for producers interested in improving soil or utilizing cover crops for forage.

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GREAT PLAINS
GRAZING
CATTLE, CLIMATE, CULTURE & CHANGE

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Chapter 1 - Cover Crop Effects on Soil Properties in a Three-Year No-Till Pumpkin Experiment

Abstract

Vegetable crop production typically involves smaller acreages than agronomic production but relies heavily on intensive cultivation of soil to manage weeds and prepare the seedbed for planting. Over time, extensive tillage can have negative effects on soil structure and microbial properties, because soil is more prone to erosion when aggregation is reduced, and nutrients cycle most efficiently with a healthy microbial community. Conservation agriculture refers to production practices which lend themselves to sustainability. This three-year study evaluates the use of cover crops and the practice of no-till in pumpkin production. For this study, no-till is defined as the pumpkin cash crop no-till planted into a terminated cover crop residue mat. Treatments were a control (no-cover crop, and tilled ≥ twice annually); the other seven treatments were either a fall-planted cereal rye or rye mixed with other species, or spring-planted oats or oat/pea mix. Soil wet aggregate stability was determined by wet sieving. Microbial biomass carbon and dissolved organic carbon were determined using the 0.5 *M* K_2SO_4 extraction method. The main soil physical property that was affected by cover crops in this study was an improvement in soil aggregation, while lesser effects were observed for water infiltration and bulk density. Soil aggregation improved over the duration of this study at both sites. While these changes did not occur immediately, soil aggregation showed differences between cover crop treatments (tilled once/year) compared with the control (tilled ≥twice/year). The cover crop treatments were first planted in fall 2012 but the differences between the control and the cover cropped treatments were not statistically significant until fall 2014 for Olathe and spring 2014 for Wichita. These differences continued to become more pronounced at both sites

throughout the remainder of the study. This study illustrates the potential for conservation agriculture practices as having a positive effect on soil health, and for some parameters, this change can happen in as little as 1.5 to 2 years.

Introduction

Conservation agriculture (CA) provides many potential benefits to soil and ecosystems. Some of these benefits may include reduced soil erosion, increased soil microbial properties, and improved water infiltration rates (Magdoff and Van Es, 2009). According to the Food and Agriculture Organization of the United Nations, CA is defined as

> "an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. CA is characterized by three linked principles, namely: 1) Continuous minimum mechanical soil disturbance. 2) Permanent organic soil cover. 3) Diversification of crop species grown in sequences and/or associations." (FAO, 2015)

Tillage practices, residue cover, and cover crops can have significant impacts on some of the most sensitive soil properties almost immediately, while other properties (such as the soil organic matter) may take several years to change (Balesdent, et al., 2000).

Wind and water erosion can reduce soil quality and crop productivity through loss of nutrients (Al-Kaisi, 2009). Soil erosion also results in reduced organic matter levels (Fenton, et al., 2005). Cover crops with fibrous root systems such as cereal rye (*Secale cereale*) help to keep soil in place and reduce erosion from runoff (Locke, et al., 2015).

Although these benefits are important for long-term sustainability of crop yields and soil resources, the amount of acreage in Kansas that is cover cropped is a small fraction, with ≈

121,000 ha planted to cover crops out of ≈ 8 million hectares of cropland according to the most recent data collected in the 2012 Census of Agriculture (USDA-NASS, 2014). To encourage wider adoption of this practice necessitates additional research to understand the various impacts on soil properties.

A cover crop is grown during the dormant period following a cash crop and terminated before the planting of the next crop (Hartwig and Ammon, 2002). Cover crops are not a new idea; the USDA 1938 Yearbook of Agriculture refers to their use in maintaining soil organic matter (Pieters and McKee, 1938). Sweet clover was commonly grown prior to WWII as a green manure crop to provide nitrogen (N) to the soil prior to the production of N fertilizer (Sarrantonio and Gallandt, 2003).

According to the Sustainable Agriculture Research and Education 2015-2016 Cover Crop Survey, 82% (994) of the 1,219 respondents planted cereal rye as a cover crop (SARE, 2015-2016). Cereal rye (*Secale cereale*) is one of the most common fall-planted cover crops because the fibrous root system has the ability to hold soil together, reducing erosion, and can also take up excess nitrogen (N) (Brandi-Dohrn, et al., 1997, Clark, 2008). Cereal rye can help to suppress weeds (Mischler, et al., 2010).

Different cover crop species can have varying effects on soil properties and species selection is naturally limited by producer needs such as time of planting, time of termination, cost, and potential weed or pest issues in future crop rotations. For example, cereal rye can be a weed problem in wheat production (Pester, et al., 2000).

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Cover crops used in no-till crop production systems have been found to enhance soil physical properties such as improved water infiltration rates, reduced surface bulk density, increased soil organic carbon (SOC) concentration, and increased volumetric water content (Blanco-Canqui, et al., 2011, Haruna and Nkongolo, 2015). These improved physical properties suggest that the use of cover crops may reduce soil susceptibility to compaction. Haruna and Nkongolo (2015) reported a 9% reduction in bulk density in the second year of using cereal rye as a cover crop in a no-till field (Haruna and Nkongolo, 2015). Blanco-Canqui, et al. (2011) observed increased soil water content and reduced soil temperature using sunn hemp (*Crotalaria juncea*) and late-maturing soybean (*Glycine max*). A study in California's Sacramento Valley found the use of common vetch (*Vicia sativa*) as a single winter cover crop in addition to oats (*Avena sativa* L.) and purple vetch (*Vicia benghalensis* L.) reduced runoff compared to fallow treatments (Joyce, et al., 2002)

There has been considerable interest recently concerning the question of mixed vs. single species cover crops. Cover crop mixtures are thought to increase the benefits from cover crop monocultures by offering diverse soil health benefits due to different plant types and rooting structures. Some observed benefits to planting a cover crop containing multiple plant species include increased utilization of sunlight, water and soil nutrients through complementary rooting and growth structures (Buck, 2013, Russell and Bisinger, 2015). By mixing different plant species into a cover crop mix, producers could potentially utilize beneficial properties of nitrogen-fixing legumes, high biomass-producing grasses, and nitrogen-scavenging brassicas.

Research comparing the benefits of cover crop mixtures to monocultures is not extensive. Brennan et al. (2011) evaluated five legume-rye mixtures, as well as rye alone, in a vegetable production system in California and measured aboveground biomass and tissue C and N, but did not evaluate subsequent effects on soil health or vegetable yield (Brennan, et al., 2011). Finney et al. (2016) evaluated cover crop mixtures in relation to biomass production and ecosystem services in Pennsylvania, finding cover crop mixtures did not produce greater biomass than a high-yielding cover crop monoculture, indicating that functional traits should be considered in addition to biomass alone (Finney, et al., 2016).

Vegetable production systems typically center on high-value crops produced on small acreages with intensive soil cultivation which can be detrimental to soil health by reducing soil aggregation, increasing compaction and reducing soil organic matter (SOM) (Magdoff and Van Es, 2009, Nair, et al., 2014, Uri, 1999). In the last decade, the high-value crops—lettuce, tomatoes, sweet corn, green beans and peppers—are frequently raised in these environments and sold at local farmers markets and community supported agriculture groups (CSA).

Pumpkins are also a common horticultural crop which are frequently sold at local pumpkin patches and farmers markets. In 2015, 17,482 hectares were planted in the U.S. worth $90.2 million (USDA Vegetables 2015 Summary). In 2014 per capita consumption of pumpkins was 2.4 kg per person (USDA-ERS, 2015). In 2012 pumpkins were grown on 98 farms covering 204 hectares in Kansas, down from 135 farms and 396 ha in 2007 (USDA-NASS, 2014).

Hoyt, et al. (1994) reviewed the benefits and challenges of conservation tillage in vegetable production systems. Soil and water conservation and labor-related parameters were the most common benefits, and weed and nutrient management were among the disadvantages at the time of the review.

In addition to the benefits of cover crops on soil aggregation and overall soil health, there is also potential for cover crops to influence soil microbial biomass. A study in Argentina found that cover crops in no-till sorghum production increased soil microbial biomass carbon (MBC) compared to treatments without a cover crop (Frasier, et al., 2016). Dinesh et al (2009) observed more than 50% greater MBC in soils with leguminous cover crops versus a non-cover cropped control 12 years after the study was initiated (Dinesh, et al., 2009).

Though many studies have reported the benefits of cover crops to soil health, some properties take longer to change than others. Therefore, the focus of this three-year project was on measuring the most dynamic soil properties. The specific objectives of this study were to evaluate changes in soil structural properties as well as microbial biomass and dissolved organic C in soil resulting from conservation practices such as cover crops and reduced tillage in a horticultural production system and compare these to the common practice of intensive tillage.

Materials and Methods

Description of Study Sites and Soils

Replicated research plots were planted at two university locations (Figure 1) which were (1) Kansas State University Research and Extension Center-Olathe (38.90 N, -95.00 W, 264 m above sea level), on a Kennebec silt loam soil; and (2) the John C. Pair Horticulture Center (near Wichita, KS, 37.52 N, -97.31 W, 378 m above sea level) on a Canadian-Waldeck fine sandy loam soil. For brevity, these sites will be referred to as Olathe and Wichita for the remainder of the paper. The study began in 2012 and concluded in 2015 at the end of the pumpkin growing season.

Description of Field Management

All plots were tilled with a John Deere rototiller (Moline, IL) in October 2012; following tillage, rye and rye-mixed cover crops were planted. The cover crops were seeded with a handheld rotary spreader, then incorporated with a Brillion cultipacker (Landoll Corporation, Marysville, KS) to firm the seed into the soil. The treatments included conventional tillage (control) and seven cover crop treatments. Cover crops were terminated with a crimper roller each June, approximately 2-weeks before pumpkin planting. One exception was in 2013 the cover crops at the Wichita location were terminated with a flail mower. Following cover crop termination, pumpkins were planted as seeds or transplants directly into the soil (see Table 1.2 for timeline of field operations and whether pumpkins were planted as seeds or transplants). The control plot was tilled both in fall and spring prior to pumpkin planting. A diagram of the pumpkin plot is shown Figure 1.2. Each cover crop plot was 9.1 x 18.3 meters, containing three rows of pumpkins. All treatments were replicated three times in a randomized complete block design. The cover crop species were cereal rye (*Secale cereale*), Austrian winter pea (*Pisum sativum subsp. arvense*) hairy vetch (*Vicia villosa*), canola (*Brassica napus*), and oat (*Avena sativa*). Seeding rates are found in Table 1.2. Cover crops planted in October consisted of rye, and rye mixes. Cover crops planted in March consisted of oat or an oat/pea mixture. At each of the study sites, soil health was assessed at two key times; plots were sampled 2-3 weeks after pumpkin planting, and immediately after pumpkin harvest. In this thesis pumpkin yield and other parameters such as disease incidence, are not presented but were collected by other researchers involved in this project.

Baseline soil sampling and measurements

Soil samples were collected in fall 2013 to characterize the particle size and SOC in general for the site. Fifteen soil cores from the 0-15 cm depth were randomly sampled from across the entire study area shown in Figure 1.3, composited into a plastic bag and transported to the Kansas State University Department of Agronomy Soil Testing Laboratory. Particle size analysis was done by the pipette method (Gee and Bauder, 1986) to determine soil texture. SOC was measured by the LECO TruSpecCN analyzer (LECO Corp., St. Joseph, MI). Note that these soils do not contain free calcium carbonate.

Cover Crop Biomass

Cover crop biomass was clipped in June 2014 and 2015 (not collected in 2013). Biomass was collected by clipping one square meter area after cover crop termination by crimper roller and prior to pumpkin planting. One square meter area was clipped in each plot. Biomass was then dried at 70^{o} C for at least 96 hours to determine dry matter.

Water Stable Aggregates

Wet sieving procedures were used to determine water stable aggregate (WSA) distributions of the 0-5 cm soil depth. Samples were collected twice each year of the project, 2-3 weeks after pumpkin planting and again post-harvest. Approximately 2 kg of soil were collected from the surface 5 cm depth from three random areas in each plot and placed into cloth bags and allowed to air dry. Once air dried, the soil was sieved to collect aggregates <8 mm and >4.75 mm in size to determine the percent WSA. A sub sample containing a minimum of 40 g of >4.75 mm aggregates was oven dried for a minimum of 48 hours at 105°C to determine gravimetric water content. Size distribution of WSA was determined using a 50 g subsample of air-dried soil and a wet sieving method noted by Kemper and Rosenau (1986). This was accomplished using a machine (Grainger, Inc., Lake Forest, IL) that moved four nests of sieves, each set in a separate compartment, through vertical displacement of 35 mm at 30 cycles min^{-1}. Each nest of sieves contained five sieves of 127 mm diameter and 40 mm depth with the following screen openings: 4.75; 2.00; 1.00; 0.50; and 0.25 mm (Newark Wire Cloth Company, Clifton, NJ).

The air-dry aggregates were placed on the top sieve (4.75 mm), saturated with water for 10 min, and then mechanically sieved in water for 10 min. The soil remaining on each sieve after wet sieving was washed into pre-weighed glass jars and oven dried for a minimum of 48 hours at 105°C to obtain soil mass. The oven-dry soil was soaked for a minimum of 24 hours in a 13.9 g L^{-1} sodium hexametaphosphate solution to facilitate the separation of coarse fragments from soil particles. The dispersed samples were then washed through the corresponding sieves in order to collect and account for coarse fragment content. Using the equation from Stone and Schlegel (2010), MWD was calculated as shown:

$$MWD = \Sigma\ (i=1, \text{ to } 6)\ (w_i/m_a)x_i$$

where

w_i represents the oven-dry mass of aggregates (w_1 through w_5) determined for each of the five sieve sizes (aggregates and fragments after sieving [m_m] minus fragments on the same sieve after dispersion [m_f]) and dry mass (w_6) of material passing through the sieve with 0.25 mm openings during sieving (Kemper and Rosenau, 1986), x_i represents the mean diameter of each of the six size fractions (size of smallest fraction [x_6] was calculated as 0.25 mm/2)

m_a is the total dry mass of aggregates (sum of w_1 through w_6).

Microbial Biomass Carbon (MBC) and Dissolved Organic Carbon (DOC)

Composite soil samples were collected from each plot for MBC analysis (Cabrera and Beare, 1993, Jones and Willett, 2006, Vance, et al., 1987) using a single 0.5 *M* K_2SO_4 extraction method A composite sample of soil cores from 0 - 15 cm depth and 2.5 cm diameter were collected from 15 random locations within each plot twice during each year. Samples were collected two to three weeks after planting pumpkins, and again post-harvest. Soil probes were sanitized in the field between each plot using rubbing alcohol and paper towels. The first core from each plot was discarded prior to collecting sample cores to prevent cross contamination between samples. After collecting the composite sample from each plot, samples were sealed in plastic bags and stored in a cooler with ice until samples could be transported to a refrigerator. Once back at the lab, samples were stored in a refrigerator at 4^{o} C until they could be sieved through a 2 mm sieve (W.S. Tyler Industrial Group, Mentor, OH) at field moisture. Sieves were washed between samples and sanitized with ethanol. Once sieved to achieve homogeneity, 8 grams of soil were weighed in duplicate into 125 mL Erlenmeyer flasks. The first of the duplicate samples (unfumigated) was extracted with 40 ml 0.5 *M* K_2SO_4. The flasks were capped and shaken for 30 minutes at slow speed on an oscillating shaker (Eberbach Corporation, Ann Arbor, MI). After shaking, samples were filtered through Whatman 42 filter paper (11-cm diameter) to remove soil particles. At the same time the second set of flasks were fumigated with chloroform under vacuum in a vacuum desiccator (Corning Inc., Corning, NY) for 24 hours prior to extraction (Fum_c). Moist paper towels lined the desiccator to maintain humidity. Approximately 25 mL chloroform was added to a 100 mL beaker and placed inside the desiccator. A vacuum pump was attached and used to evacuate until the chloroform boiled for 5 minutes. The air vent was then closed and the samples fumigated for 24 hours. Following fumigation, the vacuum was released, chloroform and paper towels removed, and the desiccator was evacuated six times for 3 minutes each to facilitate the removal of chloroform. Samples were then extracted in the same manner as the unfumigated samples. Filtrate was stored at $4^{o}C$ until analyzed for carbon using a Total Organic Carbon analyzer (TOC-L) (Shimadzu Corporation, Columbia, MD). The instrument was calibrated with standards and accuracy was verified throughout the run with standards analyzed as unknowns and with certified quality control samples. To account for carbon in the filter paper, a blank was run with each extraction set (unfumigated) and each desiccator (fumigated). Microbial biomass was calculated from the difference between C in the fumigated and unfumigated samples and expressed per g dry soil.

$$MBC = (C_{fum} - C_{unfum})$$

Where MBC = microbial biomass carbon (μg C g^{-1} soil), C_{fum} = organic C in fumigated sample (μg C g^{-1} soil), and C_{unfum} = organic C in unfumigated sample (μg C g^{-1} soil).

Dissolved organic carbon (DOC) was determined to be the C measured in the unfumigated samples C_{unfum} expressed per g dry soil.

Infiltration and Runoff

Infiltration was measured using the single ring (flooded/ponded) method as described in the NRCS Soil Quality Test Kit Guide (USDA-NRCS, 2008). A 25.25 cm diameter ring was pounded into the soil to a depth of 7.62 cm using a wooden block and a sledge hammer. A sheet of plastic wrap was placed over the ring and 2.5 cm of water (444 ml) was poured over the plastic. The plastic was gently removed and the timer started. Each ring was timed until the soil surface was glistening. Infiltration rate was calculated by dividing the minutes it took for 2.5 cm of water to infiltrate.

Bulk Density and Soil Water Content

Samples were collected two different times during the project year: two-three weeks after planting and post-harvest. Samples were collected from one random location within each plot; dry bulk density was determined using the core method (Blake and Hartge, 1986). Using a slide hammer sampler (AMS Inc., American Falls, ID), 5-cm diameter samples were collected at depths of 0-5, and 5-10 cm. Soil cores obtained were placed in airtight cans and the wet weight was determined the same day as collection. Samples were then oven dried at 105°C for a minimum of 48 hours. Once a constant mass was reached, bulk density was calculated as shown:

$$P_b = W_{ods}/V_s$$

where

P_b = dry bulk density (g/cm^3)

W_{ods} = weight of oven-dry soil (g)

V_s = total volume of soil (cm^3)

From these same samples, water content by mass was calculated as shown:

$$w = M_w/M_s$$

where

w = water content by mass (g/g)

Mw = mass of the water (g)

Ms = mass of the dry soil (g)

Statistical Analysis

The study was randomized complete block design (RCBD). Factors were control, fall-planted cover crops, spring-planted cover crops, all cover crops, and all eight treatments. Each sampling period was analyzed separately by site and sampling time. A one-way analysis of variance was performed four different ways: a) comparison of cover vs. control treatments, b) comparison of fall cover vs. spring cover, c) comparison of fall cover vs. spring cover vs. control, d) comparison of all 8 treatments together.

Statistical analysis was completed using SAS 9.4 (Cary, NC) with the Proc Mixed procedure. Means were separated at a least significance of 0.10. Values shown in tables and figures are arithmetic means.

Results

The baseline soil characterization data is presented in Table 1.1. The Olathe soil is a silt loam with 2.2 % SOC. The Wichita soil is a loamy sand with 0.96 % SOC.

The data is organized in the following manner. The first heading will be the soil or plant property that was analyzed. For each property, the data will be discussed by year, and each year, the data will be shown for each site (first for Olathe, and then for Wichita).

Cover Crop Biomass

Cover crop biomass production differed at both sites from 2014 to 2015 Table 1.4 compares cover crop biomass by treatment. At Olathe in 2014, rye/vetch/canola and oat treatments produced more biomass than rye, and rye/canola treatments with the other treatments ranking intermediate (p=0.01). At Wichita in 2014, the spring-planted cover crop species (oat and oat/pea produced) the more biomass, than the fall-planted (rye, rye/vetch, rye/canola, rye/vetch/canola) treatments with the exception of rye/pea which was intermediate (p=0.01) Table 1.4.

Comparing spring- and fall-planted cover crop species, in 2014 at Olathe, spring planted cover crop biomass was 5690 kg ha^{1} versus 4909 kg ha-^{1} for fall-planted covers; however, this difference was not significant (p=0.14). In Wichita, in 2014, the spring-planted covers yielded significantly more biomass with 7373 kg ha^{-1}, and the fall-planted covers yielded 5865 kg ha^{-1} (p=<0.0001) Table 1.5.

In 2015, there were no treatment differences at either site for fall- versus spring-planted and there were no differences in biomass when compared among individual treatments Tables 1.4, 1.5.

Wet Aggregate Stability

Water stable aggregate data is presented as the percent of aggregates retained on each sieve, sum of aggregates retained on sieves, and the mean weight diameter (MWD) of the aggregates. MWD is a single value that represents the average sized aggregate diameter for a soil sample.

At Olathe in the fall 2013 sampling period there were no significant treatment differences in water stable aggregates (Figure 1.3 and Table 1.6). There was also no difference in MWD for any treatments, nor was there a difference when comparing the no-cover control versus all cover crop treatments. In addition, there were no differences between the different cover crop treatments (Table 1.7)

At Wichita in fall 2013, there were no differences in the MWD when comparing the control to the cover cropped treatments (Table 1.9), nor for any of the size fractions (Figure 1.4a). There were however differences within the size fractions when comparing the fall-planted versus spring-planted cover crop treatments (Figure 1.4b). The spring cover treatments contained a greater amount of >4.75 mm size aggregates, whereas the fall cover contained more aggregates in the 2 to 4.75 and 0.5 to 1 mm fractions.

At Olathe in spring 2014 the only difference between the no-cover control and the cover crop treatments was in the middle two size fractions where the control contained more aggregates in the 1 to 2 mm and the 0.5 to 1 mm size fractions than the cover crop treatments (Figure 1.5), however, there were no differences in total aggregation. Similarly there were no differences in MWD (Table 1.11).

At Wichita in spring 2014 (Table 1.13) the MWD was larger for all cover crop treatments compared to control (p=0.03). The MWD for control was smaller (2.44 mm), compared to spring planted cover (3.28 mm) and fall planted cover (4.3 mm). Figure 1.6 displays the aggregation by size fraction. On average, the total aggregation was 81% for the cover and 62% for the control (p=0.015). This difference is largely due to fact that the control contained 54% of aggregates >4.75 mm while the control contained 29%. In the smallest two size fractions, 0.25 to 0.5 and <0.25 mm the cover contained less than the control. When comparing fall vs spring planted cover crops, the fall had a greater proportion of the largest aggregates, greater total aggregation, and a larger MWD than the spring (Figure 1.6 and Table 1.13). When comparing control to spring and fall planted cover, the fall contained the greatest amount of >4.75 and total aggregation, while the spring and control were not different from each other (Figure 1.6c and Table 1.13). Between the individual treatments, one cover crop treatment that differed from the others is the oat/pea mixture. This treatment was more similar to the control than the other cover crop treatments. The oat/pea and the control contained the least amount of >4.75 mm and largest proportion of <0.25 mm, and less total aggregation compared to the other cover crop treatments (Table 1.12) These two treatments also had the smallest MWD values approximately half the average diameter compared to the rye/canola treatment Table 1.13.

Fall 2014 was the first time differences in water stable aggregates (WSA) were measured at the Olathe site. Cover crop treatments had greater total aggregation, larger mean weight diameter, and larger percent of large aggregates (>4.75 mm) when compared to control (Figure 1.7 and Table 1.14). Fall-planted cover crops had greater total aggregation, larger MWD, and larger percent of large aggregate size compared to spring-planted cover crops. When comparing fall, spring, and control together, the spring-planted cover crops were more similar to the control than the fall-planted cover crops for the >4.75, 2 to 4.75, and 0.25 to 0.5 mm size classes. The control, fall, and spring-planted cover crops grouped separately for <0.25 mm and total aggregation (Figure 1.7c). The fall-planted cover crops appear to be showing improved soil structure with increased total aggregation and more large size aggregates. Between treatments, the greatest differences were observed when comparing rye/canola and rye/vetch/canola, which had more than 34 percent aggregates >4.75 mm, versus the oat, oat/pea, and control treatments, which had less than 22 percent in that same size fraction ($p=0.007$) (Table 1.14).

At Wichita in fall 2014 cover crop treatments had more aggregates in the largest size fraction >4.75 mm compared with the control treatment (Figure 1.8a), but there were few differences in the other size fractions and no difference in total aggregation or MWD (Table 1.17). Between individual treatments, the greatest difference in aggregates >4.75 mm were between the treatments containing rye, versus the oat and control (Table 1.16). The oat/pea treatment contained 20 percent more aggregates in the >4.75 mm fraction than the oat treatment but these two treatments did not differ from each other in any other size fraction and the reason for this difference is not known, particularly because these treatments contained similar cover crop biomass (>7500 kg ha^{-1}) (Table 1.4).

For the spring 2015 Olathe aggregates, cover versus control comparison, there are differences in 4 of the 6 size class fractions. The cover crop contained more aggregates in the >4.75, mm size fraction, and the control contained more aggregates in the three size ranges spanning 0.25 to 2 mm (Figure 1.9a). When comparing spring and fall cover crops, fall planted cover crop treatments showed more aggregates in the largest size class (>4.75 mm) and the spring cover crops contained more aggregates in the <0.25 size fraction (Figure 1.9b). When comparing spring, fall, and control, the spring and control treatments tended to be more similar to each other, or intermediate versus the fall (Figure 1.9c). There was no difference in total aggregation between cover and the control (Figure 1.9a), fall versus spring cover crops (Figure

1.9b), or between any of the individual treatments (Table 1.19). When comparing treatments separately, the rye/vetch/canola and rye treatments contained significantly more >4.75 mm aggregates and a greater MWD as compared to the oat, oat/pea, and control treatments (Table 1.19).

At Wichita in spring 2015, there are many differences between cover crops and control. (Figure 1.10a and Table 1.21). In all of these comparisons, the cover crop treatments exhibit more aggregates in the largest size class, fewer in the smaller size classes, more total aggregation, and a larger MWD compared to control. On average, cover crop treatments had MWD values that were three times larger than the control and total aggregation was double that of the control (Table 1.21). There were no differences between fall and spring cover (Figure 1.10b). When individual treatments are compared, the cover crop treatments all differ from the control with larger MWD, more total aggregation and >4.75 and fewer aggregates spanning the 0.5 and <0.25 mm size classes (Table 1.20)

At Olathe in fall 2015 there are differences in cover vs. control, in MWD, total aggregation and all classes except for the second to largest size class (2 – 4.75 mm) (Figure 1.11 and Table 1.23) with cover crops showing increased aggregation, larger aggregate size, and larger MWD than control. There were no differences in spring versus fall cover crops. When comparing control, fall-planted, and spring-planted cover crops, the same differences occur as with cover versus control. Between individual treatments, there are differences in the 0.5 to 1, and <0.25 mm size classes with cover crops grouping separate from control. There is also a difference in total aggregation (p=0.09) with cover crop treatments exhibiting more total aggregation (>90%) than the control treatment (85%) (Table 1.22).

At Wichita in fall 2015 all size fractions, total aggregation, and MWD were significantly different when comparing cover to control. The cover crop treatments had more aggregates in the largest size class (>4.75), and more total aggregation as well as a larger MWD (Figure 1.12a and Table 1.24). No differences were present between fall and spring-planted cover crops Figure 1.12b). When comparing between individual treatments, all water stable aggregate properties were significant between the control and cover crop treatments (Tables 1.24, 1.25). The most notable difference is for the >4.75 mm size fraction where cover crop treatments ranged from 83 to 92% of the aggregates retained on this sieve versus 56% for the control (p=0.0001). The total aggregation was greater than 93% for all covers versus 83% for the control. There were not however differences between individual cover crop treatments.

Some themes that have emerged for water stable aggregates, in most sampling periods, was that the cover cropped treatments differed from the control, especially toward middle and end of the project. The first sampling where notable differences were observed was Wichita spring 2014, and Olathe fall 2014. These trends continued through the remainder of the project. Overall, in the earlier stages of the project, it looked like fall-planted treatments grouped separate of spring-planted and control. This may be a result of the ground being protected by a cover crop over the winter. As the project progressed, the fall and spring cover crops appeared to have a similar effect on water stable aggregates, and cover crop treatments were better than the control. The differences appeared more significant in the spring sampling period than the fall. This may be due to the control plots being tilled 2-3 weeks prior to that sampling period which could reduce soil aggregate stability in the control plots compared to the plots only tilled in the fall (following soil samples).

Microbial Biomass Carbon (MBC) and Dissolved Organic Carbon (DOC)

MBC measures fungi and bacteria present in the soil, DOC measures labile carbon in the soil. These properties can change slowly and there were very few differences in these properties in this three-year study.

At Olathe in fall 2013, there are no statistical differences for either MBC or DOC in any of the comparisons (Table 1.7).

At Wichita in fall 2013, the MBC data is not presented due to laboratory error. Overall there are no differences between control versus or between fall- and spring planted cover crop treatments in DOC (Table 1.9), however, there were differences among treatments for DOC (Table 1.9). The rye treatment contained the most DOC, the control contained the least, and the other treatments were intermediate (p=0.094).

At Olathe in spring 2014 the MBC was greater and the DOC was lower for the cover crop treatments (Table 1.11). There was no difference in MBC or DOC when comparing the fall and spring cover crop treatments. There were significant treatment differences in MBC (p=0.08) between the rye/vetch (218.86 $\mu g\ C\ g^{-1}$ soil) which is two times as much MBC compared to rye/pea, rye/vetch/canola, oat, oat/pea, and control treatments (Table 1.11). There were no differences in DOC among treatments.

At Wichita in spring 2014, the cover crop treatments had more MBC than the control (p=0.01) but there was no difference in DOC (Table 1.13). There was however no difference in MBC when comparing fall- versus spring-planted cover, however the fall-planted contained more DOC than the spring-planted cover (p=0.02). There were not significant treatment differences in MBC, however there were differences among treatments in DOC (p=0.04). The treatments containing the most DOC were rye/vetch/canola, and rye/pea, and the treatments which contained the least were oat, rye, and control (Table 1.13). It is interesting to note that the cover crop mixtures all contained more DOC than the plots that contained just oat or rye alone.

At Olathe in fall 2014 there are no differences in MBC or DOC when comparing cover to control, or fall- versus spring-planted cover crops, or when comparing individual treatments (Table 1.15).

At Wichita in fall 2014 there were no differences in MBC, and the only difference was that the DOC was greater for cover crop treatments than the control (p=0.09) (Table 1.17).

At Olathe in spring 2015 there were no differences in MBC or DOC (Table 1.19).

At Wichita in spring 2015 there were no differences for MBC, but the DOC was greater for the cover than the control (p=0.02). There were no differences among individual treatments (Table 1.21).

At Olathe in fall 2015 there were no differences in MBC or DOC (Table 1.23).

At Wichita in fall 2015 there were no differences in MBC but the DOC was greater for the cover crop treatments than the control (p=0.04), and the fall-planted cover crops contained more DOC than the spring-planted cover crops (p=0.02) (Table 1.25). Among individual treatments rye/vetch/canola contained the most DOC than did the oat, oat/pea, and control treatments (p=0.05) (Table 1.25).

Infiltration

Infiltration was not measured at either site in fall 2013 (Tables 1.7, 1.9).

There were no significant differences at either site in spring 2014 (Tables 1.11, 1.13).

In fall 2014, there were no differences at Olathe, and infiltration was not measured at Wichita due to inclement weather (Tables 1.15, 1.17)

In spring 2015, there were no differences at Olathe (Table 1.19). At Wichita in spring 2015, the infiltration was 9.90 min cm^{-1} for the control and 3.47 min cm^{-1} for the cover crop treatments (p=0.002). There were no differences between fall- and spring-planted cover crops (Table 1.21).

There were no significant differences at either site in fall 2015 (Tables 1.23, 1.25).

Bulk Density (BD)

The only significant difference in the fall 2013 Olathe bulk density is the 0-5 cm depth when comparing fall- and spring-planted cover crops (p=0.097) (Table 1.7).

At Wichita in fall 2013, there were no differences in BD. Note that the 5-10 cm depth was not collected in the fall of 2013 for either location (Table 1.9)

At Olathe in spring 2014, in BD 5-10 cm depth, the control had a bulk density of 1.07 g cm^{-3} compared to the cover crop treatments with 1.22 g cm^{-3} (p=0.03). There was no difference between fall- and spring-planted cover crops (Tables 1.11).

There were no differences in bulk density at Wichita in spring 2014 (Table 1.13).

At Olathe in fall 2014, there was a difference in BD at the 5-10 cm depth between control with 1.13 g cm^{-3} and cover crop treatments 1.25 g cm^{-3} (p=0.07). There were no differences in any other comparisons (Table 1.15).

At Wichita in fall 2014, there was not a difference between cover and control at either depths but there was a difference in the 0-5 cm depth between spring- and fall-planted cover crops (p=0.02). The fall-planted cover crops had a lower bulk density averaging 0.98 g cm^{-3} compared to spring planted cover crops which were 1.18 g cm^{-3}. When comparing fall-planted, spring-planted, and control, the spring-planted cover crops were the same as control (p=0.02) (Table 1.17). There were no differences by individual treatment (Table 1.17).

At Olathe in spring 2015, there were no differences in bulk density at the 0-5 cm depth but the control was significantly denser at the $p<0.1$ level than the cover in the 5-10 cm depth (Table 1.19).

At Wichita in spring 2015, there was a difference in the 0-5 cm depth between cover 1.25 g cm^{-3} and control 1.39 g cm^{-3} ($p=0.06$). There were no differences between fall- and spring-planted cover crops or between individual treatments (Table 1.21).

At Olathe in fall 2015 there were no differences between any of the treatments at either depth (Tables 1.23).

At Wichita in fall 2015, the bulk density was significantly lower for the cover crop versus the control for both the 0-5 and 5-10 cm depths ($p=0.06$, and 0.02 respectively) (Table 1.25). There was also a difference in the 0-5 cm depth between the spring- and fall-planted cover crop treatments ($p=0.09$) with the spring-planted cover crops averaging 1.29 g cm^{-3} and the fall-planted at 1.20 g cm^{-3}. Comparing among individual treatments, there were differences in the 0-5 cm depth ($p=0.07$), the control and the oat treatments had greater BD than either the rye/canola, or rye treatments. There were no differences among treatments in the 5-10 cm depth (Table 1.25).

Discussion

The main soil physical property that was affected by cover crops in this study was an improvement in soil aggregation, while lesser effects were observed for water infiltration and bulk density. Although the statistical analyses were performed independently for each site year, it appears that the soil aggregation property changed over the duration of this study at both sites. While these changes did not occur immediately, soil aggregation showed differences between cover crop treatments (tilled once/year) compared with the control (tilled ≥ twice/year). The cover crop treatments were planted in fall 2012 but differences between the control and the cover cropped treatments were not statistically significant until fall 2014 for Olathe and spring 2014 for Wichita. These differences continued to become more pronounced at both sites throughout the remainder of the study.

Based on the results of the fall 2013 and spring 2014 Wichita wet aggregate stability data, it was thought that the fall-planted cover crops showed improvement in large and total soil aggregation quicker than spring-planted cover crops. However, in later samplings this did not hold true, even though fall-planted species covered the soil for a longer period of time and protected the soil during spring, a typically rainy season. As the study progressed, these differences became less pronounced. By the end of the study, there were no differences between fall- and spring-planted cover crop effects on soil aggregation. This increase in water stable aggregates over time was also observed in a three-year study in Rhode Island that compared tillage methods with cover crops in a vegetable production system. This study found cover crops with strip tillage resulted in significantly increased soil wet aggregate stability over cover crops with conventional tillage in the second and third years of the study (Pieper, et al., 2015).

Despite the differences in water stable aggregation, particularly in the larger size fraction, the only sampling period when there were any differences in ponded water infiltration was between cover crop treatments and the control at Wichita in spring 2015 ($p=0.002$) (Table 1.21). This is likely because macropores may take longer than a year to develop, and macropores are important for ponded infiltration where gravity is the primary force. Since all of the treatments were tilled each year in the fall, macropores may not have had time to develop before tillage occurred again.

Soil bulk density did not differ among treatments for most of the sampling periods at either site. At Wichita, differences between cover and control treatments were not observed at the 0-5 cm depth until spring 2015. Differences were present at both depths in fall 2015 with a lower soil bulk density in the cover crop treatments compared to control (Table 1.25). There were no differences between spring- and fall-planted cover crops. According to the USDA-NRCS (2008), the ideal bulk density for a silt loam is <1.40, the bulk density that would affect root growth is 1.55, and the root-restricting value is >1.65 g cm^{-3}, respectively. For a loamy sand textured-soil the corresponding values are <1.60, 1.69, and >1.80 g cm^{-3}, respectively (USDA-NRCS, 2008). The values measured in this study were always equal to or less than the ideal level, particularly for Wichita. At Olathe there were several mean values that approached the 1.40 g cm^{-3} level-cutoff for the ideal range. Several wheel ruts were observed at Olathe when soil sampling occurred, likely from tractors that were used to terminate the cover crops. Care was taken to collect soil samples outside of the wheel ruts. No ruts were observed at Wichita.

For the biological properties, MBC measures fungi and bacteria in soil while DOC measures labile carbon. The only time MBC was significant at either site was during the spring 2014 sampling period, when the treatments with cover crops had 2.5 times as much MBC at Olathe (Table 1.11) and almost double at Wichita (Table 1.13) compared to the control treatment.

The only time DOC was significant at Olathe was spring 2014 when the control treatment had 1.3 times as much DOC as the cover crop treatments (Table 1.11). At Wichita, DOC was significant in fall 2014, spring 2015, and fall 2015, although numerically, the difference in values was less than 10. In the previously mentioned study from Rhode Island, active or labile carbon was only different among treatments in the third year, and microbial activity (Solvita Soil CO_2

respiration kit, Woods End Laboratories, Mt. Vernon, ME) was generally greater for the reduced tillage treatments, all of which had cover crops, than the non-covercropped, highly tilled, control (Pieper, et al., 2015).

Our study examined the combination of using both reduced tillage and cover crops to improve soil structure. It would be interesting for a future study to examine these two components of conservation agriculture separately by adding a treatment with the same tillage as the control (twice/year) plus cover crops, and also adding cover crop treatments which are completely no-till. That way the differences between tillage and cover crops could be analyzed separately.

This study was conducted with plots in place for three years of continuous pumpkin production, while typically, horticultural producers use a crop rotation. Although this study used some mixed-species cover crop combinations, it did not quantify the cover crop species composition or how that may have changed throughout the growing season. For example, some cover crop mixtures are frequently planted by taking the monoculture planting rate and dividing it by the number of species planted in mix (Bybee-Finley, et al., 2016). More research is needed to know if this is a good method for determining planting rates and if competition between species negates the benefits of a mixed species cover crop.

Conclusions

Overall, this study found that adding cover crops and reducing tillage to a pumpkin production system can cause a measurable change in soils. Despite the differences in aggregates, and particularly the presence of more large aggregates (>4.75 mm) in diameter, the ponded infiltration rate was not affected by cover crop treatments in 9 out of 10 sampling intervals. This may be due to the fact that all plots are tilled after the pumpkin harvest each year, and thus, long, continuous macropores may not be forming. The microbial measurements also did not produce a consistent trend among treatments and sampling intervals. At the beginning of the study, it appeared that soil physical properties in the treatments containing fall-planted cover crops improved quicker than the spring planted cover crops, however, as the study went on, this difference became less significant and at the end of the study, there was no significant difference between fall- and spring-planted cover crops.

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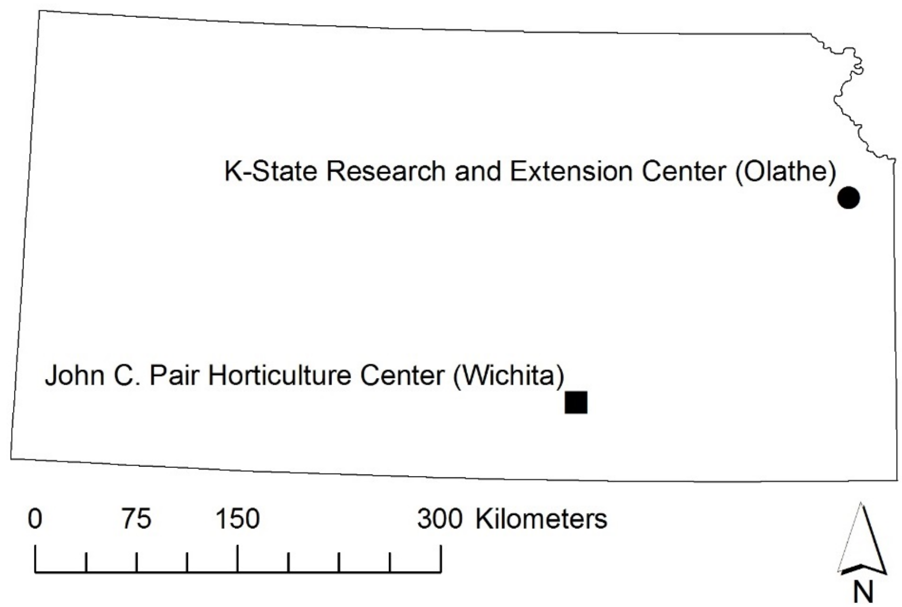
Figures and Tables

Figure 1.1 a) Map of site locations in Kansas b) Soil Texture Triangle, the soil texture at Olathe is a silt loam (circle), Wichita is a loamy sand (square).

a



b

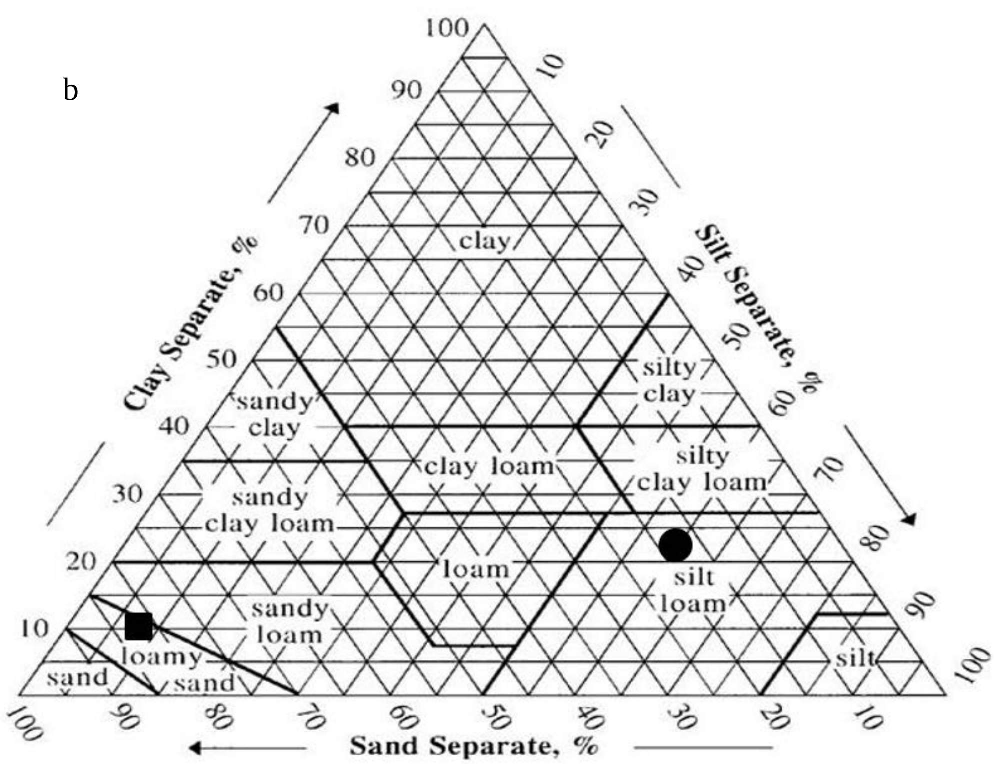


Figure 1.2 Example plot diagram, showing one block of the experiment. The experimental design was randomized complete block with three replications. The diagram illustrates one block. Plot dimensions were 9.14 meters by 18.28 meters.

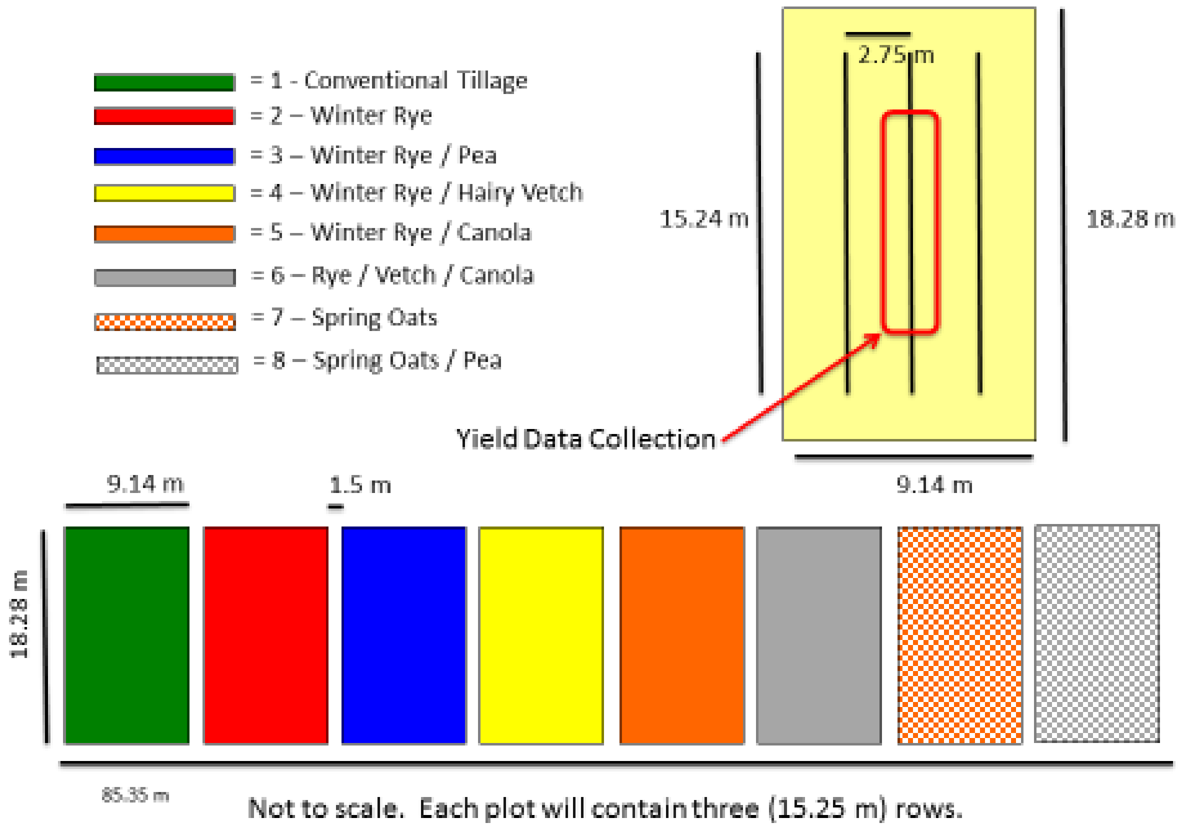


Figure 1.3 Olathe Fall 2013 a) comparison between cover crop and control crop treatments. b) comparison between spring planted and fall planted cover crops. c) comparison between control, fall planted and spring planted cover crops. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments.

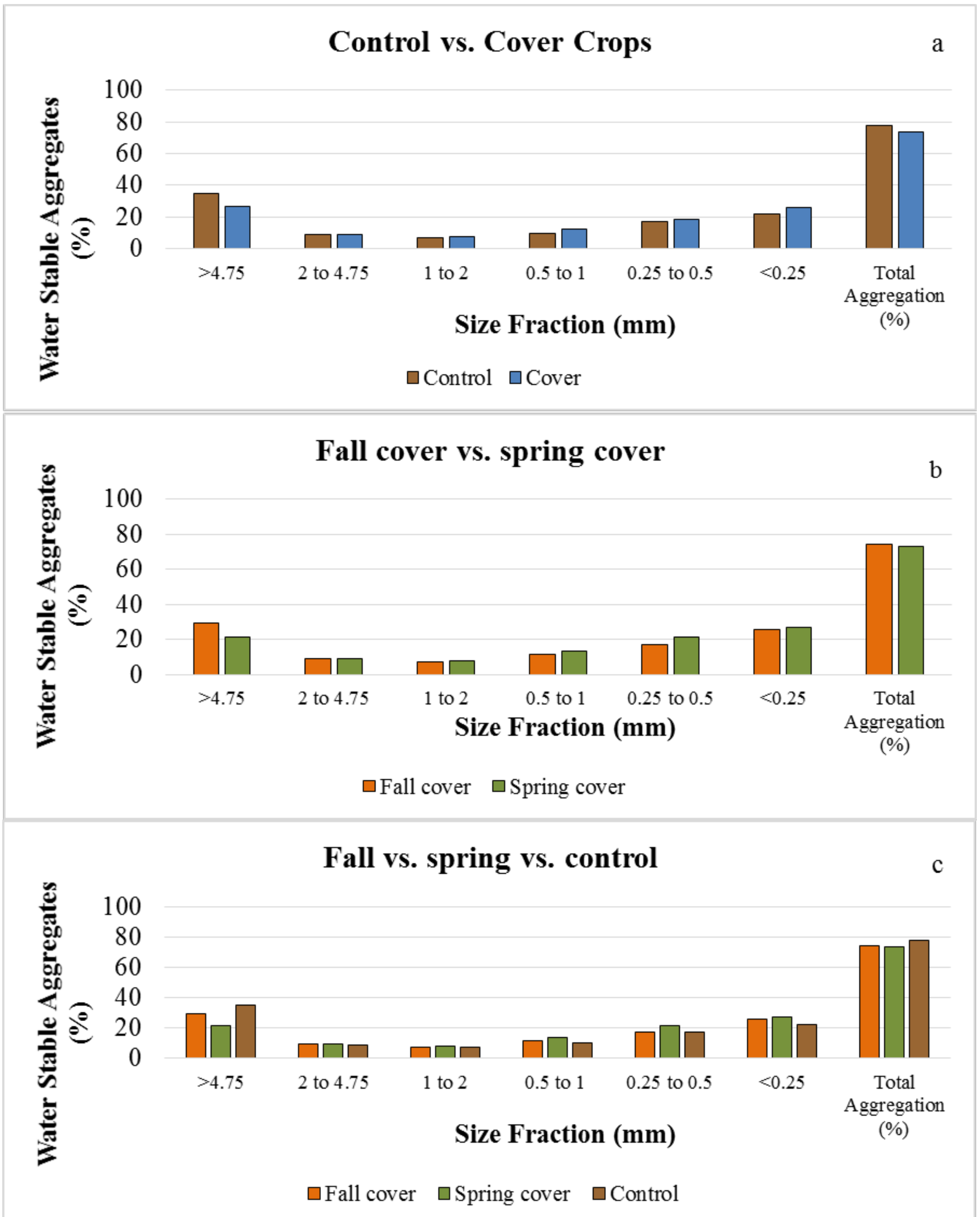


Figure 1.4 Wichita fall 2013 a) comparison between cover crop and control treatments. b) comparison between spring planted and fall planted cover crops. c) comparison between fall-planted, spring-planted cover crops and control. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

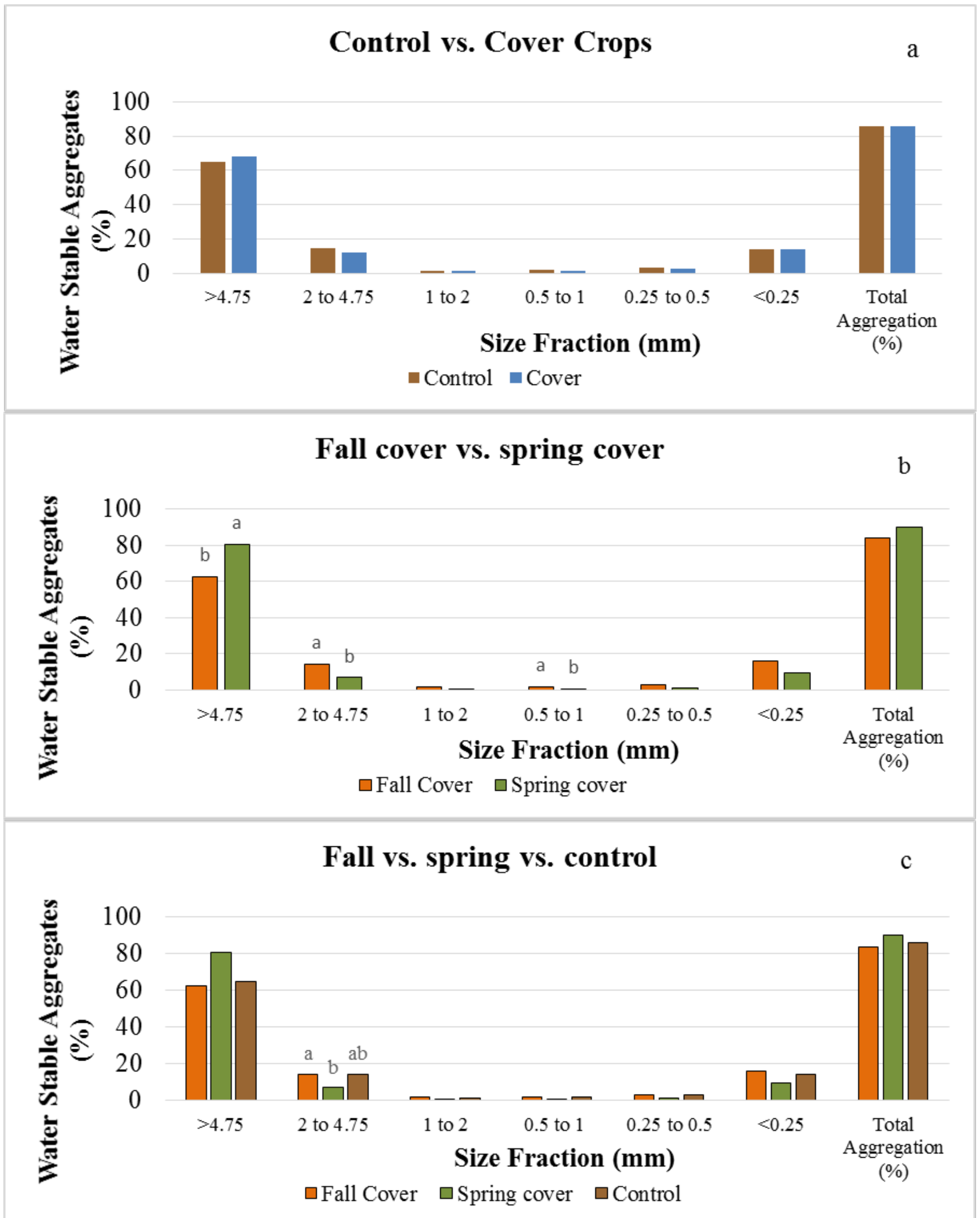


Figure 1.5 a) Olathe spring 2014 comparison between cover crop and control crop treatments. b) comparison between spring planted and fall planted cover crops. c) comparison between control, fall planted and spring planted cover crops. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

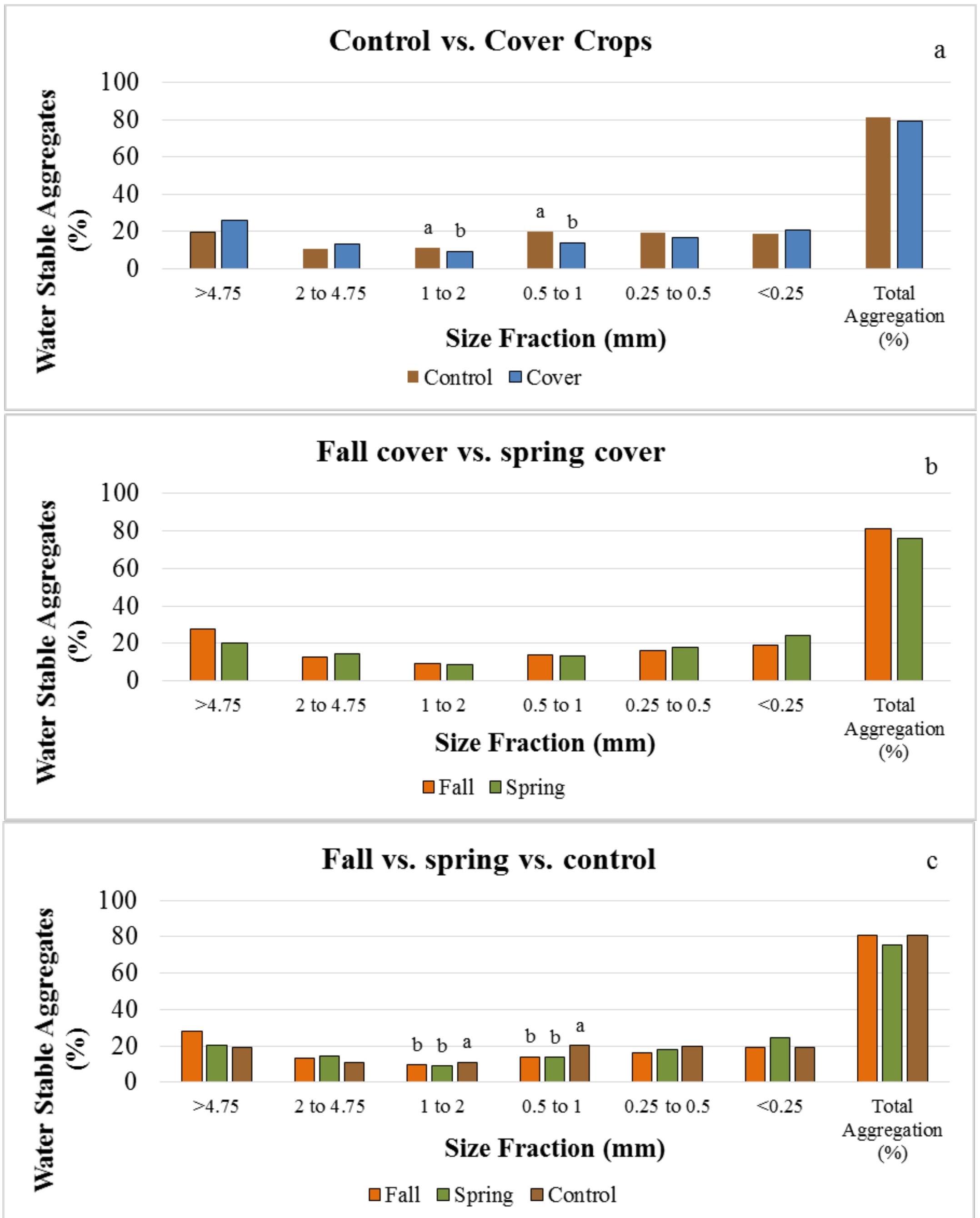
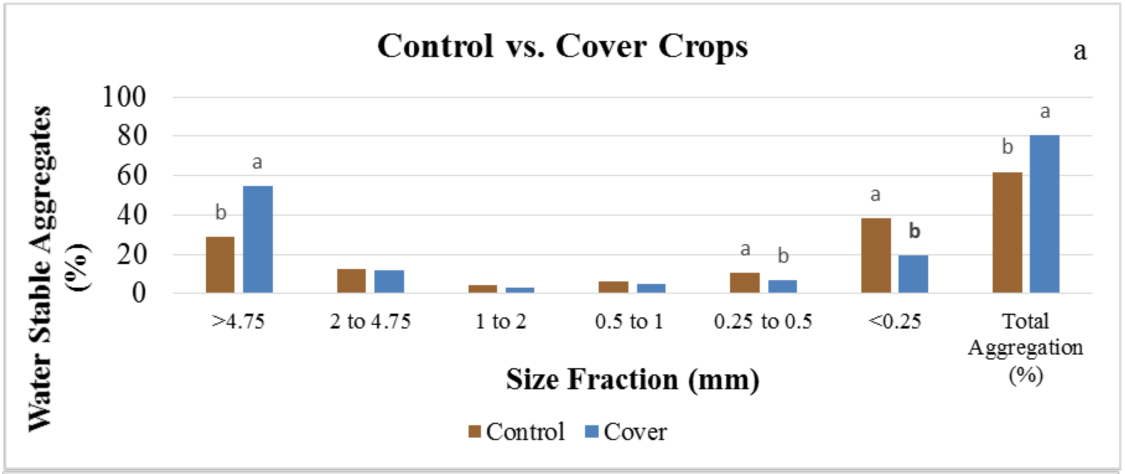
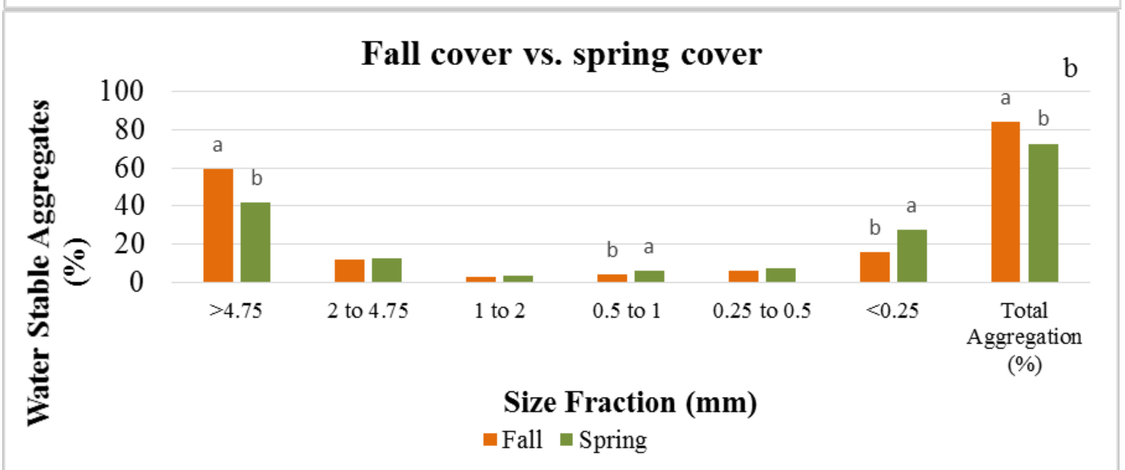


Figure 1.6 a) Wichita spring 2014 comparison between cover crop and control crop treatments. b) comparison between spring planted and fall planted cover crops. c) comparison between control, fall planted and spring planted cover crops. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments.





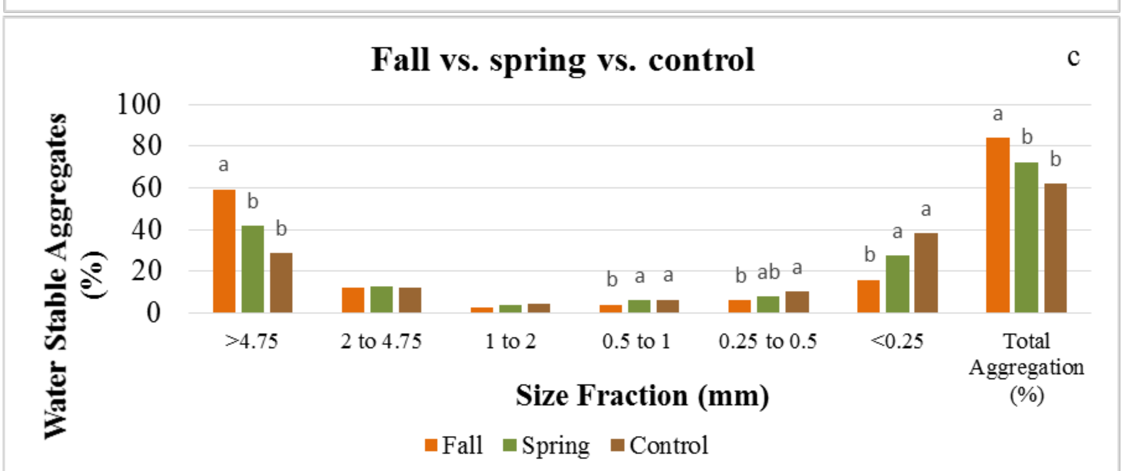


Figure 1.7 Olathe fall 2014 comparison between cover crop and control crop treatments. b) comparison between spring planted and fall planted cover crops. c) comparison between control, fall planted and spring planted cover crops. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

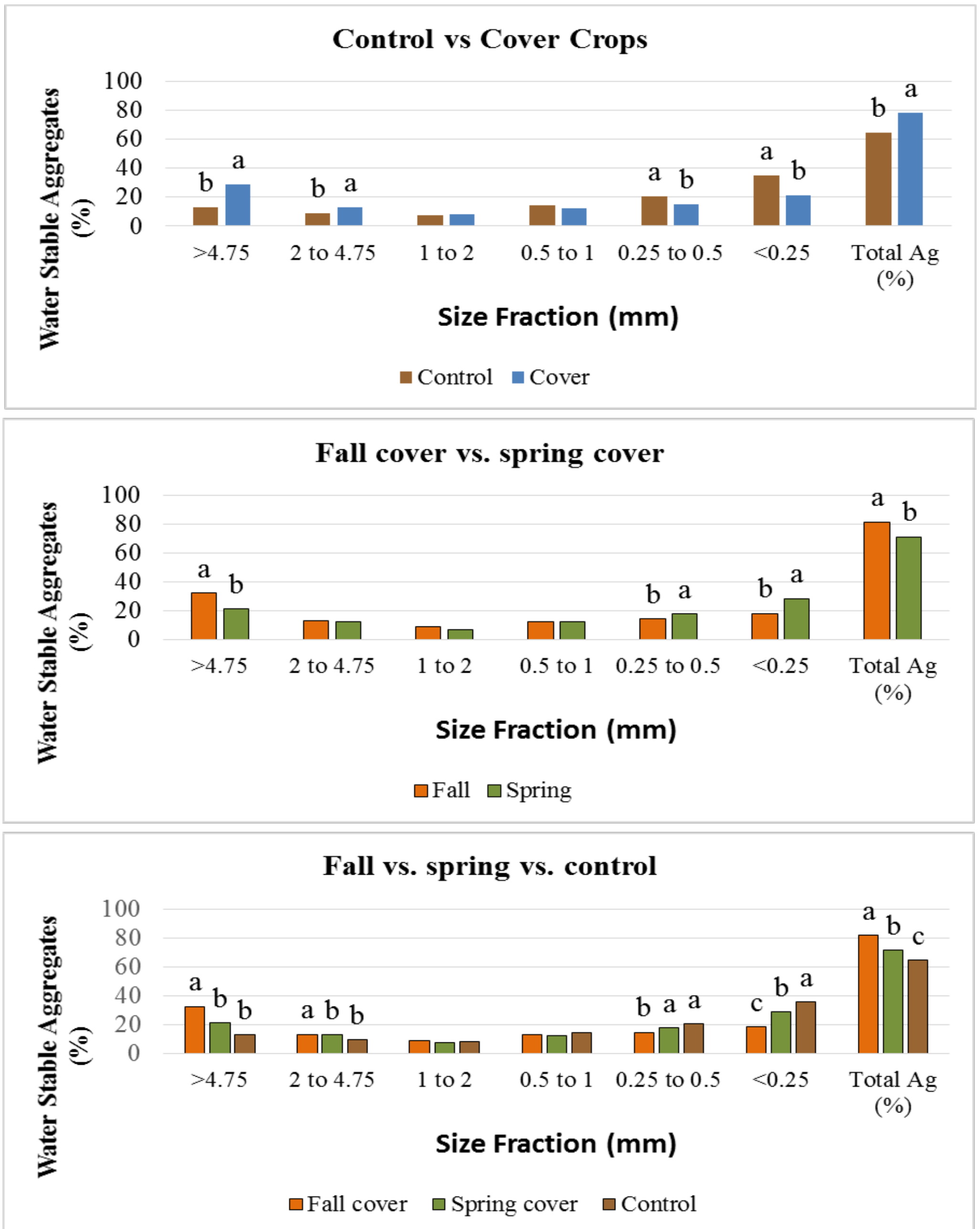


Figure 1.8 Wichita fall 2014 comparison between cover crop and control treatments. b) comparison between spring planted and fall planted cover crops. c) comparison between control, fall planted and spring planted cover crops. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

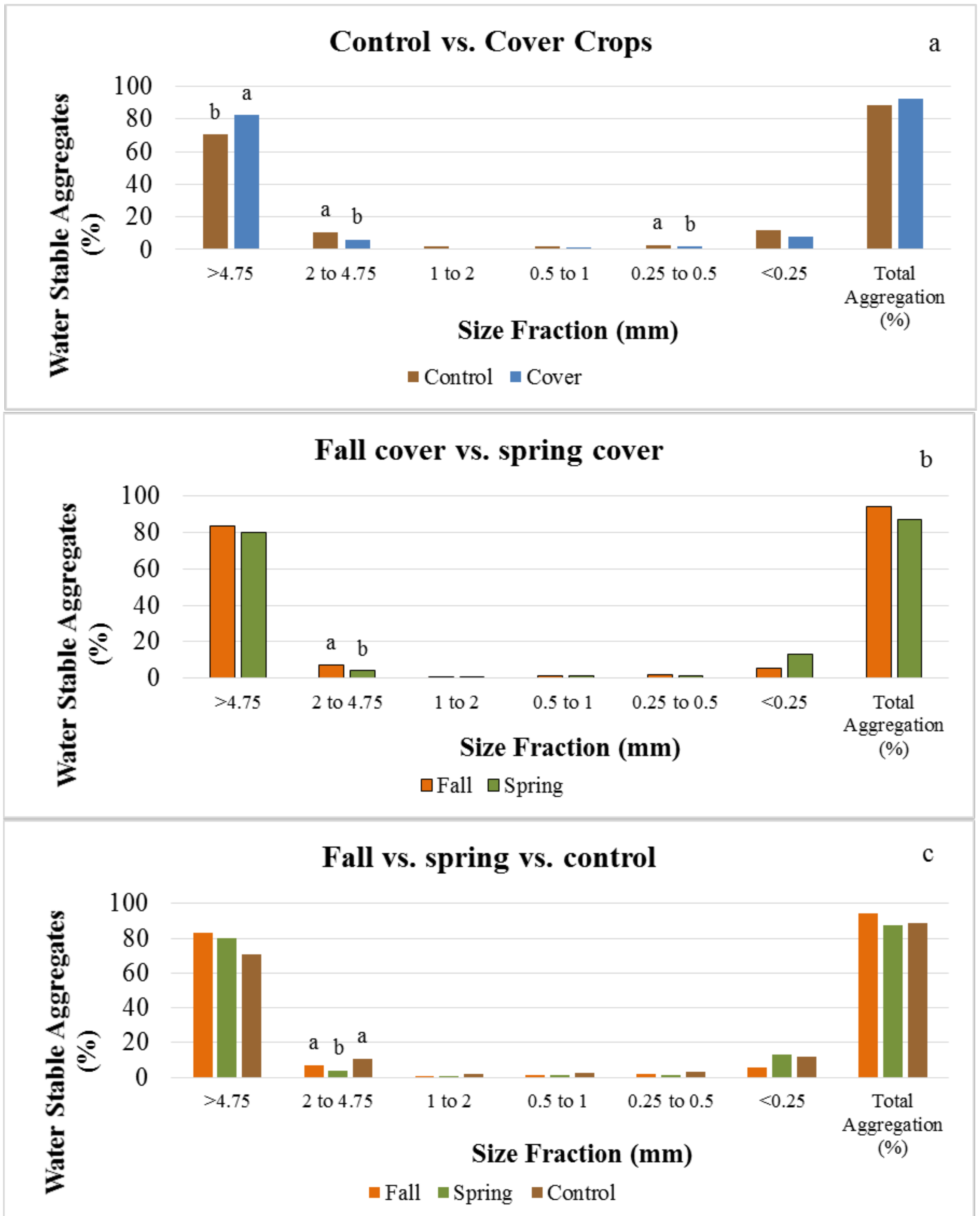


Figure 1.9 Olathe spring 2015 comparison between cover crop and control crop treatments. b) comparison between spring planted and fall planted cover crops. c) comparison between control, fall planted and spring planted cover crops. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

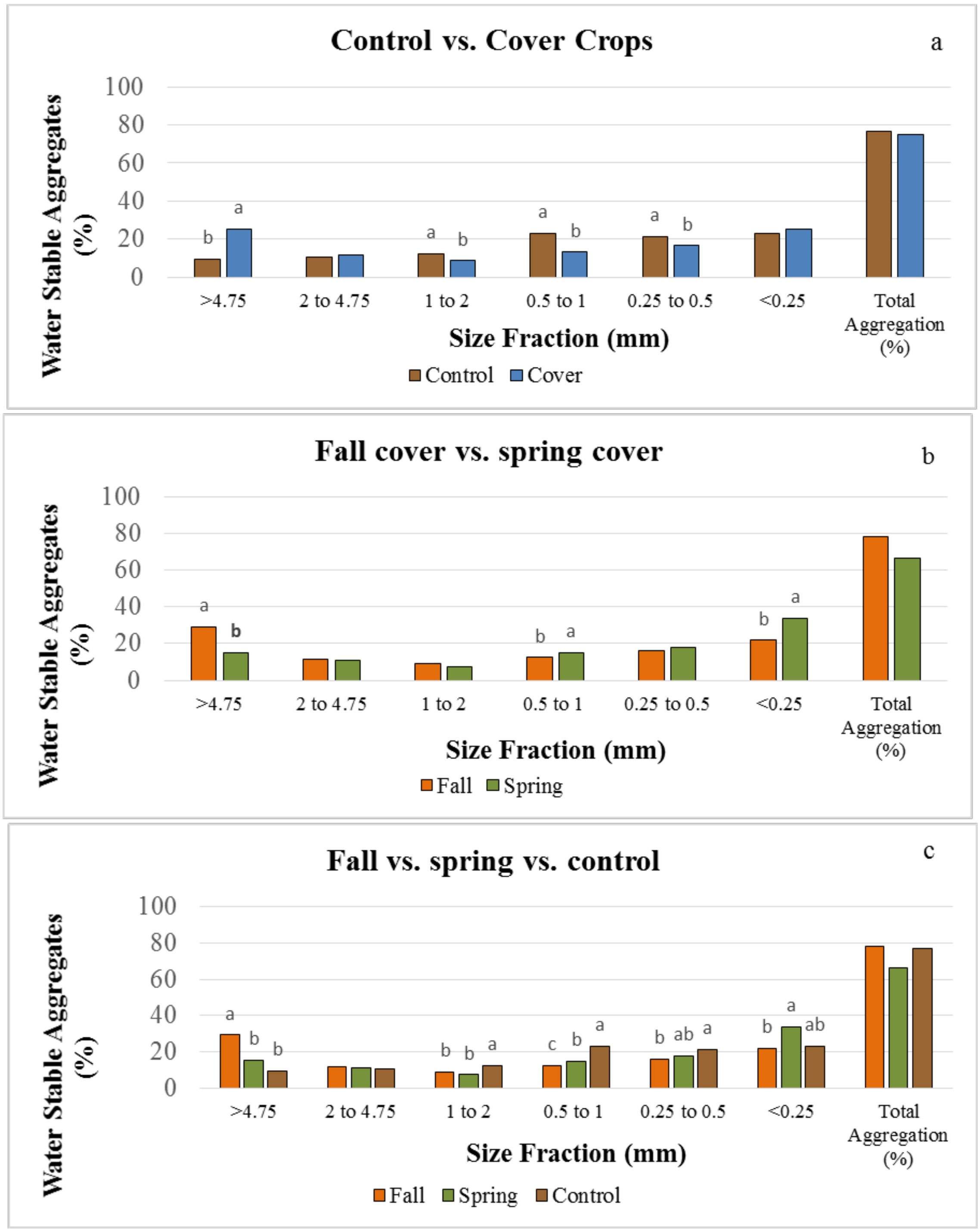


Figure 1.10 Wichita spring 2015 comparison between cover crop and control crop treatments. b) comparison between spring planted and fall planted cover crops. c) comparison between control, fall planted and spring planted cover crops. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

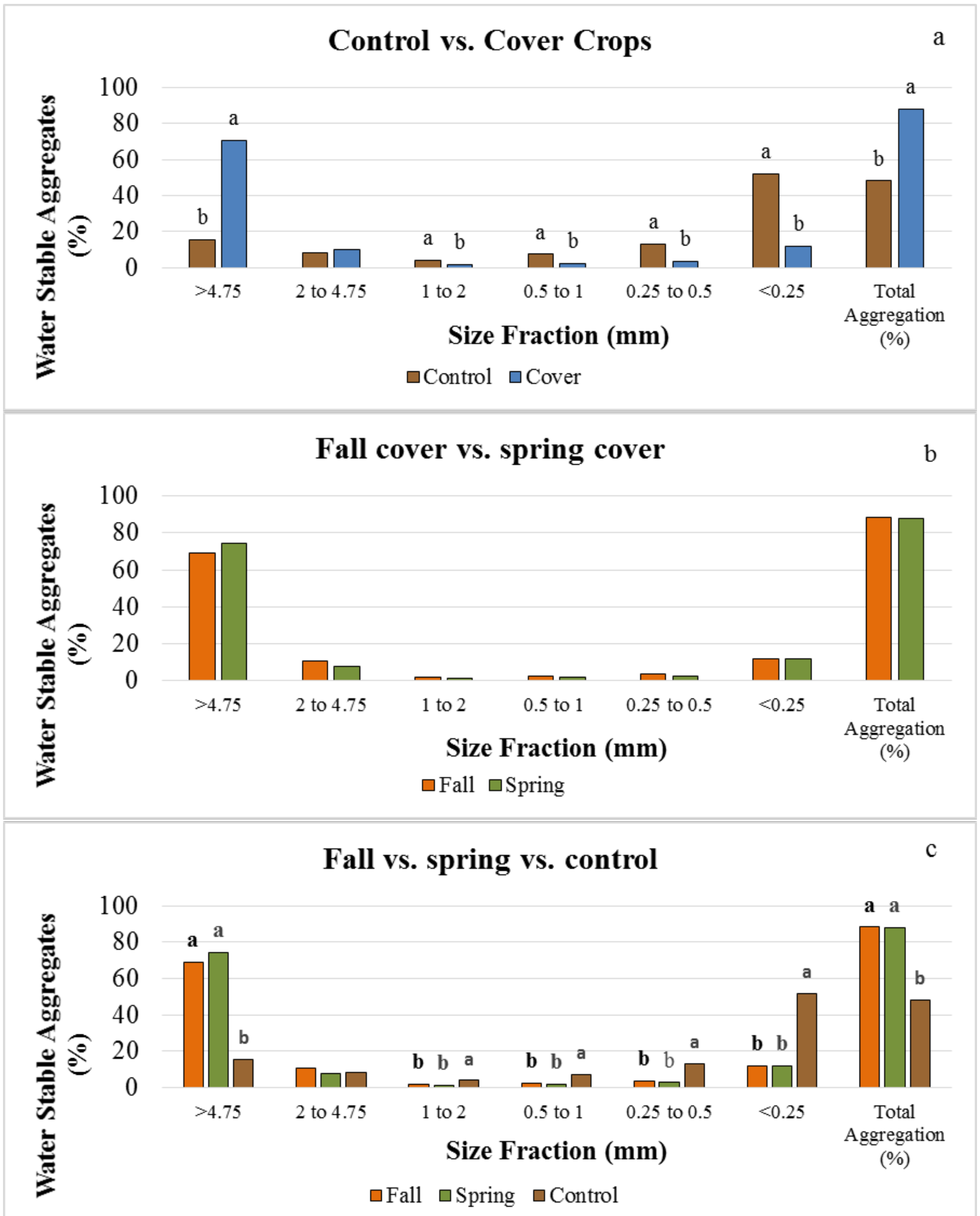


Figure 1.11 Olathe fall 2015 comparison between cover crop and control crop treatments. b) comparison between spring planted and fall planted cover crops. c) comparison between control, fall planted and spring planted cover crops. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

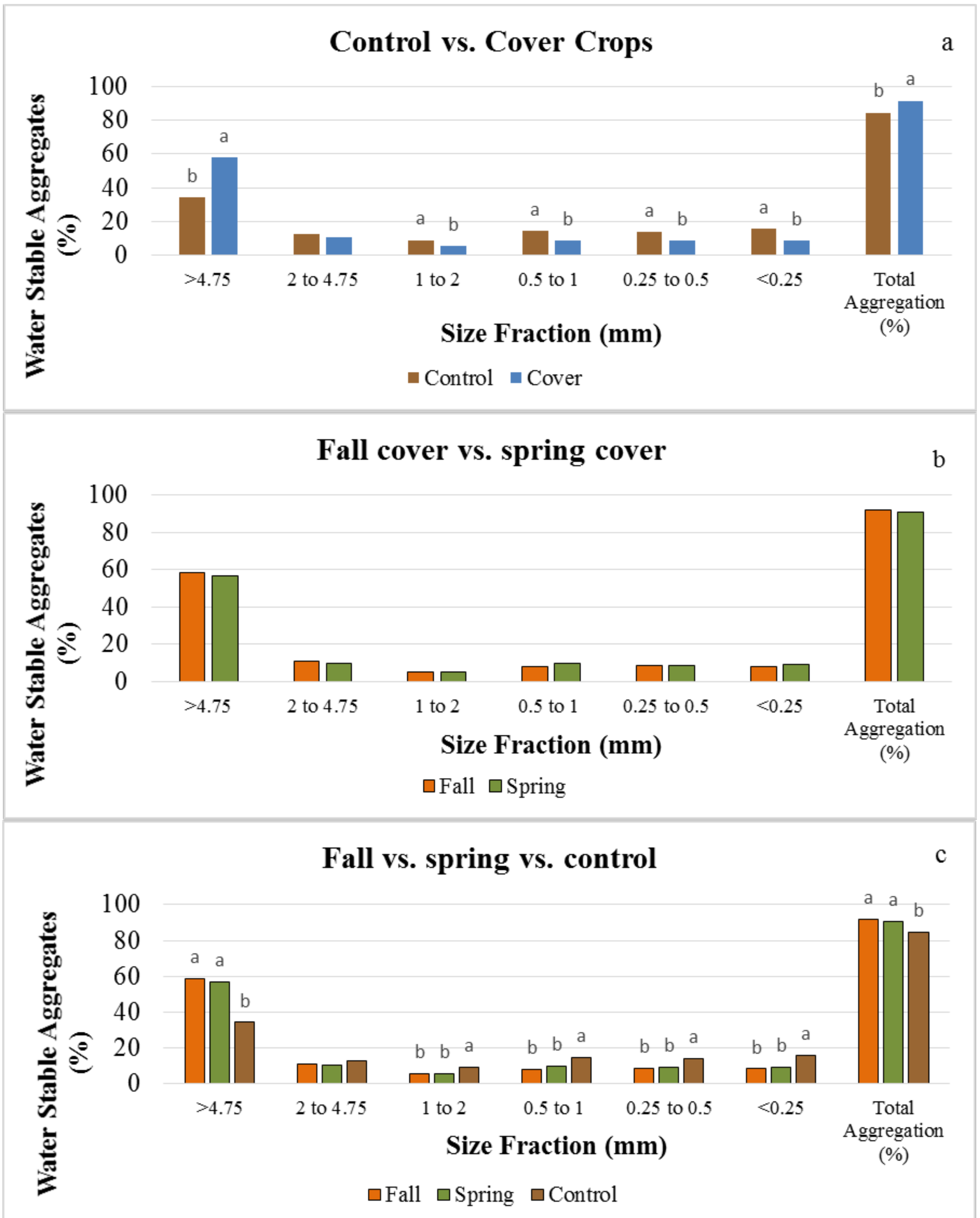


Figure 1.12 Wichita fall 2015 comparison between cover crop and control crop treatments. b) comparison between spring planted and fall planted cover crops. c) comparison between control, fall planted and spring planted cover crops. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

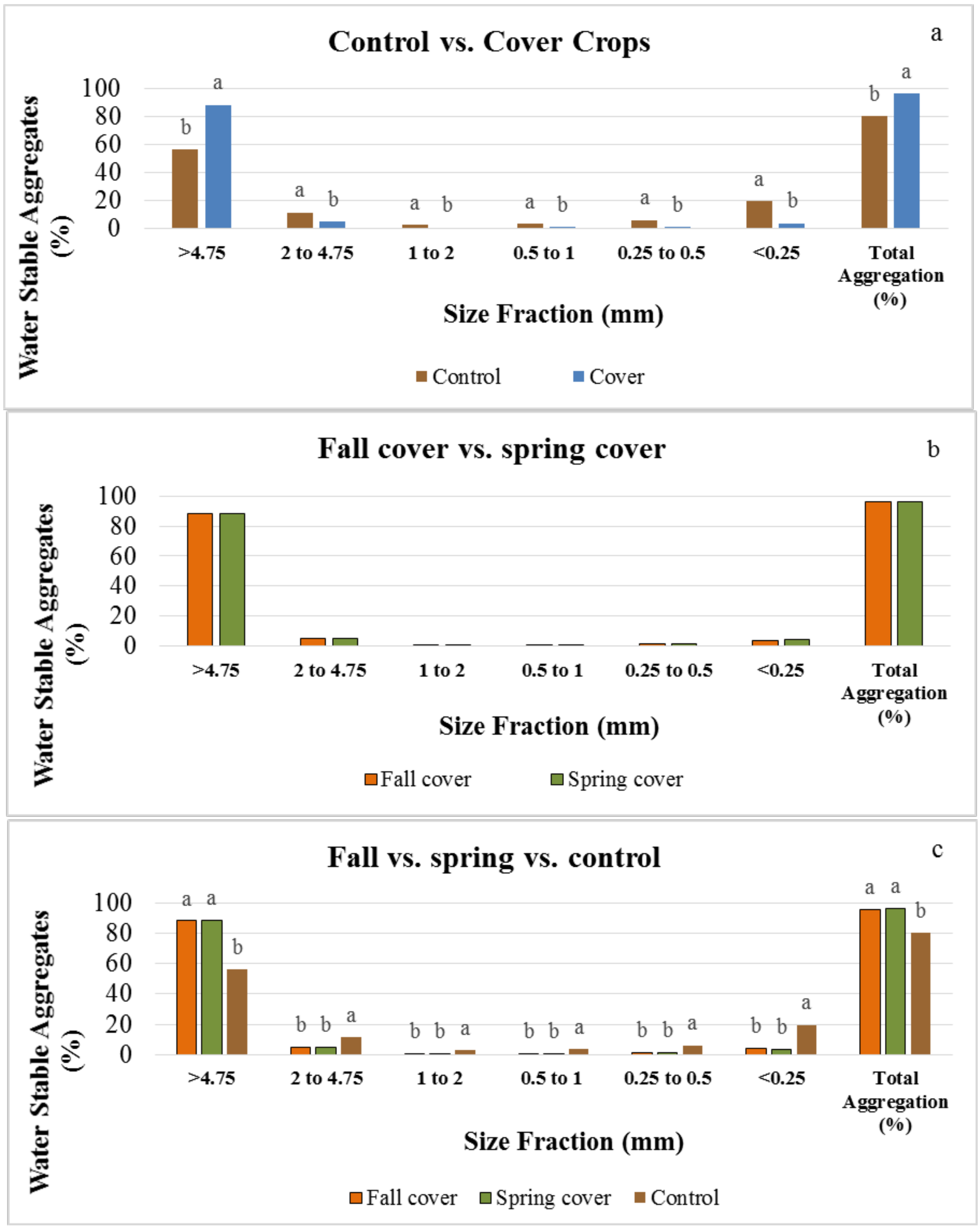


Table 1.1 General soil characterization information sampled at the start of the experiment. Samples represent baseline data and the cores were collected from throughout the entire experimental site.

	Sand	Silt	Clay	Soil texture	Total Nitrogen	Soil Organic Carbon
		%			%	
Olathe	18	60	22	Silt Loam	0.21	2.20
Wichita	82	8	10	Loamy Sand	0.05	0.96

Table 1.2 Cover Crop Seeding rates

	Cover Crop Planting Rates kg ha^{-1}				
Treatment	Rye	Oat	Winter Pea	Vetch	Canola
Control	-	-	-	-	-
Rye	84	-	-	-	-
Rye/pea	56	-	28	-	-
Rye/vetch	56	-	-	22	-
Rye/canola	56	-	-	-	6
Rye/canola/vetch	56	-	-	22	6
Oats (spring)	-	90	-	-	-
Oats/peas (spring)	-	56	28	-	-

Table 1.3 Timeline of field operations. Cover crop termination refers to the date that the cover crops were rolled with a roller crimper. In 2013, cover crops were terminated by flail mowing, not crimping. Cover crops were rolled down prior to clipping 1 m2 area of the flat biomass.

	Production year					
	2013		2014		2015	
Operation	Olathe	Wichita	Olathe	Wichita	Olathe	Wichita
Cover crop seeding	10/14/2012	10/11/2012	10/14/2013	10/14/2013	10/14/2014	10/15/2014
Cover crop seeding	3/31/2013	3/14/2013	3/31/2014	3/14/2014	3/20/2015	3/13/2015
Cover crop termination	6/6/2013	6/10/2013	6/4/2014	6/23/2014	6/5/2015	6/9/2015
Cover crop biomass clipping	n/a	n/a	6/18/2014	6/17/2014	6/15/2015	6/18/2015
Pumpkin planting	7/3/2013	6/24/2013	6/18/2014	6/26/2014	6/15/2015	6/18/2015
Summer soil sample	n/a	n/a	7/7/2014	7/2/2014	7/1/2015	7/2/2015
Pumpkin harvest	9/25/2013	9/26/2013	10/2/2014	10/6/2014	10/5/2015	No harvest†
Fall soil sample	9/30/2013	9/30/2013	10/22/2014	10/10/2014	10/9/2015	10/12/2015
Pumpkins planted	Transplants	Seed	Seed	Seed	Transplants	Transplants

† No harvest due to weed pressure that greatly affected the pumpkin stand.

Table 1.4 Cover Crop Biomass by treatment. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

Cover crop biomass kg ha^{-1}				
	2014		2015	
Treatment	Olathe	Wichita	Olathe	Wichita
Control	n/a	n/a	n/a	n/a
Rye	4007 b	5443 c	4577	5860
Rye/Pea	5217 ab	6237 bc	3150	5947
Rye/Vetch	5213 ab	5983 c	3983	4980
Rye/Canola	3917 b	5873 c	3300	5123
Rye/Vetch/Canola	6193 a	5787 c	4960	6510
Oat	6210 a	7230 ab	4197	5063
Oat/Pea	5170 ab	7517 a	4810	6310
p-value	0.01	0.01	0.37	0.61

Table 1.5 Cover Crop Biomass by planting date. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

Cover crop biomass kg ha^{-1}				
	2014		2015	
	Olathe	Wichita	Olathe	Wichita
Fall planted	4909	5865 b	3994	5684
Spring planted	5690	7373 a	4503	5687
p-value	0.14	<0.0001	0.38	1.00

Table 1.6 Olathe fall 2013 water stable aggregate mean values. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

	Water Stable Aggregates (g sand-free 100 g^{-1} soil)						Total Aggregation
	>4.75	2 to 4.75	1 to 2	0.5 to 1	0.25 to 0.50	<0.25	%
Control	35.08	8.87	6.98	9.92	17.04	22.1	77.9
Rye	20.34	10.01	9.98	17.43	21.79	20.45	79.5
Rye/Pea	20.14	8.46	7.49	11.38	20.14	32.38	67.6
Rye/Vetch	29.59	9.84	6.47	8.72	15.65	29.73	70.3
Rye/Canola	40.59	9.54	7.54	12.43	15.42	14.49	85.5
Rye/Vetch/Canola	35.24	7.78	4.84	7.71	12.47	31.96	68
Oat	19.10	8.62	8.7	15.85	23.61	24.11	75.9
Oat/Pea	23.20	9.61	7.43	11.28	18.89	29.59	70.4
p-value	0.66	0.96	0.23	0.11	0.24	0.43	0.43

Table 1.7 Olathe fall 2013 soil property mean values. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

	MWD†	MBC‡	DOC§	Infiltration	BD¶ (0-5 cm)	BD (5-10 cm)
		μg C g^{-1} soil		min cm^{-1}	g cm^{-3}	
Control	2.8	217.6	30.62	nd	1.32	nd
Rye	2.0	216.2	48.29	nd	1.35	nd
Rye/Pea	1.9	194	40.7	nd	1.39	nd
Rye/Vetch	2.5	197.1	32.75	nd	1.35	nd
Rye/Canola	3.2	232.6	28.85	nd	1.36	nd
Rye/Vetch/Canola	2.7	191.4	35.72	nd	1.4	nd
Oat	1.9	213.1	31.07	nd	1.33	nd
Oat/Pea	2.1	215.7	35.37	nd	1.29	nd
p-value	0.72	0.60	0.42	-	0.63	-
Control	2.8	217.6	30.6	nd	1.32	nd
Cover	2.3	208.6	36.1	nd	1.35	nd
p-value	0.44	0.60	0.42	-	0.86	n/a
Spring cover	2.0	214.4	33.2	nd	1.31 b	nd
Fall cover	2.5	206.3	37.3	nd	1.37 a	nd
p-value	0.34	0.56	0.47	-	0.03	n/a
Control	2.8	217.6	30.6	nd	1.32	nd
Spring cover	2.0	214.4	33.2	nd	1.31	nd
Fall cover	2.5	206.3	37.3	nd	1.37	nd
p-value	0.48	0.72	0.55	-	0.08	n/a

† MWD: Mean Weight Diameter

‡ MBC: Microbial Biomass Carbon

§ DOC: Dissolved Organic Carbon

¶ BD: Bulk Density

nd: no data measured at this sampling period.

Table 1.8 Wichita fall 2013 mean values. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

	Water Stable Aggregates (g sand-free 100 g^{-1} soil)						Total Aggregation
	>4.75	2 to 4.75	1 to 2	0.5 to 1	0.25 to 0.5	<0.25	%
Control	64.81	14.39	1.35	2.05	3.21	14.19	85.81
Rye	61.35	16.19	1.97	2.35	4.12	14.02	85.98
Rye/Pea	61.34	17.23	2.06	2.37	3.42	13.58	86.42
Rye/Vetch	60.04	7.58	1.81	2.12	4.42	24.03	75.97
Rye/Canola	65.88	12.45	1.37	1.47	2.43	16.39	83.61
Rye/Vetch/Canola	65.08	18.28	1.32	1.26	1.61	12.45	87.55
Oat	75.85	7.07	0.73	0.75	1.25	14.35	85.65
Oat/Pea	85.25	6.95	0.33	0.64	1.62	5.21	94.79
p-value	0.82	0.12	0.76	0.64	0.79	0.90	0.90

Table 1.9 Wichita fall 2013 soil property mean values. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period. Infiltration and bulk density were not determined at this sampling period.

	MWD†	MBC‡	DOC§	Infiltration	BD¶ (0-5 cm)	BD (5-10 cm)
	mm	μg C g^{-1} soil		min cm^{-1}	g cm^{-3}	
Control	4.68	nd	19.85	nd	1.33	ns
Rye	4.54	nd	32.54	nd	1.30	ns
Rye/Pea	4.57	nd	20.39	nd	1.27	ns
Rye/Vetch	4.17	nd	26.81	nd	1.32	ns
Rye/Canola	4.68	nd	24.31	nd	1.30	ns
Rye/Vetch/Canola	4.82	nd	23.04	nd	1.30	ns
Oat	5.11	nd	21.32	nd	1.38	ns
Oat/Pea	5.69	nd	22.59	nd	1.39	ns
p-value	0.88	-	0.09	-	0.71	n/a
Control	4.68	nd	19.85	nd	1.33	nd
Cover	4.8	nd	24.43	nd	1.32	nd
p-value	0.86	-	0.2	-	0.58	-
Fall cover	4.56	nd	25.42	nd	1.3	nd
Spring cover	5.4	nd	21.96	nd	1.39	nd
p-value	0.14	-	0.23	-	0.1	-
Control	4.68	nd	19.85	nd	1.33	nd
Fall cover	4.56	nd	25.42	nd	1.3	nd
Spring cover	5.4	nd	21.96	nd	1.39	nd
p-value	0.3	-	0.2	-	0.19	-

† MWD: Mean Weight Diameter

‡ MBC: Microbial Biomass Carbon

§ DOC: Dissolved Organic Carbon

¶ BD: Bulk Density

nd: no data measured at this sampling period.

Table 1.10 Olathe spring 2014 water stable aggregate mean values. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

	Water Stable Aggregates (g sand-free 100 g^{-1} soil)						Total Aggregation
	>4.75	2 to 4.75	1 to 2	0.5 to 1	0.25 to 0.5	<0.25	%
Control	19.40	10.88	11.02	20.18	19.6	18.92	81.08
Rye	30.75	13.04	8.65	13.2	16.32	18.03	81.97
Rye/Pea	29.07	13.22	9.79	13.94	15.16	18.83	81.17
Rye/Vetch	17.6	11.92	9.55	14.94	19.75	26.24	73.76
Rye/Canola	29.4	13.22	9.85	14.31	15.7	17.52	82.48
Rye/Vetch/Canola	32.49	13.36	9.78	13.94	14.78	15.64	84.36
Oat	20.46	12.81	9.4	15.29	20.12	21.91	78.09
Oat/Pea	20.39	16.26	8.77	11.79	15.77	27.02	72.98
p-value	0.72	0.9	0.5	0.12	0.73	0.34	0.34

Table 1.11 Olathe spring 2014 soil property mean values. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

	MWD†	MBC‡	DOC§	Infiltration	BD¶ (0-5 cm)	BD (5-10 cm)
	mm	μg C g^{-1} soil		min cm^{-1}	g cm^{-3}	
Control	2.02	51.87 b	55.56	0.31	0.81	1.07
Rye	2.71	152.39 ab	37.21	3.95	0.77	1.23
Rye/Pea	2.63	94.86 b	40.87	2.4	0.94	1.18
Rye/Vetch	1.89	218.86 a	50.41	1.1	0.8	1.26
Rye/Canola	2.66	150.13 ab	35.74	3.04	0.84	1.31
Rye/Vetch/Canola	2.85	97.20 b	45.24	0.9	0.68	1.2
Oat	2.1	107.57 b	36.58	3.23	0.81	1.11
Oat/Pea	2.16	96.53 b	30.08	2.42	0.78	1.23
p-value	0.67	0.08	0.48	0.42	1.00	0.21
Control	2.02	51.87 b	55.56 a	0.31	0.81	1.07 b
Cover	2.43	131.08 a	39.45 b	2.43	0.8	1.22 a
p-value	0.38	0.06	0.08	0.11	0.96	0.03
Fall cover	2.55	142.7	41.89	2.28	0.81	1.24
Spring cover	2.13	102.05	33.33	2.83	0.8	1.17
p-value	0.26	0.22	0.21	0.61	0.82	0.25
Control	2.02	51.87 b	55.56 a	0.31	0.81	1.07 b
Fall cover	2.55	142.69 a	41.89 ab	2.28	0.81	1.24 a
Spring cover	2.13	102.05 ab	33.33 b	2.83	0.8	1.17 ab
p-value	0.35	0.08	0.098	0.25	0.97	0.05

† MWD: Mean Weight Diameter

‡ MBC: Microbial Biomass Carbon

§ DOC: Dissolved Organic Carbon

¶ BD: Bulk Density

nd: no data measured at this sampling period.

Table 1.12 Wichita spring 2014 mean values. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

	Water Stable Aggregates (g sand-free 100 g^{-1} soil)						Total Aggregation
	>4.75	2 to 4.75	1 to 2	0.5 to 1	0.25 to 0.5	<0.25	%
Control	28.68 b	12.2	4.36	6.42	10.26	38.08 a	61.92 b
Rye	60.87 a	11.9	2.64	4.8	5.53	14.26 b	85.74 a
Rye/Pea	59.24 a	12.24	2.7	3.94	4.65	17.23 b	82.77 a
Rye/Vetch	59.52 a	11.66	3.06	2.7	7.47	15.60 b	84.40 a
Rye/Canola	68.65 a	8.88	2.25	3.99	5.2	11.03 b	88.97 a
Rye/Vetch/Canola	48.74 ab	14.59	3.26	4.75	7.06	21.60 b	78.40 a
Oat	55.26 ab	12.28	3.15	5.25	6.48	17.59 b	82.41 a
Oat/Pea	28.76 b	13.05	4.54	7.1	9.13	37.42 a	62.58 b
p-value	0.09	0.87	0.44	0.21	0.37	0.01	0.01

Table 1.13 Wichita spring 2014 soil property mean values. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

	MWD†	MBC‡	DOC§	Infiltration	BD¶ (0-5 cm)	BD (5-10 cm)
	mm	µg C g^{-1} soil		min cm^{-1}	g cm^{-3}	
Control	2.44 b	29.99	21.23 c	5.9	1.07	1.3
Rye	4.40 a	45.52	21.25 c	5.9	0.98	1.3
Rye/Pea	4.30 a	66.05	28.20 a	2.6	1.14	1.4
Rye/Vetch	4.30 a	49.05	26.12 ab	5.8	1.03	1.3
Rye/Canola	4.77 a	55.18	26.86 ab	3.6	1.1	1.4
Rye/Vetch/Canola	3.74 ab	61.42	27.63 a	5.4	1.09	1.3
Oat	4.07 a	66.99	20.20 c	4.9	1.3	1.4
Oat/Pea	2.48 b	62.25	22.36 bc	4.1	1.07	1.3
p-value	0.049	0.19	0.04	0.42	0.19	0.57
Control	2.44 b	29.99 b	21.23	5.91	1.07	1.29
Cover	4.01 a	58.07 a	24.66	4.6	1.1	1.35
p-value	0.03	0.01	0.19	0.32	0.71	0.32
Fall cover	4.30 a	55.4	26.01 a	4.65	1.07	1.35
Spring cover	3.28 b	64.62	21.28 b	4.5	1.18	1.35
p-value	0.04	0.27	0.02	0.89	0.11	0.97
Control	2.44 b	29.99 b	21.23 b	5.91	1.07	1.29
Fall cover	4.30 a	55.45 a	26.01 a	4.65	1.07	1.35
Spring cover	3.28 b	64.62 a	21.28 b	4.5	1.18	1.35
p-value	0.01	0.02	0.02	0.62	0.23	0.62

† MWD: Mean Weight Diameter

‡ MBC: Microbial Biomass Carbon

§ DOC: Dissolved Organic Carbon

¶ BD: Bulk Density

Table 1.14 Olathe fall 2014 mean values. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

	Water Stable Aggregates (g sand-free 100 g^{-1} soil)						Total Aggregation
	>4.75	2 to 4.75	1 to 2	0.5 to 1	0.25 to 0.5	<0.25	%
Control	12.88 d	9.15 b	7.81	14.27	20.48 a	35.41 a	64.59 c
Rye	28.94 abc	13.68 a	8.75	12.61	14.82 bc	21.18 bc	78.82 ab
Rye/Pea	30.99 abc	12.47 a	9.43	13.48	15.27 bc	18.36 c	81.64 a
Rye/Vetch	27.13 bc	12.84 a	10.39	15.59	16.51 b	17.54 c	82.46 a
Rye/Canola	40.61 a	13.44 a	7.44	10.66	11.84 c	16.01 c	83.99 a
Rye/Vetch/Canola	34.17 ab	13.10 a	8.23	11.79	14.52 bc	18.19 c	81.81 a
Oat	20.48 cd	12.96 a	7.11	12.37	18.07 ab	29.00 ab	71.00 bc
Oat/Pea	21.97 cd	12.32 a	7.52	12.72	17.30 ab	28.17 ab	71.83 bc
p-value	0.01	0.04	0.5	0.38	0.01	0.001	0.001

Table 1.15 Olathe fall 2014 mean values. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

	MWD†	MBC‡	DOC§	Infiltration	BD¶ (0-5 cm)	BD (5-10 cm)
	mm	μg C g^{-1} soil		min cm^{-1}	g cm^{-3}	
Control	1.48 d	185.46	61.13	5.17 a	0.76	1.13
Rye	2.61 abc	354.37	46.2	5.91 a	0.75	1.27
Rye/Pea	2.72 abc	205.5	56.09	5.91 a	0.88	1.23
Rye/Vetch	2.52 bc	244.79	53.03	5.91 a	1.05	1.27
Rye/Canola	3.30 a	225.63	47.71	4.51 a	0.83	1.28
Rye/Vetch/Canola	2.91 ab	260.15	56.88	2.01 b	0.87	1.21
Oat	2.05 cd	222.42	47.81	5.91 a	0.93	1.25
Oat/Pea	2.12 cd	193.66	43.32	5.35 a	0.63	1.24
p-value	0.004	0.26	0.51	0.02	0.18	0.78
Control	1.48 b	185.46	61.13	5.17	0.76	1.13 b
Cover	2.60 a	243.79	50.15	5.07	0.85	1.25 a
p-value	0.003	0.12	0.11	0.93	0.49	0.07
Fall cover	2.81 a	258.1	51.98	4.85	0.88	1.25
Spring cover	2.09 b	208.04	45.57	5.63	0.78	1.24
p-value	0.003	0.44	0.23	0.37	0.34	0.99
Control	1.48 c	185.46	61.13	5.17	0.76	1.13
Fall cover	2.81 a	258.09	51.98	4.85	0.88	1.25
Spring cover	2.09 b	208.04	45.57	5.63	0.78	1.24
p-value	0.0001	0.23	0.13	0.64	0.5	0.21

† MWD: Mean Weight Diameter

‡ MBC: Microbial Biomass Carbon

§ DOC: Dissolved Organic Carbon

¶ BD: Bulk Density

Table 1.16 Wichita fall 2014 mean values. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

	Water Stable Aggregates (g sand-free 100 g^{-1} soil)						Total Aggregation
	>4.75	2 to 4.75	1 to 2	0.5 to 1	0.25 to 0.5	<0.25	%
Control	70.64 b	10.83 a	1.92	2.21	2.86	11.75	88.25
Rye	88.60 a	5.62 abc	0.55	0.68	1.04	3.44	96.56
Rye/Pea	80.2 ab	9.26 ab	0.9	1.19	1.88	6.64	93.36
Rye/Vetch	83.54 a	6.02 abc	0.83	1.04	2.23	6.47	93.53
Rye/Canola	84.85 a	6.30 abc	1.91	1.38	1.75	4.79	95.21
Rye/Vetch/Canola	79.71 ab	8.01 abc	0.41	1.94	2.22	6.92	93.08
Oat	69.74 b	4.50 bc	1.3	1.29	1.73	21.98	78.02
Oat/Pea	89.74 a	3.47 c	0.53	0.76	1.4	4.14	95.86
p-value	0.08	0.09	0.83	0.69	0.6	0.21	0.21

Table 1.17 Wichita fall 2014 mean values. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

	MWD†	MBC‡	DOC§	Infiltration	BD¶ (0-5 cm)	BD (5-10 cm)
	mm	μg C g^{-1} soil		min cm^{-1}	g cm^{-3}	
Control	4.94	87.4	22.1	nd	1.16	1.39
Rye	5.86	136.1	24.6	nd	0.91	1.32
Rye/Pea	5.46	109.2	24.6	nd	1.04	1.22
Rye/Vetch	5.56	92.4	27	nd	1.01	1.24
Rye/Canola	5.66	118.6	25.1	nd	0.95	1.36
Rye/Vetch/Canola	5.4	109.6	23.6	nd	1.01	1.18
Oat	4.65	94.6	24.4	nd	1.22	1.23
Oat/Pea	5.86	115	25.4	nd	1.14	1.19
p-value	0.12	0.93	0.65	-	0.35	0.57
Control	4.68	nd	19.85	nd	1.33	nd
Cover	4.8	nd	24.43	nd	1.32	nd
p-value	0.86	-	0.2	-	0.58	-
Fall cover	4.56	nd	25.42	nd	1.3	nd
Spring cover	5.4	nd	21.96	nd	1.39	nd
p-value	0.14	-	0.23	-	0.1	-
Control	4.68	nd	19.85	nd	1.33	nd
Fall cover	4.56	nd	25.42	nd	1.3	nd
Spring cover	5.4	nd	21.96	nd	1.39	nd
p-value	0.3	-	0.2	-	0.19	-

† MWD: Mean Weight Diameter

‡ MBC: Microbial Biomass Carbon

§ DOC: Dissolved Organic Carbon

¶ BD: Bulk Density

nd: no data measured at this sampling period.

Table 1.18 Olathe spring 2015 soil aggregate mean values. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

	Water Stable Aggregates (g sand-free 100 g^{-1} soil)						Total Aggregation
	>4.75	2 to 4.75	1 to 2	0.5 to 1	0.25 to 0.5	<0.25	%
Control	9.39 d	10.74	12.2 a	23.11 a	21.41	23.14	76.86
Rye	31.68 ab	12.9	9.3 ab	13.83 bc	14.98	17.32	82.68
Rye/Pea	27.34 abc	11.19	9.28 ab	14.51 bc	17.15	20.54	79.46
Rye/Vetch	20.72 bcd	12.26	11.89 a	11.27 c	16.04	27.82	72.18
Rye/Canola	29.45 abc	10.32	6.97 b	11.11 c	16.61	25.54	74.46
Rye/Vetch/Canola	37.54 a	11.22	7.53 b	11.28 c	14.78	17.65	82.35
Oat	17.72 cd	11.01	8.15 b	13.83 bc	16.37	32.92	67.08
Oat/Pea	12.62 d	10.89	6.71 b	16.01 b	19.37	34.41	65.59
p-value	0.02	0.86	0.02	0.001	0.46	0.13	0.29

Table 1.19 Olathe spring 2015 soil property mean values. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

	MWD†	MBC‡	DOC§	Infiltration	BD¶ (0-5 cm)	BD (5-10 cm)
	mm	μg C g^{-1} soil		min cm^{-1}	g cm^{-3}	
Control	1.43 d	73.03	44.12	8.23	1.19	1.29
Rye	2.78 ab	119.53	40.78	23.62	1.15	1.18
Rye/Pea	2.46 abc	81.06	45.37	11.66	1.27	1.21
Rye/Vetch	2.09 bcd	179.57	47.72	12.92	1.16	1.18
Rye/Canola	2.51 abc	276.27	41.49	16.49	1.21	1.22
Rye/Vetch/Canola	3.05 a	164.98	45.22	13.52	1.19	1.23
Oat	1.83 cd	79.09	44.5	5.52	1.19	1.2
Oat/Pea	1.51 d	226.05	37.53	12.43	1.1	1.18
p-value	0.03	0.4	0.87	0.42	0.51	0.84
Control	1.43 b	73.03	44.12	8.23	1.19	1.29 a
Cover	2.32 a	160.94	43.23	13.74	1.18	1.20 b
p-value	0.05	0.26	0.86	0.25	0.81	0.096
Fall cover	2.58 a	164.28	44.11	15.64	1.2	1.2
Spring cover	1.67 b	152.57	41.02	8.97	1.15	1.19
p-value	0.004	0.86	0.43	0.23	0.24	0.67
Control	1.43 b	73.03	44.12	8.23	1.19	1.29
Fall cover	2.58 a	164.28	44.11	15.64	1.2	1.2
Spring cover	1.67 b	152.57	41.02	8.97	1.15	1.15
p-value	0.002	0.53	0.72	0.28	0.49	0.24

† MWD: Mean Weight Diameter

‡ MBC: Microbial Biomass Carbon

§ DOC: Dissolved Organic Carbon

¶ BD: Bulk Density

Table 1.20 Wichita spring 2015 mean values. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

	Water Stable Aggregates (g sand-free 100 g^{-1} soil)						Total Aggregation
	>4.75	2 to 4.75	1 to 2	0.5 to 1	0.25 to 0.5	<0.25	%
Control	15.55 b	8.12	4.02 a	7.40 a	13.04 a	51.86 a	48.14 b
Rye	68.43 a	12.32	1.45 b	2.23 b	3.61 b	11.95 b	88.05 a
Rye/Pea	64.29 a	11.51	2.62 ab	3.74 b	4.69 b	13.15 b	57.9 a
Rye/Vetch	72.51 a	9.83	1.58 b	2.12 b	4.13 b	9.83 b	90.17 a
Rye/Canola	66.69 a	10.9	2.58 ab	3.19 b	3.95 b	12.7 b	87.3 a
Rye/Vetch/Canola	73.70 a	9.79	1.27 b	2.00 b	2.27 b	10.97 b	89.03 a
Oat	70.20 a	8.56	1.63 b	2.20 b	2.99 b	14.43 b	57.05 a
Oat/Pea	78.11 a	6.76	1.06 b	1.61 b	2.53 b	9.93 b	90.07 a
p-value	0.001	0.84	0.03	0.005	0.001	<.0001	<.0001

Table 1.21 Wichita spring 2015 soil property mean values. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

	MWD†	MBC‡	DOC§	Infiltration	BD¶ (0-5 cm)	BD (5-10 cm)
	mm	μg C g^{-1} soil		min cm^{-1}	g cm^{-3}	
Control	1.5 b	21.88	25.69	9.9	1.39	1.34
Rye	4.85 a	21.54	31.68	2.56	1.19	1.22
Rye/Pea	4.59 a	30.17	29.97	2.31	1.18	1.32
Rye/Vetch	5.02 a	56.47	34.52	2.42	1.27	1.25
Rye/Canola	4.71 a	24.45	37.14	3.38	1.28	1.27
Rye/Vetch/Canola	5.08 a	38.98	32.44	5.9	1.29	1.38
Oat	4.83 a	18.91	30.59	3.62	1.21	1.35
Oat/Pea	5.26 a	16.82	30.51	4.12	1.37	1.32
p-value	<.0001	0.52	0.11	0.14	0.21	0.46
Control	1.50 b	21.88	25.69 b	9.90 a	1.39 a	1.34
Cover	4.91 a	29.62	32.41 a	3.47 b	1.25 b	1.3
p-value	<.0001	0.61	0.02	0.002	0.06	0.51
Fall cover	4.85	34.3	33.15	3.31	1.24	1.29
Spring cover	5.05	17.86	30.55	3.87	1.29	1.33
p-value	0.46	0.18	0.22	0.72	0.4	0.31
Control	1.50 b	21.88	25.69 b	9.90 a	1.39	1.34
Fall cover	4.85 a	34.32	34.32 a	3.31 b	1.24	1.29
Spring cover	5.05 a	17.86	17.86 ab	3.87 b	1.29	1.33
p-value	<.0001	0.32	0.03	0.01	0.12	0.48

† MWD: Mean Weight Diameter

‡ MBC: Microbial Biomass Carbon

§ DOC: Dissolved Organic Carbon

¶ BD: Bulk Density

Table 1.22 Olathe fall 2015 mean values. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

	Water Stable Aggregates (g sand-free 100 g^{-1} soil)						Total Aggregation
	>4.75	2 to 4.75	1 to 2	0.5 to 1	0.25 to 0.5	<0.25	%
Control	34.21	12.8	9.09 a	14.44 a	13.94	15.52 a	84.48 b
Rye	66.77	10.52	4.42 b	6.27 b	6.22	5.80 b	94.20 a
Rye/Pea	57.92	10.53	5.29 b	8.76 b	8.99	8.51 b	91.49 a
Rye/Vetch	55.78	10.7	5.24 b	8.63 b	10.3	9.35 b	90.65 a
Rye/Canola	58.99	11.46	5.29 b	7.80 b	8.29	8.17 b	91.83 a
Rye/Vetch/Canola	53.42	12.13	6.44 ab	8.98 b	9.64	9.38 b	90.62 a
Oat	54.17	10.93	5.37 b	9.75 b	9.52	10.25 b	89.75 a
Oat/Pea	59.59	9.09	5.38 b	9.52 b	8.32	8.11 b	91.89 a
p-value	0.13	0.82	0.1	0.09	0.39	0.09	0.09

Table 1.23 Olathe fall 2015 soil property mean values. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

	MWD†	MBC‡	DOC§	Infiltration	BD¶ (0-5 cm)	BD (5-10 cm)
	mm	μg C g^{-1} soil		min cm^{-1}	g cm^{-3}	
Control	2.93	109.21	40.36	22.8	1.24	1.19
Rye	4.76	141.81	36.62	22.76	1.28	1.26
Rye/Pea	4.24	71.35	37.23	16.78	1.26	1.26
Rye/Vetch	4.11	88.1	39.11	22.71	1.27	1.23
Rye/Canola	4.33	137.17	40.1	28.13	1.23	1.17
Rye/Vetch/Canola	4.03	121.23	31.87	20.86	1.32	1.25
Oat	4.02	135.55	32.94	20.44	1.26	1.23
Oat/Pea	4.3	125.66	34.27	23.13	1.24	1.17
p-value	0.10	0.99	0.56	0.99	0.96	0.81
Control	4.10 b	65.15	13.92	3.1	1.39	1.38
Cover	5.83 a	80.45	17.26	3.35	1.23	1.26
p-value	0.001	0.89	0.25	0.89	0.61	0.58
Fall cover	5.84	108.52	15.29	2.97	1.29	1.29
Spring cover	5.83	69.2	18.05	4.28	1.2	1.25
p-value	0.66	0.68	0.22	0.99	0.52	0.38
Control	2.93 b	65.15	13.92	7.87	1.39	1.38
Fall cover	4.29 a	108.52	15.29	10.88	1.29	1.29
Spring cover	4.16 a	69.22	18.05	7.55	1.2	1.25
p-value	0.01	0.91	0.26	0.99	0.75	0.6

† MWD: Mean Weight Diameter

‡ MBC: Microbial Biomass Carbon

§ DOC: Dissolved Organic Carbon

¶ BD: Bulk Density

Table 1.24 Wichita fall 2015 water stable aggregate mean values. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

	Water Stable Aggregates (g sand-free 100 g^{-1} soil)						Total Aggregation
	>4.75	2 to 4.75	1 to 2	0.5 to 1	0.25 to 0.5	<0.25	%
Control	56.33 b	11.58 a	2.90 a	3.49 a	6.14 a	19.57 a	80.44 b
Rye	90.35 a	5.24 b	0.65 b	0.85 b	1.53 b	1.39 b	98.62 a
Rye/Pea	83.95 a	5.73 b	0.84 b	1.04 b	1.84 b	6.6 b	93.40 a
Rye/Vetch	92.53 a	3.67 b	0.50 b	0.64 b	1.13 b	2.15 b	98.47 a
Rye/Canola	88.38 a	5.02 b	0.62 b	1.13 b	1.26 b	3.59 b	96.41 a
Rye/Vetch/Canola	87.38 a	5.92 b	0.54 b	0.60 b	1.14 b	4.41 b	95.58 a
Oat	86.29 a	6.25 b	0.65 b	0.76 b	1.21 b	4.84 b	95.16 a
Oat/Pea	90.61 a	3.67 b	0.56 b	0.85 b	1.10 b	3.23 b	96.79 a
p-value	0.0001	0.04	0.001	0.001	<.0001	0.0003	0.002

Table 1.25 Wichita fall 2015 soil property mean values. Treatments with different letters indicate significant differences at the p=0.1 level. The absence of letters indicates no significant differences among treatments for this particular sampling period.

	MWD†	MBC‡	DOC§	Infiltration	BD¶ (0-5 cm)	BD (5-10 cm)
	mm	μg C g^{-1} soil		min cm^{-1}	g cm^{-3}	
Control	4.10 b	65.15	13.92 e	3.1	1.39 a	1.38
Rye	5.96 a	65.24	16.45 bcde	3.64	1.18 bc	1.24
Rye/Pea	5.58 a	65.81	19.02 ab	3.92	1.30 ab	1.3
Rye/Vetch	6.04 a	91.11	17.08 abcd	3.87	1.23 ab	1.23
Rye/Canola	5.81 a	60.69	18.05 abc	1.56	1.06 c	1.19
Rye/Vetch/Canola	5.79 a	63.27	19.63 a	1.88	1.23 ab	1.26
Oat	5.74 a	76.69	14.68 de	4.49	1.35 a	1.32
Oat/Pea	5.92 a	140.35	15.91 e	4.08	1.23 ab	1.26
p-value	<.0001	0.53	0.05	0.68	0.07	0.12
Control	4.10 b	65.15	13.92 b	3.1	1.39 a	1.38 a
Cover	5.83 a	80.45	17.26 a	3.35	1.23 b	1.26 b
p-value	<.0001	0.62	0.04	0.86	0.06	0.02
Fall cover	5.84	69.2	18.05 a	2.97	1.20 b	1.25
Spring cover	5.83	108.52	15.29 b	4.28	1.29 a	1.29
p-value	0.97	0.1	0.02	0.22	0.09	0.22
Control	4.10 b	65.15	13.92 b	7.87	1.39 a	1.38 a
Fall cover	5.83 a	69.22	18.05 a	2.97	1.20 ab	1.25 b
Spring cover	5.84 a	108.52	15.29 b	4.28	1.29 b	1.29 b
p-value	<.0001	0.22	0.01	0.45	0.06	0.03

† MWD: Mean Weight Diameter

‡ MBC: Microbial Biomass Carbon

§ DOC: Dissolved Organic Carbon

¶ BD: Bulk Density

Chapter 2 - Species Composition and Forage Quality of a Three-Species Cover Crop Mix

Abstract

Cover crops offer many benefits to soil properties, however cost can be a barrier for some producers to adopt this conservation practice. In addition to the benefits to soil health, many cover crop species are annuals which produce excellent quality forage. This forage can then be grazed or hayed to provide supplemental forage for livestock. There is a high interest among some farmers grazing cover crops and mixed species cover crops. The idea of a mixed-species cover crop has been promoted on the premise that native prairies consist of diverse species with the potential for complementary plant structures leading to greater utilization of available resources (sunlight, water, nutrients, etc.). In August 2014 and 2015, sixteen treatments were drill seeded at the Southeast Kansas Research Station near Columbus, Kansas. Each treatment consisted of a three-way mix representing popular cover crops from the plant families Brassicaceae, Poaceae, and Fabaceae. Eight species were planted, Forage radish (*Raphanus sativus*), Purple top turnip (*Brassica rapa*), Oat (*Avena sativa*), Rye (*Secale cereale*), Barley (*Hordeum vulgare*), Wheat (*Triticum aestivium*), Austrian winter pea (*Pisum sativum subsp. arvense*), and Berseem clover (*Trifolium alexandrinum*). The clipped biomass was then evaluated to determine biomass, species composition, and forage quality parameters including acid detergent fiber (ADF), neutral detergent fiber (NDF), and crude protein content. This study found that the composition of the cover crop mixture varied substantially from year to year based primarily on weather and species establishment. On average 2014 biomass was roughly two thirds brassica species while 2015 was roughly two thirds grasses. Overall all treatments produced prime quality forage (as compared to hay values), however some treatments cost

significantly more to plant than others. Therefore an economic analysis compared the treatments and found that the treatments containing turnips and oats generally provided the best return on investment given that both of these species were among the cheapest to plant and produced moderate to high biomass compared to the other treatments. The results of these projects point to the potential benefits that cover crops can have for producers interested in utilizing cover crops for forage.

Introduction

A cover crop is defined as "A close-growing crop, that provides soil protection, seeding protection and soil improvement between periods of normal crop production…"(SSSA, 2008). Cover crops offer many benefits to soil health by improving soil structure, protecting soil from erosion, scavenging excess nitrogen and nutrients, and providing other ecosystem services (Blanco-Canqui, et al., 2015), but establishment and termination costs may prevent many producers from using cover crops in crop rotations (Rodriguez, et al., 2009).

Soil health has been defined as "the capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health" (Doran and Zeiss, 2000). Tiemann, et al. (2015) studied soil microbial communities under diverse crop rotations and found different plant species can increase the diversity of belowground microbial communities.

A limitation for increasing crop diversity for many producers is a lack of local markets for diverse crops. Since a cover crop is used to benefit soil instead of as a cash crop, it provides additional flexibility in species selection for crop diversity as no market is needed for the product. Archer et al, 2007 evaluated strip and conventional tillage systems with organic and conventional crop production and diverse crop rotations (corn, soybean, wheat, alfalfa hay). With the exception of the organic system yielding less, the production costs for reduced tillage and diverse rotations were generally lower than conventional tillage and continuous cropping systems (Archer, et al., 2007).

Cover crops offer many benefits for improving soil health and providing ecosystem services but the costs involved in establishment, termination, and potential negative effect on cash crop yield, can discourage farmers from using them. In a review of literature by Blanco-Canqui et al, 2015, they summarized that animal use by grazing or haying a cover crop did not have an adverse effect on ecosystem services or crop production. Many cover crop species are edible for consumption by livestock and produce excellent forage. Forage crops are defined as "food for animals especially when taken by browsing or grazing" (Merriam-Webster, 2016). Therefore, one option for producers who are interested in improving soil health is to offset the costs involved with cover crops by selecting crops that can be grazed, produce large biomass and quality forage while also providing soil benefits.

Cereal grasses, legumes, and brassicas are three general types of cover crops used and each have their own advantages and disadvantages, depending on the objective of the producer. For example, cereal rye (*Secale cereale*) is one of the most common fall-planted cover crops because the fibrous root system has the ability to hold soil together, reducing erosion, and can also take up excess nitrogen (N) (Brandi-Dohrn, et al., 1997, Clark, 2008). Brassicas such as tillage radish have deep taproots and can scavenge excess N (Chen and Weil, 2010) and legumes fix atmospheric N (which increases protein). One line of thought is that if cover crops are planted as a mixture, multiple benefits may be achieved; however, this is not well-quantified in research on annual cover crop mixtures.

Finney, et al. (2016) in Pennsylvania evaluated cover crops grown in monocultures compared to mixed species cover crops and found that mixed species cover crops did not yield greater biomass over a high yielding monoculture. They also observed that the ecosystem services such as weed suppression and preventing N-leaching was a function of biomass production and not strictly of plant diversity. In other words, cover crops that produced a greater amount of biomass did a better job of suppressing weeds than a low biomass producing mixture of diverse species.

Wortman et al. (2012) studied spring-seeded legumes and brassicas as monocultures and mixtures in Nebraska and observed that the mixtures generally yielded intermediately compared to some of the monocultures. Generally, the brassica monocultures yielded the most, followed by mixtures, then legumes. Wortman et al. (2012) concluded that mixtures, although they were not the highest yielding, allowed for some resilience against environmental conditions. For example, their research plots were hailed on and some species were more tolerant of the hail than others (Wortman, et al., 2012).

In the central Great Plains, Nielsen et al., (2015) evaluated biomass and water use efficiency of monocultures and mixed species cover crops. The monoculture species included flax, oat, pea, and rape. The ten-way mixture included rape, oat, pea, lentil, common vetch, berseem clover, barley, phacelia, and safflower. The biomass of the mixture was dominated by oat and barley in most of the site-years and the legumes were often less than 10% of the biomass. The biomass of the mixture was not greater than any of the monocultures, nor was the water use more efficient (Nielsen, et al., 2015).

A study in Greece evaluating oat, triticale, and common vetch as both monocultures and mixes found that adding common vetch to a cereal grass in a mixture resulted in lower forage yield compared to a cereal grass planted as a monoculture. For example, oat monoculture produced the greatest biomass at 11.62 Mg ha^{-1} while common vetch monoculture produced 7.17 Mg ha^{-1}. Mixtures of vetch and a cereal grass ranged from 7.7 – 9.58 Mg ha^{-1} dry matter yield (Lithourgidis, et al., 2006). This study also found that the crude protein (CP) content of the forage was highest in the treatments containing the highest common vetch seeding rates (i.e. common vetch monocultures resulted in the highest CP, followed by the mixtures with the largest proportion of vetch, between the cereal species, triticale produced more CP than oat) (Lithourgidis, et al., 2006). In respect to fiber, the same pattern observed with CP was also observed with neutral detergent fiber (NDF), the vetch monoculture and the vetch/triticale mixtures contained higher NDF values than cereal grass monocultures. There were only minor differences in acid detergent fiber (ADF) between treatments in the mixtures with different vetch seeding rates.

Creamer et al, 1997 evaluated thirteen cover crop mixtures in vegetable production in Columbus and Freemont Ohio. Species used in the mixtures included both annual and perennial forage species with diverse characteristics including, alfalfa, ladino clover, subterranean clover, Austrian winter peas, annual ryegrass, perennial ryegrass, orchardgrass, tall fescue, yellow and white sweetclover and others. The study found that species performed differently in mixtures than when planted as a monoculture. Of the mixture combinations evaluated, all mixtures had at least one component that was not considered to be suitable as a cover crop when planted in the given mixture. Another complication of mixtures is termination methods, as some species require various termination options (Creamer, et al., 1997).

Forage quality varies substantially among species, growth stage, and growing conditions. Annual forages are generally of a higher forage quality than perennials forage crops depending on the growth stage that the plant is grazed at (Entz, et al., 2002).

The objectives of this study were to investigate the quantity and quality of forage produced from 3-way cover crop mixes. In addition to the overall biomass, this study also identified the species composition of the mixtures. A secondary objective was to examine the economics of using a cover crop as a supplemental forage and which mixtures provide the best return on investment (ROI) to a producer in terms of forage quantity and quality in relation to seed cost. The hypotheses for this project are:

Planting a three-way mix of cover crops by planting a third of the recommended seeding rate for each species should result in a mixture with an even distribution of species from the mixture.

Adding a legume species to a mixture should increase the crude protein content

Species that cost more to plant should yield more biomass or a higher quality forage than cheaper species.

Materials and Methods

Description of Study Site and Soil

This study, initiated in August 2014 took place at the Kansas State University Research and Extension Agronomy Southeast Research Center in Columbus KS at 37.215102, -94.868647 approximately 278 m above sea level on a Parsons silt loam soil. Daily maximum air temperature and precipitation data was obtained from the Kansas State University Mesonet location in Cherokee KS at 37.215102,-94.868647. This location is 10 km west of the study site noted in Figure 1.1.

A randomized complete block design with 16 treatments in triplicate was laid out in approximately 36.5 by 3.5 m plots. The 16 treatments each consisted of a three-way mix with combinations of popular cover crops from each of the three plant families (Brassicaceae, Poaceae, and Fabaceae), as illustrated in Table 2.1. The plots were planted August 12, 2014, and August 21, 2015, with a 3 m Great Plains no-till drill with two seed boxes (Salina, KS). Seeds of similar size were mixed and planted using one seed box; the other seed was placed in the second box. For example, in treatment one, the berseem clover and turnip seeds were placed in the small box and the wheat was placed in the larger seed box.

Species composition and Dry matter

The plots were clipped on September 26, 2014; October 25, 2014; and November 11, 2014. The second year of the study, the plots were clipped on October 6, November 3, and November 23, 2015. For both years, these dates correspond to 45, 74, and 91 days after planting.

The area clipped was 0.35 m^2. Forage samples were placed in plastic bags and transported to the lab in Manhattan, KS.

For each sample, the whole sample was weighed, then the species were sorted and weighed separately. The sample was then mixed together again and a random handful representative of the whole sample was collected. The handful sample was then weighed and dried at 100^o C for 24 hours in a forced-air lab oven. Dry samples were weighed and moisture was determined using:

$$\text{Moisture content (\%)} = \frac{\text{wet weight} - \text{dry weight}}{wet\ weight}\ x\ 100$$

Species composition was calculated by:

$$\frac{Individual\ Species\ Wet\ Weight}{Total\ tared\ sample\ wet\ weight} \times \%\ Dry\ Matter\ for\ individual\ species$$

Species composition was determined based on the wet weight of the total mass from the area clipped and multiplied by the individual species dry matter percent to determine dry matter mass.

Forage Quality

Forage quality parameters measured were Crude Protein (CP), Acid Detergent Fiber (ADF), and Neutral Detergent Fiber (NDF). CP was determined by the nitrogen percent of the forage multiplied by 6.25. Animals need a diet high in protein. The exact requirements vary depending on the class of livestock but greater than 19 percent is considered prime quality hay according to Forage quality standards taken from Southern Forages and shown in Table 2.16 provides quality standards for comparing hay (Ball, et al., 2007). ADF measures the cellulose, and lignin content in a forage, prime quality hay should contain less than 31 percent ADF. NDF measures the cellulose, hemicellulose, and lignin content in forage, prime quality hay should have a value less than 40 percent. Other fiber in forages exists in the form of pectin and other solutes. These components are washed out of the forage through the process of measuring ADF and NDF. Although some species used in these mixtures are not suitable for hay production (such as the brassica species due to high moisture content and drying/harvesting issues), comparing forages to hay quality indices can provide a simple quantitative value to aid in quality distinctions.

Acid Detergent Fiber (ADF)

Oven dried samples were prepared for fiber analysis by grinding to pass through a 1 mm screen in a Wiley mill (Thomas Scientific, Swedesboro, NJ). Acid Detergent Fiber was measured using the method developed by Van Soest, et al. (1991). The grinder was cleaned between samples using a ShopVac™. Samples were stored in the lab in airtight plastic containers until analyzed for fiber. Acid Detergent Fiber was analyzed using an ANKOM 200 (Macedon, NY).

F57 fiber filter bags with 25 micron porosity (ANKOM Technology Macedon, NY) were weighed (W_1) and 0.45 - 0.50 g of prepared sample was added to the bag weight (W_2). Filter bags were sealed using an AIE-200 heat sealer (American International Electric Inc. City of Industry, CA). Bags were loaded into the bag suspender trays and placed in the ANKOM 200. 1900 – 2000 mL of ambient temperature Acid Detergent solution was added to the machine. Heat and agitation were turned on, the lid was closed, and the machine ran for 60 minutes. Following this step, the exhaust valve was opened, to drain the detergent solution. Then the lid was opened. After the waste solution was drained, the exhaust valve was closed and 1900 – 2000 mL of 70 – 90^{o}C rinse water added to the chamber and bags and were agitated for 5 minutes. The rinse step was repeated twice. Following the third rinse, the bag suspender was removed from the vessel and bags were gently squeezed by hand to remove excess moisture. Bags were then covered with acetone in a 250ml beaker for 3-5 minutes. Once filter bags were removed from acetone, they were spread in a single layer and placed in the fume hood for 20 minutes to allow acetone to evaporate. After the acetone had evaporated, the bags were placed in a lab oven at 102 $\pm$ 2^{o}C for 24 hours. Filter bags were then removed from the oven, cooled to an ambient temperature, and weighed (W_3). A blank bag is also weighed and run to determine a correction factor to account for moisture which may present in bags (C_1).

ADF was calculated as:

$$\%\ \text{ADF (as-received basis)} = \frac{100\ x\ (W3-(W1\ x\ C1))}{W2}$$

Where: W_1 = Bag tare weight

W_2 = Sample weight

W_3 = Dried weight of bag with fiber after extraction process

C_1 = Blank bag correction (running average of final oven-dried weight divided by original blank bag weight)

Neutral Detergent Fiber (NDF)

Neutral detergent fiber was measured using the method by Van Soest, et al. (1991). This method followed the same procedure as ADF with the following exceptions: 1900 – 2000 mL of ambient temperature Neutral detergent solution was added to the bags in the bag suspender instead of acid detergent. The samples agitate with heat on for 75 minutes (instead of 60), Once the samples are done agitating and the solution was drained, the rinse water for the first and second rinses had 4 ml of alpha amylase added in addition to the ~ 2000 mL of 85 – 90^{o}C H_2O. The third rinse was water (no amylase). The rest of the procedure is exactly the same as the ADF analysis.

Carbon to Nitrogen Ratio and Crude Protein

Crude protein % was determined by sending samples to Kansas State Soil Testing Lab (Manhattan, KS) to determine total carbon and nitrogen using the Dry Combustion method, measured by the LECO TruSpecCN analyzer (LECO Corp., St. Joseph, MI). The carbon to nitrogen ratio, C:N was calculated by division. The total nitrogen was then multiplied by 6.25 to determine crude protein percent.

Economic Analysis: Partial Budget Comparisons

Economic analyses compared the cost of seed in relation to the amount of forage and protein produced in each mixture. Biomass produced in relation to seed cost was calculated by cost of seed to plant a hectare area divided by the biomass produced in megagrams where:

$$Biomass = \frac{Seed\ cost\ per\ hectare}{biomass\ produced\ in\ Mg}$$

CP content was calculated as biomass produced in megagrams multiplied by the percent CP in the mixture where:

$$Biomass\ Mg\ ha^{-1} \times CP\ \% = Mg\ CP\ ha^{-1}$$

Dollars per megagram CP was calculated as:

$$Mg^{-1}CP^{-1} = \frac{Seed\ Cost\ ha^{-1}}{Mg\ CP^{-1}ha^{-1}}$$

Comparison of individual species in a mixture were calculated by the total DM biomass of a mixture multiplied by the percent of the mixture that was a particular species. For example if treatment 1 (turnip, wheat, clover) consisted of 50% turnip, 40% wheat, and 10% clover on a wet weight basis and a total mixture biomass of 1000 kg ha-1, than the calculated individual species biomass would be 500 kg ha-1 turnip, 400 kg ha-1 wheat, and 100 kg ha-1.

Statistical Analysis

The study was randomized complete block design (RCBD). Each sampling period was analyzed separately by site and sampling time. A one-way analysis of variance was performed comparing: a) all 16 treatments; b) comparison between individual species within plant families.

Statistical analysis was completed using SAS 9.4 (Cary, NC) with the Proc Mixed procedure. Means were separated at a least significance of 0.05. Values shown in tables and are arithmetic means.

Results and Discussion

Overall biomass and species composition was different with each mix planted. Some mixes were dominated by brassica species, while other mixtures contained a larger percentage of grass in relation to other species. Figures 2.3 and 2.4 display the overall biomass and species composition for all sampling periods. Visually in 2014, many of the mixes contained a large portion of brassicas, while in 2015, many of the mixtures were dominated by grasses. In 2014, there was very little legume biomass; in 2015, there was generally more legume biomass for particular treatments. Due to the complex nature of the data, the results are organized as total biomass by treatment, then species composition by percent of mass. In 2014, when comparing among the 16 individual treatments there were treatment differences in biomass at 45-days after planting, and in 2015 there were differences 74-days after planting (Table 2.3).

Biomass by Species Composition

An in-depth examination of the data was done to determine the effects of mixing different species on the composition by mass. At all sampling periods in 2014, the biomass was dominated by either brassicas or grasses whereas legumes produced very little biomass in relation to the portion of seeds planted. 15 of the 16 treatments had less than 14 % legume biomass in all at all sampling periods with one exception. Treatment 5 (turnip, wheat, pea) was a notable exception where the legume was 21.6 percent of the biomass at 45-days after planting. This treatment continued to produce among the greatest percent of legume compared to the other treatments during the other two sampling periods that year (Tables 2.4, 2.5, and 2.6).

In 2015, there was great variability in the composition of each mixture. The percent by mass brassica ranged from 0 to 63.2 percent, grass ranged from 2.4 to 95 percent and legume ranged from 0 to 97.6 percent at 45-days after planting (Table 2.6). This demonstrates how variable results can be with mixed species. This same variability was also observed at 74- and 91-days after planting. On average 2014 biomass was roughly two thirds brassica species while 2015 was roughly two thirds grasses (Tables 2.7, 2.8 and 2.9).

In 2014, across all sampling periods, brassicas produced the most biomass, followed by grasses, then legumes (Table 2.9). To compare between the different species of each particular type (grass, brassica, or legume) statistical comparisons were done between species of each type, averaging across all of the treatments (Table 2.9). In 2014, the greatest yielding grasses were barley and oats at the 45- and 74-day sampling periods. At 91-days the oats and barley were still the greatest yielding although barley was equal to wheat. Cereal rye was the lowest yielding grass for all three sampling periods in 2014. Between the brassica species, radish produced greater biomass at all sampling periods; turnips yielded 40 to 60 percent less biomass than radishes.

Between the two legume species, winter pea produced more biomass than clover for all sampling periods. The winter pea biomass ranged from 52 to 122 kg ha^{-1} while the clover ranged from 0 to 0.5 kg ha^{-1}. To put this in perspective, within the 0.35 m^2 area clipped, there were many samples that did not contain any clover plants. In the times where clover plants were observed, the most plants collected in any sample were five, but frequently this averaged about one or two. Another thing to note is that unlike the grasses, the legumes do not produce tillers, which might be another reason for low biomass production.

In 2015, among the grasses, oats produced the most biomass at 45- and 74-days, followed by barley (Table 2.9). At 91-days, oat and barley were equal. For all sampling periods, wheat and rye were the lowest producers. The magnitude of differences between the grass species was large. For instance, in 2015, oats produced from six to eight times as much biomass as compared to rye. Radishes yielded more than turnips at all sampling periods in 2015, however the difference was only significant at the 74-day sampling period.

As in 2014, winter pea produced more biomass than berseem clover in 2015. The winter pea biomass increased over time, from 436 kg ha^{-1} at 45-days to a maximum of 1097 kg ha^{-1} at 91-days. The maximum berseem clover biomass observed was 4.5 kg ha^{-1} which occurred at the 74-day sampling. Finney et al., (2016) observed that increasing the number of species in a cover crop could increase the biomass; however, mixtures of cover crops did not yield more than the most productive monocultures. Finney et al., (2016) also did not observe increased biomass when species that were complementary were mixed. An example of complementarity is when species with different plant architecture or different rooting systems allow for the maximum use of resources such as sunlight interception, water extraction, etc (Hooper, 1998). In a study in California, Hooper (1998) found that even when complementary plant species were mixed, the biomass production was more influenced by competitive ability than by complementarity (Hooper and Vitousek, 1998).

In the context of this project, although mixing grass, legume, and brassica species that were complementary in terms of their plant architecture, rooting structure, and N-acquisition, winter pea was more capable of competing with the grass and brassica species than berseem clover. In a cover crop study conducted in the central Great Plains, Nielsen et al. (2015) observed that grass species dominated the legume species in mixtures. Depending on the site and year, grass species comprised more than 70% of the dry matter mass Nielsen, et al. (2015).

Finney et al. (2016) point for the need for more research on the subject of optimizing seeding rates for mixed species cover crops, rather than simply dividing the recommended seeding rate for a monoculture by the number of species in the mixture (in our case, dividing each of the seeding rates by three, Tables 2.1 and 2.2).

A statistical analysis was not done to compare the 2014 versus the 2015 results. However, there was a large difference between the two years. Overall, brassicas were the greatest yielding component of the mixtures in 2014, followed by grass, followed by legume. In 2015 for 13 of the 16 treatments, the grass yielded the most biomass. Treatments containing winter pea mixed with wheat, rye, or barley produced a large amount of legume biomass (34 to 97 %). Brassicas consisted of a much smaller component of the overall biomass although treatments 2, 9, and 10 were exceptions where brassica biomass ranged from 44 – 63 percent biomass. As previously mentioned, clover produced very little biomass in either year. Wortman, et al. (2012) studied brassica-legume cover crop mixtures and also observed that legumes were less competitive than brassicas when planted together.

Figure 2.2 displays daily maximum temperature and monthly rainfall for both years. One notable difference occurred in the last two weeks of August; 2014 was hotter during this time period than 2015. Recall that the cover crops were planted August 12, 2014 and August 21, 2015. Another notable difference between the two years is that below freezing temperatures occurred prior to the 91-day clipping on November 11, 2014. At the 91-day clipping in 2014, the radishes had frost killed, while the turnips were still living. It is believed that we clipped the radishes within one to two days after this killing frost occurred, because the radishes appeared wilted, yet the leaves were still intact and could be handled without falling apart and visually, they had not yet started to decompose. Therefore the biomass expressed on a dry matter basis was not affected by the frost.

In 2014, July and August received less than 5 cm of precipitation, and then during the September and October timeframes it was relatively wetter. The opposite pattern happened in 2015, where July and August received more than 10 cm of precipitation per month while September and October were drier. Another way to state this is that at planting in 2014, it was very dry, but there was ample rainfall during September and October. Conversely in 2015, July and August were wetter than 2014; in fact, planting was delayed by nine days while the field was too wet to plant. Then in September and October in 2015, there was half as much rainfall in

September of 2015 than in September 2014 and there was about a quarter as much precipitation in October 2015 as there was in October 2014. In summary, there is almost an inverse relationship between the two years in terms of precipitation. The two years also contrasted in the daily maximum air temperatures in the two-week period after planting. These combined effects of precipitation and temperature likely contributed to the inverse species composition component between brassica and grass species in the two years.

Carbon to Nitrogen ratio (C:N)

The C:N ratio is informative for two reasons, first materials with a lower C:N ratio will decompose faster than materials with a higher ratio. Second, mature plants have a higher C:N than do younger plants which are still in a vegetative state. In Table 2.10, the C:N data is presented for the 16 different treatments for all sampling periods. Generally the C:N ratio increased from 45- to 74- to 91-days in both years (though no statistical analysis was done to compare the years). In all but the 45-day clipping in 2014, treatment differences were observed. Tables 2.13 and 2.14 help elucidate the primary reason for this difference. The type of grass affected the C:N ratio while brassicas and legumes did not. When averaging C:N across treatments, treatments containing oat were consistently greater in C:N than treatments containing rye, with barley and wheat being intermediate. This makes sense because of the life cycle of these grasses. Oat has a shorter growing season and will winter kill while the other grasses will vernalize over the winter and enter the reproductive phase in the spring.

Forage Quality: CP, ADF, and NDF

For this section, the forage quality data will be presented for all of the 2014 samplings followed by all of the 2015.

In 2014 crude protein did not differ among the 16 treatments at the 45-day sampling period but it differed at the 74- and 91-day periods. At 45-days, the CP ranged from 26.3 to 31.3 percent (Table 2.11). At 74-days crude protein ranged from 17.0 to 25.8 and at 91-days it was 13.6 to 20.0 percent. Therefore, the CP decreased over time during the growing season.

In 2014 the ADF was significantly different between treatments at the 45-day period but not at the 74- or 91-day sampling periods. In general, ADF increased over time for the individual treatments. At 45-days the greatest ADF was 13.9 %, at 74-days 14.0, and at 91-days 18.5 %. These values are all low and indicate high digestibility according to Ball, et al. (2007). These values are also consistent with Westwood and Mulcock (2012) who evaluated five different brassica species in New Zealand to determine forage quality (Westwood and Mulcock, 2012).

In 2014 the NDF was not significant between treatments at 45-days but it was at the 74- and 91-day sampling periods which is the opposite of the ADF.

In 2015 the CP % was significant at all sampling periods with a range of 18.5 to 28.9 at 45-days, 14.1 to 24.5 at 74-days, and 14.2 to 25.5 at 91-days. Unlike 2014, where the CP decreased over time for most treatments, in 2015, there was no clear pattern. Some of the treatments decreased as the time increased, however some treatments stayed about the same CP (Table 2.12).

In 2015 the ADF was only significant at the 74-day sampling period with a range of 9.9 to 14.2 percent. When looking between the 45- and 91-day sampling periods, the values increased over time for most treatments, however no statistical analysis was done to compare between sampling periods.

In 2015 the NDF was not significant between treatments at any sampling period.

In order to make some interpretations to explain the forage quality parameter differences among treatments, a statistical analysis was done to determine the effect that the different species within each type (grass, brassica, legume), had on the overall forage quality of the cover crop. Table 2.13 displays the analysis breakdown by species type.

Table 2.15 provides quality standards for hay, according to the table, in 2014 at 45-days, all treatments would classify as prime hay (CP >19%, ADF <31%, and NDF <40%). The fiber analysis indicated very high digestibility and dry matter intake for all treatments and sampling periods. The main difference in classification therefore came from the CP content. In 2014 at 74-days and in 2015 at 45-days, all treatments classified as at least hay grade 1. In 2015 at 74-days and 91-days, all treatments classified as at least hay grade 2, and in 2014 at 91-days, all treatments classified as hay grade 3 or higher.

It appears that the type of grass has more effect on forage quality properties than brassica or legume. For example, for all three sampling periods in 2014, the barley and oat treatments were consistently higher in NDF, wheat was intermediate, and rye was consistently lowest (Table 2.13). Conversely, wheat and rye contained more CP at 74- and 91-days than oat and barley. There was one instance in 2014 where the type of grass species affected the ADF where treatments containing oat or barley had a higher ADF % than treatments containing either wheat or rye.

The type of brassica affected the ADF at 45-days with treatments containing radish having 11.9% ADF compared to 10.5 %. At 91-days treatments containing turnip had more NDF than radish. Recall from the previous section regarding that radishes were frozen at 91-days versus the turnips which were still living when clipped. The data presented in Table 2.13 only illustrates a difference in NDF, with no effect on CP or ADF. It is unknown if the differences in NDF has anything to do with the freeze or not or if this is due to another reason.

The type of legume affected ADF and NDF at the 74-day sampling period only, with treatments containing clover having more ADF and NDF, however considering that the amount of clover biomass comprised less than 0.1 % of the total biomass of any of the treatments, whereas peas contributed between 0.2 and 13.8 % of the total biomass in any of the treatments where they were present (Table 2.4). Another way to state this is that essentially, the clover treatments were really a mixture of brassica and grass whereas the mixtures containing peas as the legume species were truly a three-way mixture.

In 2015, CP was affected by the type of grass for all three sampling periods. At 45-days, treatments containing rye had more CP than either wheat or oat, at 74-days treatments containing rye had more CP than either barley or oat, and at 91-days, and treatments containing rye and wheat had more CP than treatments containing barley or oat (Table 2.14).

For ADF treatments containing oat or wheat were greater than treatments containing rye at 45-days, and those containing wheat were greater than the other grasses at 74-days.

The NDF was affected by grass type at 74-days with treatments containing wheat, barley, or oat having a greater NDF % than treatments containing rye.

The type of brassica did not have any effects on forage parameters at any sampling period in 2015.

The type of legume only made a difference in the NDF at 45-days where treatments were supposed to contain clover had 22.6 % NDF versus treatments that contained winter pea had an NDF of 20.8. At the 45-day sampling period in 2015, the treatments that contained clover ranged from 0 to 1.5 % clover by mass. In contrast, the treatments that contained pea ranged from 8.8 to 97.6 % pea by mass (Table 2.6). Therefore the greater NDF value for the treatments containing clover is representative of the fact those treatments are essentially a two-way mixture of brassica and grass.

Economic Analysis

An economic analysis was conducted to determine which of the treatments would provide the best return on investment (ROI) to a producer. Economic comparisons were based on the cost of seed only, other costs to producers which were not considered include equipment, labor, and opportunity costs. Economic equations are found in the materials and methods section. Economics were compared on the basis of total biomass produced, as well as a comparison of the individual species components of the mixtures. Since a monoculture treatment was not present, individual species comparisons are based on the biomass present in the mixtures. Tables 2.17 and 2.18 show the seed cost, biomass and CP produced in the sixteen individual treatments at the 74-day sampling period in 2014 and 2015.

In 2014, there were not significant differences in the amount of biomass produced between treatments ($p=0.52$). There were also no differences in the biomass produced in relation to seed cost between the treatments in 2014 ($p=0.46$). There were few clear differences in the CP % between treatments. Comparing dollars per Mg CP treatment 1 (turnip, wheat, clover) cost the most, while there were no differences between the other treatments which all cost less ($p=0.04$). Table 2.17.

In 2015, treatments containing oat and barley produced more biomass than treatments containing wheat and rye as the grass species ($p=0.002$). Conversely, when comparing dollars spent per Mg biomass, treatments containing oat and barley were the least expensive in relation to the biomass produced. In other words, treatments containing wheat and rye as the grass species did not produce as much biomass and therefore cost more in relation to the biomass produced (p=0.0004) Table 2.18. Comparing CP % in mixtures, legumes did not affect the CP as much as grass species. Treatments containing wheat or rye tended to have a higher CP % over barley and oat treatments with the exceptions of treatment 5 (turnip, wheat, pea), treatment 7, (turnip, barley, pea), and treatment 14 (radish, rye, pea) (p=0.002) Table 2.18.

While there were more significant differences in 2015 than in 2014, it is hard to determine a consistent trend. In general, treatments containing oats or barley provided a better ROI in terms of biomass produced.

Table 2.19 provides a partial budget analysis comparison of individual species within the mixtures. Between the two brassica species, radishes yielded more biomass but there was no difference in biomass per $ spent in 2014. In 2015, radishes produced slightly more biomass per dollar spent. Among the grass species, oat produced the greatest biomass and the most biomass per dollar spent in both years, followed by barley, there was no difference between wheat or rye in either years (Table 2.19)

Although we did not compare monocultures with our mixed species treatments, other researchers have done so and made conclusions on the economic feasibility of mixed cover crops. Nielsen et al., 2015 found that a cover crop mixture did not produce more biomass than monoculture cover crops and concluded that the additional cost of a mixture is not justified unless the forage is to be grazed and the mixture adds desirable components to the forage. (Nielsen et al., 2015). In a comparison of a rye and several proportions of legume-rye cover crop mixtures in a vegetable production system in California, Brennan et al., (2011) completed a partial economic analysis and found that the cost of producing mixed rye-legume cover crops was up to three times greater on a Mg per ha^{-1} basis than the cost of producing rye by itself (Brennan, et al., 2011).

Tables 2.20 and 2.21 provide a cost comparison for mixtures with and without legume species. Because the clover did not establish well and only produced trace amounts of biomass in either year, the opportunity presented itself for a comparison of mixtures containing a legume species (in this case winter pea) with mixtures which did not contain a legume (grass + brassica mixtures). In 2014, there were no differences in total biomass produced between the individual treatments (p=0.46) or between the mean treatments of grass/brassica mixes compared to grass/brassica/pes mixtures (p=0.68). There were however differences in how much it cost to produce a megagram of biomass between individual treatments (p=0.02) but there did not seem to be a pattern as to which mixture produced the most biomass in 2014. One trend that emerged in 2015 between individual treatments is that the treatments with oat and barley tended to produce more biomass and therefore cost less per Mg of biomass produced. The exceptions to this are treatment 7 (turnip, barley, pea), and treatment 15 (radish, barley, pea). Both of these treatments contained barley and were not statistically different from the mixes containing wheat and rye. These mixes had almost no biomass from the brassica species with the biomass composition coming from approximately 59% barley and 40% pea (Tables 2.21 and 2.8).

When comparing the mean of 2-species mixes (grass + brassica) to 3-species mixes (grass + brassica + legume), the mean cost to plant a hectare of 2-species mixes was $38.37 compared to $66.86 for mixtures containing a grass, brassica, and legume. The hypothesis was that adding a legume would add to the cost but that it would increase the biomass produced and also the protein content in the forage.

The mean seed cost for planting mixtures without a legume was $38.37 compared to $66.86 for mixtures containing a grass, brassica, and legume. In 2014 there was not a difference in the mean biomass produced when comparing mixtures with a legume to those without a legume (p=0.68). However there was a difference in the cost to produce a megagram of biomass between the mixtures with and without a legume. Grass + brassica mixtures cost $14.30 per Mg biomass produced and grass + brassica + pea mixes cost $20.51 per Mg biomass produced (p=0.01) Table 2.20.

In 2015 there was also no difference in the biomass produced between treatments with and without a legume component (p=0.69). There was however a difference in the cost to produce the biomass between the mean of treatments containing pea and those without a legume. Treatments without a legume cost $27.74 per Mg biomass compared to $37.46 for mixtures containing winter peas (p=0.048) Table 2.21

Comparing the protein content between the mixtures, there were differences between the individual treatments, but there was no difference in the mean of treatments containing pea to those in which only trace amounts of clover were found. This trend was constant in both years (Tables 2.20 and 2.21)

Future work: because we had such strong contrasting results in these two years, a longer term study would be helpful in establishing long term trends. Also more work could focus on adjusting seeding rates of the individual species in the mixes. Instead of using the replacement methods, perhaps using a higher percent of legumes in the mixtures. Adding a comparison of monoculture species to mixtures to evaluate total biomass produced and forage quality of mixtures to monocultures.

Conclusions

The total biomass produced by the 16 treatments and the kilograms that each species contributed to the total are illustrated in Figures 2.1 and 2.2. In 2014, the 74-day clipping in a majority (11 of 16) of the treatments yielded the highest dry matter biomass production. In some treatments, including treatment 4 (oat, clover, turnip), treatment 7 (barley, pea, turnip), treatment 10 (rye, clover, radish), and treatment 16 (oat, pea, radish), the 91-day clipping yielded the highest biomass.

It is important to note that by the 91-day clipping, a killing freeze occurred that resulted in wilting of the brassicas. This might have led to the reduction in biomass yield for a majority of the mixtures, especially in the mixtures predominantly composed of brassicas

The cover crop mixes used in this experiment were established successfully, but certain species did not emerge with this planting method and/or combination of plants. In the first 45 days in 2014, the brassicas in all mixes contributed more than 50% of the total dry matter biomass. At the 74-day clipping, turnips were still the predominant species in the mixtures, except for the combinations that included barley and oats (treatments 3, 4, 7, and 8), and this trend continued at the 91-day clipping. This was not observed with the radish mix, where radishes contributed more than 50% of the total biomass at the 74-day clipping for all mixtures. Radishes were also the predominant species at the 91-day clipping, except in treatments 11 and 16 (radish mix with barley and oats, respectively).

The legumes (berseem clover and Austrian winter pea) were a very small component of the mixtures, if they even emerged. Austrian winter pea was a better legume in these mixes than berseem clover. Some samples contained traces of clover but it was basically non-existent. The lack of a substantial biomass contribution from legumes might have been caused by issues with planting depth. Although the planter box had separate seed boxes, the drill would only plant at one depth. The entire mixture was therefore drilled at 12.7 mm, which is deeper than the recommended planting depth for legumes. In addition, poor emergence of the legumes could have been caused by rapid growth of the brassicas within the first 45 days after planting. The brassicas appeared to outcompete and “choke out” the legumes in these mixtures. This might be a great benefit for fall weed control, but limits cover crop mixes.

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Figures and Tables

Figure 2.1 Map of Kansas with research site location.

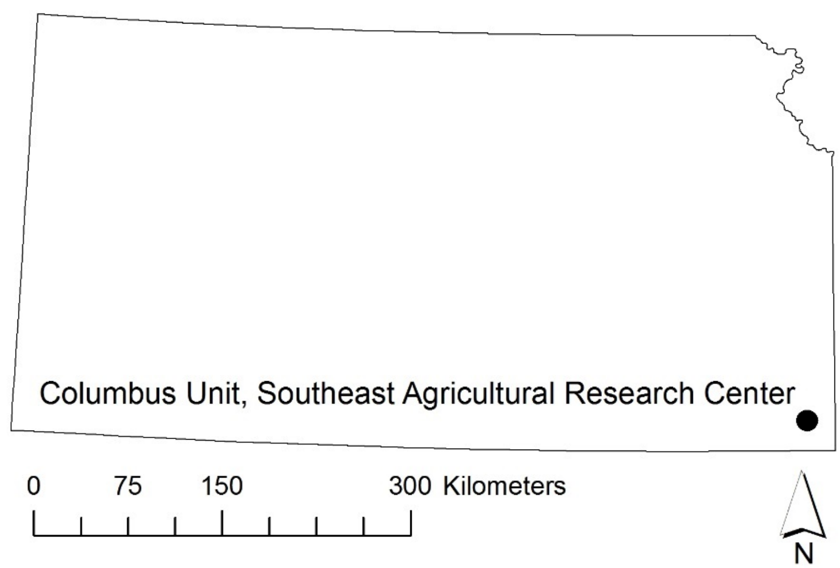
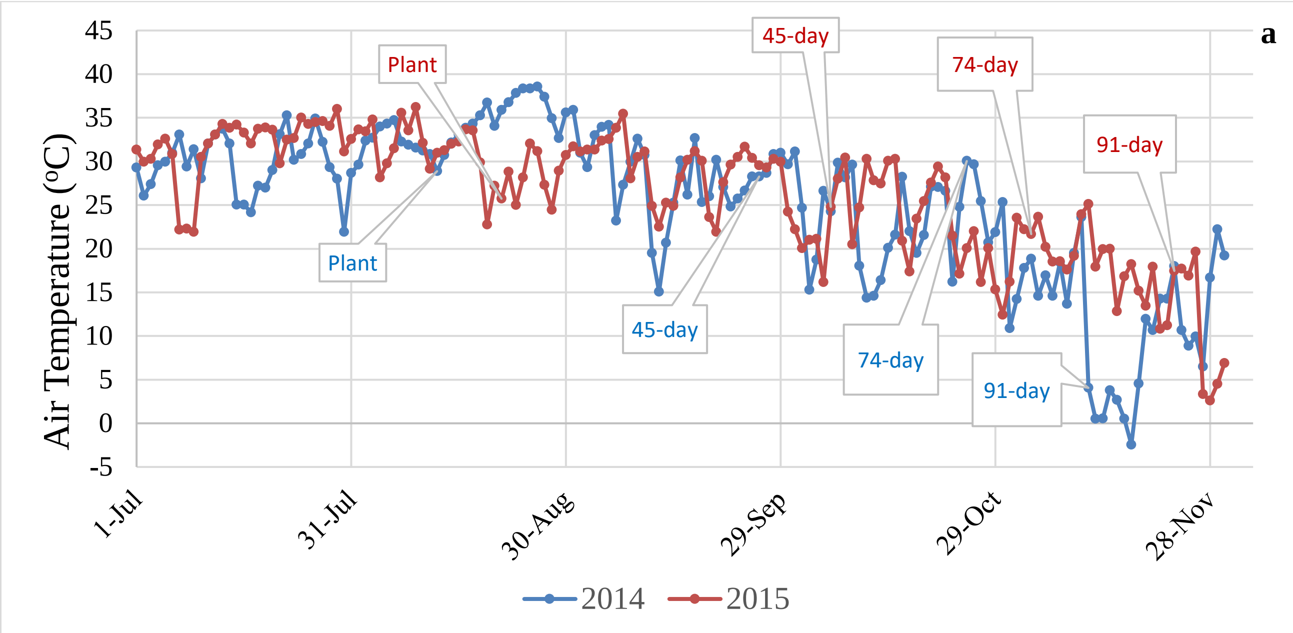


Figure 2.2 Columbus Kansas weather data from Kansas Mesonet, Cherokee Station, 10 km west of research site. a) Daily maximum air temp b) Monthly precipitation.



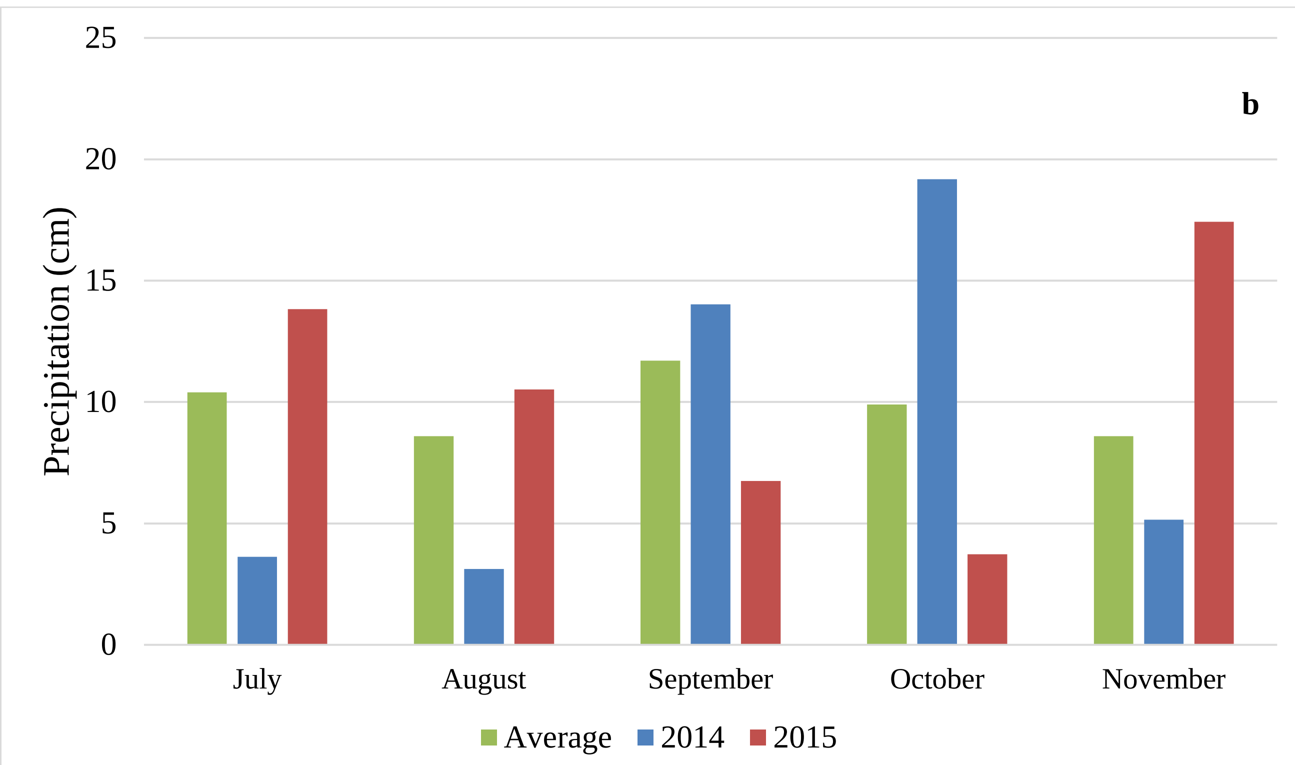
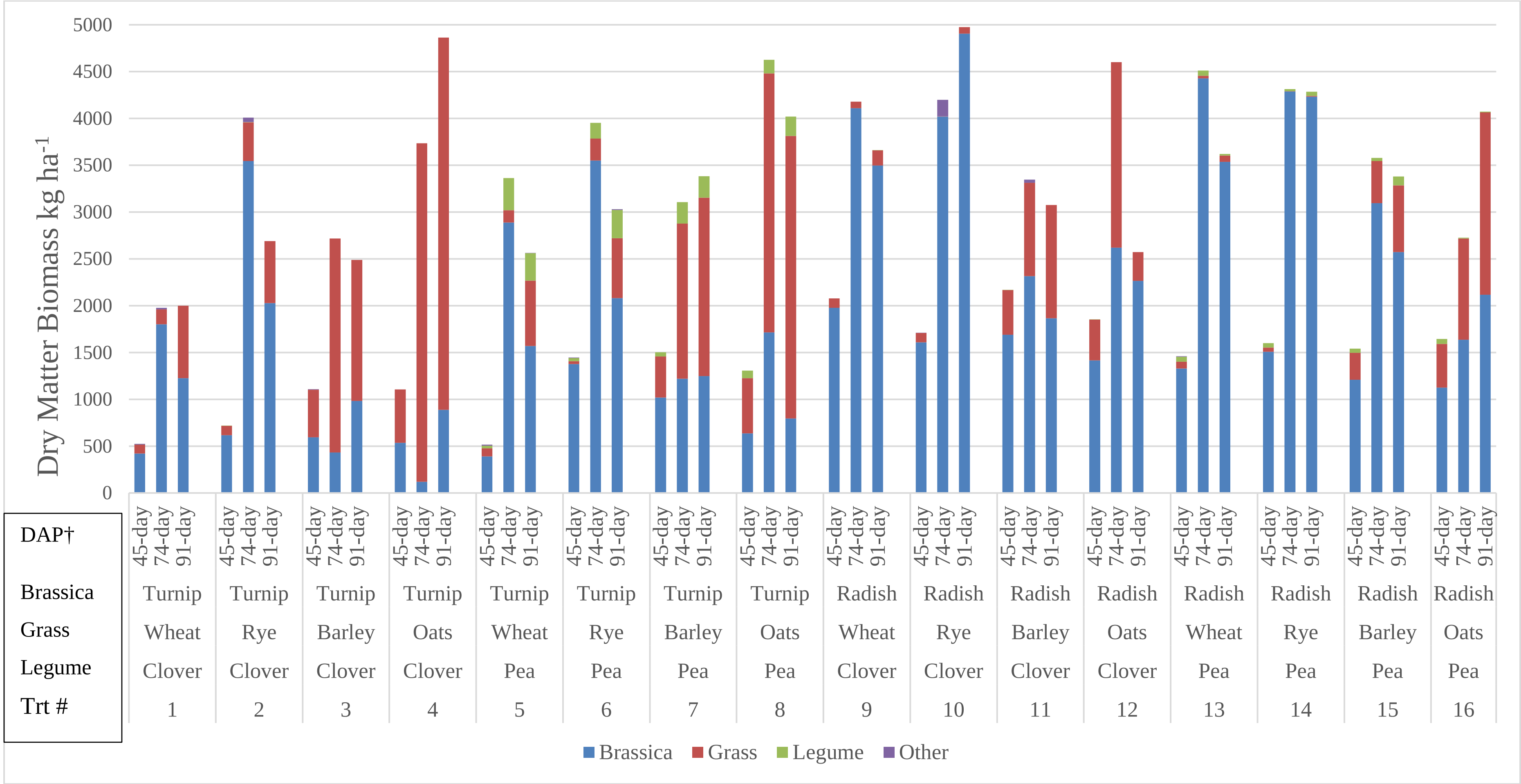
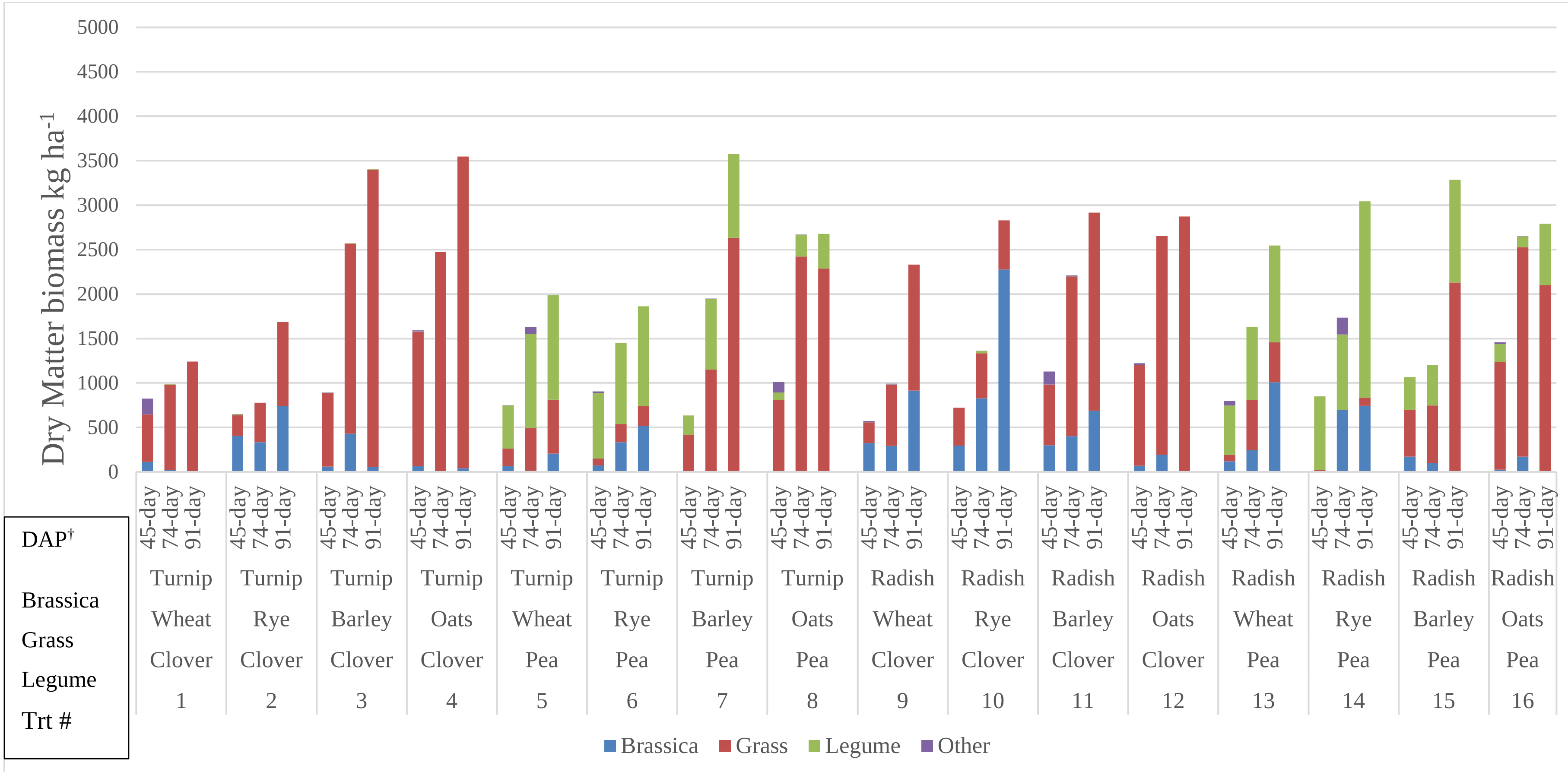


Figure 2.3 2014 forage biomass and species composition.



DAP† Days After Planting

Figure 2.4 2015 biomass and species composition.



DAP† Days After Planting

Table 2.1 Recommended planting depth and seeding rate. Seeding rates are recommended for planting species as a monoculture.

Common name	Scientific name	Recommended seeding depth	Recommended seeding rate
		---------------cm--------------	kg ha^{-1}
Forage radish	*Raphanus sativus*	0.6 - 1.9	4.5-11.2
Purple-top turnip	*Brassica rapa*	0.6 - 1.3	1.1-3.4
Wheat	*Triticum aestivium*	1.9 - 3.8	56.0-100.9
Rye	*Secale cereale*	1.9 - 3.8	44.8-100.9
Barley	*Hordeum vulgare*	1.9 - 3.8	56.0-84.1
Oat	*Avena sativa*	1.3 - 3.8	33.6-67.3
Berseem clover	*Trifolium alexandrinum*	2.5 - 3.8	9.0-11.2
Austrian winter pea	*Pisum sativum* subsp. *arvense*	0.6 - 1.3	56.0-89.7

Source: Midwest Cover Crops Field Guide Second Edition

Table 2.2 Treatments and seeding rates.

Treatment Number	Poaceae[1]		Fabaceae[2]		Brassicaceae[3]	
	Species planted[4]	Seeding rate, kg ha^{-1}	Species planted[4]	Seeding rate, kg ha^{-1}	Species planted[4]	Seeding rate, kg ha^{-1}
1	Wheat	33.6	Clover	4.1	Turnip	2.6
2	Rye	33.6	Clover	4.1	Turnip	2.6
3	Barley	33.6	Clover	4.1	Turnip	2.6
4	Oat	42.0	Clover	4.1	Turnip	2.6
5	Wheat	33.6	Pea	21.3	Turnip	2.6
6	Rye	33.6	Pea	21.3	Turnip	2.6
7	Barley	33.6	Pea	21.3	Turnip	2.6
8	Oat	42.0	Pea	21.3	Turnip	2.6
9	Wheat	33.6	Clover	4.1	Radish	3.4
10	Rye	33.6	Clover	4.1	Radish	3.4
11	Barley	33.6	Clover	4.1	Radish	3.4
12	Oat	42.0	Clover	4.1	Radish	3.4
13	Wheat	33.6	Pea	21.3	Radish	3.4
14	Rye	33.6	Pea	21.3	Radish	3.4
15	Barley	33.6	Pea	21.3	Radish	3.4
16	Oat	42.0	Pea	21.3	Radish	3.4

[1] Poaceae is the grass component in these cocktails.

[2] Fabacea is the legume component of the cocktail.

[3] Brassicaceae is commonly known as brassicas.

[4] Common names of the species planted in the cocktail are used in the table. Scientific names are: Brassicaceae: forage radish (*Raphanus sativus*) or purple-top turnip (*Brassica rapa*); Poaceae: oat (*Avena sativa*), rye (*Secale cereale*), barley (*Hordeum vulgare*), or wheat (*Triticum aestivium*); Fabaceae: Austrian winter pea (*Pisum sativum* subsp. *arvense*) or berseem clover (*Trifolium alexandrinum*).

Table 2.3 Forage quantity by treatment. Treatments with different letters indicate significant differences at the p=0.05 level. The absence of letters indicates no significant differences among treatments. Under treatment heading, letters in parentheses denote treatment species. The first letter is the brassica, where T=turnip and R=radish. The second letter is the grass where W=wheat, R=rye, B=barley, O=Oat. The third letter is the legume where C=berseem clover and P=winter pea.

	Biomass kg ha^{-1}							
	2014				2015			
Treatment	45-day		74-day	91-day	45-day	74-day		91-day
1 (TWC)	738	de	1712	2437	825	988	ef	1241
2 (TRC)	1025	bcde	3562	3505	647	777	f	1685
3 (TBC)	1469	abcd	2676	4030	891	2569	ab	3403
4 (TOC)	914	cde	3755	4067	1593	2474	abc	3548
5 (TWP)	346	e	2870	3429	747	1629	cdef	1991
6 (TRP)	1429	abcd	3761	3129	905	1451	def	1861
7 (TBP)	1461	abcd	3042	2399	634	1948	abcd	3574
8 (TOP)	1164	bcde	4483	3222	1010	2670	a	2678
9 (RWC)	1892	abcd	4101	3064	573	993	ef	2333
10 (RRC)	1570	abcd	4066	3867	722	1359	def	2828
11 (RBC)	2303	a	3065	2443	1129	2210	abcd	2917
12 (ROC)	2256	a	4409	2231	1222	2653	a	2873
13 (RWP)	1737	abc	4022	1443	798	1629	cdef	2547
14 (RRP)	1705	abc	3626	2630	850	1734	bcde	3044
15 (RBP)	1578	abcd	3357	2256	1067	2085	abcd	3285
16 (ROP)	1688	abcd	3353	2624	1458	2649	a	2791
p-value		0.02	0.46	0.52	0.13		0.002	0.34

Table 2.4 Species composition percent of mass by treatment 45-days after planting in 2014. Treatments with different letters indicate significant differences at the p=0.05 level. The absence of letters indicates no significant differences among treatments. Under treatment heading, letters in parentheses denote treatment species. The first letter is the brassica, where T=turnip and R=radish. The second letter is the grass where W=wheat, R=rye, B=barley, O=Oat. The third letter is the legume where C=berseem clover and P=winter pea.

	Brassica	Grass	Legume		Other†
Treatment	--------------------%------------------------				
1 (TWC)	81.4	17.0	0.1	b	1.5
2 (TRC)	85.3	14.3	0.4	b	0.0
3 (TBC)	46.5	52.2	0.0	b	1.4
4 (TOC)	73.0	27.0	0.0	b	0.0
5 (TWP)	64.4	11.3	21.6	a	2.7
6 (TRP)	94.9	1.0	3.9	b	0.2
7 (TBP)	48.2	48.3	3.5	b	0.0
8 (TOP)	65.3	28.4	6.4	b	0.0
9 (RWC)	95.3	4.7	0.0	b	0.0
10 (RRC)	92.4	7.2	0.0	b	0.4
11 (RBC)	75.1	24.8	0.0	b	0.0
12 (ROC)	76.2	23.8	<0.1	b	0.0
13 (RWP)	95.4	2.1	2.3	b	0.2
14 (RRP)	92.7	4.0	3.3	b	0.0
15 (RBP)	76.6	20.3	3.2	b	0.0
16 (ROP)	76.2	20.1	3.7	b	0.0
p-value	0.08	0.10	<.0001		0.51

† Other refers to weeds in sample.

Table 2.5 Species composition percent of mass by treatment 74-days after planting in 2014. Treatments with different letters indicate significant differences at the p=0.05 level. The absence of letters indicates no significant differences among treatments. Under treatment heading, letters in parentheses denote treatment species. The first letter is the brassica, where T=turnip and R=radish. The second letter is the grass where W=wheat, R=rye, B=barley, O=Oat. The third letter is the legume where C=berseem clover and P=winter pea.

	Brassica		Grass		Legume	Other†
Treatment	----------------------------		%		----------------------------	
1 (TWC)	78.3	abc	21.4	def	0.0	0.3
2 (TRC)	83.9	abc	15.7	def	0.1	0.3
3 (TBC)	17.3	e	82.7	ab	0.0	0.0
4 (TOC)	3.4	e	96.6	a	0.0	0.0
5 (TWP)	79.6	abc	6.6	ef	13.8	0.0
6 (TRP)	86.5	abc	7.1	def	6.5	0.0
7 (TBP)	32.5	de	59.1	bc	8.5	0.0
8 (TOP)	34.9	de	61.8	bc	3.3	0.0
9 (RWC)	97.3	ab	2.7	f	0.0	0.0
10 (RRC)	97.7	ab	0.1	f	0.0	2.2
11 (RBC)	71.4	abc	28.3	cdef	0.0	0.3
12 (ROC)	59.2	cd	40.8	cd	0.0	0.0
13 (RWP)	97.9	a	0.7	f	1.4	0.0
14 (RRP)	99.4	a	0.1	f	0.5	0.0
15 (RBP)	87.2	abc	12.1	def	0.8	0.0
16 (ROP)	61.6	bcd	38.3	cde	0.2	0.0
p-value		<.0001		<.0001	0.06	0.46

† Other refers to weeds in sample.

Table 2.6 Species composition percent of mass by treatment 91-days after planting in 2014. Treatments with different letters indicate significant differences at the p=0.05 level. The absence of letters indicates no significant differences among treatments. Under treatment heading, letters in parentheses denote treatment species. The first letter is the brassica, where T=turnip and R=radish. The second letter is the grass where W=wheat, R=rye, B=barley, O=Oat. The third letter is the legume where C=berseem clover and P=winter pea.

	Brassica		Grass		Legume		Other†
Treatment	-----------------------------		----%----		----------------------------		
1 (TWC)	54.3	cde	45.7	abcde	0.0	d	0.0
2 (TRC)	77.8	abcd	22.2	defg	0.0	d	0.0
3 (TBC)	34.7	de	65.3	abcd	0.0	d	0.0
4 (TOC)	33.8	e	66.2	a	0.0	d	0.0
5 (TWP)	23.4	de	67.2	bcdef	9.2	a	0.2
6 (TRP)	56.8	bcde	33.1	cdefg	10.0	ab	0.1
7 (TBP)	29.5	e	64.3	ab	6.0	bc	0.2
8 (TOP)	28.6	e	65.6	abc	5.7	bcd	0.0
9 (RWC)	48.7	abc	48.7	efg	2.6	d	0.0
10 (RRC)	97.7	a	2.3	g	0.0	d	0.0
11 (RBC)	72.0	bcde	28.0	abcdef	0.0	d	0.0
12 (ROC)	82.6	ab	17.4	fg	0.0	d	0.0
13 (RWP)	87.7	a	12.0	g	0.4	d	0.0
14 (RRP)	98.2	a	0.2	g	1.6	cd	0.0
15 (RBP)	77.1	abcd	21.9	efg	1.0	cd	0.0
16 (ROP)	60.9	cde	37.7	abcde	1.4	d	0.0
p-value		0.0004		0.0004		0.001	0.07

† Other refers to weeds in sample.

Table 2.7 Species composition percent of mass by treatment 45-days after planting in 2015. Treatments with different letters indicate significant differences at the p=0.05 level. The absence of letters indicates no significant differences among treatments. Under treatment heading, letters in parentheses denote treatment species. The first letter is the brassica, where T=turnip and R=radish. The second letter is the grass where W=wheat, R=rye, B=barley, O=Oat. The third letter is the legume where C=berseem clover and P=winter pea.

	Brassica		Grass		Legume		Other
Treatment	----------------------------%----------------------------						
1 (TWC)	12.5	cd	69.0	bc	0.0	f	18.5
2 (TRC)	63.2	a	35.2	ef	1.5	ef	0.1
3 (TBC)	5.6	d	94.3	a	0.0	f	0.0
4 (TOC)	4.1	d	95.0	a	0.1	f	0.8
5 (TWP)	7.5	cd	25.2	fg	67.2	c	0.1
6 (TRP)	8.6	cd	8.2	gh	81.2	b	2.0
7 (TBP)	0.0	d	65.7	bc	34.3	d	0
8 (TOP)	0.0	d	80.3	ab	8.8	ef	10.9
9 (RWC)	56.9	a	39.9	def	0.4	f	2.7
10 (RRC)	44.1	ab	55.9	cde	0.0	f	0.0
11 (RBC)	28.5	bc	61.5	bcd	0.0	f	10.0
12 (ROC)	6.2	d	92.6	a	0.0	f	1.2
13 (RWP)	15.1	cd	9.1	gh	69.6	bc	6.2
14 (RRP)	0.0	d	2.4	h	97.6	a	0.0
15 (RBP)	12.0	cd	50.4	cde	37.7	d	0.0
16 (ROP)	2.5	d	82.6	ab	13.8	e	1.1
p-value		<.0001		<.0001		<.0001	0.41

† Other refers to weeds in sample.

Table 2.8 Species composition percent of mass by treatment 74-days after planting in 2015. Treatments with different letters indicate significant differences at the p=0.05 level. The absence of letters indicates no significant differences among treatments. Under treatment heading, letters in parentheses denote treatment species. The first letter is the brassica, where T=turnip and R=radish. The second letter is the grass where W=wheat, R=rye, B=barley, O=Oat. The third letter is the legume where C=berseem clover and P=winter pea.

	74-day					
	Brassica	Grass		Legume		Other†
Treatment	---------------------	----------	%	----------	----------	----------
1 (TWC)	1.8	97.8	a	0.4	d	0.0
2 (TRC)	41.9	58.1	abcde	0.0	d	0.0
3 (TBC)	14.2	85.8	abc	0.1	d	0.0
4 (TOC)	0.0	99.9	a	0.0	d	0.1
5 (TWP)	0.5	42.6	cdef	53.3	ab	3.5
6 (TRP)	24.0	14.1	ef	61.8	a	<0.1
7 (TBP)	0.0	58.8	abcde	41.0	ab	0.1
8 (TOP)	0.0	90.3	ab	9.6	cd	0.1
9 (RWC)	31.9	66.9	abcd	0.3	d	0.9
10 (RRC)	52.9	45.8	bcdef	1.3	d	0.1
11 (RBC)	19.9	79.3	abcd	0.1	d	0.6
12 (ROC)	7.0	93.0	a	0.0	d	0.0
13 (RWP)	13.4	36.9	def	49.7	ab	0.0
14 (RRP)	41.1	0.0	f	49.2	ab	9.7
15 (RBP)	8.6	58.9	abcde	32.5	bc	0.0
16 (ROP)	9.5	85.9	abc	4.6	d	<0.1
p-value	0.09	0.007		0.0001		0.53

† Other refers to weeds in sample.

Table 2.9 Species Composition percent of mass by treatment 91-days after planting in 2015. Treatments with different letters indicate significant differences at the p=0.05 level. The absence of letters indicates no significant differences among treatments. Under treatment heading, letters in parentheses denote treatment species. The first letter is the brassica, where T=turnip and R=radish. The second letter is the grass where W=wheat, R=rye, B=barley, O=Oat. The third letter is the legume where C=berseem clover and P=winter pea.

	Brassica	Grass		Legume	
Treatment	----------------------	--%--		--------------------	
1 (TWC)	0.5	99.5	ab	0.0	e
2 (TRC)	43.9	56.1	abcdef	0.0	de
3 (TBC)	1.6	98.3	ab	0.1	e
4 (TOC)	0.9	99.1	ab	0.0	e
5 (TWP)	12.6	34.6	cdef	52.8	abc
6 (TRP)	20.1	8.8	ef	71.1	ab
7 (TBP)	0.0	74.0	abc	26.0	cde
8 (TOP)	0.0	81.5	ab	18.5	cde
9 (RWC)	38.3	61.7	abcd	0.0	e
10 (RRC)	45.7	54.3	bcde	0.0	e
11 (RBC)	27.4	72.6	abc	0.0	e
12 (ROC)	0.0	100.0	a	0.0	e
13 (RWP)	38.1	18.9	def	43.0	abcd
14 (RRP)	24.3	2.9	f	72.8	a
15 (RBP)	0.0	65.4	abc	34.6	bcde
16 (ROP)	0.0	73.5	abc	26.5	cde
p-value	0.29	0.004		0.004	

Table 2.10 Determination of the greatest yielding species within each type (grass, brassica, legume) when planted as a mixture. For example between brassica species, total treatment biomass is multiplied by percent species composition for each component. Means followed by different letters indicate significant differences between species at the p=0.05 level.

Biomass (kg ha^{-1})											
	Grass					Brassica			Legume		
	Wheat	Rye	Barley	Oat	p-value	Turnip	Radish	p-value	Winter Pea	Clover	p-value
2014											
45-day	72 b	93 b	459 a	317 a	<.0001	789 b	1593 a	<.0001	52 a	0.5 b	<.0001
74-day	119 b	157 b	1281 a	1900 a	<.0001	1793 b	3025 a	0.008	122 a	0.2 b	0.003
91-day	524 bc	353 c	1205 ab	1613 a	0.01	879 b	2027 a	0.0004	91 a	0 b	0.0003
2015											
45-day	259 c	189 c	614 b	1167 a	<.0001	97	163	0.22	436 a	1.8 b	<.0001
74-day	674 c	290 c	1577 b	2428 a	<.0001	194 b	455 a	0.12	604 a	8 b	<.0001
91-day	928 b	383 b	2584 a	2693 a	<.0001	159	703	0.08	1097 a	0.4 b	<.0001

Table 2.11 Carbon to Nitrogen ratio. Treatments with different letters indicate significant differences at the p=0.05 level. The absence of letters indicates no significant differences among treatments. Under treatment heading, letters in parentheses denote treatment species. The first letter is the brassica, where T=turnip and R=radish. The second letter is the grass where W=wheat, R=rye, B=barley, O=Oat. The third letter is the legume where C=berseem clover and P=winter pea.

	C:N †										
	2014					2015					
Treatment	45-day	74-day		91-day		45-day		74-day		91-day	
1 (TWC)	8.4	13.0	abc	19.8	ef	11.5	abcd	12.5	cde	12.4	bcd
2 (TRC)	8.2	10.1	e	21.6	def	8.9	de	10.6	e	11.2	bcd
3 (TBC)	9.2	13.7	abc	21.5	abc	11.2	bcd	13.8	abcde	17.3	a
4 (TOC)	9.3	11.7	bcde	20.4	abc	10.9	bcde	16.5	abc	18.5	a
5 (TWP)	8.4	11.3	cde	18.3	bcdef	11.8	ab	13.4	bcde	11.1	cd
6 (TRP)	8.3	11.7	bcde	18.5	cdef	10.1	abcd	12.3	de	12.2	bcd
7 (TBP)	8.2	12.9	abcd	17.8	def	9.1	abcd	12.8	bcde	17.9	a
8 (TOP)	8.7	12.6	bcd	18.4	abcd	14.0	a	16.8	ab	14.6	abc
9 (RWC)	8.2	12.1	bcde	19.3	f	8.3	e	11.1	e	12.5	bcd
10 (RRC)	8.0	11.8	bcde	21.9	def	8.5	e	10.5	e	10.0	d
11 (RBC)	9.5	14.4	ab	21.3	abcde	12.3	ab	17.8	a	16.1	ab
12 (ROC)	8.9	13.5	abc	19.2	abcd	11.8	ab	16.2	abcd	15.6	ab
13 (RWP)	8.6	12.2	bcde	18.3	ef	11.5	abcd	12.1	de	15.1	abc
14 (RRP)	8.4	10.7	de	20.9	abcde	10.7	bcde	14.1	abcde	15.9	ab
15 (RBP)	9.1	11.3	cde	20.6	abcde	10.0	bcde	13.9	abcde	15.2	ab
16 (ROP)	9.3	15.1	a	17.9	a	11.8	abc	16.0	abcd	16.7	a
p-value	0.52	0.02		0.02		0.02		0.03		0.01	

† C:N : Carbon to nitrogen ratio

Table 2.12 Forage quality by treatment 2014. Treatments with different letters indicate significant differences at the p=0.05 level. The absence of letters indicates no significant differences among treatments. Under treatment heading, letters in parentheses denote treatment species. The first letter is the brassica, where T=turnip and R=radish. The second letter is the grass where W=wheat, R=rye, B=barley, O=Oat. The third letter is the legume where C=berseem clover and P=winter pea.

	CP† %					ADF‡ %				NDF§ %					
Treatment	45-day	74-day		91-day		45-day		74-day	91-day	45-day		74-day		91-day	
1 (TWC)	30.6	20.3	bcde	17.2	bc	9.7	ef	11.7	16.9	17.4	abc	18.2	bcd	20.8	abcde
2 (TRC)	30.8	25.8	a	17.2	ab	10.7	cdef	10.9	15.7	17.7	abc	17.4	cde	21.2	cdef
3 (TBC)	27.9	18.8	cde	13.7	e	11.1	bcdef	13.4	16.0	19.4	ab	21.1	b	22.3	abcde
4 (TOC)	28.4	22.9	abc	13.6	e	10.9	cdef	14.0	15.8	18.4	ab	24.9	a	20.9	a
5 (TWP)	31.2	23.4	ab	16.2	bcde	10.4	def	10.2	16.0	18.6	ab	15.4	de	20.3	abcd
6 (TRP)	29.1	22.3	abcd	16.2	bcde	9.4	f	10.2	17.7	15.4	c	15.8	de	22.8	abcd
7 (TBP)	31.3	20.0	bcde	16.6	bcd	11.7	bcd	12.6	17.3	20.2	a	20.0	bc	22.6	ab
8 (TOP)	29.5	20.8	bcde	14.0	e	10.2	def	11.3	18.3	18.7	ab	17.9	bcd	22.5	a
9 (RWC)	29.3	20.7	bcde	20.0	a	10.6	cdef	13.4	18.5	16.7	bc	17.5	cde	21.9	cdef
10 (RRC)	30.5	22.1	abcd	16.2	bcde	11.4	bcde	11.7	18.1	16.9	bc	15.9	de	22.1	bcde
11 (RBC)	26.3	17.8	de	14.9	bcde	11.7	bcd	13.2	17.0	17.7	abc	18.3	bcd	20.8	abc
12 (ROC)	28.1	19.3	bcde	14.1	de	11.4	bcde	13.7	14.3	18.5	ab	20.1	bc	16.9	def
13 (RWP)	29.5	20.0	bcde	16.1	bcde	11.4	bcde	9.5	14.2	17.0	bc	14.9	e	17.4	ef
14 (RRP)	29.2	23.8	ab	14.4	cde	12.4	abc	12.3	13.8	18.2	ab	16.9	cde	19.5	f
15 (RBP)	27.0	23.1	abc	15.0	bcde	13.9	a	13.2	13.2	20.0	a	18.0	bcd	20.9	cdef
16 (ROP)	27.2	17.0	e	13.8	e	12.7	ab	13.0	11.6	19.4	ab	19.6	bc	19.5	ab
p-value	0.52	0.03		0.01		0.002		0.1	0.46	0.08		<.0001		0.001	

† CP: Crude protein

‡ ADF: Acid detergent fiber

§ NDF: Neutral detergent fiber

Table 2.13 Forage quality by treatment 2015. Treatments with different letters indicate significant differences at the p=0.05 level. The absence of letters indicates no significant differences among treatments. Under treatment heading, letters in parentheses denote treatment species. The first letter is the brassica, where T=turnip and R=radish. The second letter is the grass where W=wheat, R=rye, B=barley, O=Oat. The third letter is the legume where C=berseem clover and P=winter pea

	CP† %						ADF‡ %				NDF§ %		
Treatment	45-day		74-day		91-day		45-day	74-day		91-day	45-day	74-day	91-day
1 (TWC)	22.1	bcd	19.7	bc	22.7	ab	14.7	14.2	a	16.6	24.3	21.7	25.2
2 (TRC)	27.5	ab	24.5	ab	23.8	abcd	12.1	9.9	e	17.3	19.2	18.2	22.2
3 (TBC)	22.7	bcd	18.5	e	15.3	ef	13.9	12.0	cd	21.7	23.7	21.1	24.1
4 (TOC)	23.9	abcd	16.3	e	14.6	f	15.5	11.8	cd	16.8	22.6	20.9	25.4
5 (TWP)	21.8	bcd	19.0	bcde	24.9	a	13.7	13.8	ab	14.4	19.4	21.1	22.0
6 (TRP)	26.4	ab	20.9	bcde	22.6	abc	13.2	11.4	de	18.3	20.7	18.1	23.4
7 (TBP)	28.9	a	20.9	bcd	14.2	f	13.8	12.4	bcd	21.6	22.6	21.7	15.2
8 (TOP)	18.5	d	16.0	de	20.3	abcdef	15.1	11.5	d	15.9	22.2	20.5	13.2
9 (RWC)	27.3	ab	22.0	a	21.0	abcde	14.0	13.2	abc	15.8	23.5	21.9	23.0
10 (RRC)	28.9	a	23.5	bcde	25.5	a	12.7	11.6	cd	17.4	22.6	17.8	21.4
11 (RBC)	20.0	cd	14.1	bcde	16.3	def	14.8	12.1	cd	18.1	23.3	20.4	23.8
12 (ROC)	22.3	bcd	16.5	cde	17.4	bcdef	13.6	12.7	abcd	14.6	21.8	21.4	25.4
13 (RWP)	23.0	abcd	21.4	bcde	17.1	bcdef	12.8	12.4	bcd	12.5	19.9	19.7	18.7
14 (RRP)	25.2	abc	18.9	bcde	16.4	bcdef	11.4	12.4	bcd	11.9	18.2	21.7	19.4
15 (RBP)	26.1	ab	18.7	bcde	17.6	bcdef	12.5	12.0	cd	19.1	21.3	19.1	23.6
16 (ROP)	21.9	bcd	16.9	e	16.4	cdef	13.5	12.0	cd	17.8	21.9	20.5	26.2
p-value		0.04		0.04		0.02	0.38		0.01	0.99	0.10	0.16	0.54

† CP: Crude protein
‡ ADF: Acid detergent fiber
¶ NDF: Neutral detergent fiber

Table 2.14 Forage quality species type comparison for 2014. Statistical differences within each forage property are denoted by letters across each row within each plant type (grass, brassica, legume). Treatments with different letters indicate significant differences at the p=0.05 level.

	Grass					Brassica			Legume		
	Wheat	Rye	Barley	Oat	p-value	Turnip	Radish	p-value	Winter Pea	Clover	p-value
45-day											
C:N†	8.4 b	8.2 b	9.0 a	9.0 a	0.03	8.6	8.7	0.54	8.6	8.7	0.77
CP‡ %	30.2	29.9	28.1	28.3	0.14	29.9	28.4	0.06	29.2	29.0	0.76
ADF§ %	10.5	11.0	11.3	12.1	0.05	10.5 b	11.9 a	0.0002	11.5	10.9	0.17
NDF¶ %	17.4 bc	17.0 c	19.3 a	18.8 ab	0.005	18.2	18.1	0.78	18.4	17.8	0.28
74-day											
C:N†	12.2 ab	11.1 b	13.1 a	13.2 a	0.01	12.1	12.6	0.33	12.2	12.5	0.54
CP‡ %	21.1 ab	23.5 a	19.9 b	20.0 b	0.02	21.8	20.5	0.17	21.3	21.0	0.72
ADF§ %	11.2 b	11.3 b	13.1 a	13.0 a	0.02	11.8	12.5	0.21	11.6 b	12.7 a	0.04
NDF¶ %	16.5 b	16.5 b	19.3 a	20.6 a	<.0001	18.8	17.6	0.15	17.3 b	19.2 a	0.03
91-day											
C:N†	15.2 c	16.1 bc	17.3 b	19.2 a	<.0001	17.1	16.9	0.78	17.0	17.0	0.95
CP‡ %	17.1 a	16.0 ab	15.0 bc	13.9 c	0.00	15.6	15.4	0.72	15.3	15.7	0.53
ADF§ %	14.1	13.3	14.7	14.1	0.47	13.9	14.2	0.59	14.0	14.2	0.76
NDF¶ %	18.5 ab	17.1 b	19.9 a	20.7 a	0.02	20.4 a	17.7 b	0.002	19.1	19.1	0.97

† C:N : Carbon to nitrogen ratio
‡ CP: Crude protein
§ ADF: Acid detergent fiber
¶ NDF: Neutral detergent fiber

Table 2.15 Forage quality species type comparison for 2015. Statistical differences within each forage property are denoted by letters across each row within each plant type (grass, brassica, legume). Treatments with different letters indicate significant differences at the p=0.05 level.

	Grass					Brassica			Legume		
	Wheat	Rye	Barley	Oat	p-value	Turnip	Radish	p-value	Winter Pea	Clover	p-value
45-day											
C:N†	10.8 ab	9.5 b	10.7 ab	12.1 a	0.02	10.9	10.6	0.62	11.1	10.4	0.27
CP‡ %	23.5 b	27.0 a	24.4 ab	21.6 b	0.02	24.0	24.3	0.79	24.0	24.3	0.80
ADF§ %	13.8 a	12.3 b	13.8 ab	14.4 a	0.04	14.0	13.2	0.13	13.3	13.9	0.23
NDF¶ %	21.8	20.2	22.7	22.1	0.11	21.8	21.6	0.73	20.8 b	22.6 a	0.01
74-day											
C:N†	12.3 b	11.9 b	14.6 a	16.4 a	0.0003	13.6	14.0	0.69	13.9	13.6	0.73
CP‡ %	20.5 ab	21.9 a	18.1 bc	16.4 c	0.002	19.5	19.0	0.70	19.1	19.4	0.81
ADF§ %	13.4 a	11.3 b	12.1 b	12.0 b	0.001	12.1	12.3	0.66	12.2	12.2	0.88
NDF¶ %	21.1 a	18.9 b	20.6 a	20.8 a	0.05	20.4	20.3	0.86	20.3	20.4	0.84
91-day											
C:N†	12.8 b	12.5 b	16.6 a	16.4 a	0.001	14.6	14.6	1.00	14.8	14.4	0.67
CP‡ %	21.4 a	21.8 a	15.9 b	17.2 b	0.004	19.6	18.5	0.48	18.7	19.3	0.70
ADF§ %	15.2	16.1	20.1	16.3	0.36	17.9	16.1	0.41	16.7	17.3	0.78
NDF¶ %	22.7	21.5	21.7	22.5	0.96	21.3	23.0	0.38	20.3	23.9	0.05

† C:N : Carbon to nitrogen ratio
‡ CP: Crude protein
§ ADF: Acid detergent fiber
¶ NDF: Neutral detergent fiber

Table 2.16 Quality standards for legume, grass, or grass-legume hay

Quality standard	CP†	ADF‡	NDF§
	--------------------	%	--------------------
Prime	>19	<31	<40
1	17-19	31-35	40-46
2	14-16	36-40	47-53
3	11-13	41-42	54-60
4	8-10	43-45	61-65
5	<8	>45	>65

†CP: Crude protein
‡ADF: Acid detergent fiber
§NDF: Neutral detergent fiber
Source: Table 16.6 Southern Forages 4th edition D.M. Ball, C.S. Hoveland, and G.D. Lacefield. International Plant Nutrition Institute. Norcross, GA

Table 2.17 Partial budget economic analysis comparing individual treatments for 74-day 2014. Biomass produced in relation to dollars spent for seed. Treatments with different letters indicate significant differences at the p=0.05 level. The absence of letters indicates no significant differences among treatments. Under treatment heading, letters in parentheses denote treatment species. The first letter is the brassica, where T=turnip and R=radish. The second letter is the grass where W=wheat, R=rye, B=barley, O=Oat. The third letter is the legume where C=berseem clover and P=winter pea

Treatment	Seed Cost	Biomass		Crude Protein				
	$ ha^{-1}	Mg ha^{-1}	$ Mg^{-1}	%		Mg CP ha^{-1}	$ Mg^{-1} CP	
1 (TWC)	53.32	1.71	31.15	20.31	bcde	0.35	153.35	a
2 (TRC)	57.39	3.44	16.69	25.81	a	0.89	64.64	b
3 (TBC)	58.51	2.68	21.87	18.83	cde	0.50	116.10	b
4 (TOC)	52.8	3.75	14.06	22.85	abc	0.86	61.53	b
5 (TWP)	62.12	2.80	22.16	23.42	abc	0.66	94.65	b
6 (TRP)	66.2	3.59	18.46	22.29	abcd	0.80	82.81	b
7 (TBP)	67.31	2.98	22.61	19.96	bcde	0.59	113.29	b
8 (TOP)	52.8	4.48	11.78	20.83	bcde	0.93	56.54	b
9 (RWC)	60.62	3.88	15.61	20.73	bcde	0.81	75.30	b
10 (RRC)	64.69	3.92	16.5	22.10	abcd	0.87	74.65	b
11 (RBC)	65.8	2.91	22.64	17.79	de	0.52	127.26	b
12 (ROC)	60.1	4.28	14.04	19.29	bcde	0.83	72.76	b
13 (RWP)	69.42	3.76	18.48	19.98	bcde	0.75	92.50	b
14 (RRP)	73.49	3.52	20.88	23.81	ab	0.84	87.69	b
15 (RBP)	74.61	3.24	21.27	23.13	abc	0.75	99.59	b
16 (ROP)	68.9	2.50	27.51	17.00	e	0.43	161.84	b
p-value	-	0.52	0.46		0.03	0.26		0.04

†CP: Crude protein

Table 2.18 Partial budget economic analysis comparing individual treatments for 74-day 2015. Biomass produced in relation to dollars spent for seed. Treatments with different letters indicate significant differences at the p=0.05 level. The absence of letters indicates no significant differences among treatments. Under treatment heading, letters in parentheses denote treatment species. The first letter is the brassica, where T=turnip and R=radish. The second letter is the grass where W=wheat, R=rye, B=barley, O=Oat. The third letter is the legume where C=berseem clover and P=winter pea

Treatment	Seed Cost	Biomass				Crude Protein					
	$ ha^{-1}	Mg ha^{-1}		$ Mg^{-1}		%		Mg CP ha^{-1}		$ Mg^{-1}	
1 (TWC)	53.32	0.99	ef	55.05	bc	19.67	abcd	0.20	d	266.60	ab
2 (TRC)	57.39	0.78	f	73.93	a	24.47	a	0.19	d	286.95	a
3 (TBC)	58.51	2.57	ab	23.99	g	18.54	bcde	0.48	a	117.02	f
4 (TOC)	52.80	2.47	abc	21.34	g	16.27	de	0.40	ab	132.00	ef
5 (TWP)	62.12	1.63	cdef	44.16	bcdef	18.98	bcde	0.31	bcd	207.07	abc
6 (TRP)	66.20	1.45	def	49.4	bcde	20.88	abcd	0.31	bcd	220.67	abc
7 (TBP)	67.31	1.95	abcd	34.63	efg	20.94	abcd	0.41	ab	168.28	cdef
8 (TOP)	52.80	2.67	a	20.2	g	15.96	de	0.44	ab	132.00	ef
9 (RWC)	60.62	0.99	ef	61.75	ab	21.97	abc	0.22	cd	303.10	ab
10 (RRC)	64.69	1.36	def	53.61	bcd	23.47	ab	0.30	bcd	215.63	abcde
11 (RBC)	65.80	2.21	abcd	30.98	efg	14.14	e	0.32	bcd	219.33	abcd
12 (ROC)	60.10	2.65	a	22.73	g	16.48	de	0.44	ab	150.25	def
13 (RWP)	69.42	1.63	cdef	43.09	bcdef	21.42	abcd	0.35	abc	231.40	bcdef
14 (RRP)	73.49	1.73	bcde	43.03	cdef	18.94	bcde	0.32	bcd	244.97	abc
15 (RBP)	74.61	2.08	abcd	35.91	defg	18.73	bcde	0.20	ab	373.05	cdef
16 (ROP)	68.90	2.65	a	28.92	fg	16.88	cde	0.42	ab	172.25	cdef
p-value	-	0.002		0.0004		0.04		0.02		0.01	

Table 2.19 Partial budget analysis comparison of individual species by biomass produced in relation to cost of seed. The years were analyzed separately. These data are for the 74-day clipping. Within each plant type (brassica, grass, or legume) the letters indicate differences in mean biomass ($p<0.05$), and the biomass per $ spent on seed. Treatments with different letters indicate significant differences at the $p=0.05$ level. The absence of letters indicates no significant differences among treatments.

		2014				2015			
Common name	Seed cost ha-1 $	Biomass Mg ha-1		Biomass per $ spent on seed Mg		Biomass Mg ha-1		Biomass per $ spent on seed Mg	
Turnip	10.32	1.73	b	0.17		0.14	b	0.01	b
Radish	17.61	3.30	a	0.19		0.38	a	0.02	a
Wheat	22.22	0.12	c	0.01	c	0.67	c	0.03	c
Rye	26.30	0.17	c	0.01	c	0.29	c	0.01	c
Barley	27.41	1.29	b	0.05	b	1.58	b	0.06	b
Oat	21.70	2.29	a	0.11	a	2.43	a	0.11	a
Pea	29.58	0.12	a	<0.01	a	0.69	a	0.02	a
Clover	20.78	0.00	b	<0.001	b	0.00	b	0.00	b

Table 2.20 Comparison of the partial budget economics for the 2014 74-day after planting clipping. Due to the fact that the clover basically didn't grow, it allowed the opportunity to compare the three way mixes that contained pea with what was essentially a 2 way mix. To compare this, the cost for clover seed has been subtracted to allow for an interpretation of the "value" added by having the pea in the mix in terms of biomass, protein, etc. Treatments 1-4 and 9-12 were essentially a brassica/grass mix while treatments 5-8 and 13-16 contained winter pea.

Treatment	Seed $\$$	Biomass			Crude Protein				
	$\$$ ha^{-1}	Mg ha^{-1}	$\$$ Mg^{-1}		%		Mg ha^{-1}	$\$$ Mg^{-1}	
1 (TWC)	32.54	1.7	30.41	a	20.3	bcde	0.3	149.56	a
2 (TRC)	36.61	3.6	11.09	cd	25.8	a	0.9	43.75	d
3 (TBC)	37.73	2.7	15.49	bcd	18.8	cde	0.5	81.81	bcd
4 (TOC)	32.02	3.8	8.75	d	22.9	abc	0.8	38.46	d
5 (TWP)	62.12	2.9	27.16	ab	23.4	abc	0.7	115.62	abc
6 (TRP)	66.20	3.8	19.27	abcd	22.3	abcd	0.8	88.55	abcd
7 (TBP)	67.31	3.0	22.95	abc	20.0	bcde	0.6	114.44	abc
8 (TOP)	52.80	4.5	12.02	cd	20.8	bcde	0.9	58.69	cd
9 (RWC)	39.84	4.1	11.37	cd	20.7	bcde	0.9	56.87	cd
10 (RRC)	43.91	4.1	12.00	cd	22.1	abcd	0.9	53.70	cd
11 (RBC)	45.02	3.1	15.54	bcd	17.8	de	0.6	89.25	abcd
12 (ROC)	39.32	4.4	9.72	d	19.3	bcde	0.9	50.74	d
13 (RWP)	69.42	4.0	18.87	abcd	20.0	bcde	0.8	95.79	abcd
14 (RRP)	73.49	3.6	20.62	abcd	23.8	ab	0.9	86.46	bcd
15 (RBP)	74.61	3.4	22.32	abc	23.1	abc	0.8	97.58	abcd
16 (ROP)	68.90	3.4	20.84	abcd	17.0	e	0.6	124.25	ab
p-value	-	0.46	0.02		0.03		0.26	0.03	
Mean treatments 1-4, 9-12	38.37	3.42	14.30	b	20.97		0.72	70.52	b
Mean treatments 5-8, 13-16	66.86	3.56	20.51	a	21.30		0.76	97.67	a
p-value	<.0001	0.68	0.01		0.72		0.65	0.03	

Table 2.21 Comparison of economics 2015 74-day clipping without cost for clover. p-values at bottom of each column are for the comparison of all 16-treatments. Due to the lack of biomass from clover. The cost of the clover seed has been removed to allow for a comparison of a brassica/grass mix with a brassica/grass/legume mixture. A comparison of the mean values between treatments with and without winter pea is shown at the bottom of the table. The winter pea mixtures cost more to plant and did not increase the protein content at the time of clipping.

Treatment	Seed Cost	Biomass				Crude Protein					
	$ ha^{-1}	Mg ha^{-1}		$ Mg^{-1}		%		Mg ha^{-1}		$ Mg^{-1}	
1 (TWC)	32.54	1.0	ef	33.60	abc	19.7	abcd	0.2	d	181.58	abcd
2 (TRC)	36.61	0.8	f	47.16	a	24.5	a	0.2	d	248.60	a
3 (TBC)	37.73	2.6	ab	15.47	d	18.5	bcde	0.5	a	35.78	e
4 (TOC)	32.02	2.5	abc	12.94	d	16.3	de	0.4	ab	32.19	e
5 (TWP)	62.12	1.6	cdef	44.16	ab	19.0	bcde	0.3	bcd	184.51	abcd
6 (TRP)	66.20	1.5	def	49.40	a	20.9	abcd	0.3	bcd	195.19	ab
7 (TBP)	67.31	1.9	abcd	34.63	abc	20.9	abcd	0.4	ab	86.57	bcde
8 (TOP)	52.80	2.7	a	20.20	cd	16.0	de	0.4	ab	52.77	e
9 (RWC)	39.84	1.0	ef	40.58	ab	22.0	abc	0.2	cd	189.90	abc
10 (RRC)	43.91	1.4	def	36.39	abc	23.5	ab	0.3	bcd	133.79	abcde
11 (RBC)	45.02	2.2	abcd	21.19	cd	14.1	e	0.3	bcd	77.81	cde
12 (ROC)	39.32	2.7	a	14.87	d	16.5	de	0.4	ab	34.17	e
13 (RWP)	69.42	1.6	cdef	43.09	ab	21.4	abcd	0.3	abc	126.10	bcde
14 (RRP)	73.49	1.7	bcde	43.03	ab	18.9	bcde	0.3	bcd	134.05	abcde
15 (RBP)	74.61	2.1	abcd	35.91	abc	18.7	bcde	0.4	ab	92.57	bcde
16 (ROP)	68.90	2.6	a	28.92	bcd	16.9	cde	0.4	ab	73.48	de
p-value	-	-	0.002	-	0.002	-	0.04	-	0.01	-	0.02
Mean treatments 1-4, 9-12	38.37	1.81	-	27.74	b	19.4		0.32		138.59	b
Mean treatments 5-8, 13-16	66.86	1.91	-	37.46	a	19.1		0.37		195.34	a
p-value	<.0001	0.69	-	-	0.048	0.85		0.17		0.004	

Appendix A - Chapter 1 Raw Data

Table A.1 Plot level soil data

Site	Date	Plot	Rep	Trt	MWD	4.75	2	1	0.5	0.25	<0.25	Tot Ag	BD		Infiltration	MBC	DOC
					--mm--	Aggregate size distribution (mm) -------------g sand-free 100 g^{-1} soil-------------						%	0-5 ---cm---	5-10	min cm^{-1}	µg C g^{-1} soil	
O	9/30/13	1	1	C	2.37	0.28	0.09	0.08	0.10	0.19	0.26	74.5	1.34	nd	nd	208.8	28.9
O	9/30/13	2	1	R	2.90	0.34	0.12	0.09	0.14	0.17	0.14	85.9	1.34	nd	nd	232.3	49.4
O	9/30/13	3	1	RP	1.55	0.16	0.07	0.06	0.10	0.19	0.42	58.3	1.50	nd	nd	141.2	30.8
O	9/30/13	4	1	RV	2.13	0.24	0.09	0.07	0.10	0.18	0.32	68.4	1.28	nd	nd	205.1	41.4
O	9/30/13	5	1	Rca	2.74	0.32	0.10	0.10	0.16	0.18	0.14	85.9	1.25	nd	nd	245.6	25.6
O	9/30/13	6	1	RCa	2.54	0.32	0.07	0.07	0.10	0.13	0.31	68.8	1.37	nd	nd	194.6	26.8
O	9/30/13	7	1	O	1.84	0.17	0.10	0.10	0.20	0.24	0.18	81.6	1.30	nd	nd	244.8	31.6
O	9/30/13	8	1	OP	2.00	0.22	0.09	0.08	0.11	0.20	0.30	69.7	1.21	nd	nd	247.7	29.0
O	9/30/13	1	2	C	4.21	0.58	0.10	0.04	0.06	0.11	0.11	88.7	1.29	nd	nd	220.1	30.1
O	9/30/13	2	2	R	1.74	0.14	0.11	0.13	0.24	0.22	0.16	84.4	1.35	nd	nd	227.4	46.5
O	9/30/13	3	2	RP	2.64	0.31	0.12	0.08	0.10	0.16	0.24	76.4	1.36	nd	nd	245.9	65.8
O	9/30/13	4	2	RV	.	.	.	.	.	.	.	0.0	1.39	nd	nd	217.0	31.6
O	9/30/13	5	2	Rca	3.09	0.38	0.10	0.08	0.13	0.17	0.13	86.9	1.39	nd	nd	227.6	28.8
O	9/30/13	6	2	RCa	5.01	0.71	0.12	0.02	0.02	0.03	0.10	90.2	1.41	nd	nd	203.1	47.8
O	9/30/13	7	2	O	2.48	0.29	0.09	0.08	0.14	0.21	0.20	80.4	1.48	nd	nd	212.2	30.8
O	9/30/13	8	2	OP	1.65	0.16	0.08	0.09	0.14	0.23	0.30	70.0	1.38	nd	nd	184.0	24.7
O	9/30/13	1	3	C	1.84	0.19	0.08	0.08	0.14	0.21	0.29	70.6	1.35	nd	nd	223.8	32.9
O	9/30/13	2	3	R	1.42	0.13	0.07	0.08	0.14	0.26	0.32	68.4	1.35	nd	nd	188.9	49.0
O	9/30/13	3	3	RP	1.47	0.14	0.06	0.08	0.14	0.25	0.32	68.1	1.32	nd	nd	195.1	25.5
O	9/30/13	4	3	RV	2.83	0.35	0.10	0.06	0.07	0.13	0.28	72.1	1.39	nd	nd	169.2	25.3
O	9/30/13	5	3	Rca	3.74	0.51	0.08	0.05	0.08	0.11	0.16	83.8	1.46	nd	nd	224.6	32.2
O	9/30/13	6	3	RCa	0.63	0.02	0.05	0.06	0.11	0.21	0.55	45.1	1.43	nd	nd	176.4	32.5

O	9/30/13	7	3	O	1.31	0.11	0.07	0.07	0.14	0.27	0.34	65.6	1.20	nd	nd	182.4	30.8
O	9/30/13	8	3	OP	2.67	0.32	0.11	0.06	0.09	0.13	0.28	71.6	1.27	nd	nd	215.4	52.4
W	9/30/13	1	1	C	5.27	0.77	0.09	0.01	0.03	0.02	0.08	92.1	1.33	nd	nd	nd	16.8
W	9/30/13	2	1	R	5.43	0.80	0.09	0.01	0.01	0.02	0.08	91.8	1.26	nd	nd	nd	39.2
W	9/30/13	3	1	RP	4.90	0.69	0.12	0.02	0.03	0.03	0.11	89.5	1.32	nd	nd	nd	18.7
W	9/30/13	4	1	RV	5.74	0.84	0.12	0.00	0.00	0.00	0.04	96.4	1.35	nd	nd	nd	19.3
W	9/30/13	5	1	Rca	4.13	0.55	0.17	0.02	0.02	0.03	0.22	77.8	1.41	nd	nd	nd	19.8
W	9/30/13	6	1	RCa	4.48	0.55	0.27	0.01	0.02	0.02	0.13	86.7	1.23	nd	nd	nd	20.8
W	9/30/13	7	1	O	3.70	0.50	0.13	0.02	0.01	0.02	0.32	67.8	1.46	nd	nd	nd	23.9
W	9/30/13	8	1	OP	5.19	0.75	0.12	0.01	0.01	0.03	0.09	91.4	1.35	nd	nd	nd	18.3
W	9/30/13	1	2	C	4.66	0.64	0.16	0.02	0.02	0.04	0.12	87.6	1.29	nd	nd	nd	20.2
W	9/30/13	2	2	R	3.74	0.47	0.18	0.03	0.04	0.08	0.20	79.6	1.33	nd	nd	nd	33.6
W	9/30/13	3	2	RP	4.24	0.53	0.23	0.02	0.02	0.04	0.17	83.4	1.25	nd	nd	nd	24.0
W	9/30/13	4	2	RV	0.92	0.07	0.06	0.05	0.06	0.12	0.63	36.6	1.31	nd	nd	nd	27.7
W	9/30/13	5	2	Rca	5.24	0.78	0.07	0.01	0.01	0.03	0.10	89.8	1.33	nd	nd	nd	20.9
W	9/30/13	6	2	RCa	4.96	0.71	0.12	0.01	0.01	0.01	0.14	85.7	1.41	nd	nd	nd	24.9
W	9/30/13	7	2	O	5.96	0.91	0.03	0.00	0.00	0.01	0.04	96.3	1.19	nd	nd	nd	20.3
W	9/30/13	8	2	OP	5.93	0.91	0.04	0.00	0.01	0.01	0.03	96.5	1.41	nd	nd	nd	23.2
W	9/30/13	1	3	C	4.12	0.54	0.18	0.01	0.01	0.03	0.22	77.7	1.38	nd	nd	nd	22.6
W	9/30/13	2	3	R	4.44	0.57	0.22	0.02	0.02	0.03	0.13	86.6	1.31	nd	nd	nd	24.8
W	9/30/13	3	3	RP	.	.	.	.	.	.	.	0.0	1.24	nd	nd	nd	18.4
W	9/30/13	4	3	RV	5.86	0.89	0.04	0.00	0.00	0.01	0.05	94.9	1.31	nd	nd	nd	33.4
W	9/30/13	5	3	Rca	4.67	0.65	0.13	0.01	0.01	0.02	0.17	83.2	1.17	nd	nd	nd	32.2
W	9/30/13	6	3	RCa	5.01	0.69	0.16	0.01	0.02	0.02	0.10	90.2	1.25	nd	nd	nd	23.5
W	9/30/13	7	3	O	5.68	0.86	0.05	0.01	0.00	0.01	0.07	92.8	1.49	nd	nd	nd	19.8
W	9/30/13	8	3	OP	5.95	0.91	0.05	0.00	0.00	0.01	0.04	96.5	1.4	nd	nd	nd	26.3
O	7/7/14	1	B	C	2.75	0.31	0.13	0.12	0.17	0.14	0.14	86.13	0.75	1.09	0.5	51.2	62.8
O	7/7/14	2	B	R	2.32	0.24	0.13	0.09	0.13	0.19	0.21	78.80	0.81	1.29	5.1	254.7	29.6
O	7/7/14	3	B	RP	2.09	0.20	0.13	0.11	0.16	0.16	0.24	76.02	0.90	1.31	5.9	171.5	27.4

O	7/7/14	4	B	RV	2.81	0.31	0.15	0.10	0.13	0.15	0.17	83.27	0.76	1.24	2.2	232.6	41.6
O	7/7/14	5	B	Rca	2.34	0.26	0.10	0.10	0.17	0.19	0.18	81.51	0.81	1.34	1.1	181.8	27.3
O	7/7/14	6	B	RCa	3.73	0.47	0.14	0.08	0.12	0.09	0.09	90.72	0.61	1.10	0.1	73.4	71.9
O	7/7/14	7	B	O	2.46	0.28	0.11	0.08	0.11	0.15	0.26	74.04	0.92	0.95	5.9	148.7	23.9
O	7/7/14	8	B	OP	1.60	0.14	0.10	0.09	0.15	0.21	0.31	68.79	0.66	1.24	1.2	86.5	36.2
O	7/7/14	1	C	C	1.55	0.11	0.12	0.12	0.20	0.21	0.24	76.09	0.79	1.02	0.2	47.7	64.5
O	7/7/14	2	C	R	2.81	0.33	0.12	0.08	0.12	0.15	0.20	80.04	0.67	1.17	5.9	73.6	37.5
O	7/7/14	3	C	RP	3.91	0.49	0.16	0.09	0.11	0.08	0.07	93.19	1.05	0.95	0.2	55.3	53.8
O	7/7/14	4	C	RV	1.14	0.07	0.09	0.09	0.16	0.21	0.37	62.73	0.90	1.32	0.8	190.3	36.3
O	7/7/14	5	C	Rca	2.94	0.34	0.15	0.08	0.10	0.13	0.20	80.49	0.88	1.29	5.9	43.1	28.2
O	7/7/14	6	C	RCa	1.98	0.18	0.12	0.11	0.17	0.19	0.22	77.83	0.68	1.22	2.5	148.7	25.5
O	7/7/14	7	C	O	2.24	0.23	0.13	0.09	0.16	0.18	0.21	78.56	0.69	1.17	1.6	64.9	41.1
O	7/7/14	8	C	OP	3.43	0.45	0.10	0.07	0.08	0.08	0.22	77.84	0.88	1.36	5.9	113.2	24.0
O	7/7/14	1	D	C	1.75	0.16	0.08	0.10	0.23	0.23	0.19	81.02	0.89	1.10	0.2	56.7	39.4
O	7/7/14	2	D	R	3.01	0.35	0.14	0.09	0.14	0.15	0.13	87.07	0.83	1.24	0.8	128.8	44.4
O	7/7/14	3	D	RP	1.89	0.18	0.11	0.09	0.15	0.21	0.26	74.32	0.89	1.28	1.1	57.8	41.4
O	7/7/14	4	D	RV	1.70	0.15	0.11	0.10	0.16	0.23	0.25	75.29	0.75	1.22	0.3	233.7	73.3
O	7/7/14	5	D	Rca	2.68	0.29	0.14	0.12	0.16	0.15	0.15	85.44	0.83	1.30	2.1	225.5	51.7
O	7/7/14	6	D	RCa	2.84	0.32	0.14	0.10	0.13	0.16	0.15	84.51	0.74	1.29	0.1	69.5	38.3
O	7/7/14	7	D	O	1.59	0.11	0.14	0.11	0.19	0.27	0.18	81.66	0.81	1.22	2.2	109.1	44.8
O	7/7/14	8	D	OP	1.46	0.02	0.29	0.11	0.13	0.18	0.28	72.29	0.81	1.11	0.2	89.9	30.0
W	7/2/14	1	B	C	2.41	0.28	0.132	0.044	0.068	0.103	0.376	62.38	1.06	1.29	5.9	25.9	17.9
W	7/2/14	2	B	R	4.30	0.59	0.13	0.03	0.05	0.06	0.15	84.91	0.91	1.33	5.9	51.1	19.6
W	7/2/14	3	B	RP	3.44	0.42	0.17	0.04	0.06	0.06	0.24	75.82	1.09	1.36	3.3	50.4	17.3
W	7/2/14	4	B	RV	4.62	0.65	0.11	0.03	0.03	0.04	0.14	86.19	0.94	1.24	5.9	42.9	22.7
W	7/2/14	5	B	Rca	4.56	0.64	0.10	0.02	0.04	0.06	0.13	87.16	1.04	1.38	1.3	50.2	19.7
W	7/2/14	6	B	RCa	3.75	0.51	0.11	0.03	0.04	0.07	0.23	76.53	0.92	1.21	4.8	37.1	22.5
W	7/2/14	7	B	O	3.07	0.36	0.16	0.05	0.08	0.09	0.26	74.11	1.20	1.33	5.9	88.2	15.9
W	7/2/14	8	B	OP	2.40	0.27	0.15	0.05	0.07	0.10	0.37	63.22	1.13	1.39	5.9	64.8	20.8

W	7/2/14	1	C	C	2.47	0.30	0.11	0.04	0.06	0.10	0.39	61.46	1.07	1.28	5.9	33.7	21.6
W	7/2/14	2	C	R	4.49	0.63	0.10	0.03	0.05	0.05	0.13	86.57	1.05	1.26	5.9	52.4	20.1
W	7/2/14	3	C	RP	5.16	0.76	0.07	0.01	0.02	0.03	0.10	89.72	1.19	1.42	1.8	67.2	35.4
W	7/2/14	4	C	RV	3.98	0.54	0.12	0.03	0.02	0.11	0.17	82.62	1.13	1.39	5.7	54.4	28.7
W	7/2/14	5	C	Rca	4.98	0.73	0.07	0.02	0.04	0.04	0.09	90.78	1.15	1.50	5.9	62.6	30.1
W	7/2/14	6	C	RCa	3.73	0.47	0.18	0.04	0.05	0.07	0.20	80.27	1.25	1.40	5.9	103.5	29.4
W	7/2/14	7	C	O	5.07	0.74	0.08	0.01	0.03	0.04	0.09	90.72	1.40	1.44	3.9	51.2	20.9
W	7/2/14	8	C	OP	2.56	0.31	0.11	0.05	0.07	0.08	0.38	61.95	1.01	1.24	2.2	50.3	22.9
W	7/2/14	1	D	C	nd	nd	nd	nd	nd	nd	Nd	nd	nd	nd	nd	30.3	24.1
W	7/2/14	2	D	R	nd	nd	nd	nd	nd	nd	Nd	nd	nd	nd	nd	33.1	24.0
W	7/2/14	3	D	RP	nd	nd	nd	nd	nd	nd	Nd	nd	nd	nd	nd	80.6	31.9
W	7/2/14	4	D	RV	nd	nd	nd	nd	nd	nd	Nd	nd	nd	nd	nd	49.9	27.0
W	7/2/14	5	D	Rca	nd	nd	nd	nd	nd	nd	Nd	nd	nd	nd	nd	52.7	30.8
W	7/2/14	6	D	RCa	nd	nd	nd	nd	nd	nd	Nd	nd	nd	nd	nd	43.6	31.0
W	7/2/14	7	D	O	nd	nd	nd	nd	nd	nd	Nd	nd	nd	nd	nd	61.6	23.9
W	7/2/14	8	D	OP	nd	nd	nd	nd	nd	nd	Nd	nd	nd	nd	nd	71.7	23.4
O	10/22/14	1	1	C	1.94	0.20	0.10	0.09	0.14	0.17	0.30	70.0	0.90	1.08	3.90	85.4	61.5
O	10/22/14	2	1	R	2.99	0.36	0.14	0.06	0.09	0.12	0.23	76.9	0.74	1.18	5.91	.	41.4
O	10/22/14	3	1	RP	3.01	0.36	0.13	0.07	0.10	0.14	0.20	80.1	0.94	1.32	5.91	194.2	45.5
O	10/22/14	4	1	RV	2.63	0.28	0.14	0.11	0.15	0.15	0.17	83.0	1.11	1.18	5.91	165.2	50.4
O	10/22/14	5	1	Rca	2.83	0.33	0.14	0.08	0.12	0.13	0.21	79.5	0.96	1.24	5.91	157.2	38.5
O	10/22/14	6	1	RCa	2.69	0.30	0.14	0.11	0.14	0.13	0.19	80.8	0.86	1.10	0.49	185.1	80.3
O	10/22/14	7	1	O	1.62	0.14	0.12	0.07	0.10	0.16	0.40	59.7	1.03	1.31	5.91	90.2	43.9
O	10/22/14	8	1	OP	1.40	0.10	0.11	0.10	0.15	0.20	0.35	65.4	0.45	1.16	4.24	132.6	49.3
O	10/22/14	1	2	C	1.46	0.12	0.10	0.07	0.13	0.22	0.36	64.5	0.62	1.17	5.91	222.2	69.7
O	10/22/14	2	2	R	2.40	0.25	0.14	0.09	0.13	0.16	0.23	77.5	0.77	1.23	5.91	324.1	44.3
O	10/22/14	3	2	RP	2.63	0.28	0.14	0.12	0.17	0.13	0.16	84.4	0.81	1.15	5.91	194.9	69.6
O	10/22/14	4	2	RV	2.82	0.32	0.13	0.09	0.13	0.14	0.17	82.5	0.99	1.36	5.91	321.3	45.8
O	10/22/14	5	2	Rca	3.73	0.49	0.12	0.06	0.09	0.10	0.14	85.9	0.71	1.31	5.91	291.3	41.7

O	10/22/14	6	2	RCa	2.76	0.32	0.14	0.07	0.10	0.16	0.21	79.2	0.87	1.32	4.55	296.1	43.5
O	10/22/14	7	2	O	1.91	0.19	0.11	0.08	0.14	0.20	0.27	72.5	0.82	1.18	5.91	244.3	53.2
O	10/22/14	8	2	OP	2.35	0.25	0.14	0.07	0.11	0.17	0.26	74.3	0.81	1.32	5.91	254.7	38.3
O	10/22/14	1	3	C	1.03	0.07	0.07	0.07	0.16	0.22	0.41	59.3	.	.	5.72	248.8	52.1
O	10/22/14	2	3	R	2.45	0.26	0.13	0.12	0.16	0.16	0.18	82.0	0.74	1.40	5.91	384.6	52.9
O	10/22/14	3	3	RP	2.52	0.29	0.10	0.09	0.14	0.18	0.20	80.4	.	.	5.91	227.4	53.1
O	10/22/14	4	3	RV	2.11	0.21	0.12	0.11	0.19	0.20	0.18	81.9	.	.	5.91	247.9	62.9
O	10/22/14	5	3	Rca	3.33	0.40	0.14	0.09	0.11	0.12	0.13	86.7	.	.	1.73	228.4	62.9
O	10/22/14	6	3	RCa	3.27	0.41	0.12	0.07	0.11	0.14	0.15	85.5	0.88	1.22	1.00	299.3	46.8
O	10/22/14	7	3	O	2.61	0.28	0.15	0.06	0.14	0.18	0.19	80.8	.	.	5.91	332.8	46.4
O	10/22/14	8	3	OP	2.62	0.31	0.12	0.06	0.12	0.16	0.24	75.7	.	.	5.91	.	42.4
W	10/10/14	1	1	C	4.28	0.58	0.14	0.03	0.03	0.04	0.18	82.0	1.11	1.40	ns	107.0	18.8
W	10/10/14	2	1	R	5.86	0.89	0.06	0.01	0.01	0.01	0.04	96.5	0.92	1.35	ns	114.6	23.4
W	10/10/14	3	1	RP	5.18	0.73	0.13	0.02	0.02	0.03	0.07	93.2	0.96	1.07	ns	89.1	23.8
W	10/10/14	4	1	RV	5.41	0.81	0.07	0.01	0.01	0.02	0.08	91.7	1.01	1.30	ns	118.9	24.2
W	10/10/14	5	1	Rca	5.52	0.80	0.12	0.00	0.01	0.01	0.06	94.3	1.03	1.28	ns	73.3	25.3
W	10/10/14	6	1	RCa	5.57	0.82	0.10	0.00	0.01	0.01	0.07	93.4	1.01	1.11	ns	123.2	22.7
W	10/10/14	7	1	O	3.16	0.47	0.02	0.00	0.00	0.00	0.50	50.2	1.05	1.36	ns	36.8	26.1
W	10/10/14	8	1	OP	5.62	0.85	0.05	0.01	0.01	0.02	0.06	94.2	1.29	1.03	ns	55.3	19.1
W	10/10/14	1	2	C	5.13	0.73	0.13	0.01	0.02	0.03	0.09	91.1	1.21	1.39	ns	57.8	26.0
W	10/10/14	2	2	R	5.70	0.86	0.05	0.01	0.01	0.01	0.06	94.5	0.90	1.28	ns	157.6	26.8
W	10/10/14	3	2	RP	5.45	0.81	0.07	0.01	0.01	0.02	0.09	91.1	1.12	1.37	ns	81.8	27.5
W	10/10/14	4	2	RV	5.50	0.82	0.07	0.01	0.01	0.02	0.07	93.4	1.01	1.18	ns	38.9	28.8
W	10/10/14	5	2	Rca	6.11	0.95	0.01	0.00	0.00	0.01	0.02	97.6	0.88	1.44	ns	67.1	23.5
W	10/10/14	6	2	RCa	4.67	0.66	0.11	0.03	0.05	0.05	0.11	89.2	1.01	1.24	ns	115.8	23.0
W	10/10/14	7	2	O	5.52	0.82	0.07	0.01	0.01	0.02	0.07	93.1	1.39	1.11	ns	152.3	23.6
W	10/10/14	8	2	OP	5.84	0.89	0.04	0.00	0.01	0.01	0.05	95.4	0.98	1.35	ns	174.7	25.8
W	10/10/14	1	3	C	5.40	0.81	0.05	0.01	0.02	0.02	0.08	91.7	ns	ns	ns	97.3	21.6
W	10/10/14	2	3	R	6.02	0.91	0.06	0.00	0.01	0.01	0.01	98.8	ns	ns	ns	.	23.7

W	10/10/14	3	3	RP	5.76	0.86	0.08	0.00	0.01	0.01	0.04	95.8	ns	ns	ns	156.7	22.7
W	10/10/14	4	3	RV	5.78	0.88	0.04	0.01	0.01	0.02	0.05	95.5	ns	ns	ns	119.5	28.1
W	10/10/14	5	3	Rca	5.35	0.80	0.06	0.02	0.03	0.03	0.06	93.8	ns	ns	ns	215.4	26.6
W	10/10/14	6	3	RCa	5.97	0.91	0.04	0.00	0.00	0.01	0.03	96.6	ns	ns	ns	89.9	25.0
W	10/10/14	7	3	O	5.28	0.80	0.04	0.01	0.02	0.03	0.09	90.8	ns	ns	ns	.	23.5
W	10/10/14	8	3	OP	6.13	0.95	0.01	0.00	0.00	0.01	0.02	97.9	ns	ns	ns	.	31.3
O	7/1/2015	1	1	C	1.57	0.12	0.11	0.11	0.20	0.20	0.25	74.5	1.31	1.16	23.62	49.2	41.8
O	7/1/2015	2	1	R	.	.	.	.	.	.	.	0.0	1.28	1.21	23.62	178.5	34.4
O	7/1/2015	3	1	RP	3.02	0.37	0.11	0.09	0.12	0.16	0.16	84.3	1.31	1.31	23.62	114.3	38.7
O	7/1/2015	4	1	RV	.	.	.	.	.	.	.	0.0	1.29	1.28	10.56	102.0	43.6
O	7/1/2015	5	1	Rca	2.29	0.26	0.09	0.07	0.13	0.21	0.24	75.7	1.31	1.28	23.62	113.9	37.7
O	7/1/2015	6	1	RCa	3.40	0.44	0.11	0.07	0.10	0.13	0.15	85.1	1.15	1.23	7.63	49.0	55.1
O	7/1/2015	7	1	O	2.24	0.27	0.08	0.05	0.08	0.15	0.36	64.2	1.28	1.28	.	134.1	33.0
O	7/1/2015	8	1	OP	1.57	0.13	0.10	0.09	0.16	0.24	0.27	73.3	1.15	1.23	11.23	30.7	41.9
O	7/1/2015	1	2	C	1.53	0.11	0.10	0.13	0.25	0.22	0.20	80.3	1.09	1.29	0.39	64.7	51.4
O	7/1/2015	2	2	R	2.47	0.28	0.12	0.08	0.12	0.18	0.22	77.7	1.14	1.14	23.62	154.1	44.7
O	7/1/2015	3	2	RP	1.99	0.20	0.10	0.10	0.16	0.19	0.25	74.7	1.17	1.22	7.34	42.1	58.2
O	7/1/2015	4	2	RV	2.33	0.26	0.09	0.14	0.08	0.19	0.24	76.3	1.24	1.15	23.62	102.1	38.5
O	7/1/2015	5	2	Rca	1.93	0.20	0.11	0.07	0.10	0.20	0.32	67.6	1.24	1.28	23.62	159.2	37.8
O	7/1/2015	6	2	RCa	2.31	0.26	0.11	0.07	0.12	0.19	0.25	74.9	1.32	1.38	23.62	111.3	36.4
O	7/1/2015	7	2	O	2.23	0.22	0.14	0.10	0.18	0.17	0.19	80.5	1.15	1.14	7.57	26.6	47.1
O	7/1/2015	8	2	OP	1.88	0.18	0.12	0.08	0.15	0.18	0.30	70.2	1.10	1.16	23.62	191.1	33.1
O	7/1/2015	1	3	C	1.18	0.05	0.11	0.13	0.25	0.22	0.24	75.7	1.19	1.41	0.69	105.2	39.1
O	7/1/2015	2	3	R	3.08	0.36	0.14	0.11	0.15	0.12	0.12	87.7	1.02	1.19	23.62	26.0	43.2
O	7/1/2015	3	3	RP	2.36	0.25	0.12	0.10	0.16	0.17	0.21	79.4	1.34	1.12	4.04	86.8	39.2
O	7/1/2015	4	3	RV	1.86	0.16	0.15	0.10	0.14	0.13	0.32	68.0	0.97	1.11	4.59	334.6	61.0
O	7/1/2015	5	3	Rca	3.31	0.42	0.11	0.07	0.11	0.09	0.20	80.1	1.08	1.09	2.22	555.7	48.9
O	7/1/2015	6	3	RCa	3.42	0.43	0.11	0.08	0.11	0.13	0.13	87.0	1.11	1.08	9.32	334.6	44.2
O	7/1/2015	7	3	O	1.02	0.04	0.11	0.09	0.15	0.17	0.43	56.5	1.14	1.19	3.46	76.6	53.4

O	7/1/2015	8	3	OP	1.07	0.07	0.10	0.03	0.17	0.16	0.47	53.2	1.06	1.15	2.43	456.4	37.6
W	7/2/2015	1	1	C	1.74	0.20	0.07	0.04	0.08	0.15	0.46	53.7	1.37	1.27	11.30	23.0	19.7
W	7/2/2015	2	1	R	5.22	0.77	0.09	0.01	0.01	0.02	0.11	89.4	1.37	1.31	4.36	17.4	22.6
W	7/2/2015	3	1	RP	5.14	0.75	0.08	0.03	0.03	0.04	0.08	92.5	1.31	1.28	1.78	23.3	24.3
W	7/2/2015	4	1	RV	5.45	0.81	0.07	0.01	0.01	0.01	0.09	91.4	1.35	1.37	1.63	11.7	29.7
W	7/2/2015	5	1	Rca	4.04	0.53	0.15	0.04	0.04	0.06	0.18	82.3	1.41	1.29	3.22	20.3	35.0
W	7/2/2015	6	1	RCa	5.54	0.83	0.07	0.01	0.01	0.01	0.08	92.5	1.22	1.33	1.54	14.9	28.0
W	7/2/2015	7	1	O	.	.	.	.	.	.	.	.	1.12	1.34	1.59	9.9	26.7
W	7/2/2015	8	1	OP	5.56	0.84	0.05	0.01	0.01	0.02	0.06	93.7	1.38	1.31	4.65	13.8	31.4
W	7/2/2015	1	2	C	1.65	0.18	0.10	0.03	0.05	0.09	0.55	45.3	1.34	1.46	8.94	12.5	25.8
W	7/2/2015	2	2	R	4.95	0.71	0.10	0.01	0.02	0.04	0.12	87.9	1.20	1.29	1.84	19.6	35.3
W	7/2/2015	3	2	RP	4.04	0.54	0.15	0.03	0.04	0.06	0.19	81.2	1.20	1.43	3.93	29.2	35.3
W	7/2/2015	4	2	RV	4.87	0.70	0.09	0.01	0.02	0.07	0.10	89.8	1.34	1.25	2.23	124.8	41.5
W	7/2/2015	5	2	Rca	4.15	0.55	0.15	0.03	0.04	0.05	0.17	82.6	1.20	1.18	2.79	28.2	35.9
W	7/2/2015	6	2	RCa	4.64	0.64	0.15	0.02	0.03	0.02	0.15	84.9	1.34	1.44	14.86	68.1	31.3
W	7/2/2015	7	2	O	4.80	0.69	0.11	0.02	0.02	0.03	0.14	86.0	1.20	1.32	1.70	25.6	29.4
W	7/2/2015	8	2	OP	4.67	0.67	0.10	0.02	0.03	0.04	0.15	84.6	1.36	1.29	1.84	14.4	31.1
W	7/2/2015	1	3	C	1.10	0.09	0.08	0.05	0.09	0.15	0.55	45.5	1.46	1.29	9.48	30.1	31.5
W	7/2/2015	2	3	R	4.36	0.57	0.18	0.03	0.04	0.05	0.13	86.9	0.99	1.05	1.48	27.6	37.1
W	7/2/2015	3	3	RP	.	.	.	.	.	.	.	0.0	1.05	1.26	1.23	38.0	30.3
W	7/2/2015	4	3	RV	4.74	0.66	0.14	0.02	0.03	0.04	0.11	89.3	1.11	1.14	3.40	32.9	32.4
W	7/2/2015	5	3	Rca	5.95	0.92	0.02	0.01	0.01	0.01	0.03	97.0	1.22	1.34	4.12	24.9	40.5
W	7/2/2015	6	3	RCa	5.08	0.75	0.08	0.01	0.02	0.04	0.10	89.7	1.31	1.36	1.29	33.9	38.1
W	7/2/2015	7	3	O	4.86	0.72	0.07	0.01	0.02	0.03	0.15	85.1	1.30	1.39	7.56	21.2	35.7
W	7/2/2015	8	3	OP	5.55	0.84	0.05	0.01	0.01	0.02	0.08	91.9	1.4	1.4	5.87	22.3	28.9
O	10/9/15	1	1	C	2.61	0.28	0.13	0.12	0.19	0.14	0.14	86.1	1.04	1.02	1.19	25.7	40.1
O	10/9/15	2	1	R	5.13	0.75	0.07	0.03	0.04	0.06	0.05	94.7	1.14	1.26	36.00	49.1	36.6
O	10/9/15	3	1	RP	3.78	0.47	0.15	0.07	0.12	0.11	0.08	92.3	1.25	1.22	25.20	19.5	28.3
O	10/9/15	4	1	RV	4.17	0.56	0.12	0.05	0.09	0.09	0.09	91.2	1.30	1.24	25.40	14.9	34.7

O	10/9/15	5	1	Rca	3.50	0.45	0.12	0.06	0.10	0.13	0.15	85.3	1.30	1.27	33.86	14.0	42.1
O	10/9/15	6	1	RCa	4.87	0.67	0.09	0.15	0.07	0.06	0.00	103.5	1.24	1.18	26.59	95.5	34.2
O	10/9/15	7	1	O	4.24	0.59	0.10	0.04	0.07	0.09	0.11	89.0	1.27	1.24	24.89	62.0	28.0
O	10/9/15	8	1	OP	4.67	0.67	0.07	0.05	0.09	0.06	0.06	94.0	1.07	1.08	14.23	116.8	36.8
O	10/9/15	1	2	C	3.27	0.39	0.15	0.08	0.12	0.11	0.15	85.1	1.24	1.21	25.98	31.6	47.5
O	10/9/15	2	2	R	4.28	0.58	0.12	0.05	0.08	0.08	0.08	91.8	1.34	1.24	27.30	185.3	34.4
O	10/9/15	3	2	RP	5.05	0.74	0.05	0.04	0.06	0.05	0.06	94.4	1.27	1.25	2.92	146.3	39.3
O	10/9/15	4	2	RV	3.12	0.38	0.12	0.07	0.12	0.16	0.14	86.0	1.22	1.23	12.60	203.8	33.9
O	10/9/15	5	2	Rca	4.70	0.67	0.09	0.04	0.06	0.07	0.07	93.1	1.22	0.97	.	308.1	32.2
O	10/9/15	6	2	RCa	4.08	0.54	0.13	0.06	0.08	0.09	0.10	89.9	1.39	1.33	27.95	179.8	27.0
O	10/9/15	7	2	O	3.91	0.51	0.14	0.06	0.09	0.11	0.09	90.5	1.21	1.08	4.12	292.3	36.6
O	10/9/15	8	2	OP	4.50	0.64	0.08	0.04	0.07	0.08	0.09	91.4	1.32	1.21	21.52	215.2	26.3
O	10/9/15	1	3	C	2.91	0.35	0.11	0.07	0.13	0.16	0.18	82.2	1.44	1.34	41.22	270.4	33.5
O	10/9/15	2	3	R	4.86	0.67	0.13	0.05	0.06	0.05	0.04	96.0	1.37	1.28	4.99	191.1	38.8
O	10/9/15	3	3	RP	3.88	0.52	0.11	0.05	0.09	0.11	0.12	87.8	1.26	1.30	22.21	48.3	44.1
O	10/9/15	4	3	RV	5.04	0.73	0.08	0.03	0.05	0.06	0.05	94.8	1.30	1.21	30.14	45.6	48.7
O	10/9/15	5	3	Rca	4.78	0.65	0.14	0.05	0.07	0.06	0.03	97.0	1.18	1.25	22.40	89.4	46.0
O	10/9/15	6	3	RCa	3.27	0.39	0.15	0.09	0.12	0.14	0.11	88.6	1.32	1.26	8.04	88.4	34.4
O	10/9/15	7	3	O	3.93	0.53	0.09	0.06	0.13	0.08	0.10	89.7	1.31	1.35	32.31	52.4	34.2
O	10/9/15	8	3	OP	3.72	0.48	0.12	0.07	0.12	0.12	0.10	90.3	1.32	1.21	33.65	45.0	39.7
W	10/12/15	1	1	C	3.42	0.44	0.14	0.04	0.05	0.07	0.27	73.2	1.35	1.52	3.56	89.9	13.1
W	10/12/15	2	1	R	5.62	0.86	0.03	0.00	0.00	0.01	0.09	90.8	1.23	1.27	3.41	97.6	13.2
W	10/12/15	3	1	RP	5.94	0.92	0.02	0.01	0.01	0.01	0.03	97.2	1.29	1.29	1.31	74.0	17.3
W	10/12/15	4	1	RV	6.24	0.95	0.05	0.01	0.01	0.01	0.00	101.9	1.25	1.24	1.59	71.5	14.1
W	10/12/15	5	1	Rca	5.53	0.81	0.10	0.01	0.01	0.02	0.06	94.4	1.18	1.36	2.43	41.6	16.6
W	10/12/15	6	1	RCa	5.47	0.81	0.08	0.01	0.01	0.02	0.07	93.0	1.23	1.32	1.31	48.9	16.8
W	10/12/15	7	1	O	5.75	0.86	0.07	0.00	0.00	0.01	0.05	94.9	1.40	1.44	2.30	50.2	15.7
W	10/12/15	8	1	OP	5.83	0.89	0.04	0.00	0.01	0.02	0.04	95.8	1.28	1.30	2.45	107.4	12.5
W	10/12/15	1	2	C	4.50	0.64	0.10	0.02	0.03	0.06	0.16	84.3	1.62	1.39	2.01	60.2	14.1

W	10/12/15	2	2	R	6.41	0.97	0.05	0.01	0.02	0.03	0.00	107.9	1.14	1.30	1.14	45.3	15.2
W	10/12/15	3	2	RP	5.59	0.84	0.06	0.01	0.01	0.02	0.07	93.4	1.32	1.33	1.27	46.7	18.7
W	10/12/15	4	2	RV	6.06	0.94	0.02	0.00	0.00	0.01	0.02	97.6	1.32	1.27	3.94	48.4	19.0
W	10/12/15	5	2	Rca	6.10	0.94	0.02	0.00	0.01	0.01	0.02	97.9	0.85	1.06	0.59	58.1	18.7
W	10/12/15	6	2	RCa	6.07	0.93	0.03	0.00	0.00	0.01	0.02	98.0	1.19	1.22	2.29	72.2	20.4
W	10/12/15	7	2	O	5.61	0.83	0.08	0.01	0.01	0.02	0.05	95.1	1.31	1.23	2.33	53.0	14.2
W	10/12/15	8	2	OP	5.83	0.88	0.05	0.01	0.01	0.01	0.04	96.2	1.23	1.27	1.71	43.3	20.4
W	10/12/15	1	3	C	4.37	0.61	0.12	0.03	0.03	0.05	0.16	83.8	1.18	1.23	3.72	45.4	14.6
W	10/12/15	2	3	R	5.85	0.87	0.08	0.00	0.01	0.01	0.03	97.1	1.19	1.15	6.37	52.8	20.9
W	10/12/15	3	3	RP	5.22	0.76	0.09	0.01	0.01	0.02	0.10	89.6	1.28	1.29	9.17	76.7	21.1
W	10/12/15	4	3	RV	5.83	0.89	0.04	0.01	0.01	0.02	0.04	95.9	1.13	1.20	6.08	153.4	18.2
W	10/12/15	5	3	Rca	5.80	0.90	0.03	0.01	0.02	0.01	0.03	97.0	1.15	1.14	1.67	82.3	18.8
W	10/12/15	6	3	RCa	5.83	0.88	0.06	0.00	0.00	0.01	0.04	95.7	1.27	1.25	2.03	68.7	21.7
W	10/12/15	7	3	O	5.86	0.90	0.04	0.01	0.01	0.01	0.05	95.5	1.33	1.30	8.83	126.9	14.2
W	10/12/15	8	3	OP	6.11	0.94	0.03	0.00	0.00	0.01	0.02	98.3	1.2	1.2	8.07	270.4	14.8

Site: O=Olathe, W=Wichita (Haysville)

MWD: Mean Weight Diameter

Tot Ag: Total aggregation percent

BD: Bulk Density

MBC:Microbial Biomass Carbon

DOC: Dissolved Organic Carbon

Treatment abbreviations: C=Control, R=Rye, P=Austrian Winter Pea, V=Hairy Vetch, C=Canola

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Table A.2 Cover Crop Biomass raw data

Location	Date	Plot	Rep	Treatment	Cover crop biomass
					kg ha^{-1}
Olathe	Spring 14	1	1	Control	n/a
Olathe	Spring 14	2	1	Rye	3390
Olathe	Spring 14	3	1	Rye/pea	3870
Olathe	Spring 14	4	1	Rye/vetch	5770
Olathe	Spring 14	5	1	R/canola	3640
Olathe	Spring 14	6	1	Rye/vetch/canola	6760
Olathe	Spring 14	7	1	Oat	6100
Olathe	Spring 14	8	1	Oat/pea	5250
Olathe	Spring 14	1	2	Control	n/a
Olathe	Spring 14	2	2	Rye	3840
Olathe	Spring 14	3	2	Rye/pea	6680
Olathe	Spring 14	4	2	Rye/vetch	4800
Olathe	Spring 14	5	2	R/canola	3400
Olathe	Spring 14	6	2	Rye/vetch/canola	5330
Olathe	Spring 14	7	2	Oat	6460
Olathe	Spring 14	8	2	Oat/pea	4610
Olathe	Spring 14	1	3	Control	n/a
Olathe	Spring 14	2	3	Rye	4790
Olathe	Spring 14	3	3	Rye/pea	5100
Olathe	Spring 14	4	3	Rye/vetch	5070
Olathe	Spring 14	5	3	R/canola	4710
Olathe	Spring 14	6	3	Rye/vetch/canola	6490
Olathe	Spring 14	7	3	Oat	6070
Olathe	Spring 14	8	3	Oat/pea	5650
Wichita	Spring 14	1	1	Control	n/a
Wichita	Spring 14	2	1	Rye	4950
Wichita	Spring 14	3	1	Rye/pea	6640
Wichita	Spring 14	4	1	Rye/vetch	6110
Wichita	Spring 14	5	1	R/canola	6020
Wichita	Spring 14	6	1	Rye/vetch/canola	5000
Wichita	Spring 14	7	1	Oat	7660
Wichita	Spring 14	8	1	Oat/pea	6920
Wichita	Spring 14	1	2	Control	n/a
Wichita	Spring 14	2	2	Rye	5980
Wichita	Spring 14	3	2	Rye/pea	5370
Wichita	Spring 14	4	2	Rye/vetch	5110

Wichita	Spring 14	5	2	R/canola	6050
Wichita	Spring 14	6	2	Rye/vetch/canola	5980
Wichita	Spring 14	7	2	Oat	6290
Wichita	Spring 14	8	2	Oat/pea	7580
Wichita	Spring 14	1	3	Control	n/a
Wichita	Spring 14	2	3	Rye	5400
Wichita	Spring 14	3	3	Rye/pea	6700
Wichita	Spring 14	4	3	Rye/vetch	6730
Wichita	Spring 14	5	3	R/canola	5550
Wichita	Spring 14	6	3	Rye/vetch/canola	6380
Wichita	Spring 14	7	3	Oat	7740
Wichita	Spring 14	8	3	Oat/pea	8050
Olathe	Spring 15	1	1	Control	0
Olathe	Spring 15	2	1	Rye	4990
Olathe	Spring 15	3	1	Rye/pea	1950
Olathe	Spring 15	4	1	Rye/vetch	4690
Olathe	Spring 15	5	1	R/canola	3180
Olathe	Spring 15	6	1	Rye/vetch/canola	4320
Olathe	Spring 15	7	1	Oat	4960
Olathe	Spring 15	8	1	Oat/pea	4110
Olathe	Spring 15	1	2	Control	0
Olathe	Spring 15	2	2	Rye	4140
Olathe	Spring 15	3	2	Rye/pea	3180
Olathe	Spring 15	4	2	Rye/vetch	2630
Olathe	Spring 15	5	2	R/canola	2310
Olathe	Spring 15	6	2	Rye/vetch/canola	7150
Olathe	Spring 15	7	2	Oat	4310
Olathe	Spring 15	8	2	Oat/pea	4980
Olathe	Spring 15	1	3	Control	0
Olathe	Spring 15	2	3	Rye	4600
Olathe	Spring 15	3	3	Rye/pea	4320
Olathe	Spring 15	4	3	Rye/vetch	4630
Olathe	Spring 15	5	3	R/canola	4410
Olathe	Spring 15	6	3	Rye/vetch/canola	3410
Olathe	Spring 15	7	3	Oat	3320
Olathe	Spring 15	8	3	Oat/pea	5340
Wichita	Spring 15	1	1	Control	0
Wichita	Spring 15	2	1	Rye	5320
Wichita	Spring 15	3	1	Rye/pea	5020
Wichita	Spring 15	4	1	Rye/vetch	6050

Wichita	Spring 15	5	1	R/canola	5650
Wichita	Spring 15	6	1	Rye/vetch/canola	3970
Wichita	Spring 15	7	1	Oat	3320
Wichita	Spring 15	8	1	Oat/pea	5190
Wichita	Spring 15	1	2	Control	0
Wichita	Spring 15	2	2	Rye	5330
Wichita	Spring 15	3	2	Rye/pea	5650
Wichita	Spring 15	4	2	Rye/vetch	4750
Wichita	Spring 15	5	2	R/canola	4510
Wichita	Spring 15	6	2	Rye/vetch/canola	8150
Wichita	Spring 15	7	2	Oat	4460
Wichita	Spring 15	8	2	Oat/pea	7240
Wichita	Spring 15	1	3	Control	0
Wichita	Spring 15	2	3	Rye	6930
Wichita	Spring 15	3	3	Rye/pea	7170
Wichita	Spring 15	4	3	Rye/vetch	4140
Wichita	Spring 15	5	3	R/canola	5210
Wichita	Spring 15	6	3	Rye/vetch/canola	7410
Wichita	Spring 15	7	3	Oat	7410
Wichita	Spring 15	8	3	Oat/pea	6500

Appendix B - Chapter 2 Raw Data

Table B.1 Plot level data for Columbus. Note, in 2015 there were severe establishment and weed issues in rep 1 (no-till plots). Therefore the first rep was dropped when means were calculated.

Date	Rep	Trt	Dry Matter Biomass					N	C	ADF	NDF
			Brassica	Grass	Legume	Other	Total				
			---------------kg ha^{-1}----------------					----------------%--------------			
9/26/14	1	1	261.7	74.5	1.1	15.8	353.2	4.9	40.8	8.0	18.4
9/26/14	1	2	646.6	0.0	8.0	0.0	654.6	4.3	38.6	8.1	15.4
9/26/14	1	3	45.7	374.7	0.0	17.9	438.3	4.5	41.7	9.1	19.3
9/26/14	1	4	187.2	743.7	0.0	0.0	931.0	3.8	41.7	9.7	17.4
9/26/14	1	5	209.5	132.1	16.6	31.6	389.8	5.0	40.7	7.5	16.5
9/26/14	1	6	735.7	0.0	45.4	4.9	786.0	5.2	37.6	6.4	13.7
9/26/14	1	7	2530.8	358.8	31.1	0.0	2920.6	4.4	37.2	9.4	15.2
9/26/14	1	8	1075.0	664.7	13.0	0.0	1752.8	4.9	40.0	8.9	16.7
9/26/14	1	9	2586.0	128.5	0.0	0.0	2714.6	4.5	37.0	7.9	16.4
9/26/14	1	10	1192.9	61.2	0.0	14.8	1269.0	5.0	38.7	8.5	14.5
9/26/14	1	11	783.1	898.5	2.0	0.0	1683.6	4.1	40.3	10.2	18.3
9/26/14	1	12	393.2	836.8	1.2	0.0	1231.2	4.2	41.7	9.8	18.5
9/26/14	1	13	1704.2	68.3	20.8	10.4	1803.6	4.7	37.5	10.5	15.6
9/26/14	1	14	862.6	49.3	33.9	0.0	945.8	4.8	38.7	10.1	17.8
9/26/14	1	15	1413.4	271.7	68.3	0.0	1753.5	4.2	36.0	13.8	20.3
9/26/14	1	16	898.5	773.3	87.7	0.0	1759.5	4.3	39.6	9.4	17.9
9/26/14	2	1	765.9	137.6	0.0	0.0	903.5	4.5	40.9	9.5	15.7
9/26/14	2	2	920.4	249.3	0.0	0.0	1169.7	5.0	41.7	12.2	18.1
9/26/14	2	3	1238.6	686.0	0.0	0.0	1924.6	4.6	40.0	11.5	18.0
9/26/14	2	4	872.0	4.2	0.0	0.0	876.2	5.2	40.4	9.5	15.7
9/26/14	2	5	218.6	0.0	97.9	0.0	316.5	5.0	42.0	11.9	20.0
9/26/14	2	6	1618.5	25.6	52.3	0.0	1696.3	4.3	39.2	10.3	14.3
9/26/14	2	7	205.4	471.0	34.2	0.0	710.6	5.3	43.4	11.1	22.8
9/26/14	2	8	565.1	189.8	79.5	0.0	834.5	4.5	39.7	10.6	17.9
9/26/14	2	9	1358.8	69.9	0.0	0.0	1428.7	5.1	39.2	10.2	16.2
9/26/14	2	10	1518.5	139.6	0.0	0.0	1658.1	4.5	39.1	11.1	16.9
9/26/14	2	11	2252.2	268.0	0.0	0.0	2520.2	5.0	39.1	11.3	16.4
9/26/14	2	12	2622.9	43.5	0.0	0.0	2666.3	4.6	39.0	11.5	16.2
9/26/14	2	13	1575.2	20.6	48.8	0.0	1644.6	4.0	40.2	12.2	15.6
9/26/14	2	14	1877.0	67.6	66.6	0.0	2011.2	4.2	38.3	13.4	17.5
9/26/14	2	15	1071.2	328.0	41.5	0.0	1440.7	4.1	41.1	13.2	18.3
9/26/14	2	16	1467.5	135.0	49.5	0.0	1652.0	4.4	42.3	14.6	19.5

9/26/14	3	1	816.8	139.1	0.0	0.0	956.0	5.3	41.3	11.6	18.2
9/26/14	3	2	981.5	269.5	0.0	0.0	1251.0	5.5	40.4	11.8	19.6
9/26/14	3	3	1320.9	724.6	0.0	0.0	2045.5	4.3	41.3	12.6	20.8
9/26/14	3	4	929.9	4.9	0.0	0.0	934.8	4.6	42.1	13.3	22.2
9/26/14	3	5	233.2	0.0	97.7	0.0	330.8	4.9	42.7	11.7	19.4
9/26/14	3	6	1725.9	27.7	52.2	0.0	1805.8	4.5	38.8	11.5	18.0
9/26/14	3	7	219.0	497.5	34.1	0.0	750.6	5.3	43.2	14.6	22.6
9/26/14	3	8	602.6	221.3	79.4	0.0	903.3	4.8	43.3	11.1	21.6
9/26/14	3	9	1460.8	70.7	0.0	0.0	1531.5	4.5	38.5	13.7	17.4
9/26/14	3	10	1632.5	150.9	0.0	0.0	1783.4	5.1	38.6	14.7	19.4
9/26/14	3	11	2421.2	283.0	0.0	0.0	2704.3	3.5	38.4	13.6	18.4
9/26/14	3	12	2819.7	50.7	0.0	0.0	2870.3	4.7	38.6	12.9	20.9
9/26/14	3	13	1693.4	20.8	48.7	0.0	1762.9	5.4	42.0	11.6	19.8
9/26/14	3	14	2017.8	73.1	66.5	0.0	2157.4	4.9	40.5	13.7	19.1
9/26/14	3	15	1151.6	346.4	41.4	0.0	1539.4	4.7	40.6	14.8	21.6
9/26/14	3	16	1467.5	135.0	49.5	0.0	1652.0	4.3	39.6	14.2	20.7
10/25/14	1	1	3194.0	295.0	0.0	33.7	3522.7	2.8	42.3	14.3	18.7
10/25/14	1	2	4940.0	14.3	1.5	40.5	4996.4	4.4	41.7	12.9	16.4
10/25/14	1	3	439.8	3110.6	0.0	0.0	3550.4	3.0	41.3	13.6	22.1
10/25/14	1	4	333.8	2922.8	0.0	0.0	3256.6	3.4	41.8	15.5	25.0
10/25/14	1	5	4587.4	56.0	56.6	0.0	4700.0	3.3	41.7	11.5	15.7
10/25/14	1	6	4580.0	10.1	11.0	0.0	4601.1	3.3	41.6	9.3	14.0
10/25/14	1	7	2420.6	889.4	17.2	0.0	3327.2	2.7	38.9	11.9	17.5
10/25/14	1	8	2944.4	1831.8	7.5	0.0	4783.8	3.5	41.6	10.7	16.7
10/25/14	1	9	2087.2	176.4	0.0	0.0	2263.7	3.2	40.5	16.4	19.9
10/25/14	1	10	2509.8	0.0	0.0	175.2	2685.0	4.5	39.2	13.0	17.7
10/25/14	1	11	992.9	2032.1	0.0	29.5	3054.4	2.8	40.5	14.9	19.7
10/25/14	1	12	448.2	2744.2	0.0	0.0	3192.4	3.0	41.3	13.8	22.9
10/25/14	1	13	3116.8	72.3	108.4	0.0	3297.5	2.8	38.8	11.7	14.3
10/25/14	1	14	3357.1	1.8	9.4	0.0	3368.3	3.7	40.3	13.0	16.5
10/25/14	1	15	2219.7	870.9	32.6	0.0	3123.3	3.8	40.8	12.6	18.4
10/25/14	1	16	1306.2	2159.9	13.1	0.0	3479.3	3.0	41.4	14.0	22.0
10/25/14	2	1	694.1	11.1	0.0	0.0	705.2	2.9	39.6	11.3	16.5
10/25/14	2	2	2691.2	403.3	0.0	0.0	3094.5	4.2	40.5	9.2	16.5
10/25/14	2	3	448.5	2337.1	0.0	0.0	2785.6	3.0	41.3	14.2	20.3
10/25/14	2	4	0.0	4655.5	0.0	0.0	4655.5	3.3	41.6	13.4	24.6
10/25/14	2	5	1547.2	140.1	782.8	0.0	2470.1	4.3	42.3	7.9	14.1
10/25/14	2	6	1821.3	189.8	340.3	0.0	2351.3	3.3	40.4	10.6	16.6
10/25/14	2	7	14.6	2002.1	267.3	0.0	2284.0	3.8	41.7	14.3	23.6
10/25/14	2	8	1001.0	3746.3	279.4	0.0	5026.7	3.6	41.6	10.3	18.4
10/25/14	2	9	5995.8	23.2	0.0	0.0	6019.0	3.9	39.9	9.8	15.0

10/25/14	2	10	5922.7	0.0	0.0	0.0	5922.7	3.1	40.3	9.8	15.1
10/25/14	2	11	1911.2	290.4	0.0	0.0	2201.6	2.6	39.8	10.4	16.1
10/25/14	2	12	4768.6	1564.7	0.0	0.0	6333.2	3.2	41.8	13.8	18.5
10/25/14	2	13	2907.8	0.0	25.2	0.0	2932.9	3.4	39.5	10.8	14.0
10/25/14	2	14	4316.3	0.0	0.0	0.0	4316.3	3.7	41.5	11.1	17.9
10/25/14	2	15	3426.9	192.4	39.4	0.0	3658.8	4.0	40.5	12.6	18.8
10/25/14	2	16	3750.8	0.0	0.0	0.0	3750.8	2.7	40.3	11.5	16.3
10/25/14	3	1	414.5	492.8	0.0	0.0	907.3	4.0	42.0	9.4	19.3
10/25/14	3	2	1712.9	878.4	4.7	0.0	2595.9	3.8	42.7	10.6	19.1
10/25/14	3	3	394.5	1296.7	0.0	0.0	1691.2	3.1	41.4	12.4	20.8
10/25/14	3	4	0.0	3352.8	0.0	0.0	3352.8	4.3	43.5	12.9	25.0
10/25/14	3	5	1132.7	184.9	123.8	0.0	1441.3	3.7	42.0	11.2	16.4
10/25/14	3	6	3568.5	557.3	205.5	0.0	4331.3	4.1	41.5	10.6	16.8
10/25/14	3	7	843.5	2208.3	463.9	0.0	3515.7	3.0	41.1	11.5	19.1
10/25/14	3	8	843.9	2636.1	157.1	0.0	3637.1	3.0	41.8	13.1	18.7
10/25/14	3	9	4021.5	0.0	0.0	0.0	4021.5	2.9	38.6	14.0	17.6
10/25/14	3	10	3576.8	11.9	0.0	0.0	3588.8	3.1	41.5	12.3	14.9
10/25/14	3	11	3735.3	202.9	0.0	0.0	3938.2	3.1	42.0	14.4	19.1
10/25/14	3	12	3265.6	434.5	0.0	0.0	3700.1	3.2	41.6	13.4	18.9
10/25/14	3	13	5836.0	0.0	0.0	0.0	5836.0	3.4	38.1	6.0	16.3
10/25/14	3	14	3145.1	5.0	43.6	0.0	3193.7	4.1	40.3	12.9	16.4
10/25/14	3	15	3182.0	102.8	5.0	0.0	3289.7	3.2	42.4	14.5	16.6
10/25/14	3	16	1332.6	1490.3	6.3	0.0	2829.2	2.5	41.0	13.6	20.7
11/11/14	1	1	404.7	930.0	0.0	0.0	1334.6	2.4	42.4	19.3	22.4
11/11/14	1	2	2599.6	45.4	0.0	0.0	2645.0	2.0	41.3	14.18	16.85
11/11/14	1	3	161.6	3169.5	0.0	0.0	3331.1	2.0	42.2	17.13	23.18
11/11/14	1	4	237.0	4301.1	0.0	0.0	4538.1	1.8	41.6	15.92	23.59
11/11/14	1	5	1130.0	2672.0	418.4	0.0	4220.4	2.1	41.4	15.07	20.19
11/11/14	1	6	3356.7	84.4	0.0	0.0	3441.2	2.3	40.5	16.51	18.79
11/11/14	1	7	330.0	2226.2	0.0	0.0	2556.2	2.4	40.3	16.29	21.83
11/11/14	1	8	266.1	3049.8	4.2	0.0	3320.0	2.1	43.6	20.29	27.66
11/11/14	1	9	1044.3	208.0	0.0	0.0	1252.3	2.5	39.6	15.34	18.23
11/11/14	1	10	4855.8	237.3	0.0	0.0	5093.1	2.2	41.9	19.18	21.58
11/11/14	1	11	464.0	2380.2	0.0	0.0	2844.3	1.8	42.7	20.93	25.98
11/11/14	1	12	3664.0	0.0	0.0	0.0	3664.0	1.8	41.2	14.3	18.89
11/11/14	1	13	731.7	79.8	8.8	0.0	820.3	2.3	40.1	15.76	17.38
11/11/14	1	14	2113.1	10.4	86.0	0.0	2209.5	2.3	38.3	12.98	14.38
11/11/14	1	15	411.6	849.7	39.1	0.0	1300.5	2.0	40.4	13.71	20.34
11/11/14	1	16	219.9	4130.0	29.2	0.0	4379.2	1.7	41.8	14.65	23.87
11/11/14	2	1	518.3	569.2	0.0	0.0	1087.4	2.5	39.6	11.18	18.47
11/11/14	2	2	1461.5	943.2	0.0	0.0	2404.6	3.3	42.0	9.047	16.07

11/11/14	2	3	939.5	953.9	0.0	0.0	1893.4	2.1	40.4	12.93	16.7
11/11/14	2	4	1228.7	1170.9	0.0	0.0	2399.6	2.4	41.9	12.12	19.99
11/11/14	2	5	595.6	544.7	244.6	7.8	1392.7	2.7	41.2	10.76	19.31
11/11/14	2	6	99.5	1108.6	287.8	5.2	1501.0	2.8	42.1	10.72	20.53
11/11/14	2	7	215.4	1168.5	182.3	0.0	1566.3	2.7	41.6	12.89	21.1
11/11/14	2	8	994.0	938.5	188.8	0.0	2121.3	2.3	41.6	11.82	19.16
11/11/14	2	9	.	.	.	.	0.0	.	.	.	.
11/11/14	2	10	4390.5	18.2	0.0	0.0	4408.7	2.6	38.4	13.32	14.89
11/11/14	2	11	1130.3	315.5	0.0	0.0	1445.8	2.5	38.6	14.65	19.09
11/11/14	2	12	2035.5	119.4	0.0	0.0	2154.9	2.0	39.4	11.86	13.41
11/11/14	2	13	2049.0	0.0	2.0	0.0	2050.9	2.6	38.6	12.94	15.08
11/11/14	2	14	1946.5	7.9	0.0	0.0	1954.4	2.0	38.2	11.78	12.78
11/11/14	2	15	2491.1	402.0	105.9	0.0	2999.0	2.8	39.4	14.11	18.16
11/11/14	2	16	2220.2	389.6	0.0	0.0	2609.8	2.2	40.9	13.74	19.9
11/11/14	3	1	1335.7	461.8	0.0	0.0	1797.5	3.4	40.8	12.07	19.16
11/11/14	3	2	988.1	1008.5	0.0	0.0	1996.5	2.9	40.2	11.77	18.96
11/11/14	3	3	970.7	1184.4	0.0	0.0	2155.1	2.5	41.2	12.6	18.73
11/11/14	3	4	16.6	2450.7	0.0	0.0	2467.2	2.4	42.4	14.18	23.95
11/11/14	3	5	871.7	302.4	140.5	0.0	1314.5	2.9	42.6	14.8	21.49
11/11/14	3	6	1538.5	773.1	156.2	18.4	2486.2	2.7	42.1	14.74	19.71
11/11/14	3	7	541.4	1060.3	142.4	0.0	1744.2	2.9	42.6	13.04	20.69
11/11/14	3	8	305.2	1747.1	111.5	0.0	2163.7	2.3	42.0	13.78	21.42
11/11/14	3	9	3084.2	0.0	0.0	0.0	3084.2	3.9	40.6	13.68	16.2
11/11/14	3	10	1704.9	0.0	0.0	0.0	1704.9	3.0	40.4	13.1	16.48
11/11/14	3	11	1509.0	662.2	0.0	0.0	2171.2	2.8	40.2	15.12	18.45
11/11/14	3	12	1744.6	452.5	0.0	0.0	2197.2	3.0	40.0	11.55	16.86
11/11/14	3	13	2925.9	0.0	27.0	0.0	2953.0	2.8	38.6	14.07	16.08
11/11/14	3	14	3139.1	0.0	0.0	0.0	3139.1	2.7	40.5	12.16	13.77
11/11/14	3	15	1513.9	84.3	0.0	0.0	1598.2	2.5	38.5	13.07	14.36
11/11/14	3	16	1235.1	609.1	0.0	0.0	1844.2	2.8	40.2	15.18	19.99
10/6/15	1	1	0.0	236.4	4.4	95.3	336.1	4.2	40.4	15.3	21.4
10/6/15	1	2	0.0	0.0	0.0	468.8	468.8	1.5	39.3	23.6	32.2
10/6/15	1	3	0.8	195.2	0.6	343.5	540.1	2.6	39.5	19.0	26.9
10/6/15	1	4	0.0	1144.5	0.0	66.7	1211.3	3.1	41.6	13.8	21.6
10/6/15	1	5	0.0	68.5	123.9	226.9	419.3	3.2	40.5	17.7	23.3
10/6/15	1	6	0.0	0.5	5.7	671.9	678.2	1.4	39.3	21.2	29.2
10/6/15	1	7	0.0	0.0	28.2	351.1	522.6	2.0	36.8	19.8	25.8
10/6/15	1	8	130.3	941.5	3.9	322.4	1398.1	2.5	40.2	16.9	24.3
10/6/15	1	9	355.6	9.1	0.0	295.1	659.8	1.8	37.4	17.6	25.0
10/6/15	1	10	122.6	6.6	0.0	483.1	612.2	2.3	37.5	19.2	28.3
10/6/15	1	11	178.1	515.7	0.9	256.0	950.7	2.8	38.5	17.2	24.7

10/6/15	1	12	53.8	1221.3	0.0	171.7	1446.8	2.8	40.7	14.8	21.6
10/6/15	1	13	457.4	0.0	8.8	284.1	750.3	2.5	37.7	14.1	23.4
10/6/15	1	14	13.8	0.0	24.3	451.6	489.6	1.8	39.4	20.2	29.2
10/6/15	1	15	0.0	0.0	7.9	333.1	341.1	1.6	40.1	21.5	31.8
10/6/15	1	16	4.0	7.9	12.7	443.6	468.3	1.6	40.1	20.9	31.3
10/6/15	2	1	183.6	420.7	0.0	356.2	960.5	3.1	40.0	15.4	23.4
10/6/15	2	2	587.3	350.6	13.1	2.4	953.4	4.6	39.0	12.7	19.8
10/6/15	2	3	109.7	1022.1	0.7	1.0	1133.6	3.2	40.1	13.4	22.2
10/6/15	2	4	0.0	1653.8	4.9	26.5	1685.3	3.5	42.2	15.2	21.1
10/6/15	2	5	0.0	118.8	486.9	1.0	606.8	4.0	42.3	13.6	18.9
10/6/15	2	6	0.0	123.4	819.3	38.7	981.4	3.9	41.9	14.9	22.6
10/6/15	2	7	0.0	437.6	256.8	0.0	694.4	4.9	41.7	13.2	23.1
10/6/15	2	8	0.0	858.5	57.2	188.3	1104.0	2.8	41.9	14.8	21.3
10/6/15	2	9	345.4	157.3	4.7	20.6	528.1	4.6	37.2	12.3	23.8
10/6/15	2	10	294.8	232.4	0.0	0.0	527.2	4.8	39.0	10.8	21.9
10/6/15	2	11	316.8	851.4	0.0	292.1	1460.3	3.1	39.9	16.0	25.8
10/6/15	2	12	56.2	1395.6	0.0	35.1	1486.9	3.7	42.8	14.3	23.3
10/6/15	2	13	12.2	74.5	627.5	100.6	814.9	4.2	41.6	14.0	21.9
10/6/15	2	14	0.0	27.6	783.3	0.0	810.9	3.7	43.2	11.4	19.2
10/6/15	2	15	7.2	355.6	303.5	0.0	666.3	4.7	42.4	10.7	21.8
10/6/15	2	16	0.0	1602.1	270.5	41.1	1913.8	3.5	42.0	13.6	23.3
10/6/15	3	1	40.0	648.7	0.0	0.0	688.7	3.9	40.3	14.1	25.2
10/6/15	3	2	220.6	114.6	5.3	0.0	340.4	4.2	39.0	11.4	18.7
10/6/15	3	3	10.2	637.7	0.0	0.0	647.9	4.1	40.1	14.4	25.2
10/6/15	3	4	122.3	1378.4	0.0	0.0	1500.6	4.1	40.8	15.9	24.1
10/6/15	3	5	132.4	274.4	480.8	0.0	887.6	3.0	38.9	13.7	19.9
10/6/15	3	6	141.9	32.5	653.9	0.0	828.3	4.6	42.7	11.5	18.8
10/6/15	3	7	0.0	392.7	180.8	0.0	573.5	4.4	42.5	14.4	22.2
10/6/15	3	8	0.0	758.2	113.9	44.0	916.2	3.1	40.7	15.5	23.1
10/6/15	3	9	299.3	309.7	0.0	9.8	618.8	4.2	35.3	15.8	23.3
10/6/15	3	10	297.0	620.4	0.0	0.0	917.4	4.5	39.2	14.6	23.3
10/6/15	3	11	281.3	516.3	0.0	0.0	797.6	3.3	38.6	13.7	20.9
10/6/15	3	12	82.1	874.9	0.0	0.0	957.0	3.4	41.6	12.9	20.2
10/6/15	3	13	224.1	70.7	485.6	0.0	780.4	3.2	41.7	11.7	17.9
10/6/15	3	14	0.0	12.4	876.1	0.0	888.6	4.4	42.7	11.4	17.2
10/6/15	3	15	335.6	694.8	437.4	0.0	1467.8	3.7	40.1	14.3	20.8
10/6/15	3	16	50.8	818.3	134.1	0.0	1003.2	3.5	40.9	13.5	20.4
11/3/15	1	1	0.0	128.4	6.7	81.9	216.9	3.5	39.8	13.0	23.6
11/3/15	1	2	.	.	.	.	.	.	.	.	.
11/3/15	1	3	120.2	443.6	0.0	266.4	830.2	2.5	39.5	15.8	24.8
11/3/15	1	4	1.2	543.3	0.0	138.8	683.3	1.9	40.5	15.8	24.2

11/3/15	1	5	0.0	314.5	148.7	203.9	667.1	3.0	40.2	15.7	25.8
11/3/15	1	6	172.6	29.1	520.0	196.4	918.0	2.4	40.6	14.4	20.2
11/3/15	1	7	0.0	514.5	291.6	130.0	936.1	3.0	40.2	15.4	24.6
11/3/15	1	8	85.7	924.5	9.5	189.2	1209.0	1.8	41.4	18.5	22.6
11/3/15	1	9	225.7	31.8	7.6	154.3	419.4	2.0	37.6	15.4	21.6
11/3/15	1	10	155.3	0.1	0.9	154.6	310.9	1.6	38.8	19.9	26.8
11/3/15	1	11	144.0	28.6	0.0	239.5	412.2	1.7	39.0	19.5	28.8
11/3/15	1	12	16.6	265.6	0.0	235.4	517.6	1.8	40.1	18.3	27.6
11/3/15	1	13	57.8	0.7	15.9	200.4	274.9	1.6	40.1	20.6	30.5
11/3/15	1	14	160.7	0.0	13.3	301.2	475.2	1.7	39.0	19.1	28.2
11/3/15	1	15	32.3	16.1	72.5	114.1	234.9	2.0	39.1	20.4	29.4
11/3/15	1	16	8.7	99.5	5.0	182.4	295.6	1.7	40.2	18.5	28.1
11/3/15	2	1	41.2	1074.9	9.4	0.0	1125.6	3.3	40.0	14.1	21.6
11/3/15	2	2	124.6	629.9	0.0	0.0	754.5	3.9	42.4	9.9	20.2
11/3/15	2	3	796.1	2346.8	5.9	0.0	3148.8	2.9	40.7	11.1	20.2
11/3/15	2	4	0.0	2437.5	0.0	0.0	2437.5	2.6	42.3	12.0	21.8
11/3/15	2	5	23.3	158.2	1892.8	157.1	2231.5	2.9	42.3	13.3	21.2
11/3/15	2	6	369.4	262.2	1220.0	0.0	1851.5	3.5	43.0	10.8	16.8
11/3/15	2	7	0.0	1329.5	706.3	0.0	2035.8	3.6	42.7	12.5	22.8
11/3/15	2	8	0.0	2831.7	223.0	0.0	3054.7	2.9	42.7	11.9	21.7
11/3/15	2	9	109.0	963.1	6.1	19.1	1097.2	3.5	39.7	12.8	22.7
11/3/15	2	10	1393.8	373.0	46.2	0.0	1813.0	3.3	37.0	11.2	15.7
11/3/15	2	11	282.7	2363.5	0.4	0.0	2646.6	2.5	40.9	11.5	20.6
11/3/15	2	12	50.4	2446.2	0.0	0.0	2496.6	2.7	43.4	12.9	22.9
11/3/15	2	13	483.4	319.7	998.3	0.0	1801.4	3.4	42.1	12.3	19.7
11/3/15	2	14	665.3	0.0	905.5	377.2	1948.0	2.4	40.7	13.7	22.5
11/3/15	2	15	186.7	1272.3	506.1	0.0	1965.1	3.3	41.7	11.5	18.8
11/3/15	2	16	0.7	3344.9	143.1	0.0	3488.7	2.2	42.3	12.1	21.2
11/3/15	3	1	0.0	849.9	0.0	0.0	849.9	3.0	38.4	14.2	21.8
11/3/15	3	2	538.3	261.2	0.0	0.0	799.5	3.9	40.4	9.9	16.3
11/3/15	3	3	60.1	1930.1	0.0	0.0	1990.2	3.0	41.1	12.9	22.1
11/3/15	3	4	0.0	2508.0	0.0	3.0	2511.1	2.6	43.6	11.5	20.1
11/3/15	3	5	0.0	802.8	224.3	0.0	1027.1	3.1	38.8	14.3	21.0
11/3/15	3	6	294.6	148.2	606.5	0.8	1050.1	3.2	39.5	12.1	19.4
11/3/15	3	7	0.0	974.4	880.6	4.9	1859.8	3.1	42.6	12.4	20.7
11/3/15	3	8	0.0	2009.1	269.9	6.3	2285.3	2.2	41.2	11.2	19.3
11/3/15	3	9	478.9	409.2	0.0	0.0	888.1	3.6	38.0	13.5	21.1
11/3/15	3	10	261.3	641.8	0.0	1.2	904.3	4.3	41.1	12.0	19.9
11/3/15	3	11	518.0	1231.1	3.5	21.5	1774.1	2.0	38.6	12.8	20.1
11/3/15	3	12	335.1	2473.9	0.0	0.0	2809.0	2.5	41.9	12.4	20.0
11/3/15	3	13	0.0	816.5	640.4	0.0	1456.9	3.5	41.1	12.6	19.7

11/3/15	3	14	730.2	0.0	790.6	0.0	1520.8	3.7	41.2	11.1	20.8
11/3/15	3	15	168.7	1169.7	865.6	0.0	2203.9	2.7	40.8	12.4	19.5
11/3/15	3	16	343.1	1372.5	91.4	1.8	1808.8	3.2	41.2	11.9	19.8
11/23/15	1	1	.	.	.	.	.	.	.	.	.
11/23/15	1	2	.	.	.	.	.	.	.	.	.
11/23/15	1	3	.	.	.	.	.	.	.	.	.
11/23/15	1	4	.	.	.	.	.	.	.	.	.
11/23/15	1	5	.	.	.	.	.	.	.	.	.
11/23/15	1	6	.	.	.	.	.	.	.	.	.
11/23/15	1	7	.	.	.	.	.	.	.	.	.
11/23/15	1	8	.	.	.	.	.	.	.	.	.
11/23/15	1	9	.	.	.	.	.	.	.	.	.
11/23/15	1	10	.	.	.	.	.	.	.	.	.
11/23/15	1	11	.	.	.	.	.	.	.	.	.
11/23/15	1	12	.	.	.	.	.	.	.	.	.
11/23/15	1	13	.	.	.	.	.	.	.	.	.
11/23/15	1	14	.	.	.	.	.	.	.	.	.
11/23/15	1	15	.	.	.	.	.	.	.	.	.
11/23/15	1	16	.	.	.	.	.	.	.	.	.
11/23/15	2	1	0.0	1549.3	0.0	0.0	1549.3	3.0	41.7	13.7	22.5
11/23/15	2	2	739.7	945.0	0.0	0.0	1684.7	3.8	42.8	17.3	22.2
11/23/15	2	3	0.0	3285.6	0.0	0.0	3285.6	2.7	42.0	11.3	20.7
11/23/15	2	4	78.9	4407.4	0.0	0.0	4486.3	2.6	44.1	21.9	29.5
11/23/15	2	5	0.0	264.3	2086.1	0.0	2350.4	4.0	45.0	14.9	20.3
11/23/15	2	6	1032.4	450.8	1081.7	0.0	2564.9	3.2	42.4	12.8	18.9
11/23/15	2	7	0.0	2453.8	722.8	0.0	3176.6	2.3	41.1	11.7	5.1
11/23/15	2	8	0.0	3592.7	434.4	0.0	4027.1	2.6	45.7	20.2	7.7
11/23/15	2	9	1188.4	1548.6	0.0	0.0	2736.9	3.8	42.1	18.8	24.5
11/23/15	2	10	4548.7	426.8	0.0	0.0	4975.5	4.1	38.8	18.2	19.8
11/23/15	2	11	236.5	3229.9	0.0	0.0	3466.4	2.5	41.2	12.3	21.3
11/23/15	2	12	0.0	3208.2	0.0	0.0	3208.2	2.4	42.4	15.3	27.5
11/23/15	2	13	1433.4	271.9	1167.4	0.0	2872.7	2.6	40.1	12.5	18.7
11/23/15	2	14	904.6	96.2	2155.6	0.0	3156.4	2.9	42.4	13.1	19.9
11/23/15	2	15	0.0	2151.7	1465.4	0.0	3617.1	2.5	41.0	12.4	19.5
11/23/15	2	16	0.0	2974.0	816.1	0.0	3790.0	2.6	44.3	19.9	27.9
11/23/15	3	1	9.3	924.3	0.0	0.0	933.6	4.3	46.1	19.6	27.8
11/23/15	3	2	.	.	.	.	.	.	.	.	.
11/23/15	3	3	113.8	3400.0	6.0	0.0	3519.8	2.3	42.3	32.1	27.6
11/23/15	3	4	0.0	2609.1	0.0	0.0	2609.1	2.1	41.7	11.7	21.2
11/23/15	3	5	410.4	945.8	274.5	0.0	1630.7	4.0	43.9	13.9	23.7
11/23/15	3	6	0.0	0.0	1156.9	0.0	1156.9	4.0	45.4	23.8	27.8

11/23/15	3	7	0.0	2812.5	1159.5	0.0	3972.0	2.2	40.6	31.4	25.4
11/23/15	3	8	0.0	981.0	347.7	0.0	1328.7	3.9	44.7	11.5	18.7
11/23/15	3	9	640.7	1288.9	0.0	0.0	1929.6	2.9	40.4	12.8	21.5
11/23/15	3	10	0.0	680.7	0.0	0.0	680.7	4.0	42.8	16.5	22.9
11/23/15	3	11	1135.4	1232.8	0.0	0.0	2368.3	2.7	42.5	24.0	26.3
11/23/15	3	12	0.0	2538.5	0.0	0.0	2538.5	3.1	43.6	13.8	23.4
11/23/15	3	13	583.7	629.0	1008.1	0.0	2220.8	2.9	42.6	.	.
11/23/15	3	14	583.4	79.6	2267.7	0.0	2930.6	2.4	40.4	10.7	18.9
11/23/15	3	15	0.0	2104.7	848.3	0.0	2953.0	3.1	44.0	25.7	27.8
11/23/15	3	16	0.0	1229.5	562.8	0.0	1792.3	2.6	43.0	15.8	24.4

Appendix C - Statistical code

Example of statistical code used in SAS 9.4. A one-way ANOVA using Proc Mixed was used to determine statistical differences between treatments. Means were taken from averages calculated using Excel 2013.

```
data pumpkin_olathe_f13;
input trt$ rep MWD;
datalines;

;
run;
proc mixed data=pumpkin_olathe_f13;
class trt;
model MWD=trt;

random rep;
lsmeans trt/pdiff;
ods output diffs=ppp lsmeans=mmm;
ods listing exclude diffs lsmeans;
run;
%include 'C:\Users\cathryn\Desktop\pdmix800.sas';
%pdmix800(ppp,mmm,alpha=.05,sort=yes);
```