EARLY SEASON APPLICATIONS OF FUNGICIDES TO CONTROL DISEASES IN WINTER WHEAT

by

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Abstract

Reducing plant disease pressure in wheat (*Triticum aestivum* L.) is an important management goal for producers. Over the last 10 years, steadily increasing adoption of no-till management has resulted in both over wintering as well as increased inocula levels for many diseases associated with straw residue. Reduced rates of fungicide, applied at early stages of plant development were investigated to measure their effect on reducing inocula density, controlling disease pressure and ultimately increasing grain yield in both no-till and conventionally planted wheat in Kansas from 2004-2008. Different cultivars were chosen based upon their resistance or susceptibility to specific diseases. The main diseases of interest were leaf rust (*Puccinia triticina*), speckled leaf blotch (*Septoria triticii*), tan spot (*Pyrenophora tritici-repentis*), and powdery mildew *(Blumeria graminis (DC.) E.O. Speer f.sp. tritici*). Two different studies were conducted. In 2004-2007, studies focused on the impact of spraying 133g/ha, half the normal rate, of propiconazole at Feekes 4.0. Disease levels and grain yields were evaluated. In 2008, four fungicide treatments and six cultivars were evaluated at 6 locations. Grain yield, measurements of green leaf duration, and grain yield components were also evaluated. No statistical differences were found in the 2004-2006 studies, but trends were apparent with grain yield increasing by 10.9%. The 2006-2007 growing season was a failure due to a late spring freeze. In the 2007-2008 growing season, statistically different grain yields were observed among some cultivars at two locations. At Partridge, KS and Salina, KS, Jagalene treated with an early-season application of propiconazole yielded significantly more than the untreated check, providing 11.4% and 9.5% increases, respectively. Early fungicide treatments also increased green leaf duration and reduced disease pressure. Further, larger scale studies need to be conducted to more accurate quantify the benefits of early applications of fungicides.

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Dedication

I dedicate this paper to my parents, Randy and Jill Rich, who always stood behind me through everything. They never wavered in their love and support, through good times and bad. It is hard for me to put into words how much they both mean to me. The only thing that comes to mind is I Love both of you very much!!

CHAPTER 1 - Review of Literature

“Increased interest in soil conservation and the need to improve soil structure and organic matter have more growers considering no-till cropping systems.” (Heiniger and Weisz, 2004). No-till is generally defined as the ability to increase organic matter, soil water availability and improve structure by never disturbing the soil using agriculture tillage equipment. The recognized savings in fuel consumption, as well as the benefits associated with reduced labor, have also increased the interest in minimum or no-till management. Total area planted as either minimum till or no-till in Kansas has risen dramatically since 1989, from 2% to 22% of total planted wheat (*Triticum aestivum* L.) acres (Karstens et al., 2006). Kansas planted 10.3 million acres of wheat in 2007 (Goltz et al., 2007), indicating over 1.5 million acres of wheat was planted in a no-till situation. Along with the significant positive effects such as improved soil water availability, there are some negatives associated with no-till. Increased severity in disease and insect infestation can occur as residue from small grains can create a bridge to the next crop (Heiniger and Weisz, 2004). Similar effects occur in continuous wheat; a common practice in central Kansas, where the fields are either tilled or chemical fallowed during the summer and planted in the fall. A study by Bockus and Claassen (1992) determined that moldboard plowing reduced the incidence of tan spot compared to chiseling and no-till in a continuous wheat situation. They also determined there were very little to no differences among the three treatments in a wheat-sorghum (*Sorghum bicolor* L.) rotation. With the increase in no-till planted acres and the inability of some producers to plan a crop rotation that reduces disease severity, fungicides provide an opportunity to control disease and increase yields. This research was designed to estimate the level of control early-season reduced rate fungicide applications would have on a range of wheat diseases and, ultimately, on grain yield.

Diseases

Tan spot (*Pyrenophora tritici-repentis*) along with the Septoria leaf disease complex (SLDC): *Stagonospora nodorum* (glume blotch), *Septoria tritici* (speckled leaf blotch), make up the set of leaf spot diseases that reduce yields and test weights when epidemics occur (McMullen, 2003). In 2007, the leaf spot complex caused an estimated 3.1% yield loss in the state of Kansas (Appel et al., 2007), corresponding to the loss of about 1 bushel per acre (67.8 Kg ha^{-1}). Tan spot survives and reproduces in standing wheat stubble and residue that is laying on the soil surface (McMullen, 2003). The pathogen survives as mycelia or pseudothecial initials in residue (Bockus and Claassen, 1992). The fungus produces black pinhead like structures, called pseudothecia, on wheat residue, which release ascospores in spring and early summer. Also, asexual spores, known as conidia, are released from dead leaves and lesions during the growing season, providing secondary inoculum (Bockus and Claassen, 1992). Air currents carry the ascospores within the same field or to nearby fields. The amount of primary inoculum, or pseudothecia, is a factor affecting disease severity during the growing season (Bockus and Claassen, 1992). Wheat planted into fields with wheat stubble or residue is more vulnerable than wheat planted into a field without any stubble (McMullen, 2003). Also, Watkins et al. (1978) concluded that a severe outbreak in Nebraska on wheat grown without residue was likely caused by secondary inoculum.

Tan spot is an important disease in wheat. In Kansas it ranks as the third most important wheat disease, following leaf rust and wheat streak mosaic virus (Appel et al., 2007). The likely increase in no-till acres in the future will make tan spot even more important. There are many different ways to prevent or manage an outbreak. Non-host crops in a rotation and burying or destroying residue can create a barrier by keeping tan spot mycelium from surviving on residue (Bockus and Claassen, 1992; Bockus and Shroyer., 1998). Fungicides can also be used to help control tan spot (Bockus, 2004). However, host plant resistance is the management strategy that gives farmers the greatest degree of flexibility. Moderate levels of resistance have been deployed, but there is no source of complete resistance. In Kansas, wheat cultivars with resistance or tolerance currently reduce damage 50 to 75% (Bockus et al., 2001). This resistance has been very helpful in reducing tan spot losses by 63% between 1976 and 2000 (Bockus et al., 2001). According to an unpublished study by Bockus, that trend has continued with 75% reduction in 2006 (Singh et al., 2008). However, there is still room for improvement.

Races of tan spot have been identified by their ability to produce necrotic and/or chlorotic lesions on wheat lines (Andrie et al., 2007; Ciufetti et al., 1998). Tan spot has been shown to be in the host selective toxin system (HST). In the HST system, the fungus uses multiple proteinaceous toxins to cause disease symptoms (Walton, 1996). Three host selective toxins have been found within *Pyrenophora tritici-repentis* (Singh et al., 2008; Andrie et al., 2007). *Ptr Tox A* produces necrotic symptoms in susceptible wheat cultivars (Balance et. Al., 1989; Tomas et. al., 1990). *Tsn1* is the insensitivity gene to *Ptr ToxA* and is inherited recessively (Anderson et al., 1999). *Tsn1* is located on the long arm of chromosome 5B (Faris et al., 1996). *Ptr ToxB* produces extensive leaf chlorosis. The insensisivity gene is *tsc2* and is located on the short arm of chromosome 2B (Strelkov et al., 1999; Friesen and Faris, 2004). The last of the known host selective toxins, *Ptr Tox C*, is a low molecular weight, nonionic, polar molecule that causes leaf chlorosis. An insensitivity gene, *tsc1*, has been mapped on the short arm of chromosome 1A (Effertz et al., 2002; Faris et al., 1997). The toxic components were identified after Lamari and Bernier (1989) had set up a classification system based on lesion types. Resistance was classified as very small dark brown to black spots with little to no chlorosis. Susceptibility was classified as coalescing chlorotic or tan necrotic lesions. Lamari et al. (1995) developed a proposed race classification based on chlorotic and necrotic symptoms on a differential set of wheat genotypes. Race 1, which is the most prevalent in the Great Plains (Singh et al., 2008), produces both necrotic and chlorotic symptoms. Race 2 produces necrotic symptoms only, where as races 3 and 5 produce chlorotic symptoms. Race 4 appears to be avirulent according to Lamari et al. (1995). *Ptr Tox A* is produced by both races 1 and 2 (Tomas and Bockus, 1987;

Touri et al., 1995; Lamari and Bernier, 1989). Race 3 and race 5 produce *Ptr Tox C* and *Ptr Tox B* respectively (Effertz et al., 2002; Orolaza et al.1995). Race 1 also has the chlorosis toxin *Ptr Tox C* (Singh et al., 2008). Recently, up to 11 races have been found around the world. Races 1-5 and 9 have been found in the United States, while races 6-8 were identified in North Africa and the Middle East and races 10 and 11 were found in South America (Singh et al., 2006). Tan spot resistance can have both qualitative (Gamba and Lamari. 1998; Lamari and Bernier, 1989; Singh and Hughes, 2005) and quantitative inheritance (Elias et al., 1989; Faris et al.,1997). The majority of recent literature reports that a single recessive gene, *tsn1*, is the primary source of resistance against necrosis caused by races 1 and 2 (Singh and Hughes, 2005; Anderson et al.,1999). These studies indicate a very narrow genetic base for resistance and a need for better control of tan spot. Quantitative resistance is a number of genes with small effects working together to provide, broader more durable resistance. Quantitative trait loci (QTL) corresponding to race specific genes have been found. Major QTL were found on chromosomes 1BS and 3BL that conditioned resistance to the chlorosis-inducing toxin in races 1 and 3 (Faris et al., 1997; Faris and Friesen, 2005). A QTL conditioning resistance for race 1 (Effertz et al., 2002) and race 5 (Freisen and Faris, 2004) has also been identified. In a recent study by Faris and Friesen (2005), they were able to identify two QTL that condition resistance to races 1-3 and 5 on chromosome 1BS and 3BL. This was the first report of a QTL for non-race specific resistance to tan spot. These studies show there has been progress in identification of resistance genes and understanding of the genetics behind tan spot resistance, but additional time, effort and resources are needed to provide broad spectrum resistance in commercial production.

SLDC is similar to tan spot in over-wintering habit (McMullen, 2003). SLDC differs because the complex can over-winter on wild grasses and, once the disease is established spores from pycnidia are rain-splashed to higher leaves and spikes of the wheat plant, resulting in further, more severe infection (McMullen, 2003). Seed-borne infection and infected plant debris are the main sources of inoculum. Airborne ascospores and rain-splashed pycnidiospores from infected debris continue the disease cycle (Eyal, 1999). Parker et al. (1999) suggested that airborne ascospores discharged from pseudothecia are the primary source of inoculum that causes epidemics.

SLDC is caused by both *S.tritici* (speckled leaf blotch) and *S.nodorum* (glume blotch). These two diseases are very distinct in many ways (Eyal, 1999). Speckled leaf blotch is usually observed in temperate climates with wet winters. Glume blotch is found in more northern climates (Leath et al., 1993). Speckled leaf blotch has a 14-21 day window in which pycnidial formation begins, while glume blotch has a 7-14 day period. The shorter period to inoculum production of glume blotch suggests it could cause greater damage than Speckled leaf blotch (Royle et al., 1986). For speckled leaf blotch germinating pycnidiospores penetrate through the stomata (Cohen and Eyal, 1993), while glume blotch has been shown to penetrate directly through the cuticle (Karjalainen and Lountamaa, 1986).

To date, there are 13 genes for resistance to speckled leaf blotch (*Stb1-Stb12, Stb15*) that have been identified and mapped (Table 1.1). The host x fungal genetic interaction of speckled leaf blotch is the least studied of the major diseases in wheat. Resistance has been shown to be both quantitative and qualitative, with qualitative resistance following a gene for gene relationship (Jlibene et al., 1994; Zhang et al., 2001; Brading et al., 2002).

Glume blotch can infect both leaves and spikes. Studies have indicated that resistance on leaves is independent of resistance on spikes, thus seedling testing cannot replace field evaluations for spike resistance. (Fried and Meister,1987).

Glume blotch is similar to tan spot in that it has been shown to be part of the (HST) system (Liu et al., 2006). To date, three glume blotch HSTs, *SnTox A, SnTox 1* and *SnTox 2*, have been identified (Friesen et al., 2007; Friesen et al., 2006; Liu et al., 2004a). Quantitative resistance has also been found (Xu et al., 2004) with QTL being identified on 1B, 4B, 6A, and 7B (Liu et al., 2004b; Xu et al., 2004).

Wheat leaf rust, caused by *Puccinia triticina,* is another disease that is of economic importance. Pustules, also known as uredia, are spore masses that are reddish-orange and develop under favorable conditions. Warm days and cool nights with moisture are major factors favoring disease development. These conditions allow penetration of leaf cells and germination of the spores. Nutrients from the wheat plant are utilized to develop new spores which are blown to other wheat plants to continue the cycle (McMullen and Rasmussen., 2002). Urediospores over-winter in more moderate climates and blow northward in the spring (Lipps, 1996). Moderate winters in the northern Central Plains can allow over wintering resulting in an earlier, more severe outbreak of leaf rust. Yield losses can vary from year to year. Losses are greater when the wheat plant is affected from the seedling stage through maturity (McMullen and Rasmussen, 2002). Yield reductions are caused by planting susceptible wheat cultivars and the regular occurrence of leaf rust. Losses can vary from trace to 20%. Losses due to leaf rust in the state of Kansas averaged 3.0% from 1993 to 2005 (Kolmer et al., 2007). Losses in any specific year during the same time period ranged from trace levels to 11.0%.

Leaf rust survival depends on moisture and temperatures, both maximum and minimum, which occur between harvest and emergence of the new crop in the fall. When any of these factors are not met, leaf rust survival from the previous crop is reduced or prevented (Chester, 1946). Sufficient moisture and protection of infected leaves from the winter will help facilitate a flush of urediospores that can cause an epidemic (Hassan et al.1986; Eversmeyer and Kramer, 1994). In Manhattan, KS, leaf rust survived the winter 4 of 7 years (Eversmeyer et al., 1988). In years in which there was no fungal survival, yield reductions were less than 2.0% and years in which there was winter survival of leaf rust yield reductions were greater than 2.0%. Maximum disease severity was the same, but those severities were reached two weeks earlier during the over-wintering years causing the greater yield losses. Eversmeyer et al. (1988) also proposed the possibility of pathogenicity being different from over-wintering inoculum compared to airborne inoculum blown in from southern locations. Eversmeyer and Kramer (1998) set out to develop a model of over-wintering of leaf rust using weather data from 1980 to 1992. They were able use these models to help develop forecasts for leaf rust epidemics. These forecasts, in turn, could help local extension personnel assist producers with timely managment decisions of their wheat crops.

McIntosh et al. (2005) described more than 50 resistance genes. Major resistant genes are race specific and work in a gene-for-gene relationship with leaf rust. The interaction of the resistance gene (R-gene) with the corresponding avirulence (Avr) gene of the pathogen determines whether the reaction is compatible or incompatible (Hulbert et al., 2007). Epidemiologically, selection and the increase of virulent races are the main reasons wheat cultivars lose their effectiveness against leaf rust (Sambroski and Dyck, 1968). To show how virulence to a specific resistance gene can rapidly change, Long et al. (2000) determined that the frequency of a given leaf rust isolate went from 5% to 60% in just a few years. They also stated that there were between 31 and 56 races of leaf rust in the United States. Population structures vary from year to year depending on the current cultivars that are deployed within a certain area. In conclusion, this study determined that epidemics in different parts of the United States are localized from over-wintering sources.

Major gene resistance is not durable and new resistant cultivars have to be released more rapidly. Some sources of adult plant resistance (genes that are turned on when the wheat plant gets to a certain stage of growth) have shown signs of being able to deliver more durable resistance. *Lr34* and *Lr46* have been shown to have durable resistance (Hulbert et al., 2007; Singh et al., 1998). *Lr34* has also been shown to be race non-specific (Kolmer, 1996; Singh et al., 2005), meaning that rust pathotypes are not completely virulent on lines carrying this gene. These durable resistance genes are also known for their slow rusting or partial resistance (Caldwell, 1968). Slow rusting was more fully described in later studies. Ohm and Shaner (1976) and Kuhn et al (1978) both described longer latent periods with fewer and smaller uredinia at 10-14 days compared to susceptible cultivars. *Lr34* alone does not confer an economic level of resistance but in combination with other minor or major genes can confer a high level of resistance. A study by Singh et al. (2005) showed that *Lr34*, combined with different numbers of minor genes, provided a higher level of resistance for each gene added. Hulbert et al. (2007) examined differential gene expression on lines with and without *Lr34* and reported that rust infection down-regulated several genes that are involved with senescence and ethylene biosynthesis. This study also brought up some other issues in terms of which genes are up-regulated and how they could be detrimental to grain yield. A susceptible cultivar without *Lr34* was compared with the same cultivar with *Lr34* (Singh and Huerto-Espino, 1997). The lines were sprayed with fungicide and yields were evaluated. The line without *Lr34* yielded 6% higher than the line carrying *Lr34*.

Powdery mildew (*Blumeria graminis* f. sp. *tritici* Em.Marchal, syn. *Erysiphe graminis* f. sp. *tritici*) is also a very important cool season wheat disease. In very severe situations, yield reductions of 13-34% are observed in the eastern United States (Griffey et al., 1993). In a 2006 state survey by the Kansas Department of Agriculture, powdery mildew caused an estimated 0.1% yield reduction, with a 20-year average loss of 0.22% (Appel et al., 2006).

Stromberg (2000) described powdery mildew symptoms as a group of white patchy spots caused by mycelia. The fungus matures to form sexual structures known as cleistothecia. The sexual cycle allows for genetic recombination in the pathogen (Gotz and Boyle, 1998). The cleistothecia rupture and spores (ascospores) pour out to infect more plants. The fungus also undergoes vegetative sporulation where conidiospores are formed from the mycelium, either in chains or singly. Trigiano et al. (2004) stated that a haustoria feeding structure penetrates the leaf to initiate disease. The fungus is favored by cool, wet climates and can summer on wheat debris to infect new seedlings in the fall.

There have been 34 major powdery mildew resistance genes identified to date. *Pm1, 3, 4, 5* and *8* have more than one allele. The total number of alleles conferring resistance is 49 (Liu et al., 2002; Huang and Roder, 2004; Miranda et al., 2006). Just like the other diseases mentioned above, major gene resistance has been widely used but tends to become ineffective after several years.

Suppression of spore production has been heavily researched. Even with all of the control measures available, we still need more ways to prevent severe epidemics. Severe epidemics start with a heavy spore load from either over-wintering or survival on residue (Eversmeyer and Kramer, 1998; McMullen, 2003). The use of cultivar mixtures has been studied to determine if there can be reductions in spore load of certain diseases. Many studies have been performed on wind-dispersed diseases such as powdery mildew and leaf rust (Mahmood et al., 1991; Mundt, 2002; Jackson and Wennig, 1997). All of these studies were able to show reductions in disease.

The splash-dispersed diseases have not been studied as heavily as the wind-dispersed diseases. When the use of blends to manage these diseases was studied, the results were inconsistent, leading to the conclusion that more research was needed. (Cowger and Mundt, 2002). Cox et al. (2004) conducted a study to assess simultaneous control of tan spot and leaf rust with the use of cultivar mixtures. They concluded that the mixtures were able to reduce leaf rust more than tan spot. The slight yield increases in the study indicated some potential in the ability of cultivar mixtures to suppress diseases simultaneously.

Fungicides

Strobilurins are a set of fungicides that come from the discovery of *Stroblilurus tenacellus,* the mushroom fungus that causes wood-rotting. The isolated natural fungicide is thought to be used to protect the fungus against microbes in the decomposition of the wood (Vincelli, 2002). The discovery of strobilurins led scientist to isolate and produce synthetic strobilurins by chemically altering the compound to be able to tolerate sunlight (Vincelli, 2002).

As a fungicide family, the strobilurins all have a common mode of action. Electron transfer is blocked at the site of quinol oxidation in the cytochrome complex (bc1). This blocks ATP availability for the fungus (Vincelli, 2002; Balba, 2007). Vincelli (2002) noted the importance of this mode of action when he said, “There are millions of biochemical reactions that occur in the fungal cell, these fungicides interfere with just one, very specific biochemical site.” The importance is that the fungus only has to make one change at that site to become resistant to the fungicide. Strobilurins have a preventive effect due to this mode of action, meaning they can affect the fungus by not allowing spores to germinate. Fungal spores are more susceptible to strobilurins than the fungal mycelium (Balba, 2007). Balba reported that once the fungus is growing inside the leaf, strobilurins have very little effect. The majority of the literature states that strobilurins are preventative, but Pataky et al. (2000) studied common leaf rust in sweet corn and determined that even when outbreaks were severe, the strobilurins were able to have some curative effects. There are many types of strobilurins, but they all share the same mode of action. Fungi do not differentiate between the different chemicals and only react to the mode of action (Vincelli, 2002).

Strobilurins have shown some effects in boosting yields in wheat and in other crops. Wheat grain yields were higher in a study by Ruske et al. (2003). The increased biomass had the biggest impact on grain yields. Kresoxim methyl, a strobilurin, has been shown to affect the hormonal balance in wheat. Water- conserving effects and delayed leaf senescence have been also been associated with higher yields (Vincelli, 2002). Also, strobilurins showed a yield increase compared to triazoles in field studies conducted in Wittshire, England. Different amounts of nitrogen fertilizer were applied with both strobilurins and triazoles and, in every case, the strobilurins boosted yields even when disease was not present (www.Kemira.Growhow.com).

The commonly used strobilurin fungicides found in the market place today are azoxystrobin (Quadris®), pyraclostrobin (Headline®) and trifloxystrobin (Compass®), but there are many products available depending on geographic location and the target crop. Most of these fungicides have about a 21-day window of effectiveness. The amount of the active ingredient applied can have a major impact on the duration of control.

Triazoles are the set of fungicides most widely used on a worldwide basis (Fishel, 2005). They are used because of their wide adaptation to many crops from ornamentals to small grains. Triazoles differ from the strobilurins in their mode of action. These fungicides work by inhibiting the biosynthesis of sterol. Sterol is a major component of fungal cell membrane structure (Fishel, 2005). The mode of action is very specific, so there are concerns about development of resistance. Triazoles are taken up by the leaves and moved within the leaf. Triazoles are xylem systemic giving them upward movement, though they are not as mobile as most herbicides. Studies have shown that 3 drops applied to a leaf were taken up and spread throughout the leaf within one day and by days three and seven had increased the amount of fungicide in the leaf (Fishel, 2005). The triazoles have to be taken up by the fungus in order to be effective. For this reason the triazole group of fungicides, are referred to as curative fungicides.

Some of the most common fungicides used in the triazole family are the propiconazoles, in which Tilt® and Bumper® are the most common registered fungicides. Triazoles are also used in seed treatments, the most common of which would be difenoconazole or Dividend®. A full application of triazoles allows around 21 days of protection. A half rate will allow about 14 days of prevention (Syngenta www.syngentacropprotection-us.com).

Previous Efforts in Reduced Rate Fungicide Applications

Propiconazole, from the triazole family of fungicides, and azoxystrobin, from the strobilurin family, are the two fungicides that we will look at extensively. Propiconazole is excellent against powdery mildew but only good to very good on all rusts and tan spot (Hunger and Jackson, 2002). Azoxystrobin is excellent on rusts but is only good on powdery mildew and tan spot (Hunger et al. 2002). Propiconazole should be applied at 4oz. per acre, but can be used up to 6oz. by label. azoxystrobin can be used at 10oz. per acre. A formulation of 4oz of propiconazole and 10oz. of azoxystrobin combines chemistries to provide different modes of action in a single product. A 2oz.

early application of propiconazole can be used in combination with application of a 14oz. rate of propiconazole-azoxystrobin formulation at flag leaf and still be within U.S. federal label requirements.

The 2oz. propiconazole treatment can be tank mixed in the spring along with fertilizer or herbicide to reduce the cost application. There are no negative effects associated with tank mixing of fungicide and herbicide early in the growing season (Severson and Hollingsworth, 2004). In a study done by Ashley et al. (2001) on hard red spring wheat in North Dakota, an early application of propiconazole had some encouraging results. The propiconazole (2oz.) fungicide was applied at the 4-6 leaf stage at three locations. Two locations were planted into continuous wheat. The third location was planted after sunflower (*Helianthus annuus* L.) The two locations planted into continuous wheat had 6.9 and 4.5 bushel/acre increases when compared to the non-treated check. The yield difference at the first location was statistically significant, but test weight was not significantly different. The yield difference at the second location was not statistically significant, but the treated entry did have a significantly higher test weight than the check treatment. The third location planted after sunflower showed no significant effect for yield or test weight. Ashley et al. (2001) explained that there was a significantly higher incidence and severity of tan spot at the continuous sites at the time of fungicide application compared to the third site where sunflower was the previous crop. Incidence refers to the proportion of plants showing signs of disease and severity is the amount of leaf area affected. The two continuous wheat fields had 60 and 70 percent incidence compared with non-host field incidence of 10 percent. Severity was 15 and 10 percent on the continuous wheat fields compared to less than 1 percent at the third site. The early control of tan spot and SLDC in the continuous wheat fields coincided with our anecdotal observations regarding the effect of early infections on yield and test weight.

The rise in no-till cropping systems is part of the effort by producers to farm more efficiently. Disease management is an integral component of crop production. This research on the effects of a reduced rate, early season fungicide application was designed to better understand the value of this practice in wheat production.

Figures and Tables

Table 1.1. Summary of known genes conditioning resistance to S. tritici.

GENE	CHROMOSOMAL LOCATION	Reference
Stb1	5BL	Adhikari et al., 2004b
Stb2	3BS	Adhikari et al., 2004c
Stb3	6DS	Adhikari et al., 2004c
Stb4	7DS	Adhikari et al., 2004a
Stb5	7DS	Arraiano et al., 2001
Stb6	3AS	Brading et al., 2002
Stb7	4AL	McCartney et al., 2003
Stb8	7BL	Adhikari et al., 2003
Stb9	6BS	Chartrain 2004
Stb10	4AS	Chartrain et al., 2005a
Stb11	1BS	Chartrain et al., 2005b
Stb12	4AS	Chartrain et al., 2005a
Stb15	6AS	Arraiano et al., 2007

CHAPTER 2 - Introduction

During the past decade more acres of reduced and no-till systems have been adopted by wheat producers who are looking to reduce input costs as well as increase grain yields. Management systems that increase the amount of crop residue on the soil surface also increase the likelihood of both disease and insect damage (Heiniger and Weisz., 2004). This damage can be reduced or eliminated by planting resistant cultivars, crop rotation, or by utilizing a combination of resistant cultivars and recommended crop protection chemicals. Rotations that involve continuous wheat are especially problematic because of the increased residue and over-wintering potential of wheat diseases. This research was undertaken to investigate the possibility of using early applications of a fungicide to reduce early disease development in central Kansas wheat fields.

No-till systems have been implemented because they increase water use efficiency, minimize both water and wind erosion, increase soil organic matter and improve soil structure (Havlin et al., 1992; Black, 1973). Also, these systems save on fuel costs because the grower is making fewer trips across his land, which also reduces soil compaction. No-till may increasingly be used to fix carbon and reduce carbon dioxide emissions into the earth’s atmosphere (Lal et al., 1998). The increased amount of residue on the soil surface, however, favors diseases and can cause epidemics when primary inocula are allowed to over-winter or survive through the growing season on plant residue (Eversmeyer and Kramer, 1998). Tan spot (*Pyrenophora tritici-repentis*) along with speckled leaf blotch (*Septoria triticii*) and glume blotch (*Stagonospora nodorum*) are three diseases that can increase incrementally under no-till or minimum tillage management (McMullen, 2003). Controlling these diseases is important for continued successful adoption of no-till management, as well as profitability for wheat producer.

Planting cultivars with either resistance or tolerance is an economical and environmentally sound method of control. Tan spot has been reported to reduce wheat grain yields by as much as 20-

50%. *Septoria* species can cause similar yield reductions (Sharp et al., 1976; Rees and Platz, 1983; Shabeer and Bockus, 1988). Cultivars with resistance to tan spot or *Septoria* species were shown to have yield reductions between 1 and 9% compared to disease free plots (Bockus et al., 1997), demonstrating that host plant resistance can still be either improved or supplemented with fungicide. Cultivar mixtures and seed treatments have shown positive results in reducing spore production in wind dispersed diseases such as leaf rust and powdery mildew. Results from these methods on splash-dispersed diseases, like tan spot and the SLDC have been inconsistent and have not been researched as thoroughly (Cowger and Mundt, 2002). A cultivar mixture study conducted in Kansas (Cox et al., 2004) showed that leaf rust was better controlled than tan spot. Simultaneous control using mixtures showed potential and further studies are needed.

The objectives of this research were to examine the effect of early season fungicide treatments, on disease and yield of resistant and susceptible cultivars in no-till and conventional tillage systems. Specifically, our objectives were to: (i) assess the effect of an early fungicide treatment on diseases likely to be elevated in no-till environments; (ii) determine the effect of early fungicide treatments on yield and yield components; (iii) evaluate these effects across several cultivars to better identify parameters critical to the economic benefit of this practice.

CHAPTER 3 - Materials and Methods

Field studies were conducted during the 2004-2005, 2005-2006, 2006-2007 and 2007-2008 growing seasons. During the 2004-2005 and 2005-2006 growing seasons, studies were conducted at three locations. The first was near Partridge, KS where the previous crop was spring oats (*Avena sativa* L.) which was tilled prior to planting. The second location was near Salina, KS where the previous crop was soybeans (*Glycine max* L.) and was tilled prior to planting. The third location was near Belleville, KS and was planted no-till into soybean residue. The 2006-2007 field plots were planted at six locations but were all lost due to the Easter weekend freeze. In 2007-2008 six locations were planted. The first location was near Nardin, OK where the previous crop was sorghum (*Sorghum bicolor L.*) and the land was tilled prior to planting. At the Partridge, KS site, wheat was planted into tilled spring oats. The location near Winfield, KS was no-till planted into double-cropped soybeans that followed a hailed out wheat crop. The location near Salina, KS was planted into corn (*Zea mays L.*) stubble that was tilled prior to planting. Conway Springs, KS was no-till planted into wheat stubble. The location near Junction City, KS was planted after soybeans that were tilled prior to wheat planting. The last location was near Manhattan, KS at the Ashland Bottoms farm managed by Kansas State University. This study was planted into fallowed wheat stubble that had been tilled prior to planting. All studies were planted with a 7-row double disc-opener drill with 19.05 cm spacing between rows. The planter was custom built by several Agripro Wheat employees. Planted plot dimensions were 1.5m wide by 6m long. Fertilizer (11-52-0) was banded within the row at the rate of 84 kg ha^{-1}. All studies were managed by the farmer-cooperator and were fertilized based on yield goals for the area.

The experimental design during 2004-2005 was a randomized complete block design with three replications. In 2005-2006, a randomized complete block with two replications was used. In 2006-2007 and 2007-2008 a split-plot design with four replications was used. Fungicide was the main plot and cultivar being the sub-plot. Statistical analyses were performed with proprietary software from Syngenta.

In 2004-2005, '2145' (Fritz et al., 2002) and Jagalene (PVP# 200200160) from Agripro Wheat were used. In 2005-2006, Jagalene and Neosho (PVP# 200500273) both from Agripro Wheat were used. In 2006-2007 and 2007-2008 Jagalene, 2145, Overley (Fritz et al., 2004), Santa Fe (Westbred LLC; PVP# 200500319), Karl 92 (Sears et al., 1993) and Coker 9184 (PVP# 200200135) from Agripro Wheat were the cultivars tested. Seeding rate for all of the cultivars was targeted for 84 kg ha^{-1}.

Four fungicide treatments were employed: treatment 1- untreated plot; treatment 2- 133g/ha^{-1} rate of propiconazole (Tilt®), at Feekes 4.0; treatment 3- 932g /ha^{-1} application of a mixture of azoxystrobin and propiconazole (Quilt®), at Feekes 10.0; treatment 4- Combination of 133g/ha^{-1} rate of, propiconazole, at Feekes 4.0 and 932g /ha^{-1} application of, a mixture of azoxystrobin and propiconazole at Feekes 10.0. All fungicide applications were made using a backpack sprayer calibrated to spray 200 L ha^{-1}. In 2004-2005 and 2005-2006 growing seasons, only treatments 1, 2 and 3 were applied.

Grain yield, test weight and grain moisture were measured by harvesting the plots with a plot combine (model PMC 20, ALMACO, Nevada, IA). The harvested area was 1.5 m wide by 4.5 m long. Grain yield was adjusted to 130 g kg^{-1} water content.

Tan spot disease severity was determined at Conway Springs, KS in the spring of 2008. The reading was based on a 1-9 rating. Tan spot ratings taken during the seedling stage and then at Feekes 5.0 were based on leaf area affected by tan spot. The final tan spot rating was taken at or around Feekes 10.5.4. At this stage, a 1-6 rating corresponded to levels of tan spot on lower leaves up to 60% with no tan spot on flag leaves, while ratings of 7-9 were given for plots with tan spot on the flag leaves and up to 90% incidence on lower leaves.

Disease interpretations at Conway Springs, KS were made by randomly retrieving 40 leaves from throughout the plot. Sixty-five lesions were evaluated and were determined to be tan spot (46) and *stagnospora* (19). (Erick DeWolf, KSU, personal correspondence)

A green leaf duration (GLD) note was also taken using a 1-9 scale. Green leaf duration is the amount of green leaf retention on the flag leaf over a period of time. A 1 rating implies less than 10% senescence on the flag leaf, where as 9 implies senescence greater than 90%. GLD-1 was taken near Feekes 11.1. GLD-2 was taken near Feekes 11.2, or about 10 days after GLD-1.

Yield components were taken in the 2007-2008 growing season. A 0.1 m^2 sub-sample was taken from the third row of each plot approximately 0.2 m into the plot. The 0.1 m^2 sub-sample was hand harvested with a sickle, tied with twine and placed into a paper bag. Tiller counts were taken by counting each tiller within the sub-sample. Twenty-five heads were randomly taken from each sub-sample and threshed with a single-head thresher. Seeds from the 25 heads were counted on an electronic seed counter and then weighed with an electronic scale. The number of kernels $spike^{-1}$ was determined by [(# seeds/ 25 heads)]. Thousand-kernel weights (TKW) were determined by [(1000/ # seeds per 25 heads)*(g per 25 heads)]. The timing of applications and other experimental factors can be found in (Table 3.1).

Figures and Tables

Table 3.1. Planting dates, fungicide application timings, and other miscellaneous factors over all years and locations.

Year	Locations	Previous Crop	Planting Date	133g ha-1 Tilt application time	Stage (Feekes)	932 g ha-1 Tilt application time	Stage (Feekes)
2004-2005	Partridge, KS	Tilled spring oats	14-Oct	28-Mar	4.0	9-May	10.5
	Salina, KS	Tilled after soybeans	4-Oct	16-Mar	4.0	5-May	10.0
	Belliville, KS	No-till after beans	10-Oct	16-Mar	3.0	10-May	10.2
2005-2006	Partridge, KS	tilled spring oats	25-Oct	14-Mar	4.0	3-May	10.5
	Salina,KS	Tilled after soybeans	6-Oct	14-Mar	4.0	3-May	10.3
	Belleville, KS	No-till after beans	12-Oct	n/a		n/a	
2006-2007	Nardin, OK	Tilled after wheat	16-Oct	19-Mar	4.0	27-Apr	10.0
	Partridge, KS	Tilled sping oats oats	19-Oct	19-Mar	4.0	n/a	
	Salina, KS	Tilled after soybeans	6-Oct	n/a		n/a	
	Belleville, KS	No-till after beans	31-Oct	n/a		n/a	
	Junction City, Ks	Tilled after soybeans	9-Oct	n/a		n/a	
2007-2008	Junction City, Ks	Tilled after soybeans	31-Oct	17-Apr	4.0	19-May	10.0
	Winfield, KS	DC soybeans,hailed wheat	8-Nov	n/a		n/a	
	Partridge, KS	Tilled sping oats oats	25-Oct	14-Apr	5.0	14-May	10.1
	Salina, KS	Tilled Corn	28-Oct	15-Apr	5.0	15-May	10.0
	Conway Springs, KS	No- till wheat	9-Nov	14-Apr	5.0	14-May	10.2
	Ashland Bottoms	Tilled after wheat	1-Nov	17-Apr	4.0	n/a	10.0
	Nardin, OK	Tilled after sorghum	8-Nov	14-Apr	5.0	14-May	10.0

CHAPTER 4 - Results and Discussion

2004-2005 and 2005-2006 Growing Seasons

The spring of 2005 at Partridge, KS began dry with very little disease pressure. No disease was present at the time treatment 2 was applied. Moisture was received shortly after spraying and diseases started to increase. Several weeks after treatment 2, powdery mildew, tan spot and stripe rust were identified within the field. Fifteen days after treatment 2 was applied powdery mildew was heavy on lower leaves of both cultivars in treatment 1.

Jagalene grain yields showed no statistical difference between treatment 1 and treatment 2 (Table 4.1), although treatment 2 yielded 10.9% more than treatment 1. Treatment 3 resulted in a yield of 3463.99 kg ha^{-1}, which was statistically greater than treatment 1 (Table 4.1). Treatment 3 had a yield increase of 18.1% and 6.5% over treatments 1 and 2, respectively, though the difference between treatments 2 and 3 did not reach the threshold of statistical significance.

2145 grain yields showed similar differences at Partridge, KS. Treatments 1 and 2 were not significantly different, but treatment 3 yielded significantly more than treatment 1. The difference in grain yield between treatment 1 and treatments 2 and 3 was 6.6% and 15.3% respectively.

At Salina, KS (Table 4.1) there was minimal disease development at the time of the early spray due to dry spring conditions. Later in the season minimal amounts of speckled leaf blotch and powdery mildew were noticed on some lower leaves. Conditions remained dry throughout the growing season with leaf rust developing very late.

There were no statistical yield differences among treatments for Jagalene. Although not significant, treatment 2 over actually yielded 5.8% more than treatment 3. Treatment 2 also had a 6.5% advantage in grain yield treatment 1.

2145 grain yields also showed no statistical differences among any of the treatments. There was an 11.1% increase in yield from treatment 1 to treatment 3, and an 8.1% yield increase from treatment 1 to treatment 2.

At Belleville, KS in the spring of 2005, no signs of disease were seen at the time the early application was made. Leaf rust (*P. triticina*) and low levels of stripe rust (*Puccinia striiformis*) occurred later in the growing season. Environmental conditions halted the progression of stripe rust and leaf rust became the disease of greatest importance. Both Jagalene and 2145 were noted to have been susceptible to leaf rust and had a significant proportion of flag leaf area affected by disease as noted in written observations.

Jagalene, was not significant at the P<.10 level, when comparing treatment 1 with treatment 2, although a 3.6% increase in grain yield was observed for treatment 2 compared to treatment 1 (Table 4.1). Treatment 3 on Jagalene produced statistically greater yield compared to treatments 1 ans 2. Grain yields for treatment 3 (Table 4.1) represented an approximate 36% increase compared to the other two treatments.

There were no significant yield differences among treatments for 2145. The total difference between treatment 1 and 2 was only 1.2%. Treatment 3 had a 17.7% increase in yield compared to treatment 1 and a 12.2% increase over treatment 2.

Although, there was a trend toward higher yields (7.2% between treatment 1 and 2) with early season fungicide applications, no statistical differences were seen during the 2004-2005 growing season. These locations were in conventional till and no-till after beans, which are situations where we would not expect a great benefit from the early season treatment.

The 2005-2006 growing season started with good moisture in the fall, but the spring was dry, and consequently there was no significant disease at any location. As a result, there were no statistical differences among the treatments (Table 4.2). The 2004-2005 growing season along with the 2005-2006 season led us to revise our research to include more locations and cultivars in a different statistical design.

2006-2007 Growing Season

The 2006-2007 growing season was lost due to a late spring freeze event on April 6th that severely affected the crop.

2007-2008 Growing Season

Planting at the Partridge, KS location was slightly delayed by wet conditions and stands were good going into the winter. Moisture during the spring was good, resulting in minimal stress to the crop during this time period, as noted in personal observations. There was little disease present when treatment 2 was applied. Moderate levels of powdery mildew, tan spot and speckled leaf blotch were seen on lower leaves when treatments 3 and 4 were applied at Feekes 10.1. Several leaf rust pustules were noted on the flag leaves at that time. Leaf rust was ultimately the most prevalent disease.

We had significant differences over all cultivars. The analysis (Table 4.3) of all cultivars together showed statistical differences at the P<.10 level between the two treatments (3 and 4) sprayed with the late application of fungicide and the two treatments (1 and 2) with no late application of fungicide. There were no statistical grain yield differences between treatments 1 and 2. The seed weight (TKW) followed a similar statistical pattern as the grain yields, indicating the late application of fungicide (treatment 3 and 4) was working better than the early application (treatment 2). There were no statistical differences for seeds per head or tillers. The first green leaf duration ratings (GLD-1) showed statistical differences between treatment 1 and 2. The differences demonstrated there were benefits on GLD-1 from the early season application of fungicide (treatment 2). Both GLD-1 and GLD-2 ratings were statistically different when fungicides were applied late at Feekes 10.1(treatment 3 and 4), compared to no late application of fungicide (treatments 1 and 2).

Also, late fungicide application protected the flag leaf for a longer period of time than the early season application. Karl 92 (Table 4.4), showed significant difference in grain yield between treatment 4 and treatment 2. Leaf rust was the most prevalent disease and Karl 92 has a moderate level of resistance due to relatively low frequencies of races virulent on this line. Overley (Table 4.5), Coker 9184 (Table 4.6), and 2145 (Table 4.7) showed similar trends for grain yield, yield components and green leaf duration as seen in the overall analyses. Jagalene (Table 4.8) had a statistical difference in grain yields between all treatments at the P>.10 level. The yield gain was 11.4% from treatment 1 to treatment 2, 17.7% from treatment 2 to treatment 3 and 7.2% from treatment 3 to treatment 4. Jagalene is very susceptible to leaf rust. That level of susceptibility could help explain these results. The 394 kg ha^{-1} difference in yield between treatment 1 and 2 would warrant the use of the early season application of fungicide. For example, we assumed wheat priced at $.18/kg ($5.00/bu) and propiconazole applied with fertilizer at a cost of $9.88/ha ($4.00/ac). The 394 kg ha^{-1} (5.87 bu/ac) , difference in yield between treatment 1 and 2, multiplied by $.18/kg is equal to $70.92/ha ($28.70/ac). Subtract the cost of fungicide ($9.88/ha) and the investment would have paid $61.04/ha ($24.70/ac) over no early season fungicide treatment (treatment 1). The seed weight was statistically different only between treatments with late applications of fungicide (treatment 3 and 4) and those where no late fungicide was applied (treatment 1 and 2). Grain yield on Santa Fe (Table 4.9) increased by 7.9% from treatment 3 to treatment 4. Yield components showed no statistical differences in any category. The application cost of $59.30/ha ($24.00/ac) for both fungicide applications (treatment 4) and the $103.77/ha ($42.00/ac) increase in net revenue made from treatment 1 to treatment 4 would have paid $44.47/ha ($18.00/ac) over no fungicide applied (treatment 1). The combination of fungicides was able to give a boost in yield over the late application alone. These results suggest that, with more testing, information could be provided to producers on how specific cultivars respond to reduced rate early season application of fungicides.

The Salina, KS location had good stands going into the winter. Moisture was good and there were no diseases when the early application of fungicide (treatment 2) was made. Very little disease was present at the late application of fungicide (treatment 3 and 4). Several pustules of leaf rust were found on lower leaves, along with tan spot and/or speckled leaf blotch, were present on the lower leaves later in the season. Leaf rust was ultimately the most prevalent disease during the growing season.

Over all the cultivars (Table 4.10) there were positive statistical grain yield differences between treatment 1 and treatment 2 at the P<.10 level. Also, a statistical difference between treatment 3 and treatment 4 was seen. These statistical differences show reduced rate early applications of fungicides have a positive effect over a broad range of cultivars with varying levels of resistance. Seed weight (TKW) showed statistical differences between treatments 1 and 2 and the late application treatments (3 and 4), demonstrating that fungicides affected the TKW. GLD-1 showed statistical differences between treatment 1 and 2. Both GLD-1 and GLD-2 ratings were statistically lower when fungicides were applied late (treatment 3 and 4) compared to treatment 1 and 2.

Karl 92 (Table 4.11) was very similar to the overall pattern over all cultivars. Karl 92 grain yields trended upward in all treatments. Jagalene (Table 4.12) showed a significant grain yield increase from treatment 1 to treatment 2 at the P<.10 level, corresponding to a 9.5% increase in yield. Return on investment from treatment 2 over treatment 1 would have been $37.68/ha ($15.24/ac). Seed weight was only statistically different between the late application of fungicides (treatments 3 and 4) and the treatments 1 and 2. GLD-1 showed a difference between treatment 1 and treatment 2. Grain yields of Overley (Table 4.13) and 2145 (Table 4.14) were statistically different between all treatments. Overley yield increased 11.2% from treatment 1 to treatment 2. Treatment 4 also yielded 7.6% more than treatment 3. Return on investment would have been $54.90/ha ($22.22/ac) for the application of treatment 2 compared to treatment 1. Treatment 4 over treatment 1 would have paid

$115.86/ha ($46.89/ac). Seed weight trended higher and was significantly different between treatment 1 and the late application treatments (3 and 4) but was not significantly different than treatment 2. Treatment 2 had a lower GLD-1 than treatment 1 (Table 4.14).

Treatment 2 of 2145 yielded 7.1% more than treatment 1. There was an 8.3% yield increase from treatment 3 to treatment 4. Return on investment from treatment 1 to 2 and 1 to 4 would have been $38.05/ha ($15.40/ac) and $122.51/ha ($49.58/ac), respectively. Seed weight was higher in the treatments with fungicides applied at Feekes 10.0 (treatments 3 and 4). GLD-1 was significantly lower for treatment 2 compared to treatment 1 (Table 4.14). The significant difference showed that treatment 2 was having some residual effect and helped the wheat plant stay healthier throughout the growing season.

Santa Fe (Table 4.15) yielded 10.3% more in treatment 4 compared to treatment 3, however there were no yield differences between treatment 1 and 2. The return on investment between treatments 1 and 4 would have been $28.72/ha (11.62/ac). GLD-1 of Santa Fe showed a reduction from treatment 1 to treatment 2. Treatments 3 and 4 were also significantly different than treatments 1 and 2.

Coker 9184 (Table 4.16) had a 9.8% increase in grain yield from treatment 1 to treatment 2 at the P<.10 level, although treatments 2 through 4 were not significantly different. Seed weight was higher in the treatments containing the late application of fungicide (3 and 4) compared to treatments 1 and 2. Green leaf ratings were also lower for GLD-1. There was a reduction in flag leaf senescence from treatment 1 to 2.

Similar yield results were found when the early reduced-rate was applied alone in North Dakota under continuous wheat. The same study showed no difference when planted after sunflowers (Ashley et al., 2001). No studies were found that studied the effect of having a combination of fungicide regimes.

The yield differences could have been influenced by the ability of the reduced early application of fungicide (treatment 2) to reduce senescence on the flag leaf for a short but significant amount of time. The first green leaf rating was able to show significant reduction in flag leaf senescence. GLD-2 showed complete senescence under treatment 2 in most cultivars. This extra length of time for the plant to continue photosynthesis allowed for the incremental increase in yield. Additional studies are needed to truly understand the benefits of using treatment 4. The above data would suggest that there would be a benefit to the combination of fungicide regimes. The highest expectation for the combination of fungicide regimes would be in situations where disease pressure is high throughout the growing season. Years with over-wintering leaf rust and fields with high levels of residue would be situations where the combination of fungicide treatments would work the best.

Tillers and seeds per head were not influenced by the various treatments. A study by (2001) by Kelley (2001) observed that foliar fungicides did not influence seeds per head due to this yield component being determined prior to fungicide application. Another study suggested that kernels spike^{-1} was affected by location x cultivar x fungicide treatment interaction (Carignano et al., 2008). Tiller numbers in the current study apparently were determined prior to fungicide application, as reported in studies by Kelley (1993). Expectations were that treatment 2 could have an effect on tiller number due to early season protection against powdery mildew. We also suggest that better plant health early in the season would allow the plant to put on more tillers.

A combined analysis on Partridge and Salina, KS could not be run because of significant fungicide x cultivar interaction between locations. These interactions can be seen graphically (Figure 4.1 and 4.2). There are several reasons for the interaction. The cultivars selected have different levels of resistance to leaf rust, the most prevalent disease at both locations, thus yields of susceptible cultivars would be more greatly affected. Also, a cultivar such as Jagalene, which is very susceptible to leaf rust, was infected earlier and at a higher rate than a cultivar such as Karl 92 which, while still susceptible, benefited from lower levels of virulence in the current race structure. Jagalene yields have also been shown to be very responsive to fungicide treatment (Ransom and McMullen, 2008).

Grain yield increases often correspond with disease reduction and significant reductions in disease were observed at Conway Springs, KS had. The fall of 2007 was unusually wet causing delayed planting times across central Kansas. Conway Springs, KS was planted late, November 9th, resulting in poor stands going into the winter. Stands remained poor throughout the growing season. Yields were taken and analyzed but were not used due to a high amount of variability within the trial.

Foliar disease was very heavy early in the spring. Based on the sampling of leaves from multiple seedlings randomly taken from the trial, tan spot was the most prevalent disease. Speckled leaf blotch was also identified in the field, but at lower levels. Over all cultivars (Table 4.17), the seedling tan spot rating was a 7 for all treatments. The April 24th tan spot ratings showed a decline in incidence from treatment 1, (rating of 7), to treatment 2 (rating of 5). The May 19th note continued the same trend. The majority of the specific cultivars (Tables 4.18-4.23) showed the same trend as well. Overley (Table 4.18), Jagalene (Table 4.19), Santa Fe (Table 4.20) and 2145 (Table 4.21) were all in line with previous over all ratings. Karl 92 (Table 4.22) and Coker 9184 (Table 4.23) showed statistically lower levels of tan spot during the April 24th rating, but lower by only 1 level compared to 2 for all of the other cultivars. The last rating date showed statistical differences among all cultivars for treatment 2 versus treatment 1. Karl 92 went from 4 to 2 and Jagalene from 8 to 6 to represent the most extreme differences. The reduction in severity early in the season led to reduced severity on the flag leaf later in the season. The flag leaf rating for tan spot was equivalent to a resistant level for treatment 2 compared to a moderately resistant to susceptible reaction in treatment 1.

GLD-1 over all cultivars (Table 4.24) revealed statistical differences for treatment 1 (5 rating), compared to treatment 2 (4 rating). The full rates of fungicide had a green leaf rating of 1.

GLD-2 rated as a 7 for both treatments 1 and 2. Treatments 3 and 4 had a rating of 4. The specific cultivars (Table 4.25-4.30) all showed the same trends.

The results show we were able to reduce tan spot infection through the whole season. Fungicide applications at flag leaf were shown to control tan spot by (Carignano et al., 2008), but no previous studies were able to show a full season suppression of tan spot. It should be noted that no early applications of fungicide were used in that study. Further studies are needed to determine the full season effectiveness of reduced-rate early applications of fungicide against other diseases of importance, in addition to tan spot. The combination of seed treatments, along with early season fungicide applications, also needs to be researched further. The expectations would be to see similar results as reported above. The early control of disease, especially in the rain-splashed diseases, will allow the amounts of inoculum to be reduced and thus reduce the possibility of an epidemic and resulting in protection of the crop from severe economic losses.

These results also demonstrated that educated management decisions regarding this practice could be possible with further research on specific cultivars. The life span of certain cultivars could, also be increased with the use of an early reduced-rate application of fungicide. Susceptible cultivars that yield well under these fungicide treatments could be used with proper management thus prolonging their utility. Cultivars that are highly responsive to fungicide treatments are used could be recommended to producers willing to employ a higher level of management.

In spite of these benefits, resistance breeding needs to be maintained because of the economic and environmental benefits. Not all producers can afford the extra cost that fungicides entail and rely on resistant cultivars for consistent grain yields. Heavy use of susceptible cultivars could lead to an epidemic and/or drive resistance to fungicides.

Further research on this subject needs to be done. I would propose research where we study different application timings in the spring from Feekes 3.0 to Feekes 6.0. This will help narrow down the specific time when the greatest benefit of the early reduced-rate fungicide application will be achieved. Research should also be done on up and coming cultivars to keep up with new genetics and provide agronomists with information that would allow producers to make educated decisions. A proposed decision tree based on our preliminary results is as follows:

1- Planting of susceptible cultivar. (Depends on diseases of importance and/or cultivars that are susceptible to multiple diseases of importance.)
2- Planting into no-till wheat after wheat.
3- Planting into no-till where wheat was in crop rotation.
4- Above normal precipitation level in the spring.

When two of the criteria have been met producers should seriously consider an early application of fungicide, along with the full rate at Feekes 10.0. Further studies should allow the decision tree to be greatly refined.

Figures and Tables

Table 4.1. Grain yields for 2004-2005 growing season at Partridge, Salina and Belleville, KS for Jagalene and 2145.

	Jagalene					2145			
Treatment[a]	Partridge	Salina	Belleville	Overall		Partridge	Salina	Belleville	Overall
					kg/ha $^{-1}$				
1	2932.94b	4183.72a	2848.40b	3321.69b		3362.2b	3951.74a	2839.75a	3384.56b
2	3253.76ab	4474.24a	2950.29b	3559.43ab		3585.43ab	4272.61a	2874.41a	3577.48ab
3	3463.99a	4227.06a	3893.24a	3861.44a		3878.09a	4391.84a	3344.80a	3871.58a

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0

Different letters indicate significant difference within columns using LSD at (P<.10).

Table 4.2. Grain yields for 2005-2006 growing season at Partridge, Salina and Belleville, KS for Jagalene and Neosho.

	Jagalene					Neosho			
Treatment[a]	**Partridge**	**Salina**	**Belleville**	**Overall**		**Partridge**	**Salina**	**Belleville**	**Overall**
					kg/ha $^{-1}$				
1	3651.52a	3163.77a	2728.14a	3181.14a		3495.46a	3547.51a	2549.28a	3197.41a
2	3664.57a	3124.77a	2991.44a	3260.26a		3384.92a	2851.66a	2113.5a	2783.36a
3	3485.71a	3355.67a	2773.66a	3205.01a		3420.69a	3615.82a	2438.67a	3158.39a

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

Different letters indicate significant difference within columns using LSD at (P<.10).

Table 4.3. Grain yields, yield components and green leaf duration scores (1-best, 9-worst) at Partridge, KS during 2007-2008 growing season over all cultivars.

	Over all Cultivars															
Treatment[a]	**Yield kg/ha^{-1}**	**P<.05[b]**	**P<.10[c]**	**Seeds per Head**	**P<.05[b]**	**P<.10[c]**	**Tillers .1m^{-2}**	**P<.05[b]**	**P<.10[c]**	**TKW**	**P<.05[b]**	**P<.10[c]**	**GLD 1**	**P<.10[c]**	**GLD 2**	**P<.10[c]**
1	4034.56	b	b	30.1	a	a	64	a	a	28.1	c	c	6	c	9	c
2	4096.55	b	b	29.5	a	a	66	a	a	28.7	bc	bc	5	b	9	b
3	4502.93	a	a	30.2	a	a	67	a	a	29.7	ab	ab	2	a	7	a
4	4737.12	a	a	29.8	a	a	66	a	a	30.7	a	a	2	a	7	a

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

[b] Different letters indicate significant difference within columns using LSD at (P<.05).

[c] Different letters indicate significant difference within columns using LSD at (P<.10).

Table 4.4. Grain yields, yield components and green leaf duration scores (1-best, 9-worst) at Partridge, KS during 2007-2008 growing season for Karl 92.

	Karl '92															
Treatment[a]	Yield kg/ha^{-1}	P<.05[b]	P<.10[c]	Seeds per Head	P<.05[b]	P<.10[c]	Tillers .1m^{-2}	P<.05[b]	P<.10[c]	TKW	P<.05[b]	P<.10[c]	GLD 1	P<.10[c]	GLD 2	P<.10[c]
1	4316.89	ab	ab	27.18	a	a	71	a	a	28.74	a	b	5	c	9	b
2	4125.37	b	b	27.39	a	a	69	ab	ab	30.78	a	ab	4	b	9	b
3	4457.96	ab	ab	29.28	a	a	64	b	b	30.33	a	ab	2	a	8	ab
4	4585.73	a	a	28.32	a	a	66	ab	ab	31.33	a	a	2	a	7	a

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

[b] Different letters indicate significant difference within columns using LSD at (P<.05).

[c] Different letters indicate significant difference within columns using LSD at (P<.10).

Table 4.5. Grain yields, yield components and green leaf duration scores (1-best, 9-worst) at Partridge, KS during 2007-2008 growing season for Overley.

	Overley																
Treatment[a]	**Yield kg/ha^{-1}**	**P<.05[b]**	**P<.10[c]**	**Seeds per Head**	**P<.05[b]**	**P<.10[c]**	**Tillers .1m^{-2}**	**P<.05[b]**	**P<.10[c]**	**TKW**	**P<.05[b]**	**P<.10[c]**	**GLD 1**	**P<.10[c]**	**GLD 2**	**P<.10[c]**
1	3978.84	b	c	30.5	a	a	62	bc	bc	29.9	b	c	6c	c	9b	b
2	4296.78	ab	bc	29.3	a	a	58	c	c	31.0	b	bc	4b	b	8ab	ab
3	4396.73	a	ab	30.9	a	a	70	a	a	32.3	ab	ab	2a	a	7a	a
4	4625.82	a	a	28.3	a	a	66	ab	ab	34.2	a	a	2a	a	7a	a

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

[b] Different letters indicate significant difference within columns using LSD at (P<.05).

[c] Different letters indicate significant difference within columns using LSD at (P<.10).

Table 4.6. Grain yields, yield components and green leaf duration scores (1-best, 9-worst) at Partridge, KS during 2007-2008 growing season for Coker 9184.

	Coker 9184															
Treatment[a]	**Yield kg/ha^{-1}**	**P<.05[b]**	**P<.10[c]**	**Seeds per Head**	**P<.05[b]**	**P<.10[c]**	**Tillers .1m^{-2}**	**P<.05[b]**	**P<.10[c]**	**TKW**	**P<.05[b]**	**P<.10[c]**	**GLD 1**	**P<.10[c]**	**GLD 2**	**P<.10[c]**
1	4342.66	ab	ab	28.6	a	a	58	c	c	28.5	b	b	4	d	8	b
2	4235.16	b	b	29.6	a	a	74	a	a	28.1	b	b	3	c	7	b
3	4639.51	a	a	29.1	a	a	67	b	b	29.8	ab	ab	2	b	5	a
4	4877.9	a	a	29.9	a	a	66	b	b	31.0	a	a	1	a	7	b

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

[b] Different letters indicate significant difference within columns using LSD at (P<.05).

[c] Different letters indicate significant difference within columns using LSD at (P<.10).

Table 4.7. Grain yields, yield components and green leaf duration scores (1-best, 9-worst) at Partridge, KS during 2007-2008 growing season for 2145.

	2145																
Treatment[a]	Yield kg/ha^{-1}	P<.05[b]	P<.10[c]	Seeds per Head	P<.05[b]	P<.10[c]	Tillers .1m^{-2}	P<.05[b]	P<.10[c]	TKW	P<.05[b]	P<.10[c]	GLD 1	P<.10[c]	GLD 2	P<.10[c]
1	4019.84	b	b	32.2	a	b	62	b	b	26.7	ab	ab	7	b	9	b
2	3850.58	b	b	30.8	a	ab	67	ab	ab	26.1	b	b	7	b	9	b
3	4695.39	a	a	30.3	a	ab	67	ab	ab	29.5	a	a	3	a	8	ab
4	4808.43	a	a	28.9	a	a	70	a	a	28.6	a	a	3	a	7	a

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

[b] Different letters indicate significant difference within columns using LSD at (P<.05).

[c] Different letters indicate significant difference within columns using LSD at (P<.10).

Table 4.8. Grain yields, yield components and green leaf duration scores (1-best, 9-worst) at Partridge, KS during 2007-2008 growing season for Jagalene.

	Jagalene															
Treatment[a]	**Yield kg/ha^{-1}**	**P<.05[b]**	**P<.10[c]**	**Seeds per Head**	**P<.05[b]**	**P<.10[c]**	**Tillers .1m^{-2}**	**P<.05[b]**	**P<.10[c]**	**TKW**	**P<.05[b]**	**P<.10[c]**	**GLD 1**	**P<.10[c]**	**GLD 2**	**P<.10[c]**
1	3442.78	c	d	32.4	a	a	60	b	b	27.4	b	b	7	c	9	b
2	3836.77	b	c	31.5	a	a	64	ab	ab	27.1	b	b	6	b	9	b
3	4514.99	a	b	32.1	a	a	69	a	a	30.2	a	a	2	a	7	a
4	4841.96	a	a	32.7	a	a	62	b	b	31.2	a	a	2	a	7	a

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

[b] Different letters indicate significant difference within columns using LSD at (P<.05).

[c] Different letters indicate significant difference within columns using LSD at (P<.10).

Table 4.9. Grain yields, yield components and green leaf duration scores (1-best, 9-worst) at Partridge, KS during 2007-2008 growing season for Santa Fe.

	Santa Fe															
Treatment[a]	**Yield kg/ha^{-1}**	**P<.05**[b]	**P<.10**[c]	**Seeds per Head**	**P<.05**[b]	**P<.10**[c]	**Tillers .1m^{-2}**	**P<.05**[b]	**P<.10**[c]	**TKW**	**P<.05**[b]	**P<.10**[c]	**GLD 1**	**P<.10**[c]	**GLD 2**	**P<.10**[c]
1	4106.36	b	b	29.6	a	a	71	a	a	27.2	a	ab	6	b	9	a
2	4234.65	b	b	28.2	a	a	61	b	b	29.2	a	a	4	b	9	a
3	4312.95	ab	b	29.3	a	a	66	ab	ab	26.9	a	b	2	a	8	a
4	4682.88	a	a	30.5	a	a	66	ab	ab	28.0	a	a	2	a	9	a

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

[b] Different letters indicate significant difference within columns using LSD at (P<.05).

[c] Different letters indicate significant difference within columns using LSD at (P<.10).

Table 4.10. Grain yields, yield components and green leaf duration scores (1-best, 9-worst) at Salina, KS during 2007-2008 growing season over all cultivars.

	Over all Cutilvars															
Treatment[a]	**Yield kg/ha^{-1}**	**P<.05[b]**	**P<.10[c]**	**Seeds per Head**	**P<.05[b]**	**P<.10[c]**	**Tillers .1m^{-2}**	**P<.05[b]**	**P<.10[c]**	**TKW**	**P<.05[b]**	**P<.10[c]**	**GLD 1**	**P<.10[c]**	**GLD 2**	**P<.10[c]**
1	3438.68	c	c	33.9	a	a	66	b	b	30.0	b	b	7	c	9	b
2	3708.48	bc	b	32.5	a	a	69	ab	ab	30.7	b	b	5	b	9	b
3	3950.44	ab	b	33.5	a	a	72	a	a	32.4	a	a	3	a	7	a
4	4233.84	a	a	31.8	a	a	67	b	b	33.0	a	a	3	a	7	a

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

[b] Different letters indicate significant difference within columns using LSD at (P<.05).

[c] Different letters indicate significant difference within columns using LSD at (P<.10).

Table 4.11. Grain yields, yield components and green leaf duration scores (1-best, 9-worst) at Salina, KS during 2007-2008 growing season for Karl 92.

	Karl '92															
Treatment[a]	Yield kg ha^{-1}	P<.05[b]	P<.10[c]	Seeds per Head	P<.05[b]	P<.10[c]	Tillers $.1m^{-2}$	P<.05[b]	P<.10[c]	TKW	P<.05[b]	P<.10[c]	GLD 1	P<.10[c]	GLD 2	P<.10[c]
1	3740.84	b	b	30.71	a	a	71	a	a	31.07	a	a	7	d	9	a
2	3956.27	ab	ab	27.97	ab	ab	75	a	a	31.10	a	a	4	c	9	a
3	4014.47	a	a	26.89	ab	b	73	a	a	33.15	a	a	3	b	9	a
4	4209.53	a	a	24.98	b	b	70	a	a	32.94	a	a	2	a	9	a

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

[b] Different letters indicate significant difference within columns using LSD at (P<.05).

[c] Different letters indicate significant difference within columns using LSD at (P<.10).

Table 4.12. Grain yields, yield components and green leaf duration scores (1-best, 9-worst) at Salina, KS during 2007-2008 growing season for Jagalene.

	Jagalene															
Treatment[a]	**Yield kg/ha^{-1}**	**P<.05[b]**	**P<.10[c]**	**Seeds per Head**	**P<.05[b]**	**P<.10[c]**	**Tillers .1m^{-2}**	**P<.05[b]**	**P<.10[c]**	**TKW**	**P<.05[b]**	**P<.10[c]**	**GLD 1**	**P<.10[c]**	**GLD 2**	**P<.10[c]**
1	2705.46	b	c	35.08	ab	ab	56	b	b	28.13	c	b	8	c	9	b
2	2969.72	b	b	34.10	ab	b	67	a	a	29.93	bc	b	5	b	9	b
3	3894.96	a	a	38.29	b	a	66	a	a	32.26	ab	a	3	a	6	a
4	4070.79	a	a	33.75	a	b	67	a	a	33.03	a	a	3	a	6	a

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

[b] Different letters indicate significant difference within columns using LSD at (P<.05).

[c] Different letters indicate significant difference within columns using LSD at (P<.10).

Table 4.13. Grain yields, yield components and green leaf duration scores (1-best, 9-worst) at Salina, KS during 2007-2008 growing season for Overley.

	Overley															
Treatment[a]	**Yield kg/ha^{-1}**	**P<.05[b]**	**P<.10[c]**	**Seeds per Head**	**P<.05[b]**	**P<.10[c]**	**Tillers .1m^{-2}**	**P<.05[b]**	**P<.10[c]**	**TKW**	**P<.05[b]**	**P<.10[c]**	**GLD 1**	**P<.05[b]**	**GLD 2**	**P<.05[b]**
1	3210.17	c	d	34.72	a	a	56	b	b	33.53	b	b	7	d	9	b
2	3570.08	b	c	36.94	a	a	58	b	b	35.06	ab	ab	4	c	9	b
3	3888.81	ab	b	37.34	a	a	68	a	a	35.96	ab	a	2	a	7	a
4	4183.30	a	a	35.11	a	a	59	b	b	36.52	a	a	3	b	7	a

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

[b] Different letters indicate significant difference within columns using LSD at ($P<.05$).

[c] Different letters indicate significant difference within columns using LSD at ($P<.10$).

Table 4.14. Grain yields, yield components and green leaf duration scores (1-best, 9-worst) at Salina, KS during 2007-2008 growing season for 2145.

Grain yields for Salina, KS during 2007-2008 growing season.

	2145																
Treatment[a]	**Yield kg/ha^{-1}**	**P<.05**[b]	**P<.10**[c]	**Seeds per Head**	**P<.05**[b]	**P<.10**[c]	**Tillers .1m^{-2}**	**P<.05**[b]	**P<.10**[c]	**TKW**	**P<.05**[b]	**P<.10**[c]	**GLD 1**	**P<.10**[c]	**GLD 2**	**P<.10**[c]
1	3489.37	c	d	33.48	a	a	69	b	b	26.51	b	b	8	c	9	b
2	3755.66	c	c	33.85	a	a	72	ab	ab	27.26	b	b	6	b	9	b
3	4127.03	b	b	31.94	a	a	70	b	b	29.53	ab	a	3	a	8	a
4	4499.4	a	a	34.21	a	a	79	a	a	30.74	a	a	3	a	8	a

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

[b] Different letters indicate significant difference within columns using LSD at (P<.05).

[c] Different letters indicate significant difference within columns using LSD at (P<.10).

Table 4.15. Grain yields, yield components and green leaf duration scores (1-best, 9-worst) at Salina, KS during 2007-2008 growing season for Santa Fe.

	Santa Fe															
Treatment[a]	**Yield kg/ha^{-1}**	**P<.05[b]**	**P<.10[c]**	**Seeds per Head**	**P<.05[b]**	**P<.10[c]**	**Tillers .1m^{-2}**	**P<.05[b]**	**P<.10[c]**	**TKW**	**P<.05[b]**	**P<.10[c]**	**GLD 1**	**P<.10[c]**	**GLD 2**	**P<.10[c]**
1	3831.13	b	b	35.2	a	a	68	b	b	33.57	ab	ab	7	c	9	b
2	3990.75	b	b	34.4	ab	a	76	a	a	31.69	b	b	5	b	9	b
3	3876.69	b	b	30.1	b	b	68	b	b	32.83	ab	ab	3	a	8	a
4	4320.13	a	a	34.2	ab	a	63	b	b	34.54	a	a	3	a	8	a

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

[b] Different letters indicate significant difference within columns using LSD at (P<.05).

[c] Different letters indicate significant difference within columns using LSD at (P<.10).

Table 4.16. Grain yields, yield components and green leaf duration scores (1-best, 9-worst) at Salina, KS during 2007-2008 growing season for Coker 9184.

	Coker 9184																
Treatment[a]	**Yield kg/ha^{-1}**	**P<.05[b]**	**P<.10[c]**	**Seeds per Head**	**P<.05[b]**	**P<.10[c]**	**Tillers .1m^{-2}**	**P<.05[b]**	**P<.10[c]**	**TKW**	**P<.05[b]**	**P<.10[c]**	**GLD 1**	**P<.10[c]**	**GLD 2**	**P<.10[c]**
1	3655.12	b	b	33.69	ab	a	70	ab	b	27.38	b	b	4	c	6	b
2	4015.42	a	a	29.60	ab	b	67	b	b	29.27	ab	ab	3	b	6	b
3	3900.65	ab	ab	34.07	a	a	76	a	a	30.43	ab	ab	3	b	4	a
4	4119.88	a	a	29.38	b	b	69	ab	b	30.25	ab	ab	2	a	4	a

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

[b] Different letters indicate significant difference within columns using LSD at (P<.05).

[c] Different letters indicate significant difference within columns using LSD at (P<.10).

Table 4.17. Tan spot and green leaf duration scores (1-best, 9-worst) at Conway Springs, KS for over all cultivars.

	Over all Cultivars				
Treatment	**Tan Spot-Seedling**	**Tan Spot-Feekes 5.0**	**Tan Spot-Feekes 10.5.4**	**GLD 1**	**GLD 2**
1	7a	7b	7c	5c	7b
2	7a	5a	4a	4b	7b
3	7a	7b	6b	1a	4a
4	7a	5a	4a	1a	4a

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixtureof azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

Different letters indicate significant difference within columns using LSD at (P<.10).

Table 4.18. Tan spot and green leaf duration scores (1-best, 9-worst) at Conway Springs, KS for Overley.

	Overley				
Treatment[a]	**Tan Spot-Seedling**	**Tan Spot-Feekes 5.0**	**Tan Spot-Feekes 10.5.4**	**GLD 1**	**GLD 2**
1	6a	6c	4c	5c	9b
2	6a	4a	2a	4b	9b
3	6a	6c	3b	1a	4a
4	6a	5b	2a	1a	4a

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixtureof azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

Different letters indicate significant difference within columns using LSD at (P<.10).

Table 4.19. Tan spot and green leaf duration scores (1-best, 9-worst) at Conway Springs, KS for Jagalene.

	Jagalene				
Treatment[a]	**Tan Spot-Seedling**	**Tan Spot-Feekes 5.0**	**Tan Spot-Feekes 10.5.4**	**GLD 1**	**GLD 2**
1	8a	8b	8b	7c	9b
2	8a	6a	5a	6b	9b
3	8a	8b	8b	1a	4a
4	8a	6a	5a	1a	4a

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixtureof azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

Different letters indicate significant difference within columns using LSD at (P<.10).

Table 4.20. Tan spot and green leaf duration scores (1-best, 9-worst) at Conway Springs, KS for Santa Fe.

	Santa Fe				
Treatment[a]	**Tan Spot-Seedling**	**Tan Spot-Feekes 5.0**	**Tan Spot-Feekes 10.5.4**	**GLD 1**	**GLD 2**
1	8a	7b	8c	3b	6b
2	8a	5a	5a	2b	6b
3	8a	7b	7b	1a	3a
4	7b	5a	5a	1a	3a

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixtureof azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

Different letters indicate significant difference within columns using LSD at (P<.10).

Table 4.21. Tan spot and green leaf duration scores (1-best, 9-worst) at Conway Springs, KS for 2145.

	2145				
Treatment[a]	**Tan Spot-Seedling**	**Tan Spot-Feekes 5.0**	**Tan Spot-Feekes 10.5.4**	**GLD 1**	**GLD 2**
1	8a	7b	9d	7b	9d
2	8a	5a	6b	5b	9c
3	8a	7b	8c	1a	6b
4	8a	5a	5a	1a	5a

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixtureof azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

Different letters indicate significant difference within columns using LSD at (P<.10).

Table 4.22. Tan spot and green leaf duration scores (1-best, 9-worst) at Conway Springs, KS for Karl 92.

	Karl '92				
Treatment[a]	**Tan Spot-Seedling**	**Tan Spot-Feekes 5.0**	**Tan Spot-Feekes 10.5.4**	**GLD 1**	**GLD 2**
1	4a	4b	5c	5c	9c
2	5b	3a	2a	4b	9c
3	5b	5c	4b	1a	5b
4	5b	4b	2a	1a	4a

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixtureof azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

Different letters indicate significant difference within columns using LSD at (P<.10).

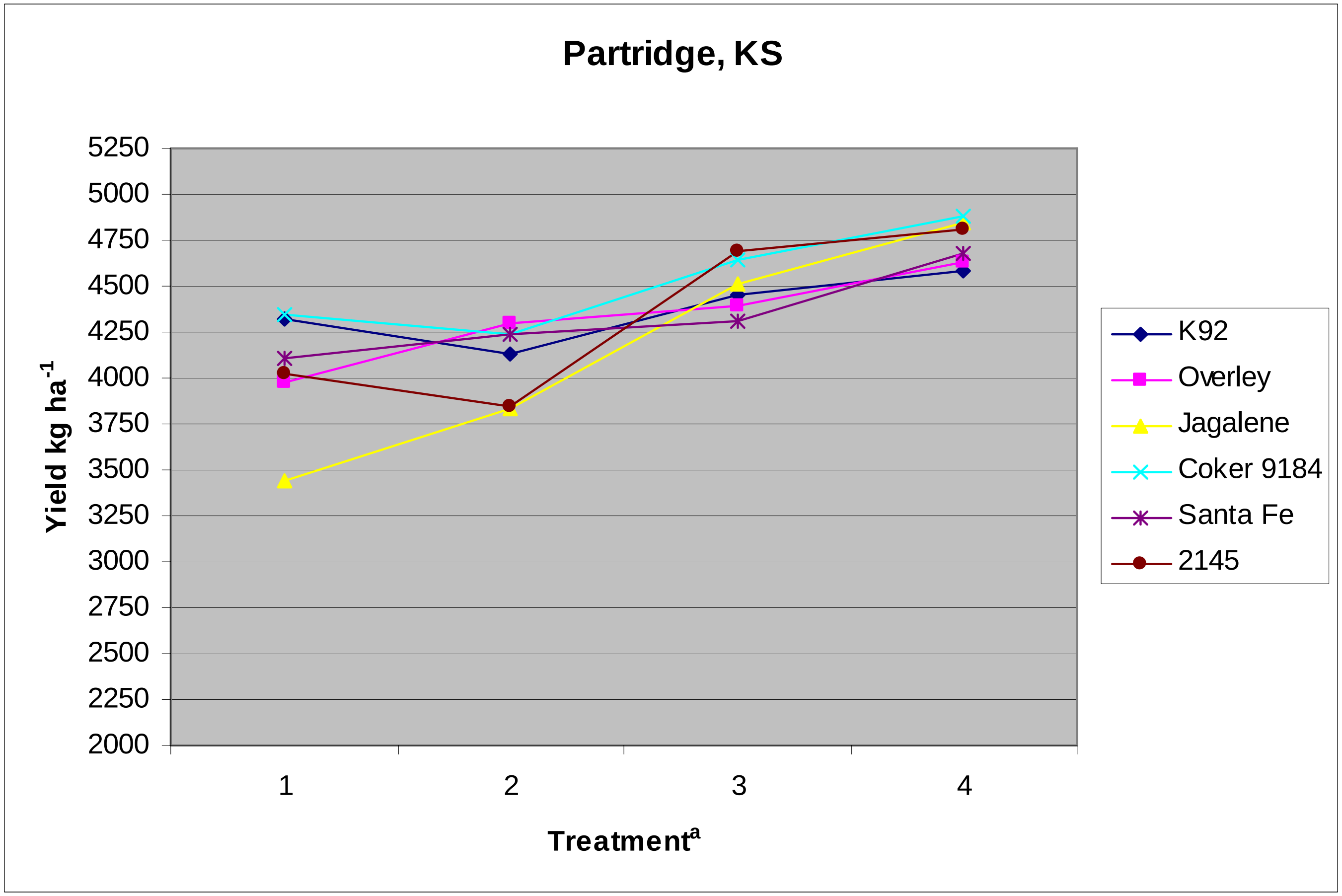
Table 4.23. Tan spot and green leaf duration scores (1-best, 9-worst) at Conway Springs, KS for Coker 9184.

	Coker 9184				
Treatment[a]	**Tan Spot-Seedling**	**Tan Spot-Feekes 5.0**	**Tan Spot-Feekes 10.5.4**	**GLD 1**	**GLD 2**
1	7a	6b	6b	3b	3a
2	7a	6b	4a	2b	3a
3	7a	6b	6b	1a	2a
4	7a	5a	4a	1a	2a

[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixtureof azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

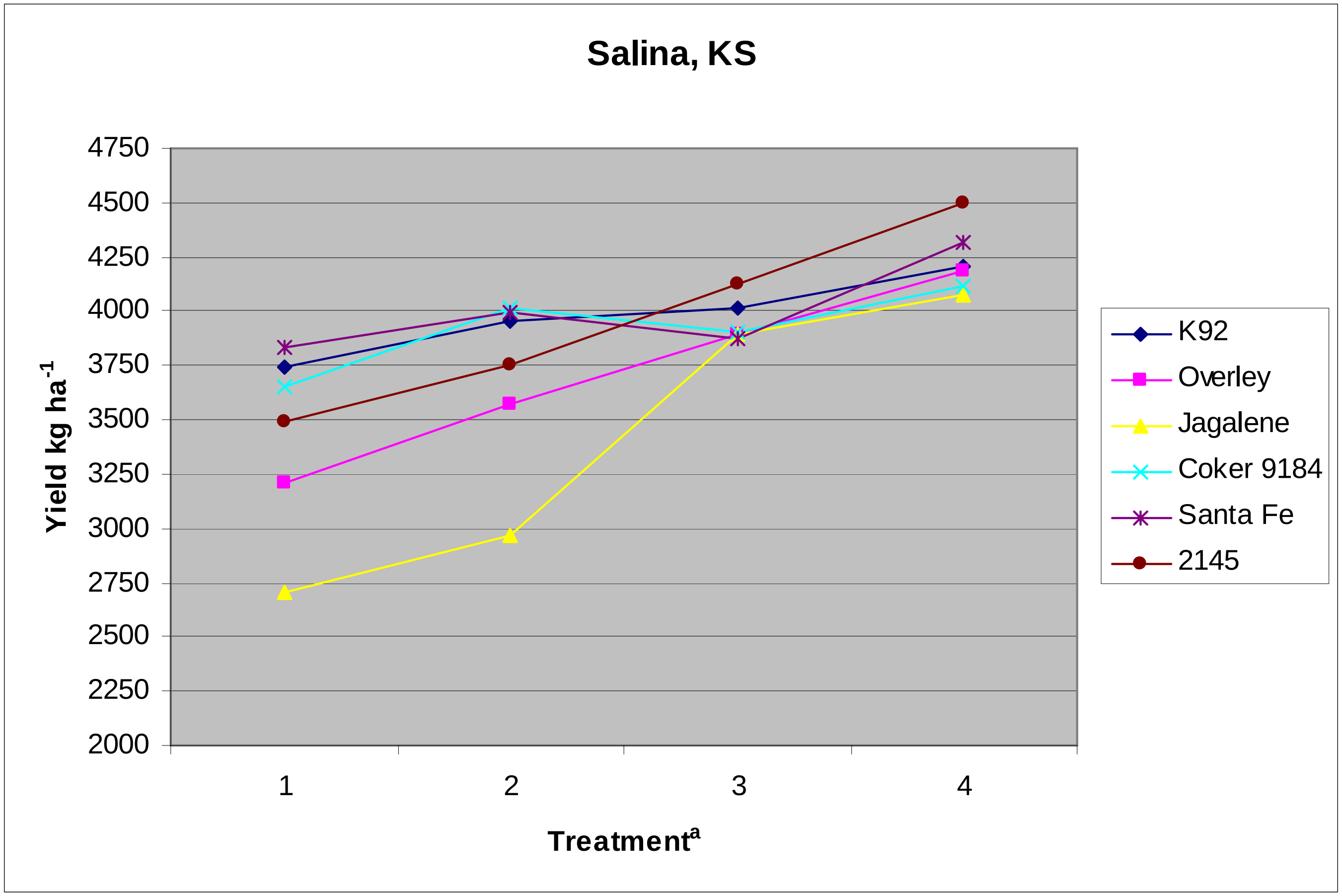
Different letters indicate significant difference within columns using LSD at (P<.10).

Figure 4.1. Grain yield interactions Partridge, KS 2007-2008.



[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

Figure 4.2. Grain yield interactions Salina, KS 2007-2008.



[a] Treatment 1-untreated; Treatment 2- 133g ha^{-1} rate of propiconazole, at Feekes 4.0; Treatment 3- 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0; Treatment 4- Combination of 133g ha^{-1} rate of propiconazole at Feekes 4.0 and 932g ha^{-1} application of a mixture of azoxystrobin and propiconazole at Feekes 10.0.

CHAPTER 5 - Conclusions

An early reduced rate application of fungicide showed potential utility. Disease severities were reduced under a no-till continuous wheat system. Yields were also increased under conventional tillage systems. Specific cultivars increased in yield when treated with the early fungicide application. While specific cultivar recommendations would be hard to make given that the analysis was based on only one year of good data. However, the grain yield increase of approximately 10.0% from treatment 1 to treatment 2 on several cultivars gives us confidence that it would be possible to help producers make educated decisions. The additive effect of both fungicide application shows some exciting trends based on cultivar selection. The increased yields under conventional tillage systems and decreased disease pressure in a no-till system are promising for increasing yields in continuous no-till wheat fields. Early season fungicide applications should be recommended under no-till and strongly considered under conventional tillage continuous wheat situations. Recommendations should also be made for cultivars that are susceptible to multiple diseases. The potential return on investment of early season fungicide applications is good and should be followed by an application of fungicide at Feekes 10.0. The ability to control multiple diseases simultaneously will give producers more management options. Studies on a larger scale should be implemented to further determine how this practice will enhance production. In addition, on-going evaluations of new cultivars under the various fungicide regimes will need to be conducted to provide the best, most current information to producers.

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Appendix A - ANOVA Partridge, KS 2004-2005 grain yield.

SOURCE	DF	SS	MS	F	P%
Replication	2	24.77	12.38	0.71	51.45
Entry (Type I)	5	337.04	67.41	3.87	3.27
Entry (Type III)		337.04	67.41	3.87	3.27
Residual	10	174.21	17.42		
Total	17	536.01			

Appendix B - ANOVA Salina, KS 2004-2005 grain yield.

SOURCE	DF	SS	MS	F	P%
Replication	2	8.64	4.32	0.23	79.49
Entry (Type I)	5	109.54	21.91	1.19	37.91
Entry (Type III)		109.54	21.91	1.19	37.91
Residual	10	183.90	18.39		
Total	17	302.07			

Appendix C - ANOVA Belleville, KS 2004-2005 grain yield.

SOURCE	DF	SS	MS	F	P%
Replication	2	9.41	4.70	0.19	82.63
Entry (Type I)	5	591.41	118.28	4.89	1.60
Entry (Type III)		591.41	118.28	4.89	1.60
Residual	10	241.85	24.19		
Total	17	842.67			

Appendix D - ANOVA combined analysis for 2004-2005 grain yield.

SOURCE	DF	SS1	SS2	MS	F	P%
Treatment	5	178.17	178.17	35.63	2.12	14.5554
Location	2	908.36		454.18	27.06	0.0092
Treatment*Location	10	167.83		16.78		
Total	17	1254.36				

Appendix E - ANOVA Partridge, KS 2005-2006 grain yield.

SOURCE	DF	SS	MS	F	P%
Replication	1	25.32	25.32	2.72	15.98
Entry (Type I)	5	30.15	6.03	0.65	67.68
Entry (Type III)		30.15	6.03	0.65	67.68
Residual	5	46.48	9.30		
Total	11	101.95			

Appendix F - ANOVA Salina, KS 2005-2006 grain yield.

SOURCE	DF	SS	MS	F	P%
Replication	1	95.66	95.66	2.33	18.72
Entry (Type I)	5	182.17	36.43	0.89	55.00
Entry (Type III)		182.17	36.43	0.89	55.00
Residual	5	205.00	41.00		
Total	11	482.83			

Appendix G - ANOVA Belleville, KS 2005-2006 grain yield.

SOURCE	DF	SS	MS	F	P%
Replication	1	25.86	25.86	2.16	20.19
Entry (Type I)	5	206.10	41.22	3.44	10.08
Entry (Type III)		206.10	41.22	3.44	10.08
Residual	5	59.97	11.99		
Total	11	291.93			

Appendix H - ANOVA Partridge, KS 2007-2008 grain yield.

SOURCE	DF	SS	MS	F	P%
Replication	3	140.09	46.70	0.84	50.49
A	3	1790.90	596.97	10.75	0.25
Error A	9	499.67	55.52		
B	5	240.11	48.02	3.70	0.56
A x B	15	575.18	38.35	2.95	0.15
Error B	60	779.66	12.99		
Total	95	4025.61			

Appendix I - ANOVA Partridge, KS 2004-2005 seeds per head.

SOURCE	DF	SS	MS	F	P%
Replication	3	59.0	19.7	3.1	7.9
A	3	7.1	2.4	0.4	77.1
Error A	9	56.2	6.2		
B	5	152.7	30.5	4.9	0.1
A x B	15	60.1	4.0	0.6	82.9
Error B	60	374.9	6.2		
Total	95	710.0			

Appendix J - ANOVA Partridge, KS 2007-2008 tillers.

SOURCE	DF	SS	MS	F	P%
Replication	3	153	51	1	42
A	3	110	37	1	55
Error A	9	445	49		
B	5	173	35	2	10
A x B	15	1313	88	5	0
Error B	60	1055	18		
Total	95	3249			

Appendix K - ANOVA Partridge, KS 2007-2008 TKW.

SOURCE	DF	SS	MS	F	P%
Replication	3	93.7	31.2	6.0	1.6
A	3	95.3	31.8	6.1	1.5
Error A	9	46.8	5.2		
B	5	210.2	42.0	14.1	0.0
A x B	15	87.4	5.8	2.0	3.5
Error B	60	178.8	3.0		
Total	95	712.1			

Appendix L - ANOVA Partridge, KS 2007-2008 GLD-1.

SOURCE	DF	SS	MS	F	P%
Replication	3	0	0	0	95
A	3	259	86	66	0
Error A	9	12	1		
B	5	55	11	23	0
A x B	15	21	1	3	0
Error B	60	29	0		
Total	95	376			

Appendix M - ANOVA Partridge, KS 2007-2008 GLD-2.

SOURCE	DF	SS	MS	F	P%
Replication	2	3.0	1.5	1.1	38.0
A	3	44.4	14.8	11.2	0.7
Error A	6	8.0	1.3		
B	5	14.4	2.9	2.2	7.6
A x B	15	18.9	1.3	1.0	52.1
Error B	40	53.0	1.3		
Total	71	141.8			

Appendix N - ANOVA Salina, KS 2007-2008 grain yields.

SOURCE	DF	SS	MS	F	P%
Replication	3	356.96	118.99	2.09	17.24
A	3	1837.05	612.35	10.73	0.25
Error A	9	513.38	57.04		
B	5	964.32	192.86	31.87	0.00
A x B	15	691.44	46.10	7.62	0.00
Error B	60	363.10	6.05		
Total	95	4726.23			

Appendix O - ANOVA Salina, KS 2007-2008 seeds per head.

SOURCE	**DF**	**SS**	**MS**	**F**	**P%**
Replication	3	6.9	2.3	0.1	95.9
A	3	62.1	20.7	0.9	48.6
Error A	9	211.0	23.4		
B	5	675.1	135.0	14.0	0.0
A x B	15	342.8	22.9	2.4	1.0
Error B	60	580.5	9.7		
Total	95	1878.3			

Appendix P - ANOVA Salina, KS 2007-2008 tillers.

SOURCE	**DF**	**SS**	**MS**	**F**	**P%**
Replication	3	54	18	1	66
A	3	491	164	5	3
Error A	9	296	33		
B	5	2086	417	13	0
A x B	15	968	65	2	3
Error B	60	1975	33		
Total	95	5872			

Appendix Q - ANOVA Salina, KS 2007-2008 TKW.

SOURCE	DF	SS	MS	F	P%
Replication	3	4.2	1.4	0.3	83.3
A	3	138.2	46.1	9.6	0.4
Error A	9	43.3	4.8		
B	5	501.3	100.3	30.0	0.0
A x B	15	44.6	3.0	0.9	57.8
Error B	60	200.5	3.3		
Total	95	932.1			

Appendix R - ANOVA for Salina, KS 2007-2008 GLD-1.

SOURCE	**DF**	**SS**	**MS**	**F**	**P%**
Replication	3	3	1	3	9
A	3	280	93	271	0
Error A	9	3	0		
B	5	32	6	19	0
A x B	15	30	2	6	0
Error B	60	21	0		
Total	95	368			

Appendix S - ANOVA for Salina, KS 2007-2008 GLD-2.

SOURCE	DF	SS	MS	F	P%
Replication	3	1.6	0.5	1.2	37.0
A	3	44.0	14.7	32.3	0.0
Error A	9	4.1	0.5		
B	5	155.1	31.0	128.0	0.0
A x B	15	17.9	1.2	4.9	0.0
Error B	60	14.5	0.2		
Total	95	237.2			

Appendix T - ANOVA for Conway Springs, KS 2007-2008 tan spot seedling rating.

SOURCE	DF	SS	MS	F	P%
Replication	1	0.75	0.75	1.68	28.53
A	3	0.83	0.28	0.62	64.64
Error A	3	1.34	0.45		
B	5	69.67	13.93	31.27	0.00
A x B	15	5.17	0.34	0.77	69.10
Error B	20	8.91	0.45		
Total	47	86.67			

Appendix U - ANOVA for Conway Springs, KS 2007-2008 tan spot Feekes 5.0 rating.

SOURCE	DF	SS	MS	F	P%
Replication	3	0.0	0.0	0.0	98.8
A	3	55.9	18.6	55.1	0.0
Error A	9	3.0	0.3		
B	5	88.9	17.8	53.5	0.0
A x B	15	14.9	1.0	3.0	0.1
Error B	60	19.9	0.3		
Total	95	182.6			

Appendix V - ANOVA for Conway Springs, KS 2007-2008 tan spot Feekes 10.5.4 rating.

SOURCE	DF	SS	MS	F	P%
Replication	3	2.8	0.9	0.9	47.7
A	3	141.9	47.3	45.2	0.0
Error A	9	9.4	1.0		
B	5	261.6	52.3	126.8	0.0
A x B	15	9.3	0.6	1.5	13.1
Error B	60	24.8	0.4		
Total	95	449.8			

Appendix W - ANOVA for Conway Springs, KS 2007-2008 GLD-1.

SOURCE	DF	SS	MS	F	P%
Replication	3	1	0	1	44
A	3	250	83	353	0
Error A	9	2	0		
B	5	58	12	49	0
A x B	15	60	4	17	0
Error B	60	14	0		
Total	95	385			

Appendix X - ANOVA for Conway Springs, KS 2007-2008 GLD-2.

SOURCE	DF	SS	MS	F	P%
Replication	3	0.6	0.2	0.2	85.9
A	3.0	298.1	99.4	127.7	0.0
Error A	9	7.0	0.8		
B	5	289.3	57.9	91.6	0.0
A x B	15	40.4	2.7	4.3	0.0
Error B	60.0	37.9	0.6		
Total	95	673.3			