DRYLAND NO-TILL WHEAT SEEDING AND FERTILITY RATES FOR NORTH CENTRAL KANSAS

by

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Abstract

Hard red winter wheat (Triticum aestivum L.) is the predominate crop grown in North Central Kansas; and no-till wheat production practices have gained popularity in this region. No-till advantages may include: increased stored soil moisture, decreased labor costs, and increased soil conservation compared with conventional cropping systems.

Seeding rates and fertility rates are two important no-till management decisions for producers. Therefore, a two-year study was conducted to determine the optimum wheat seeding and fertility rates in north central Kansas comparing the winter wheat cultivars ‘Overley’ and ‘2145’. Treatments also included seeding rates (100 kg ha^{-1} vs. 134 kg ha^{-1}) and fertility rates (0, 78, 112, 146 kg ha^{-1}). A fungicide application study was also conducted with this two-year study but proved to be statistically insignificant during the two years.

Overall, the variety selection and fertility rates affected grain yields. The higher fertilizer treatments increased wheat grain yields. However, the seeding rate yield differences were not significant either year of this study. In the fungicide study, 2145 responded more to fungicide applications than Overley in 2006; but in 2005 there was no statistical advantage for a fungicide treatment with either variety.

For this study, wheat varieties were planted during the recommended optimum “fly-free” seeding date period (4 October through 10 October). Although this study did not record yield differences between wheat drilled at higher or lower seeding rate during the recommended seeding period, other research does indicate that seeding rates should be increased if planting dates are extended well beyond the optimum period. Further outcomes from this study indicate that nitrogen rates should be adjusted based on field yield expectations. Although timely rainfall and/or stored soil moisture are the most limiting yield factors in dryland wheat production in north central Kansas, research results indicate that wheat yields increase with higher fertility rates when moisture is not a limiting factor. This research may be applied to north central Kansas wheat fields particularly where no-till farming practices are being used in wheat following wheat fields.

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Dedication

My "distance" Master of Science endeavor is dedicated to future Kansas State University extension agents seeking completion of their Master of Science degree through the K-State Agronomy distance degree program.

During my seven years advanced degree pursuit, I have appreciated those who have conveyed the "never quit" spirit. I especially have been inspired by my father, Gary Whitney, who has demonstrated persistence with his on-going Hodgkin's (cancer) disease treatments during the last few years.

Also, this thesis is dedicated to the hard working wheat farmers / crop producers in north central Kansas.

CHAPTER 1 - No-till Wheat Production Literature Review

Fertility for no-till systems is a unique challenge due to potential nutrient tie-up with the added residue. The following is a literature review relating to no-till fertility issues for north central Kansas.

No-till Wheat Soil Sampling / Acid Soils Recommendations

No-till systems change the movement of water, lime and nutrients in the soil profile (Heiniger and Weisz, 2004). As the soil structure improves under no-till, water movement through the upper soil profile generally increases on well-drained silt loam or clay loam soils. On poorly drained soils or soils where compaction is a problem; water movement through the profile often results in poor plant growth. Without tillage, lime and nutrients in true no-till systems are not incorporated or mixed throughout the upper soil profile (Heiniger et al. 2004). When water movement through the soil is reduced, lime and nonsoluble nutrients, such as phosphorus, may concentrate in the upper few inches of the soil profile.

As a result, well-drained, silt loam and clay soils are best suited for no-till production. Sandy soils have been less successful, and poorly drained soils are not recommended for no-till wheat unless drainage is corrected (Weisz et al. 2004). Therefore, before starting a no-till cropping system, it is important for producers to assess each field and determine if the field is suitable for no-till based on soil classification and drainage. Also, the field(s) may need tilled, prior to initiating no-till; leveling gullies and wheel ruts as much as possible.

No-till Wheat Fertility Management

With proper management, no-till planted wheat can produce yields similar to conventionally drilled wheat fields. Generally, no-till wheat fertility needs are comparable to conventional systems; however, nitrogen is an exception. The cool, moist conditions in early spring slow early plant growth in no-till fields, and the surface residue can immobilize surface-applied nitrogen. Therefore, the spring-applied nitrogen rate for no-till may need to be increased by 17.8 to 26.7 kg ha^{-1} compared with conventional wheat nitrogen rates (Herbek and Murdock, 2006).

Research in Kansas has shown that nutrient shortages can have two consequences depending on plant development stage: an interruption of the tillering process (auxiliary buds slowing or failing to elongate normally); and a reduction of the youngest tillers growth rate (most notably caused by nitrogen deficiency) (Leikam, et al. 2003). Increased grain yield from nitrogen applications can result from improved tiller development and maturation. Nitrogen can reduce wheat tiller mortality, particularly the youngest, providing more spikes per area and subsequently greater grain yield. Thus, grain production is related closely to the secondary tiller (higher order) numbers that produce spikes.

When nitrogen is the first factor for which there is competition, only those tillers with at least three leaves at the time that nitrogen became limiting will maintain growth (Herbek and Murdock, 2006). Therefore, the critical tiller development stage in relation to nitrogen uptake corresponds to a particular stage in the morphogenesis of the root system.

No-till crop production practices leave a protective crop residue (mulch) cover to reduce soil erosion. In many situations, though, these practices lead to reduced nitrogen fertilizer uptake efficiency. Residues on the surface have an effect on nitrogen fertilizer efficiency, particularly when fertilizer is applied directly to the residue. Nitrogen studies in Indiana indicate that nitrogen fertilizer placed in direct contact with surface residue in no-till systems, can result in yields generally not as good as when nitrogen is placed below the residue (Vitosh, et al. 1995).

Surface residue cover can cause a number of changes to occur in soil which also affect nitrogen fertilizer efficiency. The surface cover reduces runoff, increases infiltration, and reduces evaporation; all factors leading to higher soil moisture contents. This can then lead to greater nitrogen leaching. Changes in microbial populations have also been associated with a surface residue layer. Increased bacterial populations have increased both nitrification (the conversion of ammonium nitrogen to nitrate-nitrogen) and denitrification (the conversion of nitrate-nitrogen to N_2 gas) when the soil surface is covered with residue mulch (Herbek and Murdock, 2006). This suggests that nitrogen transformations can occur more quickly in reduced tillage systems and that greater potential for nitrogen immobilization might also exist with the surface mulch. Nitrogen immobilization is the incorporation of nitrogen into soil organic matter. The more nitrogen that is immobilized, the less there is available for the growing crop.

Besides the potential for increased leaching, denitrification, and increased immobilization, the possibility of ammonia volatilization also exists in no-till systems. Applying urea or urea-containing fertilizers to a soil surface covered with residue can result in nitrogen loss.

Research has been conducted on source effects on nitrogen use efficiency in no-till. In all cases, differences were observed among sources when little or no rainfall occurred in the first few days after nitrogen application (Ritchie, et al. 1996). Conversely, if rainfall occurred shortly after nitrogen application, no performance differences were noted among surface-applied nitrogen sources. These results suggest that if dry weather prevails after fertilizer applications; then urea or urea-containing materials will potentially have higher nitrogen losses than other nitrogen sources.

In Pennsylvania, both ammonium sulfate and ammonium nitrate performed better than urea and UAN. Total nitrogen uptake was highest for ammonium nitrate and ammonium sulfate; and lowest with urea and UAN (Mengel, 1986). For no-till cropping practices, injection of nitrogen below the residue is preferred over nitrogen being applied to the crop residue. Injection assures that more of the applied nitrogen will be utilized by the crop, and it removes the weather variable. However, if no-till wheat producers are unable to inject nitrogen fertilizer, then surface banding may provide better performance compared with broadcasting urea or UAN in the more traditional manner.

Surface-applied UAN solutions are used commonly in north central Kansas. These applications can result in nitrogen losses, but these losses are likely to be lower during dry conditions than urea applications. If the fertilizer is in contact with residue and/or with the soil surface, it is important for the urea-based fertilizers to be applied below the soil surface to protect the fertilizer and associated reactions from environmental conditions including: temperature, moisture, and air movement; all of which will affect the urea hydrolysis rate and potential ammonia volatilization (Olson and Swallow, 1984). Nitrogen losses via volatilization increase when urea-containing fertilizers are surface applied to warm, moist soils with large surface residue amounts.

Spring nitrogen applications in a 5-year study (1975-80) resulted in more efficient fertilizer use in four of the five years compared with fall treatments (Staggenborg, et al. 2003). These differences were attributed to immobilization of the fall-applied nitrogen. The possibility exists, however, that weather conditions may interfere with spring nitrogen applications causing very low fertilizer use efficiency or timely application.

No-till Wheat Seeding Rates and Variety Selection

No-till wheat variety selection should be based on yield potential, disease resistance and lodging resistance. Past seeding rate recommendations have been based on kg ha^{-1}. However, wheat seed sizes can lead to a doubling or even tripling of plant populations if seeding rates are based on kilograms per hectare rather than seeds per hectare. Maximum yields, based on a 17.8 cm row spacing research at the University of Delaware, were achieved with a minimum of 45 to 54 plants m^{-1} or a target rate of 60 to 75 seeds m^{-1} of row (Walker, et al. 1998).

In 2003, a no-till winter wheat seeding rate study was conducted for wheat following grain sorghum and soybeans. Seeding rates greater than 134 kg ha^{-1} were required to maximize grain yields, regardless of the previous crop. This was approximately 35 kg ha^{-1} higher than the recommended seeding rate for continuous wheat. Previous crop influenced nitrogen management, with wheat following grain sorghum requiring approximately 21 kg ha^{-1} more nitrogen fertilizer to maximize yields than wheat following soybeans (Staggenborg et al. 2003). The higher nitrogen requirement following grain sorghum was attributed to the higher residue levels produced by grain sorghum and greater nitrogen immobilization by the residue.

Research in north central Kansas with no-till wheat drilled into fields after row crop harvest reported a decline in tillers when planting dates were delayed. If the wheat drilling was delayed 2 weeks past the optimal 4 to 10 October planting date, then recommended wheat seeding rates increased to 134 kg ha^{-1} or above. The increased seeding rates compensated for reduced tillering that typically occurs with later planting dates. However, the 100 kg ha^{-1} rate was sufficient for the late September plantings (Staggenborg, et al. 2004).

A no-till wheat seeding rate study conducted in 1997 at Ohio State University concluded that there was no difference in yields among different seeding rates (Baker, 1998). These results were consistent with similar plot results during the previous ten years. Straw thickness was noticeably larger in the lower seeding rates. When wheat spike numbers were compared with seeding rates, the wheat plants had compensated resulting in similar spike numbers; and lower seeding rates produced more tillers per plant than higher seeding rates.

Tillering enables winter wheat to compensate for low plant populations early in the season or to recover from stress. When winter conditions are harsh, though, tillering may be slower in the spring depending on spring weather. Spike numbers and yield may be low, because spring tiller production cannot compensate for low plant density, inadequate tillering in the fall, or winterkilling of whole plants or individual tillers (Darwinkel, 1978).

No-till Continuous Wheat / Fungicide Management Research

No-till continuous wheat production systems, which leave wheat residues on the soil surface, may create a bridge that allows certain pests and diseases to move from one wheat crop to the next. Foliar diseases, such as tan spot (*Pyrenophora tritici-repentis)*, Septoria leaf blotch or speckled leaf blotch (*Septoria tritici)*, glume blotch (Stagonospora nodorum), and take-all root rot (Gaeumannomyces graminis var. tritici) take advantage of this residue bridge and are often worse in no-till fields. In fact, tan spot is rarely seen in wheat fields conventionally tilled, but is often seen in no-till fields when wheat is planted continuously for two years or more. Tan spot spores over summer on the wheat straw residue from the previous crop and have the potential to inoculate the seedlings in the fall.

Fusarium head blight (scab) infections are also more prevalent in no-till wheat fields (Bowden, 2000). Scab lives on corn and wheat residues left on the soil surface. If the weather is hot and humid during heading, and if there are wet springs with plenty of rain to splash Fusarium spores onto the developing heads, scab can become serious. Consequently, no-till producers are encouraged to select wheat varieties with better head scab resistance; however, there area no varieties with correlated resistance.

Wheat producers are encouraged to choose varieties with resistance to important diseases. Genetic resistance is available against tan spot, powdery mildew, speckled leaf blotch, and Septoria tritici blotch. Also, good resistance is available against wheat streak mosaic and leaf rust. Seed treatment fungicides may improve emergence, reduce no-till wheat post-emergence damping-off, and seedborne pathogens.

Avoiding early planting can reduce incidence of barley yellow dwarf, wheat streak mosaic, take-all, and common root rot. Foliar fungicides can reduce leaf rust, tan spot, Septoria tritici blotch, and powdery mildew severity. (Bowden, 2000) Interestingly, increased residue can decrease the incidence and/or severity of barley yellow dwarf virus (BYDV) by altering the behavior of the aphids that transmit this virus. Aphids are attracted to more openly spaced wheat plants, with large amounts of residue being less appealing. Thus, no-till fields may attract fewer aphids, which may translate into a lower incidence of BYDV. Also, there are fewer problems with common root rot and dryland foot rot in no-till fields (Edwards et al. 2006).

Therefore, because hard red winter wheat (Triticum aestivum L.) is the predominate crop grown in North Central Kansas; and no-till wheat production practices have gained popularity in this region. No-till continuous wheat production research has been lacking for north central Kansas producers. As input costs are increasing, no-till wheat growers are seeking answers to proper seeding rates, wheat no-till fertility issues, and fungicide management. The following research results focus on three important management issues critical for no-till wheat production: seeding rates; nitrogen fertility; and fungicide application.

This two-year study was conducted with three objectives. The first objective was to determine if increased wheat seeding rates are needed to overcome stand establishment issues in no-till conditions. The second objective was to determine if increased nitrogen (N) rates are needed to compensate for higher residue levels on the soil surface. The third objective was to determine if variety selection influenced yields due to higher disease potential under continuous no-till conditions.

CHAPTER 2 - Materials and Methods

This two-year study was conducted for wheat harvest years 2005 and 2006. The 2005 site was planted on 7 October, 2004 on the Dean & Kara Revell farm located 2 miles NW of Miltonvale, Kansas on a Crete silt loam soil (Loess –Crete-Longford-Hedville Association). The 2006 site was established on 10 October, 2005 on the Loren / Roger Koester farm located two miles south and ½ mile east of

Concordia, Kansas on a Hastings silt loam soil. Both locations were planted with a no-till plot drill with 20.3 cm spacing (Model 6053 PNT, Great Plains Mfg., Salina, KS). Treatments were arranged in a randomized complete block design with four replications. The locations were selected based on cooperators' field availability and previous crop. Since this experiment was designed for continuous wheat under no-till production systems, selected fields produced winter wheat during the previous year; and thus facilitated continuous wheat following wheat no-till study into wheat residue. Plot size was 2 m wide and 90 m long. Target seeding rates were 100 and 134 kg ha^{-1}. Starter rates were 40 kg ha^{-1} rates with 0, 78, 112, and 146 kg urea N ha^{-1} rates applied as spring topdress. The wheat varieties 'Overley' and '2145' were used because of their differences in tan spot resistance (Bowden, 2004). A fungicide study was also incorporated into this project with a spring fungicide application applied after flag-leaf emergence each year. Fungicide (Quilt®) treatments were applied to plots planted at 100 kg ha^{-1} seeding & 112 kg ha^{-1} nitrogen rates at 0.13 kg a.i. ha^{-1} of propiconazole and 0.08 kg a.i. ha^{-1} of azoxystrobin using a backpack sprayer delivering approximately 70 l ha^{-1}.

Overley was selected for the study as a highly recommended no-till hard red winter variety because of its good tolerance to wheat diseases such as tan spot, wheat streak mosaic virus, soil borne mosaic virus, and Septoria. (Fritz, et al. 2004). Overley, a Kansas State University variety released in 2003, is a hard red winter wheat selected from the cross U1275-1-4-2-2/Heyne 'S'//Jagger. U1275 is a germplasm line from the USDA-ARS, Manhattan, with the pedigree TAM-107 *3/TA 2460. For north central Kansas, this variety has excellent yield potential, outstanding milling & baking qualities, and resistance to stripe rust (Puccinia striiformis).

The wheat variety 2145 was selected as a contrasting hard red winter wheat varieties planted in north central Kansas. 2145 is a Kansas State University variety released in 2001 from an F2 population given to K-State by Pioneer in 1989. The pedigree of 2145 is HBA142A/HBZ621A//Abilene. HBA142A and HBA621A were Pioneer experimental lines and their pedigrees are unknown. (Fritz, et al. 2002). It is susceptible to many wheat diseases which can be harbored in volunteer wheat and wheat residue, such as tan spot and wheat streak mosaic, and has intermediate resistance to Septoria leaf blotch and stripe rust and is resistant to soil-borne mosaic.

Stand counts were recorded each year in November approximately (one month after planting) with the topdress nitrogen applied approximately 6 weeks after planting (16 November 2004 and 20 November 2005). Plots were harvested with a plot combine (Model 20, Hege Mfg, Colwich, KS).

Yield variances were compared for the heterogeneous variance using the F_{MAX} method. It was determined that results from the two yield years were similar; therefore, the two years were combined. Data were analyzed with the General Linear Model procedures (GLM) to test main effects and interactions. Regression analysis was used to evaluate nitrogen responses. A Fisher's Least Significant Difference (LSD) was used to separate treatment means.

Chapter 3

Results and Discussion

In this study, the selected wheat seeding rates and nitrogen rates were based on the normal ranges used in north central Kansas. The year main effect was significant (Table 2.1) and yield ranges across the plots were from 2,500 to 4,500 kg ha^{-1} which is consistent with normal average area yields.

The wide variation in yields from year to year is most likely due to variations in stand establishment, temperature, nitrogen treatments, variety influence, and rainfall during the two cropping years.

Wheat variety also affected yields (Table 2.1) across both years with higher yields for both varieties in 2005 than 2006. Overley averaged 3,800 kg ha^{-1} while 2145 yielded 3,400 kg ha^{-1} (Fig. 2.1). Yields were also influenced by nitrogen rates (Table 2.1) as yields increased both years with increased nitrogen rates (Fig. 2.2).

Fungicide Study

Overall, the fungicide combination (azoxystrobin + propiconazole) treatments did not affect wheat yield results either year. In 2005, yields averaged 3,026 kg ha^{-1} with the fungicide treatment; whereas, the plots averaged 2,939 kg ha^{-1} without the fungicide application. Since the least significant difference (LSD) for the plot was 278 kg ha^{-1}; thus the fungicide treatment was insignificant. In 2006, the wheat plot yields averaged 4,506 kg ha^{-1} with the fungicide treatment; whereas, the plots averaged 4,402 kg ha^{-1} without the fungicide. Since the least significant difference (LSD) for the plot was 211.5 kg ha^{-1}; the 2006 fungicide yield comparisons also were insignificant. The ANOVA results for the fungicide test (Table 2.3) reflect that Overley significantly yielded higher than 2145 during both years; however, the fungicide x variety interaction was not significant.

Summary and Conclusions

Overall, our results support the conclusions of previous university experiments outlined in the literature review. Mainly, wheat variety selection is very important for north central Kansas no-till wheat producers. Improved varieties with enhanced wheat disease and insect resistances likely will provide higher grain yields than wheat varieties with lacking resistances. Also, wheat responds favorably to nitrogen fertilizer when moisture is not a limiting factor.

In these results, wheat yield increased both years as nitrogen fertilizer rates increased. In the lower 2004-05 production year, the plots averaged 2,391 kg ha^{-1} in the unfertilized plots. Wheat yields increased 3.52 kg ha^{-1} grain yield for each 1 kg ha^{-1} increase in nitrogen rate. Yield results from the higher 2005-06 production year recorded a similar result. The 3,934 kg ha^{-1} base yield without nitrogen fertilizer was 1,543 kg ha^{-1} higher yielding than the previous year; and corresponding response to added nitrogen was similar to the previous year. However, in both years, the optimum or maximum nitrogen rate was not identified, indicating the higher nitrogen rates may be needed in second-year no-till wheat. This is an area that should be studied in the future.

The seeding rate research provided some unexpected outcomes. For example, the standard recommendation for north central Kansas wheat producers was that wheat seeding rates should be increased for no-till production. However, based on these findings, no-till wheat planted during the recommended planting period should produce similar yields whether it is drilled at 100 kg ha^{-1} or 134 kg ha^{-1} seeding rates. Also, the reduced stands establishment rates in 2005 provided a surprising outcome; mainly, that the seeding rates did not affect yield and were consistent with the higher plant establishment rates in 2006.

Overall, north central Kansas producers still must consider cost/return economics before finalizing a no-till management program. Rainfall is still the most limiting factor in dryland wheat production. However, variety selection and nitrogen availability are critical factors for long-range sustainability. And, with narrow return margins on many production years, seed cost savings with lower seeding rates will likely improve producer return rates when wheat is drilled during the recommended planting period.

Wheat seeding rates are not as important in overall yield response as nitrogen rates and fertilizer placement. For north central Kansas, wheat planted during the recommended planting dates of 4 October through 10 October will likely have similar yields. However, if the planting date extends into the third week of October or beyond, then seeding rates should be increased to over 130 kg ha^{-1}.

North central Kansas producers should select high yielding wheat varieties with good disease resistances such as tan spot. Compared to conventionally tilled fields, no-till field nitrogen rates should be increased at least 22.4 kg ha^{-1}. Then, to reduce nitrogen application losses, nitrogen products should be injected under crop residue or combined with urease inhibitors to lower losses.

Table 2.1 Analysis-of-Variance results for no-till wheat planted in 2005 and 2006 in north central Kansas.

Source	df	Mean Square
YEAR	1	16790.3 **
REPLICATION (year)	6	20.2
TREATMENTS		
variety	1	657.0 **
nitrogen rate	3	435.9 **
seeding rate	1	75.0
nitrogen rate*variety	3	52.2
variety*seeding rate	1	4.5
nitrogen rate*seeding rate	3	45.7
year*variety	1	45.1
year*nitrogen rate	3	20.5
year*seeding rate	1	4.5
Nrate*variety*seeding rate	3	12.8
year*Nrate*variety	3	17.4
year*variety*seeding rate	1	13.8
year*Nrate*seeding rate	3	36.8
year*Nrate*variety*seed	3	41.4
ERROR	**90**	21.0
CV%	**9.7**	

Table 2.2 Analysis-of-Variance results for a wheat fungicide study conducted in 2005 and 2006 in north central Kansas.

Source	**df**	**Mean Square**
Model	6	87.3
Replication	3	26.2
TREATMENTS		
variety	1	410.1 **
fungicide	1	7.5
fungicide*variety	1	27.6
ERROR	**9**	7.7
CV%	**4.7**	

** indicates significance at the .01 level

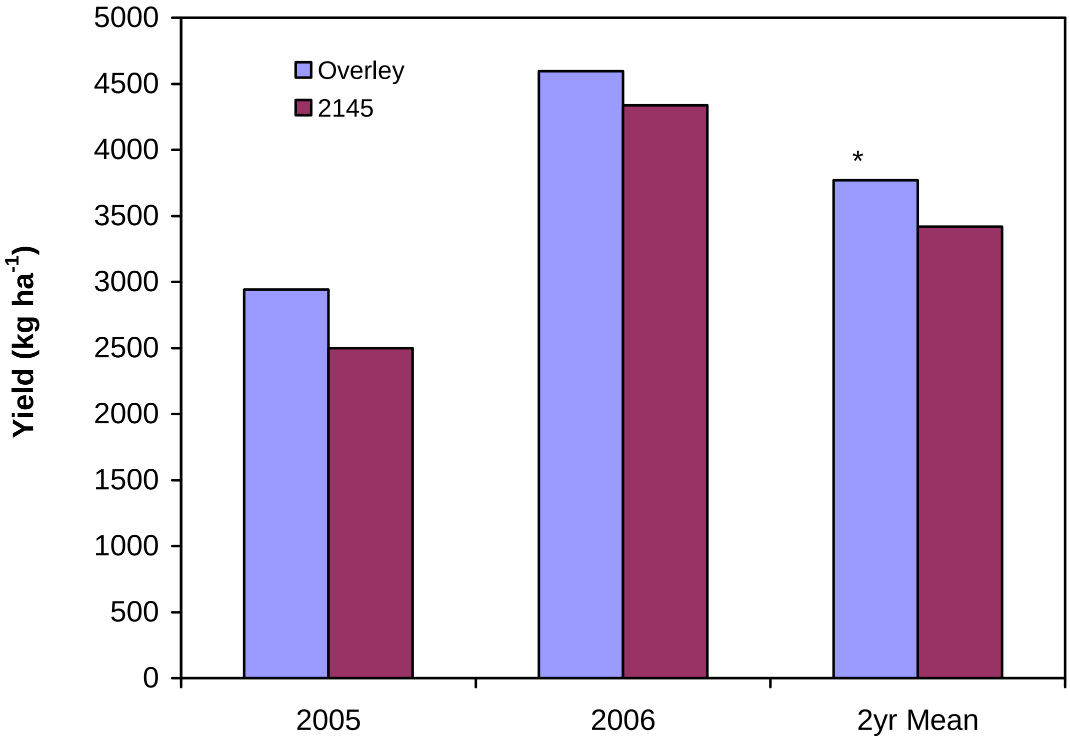

Figure 2.1 'Overley' & '2145' varieties yield response in 2005, 2006 and the mean of both years.

*** indicates significance at the 0.05 level.**

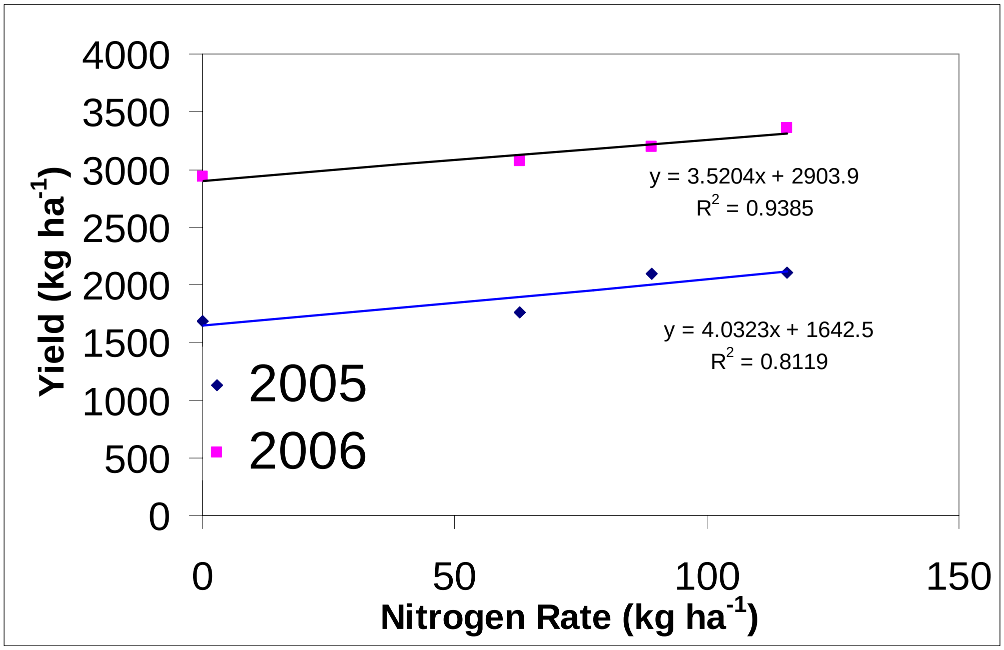

Figure 2.2 Wheat yield regression response to N rates for two years in north central Kansas.

‘Overley’ Fungicide Yield Response

2005 -- No Fungicide = 2939 kg/ha
With Fungicide = 3026 kg/ha

Yield Difference = 87 kg/ha

$LSD_{.05}$ = 278 kg/ha

* Therefore, fungicide not significant

‘Overley’ Fungicide Yield Response

<u>2006</u> -- No Fungicide = 4402 kg/ha
With Fungicide = 4506 kg/ha

Yield Difference = 104 kg/ha

$LSD_{.05}$ = 212 kg/ha

* Therefore, fungicide not significant

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Appendix A – Wheat Plant Stand Counts – 9 Nov 2004

The 2004-05 cropping year replicated plot had reduced wheat emergence due to the heavy wheat residue from the previous no-till wheat crop. Planting depth became a challenge for the small plot drill. Therefore, the 2005-06 replicated plots improved with the Great Plains no-till drill.

11/9/2004

Cloud-Revell Plot 2

	M1	plts/ac	M2	plts/ac	Aver plts/acre	plts/est
111	17	394944	21	487872	**441408**	**738349**
112	22	511104	29	673728	**592416**	**738349**
113	20	464640	27	627264	**545952**	**738349**
114	20	464640	28	650496	**557568**	**1107523**
115	31	720192	30	696960	**708576**	**1107523**
116	17	394944	36	836352	**615648**	**1107523**
117	32	743424	26	604032	**673728**	**1476698**
118	30	696960	28	650496	**673728**	**1476698**

	M1	plts/ac	M2	plts/ac	Aver plts/acre	plts/est
211	12	278784	22	511104	**394944**	**738349**
212	15	348480	21	487872	**418176**	**1107523**
213	25	580800	12	278784	**429792**	**1476698**
214	29	673728	27	627264	**650496**	**738349**
215	21	487872	20	464640	**476256**	**1476698**

216	28	650496	27	627264	**638880**	**1107523**
217	23	534336	22	511104	**522720**	**1476698**
218	19	441408	17	394944	**418176**	**1107523**

	M1	plts/ac	M2	plts/ac	Aver plts/acre	plts/est
311	22	511104	25	580800	**545952**	**1107523**
312	16	371712	19	441408	**406560**	**1107523**
313	29	673728	28	650496	**662112**	**1476698**
314	29	673728	28	650496	**662112**	**738349**
315	15	348480	20	464640	**406560**	**1476698**
316	29	673728	30	696960	**685344**	**738349**
317	24	557568	20	464640	**511104**	**1107523**
318	31	720192	34	789888	**755040**	**1107523**

	M1	plts/ac	M2	plts/ac	Aver plts/acre	plts/est
411	29	673728	30	696960	**685344**	**1107523**
412	31	720192	29	673728	**696960**	**1107523**
413	21	487872	23	534336	**511104**	**738349**
414	20	464640	21	487872	**476256**	**1476698**
415	30	696960	31	720192	**708576**	**1107523**
416	21	487872	20	464640	**476256**	**1476698**
417	32	743424	30	696960	**720192**	**1107523**
418	30	696960	31	720192	**708576**	**738349**

Appendix B – 2005 & 2006 Wheat Plot Yield Data Results

Plot	REP	VARI	Nrate	SEED	Yield	Year	Plot	REP	VARI	Nrate	Seed	Yield	Year
111	1	V2145	0	90	32	2005	111	1	V2145	0	90	56	2006
203	2	V2145	0	90	24	2005	203	2	V2145	0	90	62	2006
303	3	V2145	0	90	23	2005	303	3	V2145	0	90	61	2006
403	4	V2145	0	90	26	2005	403	4	V2145	0	90	52	2006
114	1	V2145	70	90	31	2005	114	1	V2145	70	90	56	2006
206	2	V2145	70	90	24	2005	206	2	V2145	70	90	61	2006
311	3	V2145	70	90	39	2005	311	3	V2145	70	90	57	2006
407	4	V2145	70	90	30	2005	407	4	V2145	70	90	50	2006
112	1	V2145	100	90	38	2005	112	1	V2145	100	90	57	2006
212	2	V2145	100	90	31	2005	212	2	V2145	100	90	55	2006
312	3	V2145	100	90	37	2005	312	3	V2145	100	90	53	2006
410	4	V2145	100	90	34	2005	410	4	V2145	100	90	52	2006
113	1	V2145	130	90	36	2005	113	1	V2145	130	90	66	2006
217	2	V2145	130	90	29	2005	217	2	V2145	130	90	53	2006
315	3	V2145	130	90	38	2005	315	3	V2145	130	90	55	2006
414	4	V2145	130	90	36	2005	414	4	V2145	130	90	52	2006
116	1	V2145	0	120	32	2005	116	1	V2145	0	120	57	2006
201	2	V2145	0	120	24	2005	201	2	V2145	0	120	56	2006
309	3	V2145	0	120	38	2005	309	3	V2145	0	120	49	2006
401	4	V2145	0	120	32	2005	401	4	V2145	0	120	51	2006
117	1	V2145	70	120	32	2005	117	1	V2145	70	120	54	2006
211	2	V2145	70	120	28	2005	211	2	V2145	70	120	48	2006
313	3	V2145	70	120	29	2005	313	3	V2145	70	120	65	2006
405	4	V2145	70	120	28	2005	405	4	V2145	70	120	52	2006
118	1	V2145	100	120	36	2005	118	1	V2145	100	120	61	2006
214	2	V2145	100	120	34	2005	214	2	V2145	100	120	64	2006
314	3	V2145	100	120	42	2005	314	3	V2145	100	120	57	2006
411	4	V2145	100	120	47	2005	411	4	V2145	100	120	63	2006
115	1	V2145	130	120	27	2005	115	1	V2145	130	120	67	2006
215	2	V2145	130	120	29	2005	215	2	V2145	130	120	53	2006
316	3	V2145	130	120	44	2005	316	3	V2145	130	120	65	2006
418	4	V2145	130	120	41	2005	418	4	V2145	130	120	62	2006
101	1	Overley	0	90	34	2005	101	1	Overley	0	90	56	2006

207	2	Overley	0	90	33	2005	207	2	Overley	0	90	52	2006
307	3	Overley	0	90	32	2005	307	3	Overley	0	90	54	2006
413	4	Overley	0	90	35	2005	413	4	Overley	0	90	51	2006
102	1	Overley	70	90	38	2005	102	1	Overley	70	90	58	2006
202	2	Overley	70	90	40	2005	202	2	Overley	70	90	57	2006
306	3	Overley	70	90	36	2005	306	3	Overley	70	90	59	2006
409	4	Overley	70	90	43	2005	409	4	Overley	70	90	55	2006
103	1	Overley	100	90	41	2005	103	1	Overley	100	90	63	2006
213	2	Overley	100	90	44	2005	213	2	Overley	100	90	58	2006
301	3	Overley	100	90	36	2005	301	3	Overley	100	90	61	2006
404	4	Overley	100	90	37	2005	404	4	Overley	100	90	65	2006
104	1	Overley	130	90	38	2005	104	1	Overley	130	90	67	2006
218	2	Overley	130	90	48	2005	218	2	Overley	130	90	60	2006
308	3	Overley	130	90	32	2005	308	3	Overley	130	90	66	2006
408	4	Overley	130	90	49	2005	408	4	Overley	130	90	65	2006
105	1	Overley	0	120	34	2005	105	1	Overley	0	120	56	2006
204	2	Overley	0	120	31	2005	204	2	Overley	0	120	52	2006
304	3	Overley	0	120	39	2005	304	3	Overley	0	120	54	2006
406	4	Overley	0	120	33	2005	406	4	Overley	0	120	57	2006
106	1	Overley	70	120	32	2005	106	1	Overley	70	120	59	2006
210	2	Overley	70	120	33	2005	210	2	Overley	70	120	61	2006
310	3	Overley	70	120	38	2005	310	3	Overley	70	120	60	2006
412	4	Overley	70	120	26	2005	412	4	Overley	70	120	65	2006
107	1	Overley	100	120	42	2005	107	1	Overley	100	120	61	2006
216	2	Overley	100	120	47	2005	216	2	Overley	100	120	69	2006
318	3	Overley	100	120	36	2005	318	3	Overley	100	120	58	2006
415	4	Overley	100	120	44	2005	415	4	Overley	100	120	59	2006
108	1	Overley	130	120	51	2005	108	1	Overley	130	120	62	2006
208	2	Overley	130	120	44	2005	208	2	Overley	130	120	69	2006
305	3	Overley	130	120	45	2005	305	3	Overley	130	120	72	2006
417	4	Overley	130	120	43	2005	417	4	Overley	130	120	68	2006

Appendix C – Combined Year Data Set

Obs	plot	rep	variety	Nrate	seed	yield	year
1	111	1	V2145	0	90	32	2005
2	203	2	V2145	0	90	24	2005
3	303	3	V2145	0	90	23	2005
4	403	4	V2145	0	90	26	2005
5	114	1	V2145	70	90	31	2005
6	206	2	V2145	70	90	24	2005
7	311	3	V2145	70	90	39	2005
8	407	4	V2145	70	90	30	2005
9	112	1	V2145	100	90	38	2005
10	212	2	V2145	100	90	31	2005
11	312	3	V2145	100	90	37	2005
12	410	4	V2145	100	90	34	2005
13	113	1	V2145	130	90	36	2005
14	217	2	V2145	130	90	29	2005
15	315	3	V2145	130	90	38	2005
16	414	4	V2145	130	90	36	2005
17	116	1	V2145	0	120	32	2005
18	201	2	V2145	0	120	24	2005
19	309	3	V2145	0	120	38	2005
20	401	4	V2145	0	120	32	2005
21	117	1	V2145	70	120	32	2005
22	211	2	V2145	70	120	28	2005
23	313	3	V2145	70	120	29	2005
24	405	4	V2145	70	120	28	2005
25	118	1	V2145	100	120	36	2005
26	214	2	V2145	100	120	34	2005
27	314	3	V2145	100	120	42	2005
28	411	4	V2145	100	120	47	2005
29	115	1	V2145	130	120	27	2005
30	215	2	V2145	130	120	29	2005
31	316	3	V2145	130	120	44	2005
32	418	4	V2145	130	120	41	2005
33	101	1	Overley	0	90	34	2005

34	207	2	Overley	0	90	33	2005
35	307	3	Overley	0	90	32	2005
36	413	4	Overley	0	90	35	2005
37	102	1	Overley	70	90	38	2005
38	202	2	Overley	70	90	40	2005
39	306	3	Overley	70	90	36	2005
40	409	4	Overley	70	90	43	2005
41	103	1	Overley	100	90	41	2005
42	213	2	Overley	100	90	44	2005
43	301	3	Overley	100	90	36	2005
44	404	4	Overley	100	90	37	2005
45	104	1	Overley	130	90	38	2005
46	218	2	Overley	130	90	48	2005
47	308	3	Overley	130	90	32	2005
48	408	4	Overley	130	90	49	2005
49	105	1	Overley	0	120	34	2005
50	204	2	Overley	0	120	31	2005
51	304	3	Overley	0	120	39	2005
52	406	4	Overley	0	120	33	2005
53	106	1	Overley	70	120	32	2005
54	210	2	Overley	70	120	33	2005
55	310	3	Overley	70	120	38	2005
56	412	4	Overley	70	120	26	2005
57	107	1	Overley	100	120	42	2005
58	216	2	Overley	100	120	47	2005
59	318	3	Overley	100	120	36	2005
60	415	4	Overley	100	120	44	2005
61	108	1	Overley	130	120	51	2005
62	208	2	Overley	130	120	44	2005
63	305	3	Overley	130	120	45	2005
64	417	4	Overley	130	120	43	2005
65	111	1	V2145	0	90	56	2006
66	203	2	V2145	0	90	62	2006
67	303	3	V2145	0	90	61	2006
68	403	4	V2145	0	90	52	2006
69	114	1	V2145	70	90	56	2006

70	206	2	V2145	70	90	61	2006
71	311	3	V2145	70	90	57	2006
72	407	4	V2145	70	90	50	2006
73	112	1	V2145	100	90	57	2006
74	212	2	V2145	100	90	55	2006
75	312	3	V2145	100	90	53	2006
76	410	4	V2145	100	90	52	2006
77	113	1	V2145	130	90	66	2006
78	217	2	V2145	130	90	53	2006
79	315	3	V2145	130	90	55	2006
80	414	4	V2145	130	90	52	2006
81	116	1	V2145	0	120	57	2006
82	201	2	V2145	0	120	56	2006
83	309	3	V2145	0	120	49	2006
84	401	4	V2145	0	120	51	2006
85	117	1	V2145	70	120	54	2006
86	211	2	V2145	70	120	48	2006
87	313	3	V2145	70	120	65	2006
88	405	4	V2145	70	120	52	2006
89	118	1	V2145	100	120	61	2006
90	214	2	V2145	100	120	64	2006
91	314	3	V2145	100	120	57	2006
92	411	4	V2145	100	120	63	2006
93	115	1	V2145	130	120	67	2006
94	215	2	V2145	130	120	53	2006
95	316	3	V2145	130	120	65	2006
96	418	4	V2145	130	120	62	2006
97	101	1	Overley	0	90	56	2006
98	207	2	Overley	0	90	52	2006
99	307	3	Overley	0	90	54	2006
100	413	4	Overley	0	90	51	2006
101	102	1	Overley	70	90	58	2006
102	202	2	Overley	70	90	57	2006
103	306	3	Overley	70	90	59	2006
104	409	4	Overley	70	90	55	2006
105	103	1	Overley	100	90	63	2006

106	213	2	Overley	100	90	58	2006
107	301	3	Overley	100	90	61	2006
108	404	4	Overley	100	90	65	2006
109	104	1	Overley	130	90	67	2006
110	218	2	Overley	130	90	60	2006
111	308	3	Overley	130	90	66	2006
112	408	4	Overley	130	90	65	2006
113	105	1	Overley	0	120	56	2006
114	204	2	Overley	0	120	52	2006
115	304	3	Overley	0	120	54	2006
116	406	4	Overley	0	120	57	2006
117	106	1	Overley	70	120	59	2006
118	210	2	Overley	70	120	61	2006
119	310	3	Overley	70	120	60	2006
120	412	4	Overley	70	120	65	2006
121	107	1	Overley	100	120	61	2006
122	216	2	Overley	100	120	69	2006
123	318	3	Overley	100	120	58	2006
124	415	4	Overley	100	120	59	2006
125	108	1	Overley	130	120	62	2006
126	208	2	Overley	130	120	69	2006
127	305	3	Overley	130	120	72	2006
128	417	4	Overley	130	120	68	2006