VERTICAL TILLAGE EFFECTS ON YIELD, DISEASE AND PATHOGENS, AND SOIL PROPERTIES

by

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Abstract

In the Midwest there has been an increase in the number of vertical tillage (VT) implements sold and a large push in marketing these newer implements to producers. Vertical tillage is defined as shallow tillage, usually in the top 5 to 7.5 cm of the soil and results in no horizontal disturbance of the soil. The objective was to determine the short-term (one growing season) effects of a vertical-tillage operation on seedling emergence, crop growth and development, yield, residue decomposition, disease incidence and severity, quantification of pathogen propagules in soil and crop residue, and effects on the near-surface soil physical properties. The study was conducted during the 2010 and 2011 growing seasons at nine locations total for the two years throughout Kansas. The study compared vertical tillage against the producer's current practice of no-till (NT), strip tillage (ST), or conventional disk (CD). Few significant differences were observed when studying soil properties, however not one treatment continuously had significant results and no trend was observed. Residue cover at all sites and across both years was significantly greater in the NT treatments. The residue cover also impacted the disease incidence and severity of *Cercospora zea-maydis* also known as gray leaf spot (GLS). Other diseases such as *Marcophomina phaseolina* and *Fusarium spp.* were not significantly impacted by one treatment or another. Overall, any differences in the soil, plant, and pathogen indicators have not resulted in significant yield improvements at any of the nine site locations of the two years of this study, but more site years will be needed to assess any potential benefits of VT. Information gained from this project will be disseminated to extension clientele including extension educators, producers, commodity groups, and agricultural professionals.

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Chapter 1 - Review of Relative Literature

In the Midwest there has been an increase in the number of vertical tillage (VT) implements sold and a large push in marketing these newer implements to producers. Vertical tillage, a form of conservation tillage, is defined as shallow tillage, usually in the top 5 to 7.5 cm of the soil and results in no horizontal disturbance of the soil (Presley, 2010). Conservation tillage is considered any tillage operation or practice that requires at least 30% of the crop residue left on the surface throughout the year. Management of crops in the United States has dramatically changed in the last 20 years, going from intensive tillage to no-tillage or other conservation practices that leaves the residue to protect the soil surface during fallow periods (Steiner et al., 1999). In 1980, in the United States, it was predicted that the number of no-till acres planted to corn would increase from 10 to 26% and that reduced till acres planted to corn would increase from 28 to 48% (Worsham, 1980). In 1999, nearly half of the acres planted to corn in the United States was under some form of reduced tillage (RT) (Uri, 1999). In 2010, a survey of tillage practices was conducted in 23 Kansas counties. The results were compared to the results of the same study from 2004. For corn tillage practices, there was an increase in no-till (NT) acres in 17 of the 23 counties, reduced tillage (15-30% residue after planting) acres declined in 14 of the 23 counties and conventional tillage (CT) (<15% residue after planting) acres declined in 10 of the 23 counties (Presley, 2011). Residue left on the soil surface from previous crops is very important in protecting the soil from wind and water erosion, and can improve the physical properties of the soil (Blanco and Lal, 2008). Conservation tillage or reduced tillage practices have a variety of reasons for why they have been adopted including resource conservation, decreased production costs, and decreased labor (Steiner et al., 2000).

With the increase in availability of selective herbicides and equipment that can plant seeds into the soil through the residue, producers have started adopting no-till or minimum till practices in corn production (de Nazareno et al., 1993). There has not been a consensus conclusion on the effects of rotational tillage or a one-time tillage pass in a NT system, and little research has been published in regards to vertical till operations. The following sections will review papers on the effects of tillage or no-till systems on soil properties, disease and pathogens, and yield.

Vertical Tillage and Soil Properties

Blanco and Lal (2000) stated that benefits from using less or no tillage is that it increases residue on the soil surface, decreases soil erosion, and increases soil organic matter which leads to improved soil physical properties. Soil properties such as arrangement of soil particles, soil aggregate sizes, porosity and aeration have been shown to degrade under conventional tillage practices (Connolly, 1998). A study in 1998 showed that over a period of 2-3 years was not enough time for tillage to affect most properties listed above in a sandy loam or silt loam soil (Buschiazzo et al., 1998) In the Great Plains region, changes in soil physical properties and soil organic carbon (SOC) are affected by any change in the cropping system, including tillage and residue management, however these changes may be accelerated through conventional tillage practices when compared to reduced or no tillage (Benjamin et al., 2007). Several studies have shown that intensive cropping systems partnered with no-till tillage practices are alternatives to traditional cropping systems and conventional tillage practices for improving soil physical properties (Benjamin et al., 2007). Soil conservation benefits of reduced or no-till practices are obtained by increased crop residue cover over a long-term period. Steiner (1994) concluded that benefits of conservation tillage include increased infiltration, reduced evaporation, reduced soil erosion, and long-term enhancements including an increase in soil organic matter and better soil structure.

Bulk Density

The marketing behind VT is to alleviate any surface compaction while also cutting up residue and incorporating it into the soil but also leaving greater amounts (>30%) of residue on the soil surface. Although the tillage alleviates the surface compaction, a compaction layer or hardpan can become prevalent at the operating depth (Gameda et al., 1985). A hardpan like this can restrict roots, water, and air as they move through the soil, and reduce crop response and yield (Feng et al., 2010). Soil maximum bulk density (BD_{max}) is equivalent to a soils maximum compactibility, and research has shown that the BD_{max} is lowest for NT and increases among RT, CT, and moldboard plow (MP) respectively (Blanco et al., 2008). Soil compaction can be created by natural forces or mechanical forces and this increases soil bulk density (Afzalinia et al., 2011). No-till farming practices can lead to soil compaction due to the lack of soil disturbance and use of heavy machinery for field operations (Blanco et al., 2009). Certain soils can have the ability to resist excessive compaction in a no-till system, but this is dependent on OM, texture, topography, climate, and management (Blanco and Lal, 2007). The ability of NT soils to resist compaction can be attributed to the increase in SOC in the upper layers of the soil profile and this is because the SOC enriched materials have low density and high elasticity (Thomas et al., 1996). No-till soils showed to have a significantly lower BD_{max} than the other tillage treatments of moldboard plow, conventional till, or even reduced till (Blanco et al., 2009). . The amount of influence that SOC has on the BDmax is dependent on the soil type and rate of SOC accumulation (Blanco et al., 2009). In a study by Stone and Schlegel (2010), dry bulk density samples taken at four different soil depths (0-102, 102-203, 203-305, and 305-406 mm) showed that treatment affect did not have any significant differences at any depth. In 2006, McVay et al. found in a NT, RT, and CT system that there were no significant treatment differences in dry bulk density at a 0-5 cm depth.

Soil Moisture

Zhai et al. (1990) concluded that soil water content can be both negatively and positively affected by reductions in tillage because of changes in infiltration, surface runoff, and evaporation. A 2004 study found that converting from conventional tillage to conservation tillage has shown to improve crop yields, soil water storage capacity, and other economic benefits (Gicheru et al., 2004). In surveying layers of a 0-40 cm depth of soil, differences were seen between no-till and tillage treatments in respect to soil moisture, and data showed that tillage depth, tillage mode, and time of tillage had a significant effect on soil moisture at a 0.05 level of significance (Jiuhao et al., 2006). Zero tillage practices have been observed to increase plant-available water during moisture stressed times which leads to a better water use efficiency by the crop (Bradford and Peterson, 2000). These results are obtained by insulating the soil surface, reflecting solar radiation, and decreasing wind velocity along the soil surface. Baumhardt and Jones (2002) observed varied results in respect to soil moisture when conservation tillage was compared against conventional tillage.

Water Stable Aggregates

Aggregate stability is the most sensitive soil structure property in assessing the damage done by tillage (Blanco and Lal, 2008). Wet aggregate stability is a measure of soil's ability to resist water erosion by determining the portion of water stabile aggregates (WSA). Increasing tillage leads to increased organic matter (OM) mineralization and nutrient consumption, but this leads to OM decline and has a negative impact on soil structure (Manea et al., 2009). In the 0-30 cm layer, a reduced tillage treatment had a tendency to improve water stable aggregates (Manea et al., 2009). A reduction of tillage intensity is shown to increase OM and slows the turnover in soil aggregates leading to an increase in soil aggregation (Six et al., 1998). Karlen et al., (1999) found that when highly erodible cropland was taken out of tillage and placed in a no-till system, it showed an improvement of the soil by increasing the percent of water stable aggregates. Stone and Schlegel (2010) observed that the concentration of WSA was significantly affected by tillage treatments. The study concluded that with large size aggregates (2.0-4.75 and >4.75 mm), NT had a significantly greater concentration than RT or CT, but the RT and CT treatments were not significantly different from one another (Stone and Schlegel, 2010). In a study by Obalum and Obi (2010), none of the tillage management practices had a significant impact on the mean weight diameter of WSA.

Infiltration

The increase in stable aggregates created by no-till systems allows water to infiltrate the soil surface at a faster rate and allows it to penetrate to a greater depth in the soil (Govaerts et al., 2007). Stone and Schlegel (2010) found a significant, positive correlation between mean weight diameter (MWD), the measure of water stable aggregates and infiltration measurements. No-till had a significantly greater ponded, steady-state infiltration rate compared to any of the other tillage treatments, but there was no significant difference between the RT and CT treatments (Stone and Schlegel, 2010). The significant difference that was observed in the NT treatments could be attributed to an increase in the percentage of larger WSA near the surface. However, zero tillage systems without residue left on the surface can have reduced infiltration rate times when compared to CT, underscoring the importance of residue cover in NT systems (Govaerts et al., 2007).

Soil Nutrients

Tillage systems often influence soil properties, including nutrients that are available to crops (Follet and Petersen, 1988). No-till systems have been shown to increase the extractable phosphorous (P) as well as potassium (K), calcium (Ca), and magnesium (Mg) available to the plant (Eckert and Johnson, 1985). Hargrove et al. (1982) found that by adopting NT systems, nutrients tended to have greater concentrations near the soil surface and decrease in concentration with more depth; however more conventional tillage systems have a more homogeneous concentration throughout the soil profile. Reeder et al., (1998) showed that approximately 60-75% loss of soil carbon is due to soil mixing done by tillage. A 36 year cropping period at 14 locations showed that SOC had decreased by 43% and total nitrogen (N) in the soil profile decreased by 39% using CT methods (Haas et al. 1957). In a 2010 tillage study, the total N and C concentrations in the soil were found to not be significantly different among any tillage treatments (Stone and Schlegel, 2010). In a long term tillage study looking at NT, minimum till (MT), and CT impact on soil nutrients, SOC in the top 0-7.5 cm was significantly greater in the NT treatment than the MT and CT treatments (Dick, 1983). In the same study, organic N followed the same pattern as organic C, with NT having a significantly greater concentration in the top 0-7.5 cm layer when compared to MT and CT. In the MT and CT treatments, there was no significant difference in the organic C and N concentrations in the top 0-7.5 cm (Dick, 1983).

Vertical Tillage and Agronomic Properties

Residue Management

In the central Great Plains, maintaining crop residue such as *Zea mays*, is important factor in preventing wind and water erosion. Measuring the amount and rate of decomposition of residue can be difficult to determine in the field due to varying environmental conditions. Deep and intensive tilling or plowing increases the soil-residue contact, creating greater nutrient consumption in the soil because of the increase in humus or OM mineralization (Manea et al., 2009). A study was done on effects of soil properties of one plowing operation after 20 years of reduced tillage. It was determined that the OM had increased by 7g/kg in the top 5 cm of the soil over the 20 years of reduced tillage, but after one plowing operation, the OM content had been reduced to levels associated with conventional tilled systems (Stockfish et al., 1999). The process of inverting the soil done by most tillage practices leads to quick mineralization of exposed OM and leads to the decline of OM content in the soil, but this can be dependent on tillage intensity and soil structure. Six et al (2000) observed that there was no statistical difference in SOM content in NT or CT. Gregory (1982) explained that there is a relationship between residue biomass produced by a crop and the amount of residue cover provided. Concluding that the biomass-cover relationship reaches a steady state at high levels where large biomass decomposition can occur without affecting residue cover, but for leafy cover, there may be considerable loss of cover with little biomass decomposition.

Crop Emergence

To control soil erosion, residue on the soil surface provides shelter with non-erodible cover and can change the flow of water or wind and reduce the amount of soil moved, but this residue can be a barrier to young plants during emergence (Steiner et al., 2000). With the cooler soil temperatures caused by no-till or reduced till practices, seed germination and seedling development may be significantly slower when compared to a conventional till system (Sumner et al., 1981). Problems with poor seedling emergence have been reported in no-till systems (Schwab et al., 2002). There was no evidence for a difference in stand counts in a 2 year study comparing NT to CT plots (Lipps et al., 1991). Across the Midwest, in the past 10 years, there has been a moving trend that has pushed starting planting dates on average eight days earlier and finishing on average up to 16 days earlier when compared to the past decade (Saab, 2005). This trend puts the seeds in less than optimum conditions for germination and seedling growth by preventing rapid drying and warming of the soil, increasing early season stress, and increasing the need for longer efficacy on seed treatments (Broders et al., 2007).

Vertical Tillage and Plant Pathogens

In the United States, disease infestation alone can cause a yield loss ranging from 2 to 15% each year which has a large economic impact (White, 1999). It has been speculated that a reduction of yield in NT or RT plots has come from increased weed and disease pressure. Various pathogens, depending on their survival strategy and lifecycles, can be influenced in various ways by a reduction in tillage (Bockus and Shroyer, 1998). A disease or pathogen species that has one or more of its lifecycles in the soil are most affected by tillage (Govaerts et al., 2007). In 1990, Stinner and House reviewed 45 studies and showed that 43% of disease species decreased with decreased tillage, 29% showed no significant effect, and 28% of the disease species increased with decreased tillage. In a two year study, it was concluded that management strategies such as tillage, fertility, and crop rotation can significantly impact disease severity (Brooks et al., 2009). The benefits of keeping residue on the soil surface are often offset by the residue providing a nutrient source and shelter for survival, growth, and reproduction of plant pathogens (Sumner et al., 1981). Barker and Koenning (1998) claimed that crop rotation could be the most beneficial practice to reduce pathogen numbers in a NT system. However, under NT systems, it could increase the number of beneficial soil microflora which would compete with the pathogens, and any change in residue management strategies indirectly influences the balance of beneficial and pathogenic organisms in the soil profile (Cook, 1990). Because of this, NT systems have the potential of using biological control against pathogens. Boosalis et al. (1986) concluded that the degree of pressure that the disease has on a crop is related to the amount of residue remaining after planting the crop, with tillage systems leaving 20% cover are less likely to have disease pressure then tillage systems that leave 90% cover. Results showed that there was a positive and significant correlation between amount of residue cover and disease severity, but environmental effects were also significantly important (de Nazareno et al., 1993). The study also indicated that residue levels of approximately 10% cover could provide enough inoculums to cause an epidemic similar to one that residue levels of 35-40% could produce if other environmental conditions were ideal for infestation. Several studies have been conducted to see the role of crop residue left on the soil surface by no or reduced till practices on disease severity. The studies concluded that no-till may increase, decrease, or have no impact on disease severity, but this is dependent on the pathogen species (Boosalis et al., 1986). Bockus et al. (1992) concluded that the amount of primary inoculum, usually available in the residue or soil, determines the disease pressure that occurs on the crop during the growing season.

Cercospora zea-maydis

Many researchers have concluded that foliar pathogens, such as gray leaf spot (*Cercospora zea-maydis*), hereafter called GLS, are normally not very competitive but with the adoption of conservation tillage practices it has become a major yield limiting pathogen (de Nazareno et al., 1992; Sumner et al., 1981). Because of conservation tillage practices, this creates extra moisture, cooler soil temperatures, and a source of inoculums, which is required for a GLS infestation (Payne et al., 1987). A two year study concluded that plants had a greater number of lesions from GLS per leaf in NT plots compared to plowed and disked treatments. In the second year of this study, the differences between NT treatments on the other treatments were more evident because of the increase in inoculums on corn residue left on the soil surface by NT (Payne et al., 1987). A study proved that the right weather is needed to facilitate the infestation of GLS. The first year of the study had a plant severity that was 10-50 times greater than in the second year, which was attributed to a greater average humidity, more rainfall, and moderate temperatures during the first year growing season. Roane et al., (1974) reported a strong correlation between residue left on the soil surface by RT practices and the severity of GLS. In another two year study involving GLS, it was concluded that precipitation was a key factor in disease severity development. The first year saw a mostly dry growing season, which led to few lesions per leaf (measurement of severity) and there was no significant difference in tillage treatments. In the second year, there was more frequent rainfall events, which led to a greater severity in the crop, but the no-till plots had a significantly greater severity rate compared to tilled plots; however there was no significant difference among the other tillage treatments (Payne et al., 1987). During the second year lesions appeared earlier in the growing season in the NT plots and by the last rating date, the NT treatments had twice as many lesions as any of the tilled plots, this is a result of the corn residue on the soil surface from the previous year, which led to a very early and infested source of inoculum (Payne et al., 1987). In a two year study conducted in 1990 and 1991, buried residue infected with GLS could not be a source of inoculum because sporulation had stopped before May in both years, which was caused by the buried residue decomposing at a much faster rate (de Nazareno et al., 1992). When infected residue was left on the soil surface and left undisturbed for several growing seasons, the GLS fungus was able to survive on the residue and produce conidia up to three years later (Sumner et al., 1981).

Macrophomina phaseolina

Charcoal rot (*Macrophomina phaseolina*), hereafter called CR, in corn is caused by a soil-borne fungus that is highly influenced by moisture stress in the plant (Jimenez, 2011). *Macrophomina* survives in the soil as hard masses of mycelium, also known as sclerotia. The sclerotia are formed in plant tissue that has been infected and often distributed into the soil by means of tillage and residue decomposition (Baird et al., 2003). Sclerotia have been known to survive for up to 10 months in dry soil conditions and up to 18 months in corn residue incorporated into the soil (Baird et al., 2003). In a three year study related to tillage practices, *Macrophomina* population densities in the 0-7.5 cm soil layer were significantly greater in NT plots as opposed to a moldboard plow treatment which had the lowest densities (Wrather et al., 1998). They also concluded that in the 0-7.5 cm layer, there was a significant positive interaction between OM content and the population density of *Macrophomina*.

Fusarium spp

There are many species of *Fusarium* that can cause stalk rots in corn such as; *F.verticilloides*, *F.proliferatum*, and *F. subglutinans*. Manzo and Claflin (1984) claimed that *F. moniliforme* hyphae and conidia could survive completely viable in crop debris for up to two Kansas winters. No-till or minimum till systems often decrease soil temperatures and increase soil moisture early in the growing season, but these conditions are often favored by damping-off and root rot soil and residue-borne pathogens (Sumner et al., 1981). In a 2007 study, NT treatments had a greater incidence of *Fusarium* root rot compared to CT, and this was caused by many root rots being a facultative disease that would survive on the corn residue, but the greater incidence of root rot did not have any effect on yield. In that study, rotation and CT significantly reduced root rot incidence in corn (Govaerts et al., 2007). Conventional tillage decreased the severity of *Fusarium* root rots and other fungal diseases in many crops including corn (Sumner et al., 1981).

Vertical Tillage and Yield

There has not been a consensus on how tillage can affect yield. Many studies have shown an increase in yield by adopting conservation tillage systems yet other studies have shown a decrease in yield by adopting the same conservation tillage systems. It has been reported that problems with NT systems have included such properties as poor seedling emergence which can lead to overall poor growth and development, greatly reducing yield (Raper et al., 2000). In a 2005-2006 study, there was a significant difference in the yield between tilled and NT systems, with NT treatments having a greater yield, although it occurred in a wheat crop (Feng et al., 2010). Linden et al (2000) compared RT system (field cultivator), NT, and CT system (plow) and found that the first five years show no yield differences, however after the 5th year, NT had reduced yields with the highest yields belonging to the CT system. Borin et al. (1997) showed that in four years of a non-irrigated corn the average yield was 8070 kg/ha for conventional tillage and 7180 kg/ha for no-till. In a four year study, data showed that tilled treatments, regardless of fertilization management, had yields that were significantly greater than NT treatments (Sistani et al., 2010). In a multiple year study in Ohio, it was determined that there was no significant difference in yield among tillage treatments, however, the combination of NT continuous corn had the lowest yields (Lipps et al., 1991).

Justification and Objectives

Vertical tillage implements are a relatively new set of tools being marketed to producers, mainly in the corn growing regions of the United States. More than a dozen models of these implements are now available on the market. Some of the common features may include gangs of flat to slightly curved blades, usually fluted, often followed by a row of harrow teeth and finished off with a set of rolling baskets or chopping reels. For reference only, some of the common models include the following: Case 330 True Tandem, Great Plains Turbo Till, Phoenix Harrow, and Landoll VT 7430 Plus. The mention of these implements are provided so that the reader may have a clearer understanding of what may be meant by vertical tillage and does not imply that the Kansas State University Department of Agronomy endorses any of these specific implements or companies.

The manufacturers are typically recommending that these VT implements be operated at speeds greater than 11.3 kilometers per hour, in dry conditions, and usually favored in the fall season. Despite the shallow depth of tillage (5 cm), the dry conditions, high speeds, and close blade spacing allows for horizontal movement of the soil. Producers in NE Kansas have voiced questions to Extension agents starting in 2008 and through the 2009 growing season. The main interest in these implements seems to be using VT to level or smooth soil surfaces, but also to size and incorporate residue in heavy residue environments.

Because there is little to no information available on this practice and due to the high cost of the implement, an in-depth study is needed to review the effects of VT in high residue environments.

The objectives of the project are as follows:

I. Determine the short-term effects of a one-time vertical tillage operation on the following properties

i. Effects on the near-surface soil physical properties throughout the growing season, and on near-surface soil chemical properties at the conclusion of the growing season (Chapter 3)

ii. Emergence, crop growth and development, and yield of the crop (Chapter 3)

iii. Residue decomposition from the previous year’s corn crop (Chapter 3)

iv. Incidence of disease on crop, and quantification of pathogens in soil and crop residue (Chapter 3)

Chapter 2 - Materials and Methods

Site Descriptions, Management, and Tillage Treatments

Experiments were conducted at four locations in 2010 and five locations in 2011 (Figure 2.1). Each location had different treatments and/or plot size, but all were arranged in a randomized complete block design and replicated multiple times. Throughout the two year project, tillage implements were used from four different companies: Case IH (Racine, WI), Great Plains (Salina, KS), Landoll (Marysville, KS), and Salford (Osceola, IA). All management decisions and operations were made and completed by the cooperating producer. Due to the fact that there were different treatments at each site and different management decisions, a detailed description will follow.

2010 Sites

Copeland, Kansas (Southwest Kansas)

This site was hosted on a producer's field, approximately 10 km south and 3 km east of Copeland, Kansas (N 37.54°, W 100.63°). The annual precipitation near this area averages 472 mm, the mean winter air temperature is 1.3°C and summer mean air temperature is 24.9°C. This was from approximately 93 years of weather data collected near Copeland, KS (HPRCC, 2012). The field was in a current irrigated continuous corn, NT system in a silty clay loam soil. This location consisted of four treatments, 1 NT and 3 different VT implements, each replicated four times. The three VT implements used were: Case IH True-Tandem 330 turbo™, Landoll 7430 VT Plus™, and Great Plains Turbo-Till Series II™. All field operations and management decisions were completed by the field owner, and samples were taken multiple times during the growing season and once more after harvest.

Fredonia, Kansas (Southeast Kansas)

These plots were located 3 km south and 6 km west of Fredonia, Kansas (N 37.53°, W 95.82°). From weather data (≈109 yr) collected at Fredonia the annual precipitation near Fredonia averages 957 mm with a mean winter air temperature of 1.9°C and a mean summer air temperature of 25.7°C (HPRCC, 2012). The field is in a current dry-land corn-soybean rotation in a silt loam soil. The two treatments were VT and the producer's current practice of strip tillage, each was replicated four times. The VT implement used was the Great Plains Turbo-Till Series II™ and the strip tillage implement was the Great Plains Turbo Chopper™. Samples were taken multiple times during the growing season, once after harvest, and all management decisions and field operations were completed by the cooperating producer.

Lincolnville, Kansas (East Central Kansas)

Located 13 km west and 2 km south of Lincolnville, Kansas (N 38.49°, W 96.96°), these plots were in a private producer's field. The annual mean weather data (≈45 yr) near Lincolnville, KS showed a precipitation of 845 mm, a mean winter air temperature of -0.83°C and a mean summer air temperature of 25.1°C (HPRCC, 2012). The field was in a current dry-land corn-wheat rotation in a silty clay loam soil. The producer's current practice of NT, and VT using the Great Plains Turbo-Till Series II™ implement were the two treatments at this location. All field operations and management decisions were completed by the field owner, and samples were taken multiple times during the growing season and once more after harvest.

Winchester, Kansas (Northeast Kansas)

This field was located 2 km north of Winchester, Kansas (N 39.32, W 95.26). The annual precipitation near Winchester averages 986 mm with a mean winter air temperature of -0.72°C and a mean summer air temperature of 24.6°C according to approximately 61 years of weather data collected. This site contains a silt loam soil and is in a current dry-land, continuous corn rotation. The three treatments were NT, a VT Case IH True-Tandem 330 Turbo™ implement, and a Case IH True-Tandem 340™ conventional disk. Samples were taken multiple times during the growing season, once after harvest, and all management decisions and field operations were completed by the cooperating producer.

2011 Sites

Atchison County, Kansas (Northeast Kansas)

This field is located near Effingham, Kansas (N 39.52°, W 95.39°) on a private producer's farm. From weather data (≈109 yr) collected near this site, annual precipitation averaged 904 mm, mean winter air temperature was -1.2°C, and mean summer air temperature was 24.3°C (HPRCC, 2012). This field contains a heavy silty clay loam and is in a current dry-land, continuous corn rotation. No-till and VT using the Great Plains Turbo-Till Series II™ was two of the treatments at this location. A third treatment was added to this location, it was a vertical tillage implement that a local producer created, called the Spader™. All field operations and management decisions were completed by the field owner, and samples were taken multiple times during the growing season and once more after harvest.

Downs, Kansas (Northwest Kansas)

Located 5 km east and 2.5 km north of Downs, Kansas (N 39.5°, W 98.54°); this site had two treatments consisting of NT and VT using the Landoll 7430 VT Plus™ implement. The field was in a current dry-land corn-soybean-sorghum rotation with a silt loam soil. Weather data (≈118 yr) collected near Downs, KS showed a mean annual precipitation of 660 mm, a mean winter air temperature of -0.94°C, and a mean summer air temperature of 24.8°C (HPRCC, 2012). All field operations and management decisions were completed by the field owner, and samples were taken multiple times during the growing season and once more after harvest.

Fredonia, Kansas (Southeast Kansas)

This field is located 10 km south of Fredonia, KS (N 37.53°, W 95.82°). From weather data (≈109 yr) collected at Fredonia the annual precipitation near Fredonia averages 957 mm with a mean winter air temperature of 1.9°C and a mean summer air temperature of 25.7°C (HPRCC, 2012). The field is in a current dry-land corn-soybean rotation in a silt loam soil. The two treatments were VT and the producer's current practice of strip tillage. The VT implement used was the Great Plains Turbo-Till Series II™ and the strip tillage implement was the Great Plains Turbo Chopper™. Samples were taken multiple times during the growing season, and all management decisions and field operations were completed by the cooperating producer.

Lincolnville, Kansas (East Central Kansas)

The field was located in Marion County approximately 13 km west and 3 km south of Lincolnville, Kansas (N 38.49°, W 96.96°). The annual mean weather data (≈45 yr) near

Lincolnville, KS showed a precipitation of 845 mm, a mean winter air temperature of -0.83°C and a mean summer air temperature of 25.1°C (HPRCC, 2012). The field was in a current dry-land corn-wheat rotation in a silty clay loam soil. The producer's current practice of NT, and VT using the Landoll 7430 VT Plus™ implement were the two treatments at this location. All field operations and management decisions were completed by the field owner, and samples were taken multiple times during the growing season and once more after harvest.

Garden City, Kansas (Southwest Kansas)

The field is located in Finney County at the Kansas State SW Research and Extension Farm 1.6 km north and 1.6 km east of Garden City, KS (N 37.97°, W 100.86°). From weather data (63 yr) collected at Garden City, mean annual precipitation is near 490 mm, mean winter air temperature is 0°C, and mean summer air temperature is 24.9°C (HPRCC, 2012). The field was under an irrigated continuous corn system in a silt loam soil. There were four treatments at this location, including one NT and three VT treatments using the following implements: Landoll 7430 VT Plus™, Case IH True-Tandem 330 Turbo™, and Salford RTS XT™. Management decisions and all field operations were completed by staff and the research station, and samples were taken multiple times during the growing season and once after harvest.

Soil Properties Measurements

Bulk Density and Soil Water Content

Samples were collected at three different times during the project year, twice during the growing season and once post-harvest and from three random spots within each plot and dry bulk density was determined using the core method (Blake and Hartge, 1986). Using a slide hammer sampler (AMS Inc., American Falls, ID), samples were collected at depths of 0-5, 5-10, and 10-15 cm and a 4.8 cm diameter. Soil cores obtained were placed in pre-labeled cans and 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 with the samples, bulk density was calculated as shown:

$$P_{\mathrm{b}} = W_{\mathrm{ods}}/V_{\mathrm{s}}$$

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)

Infiltration

Steady state soil infiltration was measured using the Cornell Sprinkle Infiltration method (Ogden et al., 1997). The Cornell Sprinkle Infiltrometer system contains a portable rainfall simulator that is placed onto a single 24.1 cm inner diameter infiltration ring. The sprinklers were calibrated to achieve a rainfall rate of approximately 30 cm/hr or 0.5 cm/min. The system was set up and then allowed to run for 3 minutes and the rainfall rate (rr) was calculated as follows:

rr = (H1-H2)/3

where

rr = rainfall rate in cm/min

H1 = initial height of water level

H2 = water level height after 3 min

The system was adjusted until the desirable rainfall rate was obtained.

The infiltration ring was inserted without causing significant disturbance to the soil around the ring. The ring was inserted 7 cm deep so the lower overflow edge is flush with the soil surface and the overflow tube system (stopper and tubing) was placed into the overflow hole. The overflow tube was sloped away from the infiltration ring to insure good flow, and was a minimum of 30 cm in length. At the edge of the tube, a small hole was dug to hold a beaker to collect the runoff from the overflow tube. Measurements were taken according to the outline of steps given and the data was analyzed as follows:

Srr = (H1-H2)/Tf

where

Srr = simulated rainfall rate in cm/min

H1 = initial height of water level in sprinkler in cm

H2 = water level at end of measurement period in cm

Tf = time the final measurement is taken in minutes

ror = Vt/(457.30*t)

where

ror = runoff rates in cm/min

Vt = total volume of runoff water collected in mL at each time interval

t = time interval for which runoff water was collected

457.30 = the area of the infiltration ring

it = Srr – ror

where

it = infiltration rate in cm/min

Srr = simulated rainfall rate in cm/min

ror = runoff rate

Water Stable Aggregates (WSA)

Samples were collected three times throughout each year of the project, twice during the growing season and once post-harvest. Approximately 2 kg of total soil was collected from the top 0-5 cm depth from three random areas in each plot and placed into bags and allowed to air dry. Once air dried, the soil was sieved to collect aggregates >4.75 mm and <8 mm in size to determine the percent of wet stable aggregates (WSA). A sub sample of 40 g of >4.75 mm aggregates was oven dried for a minimum of 24 hours at 105°C to determine gravimetric water content. Size distribution of WSA and mean weight diameter (MWD) was determined using a 50 g subsample of air-dried soil and a wet sieving method noted by Kemper and Chepil (1965) or

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 screen openings of 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 a method from Stone and Schlegel (2010), MWD was calculated in accord with as:

$$MWD = \Sigma \text{ (i=1, to 6) } (w\text{i}/m\text{a})x\text{i}$$

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).

Active Carbon

After the 2 kg of soil collected for aggregate stability was sieved, the remaining soil was run through an 2 mm sieve and 50 g was collected for active carbon. The 50 g of soil was mixed thoroughly and a 2.5 g sub sample was weighed to be used for analysis. The analysis was done using a method from Weil (2009) to determine the amount of active organic carbon in soils. Following the protocol set by Weil, a stock solution of 0.2 M of potassium permanganate

($KMnO_4$) was made and stored in a cool, dark place to prevent from deterioration of the chemicals. From the 0.2 M stock solution, a 0.02 M working solution of $KMnO_4$ was created by adding 100 mL of stock $KMnO_4$ into a 1000 mL flask and bringing to volume with distilled water. After thoroughly mixed, the 0.02 M $KMnO_4$ working solution was also stored in a cool, dark place.

For each sample, the 2.5 g sub sample was placed into a 50 mL centrifuge tube and 20 mL of $KMnO_4$ was added to the tube, capped, and shaken horizontally at 120 strokes/min for 120 seconds. The sample was placed in a rack and held vertically for 10 minutes to allow the soil to settle. After settling for 10 minutes, a pipette removed 500 uL from the upper 1 cm of the soil-$KMnO_4$ solution and was transferred to another 50 mL centrifuge tube and brought to a total volume of 50 mL with distilled water. The tube was inverted several times to mix the solution. From the diluted 50 mL tube, a spectrophotometer cuvette was filled about 2/3 full, placed in the spectrophotometer and the absorbance was recorded. Active Carbon is calculated as follows:

Active Carbon (mg/kg) = ((0.02)-(0.021*Abs))*72000

where

Abs = the recorded absorbance of the sample

Soil Nutrient Measurement

Soil samples were taken to measure soil levels of N, P, K, and pH to determine any difference at depth increments among treatments. Fifteen soil cores per individual plot were taken to a depth of 0-15 cm and divided into 0-2.5, 2.5-5, 5-10, and 10-15 cm depth sub-samples. Samples were then submitted to the Kansas State University Soil Testing Lab. Soil was analyzed for available phosphorus (P), exchangeable potassium (K), and total carbon (C) and nitrogen (N). The Mehlich 3 extraction procedure (Frank et al., 2011) was used to determine available P. Plant available K was measured using the 1 mol L^{-1} NH_4OAc soil extraction method (Warncke and Brown, 2011). Potassium analysis is done using a model 3110 Flame Atomic Absorption (AA)

Spectrometer (Perkin Elmer Corp., Norwalk, CT). Total C and N were determined using a LECO TruSpec CN (LECO Corporation, St Joseph, MI) combustion analyzer in a private laboratory (Kansas State University, Manhattan, KS).

Yield Measurement

Yields were collected using the cooperating producers' equipment. Each site location had a different method of harvest and yield measurement. This was dependent on combine used and size of corn or soybean header on the combine. An area within each plot, usually the width of the combine header and length of the plot was harvested. Grain from each harvested plot was collected, weighed using a weigh wagon, and a sub sample of grain from each plot was taken and later analyzed for test weight and moisture using a GAC 2000 by DICKEY-john (DICKEY-john, Minneapolis, MN). Yield was calculated using the following equation:

$$\text{Yield (Mg/ha)} = [(G_{Mg}/A_1)*A_2]*2.471$$

where

G_{Mg}=weight of grain harvested in Mg

A_1=area harvested in ft^2

A_2=area of 1 acre in ft^2

2.471= number of acres in one ha

Yield was normalized to a moisture content of 15.5% for data analysis and reporting.

Plant Pathogen, Residue, and Agronomic Properties

Residue Management

Residue Decomposition: Percent of Ash-free residue

Residue was collected for multiple purposes for this project. Residue was collected from a 1 m^2 area in each plot, bagged, and then dried in an oven at 43°C for a minimum of 7 days.

From the residue that was collected from the 1m^2 area, a large sub-sample was taken and ground to fill two specimen cups. The method used for this comes from Steiner et al. (2000). A pre-determined amount of residue was weighed out for each sample and placed in a 10 mL Pyrex beaker. The beaker was placed in a muffle furnace at 500°C for four hours. The mass was then corrected to ash-free mass calculated as:

$$AFR = (Wir - Wfr)/Wir * 100$$

Where

AFR= ash-free residue (percent)

Wir = initial weight of residue

Wfr = final weight of residue

Residue cover

Shortly after the tillage was completed, measurements were taken to determine the amount of residue cover left. This was done using a modified version of the line-transect method established by the United States Department of Agriculture Natural Resource Service (NRCS). A 15 m tape with marks every 15 cm (for a total of 100 marks) was laid across the rows at a 45° angle. If residue was present under a mark it was counted and residue cover is calculated as:

$$R_{cover} = N/100$$

Where

R_{cover}= residue cover in percent

N=number of marks where residue was present

Agronomic Properties

Stand Emergence

Stand emergence was done by doing stand counts around the V2 growth stage. A distance of 5.3 m (or 17 ft 5 in) was measured out, which represents 0.40 ha (or 1/1000th of an acre). Plants were counted in one row at that distance. Final stand emergence was determined by:

Pop = PC*1000

Where:

Pop = final stand population

PC = plants counted in sample row

Leaf nutrients

During the growing season leaf samples were taken to determine the nutrient concentration of nitrogen, phosphorous, and potassium in the leaf. The leaf samples were taken at the R1 (silk) stage and 25 ear leaves per individual plot were taken and placed in a paper bag. The samples were submitted to the Kansas State University Soil Testing Lab to be analyzed.

Disease and Pathogens

There are many diseases that can affect any crop, at any time, and any year. However, three of the most economic or yield limiting diseases for corn in the state of Kansas were chosen for this project: gray leaf spot (*Cercospora zea-maydis*), charcoal rot (*Macrophomenia phaseolina*), and *Fusarium* stalk rot (*Fusarium spp*). All three of these are fungal pathogens.

Cercospora zea-maydis

Cercospora zea-maydis, also known as gray leaf spot, was the only disease scouted for in the field during the growing season. The disease is more easily detectable in the field compared to the other two diseases and is often scouted for in the field to determine if chemical control is needed. *Cercospora* incidence was measured by percent population affected. An area equivalent to 1/1000th of an acre (4 m^2) was measured out and plants affected with *Cercospora* were counted within that area and this was done at 3 random spots within each plot. Incidence (C_i) was calculated as shown:

$$C_i = (P_c*1000)/P_t$$

Where

C_i = *Cercospora* incidence

P_c = number of plants with *Cercospora*

P_t = total Plant Population

Disease severity (C_{sev}) was measured by total number of lesions per plant. This was done by collecting 5 affected leaves (the leaf directly below the ear leaf) within each of the 3 random spots within each plot. The leaves were then inspected and *Cercospora* lesions were counted on each leaf and an average of lesions per leaf was determined as shown:

$$C_{sev} = L_t/15$$

Where

C_{sev} = *Cercospora* severity

L_t = total number of *Cercospora* lesions counted

Macrophomina phaseolina

To quantify soil-borne pathogens such as charcoal rot, soil samples were obtained for lab analysis. Samples were pulled at the same time that the plots were scouted for gray leaf spot, to help determine all disease issues at the same point in the growing season. For each individual plot, a total of 5 soil cores per plot were taken to a depth of 15 cm using a soil probe, placed in bags, and allowed to air dry. The soil was finely ground, placed in a specimen cup, and kept in a cold room to preserve pathogens until lab analysis began. Quantifying *Macrophomina* was done using a colony forming units (CFU) method from the Kansas State University Plant Pathology Row Crops Lab. For each sample, a predetermined weight of finely ground soil was weighed out, placed in a blender with 100 mL of 0.525% NaOCl and blended on high speed for three minutes. The sample was then washed over a 45 µm pore size sieve with distilled water and the contents from the sieve were collected and put in a 50 mL falcon tube keeping the total volume under 10 mL in the tube. Semi selective media was used to isolate the *Macrophomina* fungus using the following media and antibiotics:

Semi selective PDA media-autoclaved at 121°C for 20 minutes

39 grams of Potato Dextrose Agar (PDA) per 1000 mL of H_2O

After the selective media was autoclaved, it was allowed to cool down before the antibiotics were added to prevent the antibiotics from being degraded by the heat.

Antibiotics

40 µl of Penicillin per 100 mL of media

200 µl of Tetracycline per 100 mL of media

100 µl of Streptomycin per 100 mL of media

0.1 g of Rifampicin per 1000 mL of media

1 ml of Tergitol per 1000 mL of media

Each sample tube was filled with media to a total volume of 50 mL and shaken to thoroughly mix the media and soil. The 50 mL was quickly poured equally into four different pre-labeled Petri dishes. The Petri dishes were allowed to incubate for 3-5 days at 30°C and then colonies of *Macrophomina* fungus were counted and CFU's per gram of soil were calculated as shown:

$CFU_{mac} = ((P1+P2+P3+P4)/4)/W_{soil}$

Where

CFU_{mac}= colony forming units of *Macrophomina* per gram of soil

P1, P2, P3, P4= each of the four Petri dishes per sample

W_{soil} = the predetermined weight of soil measured out

Fusarium spp.

Residue was collected when sampling was done for *Macrophomina* and *Cercospora*. There are multiple species of the *Fusarium* genus that can cause stalk rot in corn, but the method used to quantify the CFUs in the residue gave an overall picture of most *Fusarium* species. From the residue that was obtained in the field and ground up, a thoroughly mixed 0.05 g sample was weighed out and placed in a centrifuge tube. One to two mL of 0.525% NaOCL was added to the tube and shaken for three minutes. The sample was then washed over a 45 um pore size sieve with distilled water and the contents of the sieve were washed into a 50 mL falcon tube, keeping the total volume under 10 mL. The Nash-Snyder semi selective media and antibiotics used to isolate the *Fusarium* fungus came from a protocol from the Kansas State University Plant Pathology Row Crops Lab and the details are listed below:

Nash-Snyder semi selective Media-autoclaved at 121°C for 20 minutes

15 g of Agar per 1000 mL of H_2O

15 g of Peptone per 1000 mL of H_2O

1.0 g of KH_2PO_4 per 1000 mL of H_2O

0.5 g of $MgSO4 \cdot 7H_2O$ per 1000 mL of H_2O

After the selective media was autoclaved, it was allowed to cool down before the antibiotics were added to prevent the antibiotics from being degraded by the heat.

Antibiotics (all values per 1000 mL of H_2O)

1.0 g of Streptomycin

2.4 g of PCNB Terraclor (75% wettable powder)

1.0 g of Tetracycline

0.5 g of Rifampicin

2.0 mL of Tergitol

Each sample tube was filled with media to a total volume of 50 mL and shaken to thoroughly mix the media and residue. The 50 mL was quickly poured equally into four different pre-labeled Petri dishes. The Petri dishes were allowed to incubate for 3-5 days at 30°C and then colonies of *Fusarium* fungus were counted and CFU's per gram of soil were calculated as shown:

CFU_{fus}= ((P1+P2+P3+P4)/4)/W_{res}

Where

CFU_{fus}= colony forming units of *Fusarium* per gram of soil

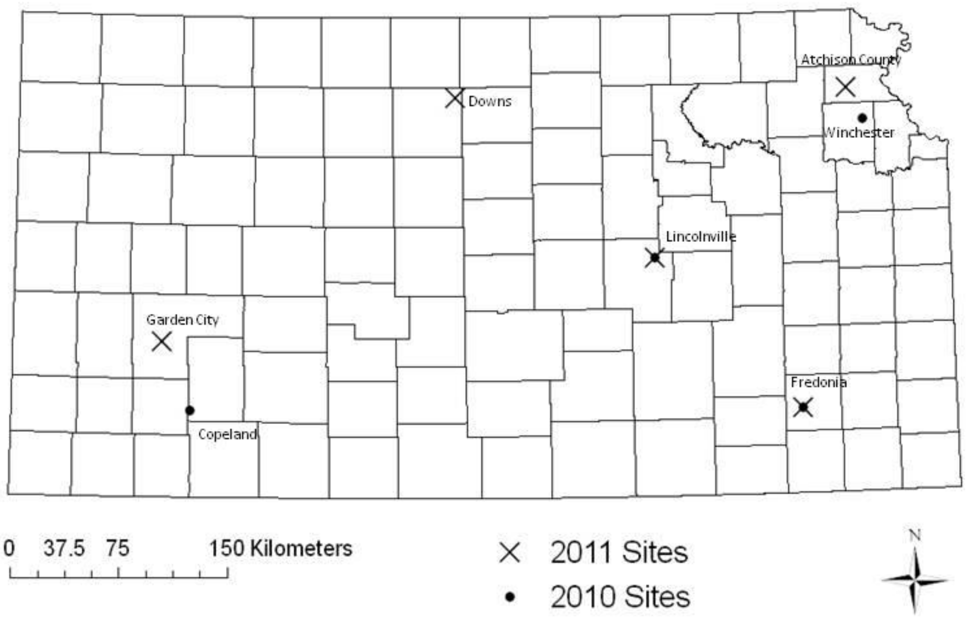
P1, P2, P3, P4= each of the four Petri dishes per sample

W_{res}= the predetermined weight of residue measured out

Statistical Analysis of Data

Statistical analysis of all measurements was conducted using analysis of variance (ANOVA). It was a randomized complete block design with tillage treatments as the factor and block as a random variable. The Proc GLM procedure of SAS 9.2 (SAS Institute Inc, 2008) was used for separation of means and ANOVA. Results are considered significantly different at P=0.05 unless otherwise noted. Treatment comparisons were only made within each site due to various management practices, soils, and climate.

Figure 2.1 Map of Kansas with the Site locations



Chapter 3 - Results and Discussion

During the course of this study, there were several tillage tools that were evaluated at different sites. The following is the abbreviation list for the treatments, in the discussion the VT treatments will be listed by the abbreviation for the tillage implement used:

- Copeland, KS: Case IH True-Tandem 330 Turbo™ (CS), Great Plains Turbo-Till Series II™ (GP), Landoll 7430 VT Plus™ (LD), and no-till (NT)

- Fredonia, KS: strip till (ST) and vertical till with Great Plains Turbo-Till Series II™ (GP)

- Lincolnville, KS: no-till (NT) and vertical till with Great Plains Turbo-Till Series II™ (GP)

- Winchester, KS: conventional disk (CD), no-till (NT), and vertical till with Case IH True Tandem 330 Turbo™ (CS)

- Atchison County, KS: no-till (NT), Spader™ (SP), and vertical till with the Great Plains Turbo-Till Series II™ (GP)

- Downs, KS: no-till (NT) and vertical till with the Landoll 7430 VT Plus™ (LD)

- Garden City, KS: no-till (NT), Case IH True-Tandem 330 Turbo™ (CS), Landoll 7430 VT Plus™ (LD), and Salford RTS XT (SF).

This chapter is organized using the following headings: soil properties, agronomic properties, etc. Within each heading, the results will be explained for by each specific property (such as bulk density, water stable aggregates, etc.) by year and then by site.

Soil Properties

Bulk Density 2010

The collection of cores for bulk density was attempted three times during the crop year; once early in the growing season (V6), once late in the growing season (VT), and again after the crop was harvested. However due to weather and other issues not all locations will have data for all three sampling periods. Results for 2010 are shown in Table 3-1.

At the Copeland site, in late spring 2010, no significant differences were found in the four treatments of CS, GP, LD, and NT at the 0-5 cm depth. Bulk densities were not significantly different between the four treatments at depths of 5-10 cm and 10-15 cm. The second round of sampling yielded similar results at a depth of 0-5 cm with no significant difference between the CS, GP, LD, and NT treatments. Late growing season did show a significantly ($p=0.05$) greater bulk density for the NT treatment compared to the CS, GP, and LD treatments with no significant difference observed between those three treatments. After harvest, no significant difference in bulk density was observed across all plots.

Early season soil sampling for bulk density measurement yielded no significant difference between the ST and GP treatments at all depths at the Fredonia, KS location. Bulk density results from the late growing season measurement period yielded no significant differences between the ST and GP at all depths as well. After harvest, at a depth of 5-10 cm the ST treatment had a bulk density that was 12% greater and significantly ($p=0.05$) different than the GP treatment after harvest. The bulk density at 0-5 cm and 10-15 cm was not significantly different between the ST and GP treatments at that sampling date.

At the Lincolnville, KS site the bulk density at a depth of 0-5 cm in the NT plots was 20% greater than the GP plots, however, there was no significant difference between the treatments on the first sampling date. Bulk density values for NT and GP treatments were very similar and no significant differences were observed at the 5-10 cm and 10-15 cm depths for the early growing season sample. Later in the growing season, the NT treatment once again had a bulk density that was 17% greater than the GP treatment and significant at $p=0.05$.

In 2010, the site at Winchester, KS only had two sampling dates, once early in the growing season and another one late in the growing season. No sampling was done after harvest due to the whole field being tilled shortly after harvest. The CD treatment with the first sampling had a greater BD value at the 0-5 cm depth than the NT and CS treatments respectively although not statistically (p=0.05) different across the treatments. At the 5-10 cm and 10-15 cm depths the CD treatment had the greater BD value, then NT, and CS had the lowest BD value. These observed differences were not statistically (p=0.05) different across the treatments and depths. The second sampling at Winchester saw lower BD values than the first sampling. The NT treatment had a significantly higher BD, approximately 20% greater than the CD and CS treatments at the 0-5 cm depth. No significant difference was observed between the CD and CS treatments at the same depth. No statistical differences were observed at the 5-10 cm and 10-15 cm depths across all treatments.

Bulk Density 2011

Late in the 2011 growing season (Table 3-2) at Atchison County, the GP treatment had a greater BD in the top 0-5 cm. The GP treatment was 8% greater than the NT treatment and 15% greater than the SP treatment. None of those differences were considered statistically significant (p=0.05). At the depths of 5-10 cm and 10-15 cm, the NT treatment had a greater BD value. At both depths, the GP treatment had the second highest BD value and the SP treatment had the lowest values at those depths. No significant differences were observed at the 5-10 cm and 10-15 cm depth across all three treatments.

At the Downs, KS plot location early in the growing season, the NT treatment had a greater BD value at the 0-5 cm depth compared to the LD treatment but was not statistically significant. At the depths of 5-10 cm and 10-15 cm, the average BD of the LD plots was greater than the NT plots by approximately 3%. That difference was not significant at both depths between the treatments. Later in the growing season, the LD treatment had greater soil BD values at depths of 0-5 cm ad 5-10 cm. The NT treatment had a greater BD value at the 10-15 cm depth and none of these differences were considered significant (p=0.05).

At Fredonia in 2011, the ST treatment had a greater soil BD value at 0-5 cm soil depth compared to the GP treatment early in the growing season. The same held true at a depth of 5-10 cm soil depth and at both depths the results were not considered significant. The GP treatment had a slightly greater soil BD value compared to the ST treatment at a depth of 10-15 cm but again that was not significant. Later in the growing season, the GP treatment had a greater soil BD value at the 0-5 cm soil depth compared to the ST treatment. At the depth of 5-10 cm however, the ST treatment had the greater soil BD. At both depths however, those results were not considered significant. The ST treatment, with a soil BD value that was 10% greater than the GP, was significantly (p=0.05) greater than the GP treatment at a soil depth of 10-15 cm.

One concern that has been voiced with the use of vertical tillage equipment is the possibility of creating a tillage compaction layer in the zone just below the tillage depth. That concern may have been observed at Lincolnville in 2011. Early in the growing season, the NT had a significantly (p=0.05) greater soil BD value at a depth of 0-5 cm, approximately 16% greater than the GP treatment. However, at the soil depths of 5-10 and 10-15 cm, the soil BD values increased for the GP treatments and had greater BD values compared to the NT treatment. This difference was not significant, however the results may point to the creation of a tillage compaction layer. Similar results were seen during the second sampling dates as well. At the depth of 0-5 cm, the NT treatment again had a significantly (p=0.05) greater soil BD compared to the GP treatment. However, past that depth, the GP treatment again had increased soil BD values and were greater than those of the NT treatments. These results were not significant as well, but potentially pointed to a trend at Lincolnville.

The first sampling date at Garden City in 2011 saw no statistical differences between the four treatments and across all depths. The CS treatment had the greater soil BD at the 0-5 cm depth followed by the NT, LD, and SF treatments respectively. At the depth of 5-10 cm, the CS treatment again had the greater soil BD, but the SF was very close to it in value, followed by the NT and LD treatments respectively. The NT treatment had the greatest soil BD at the 10-15 cm depth followed by the CS, LD, and SF treatments all within 0.01g/cm^3 of each other and therefore not statistically significant. Later in the growing season a trend was noticed in the data. The SF treatment had a greater soil BD value at the shallow depth, followed by the NT, LD, and CS treatments respectively. At the depths of 5-10 and 10-15 cm the same held true. The SF treatment had the greatest soil BD followed by the NT, LD and CS treatments respectively. With the second sampling, no significant difference was observed between the treatments and across all three depths.

Water Stable Aggregates (WSA) 2010

Soil samples were collected for measurement of WSA by using the mean weight diameter (MWD) of the aggregates approximately three times during each crop year; once early in the growing season, once late in the growing season, and once after the crop was harvested. Data for all 2010 sites are shown in Table 3-3. At Copeland with the first sampling, the CS treatment had the greater MWD. The CS treatment was 17% greater than the NT treatment however that was not significantly different (at p=0.05). The CS was 50% greater than the GP treatment and 65% greater than the LD treatment. These observed differences were considered significant at p=0.05. There were no differences observed between the NT and GP treatment, but there was a significant difference between the NT and LD treatments. Later in the growing season, the CS treatment had the greatest MWD again. However, the individual plot values were so variable that there were no differences between the CS, GP, NT, and LD treatments. The third sampling date saw an increase in overall MWD values across all treatments. The NT treatment had the greatest MWD value followed by LD, CS, and GP respectively. There no significant differences observed with the third sampling date.

The first sampling date at Fredonia saw no significant differences between the ST and GP treatments. The GP treatment had a MWD that was only 0.042 mm greater than the ST treatment. The GP treatment also had a significantly (p=0.05) greater MWD with the second sampling date. The average MWD of the GP plots was 60% greater than the average of the ST plots. No trend was observed however, as the ST treatment had a greater MWD than the GP treatments with the third sampling. This observed difference between the treatments was not significant at p=0.05.

At Lincolnville, a trend was observed between the treatments across all three sampling dates. The first sampling date, a greater MWD was observed in the NT treatment. There was only a 0.039 mm difference between the NT and GP treatments and that was not statistically significant. Later in the growing season, the NT treatment again had a greater MWD compared to the GP treatment. The MWD of the NT treatment was twice as much (and significant at p=0.05) than the GP treatment. Soil samples taken after harvest showed no significant MWD difference between the NT and GP treatments. However, the NT treatment had a greater MWD than the GP treatment. Even though two of the sampling periods showed no significant difference, the NT treatment continued to show a great MWD and more stable aggregates.

Similar MWD results were observed with the first sampling date at the Winchester, KS location. A third sampling was not done due to a tillage operation directly following harvest. Early in the growing season, the NT treatment had a greater MWD than the CS and CD treatments. The NT treatment was only 21% greater the VT treatment and that was not significantly (p=0.05) different. The CD treatment had the lowest MWD. The NT treatment was 45% greater than the CD treatment, and that observed difference was significant. The CS treatment was only 20% greater than the CD and no statistical significance between the two treatments. The CS treatment had the greatest MWD later in the growing season. The average of the NT plots had the second highest MWD followed by the CD treatment. The individual plot values were so variable that no significant difference was observed across all three treatments.

Water Stable Aggregates 2011 (WSA)

Soil samples were collected for measurement of WSA testing approximately three times during each crop year; once after tillage but before planting, once during the growing season, and once after the crop was harvested. Within each sampling date the data will be discussed by location in the following order: The Atchison County location will be first followed by, Downs, Fredonia, Lincolnville, and Garden City, respectively. Data for all sites are shown in Table 3-4.

At Atchison County, the SP treatment had the greatest MWD of all three treatments with the first sampling date. The SP treatment was 50% significantly (p=0.05) greater than the GP treatment and 70% significantly greater than the NT treatment. The GP treatment was slightly greater than the NT treatment, however that was not significant difference. With the second sampling date the GP treatment had the greatest MWD. The GP treatment was slightly greater than the SP treatment and not significant. Both the GP and SP treatments had MWD averages that were considered 2.1 times as great as the NT treatment and that was significantly (p=0.05) different.

In 2011 at the site location near Downs, KS no pattern or trend was observed when determining the MWD of water stable aggregates. With the first sampling date, the LD treatment had the greatest MWD, approximately 25% greater than the NT treatment. That difference was not significant. Later in the growing season, the NT treatment had a MWD average that was only 10% greater than the LD treatment and again not statistically significant (p=0.05).

At Fredonia, the GP treatment had a greater MWD value and more stable aggregates compared to the ST treatment. With the first sampling date early in the growing season, the GP treatment had MWD that was 2.1 times as much as the ST treatment and that observed difference was statistically significant. Later in the growing season, the GP treatment had a MWD value that was only 0.05 mm greater than the ST treatment, and that was not significantly different.

Similar results were observed at Lincolnville, KS in 2011. With the sampling done early in the growing season, the NT treatment had a greater MWD value, approximately 30% greater than the GP treatment, however that was not significantly different. Later in the growing season, the GP treatment had the greater MWD of soil aggregates, approximately 15% greater than the NT treatment, but again that difference was not significant.

At Garden City, significant differences were observed with the four treatments and with both sampling dates. Early in the growing season, the SF treatment had a significantly greater MWD, 70% greater than the NT treatment, 2 times as great as the CS treatment, and 2.3 times as great as the LD treatment. All these differences were considered significant at p=0.05. The NT treatment had the second greatest MWD followed by the CS, and LD treatments respectively. No significant difference was observed with the first sampling between the other three treatments. The LD treatment had the lowest MWD average with the first sampling, however it had the greatest MWD average with the second sampling. The LD treatment was only 9% greater than the NT treatment and 40% greater than the CS treatment and in both comparisons was not significantly different. The LD treatment was nearly 2 times as much as the SF treatment and that was statistically significant (p=0.05). The NT treatment was not significantly different from the CS treatment but was 80% significantly greater than the LD treatment. No statistical difference was observed between the CS and SF treatments.

Soil Water Content 2010

In 2010 the location at Copeland, KS was irrigated, which greatly influenced soil moisture content in the soil, particularly at the 0-5 cm sampling depth in all three sampling periods. (Data for all sites are shown in Table 3-5). One would predict that in a dry arid climate that occurs in Southwest Kansas, the no-till treatment would have greater soil water content. This was not the case because early in the growing season there was no significant difference in soil water content at a depth of 0-5 cm. At a depth of 5-10 cm the GP had the highest soil water content, and it was significantly different at p=0.05 when compared to the LD and NT treatments. The CS treatment was not significantly different than all other treatments. The results at 10-15 cm were exactly the same as the 5-10 cm depth with GP having significantly greater soil water content than the LD and NT treatments and the CS treatment not significantly different then then other three treatments. The soil water content during the late season (about the time the corn started to tassel) did not differ among the four treatments at depths of 0-5 cm and 5-10 cm. The GP treatment had significantly greater soil water content at 10-15 cm when compared to the LD and NT treatments, while the CS treatment was not significantly different from the other three treatments.

The Fredonia, KS site behaved very similarly, especially in the 0-5 cm depth. The first sampling period saw no significant difference between the ST and GP treatments at all depths. Later in the growing season led to different results. At a depth of 0-5 cm, the GP had a significantly (p=0.05) greater soil water content, approximately 10% greater than the ST treatment. The GP treatment at 5-10 cm was significantly (p=0.05) greater than the ST treatment and no difference were observed at 10-15 cm depths between the two treatments. After harvest at a depth of 0-5 cm, the soil water content observed in the GP treatment was 20% greater than the ST treatment but was not significantly different at p=0.05. The GP treatment also had 12% greater soil water content compared to the ST treatments at the depths of 5-10 cm and 10-15 cm as well.

The samples collected at Lincolnville, KS were only collected two times during the growing season. This occurred because wheat (*Triticum aestivum*) was drilled into the corn stubble directly after harvest and we felt that may have interfered with the soil property results. Soil moisture content samples during early season growth yielded no significant results at 0-5 cm, 5-10 cm, and 10-15 cm. Later in the growing season the soil moisture contents differed. At the 0-5 cm depth there were no differences, but at depths of 5-10 cm and 10-15 cm the NT plots with a significantly (p=0.05) greater soil water than that of the GP plots.

The first samples taken in the early growing season at the Winchester, KS site showed that the NT treatments had greater soil water content than the CD and CS treatments at all depths. However, at a depth of 0-5 cm that greater water content in the NT plots was not significantly different than the CD and CS treatments. The results at the 5-10 cm depth and 10-15 cm were identical. In both CSs, the NT treatment was significantly (p=0.05) greater compared to the CD treatment, however, the CS treatment was not significantly different from both the NT and CD treatments. The second sampling date late in the growing season showed similar results across the treatments and depth. At all depths of 0-5 cm, 5-10 cm, and 10-15 cm no significant differences were observed between the CD, NT, and CS treatments.

Soil Water Content 2011

Data for all sites are shown in Table 3-6. Late in the 2011 growing season showed significant differences across all three treatments and at all depths. At a depth of 0-5 cm, the SP treatment had a soil water content that was 22% significantly greater than the NT treatment and 50% significantly greater than the GP treatment. The NT treatment soil water content was 20% greater than the GP treatment and that difference was considered significant at p=0.05.

Early in the growing season at Downs, the LD treatment had a greater soil water content at a depth of 0-5 cm compared to the NT treatment. That difference was not statistically significant (p=0.05). At a depth of 5-10 cm, the NT treatment had a greater soil water content, but again that was not considered significant. The LD treatment had a greater soil water content at a depth of 10-15 cm but was not statistically significant. Similar results were observed with the second sampling done later in the growing season. The LD treatment had the greater soil water content at the depth of 0-5 cm but that was not significant. At depths of 5-10 cm and 10-15 cm the NT treatment had a greater soil water content compared to the LD treatment, but those differences were not considered statistically significant (p=0.05).

At Fredonia, the ST treatment had a greater soil water content early in the growing season at all depths compared to the GP treatment. At a depth of 0-5 cm, the soil water content in the ST treatment was 12% significantly greater than the GP treatment. The ST treatment was only 1.03 times as much as the GP treatment at a depth of 5-10 cm and not considered significant. At a depth of 10-15 cm, the ST treatment had a soil water content that was only 5% greater than the GP treatment, but that difference was statistically significant (p=0.05). The results reversed later in the growing season. The GP treatment had greater soil water content at all depths compared to the ST treatment. At a depth of 0-5 cm, the GP treatment was only 0.003 g/g greater than the ST treatment and that was not significantly different. The GP treatment had a 10% greater soil water content and that was significantly (p=0.05) greater than the ST treatment. The GP treatment also had a greater soil water content than the ST treatment at a depth of 10-15 cm but that was not statistically significant.

The results that were observed early in the growing season at Lincolnville in 2011, were ones that one would predict for this study. One benefit that is often noted for no-till systems is increased soil water content. Early in the season, the NT soil water content average was approximately 25% significantly (p=0.05) greater than the GP treatment at a depth of 0-5 cm. At a depth of 5-10 cm the soil water content was greater in the NT treatment compared to the GP treatment. This observed difference was not significant. The NT treatment had a slightly greater soil water content at the 10-15 cm depth compared to the GP treatment and this was not significant. Later in the growing season, the results were identical compared to early in the season. The soil water content at 0-5 cm in the NT plots were significantly (p=0.05) greater than the GP plots by 25%. At a depth of 5-10 cm, the NT plots had a soil water content that was only 10% greater than the GP treatment but that difference was still statistically different. The NT plot also had a greater soil water content at the 10-15 cm depth compared to the GP treatment but that was not statistically significant.

The results with the early sampling date at Garden City again are results that would be predicted with this study. The NT treatment had greater soil water content at all depths compared to the three tillage treatments. At a depth of 0-5 cm, the NT treatment had the greatest soil water content and the SF treatment had the second highest soil water content followed by the LD and CS treatments respectively. No significant difference was observed at 0-5 cm between all four treatments. The soil water content at the 5-10 cm depth was greatest in the NT plots, approximately 13-15% greater than the LD, SF, and CS respectively. Again, no statistical significance (p=0.05) was observed between all four treatments at that depth. The NT plot average had significantly greater soil water content compared to the three tillage treatments at the 10-15 cm depths. No significant difference was observed between the three tillage treatments at this depth. Later in the growing season, no trend was observed across the four treatments and all depths. At the depth of 0-5 cm, the CS treatment had the greatest soil water content followed by the NT, SF, and LD treatments respectively. The CS treatment also had a greater soil water content at the depth of 10-15 cm followed by the SF, NT, and LD treatments respectively. At the lowest depth of 10-15 cm, the NT treatment had the greatest soil water content compared to the CS, LD, and SF treatments respectively. There were no significant differences observed across all four treatments and at all three depths.

Active Carbon 2010

The active carbon samples were taken to measure the biological activity of soil in each treatment (Table 3-7). Soil active carbon (SAC) is measured in mg of active carbon per kg of soil. At Copeland with the first sampling, the GP treatment had a greater SAC than the LD, Case, and NT respectively. However, those differences were not statistically different across all treatments. The same results were seen with the second and third sampling dates with different treatments having a greater SAC value but no significant differences were observed.

The first sampling date at Fredonia showed no significant difference between the ST and GP treatments although the ST treatment did have a greater SAC value. Later in the growing season, the GP treatment showed a greater SAC level, however, again there was no significant difference. After harvest, a significant difference in SAC levels was observed with the ST treatment being significantly greater than the GP treatment.

At the Lincolnville location in 2010, no statistical difference was observed with the SAC values for both treatments across all three sampling dates. The GP treatment had a greater SAC level with the first and third sampling date, with the NT treatment having a greater SAC level at the second sampling date. No trends were observed and again no significant differences were found.

The CS treatment had the greatest level of SAC at Winchester with the first soil sampling date. The CD treatment had the second greatest with the NT treatment having the lowest SAC. None of these differences were considered significant at p=0.05. The second sampling date saw the NT treatment having the greatest SAC followed by the CS, and CD treatments respectively. Again, these observed differences were not statistically significant.

Active Carbon 2011

The soil active carbon (SAC) level was greatest in the NT treatment early in the growing season at Atchison County (Table 3-8). The NT treatment had 24 mg/kg more SAC than the SP treatment but that was not significant. The NT and SP treatments were significantly (p=0.05) greater than the GP treatment. Later in the growing season the SP treatment had the greater SAC level compared to the NT and GP treatments respectively, but the results were not significant. No significant difference was observed between the NT and GP treatments either.

Early in the growing season at Downs, the LD treatment had a greater SAC level than the NT treatment but that difference was not significant. Later in the growing season the LD treatment again had a greater SAC level. The SAC in the LD treatment was 150 mg/kg greater than the NT treatment and that was a significant (p=0.05) difference.   At Fredonia, the ST treatment had a slightly greater SAC level compared to the GP treatment early in the growing season. This difference however was not considered significant. The second sampling done at Fredonia saw a significant difference between the two treatments SAC levels. The ST treatment was 111 mg/kg greater than the GP treatment and that was considered significantly greater. Both sampling dates at Lincolnville saw the NT treatment have the greater SAC level. With both dates, the difference was approximately 30 mg/kg and that was not enough to make the results significant.

At Garden City, the NT and SF treatments had the greatest and exact same SAC level at the first sampling date. The LD treatment was slightly lower by 9 mg/kg and that was not significantly different from the NT and SF treatments. Early in the growing season the CS treatment had a SAC level that was approximately 80 mg/kg lower than the NT, SF, and LD treatments. That difference was statistically significant at p=0.05. Later in the growing season, the SF treatment again had the greater SAC. It was approximately 30% greater than the CS and NT treatments and that difference was considered significant. The SF treatment was 70% significantly greater than the LD treatment. The CS treatment was slightly greater than the NT treatment, but the difference was not enough to consider the results significant. The CS and NT treatments were significantly greater than the LD treatment as well.

Infiltration 2010

Infiltration measurements were taken two times, once during early growing season and another later in the growing season (Table 3-9). A third measurement was not taken after the growing season, the project was meant to determine how the tillage treatments would impact infiltration during the growing season. Two measurements were taken when looking at vertical tillage effects on soil infiltration. Soil infiltration rate and time to runoff were looked at to see how the treatments affected those properties. The first sampling date at Copeland, it was observed that the GP treatment had a greater infiltration rate, followed by the NT, CS, LD treatments respectively. No significant differences were observed with the infiltration rates across the treatments. The CS treatment was observed having a significantly greater time to runoff by about 2 minutes. The GP, LD, and NT were not significantly different from each other. Later in the growing season, the LD treatment had the greatest soil infiltration rate. The LD treatment was not significantly different from the NT treatment, but was significantly (p=0.05) different than the CS and GP treatments. The NT treatment was 80% greater than the CS treatment but no significant difference was observed, however, the NT treatment was 4 times as much as the GP treatment and that was significantly different. The CS treatment was 2.25 times as much as the GP treatment and that difference was significant (p=0.05). The NT treatment had the greatest time to runoff followed by the GP, CS, and LD treatments respectively. There was no significant difference observed with time to runoff.

At Fredonia, a pattern was observed while taking soil infiltration measurements. Early in the growing season, the ST treatment had a greater soil infiltration rate and a greater time to runoff time. These differences observed were not significantly different. Sampling done later in the growing season the results were the same as the first sampling date. The ST treatment had a soil infiltration rate that was 2.2 times as great as the GP treatment but the difference was not significantly different at p=0.05. Time to runoff measurements were similar with the ST treatment having a 69% greater time to runoff than the GP treatment. For both the soil infiltration rate and time to runoff, it was noted that there was such a high variability across the individual plots that led to the results of large average differences that were not statistically important.

Soil infiltration rate measurements early in the growing season at the Lincolnville location were not statistically different between the NT and GP treatments. The NT soil infiltration rate was about 1.42 times as great as the GP treatment. However, the GP treatment had a statistically (p=0.05) greater time to runoff than the NT treatment. Later in the growing season the NT treatment again had a greater soil infiltration rate than the GP treatment however, that was not significantly (p=0.05) different. The NT treatments had greater steady state infiltration rates compared to the GP treatments across both sampling dates. The NT treatments also had greater MWD of the soil aggregates compared to the GP treatments and this could have led to greater steady state infiltration rates for the NT treatments. It was observed that the NT treatment had a time to runoff that was 1.34 times as great as the GP treatment but not significantly different.

At Winchester, a rain event during the first sampling date did not allow for collection of soil infiltration data. The second sampling showed a soil infiltration rate for the CS treatment that was 1.64 times as great as the CD treatment and 2.5 times as great as the NT treatment. However, there was no statistical differences observed between the treatments. The CS treatment also had a greater time to runoff, approximately 2.75 times as great as the NT and CD treatments, but that was not statistically different at p=0.05 despite the large difference.

Infiltration 2011

At Atchison County in 2011, a first infiltration measurement was not taken (Table 3-10). A new method for measuring soil infiltration (double ring infiltration) was tested, but the process was very time consuming and not easily replicated as with the Cornell Sprinkle method. All sampling was done on the same day for each location and therefore a return trip just for infiltration measurement was not done. One way that the vertical tillage implements were being marketed was it allowed the ground to be opened up to allow for better air and water infiltration. This was observed later in the growing season at Atchison County. The GP treatment had the greatest infiltration rate by 0.03 cm/min and 0.033 cm/min compared to the SP and NT treatments. These differences were not considered significant. No significant difference was observed between the SP and NT treatments. The SP treatment had a greater time to runoff value followed by the GP and NT treatments but there were no significant differences between treatments.

The average soil infiltration rate for the NT plots at Downs was greater than the LD treatment early in the growing season. The NT soil infiltration rate was almost 3 times as much as that of the LD treatment, but the individual plot values were so variable, that was not considered significant (p=0.05) The NT plots however, were the quickest to start recording water runoff but this was not significant. Later in the growing season the LD treatment had a greater soil infiltration rate by approximately 15%, but that was not significantly greater compared to the NT plots. Again, the NT plots were quicker to record runoff measurements, but no significant differences were observed.

Early in the growing season at Fredonia, the GP treatment had a greater soil water infiltration rate, approximately 2 times as great as the ST treatment. The GP treatment also had a longer time to runoff value, almost 4 minutes longer than the ST treatment but that was not a statistically significant difference. Later in the growing season it was observed that the GP treatment had a soil infiltration rate that was almost 6 times as great as the ST treatment and that was statistically significant (p=0.05). Again the GP treatment had a longer time to runoff compared to the ST but that was not statistically significant.

At Lincolnville in the 2011, the NT treatment had a greater soil infiltration than the GP treatment with the sampling done early in the growing season. The NT treatment was only 0.004 cm/min greater than the GP treatment and that difference was not significant. The GP treatment took on average about 2.25 minutes longer for runoff to being comparted to the NT treatment and that difference was significant (p=0.05). Later in the growing season the NT treatment again had a greater soil infiltration rate compared to the GP treatment however that difference was not significant. The time to runoff was slightly greater in the GP treatment, but the difference was only 0.81 minutes and that difference was not significant.

Early in the growing season at Garden City, the infiltration rates for the individual plots were so variable that the differences observed were not significant. The SF treatment had the greatest soil infiltration rate, 48% greater than the CS treatment and approximately 2.3 times as great as the LD and NT treatments. The CS treatment was 60% greater than the LD and NT treatments and the LD and NT treatments compared to each other were very close. Again, none of those differences observed were considered statistically significant. The CS treatment had a greater time to runoff, followed by the SF, LD and NT treatments respectively. The CS and SF treatments were not significantly different, but the CS treatment was significantly (p=0.05) greater in time to runoff compared to the LD and NT treatments. The SF treatment had an average time to runoff that was significantly greater than the LD and NT treatments. The LD treatment had a greater time to runoff compared to the NT treatment, but that was not significant. Later in the growing season, the LD treatment went from having one of the lowest soil infiltration rates to having the greatest rate. The LD was 20% significantly greater than the NT treatment, 2.2 times significantly as great as the CS treatment, and 4 times significantly as great as the SF treatment. The NT treatment soil infiltration rate was 80% significantly greater than the CS treatment and 3.4 times as great as the SF treatment. The CS treatment was 80% significantly greater than the SF treatment. The LD treatment also had a significantly (p=0.05) greater time to runoff compared to the NT and SF treatments, but no statistical difference was observed between the LD and CS treatments. The CS treatment was also significantly (p=0.05) greater with time to runoff compared to the NT and SF treatments. The time to runoff in the NT plot was 1.25 minutes as much as the SF treatment but that was not significantly different.

Soil Nutrients 2010

Soil sampling was done after harvest to determine the level of soil nutrients. The purpose of this was to see after the growing season if the distribution of nutrients was affected by the tillage operations. Soil cores were taken and then broken down in depths of 0-2.5 cm, 2.5-5 cm, 5-10 cm, and 10-15 cm. The soil samples were tested for pH (Table 3-11), phosphorus (P) (Table 3-12), potassium (K) (Table 3-13), ammonium nitrogen (NH_4) (Table 3-14), and nitrate nitrogen (NO_3) (Table 3-15). At Copeland, there was no significant difference observed between all four treatments with soil pH across all depths. The GP treatment had the highest soil test P level at depths from 0-10 cm. The CS treatment had the greatest soil test P level at a soil depth of 10-15 cm. None of the differences in soil test P were considered significant (p=0.05). The NT treatment had the greatest soil test K level across all the depths. The CS treatment had the second highest level of soil test K across all depths followed by the GP and LD treatments respectively. None of these soil test K level differences were considered statistically significant across all treatments and depths. No pattern or significant differences were observed with NH4 levels across all treatments and depths. The exact same results were observed with NO3 levels across all treatments and depths.

At Fredonia in 2010, the tillage operation influenced the soil pH level. The ST treatment had a significantly higher soil pH at the 0-2.5 cm depth, approximately 5% higher than the GP treatment. The ST treatment had a greater soil pH than the GP treatment at the 2.5-5 cm depth, however this was not significant. As the soil sampling got deeper, the pH trend changed. At a depth of 5-10 cm, the soil pH was greater in the GP treatment over the ST treatments. This difference was not significant. The GP treatment had a significantly greater soil pH compared to the ST treatment. This change in trend could be contributed to the ST treatment. The ST operation was done at a depth of 10-20 cm with anhydrous ammonia (NH4) and that form of nitrogen can cause an immediate impact decreasing soil pH at the tillage depth. A trend was observed with soil test P levels at all depths. The ST treatment had a greater soil P level at all 4 depths, although none of these differences were considered significant (p=0.05). Similar results were noted with soil test K levels. The ST treatment had greater soil K levels at all depths compared to the GP treatment. Only at a depth of the 10-15 cm depth was the ST soil K significantly greater than the GP treatment. No trends or significant differences were observed with NH_4 and NO_3 levels between treatments and across all depths.

No soil samples were taken at Lincolnville in 2010 due to wheat being drilled in the field directly after harvest. Fertilizer was put down with the wheat seed and it was determined that may skew the results. No soil samples were taken for analysis at Winchester in 2010 as well. The field was tilled with a conventional disk following harvest.

Soil Nutrients 2011

The depths at which the soil samples were taken for nutrient analysis were 0-2.5 cm, 2.5-5 cm, 5-10 cm, and 10-15 cm. The samples were analyzed for soil pH (Table 3-16), phosphorus (P) (Table 3-17), potassium (K) (Table 3-18), ammonium nitrogen (NH_4) (Table 3-19), and nitrate nitrogen (NO_3) (Table 3-20). No soil samples were collected at the Garden City and Fredonia in 2011. The soil samples taken after the growing season to look at nutrient distribution in the soil showed a trend in soil test P at Atchison County in 2011. Across all depths, the soil pH was not significantly different between the three treatments. At the depth of 0-2.5 cm, the GP treatment had a greater soil test P level compared to the NT and SP treatments respectively. The GP treatment also had greater soil test K, NH_4, and NO_3 levels compared to the NT and SP treatments respectively at a depth of 0-2.5 cm, however these differences were not onsidered significant. At a depth of 2.5-5 cm, there were no statistical differences between the three treatments in regards to soil test K, NH_4, and NO_3. At depths of 5-10 cm and 10-15 cm, no pattern was observed and no significant differences were observed between the three treatments and the soil nutrient levels.

At the Downs, KS site location, the soil pH was not significantly affected by the tillage treatments. At a depth of 0-2.5 cm, the LD treatment had a soil test P level that was 68 ppm greater than the NT treatment, but that was not significantly different. The LD treatment also had greater soil test P levels at the depths of 2.5-5 cm, 5-10 cm, and 10-15 cm but none of those differences were considered statistically significant ($p=0.05$). No significant differences were observed between the NT and LD treatments with soil test K, NH_4, and NO_3 levels across all 4 depths.

The soil pH level was not significantly affected by the NT or GP treatments across all depths at Lincolnville in 2011. At the top depths of 0-2.5 and 2.5-5 cm, the VT treatment had a greater soil test P and K level. A tillage operation in a field that had a history of no-till cropping can cause a release of nutrients with that tillage operation. Although the differences were not significant, that may have led to the GP treatment have greater P and K levels compared to the NT treatment. At the lower depths of 5-10 cm and 10-15 cm, no trend or significant difference was observed with soil test P and K levels. No trends or significant differences were observed between the two treatments across all depths when looking at soil levels of NH_4 and NO_3.

Agronomic Properties

Residue Cover 2010

The site at Copeland, KS was an irrigated field that had a history of no-till farming practices and heavy residue. The tillage operation for the purpose of this plot was done in early spring. The night after the tillage operation strong winds affected the distribution of the residue in the field. Residue from the tilled plots blew across the field was caught in the edges of the NT plots. Due to this distribution, the residue cover measurements taken in the NT plots were done in the middle of plot (Table 3-21). The NT treatment had a significantly (p=0.05) greater residue cover than the three VT treatments. No significant difference was observed between the three VT treatments.

The treatments at Fredonia, KS consisted of the GP operation and an aggressive ST treatment. The ST treatment had a residue cover that was slightly greater than the GP treatment but it was not statistically different. Heavy rains shortly after the tillage operations led to residue being washed out of the field and overall lower residue levels. At Lincolnville, the NT treatment had a significantly greater residue cover, being 2.2 times as great as the GP treatment. Similar results were observed at Winchester as well. The NT treatment was 50% greater than the CS treatment and 70% greater than the CD treatment. These values were considered statistically significant at p=0.05. The CS treatment was 15% significantly greater than the CD treatment. The results observed were consistent with claims made by the vertical tillage equipment manufactures that these implements will help manage residue but will also anchor residue giving more cover and residue benefits when compared to conventional tillage treatments.

Residue Cover 2011

For the second year of the project, the tillage operation was attempted to be done as early as possible, even the fall or winter before the crop was planted. At each location, residue cover measurements were taken as soon as possible after the tillage operation (Table 3-22). At the Atchison county location, the NT treatment had a residue cover that was 10% significantly (p=0.05) greater than the GP treatment and 40% significantly greater than the SP treatment. The VT treatment was statistically different than the SP treatment with a residue cover 33% greater.

The test plot location near Downs, KS was in a field that had a failed crop the previous year and was going to be planted to soybeans. The tillage was done in December of 2010 and the residue measurements were taken the same day. The NT plot had a residue cover that was 86% greater and statistically significant compared to the LD plot.

The tillage operations at Fredonia were done in the spring of 2011 just prior to planting. The GP treatment had 20% greater residue cover compared to the ST treatment but that was not significant.

At Garden City, KS the tillage operations were done in December of 2010 and residue measurements were taken the same day. The NT treatment had the highest level of residue cover compared to the CS, SF, and LD respectively. The NT and CS plots were significantly (p=0.05) different from the LD treatment. The SF treatment was not significantly different from the NT, CS, or LD treatment.

The tillage operations at Lincolnville, KS were also done in December of 2010 and residue measurements were taken the same day. The NT treatment had a residue cover that was significantly (p=0.05) greater and nearly 2.2 times as much cover as the GP treatment.

Emergence 2010

One of the main issues that is often discussed with no-till practices is the slower emergence and sometimes a poor final crop stand. Even with the residue distribution issues at Copeland that was discussed in the residue cover section that did not have any impact on the final stand of the corn (Table 3-23). The CS treatment had the greatest final stand count, followed by NT, GP, and LD respectively. The final stand count at Fredonia showed no significant difference between the ST and GP treatments. A rain event right after planting affected the final stand count at Lincolnville in 2010. The GP treatment had a final stand that was 40% times greater than the NT treatment and that was statistically different at p=0.05. At Winchester, the CD treatment had the greatest final stand emergence, followed by the CS treatment, and the NT treatment had the lowest final stand count. The CD treatment was significantly different than the NT treatment, however the CS treatment was not significantly different from the CD or the NT treatment.

Emergence 2011

At Atchison County is 2011, the emergence was not affected by the tillage treatments (Table 3-24). The GP treatment had the greatest plant population than the other two treatments. The GP treatment had only 300 more plants per acre than the NT treatment and 900 more plants per acre than the SP treatment. These differences were not considered statistically significant (p=0.05). The NT treatment had 500 more plants per acre than the SP treatment and that also was not statistically significant.

The site location at Downs, KS was planted to soybeans in 2011 due to drought conditions. The LD treatment had a better plant emergence compared to the NT treatment. The plant population in the LD treatment was 1.3% greater than the NT treatment but that was not significant (p=0.05). Similar results were seen at Lincolnville with crop emergence. At Lincolnville the GP treatment had greater plant population compared to the NT treatment. The difference was about 900 plants per acre or about 4% difference and that was not statistically (p=0.05) different. No significant difference was observed at Fredonia in 2011. The plant population in the ST treatment was only 1% greater than the GP treatment.

At Garden City the CS treatment had the greatest plant emergence compared to the other three treatments. The CS treatment had a plant population that was 1.2% greater than the NT treatment, 2.2% greater than the LD treatment, and 3.3% greater than the SF treatment. These differences were not considered statistically significant (p=0.05). The NT treatment had the second highest plant population followed by the LD and SF treatments respectively. All three values were within 2% of each other and were not considered significant (p=0.05).

Residue Decomposition 2010

One of the marketing points of the vertical tillage implements was the ability to manage residue. The decomposition of residue in the field helps reduce the amount of residue that may be on the soil surface as well as release nutrients back into the soil. The greater the percentage of ash-free residue the more decomposition of the residue is taking place. At Copeland in 2010, only the first sampling date will be reported, the residue from the second sampling date was discarded due to mold that occurred in cold storage (Table 3-25). With the first sampling date, it was observed that the LD treatment had the greatest residue breakdown compared to the other three treatments. The NT treatment had the second highest residue breakdown followed by the GP and CS respectively. None of these differences were considered statistically significant (p=0.05).

At Fredonia in 2010, the ST treatment had the greatest residue breakdown at both sampling dates compared to the GP treatment. Early in the growing season, the ST treatment had 17% greater ash-free residue content but that was not significant. Later in the growing season the ST treatment had 12% greater ash-free residue content than the GP treatment but again that was not significant.

The results at Lincolnville were not what was expected. When residue comes into contact with soil like what occurs with tillage, the microbes and biological activity in the soil speeds up residue breakdown. However, early in the growing season the NT treatment had 30% significantly (p=0.05) greater residue breakdown compared to the GP treatment. Later in the growing season the NT treatment again had greater residue decomposition compared to the GP treatment but this time the difference was not significant.

The results at Winchester were very similar to those at Lincolnville. The first sampling date saw the NT treatment with the greatest residue breakdown followed by the CD and CS treatments respectively. None of these differences between the three treatments were considered significant (p=0.05). Later in the growing season the NT treatment again had the greatest percentage of ash-free residue. This sampling date, the CS treatment had the second highest percentage of ash-free residue and the CD had the least amount of decomposition of all three treatments. None of these observed differences were considered significant (p=0.05).

Residue Decomposition 2011

In 2011 at Atchison County, the NT treatments had significantly greater amounts of ash-free residue at both sampling dates (Table 3-26). Early in the growing season the NT and SP treatments had the exact same percentage of ash-free residue. The percent of ash-free residue in the GP treatment was 6% less than the NT and SP treatments and that difference was statistically significant (p=0.05). Later in the growing season the NT treatment again had the greatest percentage of ash-free residue. The NT treatment was 10% significantly higher than both the GP and SP treatments. The GP percent ash free residue was 1% greater than the SP treatment and that was no significant.

Early in the growing season at Downs, the NT treatment had a higher percentage of ash-free residue compared to the LD treatment but that was not significant. The second sampling led to the LD treatment with a greater amount of residue decomposition and that was significantly greater than the NT treatment. At Fredonia, the GP treatment had a greater percentage of ash-free residue compared to the ST treatment but that was not significant early in the growing season. Later in the year, the GP treatment again had a greater percentage of ash-free residue and this time it was significantly greater than the ST treatment. Both sampling dates at Lincolnville saw the NT treatments have a greater percent of ash-free residue compared to the GP treatments. Early in the growing season the actual percentage only varied 1% between the two treatments and therefore was not significant. Later in the growing season the NT treatment had a percentage of ash-free residue that was 5 percent greater than the GP, but again this was not significant.

At Garden City, the NT and LD plot averages where identical to each other early in the growing season. The percent ash-free residue was greatest in the NT and LD plots and they were significantly (p=0.05) greater than the SF and CS treatments. The CS treatment was slightly greater than the SF treatment but the percent-ash free residue was not significantly different. Later in the growing season the CS treatment had the greatest residue breakdown of all the treatments. The NT treatment had the second highest percentage of ash-free residue, followed by the SF and LD treatments respectively. There were no significant differences between the CS, NT, and SF treatments. The LD treatment was significantly (p=0.05) lower than the other three treatments.

Yield 2010

In fall of 2010, yield measurements were taken at all locations (Table 3-27). The plots were harvested with normal farm equipment and grain was weighed with a grain wagon set up with a scale. At Copeland, the GP treatment had the greatest yield with the CS treatment yielding a close second. There was a little bit of a drop off to the NT yield and the LD plots yielded the least. However, none of these observed difference were considered significant at p=0.05. Grain yields at Fredonia were not significantly different between the ST and GP treatments. At Lincolnville, the GP treatment had better crop emergence and this may have led to the yield results. The GP treatment had a yield that was 10% greater than the NT treatment, although not significantly different. At Winchester in 2010, the CS treatment had a yield that was 15% greater than the NT and CD treatments. This difference was about 1.4 Mg/ha which would be economically significant to a farmer but it was not statistically significant in this study. The individual plot yields were so variable which led to these results.

Yield 2011

In 2011, the corn yields at the Atchison county location were pretty variable across each individual plot (Table 3-28). The NT and SP treatments had exact same yield values. The GP treatment was approximately 0.4 Mg/ha under the NT and SP treatments, but that difference was not significant (p=0.05).

At the plots located near the town of Downs along the border of North central and Northwest Kansas, the original crop was intended to be corn. Due to drought conditions the year before and drought conditions predicted for 2011, the crop was switched to soybeans. The field had been in no-till farming practices since 1995 and had a good history of respectable yields in drought conditions. The NT treatment yielded approximately 10% more than the LD treatment. However this observed difference was not considered statistically significant (p=0.05).

Fredonia, KS experienced a hard drought and the plot was scrapped after the second sampling date due to crop failure. The plot at Lincolnville experienced similar conditions but were still able to be harvested for yield. The NT treatment yielded only 0.02 Mg/ha more than the GP treatment and therefore not significantly different.

The only statistical difference that was observed in 2011 occurred at the Garden City location. The field was on limited irrigation and the yield results would be expected. The NT treatment had a significantly (p=0.05) greater yield, approximately 10% greater than the tillage treatments. No significant (p=0.05) difference was observed between the CS, LD, and SF treatments.

Diseases and Pathogens

Cercospora zea-maydis 2010

The growing conditions at Copeland in 2010 were in favor of an outbreak of *Cercospora zea-maydis* or gray leaf spot (GLS). To determine the level of GLS infection, data was gathered in the field during the second sampling date looking at disease incidence (percent of population affected) and disease severity (lesions per plant). The LD treatment had a greater disease incidence than the NT, CS, and GP treatments respectively (Table 3-29). No statistical difference was observed across the treatments in GLS incidence. The LD treatment also had the greater disease severity compared to the other treatments. The GP treatment had the second highest severity of GLS followed by CS and the NT treatment had the lowest GLS severity. However, there was no statistical difference observed across the treatments in relation to GLS severity. The incidence and severity of GLS was high enough that the field was treated with a fungicide.

Fredonia, KS is located in Southeast Kansas which has a climate that also favors disease. There is normally adequate rainfall (>900 mm) with warm temperatures and high humidity. The disease incidence observed was at low levels given the climate and was slightly greater in the GP treatment compared to the ST plots but was not statistically different. The overall levels of disease severity were very low during the growing season. The GP plots had a few more lesions per plant than the ST plots but the differences observed were not significant (p=0.05).

In 2010 at Lincolnville, the weather was not favorable for GLS to develop. The disease incidence was almost identical between the NT and GP treatments and therefore no statistical difference (p=0.05) was observed. The severity of GLS was 64% greater in the GP plot compared to NT but that was not a significant difference.

The results observed at the Winchester plot site would be consistent with how one might hypothesize that a tillage application would affect the incidence and severity of GLS. The disease incidence was 62% greater in the NT treatment compared to the CD and CS treatments and that was significant at p=0.05. No significant difference was observed between the CD and CS treatments. The number of lesions per plant was greater (p=0.05) in the NT treatment and approximately 62% greater than the CD and CS treatments. The NT treatment at Winchester had a significantly greater residue cover and that extra residue could harbor more GLS spores that would allow more infections in the crop.

***Cercospora zea-maydis* 2011**

Scouting and data collection for gray leaf spot (GLS) for 2011 was only done in the field. The data collection for 2011 only occurred at two sites (Table 3-30). At the Downs, KS location, no data was taken since the crop in the field was changed to soybeans due to drought conditions and GLS is not found in soybeans. Both Fredonia and Lincolnville experienced drought conditions after the crops were planted. By the time the crop was near the tassel stage (VT), the leaves that needed to be sampled for GLS were curled up and dead, therefore adequate data could not be collected. This occurred at both Fredonia and Lincolnville.

The NT and GP treatments at Atchison county were not significantly (p=0.05) different from each other when determining GLS incidence. Those two treatments had a GLS incidence that was significantly greater than the SP treatment by 43%. However, when observing how the fungal disease affected the individual plant, the NT treatment had 80% more lesions per plant than the GP and SP treatments. That difference was statistically significant, but no significance was observed between the GP and SP treatments.

At Garden City there were no significant differences observed between the treatments in either GLS incidence or severity. Conditions were not favorable for a GLS outbreak even with the limited irrigation. The overall incidence was low, with the NT plots having the greatest population affected by GLS. The Salford had the second highest incidence followed by LD and CS respectively. The LD treatment had the greatest number of lesions per plant followed by NT, CS, and SF respectively. Again, no statistical differences were observed across the treatments with GLS incidence and severity.

***Macrophomina phaseolina* 2010**

Charcoal rot in corn is a soil-borne fungal disease that infects the plant late in the season and can cause yield loss by premature death and lodging. The disease is very weather and climate dependent. Results were reported as the number of fungal colony fungal units (CFU) per gram of soil (Table 3-31). At Copeland, the GP treatment had the greatest amount of CFU per gram of soil. The GP treatment was 60% significantly (p=0.05) greater than the CS treatment which had the second highest CFU value. The GP treatment was also 92% significantly greater than the NT treatment and 2.4 times as great much *Macrophomina* compared to the LD treatment. The CS treatment was not significantly different from the NT treatment. There was also no significant difference between the CS, NT and LD treatments.

At Fredonia, very little difference was observed between the two treatments. The ST treatment only had 7% greater CFU per gram of soil compared to the GP treatment. This observed difference was not significant. In 2010 at Lincolnville, the CFU in the GP treatment was 15% greater compared to the NT treatment. This observed difference was considered significant (p=0.05)

In 2010 at Winchester the CS treatment had the greatest amount of *Macrophomina* present in the soil compared to the CD and NT treatments respectively. The CS treatment was not statistically significant (p=0.05) compared to the CD treatment. The CS treatment had significantly more *Macrophomina* in the soil, nearly 2.1 times as much as the NT treatment. The CD treatment was also significantly greater than the NT treatment by nearly 70%.

Macrophomina phaseolina 2011

The field at Atchison County had been in continuous corn for over eight years (Table 3-32). This led to a build of fungal pathogens. The levels of *Macrophomina* in the soil was greatest at Atchison County compared to all other locations. Comparisons are not being made across site locations but felt it was necessary to mention the lack of crop rotation can lead to disease issues. The NT treatment at Atchison County had the greatest amount of *Macrophomina* CFU compared to the other two treatments. The GP treatment was slightly greater than the SP treatments but the difference in *Macrophomina* CFU was not significant between any of the treatments.

At Fredonia, the ST treatment had a greater amount of *Macrophomina* in the soil compared to the GP treatment. The ST treatment was 18% in concentration of CFU but that difference was not significant. The results at Downs and Lincolnville in 2011 were very similar. At Downs, the NT treatment had 33% more *Macrophomina* in the soil compared to the LD treatment. That result was statistically significant (p=0.05). The same held true at Lincolnville. The NT treatment had 52% more *Macrophomina* CFUs per gram of soil compared to the GP treatment. Again, the NT treatment was significantly greater than the GP treatment.

The results at Garden City in 2011 did not follow a trend like at Downs and Lincolnville. The LD and CS treatments had the exact same concentration of *Macrophomina* in the soil and that was the greatest concentration compared to the other two treatments. The NT treatment was only 5 CFU per gram of soil less than the LD and CS treatments and that was not significant different. The LD and CS treatments had 39% more *Macrophomina* in the soil compared to the SF treatment. This difference was considered statistically significant at p=0.05. The NT treatment also had 33% significantly more *Macrophomina* in the soil compared to the SF treatment.

Fusarium spp (Fusarium Stalk Rot) 2010

Fusarium stalk rot is a fungal disease that can be harbored on residue left from the previous year. Residue samples were taken around the tassel stage to determine if the fungal pathogen was present and affected by the tillage operations. The data is reported in colony forming units (CFU) per gram of residue (Table 3-33). Just because the pathogen is present and sometimes n large quantities, conditions do not always favor the spread of the disease. Being a residue based pathogen, no-till systems can increase the amount of spores that will be available to infect the plants (Govaerts et al., 2007). The LD treatment at Copeland, KS had a greater amount of *Fusarium* present in the residue compared to all other treatments. The NT treatment had the second highest level present in the residue followed by the GP and CS treatments respectively. No significant differences were observed between all four treatments.

At Fredonia in 2010, the ST treatment had the greatest amount of *Fusarium* in the residue samples compared to the GP treatment. The difference was only 5 CFU per gram of soil and that was not considered significant (p=0.05). The results at Lincolnville were ones that someone might predict when trying to determine the amount of *Fusarium* in the residue. The NT treatment had *Fusarium* levels that were 20% greater than the GP treatments. This observed difference was considered statistically significant (p=0.05). The extra residue in the NT plots could have led to the increase of fungal CFUs.

The VT plots at Winchester had the greatest amount of *Fusarium* compared to the other two treatments. The CS treatment was 30% than the NT treatment but that difference was not significant. However, the average amount of *Fusarium* CFUs in the CS plots was 88% greater than the CD treatment and that was statistically significant (p=0.05). The NT treatment had 42% more *Fusarium* than the CD treatment. That difference was also significant.

Fusarium 2011

Fusarium stalk rots are very dependent on having a host to over winter or survive on. Having plenty of residue on the surface can influence this greatly and that was seen at Atchison County in 2011 (Table 3-34). The field at Atchison County had been in a continuous corn rotation for several years. That rotation was noticeable when comparing the amount of *Fusarium* CFUs per gram of soil in the three treatments. The NT treatment had the greatest amount of residue cover and that could have led to greater concentration of *Fusarium* CFUs in the residue. The VT treatment was slightly greater than the GP and SP treatments respectively but that difference was not considered significant (p=0.05). The GP treatment had 3 more CFUs per gram of soil than the SP treatment and that difference also was not statistically significant.

At Downs the NT treatment had a greater amount of *Fusarium* in the residue compared to the LD treatment. The NT treatment was only 1.7% greater than the LD treatment and that difference was not significant. At Fredonia, the GP treatment had a greater amount of *Fusarium* in the residue compared to the ST treatment. The difference was only 2 CFUs per gram of soil and that difference was not statistically significant (p=0.05). Results were similar at Lincolnville in 2011. The *Fusarium* concentration in the GP treatment residue was greater than in the NT treatment. The GP treatment was only 5% greater than the NT treatment and that was not statistically significant.

No significant (p=0.05) differences were observed at Garden City in 2011. The SF treatment had the greatest concentration of *Fusarium* present. The SF treatment was 3% greater than the CS treatment, 7% greater than the NT treatment, and 9% greater than the LD treatment. None of these differences were considered statistically significant (p=0.05). The CS treatment had the second greatest amount of *Fusarium* CFUs per gram of soil followed by the NT and LD treatments respectively. Again, no significant differences were observed between all four treatments with *Fusarium* concentration in the residue.

Table 3-1 2010 Bulk Density results

2010 Bulk Density (g/cm³)							
		Treatment[2,3]					
Location[1]	Depth	CS	GP	LD	CD	NT	ST
Copeland 1	0-5 cm	1.16 a	1.13 a	1.16 a	-	1.20 a	-
Copeland 1	5-10 cm	1.37 a	1.35 a	1.37 a	-	1.36 a	-
Copeland 1	10-15 cm	1.38 a	1.39 a	1.40 a	-	1.41 a	-
Copeland 2	0-5 cm	1.06 a	1.07 a	1.07 a	-	1.06 a	-
Copeland 2	5-10 cm	1.34 b	1.31 b	1.30 b	-	1.37 a	-
Copeland 2	10-15 cm	1.35 a	1.24 a	1.34 a	-	1.34 a	-
Copeland 3	0-5 cm	1.14 a	1.15 a	1.21 a	-	1.22 a	-
Copeland 3	5-10 cm	1.25 b	1.32 b	1.33 b	-	1.36 a	-
Copeland 3	10-15 cm	1.38 a	1.34 a	1.35 a	-	1.40 a	-
Fredonia 1	0-5 cm	-	1.16 a	-	-	-	1.15 a
Fredonia 1	5-10 cm	-	1.33 a	-	-	-	1.36 a
Fredonia 1	10-15 cm	-	1.42 a	-	-	-	1.45 a
Fredonia 2	0-5 cm	-	1.15 a	-	-	-	1.16 a
Fredonia 2	5-10 cm	-	1.35 a	-	-	-	1.36 a
Fredonia 2	10-15 cm	-	1.41 a	-	-	-	1.41 a
Fredonia 3	0-5 cm	-	1.24 a	-	-	-	1.19 a
Fredonia 3	5-10 cm	-	1.42 a	-	-	-	1.27 b
Fredonia 3	10-15 cm	-	1.42 a	-	-	-	1.37 a
Lincolnville 1	0-5 cm	-	1.07 a	-	-	1.29 a	-
Lincolnville 1	5-10 cm	-	1.37 a	-	-	1.37 a	-
Lincolnville 1	10-15 cm	-	1.37 a	-	-	1.38 a	-
Lincolnville 2	0-5 cm	-	1.03 b	-	-	1.21 a	-
Lincolnville 2	5-10 cm	-	1.43 a	-	-	1.39 a	-
Lincolnville 2	10-15 cm	-	1.44 a	-	-	1.36 a	-
Winchester 1	0-5 cm	1.05 a	-	-	1.09 a	1.08 a	-
Winchester 1	5-10 cm	1.22 a	-	-	1.27 a	1.25 a	-
Winchester 1	10-15 cm	1.32 a	-	-	1.35 a	1.34 a	-
Winchester 2	0-5 cm	0.781 b	-	-	0.805 b	0.958 a	-
Winchester 2	5-10 cm	1.23 a	-	-	1.27 a	1.29 a	-
Winchester 2	10-15 cm	1.44 a	-	-	1.41 a	1.38 a	-

1-number next to location represents sampling date

2-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

3-CS (Case), GP (Great Plains), LD (Landoll), CD (conventional disk), NT (no-till), ST (strip-till)

Table 3-2 2011 Bulk Density results

2011 Bulk Density (g/cm^3)								
		Treatment[2,3]						
Location[1]	Depth	CS	GP	LD	SF	SP	NT	ST
At. County 2	0-5 cm	-	1.06 a	-	-	0.926 a	0.981 a	-
At. County 2	5-10 cm	-	1.29 a	-	-	1.25 a	1.33 a	-
At. County 2	10-15 cm	-	1.31 a	-	-	1.26 a	1.35 a	-
Downs 1	0-5 cm	-	-	0.964 a	-	-	0.979 a	-
Downs 1	5-10 cm	-	-	1.36 a	-	-	1.32 a	-
Downs 1	10-15 cm	-	-	1.42 a	-	-	1.39 a	-
Downs 2	0-5 cm	-	-	0.901 a	-	-	0.886 a	-
Downs 2	5-10 cm	-	-	1.34 a	-	-	1.32 a	-
Downs 2	10-15 cm	-	-	1.38 a	-	-	1.39 a	-
Fredonia 1	0-5 cm	-	0.937 b	-	-	-	-	1.09 a
Fredonia 1	5-10 cm	-	1.32 a	-	-	-	-	1.38 a
Fredonia 1	10-15 cm	-	1.40 a	-	-	-	-	1.39 a
Fredonia 2	0-5 cm	-	1.03 a	-	-	-	-	0.933 a
Fredonia 2	5-10 cm	-	1.28 a	-	-	-	-	1.38 a
Fredonia 2	10-15 cm	-	1.41 b	-	-	-	-	1.54 a
Garden City 1	0-5 cm	1.11 a	-	0.955 a	0.928 a	-	1.01 a	-
Garden City 1	5-10 cm	1.35 a	-	1.17 a	1.34 a	-	1.29 a	-
Garden City 1	10-15 cm	1.36 a	-	1.36 a	1.35 a	-	1.37 a	-
Garden City 2	0-5 cm	1.11 a	-	1.11 a	1.19 a	-	1.12 a	-
Garden City 2	5-10 cm	1.25 a	-	1.29 a	1.32 a	-	1.32 a	-
Garden City 2	10-15 cm	1.32 a	-	1.37 a	1.39 a	-	1.38 a	-
Lincolnville 1	0-5 cm	-	1.04 b	-	-	-	1.21 a	-
Lincolnville 1	5-10 cm	-	1.42 a	-	-	-	1.39 a	-
Lincolnville 1	10-15 cm	-	1.40 a	-	-	-	1.36 a	-
Lincolnville 2	0-5 cm	-	1.15 b	-	-	-	1.24 a	-
Lincolnville 2	5-10 cm	-	1.39 a	-	-	-	1.37 a	-
Lincolnville 2	10-15 cm	-	1.42 a	-	-	-	1.40 a	-

1-number next to location represents sampling date

2-different lowercase letters represents significant difference at $p=0.05$ and comparisons are made across rows

3-CS (Case), GP (Great Plains), LD (Landoll), SF (Salford), SP (Spader), NT (no-till), ST (strip-till)

Table 3-3 2010 Mean Weight Diameter Results

2010 Mean Weight Diameter (MWD) (mm)						
	Treatment[2,3]					
Location[1]	CS	GP	LD	CD	NT	ST
Copeland 1	1.207 a	0.808 b	0.729 b	-	1.029 a	-
Copeland 2	1.214 a	1.025 ab	0.834 b	-	0.925 b	-
Copeland 3	1.449 a	1.414 a	1.538 a	-	1.579 a	-
Fredonia 1	-	0.749 a	-	-	-	0.707 a
Fredonia 2	-	1.049 a	-	-	-	0.649 b
Fredonia 3	-	0.881 a	-	-	-	0.998 a
Lincolnville 1	-	0.939 a	-	-	0.978 a	-
Lincolnville 2	-	0.534 b	-	-	1.076 a	-
Lincolnville 3	-	1.214 a	-	-	1.328 a	-
Winchester 1	0.906 ab	-	-	0.757 b	1.094 a	-
Winchester 2	1.291 a	-	-	1.063 a	1.153 a	-

1-number next to location represents sampling date

2-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

3-CS (Case), GP (Great Plains), LD (Landoll), CD (conventional disk), NT (no-till), ST (strip-till)

Table 3-4 2011 Mean Weight Diameter results

2011 Mean Weight Diameter (MWD) (mm)							
	Treatment[2,3]						
Location[1]	CS	GP	LD	SF	SP	NT	ST
At County 1	-	1.015 b	-	-	1.545 a	0.916 b	-
At County 2	-	3.499 a	-	-	3.217 a	1.584 b	-
Downs 1	-	-	0.899 a	-	-	0.726 a	-
Downs 2	-	-	1.016 a	-	-	1.123 a	-
Fredonia 1	-	2.156 a	-	-	-	-	1.024 b
Fredonia 2	-	1.666 a	-	-	-	-	1.616 a
Garden City 1	0.816 b	-	0.699 b	1.631 a	-	0.967 b	-
Garden City 2	0.845 ab	-	1.181 a	0.594 b	-	1.082 a	-
Lincolnville 1	-	1.521 a	-	-	-	2.017 a	-
Lincolnville 2	-	2.329 a	-	-	-	2.041 a	-

1-number next to location represents sampling date

2-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

3-CS (Case), GP (Great Plains), LD (Landoll), SF (Salford), SP (Spader), NT (no-till), ST (strip-till)

Table 3-5 2010 Soil Water Content results

2010 Soil Water Content (g/g)							
		Treatment[2,3]					
Location[1]	Depth	CS	GP	LD	CD	NT	ST
Copeland 1	0-5 cm	0.259 a	0.255 a	0.245 a	-	0.274 a	-
Copeland 1	5-10 cm	0.262 ab	0.271 a	0.253 b	-	0.259 b	-
Copeland 1	10-15 cm	0.252 ab	0.259 a	0.246 b	-	0.249 b	-
Copeland 2	0-5 cm	0.285 a	0.285 a	0.267 a	-	0.278 a	-
Copeland 2	5-10 cm	0.254 a	0.256 a	0.240 a	-	0.262 a	-
Copeland 2	10-15 cm	0.248 ab	0.265 a	0.232 b	-	0.238 b	-
Copeland 3	0-5 cm	0.143 a	0.123 a	0.131 a	-	0.148 a	-
Copeland 3	5-10 cm	0.189 a	0.186 a	0.181 a	-	0.189 a	-
Copeland 3	10-15 cm	0.210 a	0.209 a	0.205 a	-	0.207 a	-
Fredonia 1	0-5 cm	-	0.195 a	-	-	-	0.175 a
Fredonia 1	5-10 cm	-	0.221 a	-	-	-	0.222 a
Fredonia 1	10-15 cm	-	0.230 a	-	-	-	0.235 a
Fredonia 2	0-5 cm	-	0.249 a	-	-	-	0.226 b
Fredonia 2	5-10 cm	-	0.225 a	-	-	-	0.211 b
Fredonia 2	10-15 cm	-	0.220 a	-	-	-	0.211 a
Fredonia 3	0-5 cm	-	0.151 a	-	-	-	0.126 a
Fredonia 3	5-10 cm	-	0.192 a	-	-	-	0.172 b
Fredonia 3	10-15 cm	-	0.209 a	-	-	-	0.186 b
Lincolnville 1	0-5 cm	-	0.197 a	-	-	0.184 a	-
Lincolnville 1	5-10 cm	-	0.258 a	-	-	0.265 a	-
Lincolnville 1	10-15 cm	-	0.267 a	-	-	0.261 a	-
Lincolnville 2	0-5 cm	-	0.149 a	-	-	0.137 a	-
Lincolnville 2	5-10 cm	-	0.178 b	-	-	0.210 a	-
Lincolnville 2	10-15 cm	-	0.184 b	-	-	0.221 a	-
Winchester 1	0-5 cm	0.176 a	-	-	0.172 a	0.184 a	-
Winchester 1	5-10 cm	0.242 ab	-	-	0.231 b	0.249 a	-
Winchester 1	10-15 cm	0.241 ab	-	-	0.231 b	0.252 a	-
Winchester 2	0-5 cm	0.275 a	-	-	0.272 a	0.266 a	-
Winchester 2	5-10 cm	0.255 a	-	-	0.246 a	0.255 a	-
Winchester 2	10-15 cm	0.238 a	-	-	0.235 a	0.245 a	-

1-number next to location represents sampling date

2-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

3-CS (Case), GP (Great Plains), LD (Landoll), CD (conventional disk), NT (no-till), ST (strip-till)

Table 3-6 2011 Soil Water Content results

2011 Soil Water Content (g/g)								
				Treatment[2,3]				
Location[1]	Depth	CS	GP	LD	SF	SP	NT	ST
At. County 2	0-5 cm	-	0.174 c	-	-	0.256 a	0.210 b	-
At. County 2	5-10 cm	-	0.213 b	-	-	0.289 a	0.212 b	-
At. County 2	10-15 cm	-	0.235 a	-	-	0.222 b	0.231 ab	-
Downs 1	0-5 cm	-	-	0.187 a	-	-	0.171 b	-
Downs 1	5-10 cm	-	-	0.219 a	-	-	0.224 a	-
Downs 1	10-15 cm	-	-	0.239 a	-	-	0.237 a	-
Downs 2	0-5 cm	-	-	0.152 a	-	-	0.133 a	-
Downs 2	5-10 cm	-	-	0.226 a	-	-	0.267 a	-
Downs 2	10-15 cm	-	-	0.245 a	-	-	0.254 a	-
Fredonia 1	0-5 cm	-	0.210 b	-	-	-	-	0.236 a
Fredonia 1	5-10 cm	-	0.223 a	-	-	-	-	0.230 a
Fredonia 1	10-15 cm	-	0.222 b	-	-	-	-	0.234 a
Fredonia 2	0-5 cm	-	0.107 a	-	-	-	-	0.104 a
Fredonia 2	5-10 cm	-	0.152 a	-	-	-	-	0.138 b
Fredonia 2	10-15 cm	-	0.146 a	-	-	-	-	0.138 a
Garden City 1	0-5 cm	0.228 a	-	0.231 a	0.232 a	-	0.245 a	-
Garden City 1	5-10 cm	0.204 b	-	0.214 b	0.212 b	-	0.231 a	-
Garden City 1	10-15 cm	0.188 b	-	0.193 b	0.197 b	-	0.233 a	-
Garden City 2	0-5 cm	0.183 a	-	0.130 c	0.140 bc	-	0.159 b	-
Garden City 2	5-10 cm	0.238 a	-	0.211 b	0.220 b	-	0.215 b	-
Garden City 2	10-15 cm	0.219 a	-	0.214 a	0.210 a	-	0.220 a	-
Lincolnville 1	0-5 cm	-	0.151 b	-	-	-	0.187 a	-
Lincolnville 1	5-10 cm	-	0.184 a	-	-	-	0.199 a	-
Lincolnville 1	10-15 cm	-	0.203 a	-	-	-	0.212 a	-
Lincolnville 2	0-5 cm	-	0.122 b	-	-	-	0.154 a	-
Lincolnville 2	5-10 cm	-	0.165 b	-	-	-	0.182 a	-
Lincolnville 2	10-15 cm	-	0.197 a	-	-	-	0.200 a	-

1-number next to location represents sampling date

2-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

3-CS (Case), GP (Great Plains), LD (Landoll), SF (Salford), SP (Spader), NT (no-till), ST (strip-till)

Table 3-7 2010 Soil Active Carbon results

2010 Soil Active Carbon (mg/kg)						
	Treatment[2,3]					
Location[1]	CS	GP	LD	CD	NT	ST
Copeland 1	384.25 a	405.41 a	393.88 a	-	368.18 a	-
Copeland 2	538.85 a	561.34 a	564.55 a	-	543.57 a	-
Copeland 3	623.71 a	559.26 a	592.27 a	-	559.45 a	-
Fredonia 1	-	485.36 a	-	-	-	507.10 a
Fredonia 2	-	563.42 a	-	-	-	535.45 a
Fredonia 3	-	535.64 b	-	-	-	690.99 a
Lincolnville 1	-	536.01 a	-	-	529.59 a	-
Lincolnville 2	-	518.81 a	-	-	599.33 a	-
Winchester 1	500.10 a	-	-	466.46 a	458.90 a	-
Winchester 2	674.93 a	-	-	599.52 a	682.74 a	-

1-number next to location represents sampling date

2-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

3-CS (Case), GP (Great Plains), LD (Landoll), CD (conventional disk), NT (no-till), ST (strip-till)

Table 3-8 2011 Soil Active Carbon results

2011 Soil Active Carbon (mg/kg)							
	Treatment[2,3]						
Location[1]	CS	GP	LD	SF	SP	NT	ST
At County 1	-	420 b	-	-	552 a	576 a	-
At County 2	-	418 a	-	-	439 a	434 a	-
Downs 1	-	-	390 a	-	-	371 a	-
Downs 2	-	-	545 a	-	-	395 b	-
Fredonia 1	-	377 a	-	-	-	-	386 a
Fredonia 2	-	350 b	-	-	-	-	461 a
Garden City 1	166 b	-	240 a	249 a	-	249 a	-
Garden City 2	343 b	-	260 c	436 a	-	335 b	-
Lincolnville 1	-	485 a	-	-	-	521 a	-
Lincolnville 2	-	460 a	-	-	-	495 a	-

1-number next to location represents sampling date

2-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

3-CS (Case), GP (Great Plains), LD (Landoll), SF (Salford), SP (Spader), NT (no-till), ST (strip-till)

Table 3-9 2010 Soil Infiltration results

2010 Steady State Soil Infiltration Rate (cm/min)						
	Treatment[2,3]					
Location[1]	**CS**	**GP**	**LD**	**CD**	**NT**	**ST**
Copeland 1	0.0356 a	0.0544 a	0.0176 a	-	0.0491 a	-
Copeland 2	0.0398 b	0.0177 c	0.0892 a	-	0.0716 ab	-
Fredonia 1	-	0.0317 a	-	-	-	0.0443 a
Fredonia 2	-	0.0998 a	-	-	-	0.223 a
Lincolnville 1	-	0.0147 a	-	-	0.0209 a	-
Lincolnville 2	-	0.225 a	-	-	0.229 a	-
Winchester 2	0.212 a	-	-	0.129 a	0.084 a	-

2010 Time to runoff (min)						
	Treatment[2,3]					
Location[1]	**CS**	**GP**	**LD**	**CD**	**NT**	**ST**
Copeland 1	6.38 a	4.67 b	4.20 b	-	4.77 b	-
Copeland 2	4.23 a	4.66 a	3.14 a	-	4.85 a	-
Fredonia 1	-	2.33 a	-	-	-	3.94 a
Fredonia 2	-	7.93 a	-	-	-	11.53 a
Lincolnville 1	-	6.26 a	-	-	4.16 b	-
Lincolnville 2	-	8.45 a	-	-	11.36 a	-
Winchester 2	14.28 a	-	-	5.01 a	5.22 a	-

1-number next to location represents sampling date

2-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

3-CS (Case), GP (Great Plains), LD (Landoll), CD (conventional disk), NT (no-till), ST (strip-till)

Table 3-10 2011 Soil Infiltration results

2011 Steady State Soil Infiltration Rate (cm/min)							
	Treatment[2,3]						
Location[1]	CS	GP	LD	SF	SP	NT	ST
At County 2	-	0.150 a	-	-	0.120 a	0.117 a	-
Downs 1	-	-	0.0335 a	-	-	-	0.0973 a
Downs 2	-	-	0.0628 a	-	-	-	0.055 a
Fredonia 1	-	0.173 a	-	-	-	-	0.0864 a
Fredonia 2	-	0.333 a	-	-	-	-	0.057 b
Garden City 1	0.102 a	-	0.066 a	0.150 a	-	0.0628 a	-
Garden City 2	0.16 c	-	0.358 a	0.0885 c	-	0.298 b	-
Lincolnville 1	-	0.225 a	-	-	-	0.229 a	-
Lincolnville 2	-	0.187 a	-	-	-	0.199 a	-

2011 Time to runoff (min)							
	Treatment[2,3]						
Location[1]	CS	GP	LD	SF	SP	NT	ST
At County 2	-	6.29 a	-	-	7.53 a	6.24 a	-
Downs 1	-	-	5.63 a	-	-	3.62 a	-
Downs 2	-	-	5.26 a	-	-	4.66 a	-
Fredonia 1	-	6.57 a	-	-	-	-	2.73 b
Fredonia 2	-	8.8 a	-	-	-	-	6.7 a
Garden City 1	7.43 a	-	5.58 b	6.95 a	-	4.05 b	-
Garden City 2	6.24 a	-	7.29 a	3.24 b	-	4.51 b	-
Lincolnville 1	-	6.04 a	-	-	-	3.88 b	-
Lincolnville 2	-	6.94 a	-	-	-	6.13 a	-

1-number next to location represents sampling date

2-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

3-CS (Case), GP (Great Plains), LD (Landoll), SF (Salford), SP (Spader), NT (no-till), ST (strip-till)

Table 3-11 2010 Soil pH results

2010 Soil pH						
		Treatment[1,2]				
Location	Depth	CS	GP	LD	NT	ST
Copeland	0-2.5 cm	6.91 a	6.84 a	6.82 a	6.92 a	-
Copeland	2.5-5 cm	6.85 a	6.96 a	6.82 a	6.94 a	-
Copeland	5-10 cm	7.14 a	7.26 a	7.12 a	7.16 a	-
Copeland	10-15 cm	7.26 a	7.34 a	7.20 a	7.25 a	-
Fredonia	0-2.5 cm	-	6.07 b	-	-	6.37 a
Fredonia	2.5-5 cm	-	5.98 a	-	-	6.05 a
Fredonia	5-10 cm	-	6.04 a	-	-	5.99 a
Fredonia	10-15 cm	-	6.79 a	-	-	6.37 a

1-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

2-CS (Case), GP (Great Plains), LD (Landoll), NT (no-till), ST (strip-till)

Table 3-12 2010 Soil Phosphorus results

2010 Soil Phosphorus (ppm)						
		Treatment[1,2]				
Location	Depth	CS	GP	LD	NT	ST
Copeland	0-2.5 cm	24.83 a	27.96 a	22.66 a	15.65 a	-
Copeland	2.5-5 cm	11.96 a	17.94 a	12.12 a	8.93 a	-
Copeland	5-10 cm	8.54 a	9.82 a	9.52 a	7.93 a	-
Copeland	10-15 cm	10.19 a	9.70 a	7.11 a	6.40 a	-
Fredonia	0-2.5 cm	-	67.60 a	-	-	77.05 a
Fredonia	2.5-5 cm	-	59.4 a	-	-	60.58 a
Fredonia	5-10 cm	-	51.1 a	-	-	61.3 a
Fredonia	10-15 cm	-	27.63 b	-	-	44.85 a

1-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

2-CS (Case), GP (Great Plains), LD (Landoll), NT (no-till), ST (strip-till)

Table 3-13 2010 Soil Potassium results

2010 Soil Potassium (ppm)						
		Treatment[1,2]				
Location	Depth	CS	GP	LD	NT	ST
Copeland	0-2.5 cm	730 a	722.5 a	710 a	725 a	-
Copeland	2.5-5 cm	566 a	547.25 a	531.25 a	599.50 a	-
Copeland	5-10 cm	458.25 a	446 a	440.75 a	461.25 a	-
Copeland	10-15 cm	429 a	350.75 a	394 a	436.50 a	-
Fredonia	0-2.5 cm	-	358 a	-	-	411 a
Fredonia	2.5-5 cm	-	288.25 a	-	-	306 a
Fredonia	5-10 cm	-	259.75 a	-	-	316.5 a
Fredonia	10-15 cm	-	230.25 b	-	-	257.25 a

1-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

2-CS (Case), GP (Great Plains), LD (Landoll), NT (no-till), ST (strip-till)

Table 3-14 2010 Soil NH_4 results

2010 Soil NH_4 (ppm)						
		Treatment[1,2]				
Location	Depth	CS	GP	LD	NT	ST
Copeland	0-2.5 cm	4.93 a	4.77 a	5.34 a	4.84 a	-
Copeland	2.5-5 cm	3.65 a	4.62 a	4.23 a	4.12 a	-
Copeland	5-10 cm	2.99 a	2.77 a	3.34 a	3.26 a	-
Copeland	10-15 cm	2.51 a	4.27 a	3.23 a	3.61 a	-
Fredonia	0-2.5 cm	-	6.02 a	-	-	4.48 a
Fredonia	2.5-5 cm	-	4.53 a	-	-	4.72 a
Fredonia	5-10 cm	-	4.28 a	-	-	4.71 a
Fredonia	10-15 cm	-	3.77 a	-	-	4.48 a

1-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

2-CS (Case), GP (Great Plains), LD (Landoll), NT (no-till), ST (strip-till)

Table 3-15 2010 Soil NO_3 results

2010 Soil NO_3 (ppm)						
		Treatment[1,2]				
Location	Depth	CS	GP	LD	NT	ST
Copeland	0-2.5 cm	10.55 a	9.50 a	10.70 a	10.24 a	-
Copeland	2.5-5 cm	15.39 a	13.83 a	15.34 a	13.67 a	-
Copeland	5-10 cm	13.77 a	11.54 a	13.61 a	12.98 a	-
Copeland	10-15 cm	12.15 a	11.61 a	14.33 a	12.03 a	-
Fredonia	0-2.5 cm	-	11.11 a	-	-	6.67 a
Fredonia	2.5-5 cm	-	7.81 a	-	-	6.69 a
Fredonia	5-10 cm	-	7.09 a	-	-	7.02 a
Fredonia	10-15 cm	-	6.27 a	-	-	7.40 a

1-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

2-CS (Case), GP (Great Plains), LD (Landoll), NT (no-till), ST (strip-till)

Table 3-16 2011 Soil pH results

2011 Soil pH					
		Treatment[1,2]			
Location	Depth	GP	LD	SP	NT
At. County	0-2.5 cm	5.85 a	-	6.25 a	6.15 a
At. County	2.5-5 cm	6.35 a	-	6.2 a	6.4 a
At. County	5-10 cm	6.55 a	-	6.35 a	6.6 a
At. County	10-15 cm	6.65 a	-	6.25 a	6.7 a
Downs	0-2.5 cm	-	5.33 a	-	5.43 a
Downs	2.5-5 cm	-	5.18 a	-	5.35 a
Downs	5-10 cm	-	5.55 a	-	5.43 a
Downs	10-15 cm	-	6.23 a	-	6.5 a
Lincolnville	0-2.5 cm	5.45 a	-	-	5.63 a
Lincolnville	2.5-5 cm	5.15 a	-	-	5.10 a
Lincolnville	5-10 cm	5.25 a	-	-	5.2 a
Lincolnville	10-15 cm	5.47 a	-	-	5.65 a

1-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

2-GP (Great Plains), LD (Landoll), SP (Spader), NT (no-till)

Table 3-17 2011 Soil Phosphorus results

2011 Soil Phosphorus (ppm)					
			Treatment[1,2]		
Location	**Depth**	**GP**	**LD**	**SP**	**NT**
At. County	0-2.5 cm	116 a	-	97 a	107 a
At. County	2.5-5 cm	51 a	-	60 a	75 a
At. County	5-10 cm	25 a	-	35 a	25 a
At. County	10-15 cm	20 a	-	28 a	18 a
Downs	0-2.5 cm	-	156 a	-	88 a
Downs	2.5-5 cm	-	67 a	-	41 a
Downs	5-10 cm	-	24.5 a	-	16.05 a
Downs	10-15 cm	-	6.38 a	-	5.78 a
Lincolnville	0-2.5 cm	23.9 a	-	-	14.98 a
Lincolnville	2.5-5 cm	9.65 a	-	-	7.9 a
Lincolnville	5-10 cm	5.93 a	-	-	6.3 a
Lincolnville	10-15 cm	5.00 a	-	-	4.18 a

1-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

2-GP (Great Plains), LD (Landoll), SP (Spader), NT (no-till)

Table 3-18 2011 Soil Potassium results

2011 Soil Potassium (ppm)					
		Treatment[1,2]			
Location	**Depth**	**GP**	**LD**	**SP**	**NT**
At. County	0-2.5 cm	445 a	-	386 a	384 a
At. County	2.5-5 cm	252 a	-	306 a	252 a
At. County	5-10 cm	207 a	-	208 a	221 a
At. County	10-15 cm	207 a	-	184 a	200 a
Downs	0-2.5 cm	-	595 a	-	650 a
Downs	2.5-5 cm	-	534 a	-	521 a
Downs	5-10 cm	-	493 a	-	487 a
Downs	10-15 cm	-	511 a	-	490 a
Lincolnville	0-2.5 cm	311 a	-	-	273 a
Lincolnville	2.5-5 cm	216 a	-	-	208 a
Lincolnville	5-10 cm	206 a	-	-	198 a
Lincolnville	10-15 cm	210 a	-	-	212 a

1-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

2-GP (Great Plains), LD (Landoll), SP (Spader), NT (no-till)

Table 3-19 2011 Soil NH_4 results

2011 Soil NH_4 (ppm)					
		Treatment[1,2]			
Location	**Depth**	**GP**	**LD**	**SP**	**NT**
At. County	0-2.5 cm	10.6 a	-	7.9 a	8.1 a
At. County	2.5-5 cm	8.1 a	-	10.05 a	7.00 a
At. County	5-10 cm	6.6 a	-	6.5 a	5.8 a
At. County	10-15 cm	5.15 a	-	6.2 a	4.45 a
Downs	0-2.5 cm	-	13.05 a	-	7.68 a
Downs	2.5-5 cm	-	4.85 a	-	4.25 a
Downs	5-10 cm	-	4.4 a	-	3.95 a
Downs	10-15 cm	-	4.6 a	-	4.43 a
Lincolnville	0-2.5 cm	6.6 b	-	-	7.6 a
Lincolnville	2.5-5 cm	6.88 a	-	-	7.45 a
Lincolnville	5-10 cm	7.4 a	-	-	10.2 a
Lincolnville	10-15 cm	6.27 a	-	-	5.65 a

1-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

2-GP (Great Plains), LD (Landoll), SP (Spader), NT (no-till)

Table 3-20 2011 Soil NO_3 results

2011 Soil NO_3 (ppm)					
		Treatment[1,2]			
Location	**Depth**	**GP**	**LD**	**SP**	**NT**
At. County	0-2.5 cm	12.8 a	-	7.15 a	7.75 a
At. County	2.5-5 cm	13.00 a	-	10.00 a	8.2 a
At. County	5-10 cm	8.4 a	-	6.9 a	6.4 a
At. County	10-15 cm	7.15 a	-	6.8 a	5.8 a
Downs	0-2.5 cm	-	9.7 a	-	12.88 a
Downs	2.5-5 cm	-	6.1 a	-	7.73 a
Downs	5-10 cm	-	5.13 a	-	5.35 a
Downs	10-15 cm	-	4.1 a	-	4.4 a
Lincolnville	0-2.5 cm	4.2 a	-	-	5.48 a
Lincolnville	2.5-5 cm	2.63 a	-	-	2.95 a
Lincolnville	5-10 cm	3.25 a	-	-	3.25 a
Lincolnville	10-15 cm	3.30 a	-	-	3.33 a

1-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

2-GP (Great Plains), LD (Landoll), SP (Spader), NT (no-till)

Table 3-21 2010 Residue cover results

2010 Residue Cover (% cover)						
	Treatment[1,2]					
Location	CS	GP	LD	CD	NT	ST
Copeland	90.5 b	89.3 b	91.4 b	-	94.8 a	-
Fredonia	-	10.15 a	-	-	-	10.65 a
Lincolnville	-	32.75 a	-	-	72.75 a	-
Winchester	40.8 b	-	-	35.5 c	60.2 a	-

1-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

2-CS (Case), GP (Great Plains), LD (Landoll), CD (conventional disk), NT (no-till), ST (strip-till)

Table 3-22 2011 Residue Cover results

2011 Residue Cover (% cover)							
	Treatment[1,2]						
Location	CS	GP	LD	SF	SP	NT	ST
At. County	-	90.87 b	-	-	68.20 c	96.33 a	-
Downs	-	-	31.7 b	-	-	59.05 a	-
Fredonia	-	25 a	-	-	-	-	21 a
Garden City	87.25 a	-	78.75 b	83.75 ab	-	95.75 a	-
Lincolnville	-	30.85 b	-	-	-	68.25 a	-

1-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

2-CS (Case), GP (Great Plains), LD (Landoll), SF (Salford), SP (Spader), NT (no-till), ST (strip-till)

Table 3-23 2010 Crop Emergence results

2010 Crop Emergence (1000 plants/ac)						
	Treatment[1]					
Location	CS	GP	LD	CD	NT	ST
Copeland	30.3 a	29.8 a	29.7 a	-	29.9 a	-
Fredonia	-	25.05 a	-	-	-	25 a
Lincolnville	-	22.2 a	-	-	16.1 b	-
Winchester	37.6 ab	-	-	38.3 a	35.7 b	-

1-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

2-CS (Case), GP (Great Plains), LD (Landoll), CD (conventional disk), NT (no-till), ST (strip-till)

Table 3-24 2011 Crop Emergence results

2011 Crop Emergence (1000 plants/ac)							
	Treatment[1]						
Location	CS	GP	LD	SF	SP	NT	ST
At. County	-	35.3 a	-	-	34.5 a	35 a	-
Downs	-	-	116.8 a	-	-	115.2 a	-
Fredonia	-	25.76 a	-	-	-	-	26.04 a
Garden City	27.2 a	-	26.6 a	26.32 a	-	26.88 a	-
Lincolnville	-	21.7 a	-	-	-	20.8 a	-

1-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

2-CS (Case), GP (Great Plains), LD (Landoll), SF (Salford), SP (Spader), NT (no-till), ST (strip-till)

Table 3-25 2010 Residue Decomposition results

2010 Residue Decomposition (% ash free residue)						
	Treatment[2,3]					
Location[1]	CS	GP	LD	CD	NT	ST
Copeland 1	73 a	77 a	84 a	-	81 a	-
Fredonia 1	-	54 a	-	-	-	72 a
Fredonia 2	-	57 a	-	-	-	69 a
Lincolnville 1	-	60 b	-	-	77 a	-
Lincolnville 2	-	64 a	-	-	76 a	-
Winchester 1	55 a	-	-	64 a	67 a	-
Winchester 2	57 a	-	-	52 a	59 a	-

1-number next to location represents sampling date

2-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

3-CS (Case), GP (Great Plains), LD (Landoll), CD (conventional disk), NT (no-till), ST (strip-till)

Table 3-26 2011 Residue Decomposition results

2011 Residue Decomposition (% ash free residue)							
	Treatment[2,3]						
Location[1]	CS	GP	LD	SF	SP	NT	ST
At. County 1	-	79 b	-	-	85 a	85 a	-
At. County 2	-	76 b	-	-	75 b	85 a	-
Downs 1	-	-	84 a	-	-	85 a	-
Downs 2	-	-	76 a	-	-	68 a	-
Fredonia 1	-	72 a	-	-	-	-	67 a
Fredonia 2	-	54 b	-	-	-	-	65 a
Garden City 1	79 b	-	83 a	75 b	-	83 a	-
Garden City 2	88 a	-	69 c	81 b	-	85 a	-
Lincolnville 1	-	88 a	-	-	-	89 a	-
Lincolnville 2	-	77 a	-	-	-	82 a	-

1-number next to location represents sampling date

2-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

3-CS (Case), GP (Great Plains), LD (Landoll), SF (Salford), SP (Spader), NT (no-till), ST (strip-till)

Table 3-27 2010 Grain yield results

2010 Grain Yield (Mg/ha)						
	Treatment[1,2]					
Location	**CS**	**GP**	**LD**	**CD**	**NT**	**ST**
Copeland	12.79 a	12.80 a	11.93 a	-	12.25 a	-
Fredonia	-	10.88 a	-	-	-	11.07 a
Lincolnville	-	5.44 a	-	-	4.99 a	-
Winchester	11.05 a	-	-	9.68 a	9.63 a	-

1-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

2-CS (Case), GP (Great Plains), LD (Landoll), CD (conventional disk), NT (no-till), ST (strip-till)

Table 3-28 2011 Grain yield results

2011 Grain Yield (Mg/ha)						
	Treatment[1,2]					
Location	**CS**	**GP**	**LD**	**SF**	**SP**	**NT**
At. County	-	11.86 a	-	-	12.24 a	12.24 a
Downs	-	-	2.89 a	-	-	3.17 a
Garden City	8.39 b	-	8.51 b	8.55 b	-	9.29 a
Lincolnville	-	4.76 a	-	-	-	4.78 a

1-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

2-CS (Case), GP (Great Plains), LD (Landoll), SF (Salford), SP (Spader), NT (no-till)

Table 3-29 2010 Gray leaf spot (GLS) results

2010 Gray Leaf Spot Incidence (% population affected)						
	Treatment[1,2]					
Location	CS	GP	LD	CD	NT	ST
Copeland	90 a	89 a	92 a	-	90 a	-
Fredonia	-	25 a	-	-	-	22 a
Lincolnville	-	10.5 a	-	-	10.2 a	-
Winchester	17 b	-	-	16 b	26 a	-

2010 Gray Leaf Spot Severity (lesions/plant)						
	Treatment[1,2]					
Location	CS	GP	LD	CD	NT	ST
Copeland	84 a	90 a	96 a	-	79 a	-
Fredonia	-	4.58 a	-	-	-	4.3 a
Lincolnville	-	9.0 a	-	-	5.5 a	-
Winchester	46 b	-	-	43 b	72 a	-

1-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

2-CS (Case), GP (Great Plains), LD (Landoll), CD (conventional disk), NT (no-till), ST (strip-till)

Table 3-30 2011 Gray leaf spot (GLS) results

2011 Gray Leaf Spot Incidence (% population affected)						
	Treatment[1,2]					
Location	CS	GP	LD	SF	SP	NT
At County	-	28 a	-	-	21 b	32 a
Garden City	8.0 a	-	9.0 a	12.0 a	-	15.0 a

2011 Gray Leaf Spot Severity (lesions/plant)						
	Treatment[2]					
Location	CS	GP	LD	SF	SP	NT
At County	-	8 b	-	-	9 b	15 a
Garden City	7.0 a	-	12.0 a	5.0 a	-	10.0 a

1-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

2-CS (Case), GP (Great Plains), LD (Landoll), SF (Salford), SP (Spader), NT (no-till)

Table 3-31 2010 *Macrophomina phaseolina* results

2010 *Macrophomina phaseolina* (CFUs/g of soil)						
	Treatment[1,2]					
Location	CS	GP	LD	CD	NT	ST
Copeland	56 b	92 a	38 b	-	48 b	-
Fredonia	-	67 a	-	-	-	72 a
Lincolnville	-	120 a	-	-	104 b	-
Winchester	167 a	-	-	135 a	80 b	-

1-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

2-CS (Case), GP (Great Plains), LD (Landoll), CD (conventional disk), NT (no-till), ST (strip-till)

Table 3-32 2011 *Macrophomina phaseolina* results

2011 *Macrophomina phaseolina* (CFUs/g of soil)							
	Treatment[1,2]						
Location	CS	GP	LD	SF	SP	NT	ST
At County	-	213 a	-	-	250 a	241 a	-
Downs	-	-	85 b	-	-	113 a	-
Fredonia	-	169 a	-	-	-	-	201 a
Garden City	106 a	-	106 a	76 b	-	101 a	-
Lincolnville	-	114 b	-	-	-	173 a	-

1-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

2-CS (Case), GP (Great Plains), LD (Landoll), SF (Salford), SP (Spader), NT (no-till), ST (strip-till)

Table 3-33 2010 *Fusarium spp*. results

2010 *Fusarium spp.* (CFUs/g of soil)						
			Treatment[1,2]			
Location	**CS**	**GP**	**LD**	**CD**	**NT**	**ST**
Copeland	100 a	110 a	118 a	-	115 a	-
Fredonia	-	126 a	-	-	-	134 a
Lincolnville	-	100 a	-	-	121 a	-
Winchester	184 a	-	-	98 b	139 a	-

1-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

2-CS (Case), GP (Great Plains), LD (Landoll), CD (conventional disk), NT (no-till), ST (strip-till)

Table 3-34 2011 *Fusarium spp*. results

2011 *Fusarium spp.* (CFUs/g of soil)							
				Treatment[1,2]			
Location	**CS**	**GP**	**LD**	**SF**	**SP**	**NT**	**ST**
At County	-	230 a	-	-	227 a	258 a	-
Downs	-	-	230 a	-	-	234 a	-
Fredonia	-	166 a	-	-	-	-	164 a
Garden City	169 a	-	159 a	174 a	-	163 a	-
Lincolnville	-	143 a	-	-	-	139 a	-

1-different lowercase letters represents significant difference at p=0.05 and comparisons are made across rows

2-CS (Case), GP (Great Plains), LD (Landoll), SF (Salford), SP (Spader), NT (no-till), ST (strip-till)

Chapter 4 - Conclusions

The purpose of the study was to determine the short-term (one growing season) effects of a vertical-tillage operation on near surface soil properties, seedling emergence, crop growth and development, yield, residue decomposition, disease incidence and severity, and the quantification of pathogen propagules in soil and crop residue.

The effects of tillage on soil physical properties were quite variable across sites and varied with the timing of the sampling. In general, there were few significant differences with respect to bulk density. One concern that has been voiced with the use of vertical tillage equipment is the possibility of creating a tillage compaction layer in the zone just below the tillage depth. The Lincolnville 2011 site VT treatments seemed to indicate a possible compaction issue in the 5-10 and 10-15 cm depths as opposed to NT, however, this difference was not significant. It was observed at several locations where no-till or minimum till was the current practice, that the tillage treatment would have a lower bulk density in the top 0-5 cm. This occurred because the tillage operation would fluff up the top region of the soil, but usually was not enough to see significant differences. These results were similar to studies done by McVay et al. (2006) as well as Stone and Schlegel (2010).

Similarly, the MWD of WSA was not often significantly different across treatments and site years. The Winchester and Lincolnville 2010 NT tended to have larger MWD than the other tillage methods, but there were few instances where this was significant. Research in the past has shown that MWD can influence soil infiltration rates. In 2010 at Lincolnville, the NT treatments had greater MWD of soil aggregates and greater steady-state infiltration rates compared to the VT treatments. These observed were similar to when Stone and Schlegel (2010) found a significant and positive correlation between MWD and soil infiltration. Similar results were observed in 2011 at Fredonia, the VT treatment had greater MWD and soil infiltration compared to the ST treatment. No single tillage treatment independently showed to improve or reduce soil infiltration rates in 2010 or 2011 on a consistent basis. Similarly, the time to runoff measurements were not dependent on the tillage treatment. Soil time to runoff was found to be influenced at Fredonia in 2010 by soil water content. The VT treatments there had a greater soil water content and that led to quicker runoff for those plots.

At Copeland in 2010, Lincolnville in 2010, and Garden City in 2011, the NT treatment had consistently greater soil water content than the other three treatments on average. The NT treatments at several locations showed this pattern sometimes, and at other locations and across both years the tilled treatments would have greater soil water content. Baumhardt and Jones (2002) also observed varied results with soil water content when comparing conventional tillage to conservation tillage.

Soil active carbon (SAC) was meant to determine the change in soil biological activity. Most of the comparisons made between treatments across all locations had no significant difference in SAC levels and there was no treatment that continuously had a greater SAC level across all treatments and both years. Increased soil biological activity could have an impact on residue, by increasing decomposition rates, but this was not observed in our study.

When trying to determine how tillage can affect residue decomposition there are two different views that were considered. One is that by incorporating the residue into the soil and coming into contact with more soil biological activity, that might hypothetically increase soil residue decomposition. Avid no-tillers and soil health advocates would argue that by leaving the soil in a more natural state, there is increase soil biological activity that is not interrupted and that would lead to increased residue decomposition. The data with this study showed that NT treatments often had residue breakdown that was equal to or greater than the tillage treatments.

Eckert and Johnson (1985) stated that no-till systems have been shown to increase soil test P and K that is plant available. This result was not observed and in 2011 at Downs and Lincolnville where the fields had been in no-till for quite a few years the soil test P and K were positively influenced by tillage. The VT treatments showed a greater concentration of P and K at most depths compared to the NT treatments, although it was not significantly different. This could be due to the introduction of tillage which induced a release of nutrients from the soil. There were no significant differences noted when looking at soil nutrients across different depths at other locations as well.

Residue cover was very dependent on the tillage operation. Across all locations and both crop years, the NT treatments had significantly greater residue cover than the other treatments. The initial residue cover at the beginning of the crop season could have influenced the crop emergence. One complaint sometimes heard about no-till systems is the issue of cooler and wetter soils at planting and how that can affect crop emergence (Sumner et al., 1981). This was observed at Lincolnville and Winchester in 2010; the tillage treatments had the lowest amount of cover but had significantly greater crop emergence. Other locations experienced no significant differences with crop emergence.

The incidence and severity of *Cercospora zea-maydis* was influenced heavily by the tillage treatment. When looking at both years of data, the NT treatments had significantly greater incidence and severity of gray leaf spot compared to the tillage treatments. This result was consistent with what Payne et al. (1987) observed in a two year study looking at GLS in NT, CD, and plowed tillage treatments. It also appeared that the incidence and severity of GLS was also influenced by the residue left from the previous crop. *Macrophomina phaseolina* was affected by tillage treatments. At several locations the NT treatments had greater concentrations of *Macrophomina* and at others the tillage treatments had the greater concentration. Significant differences were observed at several locations but there was no trend to which treatments were affected. The same results were observed with the concentration of *Fusarium* in 2010 and 2011. Some more work that could have been done would have been to perform in-field measurements (split open stalks) to determine the population of the crop affected by *Macrophomina* and *Fusarium* and then compare that to the concentrations of the two fungal pathogens in residue and soil samples taken to see if there was a correlation between the two datasets.

Overall, any differences in the soil, plant, and pathogen indicators have not resulted in significant yield improvements in any of the site years. At Lincolnville in 2010, the yield appeared to be influenced by initial crop emergence. The NT treatments had significantly lower crop emergence and in the end, had a lower crop yield compared to the VT treatments.

From the result of this project, one could conclude that a one-time vertical tillage operation in a no-till system has no influence on many soil, agronomic, and disease properties. More site years could be done to further the amount of data that would be available to help make a conclusion. Information gained from this project will be disseminated to extension clientele including extension educators, producers, commodity groups, and agricultural professionals.

References

Afzalinia, S., Solhjou, A. A., and Eskandari, I. 2011. Effects of subsoiling on some soil physical properties and wheat yield in dry land conditions. J. of Agricultural Sci.Tech. 1:842.

Alvear, M., Rosas, A., Rouanet, J. L., and Borie, F. 2005. Effects of three soil tillage systems on some biological activities in an ultisol from southern Chile. Soil Tillage Res. 82: 195-202.

Baird, R.E., Watson, C.E., and Scruggs, M. 2003. Relative Longevity of *Macrophomina phaseolina* and Associated Mycobiota on Residual Soybean Roots in Soil. Plant Disease 87:563-566

Barker, K.R., Koenning, S.R. 1998. Developing sustainable systems for nematode management. Annu. Rev. Phytopathology. 36:165-205.

Benjamin, J.G., Mikha, M., Nielsen, D.C., Vigil, M.F., Calderon, F., and Henry, W.B. 2007. Cropping intensity effects on physical properties of a no-till silt loam. Soil Sci. Soc. Am. J. 71: 1160-1165.

Bergstrom, G. C. 1989. Be on the lookout for gray leaf spot on corn. Ag Impact, 16:8.

Bergstrom, G. C., and Nicholson, R. L. 1999. The biology of corn anthracnose: Knowledge to exploit for improved management. Plant Disease, 837. 596-608.

Bernier, H., Bostock, G., Raghavan, G. S. V., and Broughton, R. S. 1989. Subsoiling effects on moisture content and bulk density in the soil profile. Applied Eng. Ag. 5: 24-28.

Blanco-Canqui, H. and Lal, R. 2007. Regional assessment of soil compaction and structural properties under no-till farming. Soil Sci. Soc. of Am. J. 71: 1770-1778.

Blanco, H., and R. Lal. 2008. Principles of soil conservation and management. Springer Publishing Co., New York.

Blanco-Canqui, H., Stone, L. R., Schlegel, A. J., Lyon, D. J., Vigil, M. F., Mikha, M. M., Stahlman, P.W., and Rice, C.W. 2009. No-till induced increase in organic carbon reduces maximum bulk density of soils. Soil Sci. Soc. Am. J. 73: 1871-1879.

Blanco-Canqui, H., Stone, L. R., and Stahlman, P. W. 2010. Soil response to long-term cropping systems on an argiustoll in the central Great Plains. Soil Sci. Soc. Am. J. 74:602-611.

Bockus, W.W., and Classen, M.M. 1992. Effects of crop rotation and residue management practices on severity of tan spot of winter wheat. Plant Diseases 76:633-636.

Bockus, W.W., Shroyer, J.P. 1998. The impact of reduced tillage on soil borne plant pathogens. Annual Review Phytopathology. 36:485-500.

Boosalis, M. G., Doupnik, B. L., and Watkins, J. E. 1986. In Sprague M. A. T.,G.B. (Ed.), Effect of surface tillage on plant diseases.

Bradford, J.M., Peterson, G.A. 2000. Conservation tillage, In: Sumner, M.E. (Ed), Handbook of Soil Science. CRC Press, Boca Raton, FL, USA, pp G247-G270.

Broders, K. D., Lipps, P. E., Paul, P. A., and Dorrance, A. E. 2007. Characterization of *Pythium* spp. associated with corn and soybean seed and seedling disease in Ohio. Plant Disease. 91:727-735.

Brooks, S. A., Anders, M. M., and Yeater, K. M. 2009. Effect of cultural management practices on the severity of false smut and kernel smut of rice. Plant Disease. 93:1202-1208.

Buschiazzo, D.E., J.L. Panigatti, and P.W. Unger. 1998. Tillage effects on soil properties and crop production in the subhumid and semiarid Argentinean Pampas. Soil Till. Res. 49:105-116.

Carignano, M., Staggenborg, S. A., and Shroyer, J. P. 2008. Management practices to minimize tan spot in a continuous wheat rotation. Agron. J. 100:145-153.

Cook, G. E., Boosalis, M. G., Dunkle, L. D., and Odvody, G. N. 1973. Survival of *Macrophomina phaseoli* in corn and sorghum stalk residue. Plant Disease Reporter, 57:873-875.

Cook, R.J. 1990. Twenty-five years of progress towards biological control, In: Hornby, D. (Ed), Biological Control of Soilborne Pathogens, CAB International, Wallingford, United Kingdom, pp. 1-14.

Eckert, D.J., and J.W. Johnson. 1985. Phosphorus fertilization in no-tillage corn production. Agron. J. 77:789-792.

Feng, F. X., Huang, G. B., Chai, Q., and Yu, A. Z. 2010. Tillage and straw management impacts on soil properties, root growth, and grain yield of winter wheat in northwestern china. Crop Sci. 50:1465-1473.

Fernandez, M. R., Huber, D., Basnyat, P., and Zentner, R. P. 2008. Impact of agronomic practices on populations of *Fusarium* and other fungi in cereal and noncereal crop residues on the Canadian prairies. Soil Tillage Res. 100: 60-71.

Fernandez, M. R., McConkey, B. G., and Zentner, R. P. 1999. Effects of tillage method and fallow frequency on leaf spotting diseases of spring wheat in the semiarid Canadian prairies. Soil Tillage Res. 50:259-269.

Follett, R. F., & Peterson, G. A. (1988). Surface soil nutrient distribution as affected by wheat-fallow tillage systems. *Soil Science Society of America Journal*, *52*(1), 141-147.

Frank, K., D. Beegle, and J. Denning. 2011. Phosphorous. *IN* Recommended Chemical Soil Test Procedures for the North Central Region. North Central Regional Research Publication No. 221 23-25.

Gameda, S., et al., 1985. A review of subsoil compaction and crop response. Conference on Soil Dynamics. Vol 5: 970-978

Gathala, M., Ladha, J. K., Saharawat, Y., Kumar, V., and Kumar, V. 2011. Effect of tillage and crop establishment methods on physical properties of a medium-textured soil under a seven-year rice-wheat rotation. Soil Sci. Soc. Am. J. 75:1851-1862.

Govaerts, B., Fuentes, M., Mezzalama, M., Nicol, J. M., Deckers, J., Etchevers, J. D., Figueroa-Sandoval, B, and Sayre, K. 2007. Infiltration, soil moisture, root rot and nematode populations after 12 years of different tillage, residue and crop rotation managements. Soil Tillage Res. 94:209-219.

Gregory, J.M. 1982. Soil cover prediction with various amounts and types of residue. Trans. ASAE 25:1333-1337.

Haas, H.J., Evans, C.E., and Miles, E.F. 1957. Nitrogen and carbon changes in Great Plains soils as influenced by cropping and soil treatments. USDA Tech. Bull. 1164. U.S. Government Print Office, Washington, DC.

Hargrove, W.L., Reid, J.T., Touchton, J.T. and Gallaher, R.N., 1982. Influence of tillage practices on the fertility status of an acid soil double-cropped to wheat and soybeans. Agron. J. 74:684-687.

Jimenez, D.A.C. 2011. Influence of soils, nutrition, and water relations upon charcoal rot disease processes in Kansas. M.S. Thesis. Kansas State University. Dowloaded 31 Oct 2014 http://krex.k-state.edu/dspace/bitstream/handle/2097/10747/DavidCruz2011.pdf?sequence=3

Jirak-Peterson, J. C., and Esker, P. D. 2011. Tillage, crop rotation, and hybrid effects on residue and corn anthracnose occurrence in Wisconsin. Plant Disease. 95:601-610.

Karlen, D.L., Rosek, M.J., Gardner, J.C., Allan, D.L., Alms, M.J., Bezdicek, D.F., Flock, M., Huggins, D.R., Miller, B.S., and Staben, M.L. 1999. Conservation Reserve Program effects on soil quality indicators. J. Soil Water Conserv. 54: 439-444.

Keller, N. P., Bergstrom, G. C., and Carruthers, R. I. 1986. Potential yield reductions in maize associated with an anthracnose/European corn borer pest complex in New York. Phytopathology. 76:586-589.

Lehman, R. M., Osborne, S. L., and Rosentrater, K. A. 2008. No evidence that *Bacillus thuringiensis* genes and their products influence the susceptibility of corn residue to decomposition. Agronomy Journal. 100:1687-1693.

Licht, M. 2005. Strip-tillage effect on seedbed soil temperature and other soil physical properties. Soil Tillage Res. 80:233-249.

Liesch, A., Krueger, E., and Ochsner, T. 2011. Soil structure and physical properties under rye-corn silage double-cropping systems. Soil Sci. Soc. America J. 75:1307-1314.

Linden, D.R., Clapp, G.E. and Dowdy, R.H. 2000. Long-term corn grain and stover yields as a function of tillage and residue removal in east central Minnesota. Soil Tillage Research. 44:35-54.

Lipps, P. E., and Deep, I. W. 1991. Influence of tillage and crop rotation on yield, stalk rot, and recovery of *Fusarium* and *Trichoderma* spp. from corn. Plant Disease. 75:828-833.

Luo XiWen, Li JiuHao, Zhu YuQing, Yang Zhou, Li Jun, and Huang HaiQin. 2006. Effect of tillage methods on soil physical properties and moisture content of latosol. Nongye Jixie Xuebao = Transactions of the Chinese Society for Agricultural Machinery 37:62-66.

Manea, D. N., Piloca, L., Carciu, G., and Alda, S. 2009. Effect of tillage on soil physical features, weed control and yield in winter wheat and maize. Research Journal of Agricultural Science. 41:442-447.

Manzo, S. K., and Claflin, L. E. 1984. Survival of *Fusarium moniliforme* hyphae and conidia in grain sorghum stalks. Plant Disease. 68:866-867.

McVay, K. A., Budde, J. A., Fabrizzi, K., Mikha, M. M., Rice, C. W., Schlegel, A. J., Peterson, D.E., Sweeney, D.W., and C. Thompson. 2006. Management effects on soil physical properties in long-term tillage studies in Kansas. Soil Sci. Soc. Am. J. 70:434-438.

Morris, R. 2010. The adoption of non-inversion tillage systems in the United Kingdom and the agronomic impact on soil, crops and the environment-A review. Soil Tillage Res. 108:1-15.

Nazareno, N. R. X. ., Lipps, P. E., and Madden, L. V. 1992. Survival of *Cercospora zeae-maydis* in corn residue in Ohio. Plant Disease. 76:60-63.

Nazareno, N. R. X. d., Lipps, P. E., and Madden, L. V. 1993. Effect of levels of corn residue on the epidemiology of gray leaf spot of corn in Ohio. Plant Disease. 77:67-70.

Obalum, S. E., and Obi, M. E. 2010. Physical properties of a sandy loam ultisol as affected by tillage-mulch management practices and cropping systems. Soil Tillage Res. 108:30-36.

Paulitz, T. C., Schroeder, K. L., and Schillinger, W. F. 2010. Soilborne pathogens of cereals in an irrigated cropping system: Effects of tillage, residue management, and crop rotation. Plant Disease. 94:61-68.

Payne, G. A., Duncan, H. E., and Adkins, C. R. 1987. Influence of tillage on development of gray leaf spot and number of airborne conidia of *Cercospora zeae-maydis*. Plant Disease, 71:329-332.

Reeder, J.D., Schuman, G.E. and Bownman, R.A. 1998. Soil C and N changes on conservation reserve program lands in the Central Great Plains. Soil Tillage Res. 47:339-349.

Roane, C. W., Harrison, R. L., and Genter, C. F. 1974. Observations on gray leaf spot of maize in Virginia. Plant Disease Reporter. 58:456-459.

Saab, I. 2005. Stress emergence in corn. Crop Insights 5:1-4.

Sistani, K. R., Mikha, M. M., Warren, J. G., Gilfillen, B., Acosta-Martinez, V., and Willian, T. 2010. Nutrient source and tillage impact on corn grain yield and soil properties. Soil Sci. 175:593-600.

Six, J. A. E. T., Elliott, E. T., & Paustian, K. (2000). Soil macroaggregate turnover and microaggregate formation: a mechanism for C sequestration under no-tillage agriculture. *Soil Biology and Biochemistry*, *32*(14), 2099-2103.

Steiner, J. L., Schomberg, H. H., Unger, P. W., and Cresap, J. 1999. Crop residue decomposition in no-tillage small-grain fields. Soil Sci. Soc. Am. J. 63:1817-1824.

Steiner, J. L., Schomberg, H. H., Unger, P. W., and Cresap, J. 2000. Biomass and residue cover relationships of fresh and decomposing small grain residue. Soil Sci. Soc. Am. J. 64:2109-2114.

Stinner, B.R., and House. G.J. 1990. Arthropods and other invertebrates in conservation-tillage agriculture. Annual Review of Entomology 35:299-318.

Stockfisch, N., Forstreuter, T. and Ehlers, W. 1999. Plowing effects on soil organic matter after twenty years of conservation tillage in Lower Saxony, Germany, Soil Tillage Res. 52:91-101.

Stone, L. R., and Schlegel, A. J. 2010. Tillage and crop rotation phase effects on soil physical properties in the west-central Great Plains. Agronomy J. 102:483-491.

Sumner, D. R., Doupnik, B. J., and Boosalis, M. G. 1981. Effects of reduced tillage and multiple cropping on plant diseases. Ann.Rev. Phytopathology. 167-187.

Thomas, G.W., Hazler, G.R., and Blevins, R.L. 1996. The effects of organic matter and tillage on maximum compactibility of soils using the Proctor test. Soil Sci. 161:502-508.

Uri, N.D. 1999. Conservation tillage in U.S. agriculture. Food Product Press, N.Y., London, Oxford, pp 126.

van Es, H., Schindelbeck, R. Field procedures and data analysis for the Cornell sprinkle infiltrometer. Cornell Univ. Dept. of Crop and Soil Sciences Research Series R03-01. Ithaca, NY. http://soilhealth.cals.cornell.edu/research/infiltrometer/infil_manual.pdf

Verhulst, N., Nelissen, V., Jespers, N., Haven, H., and Sayre, K. 2011. Soil water content, maize yield and its stability as affected by tillage and crop residue management in rainfed semi-arid highlands. Plant and Soil. 344:73-85.

Warncke, D. and J.R. Brown. 2011. Potassium and other basic cations. *IN* Recommended Chemical Soil Test Procedures for the North Central Region. North Central Regional Research Publication No. 221 31-32

White, D.G. 1999. Compendium of Corn Diseases, 3rd edition. American Phytopathological Society, St. Paul, MN.

Worsham, A.D., 1980. No-till corn: Its outlook for the 1980's. Proc. Annu. Corn Sorghum Conf. 35:146-163.

Wrather, J.A., Kendig, S.R., and Tyler, D.D. 1998. Tillage Effects on *Macrophomina phaseolina* Population Density and Soybean Yield. Plant Disease 82:247-250.

Zhai, R., R.G. Kachanoski, and R.P. Voroney. 1990. Tillage effects on the spatial and temporal variation of soil water. Soil Sci. Soc. Am. J. 54:186-192