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Crop Rotations with Limited Irrigation

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Abstract. *Research was initiated in 2001 and conducted through 2010 under sprinkler irrigation in western Kansas to evaluate limited irrigation in several no-till crop rotations on grain yield, water use, and profitability. Crop rotations were 1) continuous corn, 2) corn-winter wheat, 3) corn-wheat-grain sorghum, and 4) corn-wheat-grain sorghum-soybean. Irrigation was limited to 10 inches annually with 5 inches applied to wheat, 15 inches to corn (when in rotation with wheat), and 10 inches to grain sorghum, soybean, and continuous corn. Crop water productivity and yield of corn was greater when grown in rotation than with continuous corn. The length of the rotation did not affect grain yield or crop water productivity of grain sorghum or winter wheat. Continuous corn was generally the most profitable cropping system. However, relatively small changes in prices or yields could result in multi-crop rotations being more profitable, indicating the potential for alternate crop rotations to reduce risk under limited irrigation.*

Introduction

Irrigated crop production is an important component of agriculture in western Kansas. However, with declining water levels in the Ogallala Aquifer and high energy costs, optimal utilization of limited irrigation water is required. Precipitation is limited and sporadic in the region with annual precipitation supplying about 60-90% of the seasonal water requirement for grain sorghum and only 50-75% for corn (Doorenbos and Kassam, 1979). While crop rotations have been used extensively in many dryland systems, the most common crop grown under irrigation in western Kansas is corn (about 50% of the irrigated acres), often in a continuous corn system. While corn responds well to irrigation, it also requires substantial amounts of water to maximize production. Almost all of the groundwater pumped from the High Plains (Ogallala) Aquifer is used for irrigation (97% of the groundwater pumped in western Kansas in 1995 [Kansas Department of Agriculture, 1997]) with 57% applied to corn (Kansas Water Office, 1997). This amount of water withdrawal from the aquifer has reduced saturated thickness in some areas up to 150 ft. Although crops other than corn are grown under irrigation, they have not been grown as extensively because of relatively inexpensive water and a ready market for corn to the livestock feeding industry in the area. The trend in western Kansas during the 1990s has been towards increasing acreage of irrigated corn (665,000 acres in 1990 compared with 1.2 million acres in 2000) with corresponding reductions in grain sorghum (326,000 acres in 1990 compared with 71,000 acres in 2000) and winter wheat (692,000 acres in 1990 compared with 455,000 acres in 2000) (Kansas Farm Facts, 1991 and 2001). Although corn is expected to remain the dominant irrigated grain crop (especially in areas with abundant groundwater), the need exists to develop strategies to more effectively utilize limited irrigation water for corn. While there have been increases in irrigated soybean acreage (71,000 acres in 1990 compared with 134,000 acres in 2000), there has been limited research on water use characteristics in western Kansas.

Alternative crop management practices are needed to reduce the amount of irrigation water required while striving to maintain economic returns sufficient for producer sustainability. To prepare for less water available for irrigation in the future, whether from physical constraints (lower well capacities and declining water tables) or from regulatory limitations, information on crop productivity and profitability with less irrigation water will be beneficial for agricultural sustainability.

Materials and Methods

A field study was conducted at the Kansas State University Southwest Research-Extension Center near Tribune, KS from 2001 to 2010 on a deep silt loam soil (Ulysses silt loam [fine-silty, mixed, superactive, mesic Aridic Haplustolls]). Only data collected beginning in 2003 are presented to allow time for establishment of the crop rotations. The region is semi arid with a summer precipitation pattern and an average annual precipitation of 440 mm. The study consisted of four crop rotations; continuous corn (CC), corn-winter wheat (CW), corn-winter wheat-grain sorghum (CWS), and corn-winter wheat-grain-sorghum-soybean (CWSB). Each phase of each rotation was present each year and replicated four times. The plots were approximately 60 ft wide and 120 ft long. Irrigations were scheduled to supply water at the most critical stress periods (near flowering) for the specific crop and were limited to 1.5 inches per week. If precipitation was sufficient within a week, then irrigation was postponed. In some years, the maximum amount of irrigation was not applied because of above normal precipitation. The average first irrigation was 14 June for corn in rotation, 23 June for continuous corn, and 4 July for sorghum and soybean. The final irrigation averaged 28 August for corn in rotation, 15 August for continuous corn, and 22 August for sorghum and soybean. If needed to aid emergence of wheat, irrigation was initiated in the fall (four years) otherwise irrigation was reserved for spring application with average final irrigation on 6 June.

Average plantings dates were 3 May for corn, 20 May for soybean, and 27 May for grain sorghum. Winter wheat was planted after corn harvest (average of 1 October). Cultural practices (e.g., pesticides, tillage, and fertilization) typical for the region were used in all years of the study. The center portion of all plots was machine harvested with grain yields adjusted to 15.5% moisture (wet basis) for corn, 13% for soybean, and 12.5% for sorghum and wheat. Plant densities were determined along with the other yield components (kernels/ear and kernel mass).

The plots were irrigated with a linear move sprinkler irrigation system which had been modified to allow for water application from different span sections as needed to accomplish the randomization of plots. Soil water measurements (8-ft depth in 1-ft increments) were taken throughout the growing season using neutron attenuation. Available soil water was calculated by subtracting unavailable water from measured soil water. All water inputs, precipitation and irrigation, were measured. Crop water use was calculated by summing soil water depletion (soil water near emergence less soil water at harvest) plus in-season irrigation and precipitation. Non-growing season soil water accumulation was the increase in soil water from harvest to the amount at emergence the following year. Precipitation storage efficiency was calculated as non-growing season soil water accumulation divided by non-growing season precipitation. Crop water productivity (WP) was calculated as grain yield (bu acre^{-1}) divided by crop water use (inches).

Statistical analyses were performed using the GLM procedure from SAS version 9.1 (SAS Institute, Cary, North Carolina).

Local crop prices and input costs were used to perform an economic analysis to determine net return to land, management, and irrigation equipment for each treatment. Custom rates were used for all machine operations. Harvest prices and input costs were kept uniform for all years based on 2010 prices.

The objectives of this research were to determine the effect of limited irrigation on crop yield, water use, and profitability in several crop rotations.

Results and Discussion

All rotations were limited to an average of 10 inches of irrigation annually; however, corn following wheat received 15 inches because the wheat received only 5 inches. This extra 5 inches of irrigation water increased the level of irrigation to nearly full and increased corn yields about 40 bu acre^{-1} compared with continuous corn (Table 1). Thus, limited irrigated corn yielded about 80% of full irrigation. Klocke et al. (2007) reported that limited irrigation (no more than 6 in water) yields were 80 to 90% of fully irrigated yields. Corn yields in the multi-crop rotations were similar regardless of length of rotation. Wheat and grain sorghum yields were similar in all rotations.

Table 1. Average grain yields of four crops as affected by crop rotation, KSU Southwest Research-Extension Center, Tribune, KS, 2003-2010.

	Crop rotation†			
Crop	CC	CW	CWS	CWSB
	bu acre^{-1}			
Corn	163 b‡	203 a	202 a	203 a
Wheat	—	35 a	36 a	37 a
Sorghum	—	—	134 a	138 a
Soybean	—	—	—	43

† CC = continuous corn; CW = corn-wheat; CWS = corn-wheat-grain sorghum; CWSB = corn-wheat-grain sorghum-soybean.
‡ Means within a row with different letters are significantly different (P≤0.05).

Crop water productivity was in the order of corn>sorghum>wheat=soybean (Table 2). Crop water productivity of corn was increased when irrigation was increased to 15 inches and grown in rotation with other crops. Grain sorghum grown in 4-yr rotations had slightly greater crop water productivity than grown in 3-yr rotations. The length of rotation had no effect on crop water productivity of wheat.

Table 2. Average crop water productivity of four crops as affected by crop rotation, KSU Southwest Research-Extension Center, Tribune, KS, 2003-2010.

	Crop rotation†			
Crop	CC	CW	CWGS	CWSB
	---lb acre-inch^{-1}---			
Corn	377 b‡	411 a	398 a	410 a
Wheat	—	115 a	125 a	122 a
Sorghum	—	—	314 b	326 a
Soybean	—	—	—	110

† CC = continuous corn; CW = corn-wheat; CWS = corn-wheat-grain sorghum; CWSB = corn-wheat-grain sorghum-soybean.
‡ Means within a row with different letters are significantly different ($P \leq 0.05$).

An economic analysis (based on grain prices and input costs in 2010 with average crop yields) found that the most profitable crop was corn in rotation with other crops (Table 3). Profitability was similar for grain sorghum and soybean in the 3- and 4-yr rotations. The least profitable crop was wheat, primarily because of reduced yields caused by hail and spring freeze injury in about 50% of the years. However, the most profitable crop rotation was continuous corn. All multi-crop rotations had net returns of \$57-69 acre^{-1} less than CC. Lower returns in the multi-crop rotations were due to low returns from wheat.

Table 3. Net return to land, irrigation equipment, and management from four crop rotations, KSU Southwest Research-Extension Center, Tribune, KS, 2003-2010.

	Crop rotation†			
Crop	CC	CW	CWS	CWSB
	--- \$ acre^{-1} ---			
Corn	237	332	326	321
Wheat	—	4	1	5
Sorghum	—	—	189	198
Soybean	—	—	—	198
Net for rotation	237	168	172	180

† CC = continuous corn; CW = corn-wheat; CWS = corn-wheat-grain sorghum; CWSB = corn-wheat-grain sorghum-soybean.

Conclusions

With limited irrigation (10 inches annually), continuous corn has been more profitable than multi-crop rotations including wheat, sorghum, and soybean primarily because of spring freeze and hail damage to wheat in the multi-crop rotations. In multi-crop rotations, relatively poor results with one crop (in this case wheat) can reduce profitability compared with a monoculture, especially when the monoculture crop does well. However, the multi-crop rotation can reduce economic risk when the monoculture crop does not perform as well. All multi-crop rotations had net returns only \$12-24 acre^{-1} less than continuous corn. Therefore, relatively small changes in prices or yields could result in any of the rotations being more profitable than continuous corn, indicating the potential for alternate crop rotations under limited irrigation.

Acknowledgements

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Nitrogen Extenders and Additives

FOR FIELD CROPS

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Nitrogen management continues to be difficult due to transformations of nitrogen fertilizers that are possible when applied to soil and the uncertainties of weather (Cabrera et al., 2008). Nitrogen (N) fertilizer in the form of urea is subject to ammonia volatilization through the activity of the urease enzyme found ubiquitously in soil (Kissel et al., 2008). Nitrate fertilizer is subject to leaching (Randall et al., 2008) or denitrification (Coyne, 2008), depending on the water content of the soil and water movement through the soil. Ammonium forms of N can be fixed (Kissel et al., 2008) or transformed to nitrate through the activities of specific soil bacteria (Norton, 2008). Because of these and other processes, nitrogen use efficiency is low.

Nitrogen often is applied to crops in the north-central region of the U.S. before planting. During the first four to six weeks after planting, corn will require only about 5 percent of the N applied. The following two to four weeks of growth require a large proportion of the total seasonal N requirement.

In winter wheat, very low levels of N are required for overwintering. However, once wheat breaks dormancy, a large proportion of N is required during the next few weeks. In spring wheat, a small of amount of N is required to establish the crop during the first two to four weeks after seeding; however, most of the remaining N is required during the next 30 days.

To address some of the delayed N requirement issues of winter wheat, much of the crop is top-dressed in the spring. In corn, some growers use side-dress applications; however, spring preplant application is most common, with fall application preferred by growers in some Northern states. In spring wheat in the northern Plains, some post-N applications are made.

Because of the lack of rain during the growing season in many years, post-N applications as a source of most of the N requirement are discouraged except under irrigation. To increase nitrogen use efficiency and thereby increase yields or decrease N rates, a number of products have been developed to delay an N transformation process so that the period of time in which the N source is available for uptake is closer to the time the crop needs the available N. These products can be classified into the following groups: nitrification inhibitors, urease inhibitor additives, and nitrification and urease inhibitors.

Nitrification Inhibitors

Nitrapyrin

N-Serve, or nitrapyrin (2-chloro-6-[trichloromethyl] pyridine) has been studied and commercially used since the late-1960s. Work by Janssen (1969), summarized by Hergert and Wiese (1980), showed that nitrapyrin was active as a nitrification inhibitor and that the degree of nitrification was influenced by the nitrapyrin rate as a ratio of nitrapyrin to anhydrous ammonia. Greater N recovery with nitrapyrin than anhydrous ammonia alone was measured in April (190 days after application), June (230 days) and July (280 days) when anhydrous ammonia was applied from late October to early November.

Illinois studies in the mid-1970s showed that when injected into anhydrous ammonia or applied with urea, the rate of nitrification decreased (Figures 1 and 2) (Touchton et al., 1978a, 1978b; Touchton et al., 1979a); however, rainfall during the years of the experiments did not result in consistent increases in corn N uptake or corn yield in Illinois (Touchton et al., 1979b). Lack of yield response from the use of nitrapyrin also was reported in Iowa by Blackmer and Sanchez (1988); however, Stehouwer and Johnson (1990) reported higher corn yield from fall-applied N, with nitrapyrin related to higher N availability later in the season.

Higher corn yield with nitrapyrin in fall-applied N also was reported by Randall et al. (2003) and Randall and Vetsch (2005) in Minnesota; however, spring-applied N was highest yielding with greatest N-use efficiency. N-Serve is labeled for immediate incorporation or injection and not as a surface-applied product. Yield increases during the seven Minnesota study years were 15 bushels per acre more for fall anhydrous ammonia + N-Serve versus fall anhydrous ammonia alone, and 27 bushels per acre more for spring anhydrous ammonia compared with fall anhydrous ammonia (Randall et al., 2008).

A Wisconsin study (Hendrickson et al.,1978) found that on May 6, 1976, following an

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Oct. 6, 1975, application of anhydrous ammonia, 53 percent of the recoverable N was ammonium-N with nitrapyrin (0.5 pound/acre active ingredient) compared with 11 percent ammonium-N without nitrapyrin. Nitrapyrin also increased the ammonium-N concentration in Minnesota research (Malzer, 1977) through June 8 of the following spring. In North Dakota (Moraghan and Albus, 1979), greater ammonium-N following fall anhydrous ammonia application was present through July 5 of the following spring.

Grain yield increases with the use of a nitrification inhibitor have been inconsistent due to the variability of rainfall necessary to lead to nitrate leaching in sandier soils or denitrification in high-clay soils. Malzer et al. (1979) recorded a corn yield increase with the optimum N rate in fall anhydrous ammonia application with nitrapyrin, but a split application of N resulted in similar yield with nitrapyrin as without it. Hergert et al. (1978) showed that the benefit of nitrapyrin use under irrigated sands increased as the irrigation water as a percent of evapotranspiration increased.

Instinct is an encapsulated nitrapyrin formulation that can be applied to fertilizer left on the soil surface for up to 10 days for delay of ammonium fertilizer nitrification. It received its label in 2009. Research is ongoing at a number of universities. University of Nebraska studies in 2008 and 2009 (Ferguson et al., 2008, 2009) showed no yield benefits to the use of nitrapyrin (GF-2017, Instinct); however, the plots were hampered by heavy rainfall in June (2008) and spatial variability (2009).

In Wisconsin, two years of work with Instinct resulted in corn yield increases in 2008 but not in 2009 (Laboski, unpublished data). In Illinois, yield did not increase due to the use of Instinct with urea ammonium nitrate (UAN) during six site-years (Fernandez, 2010). Iowa (Killorn, unpublished data) and Minnesota (Randall, unpublished data) research also showed no yield increase with Instinct compared with N fertilizer alone.

Field and laboratory studies show that nitrapyrin effectively reduces the rate of nitrification. However, these same studies show an inconsistency in yield increases due to the use of the product. The inconsistency is related to rainfall patterns within the experiment. Predicting the profitability of the use of nitrapyrin is therefore very difficult. The use of nitrapyrin to reduce N losses "needs to be considered at the scale of a sensitive region, such as a watershed, over a prolonged period of use as well as within the context of overall goals for abatement of N losses from the agroecosystem to the environment." (Wolt, 2004).

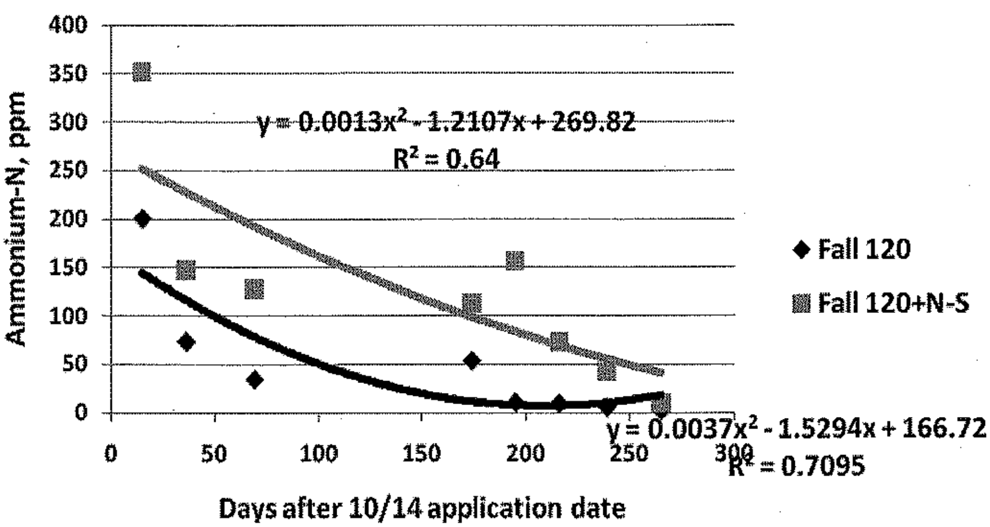
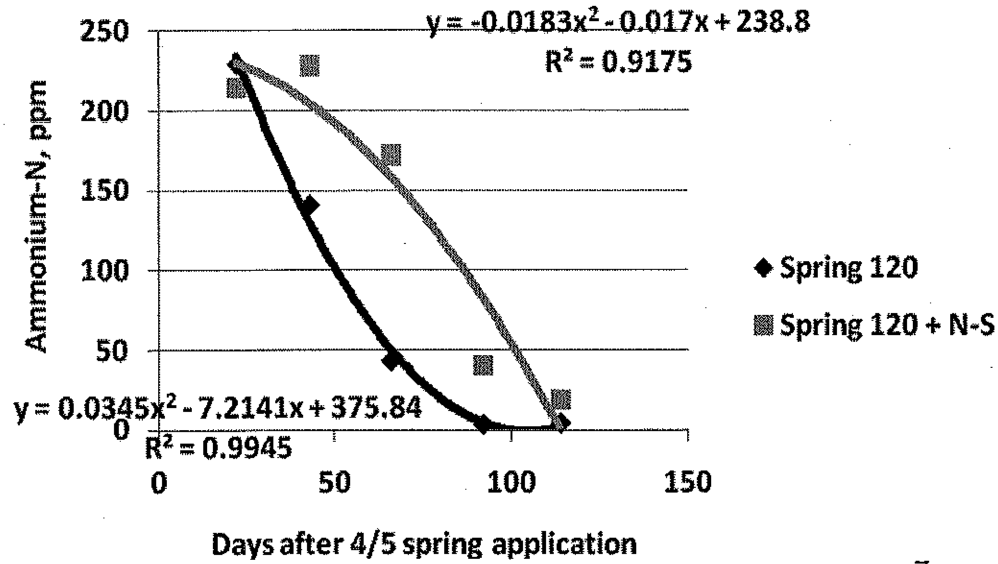


Figure 1.

Ammonium-N concentration in soil after 120 pounds/acre of N as anhydrous ammonia was applied Oct. 14, 1975, with and without 1 pound/acre of active ingredient (two times labeled rate) N-Serve®/nitrapyrin (N-S). Differences between treatments were significant at all sampling dates through day 239 (Touchton et al., 1978).

Figure 2.

Ammonium-N concentration in soil after 120 pounds/acre of N as anhydrous ammonia was applied April 5, 1976, with and without 1 pound/acre of active ingredient (two times labeled rate) N-Serve®/nitrapyrin (N-S). Differences between treatments were significant at all sampling dates through day 114 (Touchton et al., 1978).



Research on DCD (dicyandiamide or cyanoguanidine) has shown that it can be used as a nitrification inhibitor, although research generally has shown that its activity is shorter than nitrapyrin (Bronson et al., 1989). Products that contain DCD in the U.S. include Super-U (IMC Phosphate Co., licensed exclusively to Agrotain International LLC) and Guardian fertilizer additive (Conklin Co. Inc.). DCD contains about 67 percent N and was examined as an N source early in the last century (Reeves and Touchton, 1986). It was found to decrease crop yield when rates exceeded about 36 pounds/acre (Cowie, 1918). The Guardian label recommends a 2 percent addition to fertilizer. The content of DCD in Super-U is not stated. Growers likely would not overapply either product to the point of crop phytotoxicity.

A review of north-central states' research on DCD was published by Malzer et al. (1989). The review concluded that DCD was similar to nitrapyrin in its nitrification inhibition. Yield differences between fertilizer treated with DCD and fertilizer alone were inconsistent and limited to those soils and conditions where nitrate was lost through leaching or denitrification. The greatest value of either nitrification inhibitor would be in soils where nitrate loss through leaching or denitrification is more likely. A summary by Malzer et al. (1989) is reproduced in Table 1.

Table 1. Summary of corn grain yield responses to DCD and nitrapyrin at N rates equal to or less than optimum for fine-textured Midwest soils. *(From Malzer et al., 1989.)*

	DCD			Nitrapyrin		
	No. of comparisons			No. of comparisons		
	Total	With significant advantage	Average response	Total	With significant advantage	Average response
			%			%
Timing						
Fall	4	1	+1.6	2	0	-0.2
Spring	15	3	+3.4	7	1	-0.4
Sidedress	3	1	+1.4	3	2	+8.1
N Source						
Ammonium sulfate	2	0	-1.0	0	0	-
Anhydrous ammonia	6	1	+3.6	6	1	-1.8
Urea	4	4	+2.2	6	2	+1.1

Table 2. Relative effect of dicyandiamide (DCD) used with three nitrogen sources on potato yield, % Grade A US1A tubers, and apparent N recovery in tubers at Hancock, Wis., 1984-1986. *(From Malzer et al., 1989.)*

		Number of positive significant responses			Average relative response to DCD		
N Source	Number of comparisons	Yield	% Grade A	Tuber N Recovery	Yield	% Grade A	Tuber N Recovery
Ammonium nitrate	9	3	1	4	+2.0	-3.6	+6.5
Urea-ammonium sulfate	6	3	0	4	+5.1	-10.8	+23.7
Urea-ammonium nitrate solution	9	2	2	6	+4.0	-5.1	+27.6

In contrast to the relatively low frequency of corn responses in the Midwest, potato responses were more consistently positive (Table 2).

The ammonium-N remaining in the soil following ammonia application with both nitrapyrin and DCD treatments was explored at four Illinois locations by Sawyer (1985). Within 30 days of a fall application, no differences were found between the control and the DCD and nitrapyrin treatments in the percentage of remaining ammonium-N. In the spring, the DCD and nitrapyrin treatments provided a greater percentage of remaining ammonium-N compared with the control at three of four locations. The differences are presented in Figure 3 for the Urbana and Dekalb locations. Spring application of DCD and nitrapyrin were even more effective at some sites (Figure 4).

The use of nitrification inhibitors with liquid manure applications has generated considerable interest. In response to reports of poor corn growth due to injected liquid manure in Illinois, placement studies with and without nitrapyrin were conducted on similar soils. The results of one study showed that the use of nitrapyrin increased corn plant and grain N concentrations but did not translate into a yield increase (Sawyer et al., 1991). In another study, the use of nitrapyrin was useful in lowering soil nitrite levels in the liquid manure band, which was one reason why poor corn growth was observed in the banded liquid manure fields (Sawyer et al., 1990).

Urease Inhibitors

The compound that most consistently has decreased urea volatilization when mixed with urea or urea-ammonium nitrate solutions is NBPT (N-(n-butyl) thiophosphoric acid triamide). NBPT is marketed as Agrotain (Agrotain International LLC). The mechanism for NBPT is to lock onto the urease enzyme-binding sites, preventing the enzyme from reacting to the urease (Manunza et al., 1999). Agrotain has at least two possible uses in crop production: One is to protect against seed injury for growers, especially in the northern Plains, who apply urea with small-grain seed at planting. Use of Agrotain has increased the rate of urea that can be applied safely with small-grain seed in some studies (Table 3).

Agrotain also decreases the rate of ammonia volatilization from urea applied to the surface as dry urea or urea-ammonium nitrate solutions (Brouder, 1996, Table 4). Ammonia volatilization losses from urea at Brandon, Manitoba, decreased from 40 milligrams (mg) to 2 mg and from 88 mg to 12 mg with Agrotain in two separate studies for a seven-day period after application (Grant, 2004).

In a recent Kansas study (Weber and Mengel, 2009), urea was applied in three site-years to the soil surface after corn emergence using a number of nitrogen-extending additives, including Agrotain. The Agrotain treatment was superior to urea alone by 25 bushels per acre in one of the three site-years. The two locations that received significant rainfall immediately

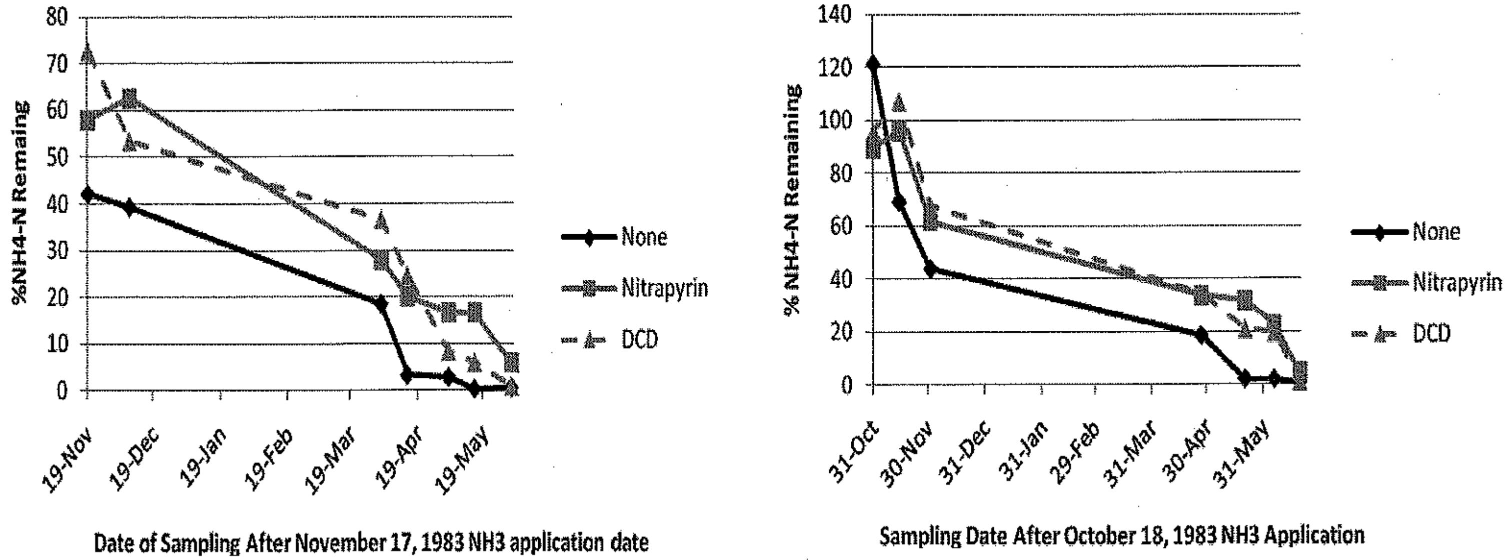


Figure 3. Percent NH4-N remaining after fall NH3 application at Urbana (left) and Dekalb (right). From Sawyer, 1985.

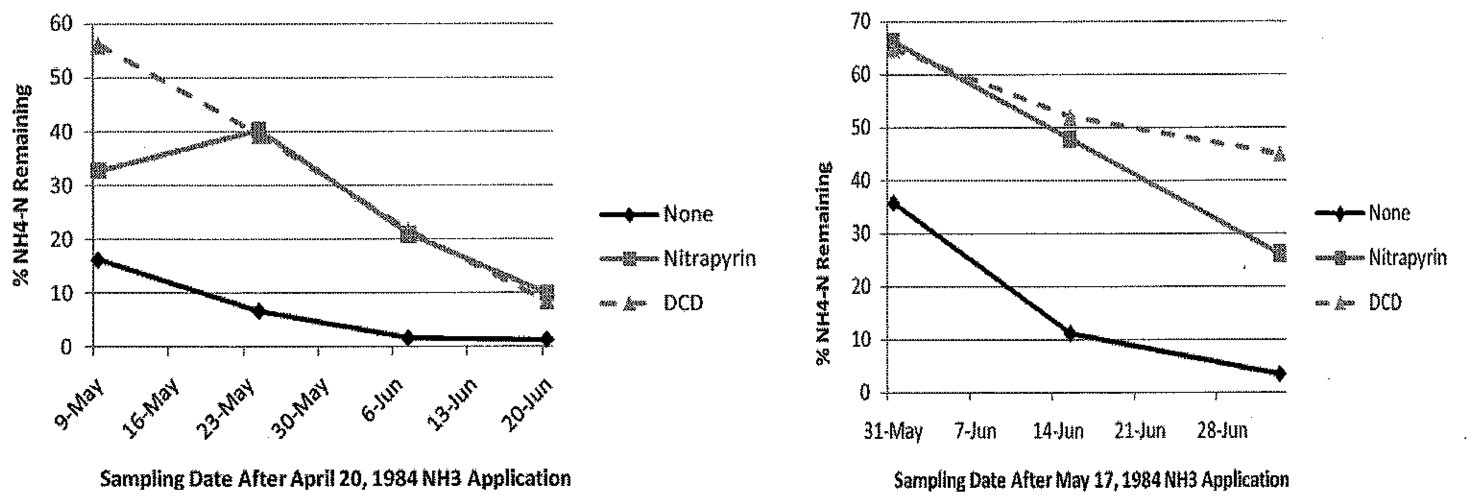


Figure 4. Percent NH4-N remaining after spring NH3 application at Monmouth (left) and Brownstown (right). From Sawyer, 1985.

following applications did not receive a yield benefit from the Agrotain treatment. In sorghum, urea + Agrotain and urea + SuperU were 11 and 12 bushels per acre, respectively, greater in yield than with urea broadcast alone (Weber et al., 2009a). At two drier locations, no yield differences occurred between urea + Agrotain and urea alone.

A 14-year study in southern Illinois (Ebelhar et al., 2010) showed a 3-bushel corn yield advantage of urea + Agrotain compared with urea broadcast in conventional till surface and incorporated during 12 years of treatments. In no-till, urea + Agrotain held an 11 bushel/acre advantage over urea surface applied during four years of treatments. Similar results were demonstration by Varsa etal 1995 (Table 5).

In Kentucky, 50 pounds of N/acre was applied preplant to all corn plots (Schwab and Murdock, 2009). Side-dress applications of urea and UAN with several additives or formulations were applied to the soil surface at the six-leaf stage. Higher yields than urea alone were achieved with urea + Agrotain and SuperU. Higher yields than UAN alone were achieved with UAN + Agrotain and UAN + Agrotain Plus (combination of NBPT and DCD formulated for use with UAN) (Table 6). Also notable: The ammonium nitrate treatment was the highest yielding treatment, suggesting that some loss of N was realized with the Agrotain treatments.

Nitrification and Urease Inhibitors

Ammonium thiosulfate (ATS) and several additional commercial thiosulfates have nitrification- (Goos, 1985; Janzen and Bettany, 1986) and soil urease-inhibiting properties (Goos, 1985). In the process of identification of thiosulfates as nitrification and soil urease inhibitors, researchers noted that the compounds would not be expected to perform as well as some other alternative nitrification and urease inhibitors due to the shorter decomposition period for ATS compared with nitrapyrin (Goos, 1985).

One study was unable to duplicate urease inhibition results, but it used different methods than originally presented at

Table 3. Effect of seed-placed urea with and without Agrotain on stand density and grain yield of barley on a fine sandy loam soil, 1994-96. *(From Grant, 2004.)*

	Stand, plants/foot		Yield, bu/acre	
N rate	No Agrotain	Agrotain	No Agrotain	Agrotain
lb/acre				
0	7.6	7.6	50	50
18	7.9	8.2	55	52
36	7.3	7.7	53	62
54	6.0	7.1	59	57
72	5.7	7.1	63	61
89	4.7	7.1	57	65

Table 4. Mean corn yield from Purdue Agronomy Farm, SEPAC, Pinney Purdue and Kosciusko locations with urea and UAN alone and treated with NBPT. *(From Brouder, 1996, citing work by Phillips, Mengel and Walker, 1989, unpublished work, Purdue University.)*

Fertilizer treatment	Yield, bu/acre
Control (20 lb N/acre in starter only)	99
Urea broadcast, surface	130
Urea + NBPT broadcast, surface	143
UAN broadcast, surface	135
UAN + NBPT broadcast, surface	140
UAN dribbled, surface	139
UAN spoke injected	142
UAN coulter injected	147
UAN knife injected	145

Table 5. No-till corn yield as affected by N fertilizer sources, Agrotain and placement in Illinois. *(From Varsa et al., 1999.)*

Treatment	Belleville	Dixon Springs		
	Yield, bu/acre			
Control (0N)	34	53	62	73
Urea	106	120	98	100
Urea + Agrotain	134	143	112	112
UAN, surface	123	137	103	107
UAN + Agrotain, surface	128	145	107	114
UAN, dribble	139	137	108	112
UAN + Agrotain, dribble	143	152	110	120
UAN injected	172	176	123	121
Anhydrous ammonia	158	166	122	130

Table 6. Yield for side-dressed no-till corn in Hardin County, Ky. *(From Schwab and Murdock, 2009.)*

Treatment	Yield, bushels per acre
Check (50 lb N/acre preplant N only)	117d*
Urea	158c
Urea + Agrotain	201b
SuperU	201b
UAN	150c
UAN + Agrotain	179bc
UAN + Agrotain Plus	175bc
Ammonium nitrate	239a

* Numbers followed by the same letter are not significantly different (5%)

rates of ATS from 3.3 to 33 times the rates of Goos, 1985 (McCarty et al., 1990). Thiosulfate activity is regulated by its concentration (effective at S rates of 25 mg kg^{-1}, Goos and Johnson, 2001).

Thiosulfate readily breaks down rapidly in temperatures of 15 C. In a laboratory study at 15 C, ATS essentially was mineralized in about a week. Under cooler temperatures, however, significant thiosulfate remained after two weeks in two of three soils, with mineralization complete in all soils by week three. When thiosulfate was placed in a band with aqua ammonia in the fall in North Dakota (Oct. 3, 1996), thiosulfate resulted in similar spring (May 12, 1997) ammonium and nitrate levels as aqua ammonia treated with nitrapyrin (Goos and Johnson, 1999). Spring wheat yields of aqua ammonia treated with thiosulfate and nitrapyrin were similar, and both were greater than aqua ammonia alone.

Janzen and Bettany (1986) expressed cautions on high rates of banded ATS (in excess of 100 parts per million, or ppm) due to nitrite accumulation from ATS inhibition of not only the ammonium to nitrite process, but the nitrite to nitrate process.

The rate used by Goos (1985) was about 43 ppm if expressed as a band with a radius of 2 inches, which did not accumulate nitrite in the Janzen/Bettany (1986) study.

Recently, the use of thiosulfate has been re-examined. In Kansas, the application in the spring of a 5 and 10 percent calcium thiosulfate by volume solution with UAN had similar yield as urea broadcast in no-till (Tucker and Mengel, 2007).

Nutrisphere-N is a product marketed by SFP (Specialty Fertilizer Products) LLC, Leawood, Kan. The formulation for dry fertilizer is a 30 to 60 percent maleic itaconic co-polymer calcium salt. The pH of the dry formulation is between 2.5 and 5, according to the label. The rate of use is 0.5 gallon per ton of urea/ammonium sulfate. The formulation for liquid fertilizer is a 40 percent minimum maleic-itaconic co-polymer. The pH of the liquid product is between 1 and 2, according to the label. The rate of mixing with liquid N products is 0.5 gallon Nutrisphere-N per 99.5 gallons of fertilizer solution. A gallon of Nutrisphere-N liquid or dry formulation weighs 9.6 pounds per gallon.

Nutrisphere-N is marketed as both a urease inhibitor and a nitrification inhibitor. Marketing literature explains that the activity of Nutrisphere-N on nitrification is related to its binding to copper ions necessary for the nitrification process in soil bacteria. The activity of the product on urease is based on its binding to nickel ions necessary for the formation and function of the enzyme. Also, the product Avail, which is marketed as a phosphate-enhancing product by SFP, contains the same active ingredient as Nutrisphere-N.

The Avail activity is attributed to binding of calcium or iron ions in the soil that normally might bind phosphate. Based on the mode of action of the active ingredient of Nutrisphere-N/Avail, the compound is highly negatively charged and would tend to bind with any compound with a positive charge, not distinguishing one ion from another.

The most consistent yield increases and crop uptake of N from the use of Nutrisphere-N has been through work by Gordon (2008). In two years of corn at Scandia, Kan., and two years of grain sorghum at Belleville, Kan., yield increases from the use of Nutrisphere-N were similar to those achieved with urea-Agrotain and ESN (Environmentally Smart Nitrogen, Agrium Inc.) (Tables 7 and 8).

The consistent results from Gordon (2008) are very curious, considering that careful laboratory experiments by Goos (2008) and Norman (Franzen et al., 2011) have shown that Nutrisphere-N has no nitrification or urease inhibitor ability (Figures 5 and 6, Table 9).

Laboratory experiments clearly show that no nitrification inhibition or urease inhibition occurs by Nutrisphere when used at label rates. Goos has observed some small nitrification inhibition when the Nutrisphere for liquid fertilizer is applied in a concentrated band. He attributes this to the strong acidity of the liquid formulation and not to the Nutrisphere itself (Goos, personal communication, 2010). Acid conditions are known to inhibit nitrification bacteria (Schmidt, 1982).

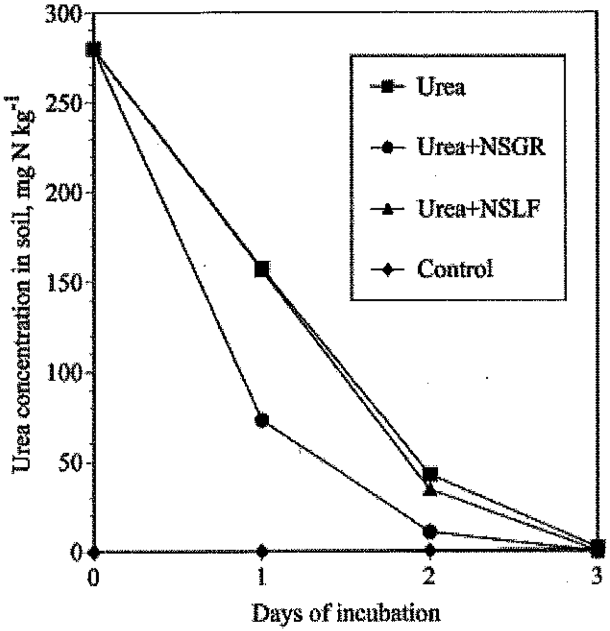


Figure 5.

Urea remaining in an Overly soil, as influenced by time of incubation, and application of urea, urea plus Nutrisphere-N for granular fertilizers (NSGR) and urea plus Nutrisphere-N for liquid fertilizers (NSLF).

Experiment by R.J. Goos in Franzen et al., 2011.

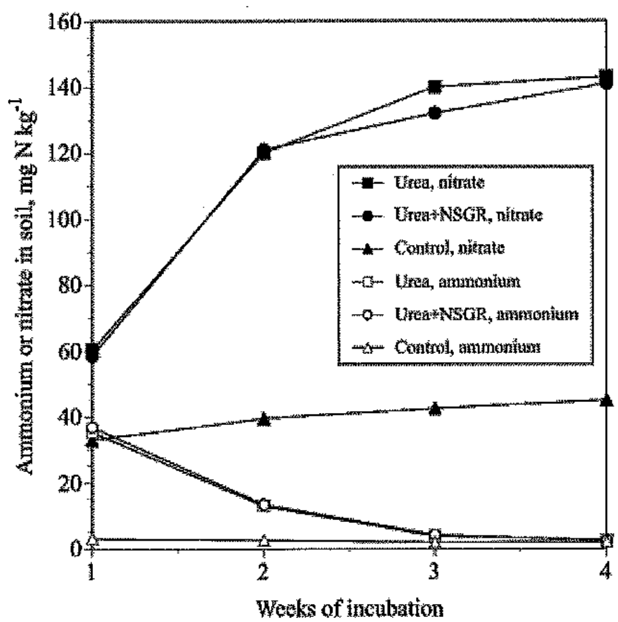


Figure 6.

Ammonium and nitrate in a Renshaw soil as influenced by length of incubation and application of urea granules, and urea granules treated with Nutrisphere-N for granular fertilizers (NSGR).

Experiment by R.J. Goos, in Franzen et al., 2011.

Table 7. Effects of N additive, averaged over source (UAN and urea) and N rate on corn grain yield, earleaf-N and grain-N, Scandia, Kan. (2-year average). *(From Gordon, 2008.)*

Treatment	Yield	Earleaf N	Grain N
	bu/acre	%	%
Check	152	1.72	1.13
Urea/UAN	168	2.57	1.26
ESN	185	2.96	1.33
Nutrisphere-N	183	2.96	1.35
Agrotain	183	2.98	1.36
LSD 5%	6	0.09	0.04

Table 8. Effects of N source and rate on grain sorghum yield, Belleville (2-year average). *(From Gordon, 2008.)*

Treatment	N-Rate	Yield
	lb/acre	bu/acre
Check	0	71
Urea	40	108
	80	122
	120	128
ESN	40	120
	80	130
	120	132
Urea + Agrotain	40	116
	80	129
	120	133
Urea+ Nutrisphere	40	120
	80	133
	120	132
LSD 5%		5

Table 9. Cumulative ammonia volatilization losses for urea, ammonium sulfate, urea + NBPT and urea + 0.25% Nutrisphere (NSN) from a Dewitt silt loam soil during a 15-day laboratory incubation at 25 C. Norman data, University of Arkansas, Fayetteville. *(From Franzen et al., 2011.)*

	Days after N source application			
	3	7	11	15
N sources	Cumulative NH3 loss, % of N applied			
Urea	14.5	35.9	51.8	56.9
Ammonium sulfate	0.1	0.2	0.5	0.6
Urea + NBPT†	0.006	2.7	12.9	18.3
Urea + 0.25% NSN	17.6	42.2	57.8	62.7
LSD(0.05)‡	12.2			
LSD(0.05)§	9.6			

† NBPT= N-(n-butyl) thiophosphoric triamide
‡ LSD to compare means between N sources within the same sampling time.
§ LSD to compare means between sampling time within the same N source.

In the field, consistently finding yield or quality responses to the use of Nutrisphere at the labeled rate is uncommon. In North Dakota studies on spring wheat at eight locations, no yield increases or grain N uptake increases were found with Nutrisphere compared with urea (Franzen et al., 2011). In Kansas (Tucker and Mengel, 2008), no increases occurred due to Nutrisphere with UAN versus UAN surface banded or injected in grain sorghum in 2007.

In two years of corn in Kansas, no yield increases were found from the use of Nutrisphere-N UAN compared with surface-applied UAN at three total sites (Weber and Mengel, 2009). In 2009, no response was found to Nutrisphere + UAN broadcast on grain sorghum compared with broadcast UAN alone in Kansas at three locations (Weber and Mengel, 2010).

One sorghum yield increase occurred with surface-banded Nutrisphere + UAN compared with UAN surface banded alone, and two sites were nonresponsive. The yield increase with surface band but not broadcast suggests that perhaps the acidity of the Nutrisphere may have delayed nitrification at this site (Schmidt, 1982).

At Waseca, Minn., in 2009, no corn yield difference was found between urea and urea with Nutrisphere applied in the fall (Randall and Vetsch, 2009). Grain and stover N between urea and urea with Nutrisphere were similar. In Illinois at two locations in 2008, Nutrisphere-urea was lower in yield than urea and similar in yield at the two locations with UAN and Nutrisphere-UAN (Ebelhar and Hart, 2009). At Dixon Springs in 2009, Nutrisphere urea, UAN and ammonium sulfate treatments did not result in higher corn yield than the N sources with Nutrisphere-N (Ebelhar and Hart, 2010), although the main effects for Nutrisphere-N on corn yield were significant.

In Arkansas and Mississippi, Nutrisphere-N had no effect on rice yields in three field studies compared with urea (Franzen et al., 2011). In South Dakota, Nutrisphere-N did not result in higher corn yield in 2007 (Bly and Woodard, 2007), 2008 (Bly et al., 2008) or 2009 at two sites (Bly et al., 2009).

In Idaho, no spring wheat yield increases were found with Nutrisphere during two years (Jeffrey Stark, personal communication, Aug. 23, 2010). In barley, however, yield increases occurred in 2008 and 2009 with Nutrisphere, but no increase occurred in grain protein versus similar rates of urea. Plant N uptake with Nutrisphere was similar to urea without Nutrisphere, suggesting that the yield increase in barley came from some response other than enhanced N nutrition (Stark, 2008; 2009).

Laboratory studies with Nutrisphere-N show no effect on nitrification or urease activity. Therefore, the findings that the great majority of studies with Nutrisphere show no yield effects are not surprising. What is surprising is that some studies show yield effects, but not from increased N nutrition. The results from Gordon (2008) suggest that under some conditions, Nutrisphere may have some effect on plant growth and development, and even N nutrition not related directly to urease inhibition or nitrification. However, the company may need to re-examine its label as a nitrification inhibitor and urease inhibitor.

Summary

Certain nitrogen additives provide growers with options for extended activity of nitrogen nutrition for their crops. Their economics depends on rainfall following application, application methods, timing and soil characteristics, especially soil texture. Nitrapyrin has been effective in delaying nitrification. Dicyandiamide also has been shown to be effective in delaying nitrification. Thiosulfates have been shown to delay nitrification, but the body of literature to support their use is much smaller than that of nitrapyrin. NBPT (Agrotain) is an effective urease inhibitor. Thiosulfates have shown some urease inhibition characteristics, but again, the body of literature that supports their use is small.

Nutrisphere has been shown to be ineffective as both a nitrification and urease inhibitor. The data that support the use of Nutrisphere is small in comparison with the data that does not support its use. If one accepts that the laboratory studies, conducted in a similar manner to those used to evaluate products such as Agrotain, show that Nutrisphere is not a nitrification or a urease inhibitor, then the small number the field studies that show a yield benefit to the use of the product, and in some circumstances even show an accumulation of N, must have other explanations. The very acidic nature of the liquid formulation of Nutrisphere suggests that in banded applications, the nitrification delay may be associated with the acidity of the solution more than the Nutrisphere itself.

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Kochia – Growth Regulator Resistance
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One of the most common weeds in all major crops in the Central Great Plains is kochia which has proven to be a potent adversary for sustainable crop production for crop producers. As a C4 plant, it is not surprising that kochia is heat and drought tolerant, but what is surprising is its ability to germinate and begin growth as early as February when nights are cold and snow is still likely. Kochia is highly competitive in a wide variety of crops causing yield reductions of 90% or more if not controlled. Well watered and fertilized kochia plants along the edge of corn fields can grow 8' tall with woody stems over 1" in diameter. Since kochia seeds exhibit little dormancy, most seeds germinate the year following their production on a mother plant. In addition, as a tumble weed, kochia plants rolling across the landscape in strong winds shed their seeds as they bounce along, thus spreading their genes across long distances.

Anecdotal evidence from senior weed scientists suggest that when 2,4-D was first released as an herbicide, it did exhibit moderate to good control of kochia. Today, most weed scientists, crop consultants, and growers would rate 2,4-D as poor to ineffective for kochia control, although 2,4-D is still a frequent tank mix partner because it is cheap and it still controls many other broadleaf weeds. It is hard to determine if the current general poor kochia control with 2,4-D is a result of resistance that is wide spread, or if kochia was never controlled very well by 2,4-D. Some more recent research suggests that new acid forms of 2,4-D can be effective for kochia control.

For more than 25 years, growers have frequently turned to dicamba to control kochia in crops or field situations where dicamba is labeled. When applied at higher labeled rates, dicamba provides the added benefit of a moderate amount of soil residual activity for several weeks. Beginning in the 1980s, however, evidence began to mount that some central great plains accessions of kochia had developed resistance to dicamba. Scientists at Montana State University documented dicamba resistant kochia that exhibitied some unusual growth characteristics. In Colorado, research focused on kochia collected from "lack of control" (LOC) sites primarily in irrigated corn fields. Kochia in these fields were frequently heavily damaged by dicamba with the damage often manifest as death of the primary kochia growing points. After some time, however, axillary buds would begin to grow and the plants would survive and produce seed even at the highest labeled rates for dicamba. Detailed genetic research at CSU suggested that dicamba resistance in kochia appears to be controlled by a single allele with a high degree of dominance. In spite of this discovery, it has always been a mystery as to why dicamba resistance never seem to rise to a very high level in any part of the central great plains. It has been speculated that this resistance trait was rapidly swamped out by pollen from the many susceptible plants still present in most ecosystems.

Perhaps the development and labeling of fluroxypyr indirectly helped in the management of dicamba resistant kochia since there appears to be little if any cross resistance in kochia to these two herbicides. Fluroxypyr became a popular kochia herbicide due to its effectiveness and to the generally good crop safety exhibited by fluroxypyr. The one drawback for fluroxypyr was its sometimes poor level of control of many other broadleaf weeds commonly found growing with kochia. There have been sporadic reports of fluroxypyr resistance in kochia, but once again, this has never blown up to be a major issue. New herbicides such as Huskie, Laudis, Callisto, and Impact have shown good to excellent kochia control when used in labeled crops based on extensive research over the past several years. Although these products are sometimes more expensive, they at least offer reasonable alternatives for kochia control.

Finally, it must be emphasized that since the introduction of herbicides a major weed control tools used by most crop producers, kochia has demonstrated an amazing ability to develop resistance to
1) 2,4-D 2) triazine herbicides 3) ALS herbicides 4) Dicamba 5) Fluroxypyr 6) Glyphosate.
It is incumbent on all of us; scientists, crop consultants, growers, etc. to be vigilant when scouting for kochia problems in fields and possible new resistance issues as they develop. Contact your extension agents or state weed scientists if you suspect an herbicide resistance problem with kochia.

Kochia History, Biology, and Implications

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Origin, Biology, and Distribution

Introduction and spread. Kochia (*Kochia scoparia* L.) is an annual forb (broadleaf plant) with a deep taproot typically penetrating to depths of 6 to 8 ft (as deep as 16 ft during severe drought) and many erect branched stems extending upward 2 to 3 ft in dry or infertile conditions but may reach up 7 ft under favorable conditions. Leaves are simple with alternate arrangement along stems; linear to lanceolate in shape and typically range from about 3/16-inch to 5/16-inch wide and 2 to 3 inches long; and lime-green to grayish-green in color, but often change to shades of yellow, red, and brown as plants mature. Stems usually are similarly colored as the leaves but stem color may be solid or stripped. Kochia is highly adaptable, drought tolerant, and grows on many soil types including saline/alkaline soils, but does not tolerate spring flooding.

Other common names for kochia include fireweed, Mexican fireweed, burning bush, summer-cypress, and tumbleweed. The species is native to southern and eastern Russia and was introduced to North American from Europe in the late 1800's for use in ornamental plantings. Kochia naturalized in the central and northern Great Plains where it flourished during periods of drought during the 1930's. It spread rapidly westward and currently is a competitive weed in cropland, rangeland and pastures, road sides, and waste areas throughout the western United States and Canada. It is one of the top 10 most-abundant agricultural weeds in the Canadian prairies and western United States. It is present throughout Kansas but is far more common and troublesome in the dryer western half of the state.

The nutritional level of kochia in early vegetative growth stages is sufficient to satisfy the requirements of most livestock. However, nutritional content decreases with age. During periods of drought and shortages of grass and cultivated forage, kochia has been used for livestock feed as a portion of the diet, but plants contain high levels of oxalates, alkaloids, and nitrates that can be toxic if large amounts are consumed. A related but improved perennial semi-shrub species (*Kochia prostrata*) is promoted as a drought tolerant, high-quality forage kochia for winter livestock grazing in intermountain and semi-desert habitats. This species lacks weedy characteristics and should not be confused with the annual, weedy species.

Reproduction. Kochia reproduces by seed that disperse as mature plants break off at the base and are blown by wind as tumbleweeds scattering seed and resulting in a high rate of spread over long distances. In the Pacific Northwest, plants were observed moving nearly 2.5 miles in 6 weeks. Plants typically produce about 15,000 seed per year; however, plants have extreme reproductive plasticity. Severely stressed plants may produce few seed and plants growing under favorable conditions may produce as many as 50,000 seeds. Seed is produced in clusters of small green flowers lacking petals located in the axis of upper leaves and terminal spikes in late summer (Aug-Sept). Flowering is temperature sensitive and does not occur until mean temperature is greater than ~60 F. Kochia will self-pollinate but flower stigmas (female structure) mature sooner and are receptive to pollen from other flowers on the same or different plants in advance of pollen shed from anthers (male structure) of the same flower. This helps ensure cross pollination and genetic diversity within the population. Pollen can move up to 500 ft.

Seedling emergence. Kochia seeds have a dormancy period of 2 to 3 months, but once dormancy is broken seeds will germinate over an extremely wide range of temperatures (~40 to 100^0 F). Few annual weeds emerge in spring as early as kochia. Seedlings are frost tolerant and frequently can be found along edges of melting snow in fence rows and other non-disturbed areas. Emergence in cultivated fields typically occurs several days later than in non-tilled areas. Studies indicate that fewer growing-degree days (cumulative heat units) are needed to initiate germination and cumulative growing-degree-days for the entire period of emergence are fewer in colder northern latitudes compared to warmer southern latitudes. At multiple sites in Kansas in 2010, emergence began after March 15, whereas emergence in western Nebraska and eastern Wyoming began after the first week of April. Approximately 70 to 90% of seedlings emerged within the first two weeks after first emergence, but at most sites a few seedlings continued to emerge as late as mid-July. The same general trend also occurred in 2011, but with longer periods of peak emergence, probably because of dryer spring conditions than in 2010. This and other evidence indicates that current farming practices are selecting or favor plants capable of germinating at higher temperatures, thus extending the period of usual emergence. Seeds have little or no seedbank viability; they either germinate or decay in 1 year.

Seedlings emerging in early spring frequently emerge in great density and form dense mats of vegetation. Before plant internodes begin to elongate, multiple ranks of compressed leaves form compact rosettes. Overlapping hairs on the margins of leaves intercept spray droplets and interfere with wetting of leaf surfaces from herbicide applications. Plants are more easily wetted and susceptible to most herbicides when they are about 2 to 6 inches tall and become more difficult to control as they grow larger, especially when stressed.

Intraspecific diversity. Kochia morphology is highly variable, likely due to high genetic variation and phenotypic plasticity. Within-population genetic diversity may equal or exceed levels of genetic diversity seen among kochia populations. Natural selection coupled with cross pollination, prolific seed production, and profuse seed dispersal over long distances contributes to the genetic diversity of kochia. Adaptation to agronomic practices including selection of herbicide-resistant variants has added to this diversity. Hybridization with related *Kochia* species does not appear to be a source of genetic diversity due to genomic differences that prohibit introgression.

Response to Herbicides

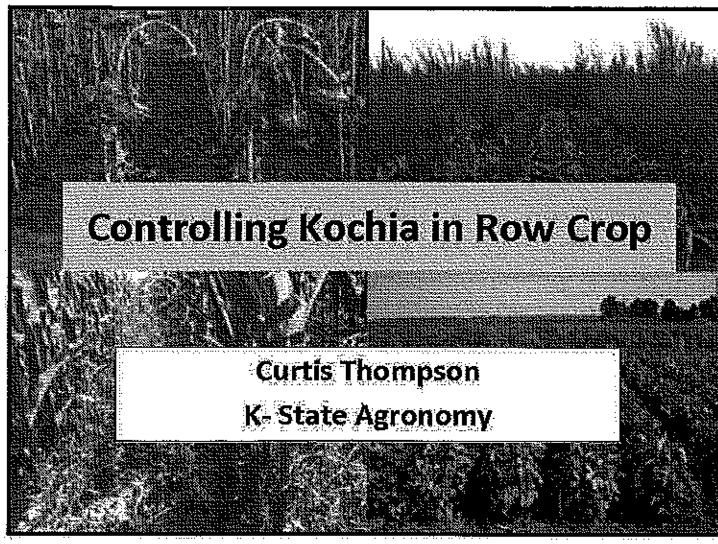
The genetic diversity within kochia populations contributes to the presence of biotypes with mutant alleles known to confer herbicide resistance. Few weed species have developed resistance to as many herbicide families as kochia. Populations of kochia resistant to triazine and acetolactate-synthase (ALS)-inhibiting herbicides are widespread, there are documented cases of resistance to synthetic auxin herbicides (2,4-D and dicamba), and resistance to glyphosate occurs throughout western Kansas and eastern Colorado. These four herbicide modes-of-action are among the most widely used herbicide groups in agricultural production systems in the United States and Canada. Loss of the use of each of these herbicide groups, especially glyphosate, for kochia control poses significant challenges in one or more major field crops and will require less simple and cost effective management strategies.

The first case of triazine resistance in kochia was documented in Idaho in 1976 and ALS herbicide resistant kochia was discovered in 1987 in wheat fields in Kansas and North Dakota, and in a non-crop area in Colorado. Triazine and ALS resistance is caused by a a single amino acid change in the protein target site. The mutation changes the shape of the binding site so the herbicide can no longer bind. Plants with the mutation are not affected by any rate of the herbicide. Lack of kochia control with dicamba in eastern Colorado and western Nebraska in the early 1990's prompted studies at Colorado State University that confirmed the presence of dicamba-resistant kochia. See Phil Westra's report for more information on dicamba-resistant kochia.

Lack of kochia control with glyphosate not due to application or abiotic reasons was first observed in southwest Kansas in 2005. Studies indicated slightly elevated tolerance to glyphosate, but could not yet be called a resistant population. However, glyphosate resistance was confirmed in four geographically-dispersed kochia populations in 2007. By 2011, glyphosate resistance was common throughout the western one-third of Kansas and present in bordering counties of Colorado and Nebraska.

Glyphoste resistance is unlike triazine or ALS resistance in that it is not due to an altered target site and plant response to glyphosate is rate dependent. This type of resistance is often called "creeping resistance" and refers to the fact that the level or degree of resistance increases in successive generations with continued selection (spraying with glyphosate). The main mechanism of resistance appears to be a process called gene amplification, in which resistant plants have multiple copies of the gene that produces an enzyme to which glyphosate binds and prevents production of essential amino acids, thereby causing plant death. Resistant plants are simply able to produce more enzyme than glyphosate can disrupt.

Major implications of glyphosate resistance in kochia are that growers must use more costly and often less effective herbicides to control kochia in crops and fallow than previously possible using glyphosate. Also, there is evidence that growers in western Kansas used more tillage than normal in 2011 to control kochia after wheat harvest. Research is ongoing to evaluate alternative (to glyphosate) kochia management strategies. Refer to contributions of other conference presenters for the latest updates.



Topics in presentation

- Control kochia
  - Ahead of planting
  - In Corn
  - In Sorghum
  - In Soybean
  - In Sunflower

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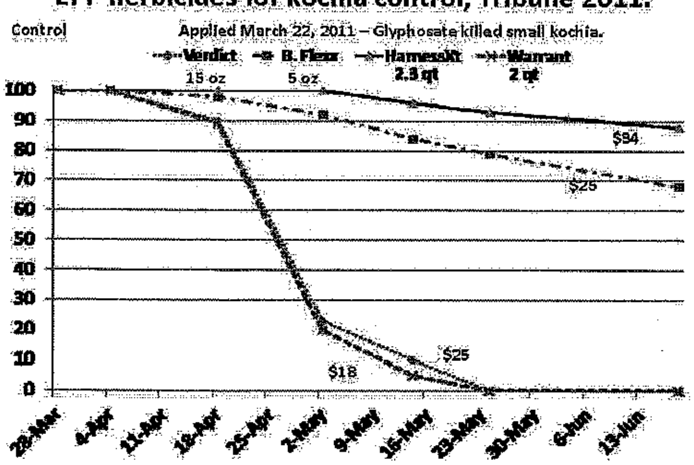
Cumulative GDD and Date for Start (10%), End (90%), and Duration of Kochia Emergence, Dille etal., 2010

Location & site	Site	GDD to 10% E	Date	GDD to 90% E	Date	GDD Duration 10% to 90% E
Lingle, WY	NC	76	3/21	191	4/10	115
Mitchell, NE	NC	84	3/17	456	5/7	372
Scottsbluff, NE	NC	69	3/15	415	4/29	346
Hays, KS	Crop	238	3/18	365	3/24	127
Hays, KS	NC	137	3/31	173	4/10	36
Ness City, KS	NC	114	3/11	475	4/18	361
Garden City, KS	Crop	283	3/31	1056	5/26	773

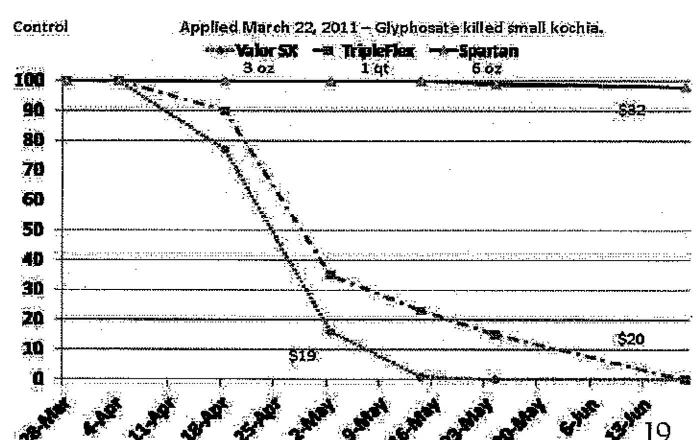
Thinking outside the box

- Conventional methods including herbicide selection and timing of application may no longer be successful due to glyphosate and possibly growth regulator resistant kochia
- The larger kochia get, the more difficult it is to control
- Dense/solid stands of little kochia may not be controlled.
- Herbicides very early PRE may be required?!

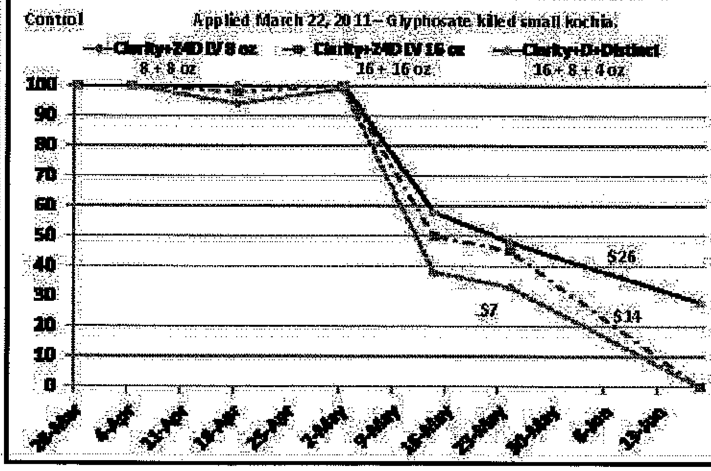
EPP herbicides for kochia control, Tribune 2011.



EPP herbicides for kochia control, Tribune 2011.



EPP herbicides for kochia control, Tribune 2011.



Postemergence control of kochia in fallow, Tribune 2011.

	Product	Prod. Cost	Kochia control (%)	
Treatment	rate	$	May 30, 16DAT	June 11, 28DAT
Distinct+AMS+NIS	4+17 lb+.5%	13.72+.74+1.84	61	68
Distinct+2,4-D LV4+AMS+MSO	4+8+ 17 lb+.5%	13.72+1.38+ 0.74+2.77	55	73
Sharpen+2,4-D LV4+AMS+MSO	1+16+ 17+1%	5.58+2.75+ 0.74+2.77	79	68
Sharpen+atrazine +AMS+MSO	1+12+ 17+1%	5.12+1.45+ 0.74+2.77	86	76
Starane NXT	14	8.34	79	75
Huskie+AMS+NIS	15+8.5 +0.5%	11.90+0.37+ 1.84	76	65
Huskie+atrazine+ AMS+NIS	15+8 Fl oz +8.5 lb+.5%	11.90+0.97+ 0.37+1.84	87	80

Postemergence control of kochia in fallow with HPPD inhibitors, Tribune 2011.

	Product	Prod. Cost	Kochia control (%)	
Treatment	rate	$	May 30, 16DAT	June 11, 28DAT
Laudis+atrazine+ AMS+MSO	3+8+ 8.5+1%	16.05+0.97+ 0.37+2.77	76	60
Callisto+atrazine+ AMS+MSO	3+8+ 8.5+1%	16.35+0.97+ 0.37+2.77	80	60
Impact*+atrazine +AMS+MSO	0.75+8+ 8.5+1%	17.43+0.97+ 0.37+2.77	76	66
Impact*+atrazine +UAN+MSO	0.75+8+ 2.5%+1%	17.43+0.97+ 0.30+2.77	82	79
Impact*+atrazine +UAN+MSO	1.0+8+ 2.5% +1%	23.25+0.97+ 0.30+77	85	84
Roundup Wmax+AMS	32 FL OZ + 17	7.25+0.74	85	85

* Impact (Amvac) = Armezon BASF

Postemergence control of kochia in fallow with photosynthetic inhibitors, Tribune 2011.

	Product	Prod. Cost	Kochia control (%)	
Treatment	rate	$	May 30, 16DAT	June 11, 28DAT
Gramoxone Inteon +atrazine +COC	48 +16+1%	13.87+1.94+ 1.50	94	91

Ideally, DON'T WAIT UNTIL MAY to begin controlling kochia!!!

Herbicides applied 6 days before planting for control of kochia in corn, Tribune 2011.

	Product	Prod. Cost	Kochia control (%)		
Treatment	Rate/acre	$	May 24	June 11	July 2
Clarity + 2,4-D LV4*	16+8 Fl oz	11.38+1.38	96	99	98
Verdict*	18 Fl oz	29.80	99	93	90
Lexar*	3 qt	42.00	100	97	96
Harness Xtra	2.3 qt	34.20	100	96	93
Degree Xtra*	3 qt	31.50	96	90	81
TripleFLEX	1 qt	20.56	89	75	68
Valor	3 oz	18.75	45	45	15
Fierce	4 oz	?	86	71	46
Anthem	7 oz	?	93	56	32
LSD (0.05)			9	14	18

Applied May 2, Corn planted May 8, *May be used in sorghum, Verdict 10 oz only.

Treatment Cost and Kochia Control in Corn 50 ± 3 DA PRE Across Three Trials, Phil Stahlman et al.

Herbicides	Rate/Ac	Cost/Acre[1]	Mean[2]
Clarity + 2,4-D LV4	16 + 8 oz	$17.30	85 bcd
Verdict	18 oz	$34.88	67 f
Balance Flexx + Atrazine 4L	4 + 20 oz	$26.43	96 a
Lumax	2.5 qt	$47.88	95 ab
Harness Xtra	2.3 qt	$38.27	77 def
Degree Xtra	3 qt	$36.60	91 ab
TripleFlex or Surestart	1 qt	$24.99	68 ef
Valor	3 oz	$22.23	68 ef
Fierce	4 oz	----	78 cde
Anthem	7 oz	----	85 abc

[1] Includes custom application ($5.13) but not preplant burndown.
[2] LSD = 0.05.

Postemergence control of kochia in Corn with HPPD inhibitors, Tribune 2011.

[illegible]	[illegible]	[illegible]	[illegible]	
Treatment	rate	$	June 11	July 2
Laudis+atrazine+ AMS+MSO	3+8+ 17+1%	16.05+0.97+ 0.74+2.77	81	91
Callisto+atrazine+ AMS+MSO	3+8+ 17+1%	16.85+0.97+ 0.74+2.77	64	77
Impact+atrazine+ AMS+MSO	0.75+8+ 17+1%	17.43+0.97+ 0.74+2.77	69	70
Impact+atrazine+ UAN+MSO	0.75+8+ 2.5% +1%	17.43+0.97+ 0.30+2.77	60	80
Impact+atrazine+ UAN+MSO	1.0+8+ 2.5% +1%	23.25+0.97+ 0.30+2.77	65	78
LSD (0.05)			14	18

Applied May 31 to 4 to 5" kochia, 2 to 3 collar corn.

7 DEPP + Postemergence control of kochia in corn, Tribune 2011.

[illegible]	[illegible]	[illegible]	[illegible]	
Treatment	rate	$	May 30, 16DAT	June 11, 28DAT
Clarity+2,4-D LV4 Halex GT + Status +AMS	16+8 3.6pt+8oz +17 lb	11.38+1.38+ 22.50+9.90 +0.74	94	91
Clarity+2,4-D LV4 Distinct+2,4-D LV4 + HSOC+AMS	16+8+ 4 oz+8oz+ 0.5%+17lb	11.38+1.38+ 13.72+1.38+ 1.50+0.74	96	94

Treatment Cost and Kochia Control in Corn 50 ± 3 DA PRE Across Three Trials 19 ± 3 DA POST or 9 ± 8 DA LTPOST

[illegible]	[illegible]	[illegible]	[illegible]
Clarity + 2,4-D LV4 PRE	16 + 8 oz	$17.30	85 ab
Clarity + 2,4-D LV4 PRE *fb* Halex GT + Status + AMS (LTPOST)	16 + 8 oz 3.6 pt + 3 oz + 2%	$48.36	85 ab
Clarity + 2,4-D LV4 PRE *fb* Distinct + 2,4-D LV4 + AMS + HSOC (LTPOST)	16 + 8 oz 4 + 8 oz + 2% + 0.5%	$39.05	84 ab
Laudis + AMS + MSO (POST)	3 oz + 1% + 1%	$24.18	78 b
Laudis + Atrazine + AMS + MSO (POST)	3 oz + 8 oz + 1% + 1%	$25.02	90 a
Impact + Atrazine + AMS + MSO (POST)	0.75 oz + 8 oz + 1% + 1%	13.04	88 a

[1] Includes custom application ($5.13) but not preplant burndown.
[2] LSD = 0.05.

Kochia control PRE in sorghum

- Preemergence products – Highly recommended!
  - Lumax 2.5 qts $43.75
  - Lexar 3.0 qts $42.00
  - Degree Xtra 2.0 to 3.7 qts $20.8-38.50
  - Guardsman Max/Gmax Lite
    2.5-4.6 pts 2 to 3.5 pts $18.40 – 34.00, $19 - 33
  - Bicep II Mag/Bicep Lite II Mag
    1.6 to 2.1 qt 1.1 to 1.5 qt $19.60 – 25.72, 17.88 – 24.34
  - Bullet/Lariat 2.5 to 4 qt $17.30 – 27.75
  - Sharpen 2 oz $10.24 (Add to chloracetamide+atrazine)
  - Verdict 10 oz $16.40 (Add to 2 to 2.75 pts Guardsman Max or 1.5 to 2 pts Gmax Lite

Kochia control POST in sorghum

- Treat kochia early!!!!!! Remember emergence patterns!!!!!
  - Banvel, Clarity, or generics or Starane products are a key component of a post program. Adding 0.5 lb atrazine could be very beneficial.
    - atrazine $3.88 / lb ai
    - Clarity 0.5 pt $5.40,
    - Starane 0.67 pt
    - Starane NXT 14 to 21 oz $8.34 to 12.52
    - Starane Ultra 0.4 pt $14.60
    - Huskie 12.8 to 16 oz $10.15 to 12.70

Huskie registration in sorghum from Bayer Crop Science, July 2011.

- Huskie, pyrasulfotole (HPPD) + bromoxynil
- Controls broadleaf weeds only
- Use rate: 12.8 to 16 fl oz/a ($ 10.15 to 12.70)
- Apply with: Atrazine (0.25-1 lb) and AMS
- Maximum 2 applications, 11 days apart, total not to exceed 32 fl oz
- Timing: 3 leaf to 12 inch sorghum
- Grain and forage sorghum. 7 DAT forage PHI and 60 DAT PHI for grain or stover

Sorghum Injury (%), 2009.

Treatment	T	Rate	Tribune	Manhattan	Colby	Hays
		Prod. / acre	14 DAT	7 DAT	8 DAT	5 DAT
Huskie+atrazine	E	13 + 16	1	12	7	18
Huskie+atrazine	E	16 + 16	3	10	10	20
H+A+2,4-D amine	E	13 + 16 + 6	6	8	8	20
H+A+2,4-D ester	E	13 + 16 + 4	4	5	5	24
H+A+dicamba	E	13 + 16 + 4	1	3	7	21
Buctril&atrazine	E	32	0	1	2	21
LSD (0.05)			3	4	10	4

Early application injury of Huskie, 2010.

Treatment	T	Product	Trib.	Man.	Top.	Gar.	Colby	Wichita Nec.	Wichita Stunt	Hays Nec.	Hays Stunt
Rating (DAT)		Rate/acre	14	7	5	30	5		7		5
Huskie+atrazine	E	13 oz+1 pt	0	10	10	0	30	13	3	4	1
Huskie+atrazine	E	16 oz+1 pt	4	12	13	3	28	17	4	5	5
H+A+2,4-D ester	E	13+1 pt+4 oz	0	15	12	0	18	7	5	6	10
H+A+dicamba	E	13+1 pt+4 oz	0	15	23	0	14	4	4	5	9
Atra+Bromoxynil	E	1 pt+1 pt	0	10	2	0	4	1	1	5	5
Aim EC+2,4-D amine	E	0.5 oz+8 oz	5	3	33	0	45	15	2	15	10
LSD (0.05)			2	7	7	5	6	6	6	2	2

Sorghum Injury (%), 2009.

Treatment	T	Rate	Tribune	Manhattan	Colby	Hays
		Prod/ acre	7 DAT	7 DAT	3 DAT	9 DAT
Huskie+atrazine	L	13 + 16	4	17	10	19
Huskie+atrazine	L	16 + 16	5	15	8	19
H+A+2,4-D amine	L	13 + 16 + 6	3	12	4	10
H+A+2,4-D ester	L	13 + 16 + 4	4	12	8	19
H+A+dicamba	L	13 + 16 + 4	3	10	5	10
Atra+Bromoxynil	L	32	0	10	0	9
LSD (0.05)			2	3	3	3

Late application injury of Huskie, 2010.

Treatment	T	Product	Trib.	Man.	Top.	Gar.	Colby	Wichita Nec.	Wichita Stunt	Hays Nec.	Hays Stunt
Rating (DAT)		Rate/acre	14	7	5	30	5		7		8
Huskie+atrazine	L	13 oz+1 pt	2	17	8	11	6	5	0	5	1
Huskie+atrazine	L	16 oz+1 pt	4	17	8	13	8	6	5	5	0
H+A+2,4-D ester	L	13+1 pt+4 oz	4	17	3	9	10	10	3	5	0
H+A+dicamba	L	13+1 pt+4 oz	2	10	5	4	8	6	3	3	6
Atra+Bromoxynil	L	1 pt+1 pt	1	2	0	8	5	7	2	5	0
Carfen+2,4-D amine	L	0.5 oz+8 oz	4	25	20	19	20	53	5	26	0
Huskie+atrazine	E	13+1 pt	0	10	5	15	30	13	4	4	3
Huskie+atrazine	L	13+1 pt									
LSD (0.05)			2	7	7	5	6	6	6	2	2

Sorghum yield response to Huskie and atrazine tank mixtures, 2009.

Treatment	T	Rate	Tribune	Man.	Hays	Colby	Garden City
		Prod / a	Bushels / acre				
Huskie+atrazine	E	13+16	94	142	129	100	26
Huskie+atrazine	E	16+16	95	148	147	101	33
H+A+2,4-D amine	E	13+16 + 6	105	122	121	108	29
H+A+2,4-D ester	E	13+16+4	99	139	125	107	19
H+A+dicamba	E	13+16+4	100	136	133	110	21
Buctril&Atrazine	E	2 pt	100	144	134	101	34
Huskie+atrazine + Huskie+atrazine	E L	13+16 fb 13+16	90	122	134	107	21
Huskie+atrazine	L	13+16	93	129	121	91	28
Huskie+atrazine	L	16+16	92	140	123	81	23
H+A+2,4-D amine	L	13+16 + 6	99	119	117	75	18
H+A+2,4-D ester	L	13+16+4	100	128	113	91	19
H+A+dicamba	L	13+16+4	92	128	118	86	23
Atra+Bromoxynil	L	2 pt	106	143	120	76	22
Untreated			91	124	109	42	30
LSD (0.05)			15	18	13	30	NS

Palmer amaranth Control, 2010.

Treatment	T	Rate (g ai/ha)	Wichita	Top.	Colby	Man.	Trib.
Untreated			0	0	0	0	0
Huskie+atrazine	E	13 oz+1 pt	92	98	97	97	99
Huskie+atrazine	E	16 oz+1 pt		97	96	100	100
H+A+2,4-D ester	E	13+1 pt+4 oz	95	98	97	100	100
H+A+dicamba	E	13+1 pt+4 oz	90	98	95	100	100
Atra+Bromoxynil	E	1 pt+1 pt	40	98	99	98	100
Aim EC+2,4-D amine	E	0.5 oz+8 oz	57	97	83	100	91
Huskie+atrazine	E	13+1 pt	91	100	97	100	99
Huskie+atrazine	L	13+1 pt					
Huskie+atrazine	L	13 oz+1 pt	90	95	66	89	89
Huskie+atrazine	L	16 oz+1 pt	90	92	70	93	87
H+A+2,4-D ester	L	13+1 pt+4 oz	94	98	75	92	84
H+A+dicamba	L	13+1 pt+4 oz	87	98	68	94	86
Atra+Bromoxynil	L	1 pt+1 pt	90	93	60	87	40
Aim EC+2,4-D amine	L	0.5 oz+8 oz	92	93	58	83	28
LSD (p=0.05)			17	8	13	4	10

Broadleaf Weed Control, 2010.

Treatment	T	Product Rate/a	Kochia Colby	Kochia Trib	Redroot pigweed Trib	Tumble pigweed Trib
Untreated			0	0	0	0
Huskie+atrazine	E	13 oz+1 pt	99	97	100	99
Huskie+atrazine	E	16 oz+1 pt	96	100	100	100
H+A+2,4-D ester	E	13+1 pt+4 oz	97	99	100	100
H+A+dicamba	E	13+1 pt+4 oz	95	99	100	100
Atra+Bromoxynil	E	1 pt+ 1 pt	99	100	98	99
Aim EC+2,4-D amine	E	0.5 oz+8 oz	83	90	86	84
Huskie+atrazine	E	13+1 pt	97	100	99	99
Huskie+atrazine	L	13+1 pt				
Huskie+atrazine	L	13 oz+1 pt	66	94	89	91
Huskie+atrazine	L	16 oz+1 pt	70	96	94	95
H+A+2,4-D ester	L	13+1 pt+4 oz	75	94	90	91
H+A+dicamba	L	13+1 pt+4 oz	68	95	91	90
Atra+Bromoxynil	L	1 pt+ 1 pt	60	60	43	41
Aim EC+2,4-D amine	L	0.5 oz+8 oz	58	28	30	28
LSD (p=0.05)			9	9	9	10

Kochia Control

Treatment	T	Rate	Colby	Hays	Garden City
		Prod/ acre	21/10	92/9	36/23
Huskie+atrazine	E	13 + 16	93	100	100
Huskie+atrazine	E	16 + 16	99	98	100
H+A+2,4-D amine	E	13 + 16 + 6	95	100	100
H+A+2,4-D ester	E	13 + 16 + 4	99	100	100
H+A+dicamba	E	13 + 16 + 4	99	100	100
Atra+Bromoxynil	E	32	98	100	100
Huskie+atrazine	L	13 + 16	81	60	99
Huskie+atrazine	L	16 + 16	60	63	100
H+A+2,4-D amine	L	13 + 16 + 6	56	65	100
H+A+2,4-D ester	L	13 + 16 + 4	92	68	100
H+A+dicamba	L	13 + 16 + 4	78	65	100
Atra+Bromoxynil	L	32	47	50	100
LSD (0.05)			19	5	1

Huskie Summary

- Huskie is an excellent tool to help control kochia.
- Kochia is best controlled when small, less than 4 inches tall
- Would NOT skip the PRE herbicide treatment
- Always add 0.25 to 1.0 lb atrazine with Huskie

Kochia control in soybean 4 and 8 WAP, Cimarron, KS 2009.

Herbicide	Rate	4 WAP	8 WAP	Cost
	g ai/ha	% control		$/acre
Valor	2 oz	83	98	12.5
Valor	3 oz	99	98	18.75
Spartan 4F	6 oz	100	100	32.58
Spartan 4F	9 oz	100	100	48.87
Authority First *	6 oz	100	100	30.75
Authority MTZ	16 oz	100	100	21.4
Valor XLT*	4 oz	100	100	18.25
Prowl H2O + Valor	3 pt + 2 oz	95	100	17+12.50
Prowl H2O + Spartan	3 pt + 6 oz	100	100	17+32.58
Prefix+ Dimetric or Tricor	1 qt+ 1 lb	100	99	14.3+17.2
Roundup Powermax	22 oz		95	3.6
Roundup Powermax	44 oz		95	7.22
LSD		9	5	

All PRE herbicide treatments were followed by POST applied Roundup Powermax at 22 fl oz/a
*Products contain ALS herbicides which could carry over to corn or sorghum especially as soil pH increases and rainfall decreases. Check herbicide labels!

Kochia control in soybean 4 and 8 WAP, Hays, KS 2009.

Herbicide	Rate	4 WAP	8 WAP	Cost
	g ai/ha	% control		$/acre
Valor	2 oz	95	100	12.5
Valor	3 oz	100	100	18.75
Spartan 4F	6 oz	100	100	32.58
Spartan 4F	9 oz	100	100	48.87
Authority First *	6 oz	100	100	30.75
Authority MTZ	16 oz	100	100	21.4
Valor XLT*	4 oz	100	100	18.25
Prowl H2O + Valor	3 pt + 2 oz	100	100	17+12.50
Prowl H2O + Spartan	3 pt + 6 oz	100	100	17+32.58
Prefix+ Dimetric or Tricor	1 qt+ 1 lb	100	100	14.3+17.2
Roundup Powermax	22 oz		100	3.6
Roundup Powermax	44 oz		100	7.22
LSD		6.6	0	

All PRE herbicide treatments were followed by POST applied Roundup Powermax at 22 fl oz/a
*Products contain ALS herbicides which could carry over to corn or sorghum especially as soil pH increases and rainfall decreases. Check herbicide labels!

Kochia control in soybean 4 and 8 WAP, Hays, KS 2010.

Herbicide	Rate	4 WAP	8 WAP	Cost
	g ai/ha	% control		$/acre
Valor	2 oz	100	100	12.50
Valor	3 oz	100	100	18.75
Spartan 4F	6 oz	100	100	32.58
Spartan 4F	9 oz	100	100	48.87
Authority First*	4.5 oz	100	100	23.06
Authority First *	6 oz	98	100	30.75
Authority MTZ	16 oz	100	100	21.40
Valor XLT*	3 oz	100	100	13.69
Valor XLT*	5 oz	100	100	22.81
Prowl H2O + Valor	3 pt + 2 oz	100	100	17+12.50
Prowl H2O + Spartan	3 pt + 6 oz	100	100	17+32.58
Prefix+ Dimetric or Tricor	1 qt+ 1 lb	100	100	14.3+17.2
Sharpen	1 oz	100	100	5.58
Optill	2 oz	100	100	6.62
Roundup Powermax	22 oz	100	100	3.60
Roundup Powermax	44 oz	100	100	7.22
LSD (0.05)		5	0	0

All PRE herbicide treatments were followed by POST applied Roundup Powermax at 22 fl oz/a
*Products contain ALS herbicides which could carry over to corn or sorghum especially as soil pH increases and rainfall decreases. Check herbicide labels!

Kochia control in soybean, 4 and 8 WAP Norton, KS 2010.

Herbicide	Rate	4 WAP	8 WAP	Cost
	Prod/acre	% Control		$/acre
Valor	2 oz	95	99	12.50
Valor	3 oz	99	100	18.75
Spartan 4F	6 oz	100	100	32.58
Spartan 4F	9 oz	98	99	48.87
Authority First*	4.5 oz	100	100	23.06
Authority First*	6 oz	100	100	30.75
Authority MTZ	16 oz	99	99	21.40
Valor XLT*	3 oz	100	100	13.69
Valor XLT*	5 oz	100	100	22.81
Prowl H2O + Valor	3 pt + 2 oz	100	100	17+12.50
Prowl H2O + Spartan	3 pt + 6 oz	95	100	17+32.58
Prefix+ Dimetric or Tricor	1 qt+ 1 lb	100	99	14.3+17.2
Sharpen	1 oz	99	100	5.58
Optill	2 oz	100	100	6.62
Roundup Powermax	22 oz		100	3.60
Roundup Powermax	44 oz		100	7.22
LSD (0.05)		7	2	

All PRE herbicide treatments were followed by POST applied Roundup Powermax at 22 fl oz/a
*Products contain ALS herbicides which could carry over to corn or sorghum especially as soil pH increases and rainfall decreases. Check herbicide labels!

Late-season weed control and soybean yield, 2012.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Authority First PRE *fb* Ignite + Cadet + AMS[4] POST	3 oz 29 oz + 0.9 oz	$39.02	83 ab	85 a	24.4 a
Authority MTZ PRE *fb* Ignite + Cadet + AMS[4] POST	10 oz 29 oz + 0.9 oz	$37.11	90 a	94 a	26.9 a
OpTill PRE *fb* Ignite + Cadet + AMS[4] POST	2 oz 29 oz + 0.9 oz	$34.61	84 ab	96 a	25.4 a
Verdict PRE *fb* Ignite + Cadet + AMS[4] POST	5 oz 29 oz + 0.9 oz	$31.71	73 abc	95 a	24.2 a
Dual II Magnum PRE *fb* Ignite + Cadet + AMS[4] POST	1.25 pt 29 oz + 0.9 oz	$38.04	63 bc	90 a	22.0 a
Prefix PRE *fb* Ignite + Cadet + AMS[4] POST	2 pt 29 oz + 0.9 oz	$38.17	71 abc	97 a	20.4 a
Boundary PRE *fb* Ignite + Cadet + AMS[4] POST	2 pt 29 oz + 0.9 oz	$38.21	85 a	99 a	25.4 a
Raptor + MSO POST	4 oz + 1% v/v	$21.63	64 bc	53 b	18.9 a
Ignite + Cadet + AMS[4] POST	29 oz + 0.9 oz	$23.21	59 c	66 b	22.3 a

[1]Application not Included [2]Mean of 3 trials [3]Mean of 2 trials [4]17 lb/100 gal
Phil Stahlman etal

Summary of kochia control in soybean

- Control kochia early before planting!
- Soil applied herbicides are essential.
- Authority (sulfentrazone) based products likely better than Valor (flumioxazin) based products for PRE kochia control.
- Postemergence control of kochia in soybean may be extremely difficult especially if kochia is ALS and glyphosate resistant.
- Depending on Ignite for post kochia control in Liberty-Link beans is very risky!

Kochia control in sunflower

- Effective early control and burndown at sunflower planting greatly reduces kochia emerging in June planted sunflower.
- If kochia are not controlled until just prior to planting sunflower, complete crop failure is very likely.
- Because of the level of ALS resistant kochia in western KS, it is very likely that Clearfield sunflower/Beyond or ExpressSun sunflower/Express will not be effective for controlling kochia.

Weed control in sunflower, Tribune 2006. Thompson/Schlegel.

Herbicide	Product	Cost	Kochia	RUTH	RRPW	PUVL
	Rate/acre	$/acre	% control			
Dual Mag.	1.5 pt	24.90	28	64	76	74
Prowl H2O	2.6 pt	15	46	65	64	80
Dual Mag.+ Prowl H2O	1.3 pt + 2.6 pt	21.60 + 15	63	80	70	79
Dual Mag. + Spartan	1.3 pt + 4 fl oz	21.60 + 21.72	94	98	90	87
Prowl H2O + Spartan	2.6 pt + 4 fl oz	15 + 21.72	95	97	82	66

Evaluations were made 40 days after PRE herbicide application.

Summary

- Managing kochia will be possible, however, will be expensive regardless of row crop planted.
- The traditional methods of conventional weed control practices may not be effective.
- Managing kochia will require planning ahead.
- Implementing strategies that control the huge early flushes of kochia may be critical to a successful kochia management program, regardless of crop planted.
- Timeliness of herbicide applications is essential!!
- Frequency of glyphosate resistant kochia likely is going to increase.

Kochia Control in Wheat and Fallow

Phil Stahlman
Agricultural Research Center-Hays
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The most sustainable weed control programs integrate the use of herbicides with other crop and soil management practices that include crop and herbicide rotation, use of competitive cultivars/hybrids, precision fertilizer placement, optimum planting dates and rates, and planting arrangements that maximize crop competitiveness with weeds. These are core principles of Integrated Weed Management (IWM).

Tillage is an ancient method of weed control and has been an integral part of crop production since the beginning of farming with simple tools. The science of modern weed control began with the discovery of 2,4-D in the early 1940's and probably has advanced more in the past 70 years than in previous recorded history. Herbicides have gradually replaced, but not eliminated, tillage for the purpose of weed control to the extent that today tillage is used as much for seedbed preparation as for weed control. Herbicides have proven so effective that other aspects of IWM are not utilized as often as in the past.

Selection pressure applied to weed populations for a long enough period of time will inevitably result in changes in weed communities favoring those species best adapted to the resulting habitat. The selective force or management practice could be herbicide, tillage, crop rotation, or other agronomic factors. However, frequent use of the same herbicide program changes the spectrum of weed populations more quickly than most other selective forces because of the greater selection herbicides impose on weed populations.

Weed species have developed resistance to several herbicide families. Those of most importance in this geography include triazine, sulfonylurea (ALS-inhibitors), and synthetic auxin herbicides (dicamba and 2,4-D) herbicides, and more recently glyphosate. The widespread presence of glyphosate-resistant kochia in the western one-third of Kansas and adjacent counties in Colorado and Nebraska pose significant challenges to current production systems throughout semi-arid regions. The purpose of this article is to briefly review various herbicide recommendations for control of kochia in winter wheat and discuss alternative herbicide options (to glyphosate) for kochia control in fallow.

Kochia control in wheat

One of the better ways to control of kochia in wheat is to establish a full stand of vigorously-growing wheat that canopies between-row spaces quickly in spring and shades kochia seedlings; they do not grow well in shaded environments. Kochia is seldom a problem in winter wheat except when wheat stand is thin, patchy, or wheat growth is slowed by disease, low fertility, or limited moisture. Narrow row spacing, optimum seeding dates, enhanced wheat seeding rates, and in-furrow starter fertilizer increase wheat competitiveness with all weeds, not just kochia. Several herbicides registered for use in wheat have both soil and foliar activity and can be applied in late-fall or early-spring before kochia seeds germinate. Many of the same and additional herbicides can be applied to wheat and weeds in spring, but the application window for crop safety is narrow for some herbicides and postemergence application may not contact seeding kochia or other weeds protected by wheat foliage.
Kochia resistant to ALS-inhibiting herbicides (sulfonylurea and imidazolinone familes) was found in Kansas, Idaho, and North Dakota in 1987. ALS resistance is still present throughout the state. Many regis-

tered wheat herbicides are ALS-inhibitors. Thus, numerous ALS-inhibiting herbicides including Affinity Broadspec®, Agility SG®, Ally®, Ally Extra®, Amber®, Express TS, Finesse®, Harmony Extra®, and several generic ALS-inhibiting products may not control kochia effectively unless a herbicide of another mode of action is tank mixed with those herbicides. Auxinic herbicides such as 2,4-D, MCPA, or occasionally dicamba are popular choices for tank mix partners with sulfonylurea herbicides.

Rave® is a mixture of triasulfuron (the active ingredient in Amber) and dicamba and is a popular wheat herbicide. However, Colorado State University weed scientists have documented dicamba resistance in kochia populations in eastern Colorado and southwest Nebraska and there have been numerous complaints that dicamba is not as effective as it was in the past. Most weed scientists agree that resistant weeds evolve more quickly when low, often sub-optimal herbicide rates are used than when higher rates are used. It is possible the low amount of dicamba in recommend rates of Rave may be slowly selecting for resistance to dicamba. Other herbicides that are effective on kochia that are not ALS-inhibitors include Huskie®, Pulsar®, Starane Ultra®, and Starane Plus Salvo®.

Additional information and more detailed use recommendations can be found on individual product labels and in print copies of the K-State 2012 Chemical Weed Control Guide found online at http://www.ksre.ksu.edu/library/crpsl2/srp1063.pdf.

Kochia control in early spring, preplant and fallow

Because kochia emerges as early as March there is need for control measures in early spring either prior to emergence or as preplant burndown treatments. Two standardized experiments (preemergence and postemergence applications) were conducted at several sites in Kansas and at least one site each in Colorado, Nebraska, Montana, and Wyoming to evaluate the effectiveness of various herbicide treatments for control of kochia. In preemergence experiments, atrazine was a component of only one treatment (Harness Xtra) so as not to limit cropping options.

Preemergence experiments. Table 1 shows the results of four experiments conducted in Kansas near Gorham, Hays, Scott City, and Tribune in which evaluation times were similar. The mean column shows the percentage weed control averaged across experiments, the median column is the percentage at which half the control ratings were greater and the other half less than the shown percentage, and the range column reports the low and high control ratings; this is a measure of variability among experiments. The approximate costs of treatments varied from $11.77 to $30.00 per acre. There was poor correlation between treatment cost and control effectiveness.

Control ratings generally were lower at Scott City (the driest location) than the three other locations. However, the two most cost-effective preemergence treatments by a wide margin at each location were the Clarity plus 2,4-D LV4 treatments. The higher rates of Clarity and 2,4-D provided no advantage over the lower rates at 5-6 weeks after treatment, but the higher rate treatment was advantageous at later evaluations (data not shown). The 6 oz/A Spartan treatment was effective at 3 of 4 locations, but was unexplainably mediocre at Hays. Verdict was effective for 3-4 weeks but control declined rapidly thereafter. Others experiment not reported here confirm that the effectiveness of Balance Flexx is considerably improved when tank mixed with atrazine. Similar enhancement of Verdict would be expected.

Table 1. Kochia control 5-6 weeks after preemergence herbicide application averaged across four experiments conducted in Kansas, 2011.

Herbicide treatment	Rate/ac	Approximate cost/ac[1]	Mean	Median	Range
			%		
Verdict	15 oz	$30.00	59	62	23 – 89
Balance Flexx	5 oz	$29.13	71	70	53 – 92
Harness Xtra	2.3 qt	$19.53	72	70	46 – 100
Warrant	2 qt	$17.00	23	23	20 – 25
Valor SX	3 oz	$22.23	29	29	16 – 40
TripleFlex	1 qt	$24.72	46	38	15 – 93
Spartan 4F	6 oz	$19.77	79	83	55 – 100
Clarity + 2,4-D LV4	8 oz + 8 oz	$11.77	97	97	95 – 100
Clarity + 2,4-D LV4	16 oz + 16 oz	$18.41	98	99	95 – 100

[1]Includes application ($5.13) based on Kansas Custom Rates but does not reflect program discounts or rebates. Thus, most indicated costs are probably high and are intended to show approximate costs for comparative purposes.

Postemergence experiments. Mean results of eight experiments are shown in Table 2. Format of the table is the same as Table 1. The approximate costs of treatments varied from $10.93 to $25.72 per acre. Much like the preemergence experiments, there was poor correlation between treatment cost and control effectiveness.

The effectiveness of most herbicide treatments varied widely among experiments; however, not Gramoxone + Atrazine + COC at the rates indicated in the table. The effectiveness of Roundup Power-Max in individual experiments clearly indicated that kochia populations in the Nebraska, Montana, and one of two Colorado experiments were glyphosate-susceptible while populations in all four of the Kansas experiments and one Colorado experiment were glyphosate-resistant. This is reflected in the range column. Only the Gramoxone Inteon + Atrazine 4L + COC treatment controlled kochia greater than 95% when averaged across all eight locations. Other effective treatments for which control percentage in individual experiments was always 65% or higher (range column) included Sharpen + Atrazine + MSO and Laudis + Atrazine + MSO. Huskie + NIS and Impact + Atrazine + MSO were moderately effective. Linex 4L + Atrazine 4L + COC was effective at all but the Montana location, where it performed poorly. Also, the Rage D-Tech + MSO performed much worse at the Nebraska location than at other locations. Distinct and Distinct + 2,4-D performed similarly with a wide range of performance among experiments.

Table 2. Kochia control 3-4 weeks after postemergence herbicide application averaged across eight experiments conducted in Kansas (4), Colorado (2), Montana (1) and Nebraska (1), 2011.

Herbicide treatment[1]	Rate	Approximate cost/ ac[2]	Mean	Median	Range
	oz/ac + % vol:vol		%		
Distinct + NIS	4 + 2%	$20.20	67	75	27 - 94
Distinct + 2,4-D LV4 + NIS	4 + 8 + 2%	$21.34	69	74	32 - 99
Sharpen + LV4 + MSO	1 + 8 + 1%	$15.12	79	84	55 - 96
Sharpen + Atrazine 4L + MSO	1 + 12 + 1%	$15.07	86	90	65 - 99
Laudis + MSO	3 + 1%	$24.30	83	87	58 - 97
Laudis + Atrazine 4L + MSO	3 + 8 + 1%	$25.72	89	93	65 - 100
Callisto + Atrazine 4L + COC	3 + 8 + 1%	$22.66	73	80	35 - 98
Impact + Atrazine 4L + MSO	0.75 + 8 + 1.5 %	$14.86	86	89	56 - 98
Starane NXT + NIS	14 + 0.5%	$13.94	63	62	18 - 99
Huskie + NIS	15 + 1%	$17.87	82	88	59 - 97
Rage D-Tech + MSO	32 + 2%	$17.30	59	61	0 - 93
Gram. + Atrazine 4L + COC	48 + 16 + 1%	$20.04	96	99	87 - 100
Linex 4L + Atrazine 4L + COC	24 + 16 + 1%	$21.82	83	96	35 - 100
RU PowerMax	32	$10.93	49	34	14 - 96

[1]All treatments except Gramaxone Inteon + Atrazine 4L and Linex 4L + Atrazine 4L also included dry ammonium sulfate at 17 lb/100 gal (2% w/v). NIS , non-ionic surfactant; COC, crop oil concentrate; and MSO, methylated seed oil.

[2]Includes application ($5.13) based on Kansas Custom Rates but does not reflect program discounts or rebates. Thus, most indicated costs are probably high and are intended to show approximate costs for comparative purposes.

It is well known that kochia plants that survive a glyphosate application are very difficult to control by respraying, even with higher rates. This is was the case in an experiment near Monument, KS in a field of failed winter wheat which was terminated in spring by spraying with glyphosate. The wheat and weeds other than kochia were killed. We established a trial in this field and applied the herbicide treatments listed in Table 3 on June 15 when kochia plants were 3-8 inches tall. Roundup PowerMax at 32 oz/A plus Banvel at 16 oz/A and 0.5% non-ionic surfactant controlled kochia less than 50% at 21 days after treatment (DAT). Roundup PowerMax at 32 oz/A plus Sharpen at 1 oz/A and 1% MSO was similarly ineffective. No treatment controlled kochia completely and few treatments provided greater than 90% kochia control at 21 DAT.

Table 3. Kochia control in failed winter wheat 7, 14, and 21 days after treatment, Monument, KS, 2011.

		Days after treatment		
Herbicides[1]	Rate	7	14	21
	oz/A or % v/v		%	
RU PowerMax + Banvel + NIS	32 + 16 + 0.5%	26 e	30 f	48 g
Sharpen + Linex 4L + MSO	1 + 24 + 2%	91 a	89 ab	86 a-c
Sharpen + Atrazine 4L + MSO	1 + 8 + 1%	91 a	85 b	80 b-d
Sharpen + Gram. Inteon + MSO	1 + 48 + 1%	90 a	84 b	73 de
Sharpen + RU PowerMax + MSO	1 + 32 + 1%	69 bc	48 e	53 fg
Laudis + Banvel 4 + MSO	3 + 16 + 1%	45 d	58 d	83 a-d
Laudis + Banvel 4 + Sencor DF + MSO	3 + 16 + 12 + 1%	61 c	86 b	92 ab
Laudis + Starane NXT + MSO	3 + 14 + 1%	75 b	89 ab	90 ab
Impact + Atrazine 4L + MSO	1 + 8 + 1%	65 c	74 c	74 c-e
Impact + RU PowerMax + MSO	1 + 32 + 1%	45 d	55 de	65 ef
Gramoxone Inteon + Linex 4L + NIS	48 + 24 + 0.5%	88 a	85 b	84 a-d
Gramoxone Inteon + Linex 4L + Sencor DF + NIS	48 + 24 + 12 + 0.5%	91 a	95 a	95 a

[1]All treatments included dry ammonium sulfate at 17 lb/100 gal (2% w/v).

Marestail & Palmer Amaranth Management

Dallas Peterson & Doug Shoup
Department of Agronomy
K-State Research & Extension

Most Problematic Weeds in Kansas

Kochia

Palmer amaranth /Waterhemp

Marestail (Horseweed)

Marestail (*Conyza Canadensis*)

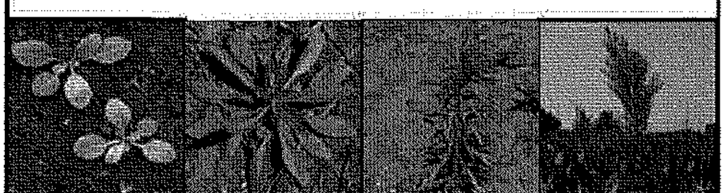
- Member of the Composite (sunflower) plant family
- Native to North America
- Not much of an agronomic problem prior to no-till
- Propensity to develop herbicide resistance

Marestail Biology

- Marestail is generally considered a winter annual weed that germinates in the fall, overwinters in the rosette stage, bolts in the spring and produces seed in the summer
  - Multiple flushes can occur in the fall, spring, summer
    - Northern areas fall germination more common
    - Southern areas spring germination more common
- Plants generally have single, unbranched stems until the flowering branches at the top of the plant.
- Leaves are linear with a slightly toothed margin, alternating, and attached directly to the stem.
- Mature plants can be from 1 to 6 ft tall.

Marestail Stages of Growth

- Marestail is generally a winter annual weed that overwinters in the rosette stage, bolts in the spring, and produces seed in the summer.

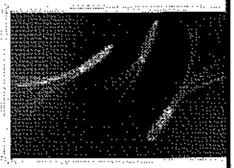


Seedling | Rosette | Bolting | Seed head

Marestail

- **Marestail can produce up to 200,000 seeds/plant**
- **Relatively short seed life in soil**
- **Limited competition research on marestail**
  - Yield loss will depend on emergence date, density, and climatic conditions
  - Study in Michigan where soybean yield reduced >80%

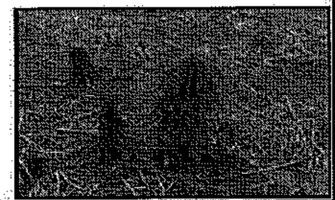
Marestail Seed Dispersal



- Seed are very small, about 1/8 the size of dandelion seed
- Seed is attached to a pappus, which can act like a parachute to carry the seed with the wind.
- Marestail seed have been found in the upper planetary boundary layer (> 450 ft above ground).
- This could allow seeds to travel up to 300 miles with a single wind event.

Herbicide Resistance

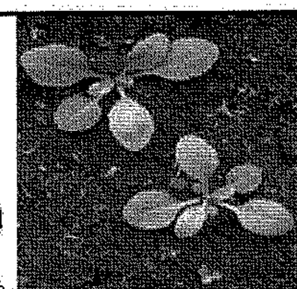
- Marestail has developed herbicide resistance to five herbicide modes of action.
  - Glyphosate
  - Paraquat
  - Atrazine
  - ALS-inhibiting herbicides
  - Diuron

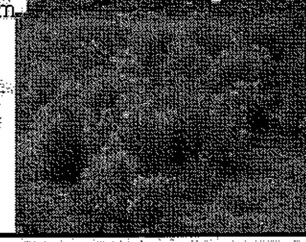


Management Effect on Marestail in Soybeans

Managing Marestail

- Timing, Timing, Timing!
- Utilize 2,4-D, dicamba, Sharpen and/or residual herbicides in fall and early spring burndown in no-till.
- Atrazine + 2,4-D in corn or sorghum.
- Ignite for late burndown control.
- Control marestail in the wheat crop.
- Don't skimp on rate or appropriate spray additives.
- Use appropriate treatments.





Marestail control in wheat (Winfield, 2011)

Treatment	Rate	Application Stage: Rosette (Dec-21)	Application Stage: Bolted (April-8)	Herb Cost
		(% Control on May 19th)		($/A)
Banvel	8 fl oz	100	--	4.05
Huskie	15 fl oz	84	100	11.80
Buctril	32 fl oz	52	32	19.85
Aim	1 fl oz	34	5	8.10
Finesse	0.4 oz	90	88	6.60
Rave	4 oz	100	--	8.00
Powerflex	3.5 oz	55	80	12.60
Harmony SG	0.9 oz	63	76	32.00
Starane Ultra	6.4 fl oz	34	85	14.60
LSD (5%)		24		

Shoup, Zimmerman, & Peterson, 2010

Fall applied herbicides for weed control prior to no-till corn, Manhattan, KS (Thompson and Peterson 1001falltrt).

Herbicide	Rate	Henbit	Downy Brome	Mares-tail	Herb. Cost
	(oz/a)	(% Control)			($/A)
Atra+2,4-D LV+COC	32+16+1%	100	96	100	6.75
Autumn+2,4-D+COC+AMS	0.3+16+1%+8.5	100	0	100	9.25
Autumn+Rupm+COC+AMS	0.3+16+1%+8.5	100	98	100	10.10
Autumn Super+2,4-D+COC+AMS	0.5+16+1%+8.5	100	92	100	13.60
Autumn Super+Rupm+COC+AMS	0.5+16+1%+8.5	100	100	100	14.40
Autumn Super+Met+COC+AMS	0.5+6+1%+8.5	100	100	100	17.25
LSD (5%)		18	7	100	

Burndown of rosette marestail at Manhattan, KS in 2011 (Peterson and Thompson).

Treatment	Date	Rate	1WAT	5/24	6/10	6/24	Herb Cost
		(oz/a)	(%)				($/A)
Sharpen+MSO	4/12	1	95	53	43	33	5.60
2,4-D	4/12	16	48	73	63	38	2.75
Clarity	4/12	4	33	81	73	59	2.85
Clarity	4/12	8	40	89	93	88	5.70
Ignite+AMS	4/12	29	80	58	43	38	13.90
LSD (5%)			4	5	4	3	

Burndown of bolted marestail at Manhattan, KS in 2011 (Peterson and Thompson).

Treatment	Date	Rate	1WAT	5/24	6/10	6/24	Herb Cost
		(oz/a)	(%)				($/A)
Sharpen+MSO	5/10	1	94	86	76	61	5.60
2,4-D	5/10	16	37	33	57	47	2.75
Clarity	5/10	4	35	38	53	60	2.85
Clarity	5/10	8	43	48	68	79	5.70
Ignite+AMS	5/10	29	81	97	88	88	13.90
Roundup Pmax	5/10	22	48	93	96	96	3.60
Roundup+Sharpen	5/10	22+1	94	100	99	99	9.20
LSD (5%)			4	5	4	3	

Marestail Control Ahead of Soybean (Hillsboro).

Treatment	Rate	Application Stage: Rosette (Mar-29)	Application Stage: Bolted (May-5)	Herb Cost
		% Control 5WAT		($/A)
Roundup PMax	22 fl oz	84	63	3.60
2,4-D amine	32 fl oz	95	54	4.00
Canopy EX	1.1 oz	59	58	8.90
Ignite	22 fl oz	77	90	10.55
Authority First	3 oz	57	61	15.40
Valor XLT	3 oz	74	58	13.70
First Rate	0.7 oz	71	71	29.75
Sharpen	1 fl oz	62	67	5.60
Gramoxone	32 fl oz	6	78	9.25
LSD (5%)		16	7	

Shoup, Roberts, & Peterson, 2010

Sharpen on Marestail

- Most consistent results when tank-mixed with 2,4-D, dicamba, or glyphosate.
- Use with methylated seed oil.
- Use adequate spray volume, 15 gpa or higher.
- 2 oz/A has been more consistent than 1 oz/A where it can be used.

Postemergence Control of Glyphosate Resistant Marestail Control in Soybean (Manhattan).

Treatment	Rate	1WAT	5 WAT	10 WAT	Herb. Cost
		% Control			($/A)
Roundup PMax	22 oz	30	57	57	3.60
Roundup PMax	44 oz	37	60	57	7.20
Cadet	0.9 oz	20	8	0	10.70
RU PMax + Cadet	22+0.9 oz	50	47	47	14.30
FirstRate	0.3 oz	47	73	63	12.75
RU PMax + FirstRate	22+0.3 oz	47	87	95	16.35
Classic	0.5 oz	53	53	40	8.20
RU PMax + Classic	22+0.5 oz	53	73	77	11.80
LSD (5%)		6	10	8	

Peterson and Thompson, 2009

Palmer amaranth (*Amaranthus Palmeri*)

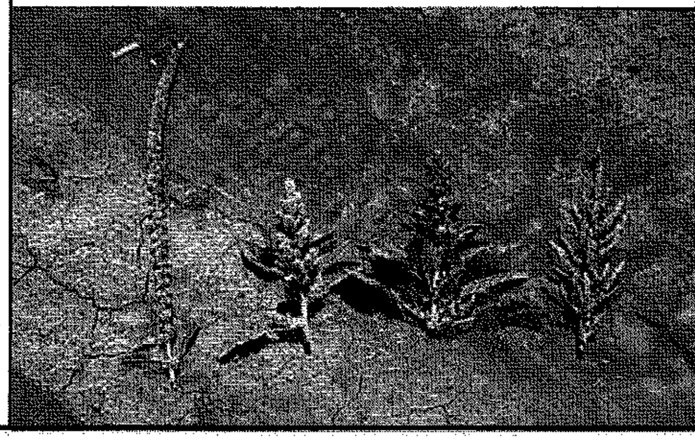
Common Waterhemp (*Amaranthus Rudis*)

- Members of the Amaranth (pigweed) plant family
- Native to North America
- Very competitive and prolific seed producers
- Propensity to develop herbicide resistance

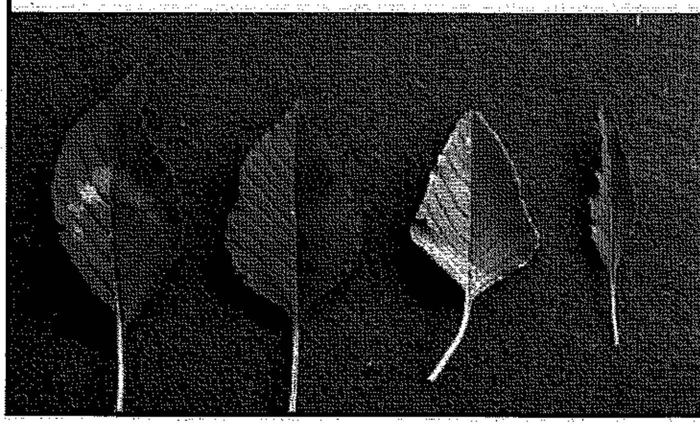
Palmer Amaranth & Waterhemp Biology

- Warm season summer annuals
  - Start to germinate in May and continue through the summer
- Palmer amaranth has ovate leaves and may reach 12 feet tall and have 3 inch diameter stems.
- Waterhemp may reach 8 feet tall, but typically has smaller stems and narrower leaves.
- Both species have smooth stems and leaves, while redroot pigweed is pubescent.
- Both species have male and female plants (Dioecious)
  - Genetic diversity
  - Gene flow

Palmer/Redroot/Smooth/Waterhemp Seedheads



Palmer-a/Palmer-b/Redroot/Waterhemp leaves



Pigweed Competition

Palmer amaranth:
- Height up to 10 ft tall
- Up to 500,000 seed/plant
- Soybean yield losses up to 79% at 8 plants/3ft-row

Common waterhemp:
- Height up to 7 ft tall
- Up to 2 million seed/plant
- Soybean yield losses up to 56% at 8 plants/3ft-row

Redroot pigweed:
- Height up to 5 ft tall
- Up to 400,000 seed/plant
- Soybean yield losses up to 38% at 8 plants/3ft-row

Herbicide Resistance

- Palmer amaranth and waterhemp have developed resistance across 6 herbicide MOA
  - Dinitroaniline (Palmer)
  - Triazine Resistance (Both)
  - ALS Resistance (Both)
  - PPO Resistance (Waterhemp)
  - Glyphosate Resistance (Both)
  - HPPD Resistance (Both)
  - 2,4-D (Waterhemp)

Glyphosate Resistant Palmer amaranth treated three times with Roundup PowerMax at 88 oz/A Stanley Culpepper, University of Georgia

Palmer Amaranth & Waterhemp Control

- **Utilize an integrated approach incorporating residual and postemergence herbicides with different MOA**
- **Foundation preemergence herbicides**
  - Soybeans: Prefix, Authority, Valor, Acetamides, Fierce
  - Corn: Atrazine/acetamide premixes, Lexar/Lumax, Balance Flexx, Corvus, Verdict
  - Sorghum: Atrazine Premixes, Lexar/Lumax, Verdict
  - Sunflower: Spartan, Dual, Prowl

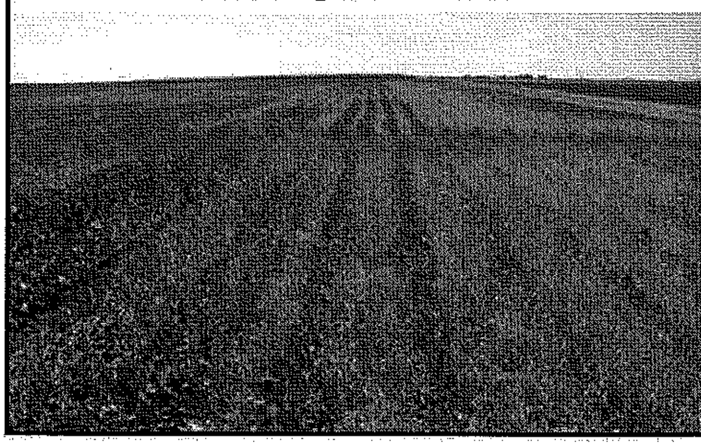
Palmer Amaranth & Waterhemp Control

- **Utilize an integrated approach incorporating residual and postemergence herbicides with different MOA**
- **Postemergence herbicide options**
  - Soybean – Flexstar, Cobra, Ultra Blazer, Glyhphosate
  - Corn – Callisto, Laudis, Capreno, Impact, Armezon, Status, 2,4-D, Glyphosate
  - Sorghum – Huskie, atrazine, dicamba, 2,4-D
  - Sunflowers – Beyond or Express???
- **Liberty Link programs in soybeans and corn**

Glyphosate resistant waterhemp control at Ottawa, KS in 2011 (Peterson, Shoup, and Putman).

Herbicide	Rate	Waterhemp Control 6/28	7/20	9/6	Herb. Cost
	(oz/a)	(% control)			($/A)
Roundup Power Max	22	-	16	15	3.60
Valor XLT/ RUPM	4 /22	91	91	86	21.85
Valor XLT/RUPM+Flexstar	4/22+20	89	92	86	43.90
Auth XL/RUPM+Flexstar	6.5/22+20	98	97	96	49.35
Auth First/RUPM+Flexstar	6.5/22+20	90	96	94	58.90
Fierce/RUPM+Flexstar	4.5/22+20	100	100	100	?
LSD (5%)		7	4	5	

Roundup Power Max



Fierce/Roundup PM+Flexstar

Broadleaf weed control at Manhattan, KS in 2010 with good activation (Peterson and Thompson).

Herbicide	Rate	Palmer amaranth	Velvet-leaf	Morning-glory	Herb. Cost
		(%)			($/a)
Valor XLT	3 oz	96	100	90	13.70
Fierce	3 oz	99	99	87	?
Authority First/Sonic	3.2 oz	97	100	87	16.40
Authority XL	4 oz	98	93	90	14.60
Prefix	2 pt	100	53	50	14.30
OpTill	2 oz	89	100	83	13.25
Prowl H2O	2.5 pt	50	83	27	14.25
LSD (5%)		7	4	5	

Broadleaf weed control at Manhattan, KS in 2010 with delayed activation (Peterson and Thompson).

Herbicide	Rate	Palmer amaranth	Velvetleaf	Ivyleaf morningglory	Herb. Cost
	(oz/a)	(% control)			($/A)
Valor XLT	3.5	99	87	73	16.00
Authority First	3.2	75	70	77	16.40
Authority XL	4	63	63	73	14.60
Authority Assist	5	80	67	80	14.40
Fierce	3	98	100	73	?
LSD (5%)		8	13	12	

Liberty Link Corn and Soybeans

- Allows the use of Ignite herbicide (newer formulation of Liberty).
- Application timing, spray coverage, temperature, humidity, light intensity, and time of day all critical to performance of Ignite.
- Works best as part of a sequential weed control program with preemergence residual herbicides.

Weed control in Liberty Link soybeans at Manhattan, KS, 2011 (Peterson and Thompson).

Herbicide	Application Rate	Application Timing	Large crabgrass	Palmer Amaranth	Velvetleaf	Morning-glory	Herb. Cost
			----------(% control)----------				($/a)
Ignite	36	EP	80	85	96	93	17.25
Ignite/Ignite	29/29	EP/SEQ	94	93	100	98	27.80
Prefix/Ignite	32/29	PRE/P	100	100	89	91	28.20
Prefix+Ignite	32+29	EP	90	90	95	95	28.20
Valor/Ignite	2/29	PRE/P	97	98	100	98	26.40
Valor XLT/Ignite	3/29	PRE/P	99	100	100	99	27.60
Auth First/Ignite	4/29	PRE/P	98	100	100	100	34.40
Auth XL/Ignite	4/29	PRE/P	100	98	100	100	28.50
Fierce/Ignite	3/29	PRE/P	100	100	100	99	?
Lsd (5%)			6	8	5	4	

Future Technologies in Soybeans

- Crops stacked with multiple herbicide resistant traits.
- Dicamba resistant soybeans from Monsanto – 2014?
  - Metabolism based resistance, stacked with Roundup Ready trait
  - Monsanto and BASF developing new lower volatility formulation of dicamba.
- DHT (Enlist) resistant soybeans from Dow AS – 2015?
  - Resistance to 2,4-D, stacked with glyphosate resistance
  - Metabolism based resistance
  - Dow developing new low volatility formulation of 2,4-D that will be pre-mixed with glyphosate called Enlist Duo.
- HPPD resistant soybeans – 2016?

Dicamba and 2,4-D Resistant Soybeans Potential Benefits

- Improved control of hard to control weeds
  - Morningglory, velvetleaf
- Improved control of herbicide resistant weeds
  - Marestail, pigweeds, ragweeds, kochia
- Improved burndown options without preplant interval restrictions

Dicamba and 2,4-D Resistant Soybeans Potential Risks

- Accurate record keeping and communication with applicator regarding resistant and non-resistant fields.
- Spray drift to non-resistant soybeans and other susceptible crops.
- Sprayer contamination when switching between resistant and non-resistant soybeans.
- Increased selection for multiple resistant weeds.

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Spray Boom Set-up on Field Sprayers

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Design attributes and expected costs of dry and wet field sprayer booms are compared and illustrated.

Field sprayer booms are an important part of the pesticide delivery system and can influence application accuracy and efficiency. Booms come in all shapes and sizes, depending on their use, and deliver the spray solution to the nozzles and tips at the desired pressure for the target. A small hand boom may be only a single nozzle while a large field sprayer could have a 120-foot or wider boom.

Nozzle Spacing

The most common nozzle spacings are 20 and 30 inches. Many sprayers are now being converted from 30 inch to 15 inch spacings. The 30-inch spacing is used for the lower application rates (7 to 10 gallons per acre) and the 15-inch spacing for the higher application rates (14 gallons per acre and higher). For most applications, the 30-inch spacing (adding 15-inch spacing if desired) works best since most row crops are in 30-inch rows. For those in 20- and 22-inch rows you may wish to have nozzle spacing the same as row width. Having nozzles spaced the same as the row width enables you to easily use drop nozzles, although with row spacing less than 30 inches it is usually difficult to use drop nozzles. The recommendation is to use 80-degree nozzles in 20-inch or narrower spacing, and to use 100-degree nozzles with 30-inch nozzle spacing. Many new nozzles are only available in 110 degrees. The 30-inch nozzle spacing also lets the applicator use a larger nozzle tip that permits use of 50 mesh nozzle screens. If possible, use 0.25 gallons per minute (GPM) nozzle tips or larger. A 0.20 GPM nozzle tip may be used with a 50 mesh nozzle screen but is just on the border of what is recommended to prevent plugging. The particle size of a 110 degree nozzle tip that is 50 percent larger (used in 30-inch spacing) and an 80-degree nozzle used in 20-inch spacing (0.3 GPM vs 0.2 GPM) is almost the same size as you do not increase the potential spray drift problem going to 30-inch nozzle spacing and 110-degree nozzles.

Stability and Strength — Boom Features

Two attributes to look for when selecting a boom are stability and strength. Stability, the most important factor, ensures that the boom maintains a constant orientation to the target. Field conditions may vary widely, but if a spray boom is expected to provide a uniform application, stability must be maintained. Also important is a boom's strength or its ability to withstand operating conditions without becoming damaged.

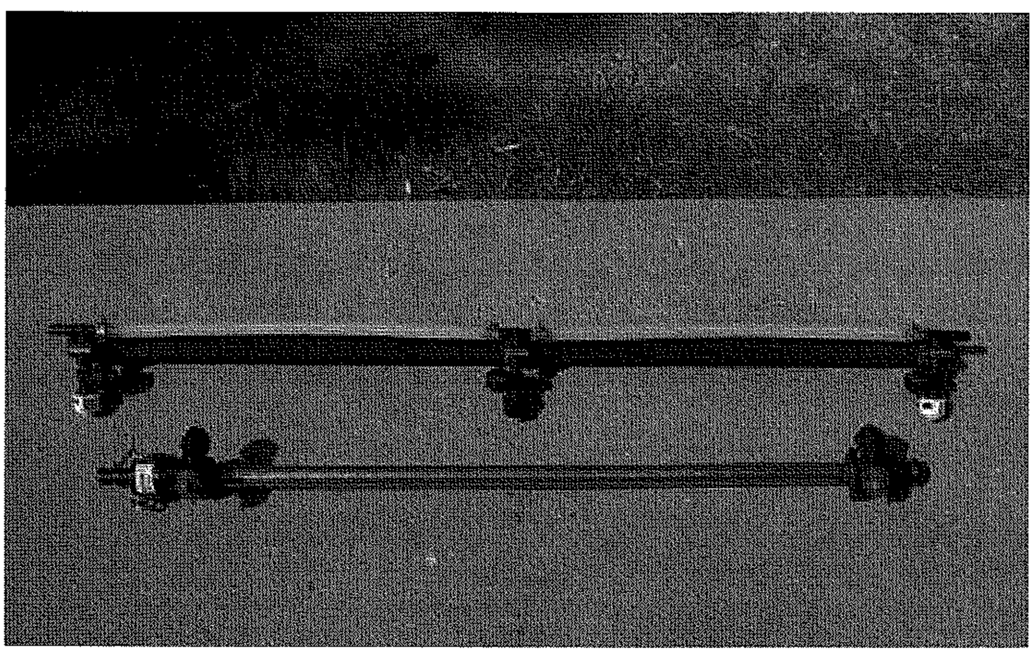

Figure 1. Sections of two booms — dry boom on top, wet boom on bottom.

Two systems are used to control boom stability. Passive systems, which include trapeze suspensions, center pivots, and dampening suspensions, all use balance. They minimize the amount of deflection transferred from the sprayer to the boom through various linkage designs. Active systems, on the other hand, use sensors and actuators in stabilizing the boom. An active system will usually have a sensor on the boom which is set to distinguish any fluctuation in distance between the target and the boom. If a difference in height is observed, the sensor signals the actuator on the boom linkage and it makes the appropriate adjustment. This usually means raising or lowering the boom in relation to the original setting.

Figure 2. Angle of boom can be changed by rotating the boom within the clamps.

Wet and Dry Booms

There are two types of booms: wet and dry. A boom is considered a wet boom *(Figure 1, bottom)* if the pipe span is not only used as a support mechanism for the spray nozzles but delivers spray solution to them as well, hence the name "wet boom." A boom that is used merely as a span along which to space the nozzles, but which does not deliver the spray solution, is considered a dry boom *(Figure 1, top)*. The solution is delivered to the nozzles via a separate hose line that runs along the boom span using it as a support mechanism to mount each nozzle.

The advantages of a wet boom are less plugging of nozzle tips since there is less area where particles could build up and the ease of flushing the boom. On the dry boom, hose and nozzle assemblies are much more subject to being contaminated with residues than stainless steel tubing or pipe. Some adjuvants used with pesticides provide excellent cleaning of the tank, hose, etc., and may cause the spray solution to become contaminated. Even though the tank has been cleaned, the spray booms often have not been cleaned.

As more glyphosate-resistant weeds appear, use of products with greater residual activity or different modes of action will increase. As this occurs, greater attention is going to need to be given to flushing the system before moving on to other crops or on to crops without the appropriate resistance traits. Because of this, wet booms are going to become more practical because of the ease of cleaning.

Unless the boom is really long or a small size pipe is used, the spray boom on a wet boom needs only to be fed with the spray solution on the end. Since the nozzle assemblies on a dry boom greatly restrict the flow rate, the boom must be fed every few nozzles to prevent a pressure drop.

Another advantage of a wet boom is that the angle of the boom can be changed *(Figure 2)* and in most situations it is easier to change the height of a wet boom than a dry boom. Additional nozzle assemblies to accommodate various row spacings on a wet boom do not restrict the flow rate *(Figure 3)* nearly as much as additional nozzle assemblies on a dry boom.

The two main disadvantages of a wet boom are initial cost and its potential for damage. If the boom contacts a non-moveable object, it may break or bend, destroying part of the boom.

Table I. Comparison of wet and dry boom costs.

20-foot wet boom:		
20 feet of 1-inch OD 16-gauge stainless steel tubing - $6.75/foot	= $135.00	
2 nipples - $6 each	= $ 12.00	
Welding 2 nipples - $4 each	= $ 8.00	
Total	$155.00	
20-foot dry boom:		
20 feet of 3/4-inch braided hose - $0.95/foot		= $19.00
If 30-inch nozzle spacing, 16 stainless steel clamps - $0.80 each		= $12.80
To keep from losing pressure, each 10-foot section of hose is fed in the middle		
Extra hose is 7 feet + 17 feet = 24 x $0.95 =		$22.80
4 more clamps at $0.80 each		= $ 3.20
Two fittings at approximately $7 each		= $14.00
		$71.80

Cost Comparison

The costs of a modern wet boom design versus a dry boom are summarized in *Table I.* The cost of 1-inch outside diameter 16-gauge stainless steel tubing is approximately $6.75 per foot. The ends of the tubing are compressed and 1-inch stainless steel pipe nipples are welded to each end of the stainless steel tubing. The nipples cost approximately

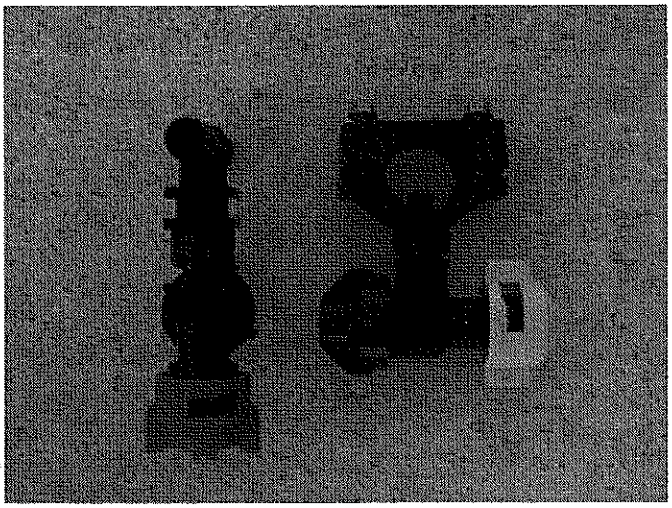

Figure 3. **Nozzle assemblies for dry *(left)* and wet *(right)* booms.**

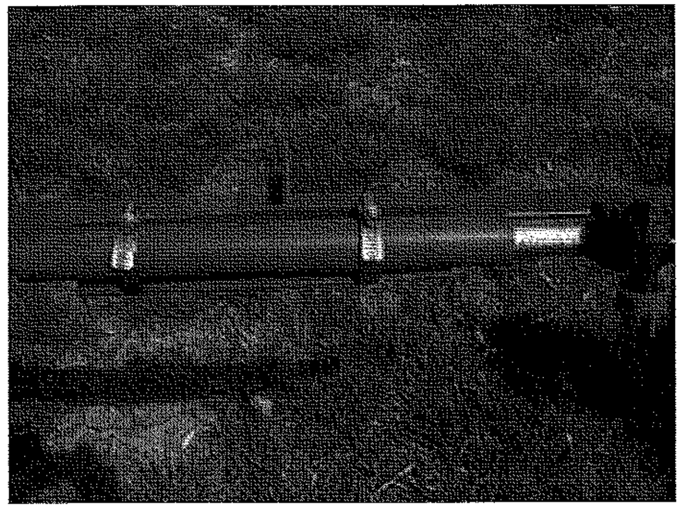

Figure 4. **The bracket to hold the wet boom. The rubber hose protects the boom and the stainless steel hose clamps hold the wet boom in place.**

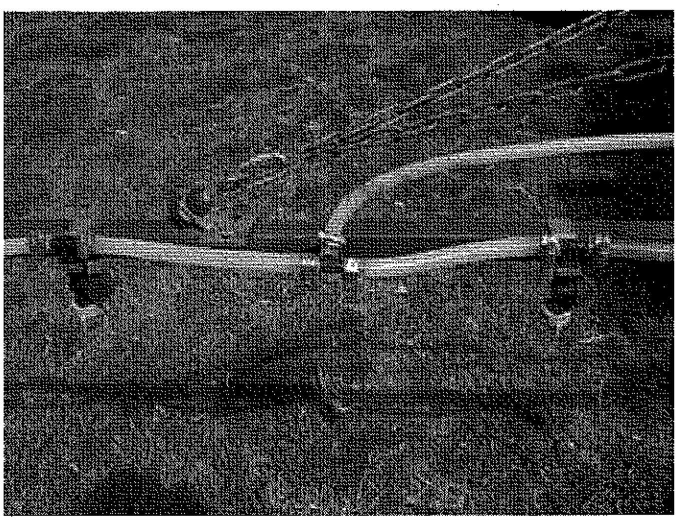

Figure 5. **How dry boom is fed — note restriction to flow rate.**

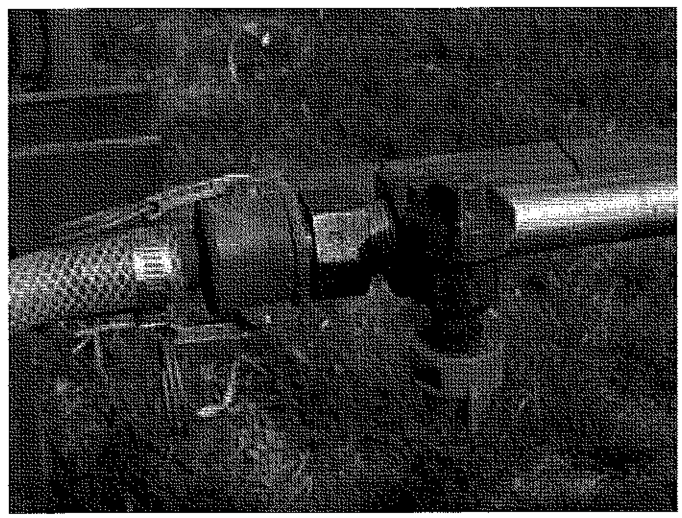

Figure 6. **How wet boom is fed.**

Figure 7. **End cap on wet boom to drain and flush boom.**

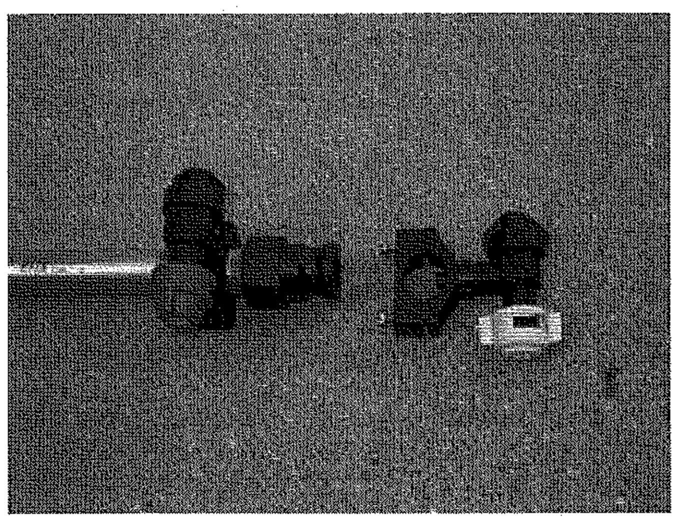

Figure 8. **Wet boom nozzle body on and off boom.**

Figure 9. **Multiple nozzle body on wet boom.**

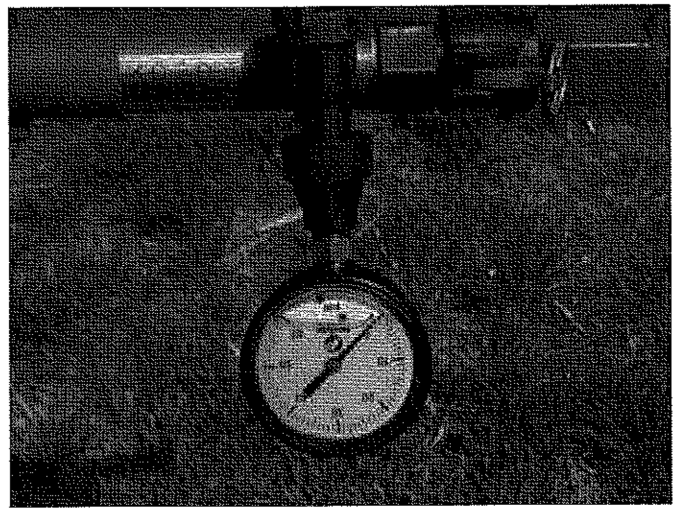

Figure 10. **Gauge to check spray pressure on a wet boom.**

$6.00 and welding each one costs about $4. The hose that feeds the boom and the plug can be attached to these nipples. Both are quick attach couplers. Holes on the boom need to be precisely drilled at the nozzle spacing being used.

This example assumes the connectors and nozzle assemblies for the hose and stainless steel tubing will be about equal to the additional hose and fittings needed on the dry boom.

If the dry boom is left outside and unprotected, the hose may need to be replaced every two or three years. The stainless steel tubing should last for many years if not damaged.

Figures 3-10 help illustrate differences between wet and dry booms.

This publication has been peer reviewed.

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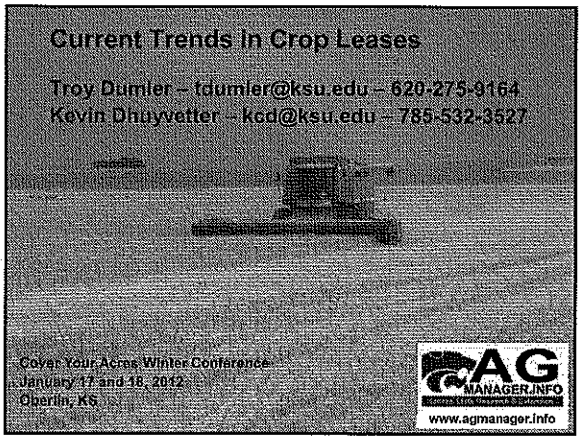

Introduction

- Types of leases
- Principles of leases
  - Technological changes
  - Tenant/Landowner communications
- Information and decision tools: www.agmanager.info

Over the years, the majority of leasing questions received pertain to:

- Impact of adopting new technologies
- Cash renting
- "Non-traditional" leases
  - Net share rent
  - Flexible cash rent
  - Bushel rent
  - Combination cash/cropshare
- Terminating leases

...regardless of topic pertaining to lease terms, method of addressing questions does not change

Types of Leases on Crop Land

- Crop share lease
  - Landowner receives a share annual revenues based (grain sales and government payments) and typically shares certain production costs
- Cash lease
  - Landowner receives a fixed annual payment in exchange for use of land
- Variations of crop share and cash leases

Non-irrigated Lease Types in Kansas

District	Fixed Cash	Crop Share	Other
NW	35.2%	54.6%	10.2%
WC	21.3%	58.5%	20.2%
SW	20.8%	76.1%	3.1%
NC	41.3%	54.8%	3.9%
C	32.8%	53.8%	13.4%
SC	34.0%	63.0%	3.0%
NE	48.7%	42.4%	8.9%
EC	50.9%	39.6%	9.5%
SE	35.9%	58.2%	5.9%
State	35.7%	55.7%	8.8%

Source: KSU, Schlegel and Tsoodle, 2011.

Determining the terms of a lease ...

- How are cash lease rates or the terms of share leases established?
  - Short answer is "the market"
- While landowners and tenants (i.e., the market) ultimately determine terms of share and cash leases, we use the *equitable* concept to arrive at a starting point for negotiations.

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Example of market established crop shares...

Crop	Landlord's Percent of Crop Received (and of Costs Paid)*			
	33% Share	40% Share	50% Share	Other % Share
Wheat (21 Leases)	19			2
% of Total Leases in Lease Arrangement	90.50%	No Responses	No Responses	9.50%
% of Leases Sharing Fertilizer Costs	100.00%			100.00%
% of Leases Sharing Herbicide Costs	68.40%			0.00%
% of Leases Sharing Insecticide Costs	21.10%			50.00%
Corn (11 Leases)	11			
% of Total Leases in Lease Arrangement	100.00%	No Responses	No Responses	No Responses
% of Leases Sharing Fertilizer Costs	90.90%			
% of Leases Sharing Herbicide Costs	81.80%			
% of Leases Sharing Insecticide Costs	54.50%			
Sorghum (7 Leases)	7			
% of Total Leases in Lease Arrangement	100.00%	No Responses	No Responses	No Responses
% of Leases Sharing Fertilizer Costs	100.00%			
% of Leases Sharing Herbicide Costs	57.10%			
% of Leases Sharing Insecticide Costs	42.90%			

* The percentages calculated in this table represent the percent of landlords sharing the same percent of costs as they share of the crop. For example, 68.4% of landlords receiving 33% of the wheat crop paid 33% of herbicide expenses.

Crop Share Arrangements in Kansas

Landlord Share	NW	WC	SW	NC	C	SC	NE	EC	SE
20.0%	0.0%	0.0%	0.0%	1.4%	0.0%	0.0%	0.0%	0.0%	0.0%
25.0%	0.0%	3.5%	1.4%	0.0%	0.7%	0.0%	5.3%	1.0%	0.0%
33.3%	**96.2%**	**96.5%**	**94.5%**	**62.7%**	**83.4%**	**90.8%**	**22.3%**	**70.7%**	**94.4%**
40.0%	0.0%	0.0%	1.4%	28.9%	13.1%	6.4%	27.7%	9.1%	0.0%
50.0%	0.0%	0.0%	2.7%	6.3%	0.7%	2.1%	44.7%	17.2%	4.2%
66.7%	0.0%	0.0%	0.0%	0.0%	0.7%	0.0%	0.0%	1.0%	0.0%
75.0%	1.9%	0.0%	0.0%	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%
Other	1.9%	0.0%	0.0%	0.7%	0.7%	0.7%	0.0%	1.0%	1.4%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: KSU, Schlegel and Tsoodle, 2011.

Problem:

The market equilibrium prices we observe (when they are available) often do not reflect individual situations.

That is, they reflect averages, but nobody is average...

... so what can we do to arrive at a price that reflects an equilibrium?

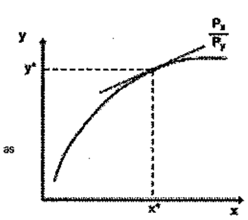
A good crop share lease should follow five basic principles ...

1. Yield increasing inputs should be shared
2. Share arrangements should be adjusted as technology changes
3. Total returns divided in same proportion as resources contributed
4. Compensation for unused long-term investments at termination
5. Good landlord/tenant communications

Principle #1: Yield increasing inputs should be shared

Example of yield increasing inputs

- Fertilizer
- Irrigation water
- Herbicides ?
- Seed ?



Sharing yield increasing inputs in the same % as income provides the economic signal for the economic optimal amount of the input to be used.

Principle #2: Technology may affect share arrangements

Examples of technological change

- Reduced-/no-till
- New crops and/or rotations
- Center pivot irrigation
- Bio-technology
- Precision agriculture (GPS)

How does technology impact relative contributions?

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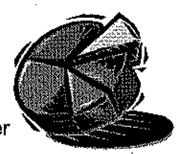
Principle #3:
Returns divided in same proportion as resources contributed.

This requires annual contributions of both parties to be identified (budgeting type approach).



Valuing inputs can depend on whether the lease being developed is a one-year lease versus multiple-year lease.

If the goal is to have an "equitable" lease ...

... then crops should be divided in the same proportion that inputs are provided, regardless of whether or not specific input costs are shared.

What is most important is communication.

Principle #4: Compensation for unused long-term investments at termination.

- It is generally recommended that landowner make long-term investments such as terraces, irrigation well, lime, alfalfa seed, etc.
- However, if the tenant either pays for these investments, or shares them, he should be compensated for his share of any value that remains when the lease is terminated

Principle #5: Good communications between the landlord and the tenant.

- Because so many of the terms of the lease are based on negotiation between the landowner and the tenant, good communications are critical.
- Because a lease is a legal contract in Kansas, it is suggested that terms of the lease agreed upon by both parties be put in writing.

Cash rents ...

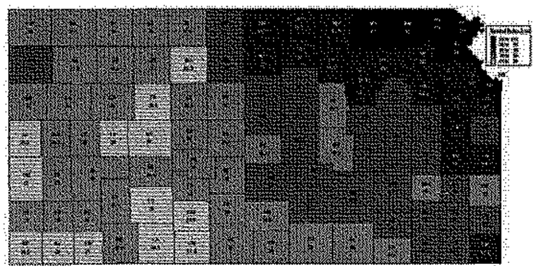
- Reasons to go to cash rent ...
  - Steady source of income for landowners
  - Increased planting flexibility
  - Increased simplicity
- Potential consequences
  - Land tends to change hands more often
  - Relative risks change

Methods of Establishing Cash Rent Values

- Market going rate (if available)

- Landowner's cost
- Crop share (adjusted for risk?)
- Amount tenant can afford to pay

Kansas Nonirrigated Cash Rents, 2011*



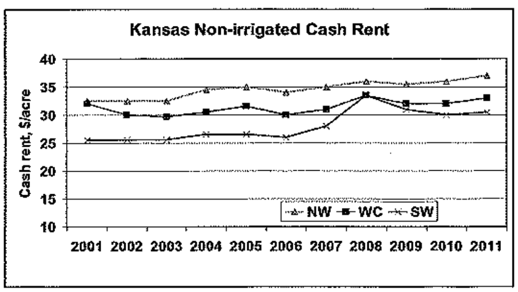
*Cash rent values as reported by USDA NASS and Kansas Agricultural Statistics (KAS).

Cropland Values and Rents

Year	Value Irrigated	Value Non-irrigated	Rent Irrigated	Rent Non-irrigated
2006	$1,200	$820	$74.00	$39.00
2007	$1,260	$880	$82.00	$41.00
2008	$1,450	$980	$92.00	$42.50
2009	$1,500	$1,000	$89.00	$43.50
2010	$1,600	$1,100	$95.00	$43.50
2011	$1,800	$1,250	$105.00	$44.00
% Change '10 to '11	12.5%	13.6%	10.5%	1.1%

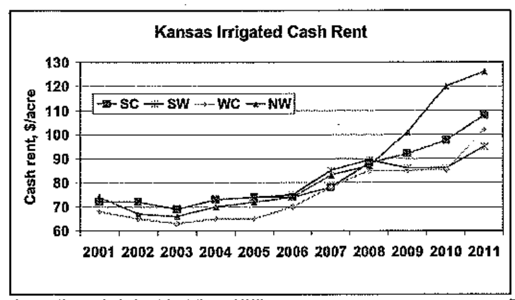
Source: Kansas Agricultural Statistics

Market going rate...



Source: Kansas Agricultural Statistics and KSU

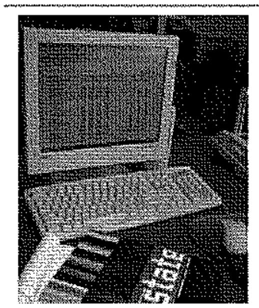
Market going rate...



Source: Kansas Agricultural Statistics and KSU

Impact of commodity prices and input costs on leases

Using "*KSU-Lease.xls*" to determine equitable crop share and cash leases ...



Information/data required:

1. Crop rotation/mix
2. Income information
3. Production inputs
4. Machinery costs
5. Land value
6. Irrigation equipment

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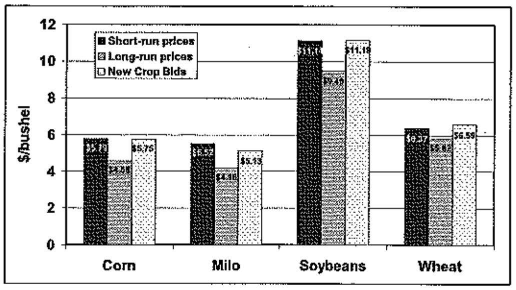
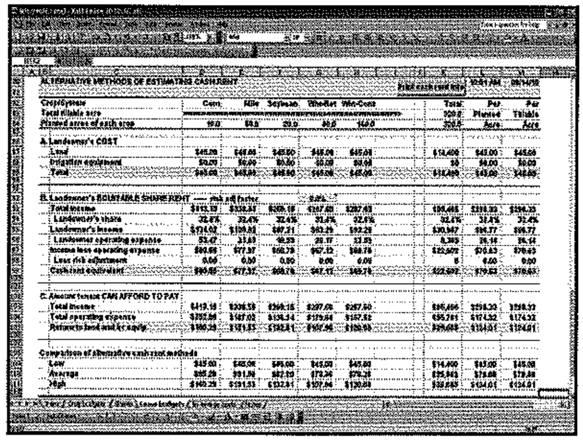
7. Contributor of input
8. Risk adjustment

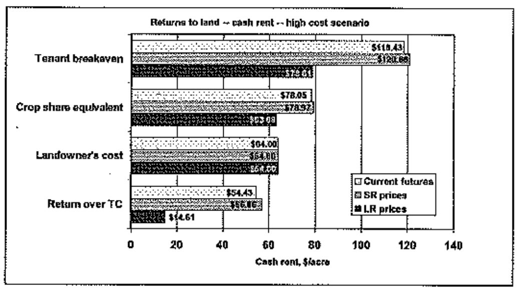
Alternative Prices to Consider



Long-run and short-run from KSU MF-1013, new crop bids for KS (1/3/12)



2011 Estimated cash rents for Western Kansas



Based on KSU Farm Management Guides (December 2011) and KSU-Lease.xls (available at www.agmanager.info)

Non-traditional Leases

Flexible Cash Rents – WHAT?

- Flexible cash rents simply refer to land rental arrangements where the amount of cash rent paid (received) can vary based upon some pre-determined formula (i.e., formalizes bonus rents)
- Methods of "flexing" rental rates, i.e., formulas are based on:
  - Yield (actual for producer, county average, etc.)
  - Price (harvest, season average, actual)
  - Revenue (yield x price, crop insurance, residue)
  - Costs
  - Other...

Flexible Cash Rents – WHY?

- Method of allowing rents to vary from year-to-year without having to renegotiate rents annually
- Trend in Kansas has been moving away from crop share leases to more cash leases
- Volatility of last few years has significantly increased the risk of *fixed* cash rents
- Way of sharing/managing risks associated with volatile markets (without hassles of crop share lease)

Flexible Cash Rents – Why Not?

- Complex!
- Theory and intuition guide conceptual design, but little help with specific details
- Not needed if cash rents are renegotiated frequently
- Hard to think of everything, which means we might need to be "tweaking" arrangement regularly
- If designed wrong, might increase risk

Flexible cash rents (method of formalizing bonuses)

1) Establish base cash rent

2) Flex/modify base rent based on...
- **price deviation from base (fixed bushel rent)**
- **yield deviation from base**
- **price and yield (revenue) deviation from base**
- **cost deviation from base**

- **Communication and documentation are important to ensure everybody understands what it is they are agreeing to.**

Bushel Rent

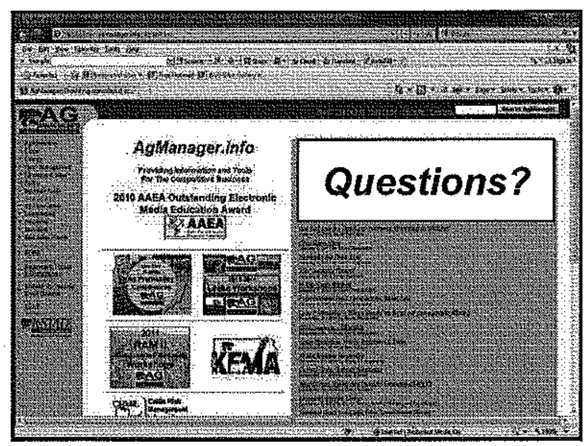
- Potential advantages versus fixed cash rent
  - Allows landowner to take advantage of high prices
  - Provides some protection for tenants when prices fall
- Must establish base yield and bushels landlord receives
- If landlord does not share production risk, they are ineligible for government subsidies

Net Share Rent

- Potential advantage
  - Allows landowner to take advantage of high prices
  - Provides some protection for tenants when prices fall
- Disadvantage
  - Violates 1st principle of good crop share leases (share yield increasing inputs)
  - Could result in more frequent negotiations if input costs are volatile

Other important considerations

- Written agreements are encouraged
- By law, oral leases are one-year leases that automatically renew unless notice of termination is given
- Termination requirements
  - Proper notice must given to tenant 30 days prior to March 1 for both crop and pasture land unless a written lease identifies another date for termination
- Kansas Agricultural Lease Law



Yield Monitoring – Concepts, Calibration, and Uses for Management

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In this session we examine three areas of common questions regarding yield monitoring, including the theory and operation of yield monitoring systems, data filtering, and potential uses of yield monitor data.

Why yield data?

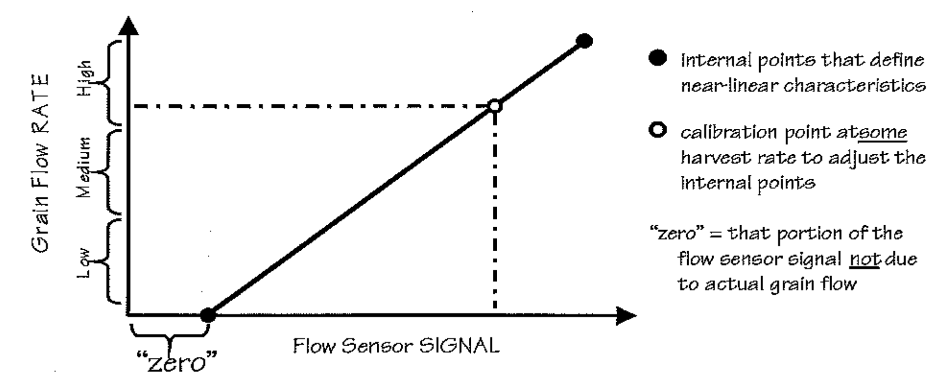
Crop yield, or yield potential is the basis of almost all agronomic decision making. Everything from nitrogen rates to seeding rates are tied to yield potential either explicitly or implicitly. Yield is the result of a combination of factors, some manageable, some not, but is the integration of everything that happens to a crop over the course of the growing season. Yield varies spatially within a field. This is recognized by all producers and yield monitor data is the only way to truly quantify spatial variability in crop yield within a field.

Yield Monitoring Systems:

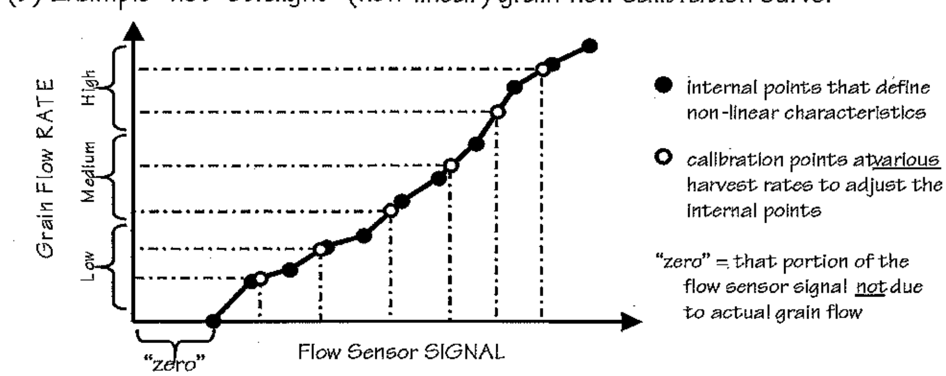
Yield monitoring systems work by measuring mass (weight) over a given area and assign that value to a geographic location via GPS. Grain mass is measured by a mass flow sensor located at the top of the clean grain elevator. Grain moisture is obtained by a capacitance type sensor that is placed in the flow of clean grain somewhere on the combine. It is important to keep the top of the clean grain elevator chain and paddles at the proper distance to the mass flow sensor. This affects the trajectory of grain into the sensor's strike plate. Any change in this distance must be accompanied by recalibration of the monitor; distances outside of tolerance will result in reduced accuracy. It is important that proper calibration procedures are implemented so that the system can correlate a measured force to a known mass. The type of calibration to be performed is dependent upon your yield monitoring system. A yield monitor can either be a single point or multi-point calibration. The differences between calibrations are shown in the figure.

It is important to remember that a yield monitor is only as good as the calibration performed on it. Distance should be calibrated first, followed by grain moisture, and lastly grain flow. A suggested procedure for a multipoint type monitor is demonstrated below. The full flow pass is done with full width and while "pushing" harvest speed. The resulting flows are then accomplished by traveling at a steady speed while using

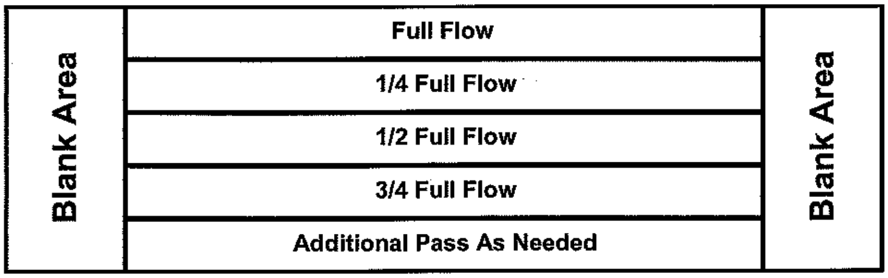
(a) Example "near-straight" (near-linear) grain flow calibration curve.



(b) Example "not-straight" (non-linear) grain flow calibration curve.



fractions of the available header width. After completing calibration errors should be in the range of 1.5 – 2.5% and must be less than 3% if the data is to be used for RMA yield reporting purposes.



Yield Monitor Data:

It is good practice to keep a raw copy (both binary direct from the data card and in some export format) before you perform any filtering or processing. Before filtering yield monitor data, it is important to understand the potential sources of errors. The most notable sources of error include unknown header width, grain flow delay, and rapid changes in combine speed. Unknown header width can be handled by newer yield monitors through autoswath technology if only one machine is running in the field. Advancements in software will be needed to fix swath errors in other scenarios. Most other yield data errors are caused by combine flow dynamics. The YieldEditor software offered by USDA-ARS (Google search: USDA-ARS Yield Editor Download) provides a simple way to help filter these errors from the data. The newest version 2.0 contains automated routines that greatly simplify the process and are described in more detail in the software documentation.

The processing of yield data is an important step that offers a variety of options. Regardless of the method used, yield monitor data is almost always processed into a grid of some form. In interpolation, a relatively small grid is used. Data are created from estimations to fill in grid cells that do not have actual combine data located within them. These procedures should be used with caution as they actually create data that did not previously exist and errors in the data can be amplified through the use of interpolation. Other appropriate options for yield data include point average and potential mapping. In these scenarios, a larger grid is used, perhaps 90 ft. In potential mapping, the mass flow values for points within the cell are summed and divided by the area. This procedure can provide a better representation of yield in fields where header width varies. The point yield procedure simply averages the point yield data within a cell and assigns it to the grid. When generating yield maps for visual interpretation, it's important to make sure the ranges and color schemes are selected to appropriately represent yield variability.

Data to Decisions:

The largest challenge in the adoption of yield monitors has been the lack of clear uses for yield monitor data. However, opportunities exist to make better agronomic, economic, and machinery management decisions. Yield monitor data can be used to analyze combine performance in the field, compare harvesting methods, or the value of unloading on the go. In agronomics, yield monitor data can be utilized in a variable rate phosphorus program whereby prescriptions are based on crop removal as indicated by the previous crop yield data. Several reference points are established within the field for annual sampling. With multiple years of yield data, it is possible through analysis to determine areas of a field that are stable high or stable low yielding, and then manage these field areas differently.

Some Opportunities to Utilize Yield Monitor Data

RMA Crop Insurance Documentation

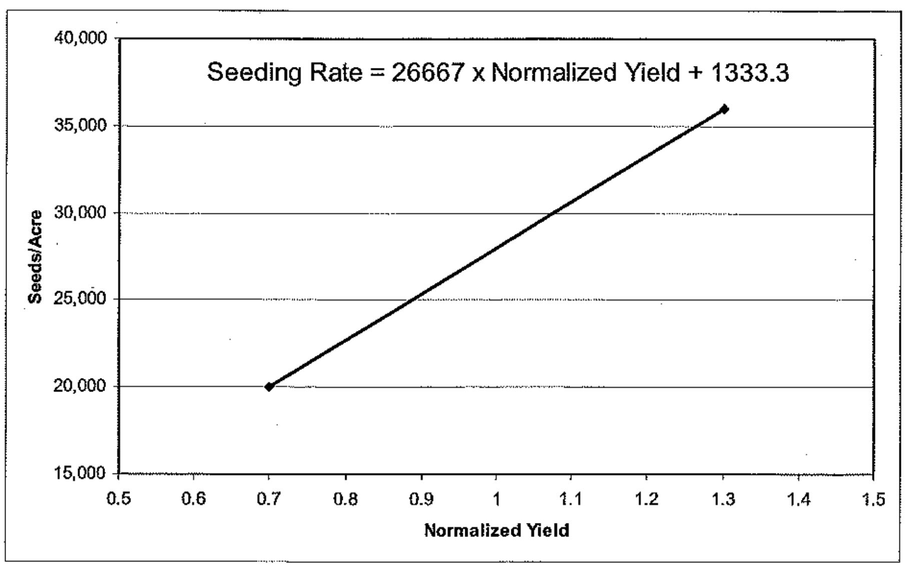
Recent changes in RMA (Risk Management Agency) procedures regarding the use of precision ag technology have opened up many opportunities. Yield monitor data can be used to document production for APH reporting. Yield monitors data can be used to report production separately for different practices even when they are planted and harvested together (e.g. pivot corners and irrigated). It is important to note than in order to meet RMA requirements, the producer must have GPS technology integrated into the planter monitor, combine yield monitor, and yield mapping software. All three are required if precision ag technology is to be used to provide information for RMA. Yield monitors used for RMA reporting must be calibrated to less than 3% error and the calibration procedure be documented.

Multiple years of yield data – determining yield stability

A key component of determining spatial yield goals for a field, which could be used to drive variable rate nitrogen or seeding recommendations, involves determining areas of yield stability. By analyzing multiple years of yield data together, areas of the field can be classified into stable high yielding, stable low yielding, and unstable or average areas. These areas can be used to further guide management strategies. Multiple years of yield data can also be normalized. This process sets each year of yield data on a relative scale by using the field average. For example, if a spot in a field yielded 112 bu/ac and the field average was 100, then its normalized yield is 1.12. This process makes it easier to combine yield maps from across years and even different crops. Multiple normalized yield maps can then be averaged to generate spatial yield goals that could drive a variable rate seeding or nitrogen prescription.

A variable-rate seeding example

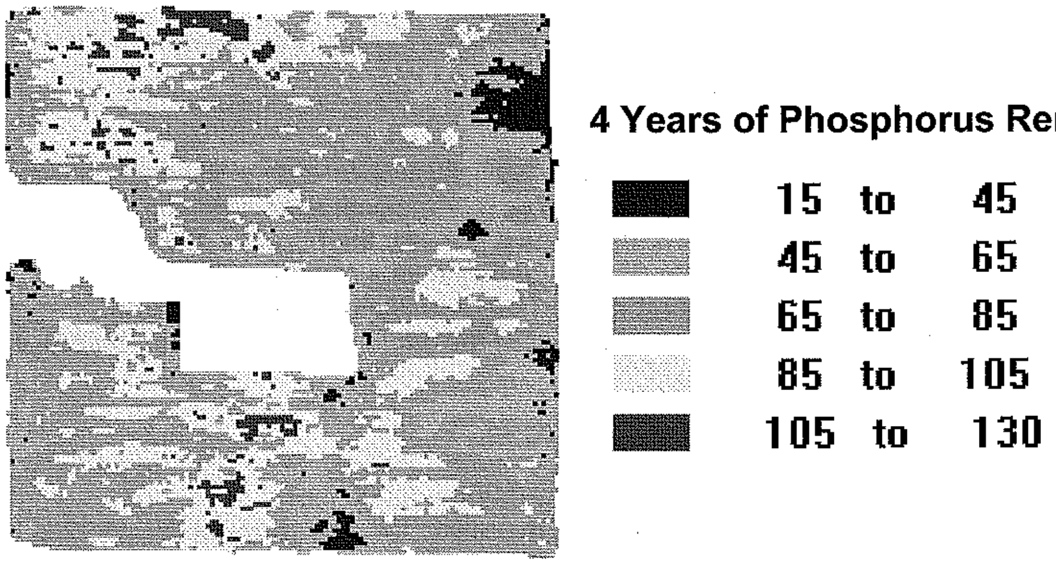
In this example, consider a field with a long term average of 190 bu/ac, the field has areas that are 30% above and 30% below average (would show up as 1.3 and 0.7 on a normalized yield map). The producer determines that at the high end to hit 247 bu/ac (a normalized yield of 1.3) a seeding rate of 36,000 is necessary, meanwhile, to hit a yield of 133 bu/ac (a normalized yield of 0.7) a seeding rate 20,000 would be appropriate. This would result in a population of 28,000 for the average yield of 190 bu/ac. So after the bounds have been set, a relationship can be easily be determined and put into an equation using a spreadsheet.



The normalized yield layer and this equation could be used to generate a variable rate planting prescription for the example field. The average normalized yield map could also be used in a similar way to the VRT seeding example to create a variable rate nitrogen prescription.

VRT of Phosphorus based on crop removal

Crop removal rates of phosphorus are fairly well established; ex. 0.50 lb P_2O_5/bu wheat, 0.33 lb P_2O_5/bu corn, and 0.40 lb P_2O_5/bu sorghum. We know that yields vary across a field, but yet we typically blanket apply phosphorus based on average yields.. Over time, this results in areas of the field that are consistently low yielding to build soil test P levels as we are applying more than we typically remove. Additionally, areas of the field that are consistently high yielding have low soil test P levels as we are applying less than removal. Multiple years of yield maps can be used to identify areas of the field for targeted sampling that may be high or low in soil test P. Once a baseline has been determined for a field, each years yield map could be used to generate a P removal map simply by multiplying yield by the P removal rates for various grains. This P removal map, or a series of removal maps, could be used to develop a VRT P application map.



Who is going to take your data to the next level?

The process of utilizing yield data may seem daunting, but the good news is that precision ag software has evolved a great deal of the past few years in terms of user friendliness. You as a producer, however, have a range of options depending on your own comfort level and computer abilities. You may decide to use your own on-farm research trials to develop your own recommendations and do all your own data analysis, or you may decide to use a completely outsourced solution from a provider. Regardless of which path you choose you must always ask yourself:

1. Does it make sense *technically*? - Is what I'm asking to be done physically possible by the equipment I'm using? Can I expect my yield monitor to detect a treatment strip of less than 300' in size? Can my VRT applicator really apply that rate, or change rates that quickly? We are capable of developing many scenarios on the computer that we cannot actually accomplish in real life due to equipment constraints.

2. Does it make sense *agronomically*? - What is the maximum or minimum seeding or fertility rate that is acceptable or reasonable under any circumstance? Is what the map or recommendation telling me relativistic in what I know about crop production?

3. Does it make sense *economically*? - What is the maximum economic rate of phosphorus I can apply to short-term rented ground? Should I adjust my variable rate recommendations based on changes in crop prices or inputs? Does the time and cost involved in my precision ag program generate a positive return? How to I quantify that what I'm doing is correct and profitable?

It's always appropriate to question, "Does this look right, do I believe that, can I test that this is the right thing to do?".

Using Yield Monitors for Demonstration or On-Farm Research Plots

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Yield monitors provide producers an excellent tool for conducting demonstration or research plots on their farm. Using a properly calibrated yield monitor allows for faster harvesting of plots and through GPS mapping provides a long-term method of storing results. However, like any tool, yield monitors must be used properly in order to provide beneficial data. Users must understand that yields differing by only several bushels, are likely not truly different as some error is inherent in data obtained from yield monitors or weigh wagons, especially in un-replicated trials. Some tips for plot preparation and harvest are outlined below.

Using Yield Monitors For Plot Harvesting - Checklist

Setting up a demonstration or on-farm research plot

- Demonstration plots are non-replicated, typically side-by-side plots, generally conducted more for observational purposes than data (a traditional seed corn strip trial)
- On-Farm Research Plots are a replicated design for the purpose of testing some factor (hybrid or variety, seeding rate, N rate, fungicide vs. untreated, etc.)
- **Regardless of plot type, a plot should be of sufficient length (>300 ft., longer lengths are preferred) for harvesting with a yield monitor. Lengths should be equal for all treatments.**

Make sure your yield monitor is calibrated

- **With the proper size of loads** (typically 3,000 – 6,000 lbs)
  Calibrations using semi-loads will seldom provide the accuracy needed for strip trials or on-farm research plots.

- **At a typical flow rate** for single point calibration monitors
  (Deere GreenStar and GreenStar2)

- **Across several flow rates** for multi-point calibration monitors
  (all AgLeader and Case-IH systems)

- **Moisture calibration** – follow manufacturer guidelines. If confident in calibration, then use dry weights as described below. If not confident, then use wet weights and your own moisture tester.

If harvesting strips plots only use total dry weight data from the yield monitor

- **DO operate the combine the same for each harvest strip, i.e. consistent ground speed, do no unload on the go**
- **DO separate plots or strips by using different yield monitor "loads" or "tanks"**
- **DO NOT** use bu./acre as calculated by the yield monitor
- **DO calculate your own area**
  Calculate your own area using traditional methods (e.g. measuring wheel or handheld GPS). Differences in timing when raising or lowering header, errors in speed sensors, or GPS errors can affect the yield calculated by your monitor over short distances. Using total dry or wet weight with measured areas will provide better data.

Remember… Bad data is WORSE than NO DATA !

Fallow Replacement in Western Kansas

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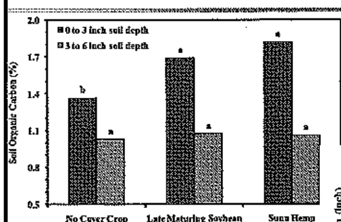
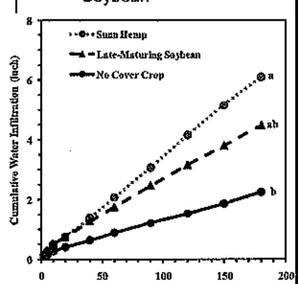
Cover Crop Benefits

- Improve soil quality
  - Increase soil organic matte
  - Reduce soil erosion
  - Reduce soil compaction
  - Increase water infiltration
    - Decrease runoff
  - Supply nitrogen
- Suppress weeds
- Government programs (EQUIP & CREP)
- Conserve soil moisture?
- Reduce nitrate leaching?
- Impact yield of following crop?

Increase in Soil C



- Claassen- Hesston, KS
  - Wheat/Cover-Sorghum, 2002-2010
  - Residue: Sun hemp > Soybean



- ↑ Soil C (0-3 in)
- ↑ Water infiltration
- = Soil aggregate stability w/N
- = Soil compaction (0-3 in) w/N
- ↑ Soil ag. and comp. wo/N
- ↑ crop yield @ low N rate only

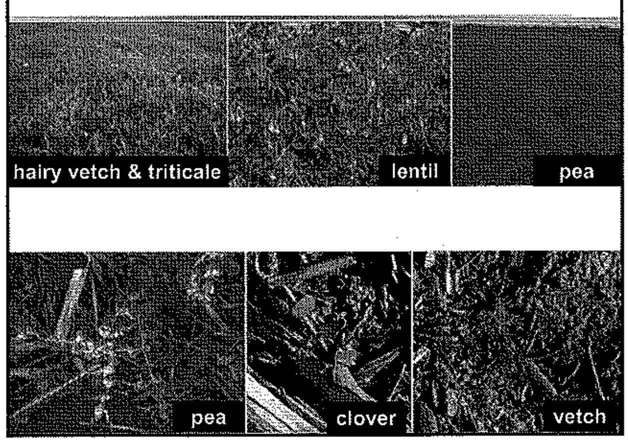
Fallow Replacement Study

- Initiated in 2006 at KSU-Garden City
- Crop rotations:
  - Wheat-Fallow, Wheat-Wheat, & Wheat-Cover Crop/Forage/Grain,
- RCB design, 4 replications, each phase of the rotation present each year
- Plots are 30' x 135', 224 plots total, 11 A study
- Measuring:
  - Cover crop water use
  - Forage yield and nutritive value
  - Water storage in seed zone and profile
  - Wheat yield, test weight, and protein
  - Profitability/loss of including cover crops in rotation

Fallow Treatments (Cover, Forage, Grain)

Season	Cover Crop	Year Produced 2007	2008	2009	2010	2011
Winter	Yellow sweet clover	x	x			
""	Yellow sweet clover/Winter triticale		x			
""	Hairy vetch	x	x	x	x	x
""	Hairy vetch/Winter triticale		x	x	x	x
""	Winter lentil			x	x	x
""	Winter lentil/Winter triticale			x	x	x
""	Winter pea (grain)		x	x		x
""	Winter pea	x	x	x	x	x
""	Winter pea/Winter triticale		x	x	x	x
""	Winter triticale	x	x	x	x	x
Spring	Spring lentil	x	x	x	x	x
""	Spring lentil/Spring triticale		x	x	x	x
""	Spring pea	x	x	x	x	x
""	Spring pea (grain)				x	x
""	Spring pea/Spring triticale		x	x	x	x
""	Spring triticale		x	x	x	x

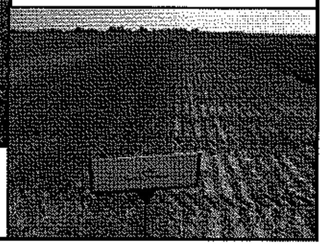
- Fallow and cont. wheat, 16 treatments total



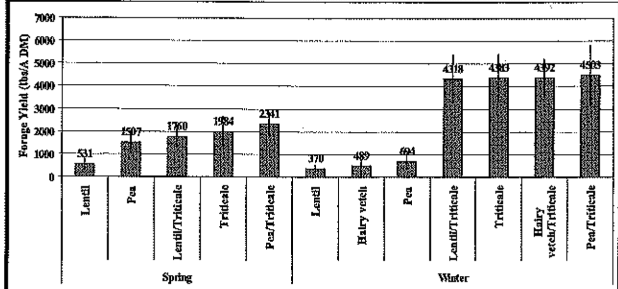
Cover and Forage Crop Termination

- Winter terminated ~May 15 (winter triticale heads)
- Spring terminated ~June 1 (spring triticale heads)
- Plots split: ½ hayed & ½ sprayed out and left standing

Winter Peas

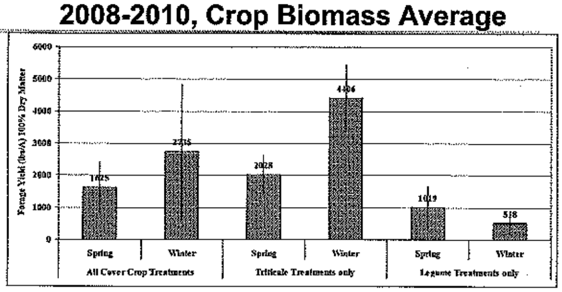


2008-2010, Crop Biomass



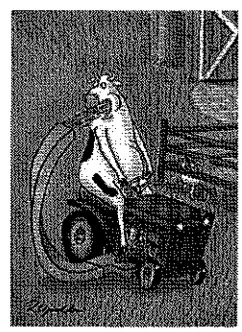
- Winter lentil: 2009-2010

2008-2010, Crop Biomass Average

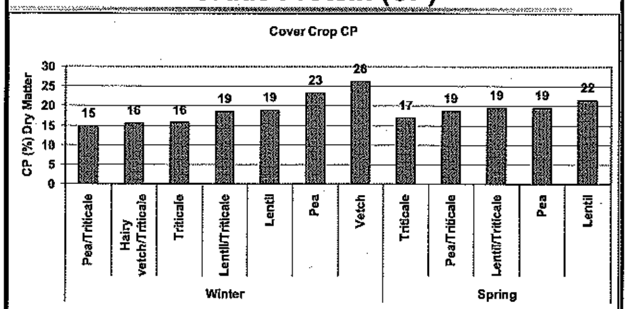


- Winter triticale yield > spring triticale
- Legumes: spring yield > winter: winter injury
  - Spring pea > winter pea
  - Winter lentil = spring lentil
  - Hairy vetch 1 year winter kill

Residue or Forage Value?

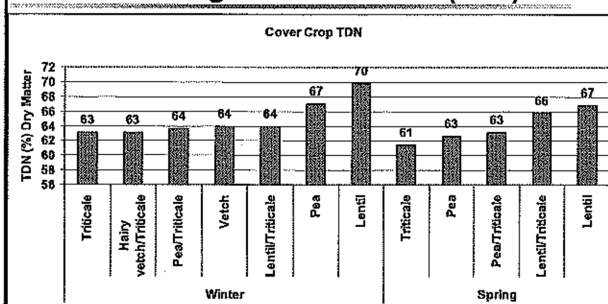


Crude Protein (CP)



- Microbial protein and amino acid production
- > 13% "premium" nutritive value
- Alfalfa 18-24% CP

Total Digestible Nutrients (TDN)

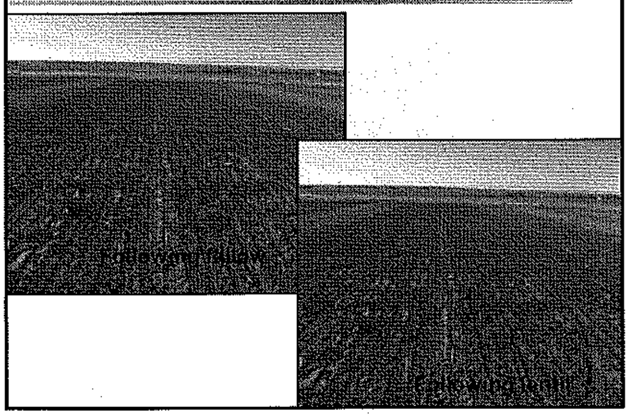


- Energy available
- Alfalfa 61-67% TDN

Cover and Forage Crop Impact on Winter Wheat

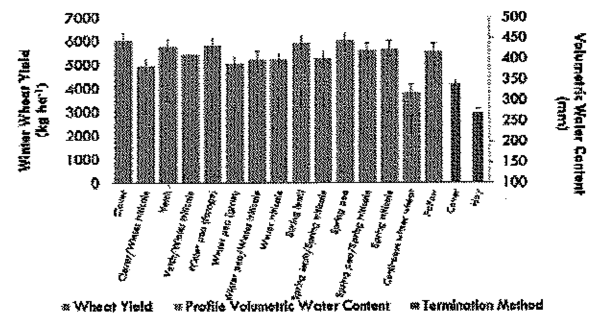
Wheat Following High Residue, 2007

Wheat Following Low Residue, 2007

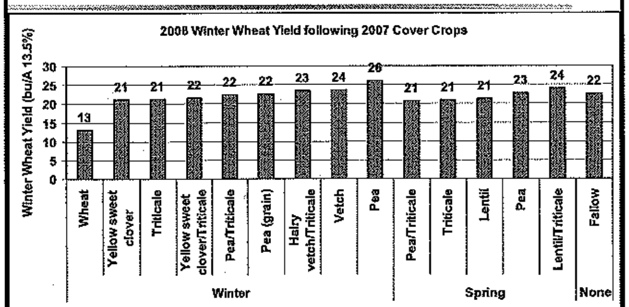


Western KS Moisture Results

- Fallow storage, 20-30% effective
- Growing cover crop used moisture
  - Improves storage and may improve stand establishment

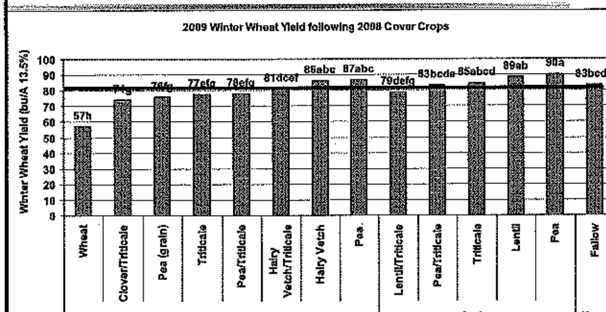


2008 Yield Results



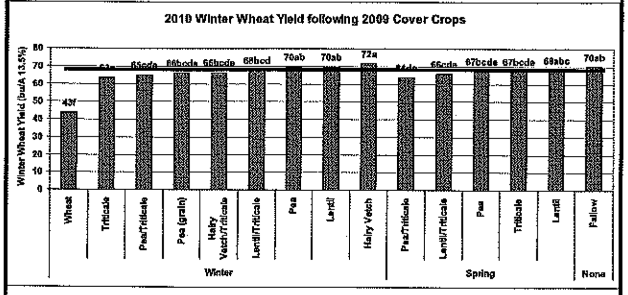
- Hail week prior to harvest
- Only visual difference was cont. wheat

2009 Yield Results



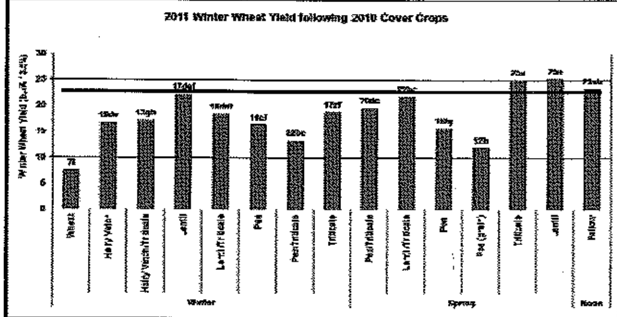
- Only visual difference was cont. wheat
- No effect of residue management treatment

2010 Yield Results



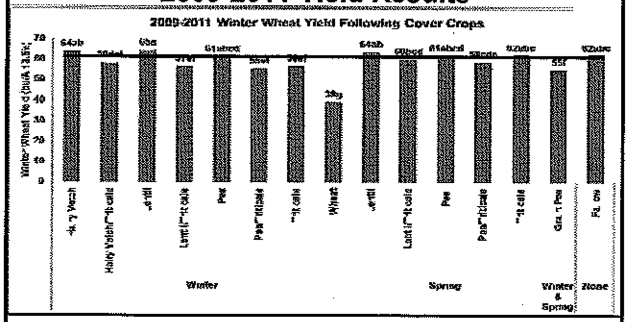
- Only visual difference was cont. wheat
- Cover yielded 2.9 bu/A more than hay

2011 Yield Results



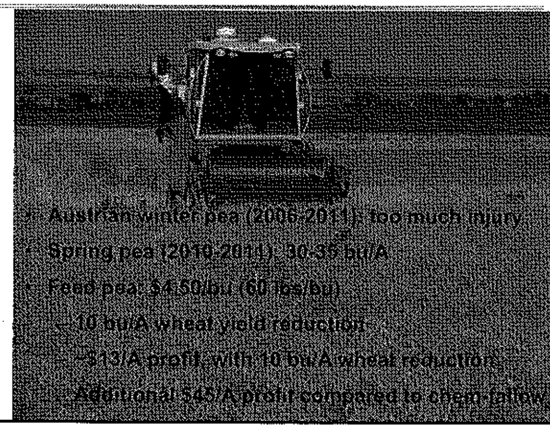
- Very dry year, marginal wheat stands
- No effect of residue management treatment
- On average spring forage reduced yield 1.4 bu/A

2009-2011 Yield Results



- 2 good years, 1 very poor year
- No effect of residue management treatment
- Winter triticale, grain pea, and cont. ww yields less

Field Pea Yields



Western KS Preliminary Results

	Winter							Spring					None
	Vetch	Vetch/Trit	Lentil	Lentil/Trit	Pea	Pea/Trit	Trit	Lentil	Lentil/Trit	Pea	Pea/Trit	Trit	Fallow
Expenses													
Drill $/A	11	11	11	11	11	11	11	11	11	11	11	11	0
Seed lb/A	25		30		100		63	30		120		76	0
Seed $/lb	2.3		0.4		0.3		0.2	0.4		0.2		0.2	0
Total seed cost $/A	56	35	12	13	25	20	14	11	14	28	23	17	0
Total drilling cost $/A	67	46	23	24	36	30	25	21	25	38	33	28	0
Swath $/A	10	10	10	10	10	10	10	10	10	10	10	10	0
Bale & Stack $/ton	16	16	16	16	16	16	16	16	16	16	16	16	0
Total hay cost $/A	15	49	14	49	17	50	49	15	26	24	31	28	0
Spray application $/A	5	5	5	5	5	5	5	5	5	5	5	5	5
RT3, $/A	3	3	3	3	3	3	3	3	3	3	3	3	3
2,4-D, $/A	3	3	3	3	3	3	3	3	3	3	3	3	3
Applications/A	3	3	3	3	3	3	3	3	3	3	3	3	4
Total spray cost $/A	34	34	34	34	34	34	34	34	34	34	34	34	46
Total Expense (cover)	101	80	57	58	70	65	69	55	59	73	67	62	46
Total Expense (hay)	116	130	71	107	86	115	109	71	85	96	99	90	46
Returns													
Yield ton/A	0.3	2.4	0.2	2.4	0.4	2.5	2.4	0.3	1.0	0.8	1.3	1.1	0.0
Price $/ton	91	91	91	91	91	91	91	91	91	91	91	91	0
Yield Return $/A	25	221	19	217	35	226	220	27	88	76	118	100	0
N Return lb/A	40	40	40	40	40	40	0	40	40	40	40	0	0
N value $/lb N	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
N Return $/A	20	20	20	20	20	20	0	20	20	20	20	0	0
Soil benefits $/A													
Net Return (cover)	-81	-60	-37	-38	-50	-45	-59	-35	-39	-53	-47	-62	-46
Net Return (hay)	-91	66	-52	85	-52	86	87	-44	-9	-21	7	-3	-46

*Assumption: N contribution from legume 0 when hayed, 50 lbs of N add for winter triticale, and 25 lbs of N add for spring triticale.

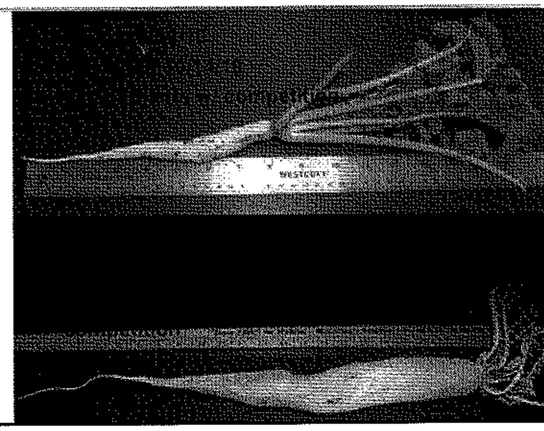
Western KS Cool-Season Crops

- **Legume**
  - **Clover: biennial-slow growth, seed cost ($25/A)**
  - **Vetch: hard seed, cattle-photosensitization and muscle problems, winter injury, seed cost ($50/A)**
  - **Peas (W & S): winter injury, fair yield, seed cost ($25/A)**
  - **Lentils (W & S): hardy, low yield, seed cost ($11/A)**
- **Non-legume**
  - **Triticale (W & S): hardy, high yield, seed cost ($15/A)**
- **Mixtures**
  - **Legumes survive better, high yield, some N fixing, reduce seed cost**

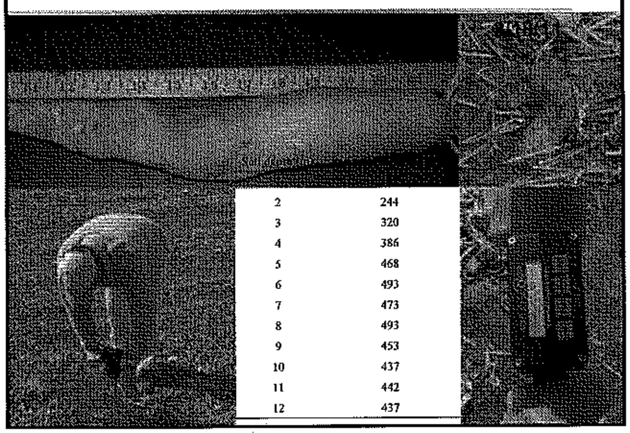
Future Direction

- Wheat-grain sorghum-(fallow/fallow replacement)
- Spring oats compared to triticale
- Radishes and turnips: large taproot-reduce soil compaction?
- Cocktail mixes?

Crop	Hay	Cover	Grain
Spring pea	x	x	x
Spring pea/Spring Oat	x	x	
Spring pea/Spring Triticale	x	x	
Spring Oat	x	x	
Spring Triticale	x	x	
Daikon radish & Shogoin turnip		x	
Cocktail mix (oat, triticale, pea, buckwheat, radish and turnip)		x	
Fallow			



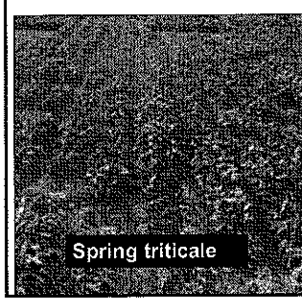
Daikon Radish

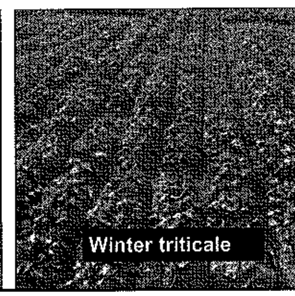


2	244
3	320
4	386
5	468
6	493
7	473
8	493
9	453
10	437
11	442
12	437

Planting Spring Crops in the Fall

- Plant a mixture of spring and winter crops for more fall grazing
- Plant a spring crop in the fall for feed in a drought





Western KS Warm-Season Crops

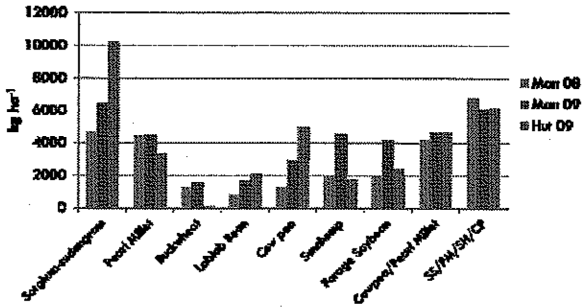
- **Legume**
  - **Oilseed: guar and soybean**
  - **Forage: cowpea, lablab, mungbean, pigeon pea, soybean**
  - **Cover: sunhemp (toxic to cattle)**
- **Brassicas**
  - **Soil & Cover: turnip, radish, and Ethiopian cabbage**
- **Grasses**
  - **Forage: forage sorghum, sorghum sudangrass, millet**
- **Drought, Weeds & Rabbits (2011)**
  - **Best: turnip, radish, guar, cowpea, lablab, Ethiopian cabbage, and grasses**

Mixtures?

- A lot of interest in mixtures
- Some species more competitive
- Select a mixture based on need, more is not necessarily better
  - Spring forage: legume improving N content of forage and N fixation, and grass for high biomass (ex: spring pea and oat)
  - Spring cover crop: large taproot may help soil quality, legume for N fixation, and large biomass crop (ex: daikon radish, spring pea, and triticale)
  - Summer grazing: large taproot for soil quality and grazing, legume, and high biomass (ex: daikon radish & turnip, cowpea, sorghum sudangrass)

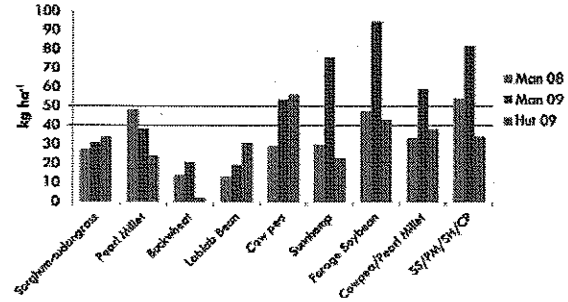
Eastern KS: Cover Crop Study

- Cover crop-grain sorghum rotation 3 site yrs (Manhattan & Hutchinson)
- Cover crop biomass



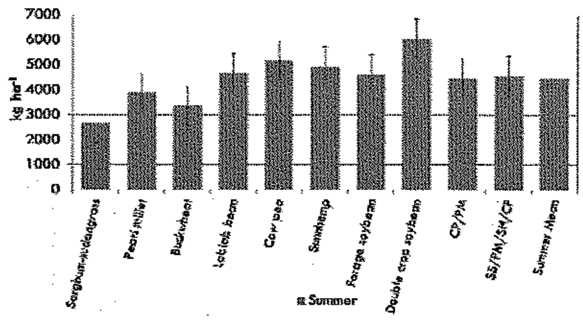
Eastern KS: Cover Crop Study

- **Cover crop N accumulation**



Eastern KS: Cover Crop Study

- **Grain sorghum yield correlated to N in cover crop**
- **Correlation to flag leaf N, $R^2 = 0.79$**



Western KS Results

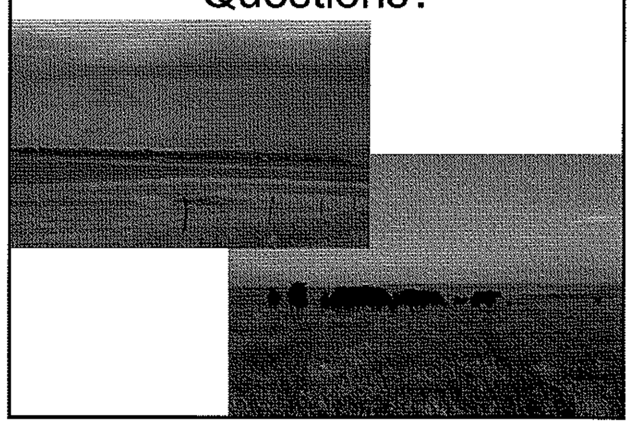
- Impact on wheat yield and profitability?
  - In wet years, little to no impact on yield
  - In drought years, all treatments reduced yield except some of the spring crops
    - On average spring crops reduced yield (1.5 bu/A)
      - 1 ton forage @ $100/ton: net $40/A more than chem-fallow

        vs.
      - 1.5 bu/A @ $8.00/bu: $12.00/A ($28 less than spring forage)
  - Averaged across years:
    - Cont. WW reduced yield 37% (25% more total than W-F)
    - Winter triticale reduced yield 9% or 5.5 bu/A
    - Grain pea reduce yield 11% or 7 bu/A (11 bu/A less in drought)
    - No difference between cover or hay

Western KS Results

- Bale it, Graze it, or Combine it!
- High seed cost, offsets N contribution- grow own seed
  - More economical to apply N
- Select fallow replacement crop adapted to region
  - Winter hardiness
  - Many proposed cover crops will not perform
- Terminate cover crop prior to June 1 for wheat
- If moisture is available consider double-crop after wheat
- Harvesting crop as forage or grain increased profitability

Questions?



Vertical tillage and Corn Production

DeAnn Presley, Soil Management Specialist
Kansas State University Agronomy
deann@ksu.edu

Residue Issues

- Bt corn residue persisting in the environment longer than non-Bt
- High quantities of crop residue, especially in irrigated, continuous corn (continuous wheat too)
- What are your options?

Options for managing heavy residue

- No-till anyway, improve planter?
- Strip-till
- Different rotation?
- Tillage
- Removal for other uses (livestock, fuel?)
- Burn

Estimating residue

- Harvest index: For every 1 pound of grain, 1 pound of residue for corn and sorghum
  - Grain/(Grain + Stover) = 0.5 (corn and sorghum)
- 200 bushel corn crop

200 bu grain/acre * 56 lbs grain/bu grain * 1 lb residue/1 lb grain

- Equals: 11,200 lbs of residue per acre (5.6 t)
  - Rough estimate, because when yields are high, the HI is usually a little lower
- Knowing what you have is important.
- Now, how much is removed with current equipment?

What is vertical tillage?

- High speed tillage: 8-10 mph
- Disks a.k.a. coulters that cut residue
- If concave: Throw some soil laterally
  - Which causes some smoothing
- Rolling or tine harrow: Anchors residue
- Gang angle varies between mfrs
  - More angle = more aggressive
  - Salford: Disks on springs, not gangs
- Disk properties vary: Concavity vs. straight, smooth vs. rippled

Vertical Tillage Research

- YouTube video: www.youtube.com/ksrevideos
- Parts:
  - Coulters cut the residue and
  - Flutes lift some soil so the leveling tines can work.
  - The rolling basket behind that does some minimal leveling as well and breaks up any clods that might have made their way through.
- $2000+ per foot
- Require 5-10 pto hp per foot
- Producers want (even some no-tillers)
  - Residue to break down faster (Bt corn)
  - Anchor so it doesn't wash or blow
  - Some levelling capability—improves "plantability"
  - Seedbed preparation
- Lively debate on agtalk: http://talk.newagtalk.com/forums/thread-view.asp?tid=197561&mid=1452050

Objectives of study:

- Evaluate effects of vertical tillage versus farmer practices at multiple times during growing season on:
  1. Residue % coverage and mass
  2. Disease incidence and severity
  3. Crop vegetative properties
  4. Soil properties
  5. Soil- and residue-born pathogens

Results: Vegetative and Disease

2010 Results: Meade Co. Continuous, Irrigated Corn

	Stand *1000/ac	Disease % pop	Severity lesions/plt	Yield bu/ac
No-till	29.9	90.0	78.5	195
Case	30.3	89.5	83.8	204
Landoll	29.7	91.8	96.0	190
Great Plains	29.8	89.3	89.8	204
LSD*	--	--	--	--

High levels of disease on all treatments *0.05 level, all sites

2010 Results: Jefferson Co. Continuous Corn

	Stand *1000/ac	Disease % pop	Severity lesions/plt	Yield bu/ac
No-till	35.7	26.0 a	71.8 a	154
Case	37.6	17.0 b	46.3 b	176
Disk	38.2	16.0 b	42.8 b	154
LSD	--	1.9	6.4	--

Difference in disease didn't translate into significant difference in yield

2010 Results: Wilson Co. Corn after soybeans

	Stand *1000/ac	Disease % pop	Severity lesions/plt	Yield bu/ac
Great Plains	25.1	24.8 a	45.8	110
Strip-till	25.0	22.3 b	43.0	112
LSD	--	1.6	--	--

2010 Results: Marion Co. Corn after soybeans

	Stand *1000/ac	Disease % pop	Severity lesions/plt	Yield bu/ac
No-till	16.1	33.0	32.0	79.5
Great Plains	22.2	33.0	37.8	86.6
LSD	--	--	--	--

No differences despite large difference in % residue coverage
73% no-till, 33% vertical tillage after planting

Results: Soil and Residue Properties

2010 Results: Meade Co. Continuous, Irrigated Corn

May 27th 26 DAP	% Residue	0-2" BD g/cm³	Infiltration mm/hr	Moisture cm³/cm³
No-till	94.8 a	1.21	0.49	40.53 a
Case	90.5 ab	1.16	0.36	37.01 ab
Landoll	91.4 ab	1.16	0.18	36.40 ab
Great Plains	89.3 b	1.13	0.54	33.17 b
LSD	3.7	--	--	4.34

Great Plains: Lower residue because was less anchored and more blew away, which caused lower soil moisture, trend lasted through season (not shown)

2010 Results: Jefferson Co. Continuous Corn

July 19th	% Residue	0-2" BD g/cm³	Infiltration mm/hr	6-2 Moisture cm³/cm³
No-till	60.2 a	0.96 a	0.84 b	33.99
Case	40.8 b	0.78 b	2.12 a	29.75
Disk	35.6 b	0.80 b	1.30 ab	30.10
LSD	7.7	0.12	0.95	--

At this site, tillage was done in fall, resulted in more treatment differences

2010 Results: Wilson Co. Corn after soybeans

June 3rd	% Residue	0-2" BD g/cm³	Infiltration mm/hr	Moisture cm³/cm³
Great Plains	10.2	1.33	0.32	23.95 a
Strip-till	10.7	1.25	0.44	21.79 b
LSD	--	--	--	1.64

Low residue for both treatments, and spring tillage, caused few treatment differences

2010 Results: Marion Co. Corn after soybeans

June 24	% Residue	0-2" BD g/cm^3	Infiltration mm/hr	5-28 Moisture cm^3/cm^3
No-till	72.8 a	1.23	2.29	37.70
Great Plains	32.8 b	1.03	2.24	35.94
LSD	10.8	--	--	--

Large difference in % residue cover, did not affect soil properties

Summary

- Fall tillage causes more treatment differences than spring tillage
  - 4 out of 5 sites tilled in fall for 2011 corn
- More treatment differences in continuous corn and in heavier residue
- 2011 data will presented during my talk

Here are a few agronomy-related websites that you may find useful:

Weather:	
National Weather Service	www.weather.gov
The Weather Channel	www.weather.com
Weather Underground	www.wunderground.com
Drought Monitor	www.droughtmonitor.unl.edu
Markets:	
Chicago Board of Trade	www.cbot.com
Kansas City Board of Trade	www.kcbt.com
DTN	www.dtnprogressivefarmer.com
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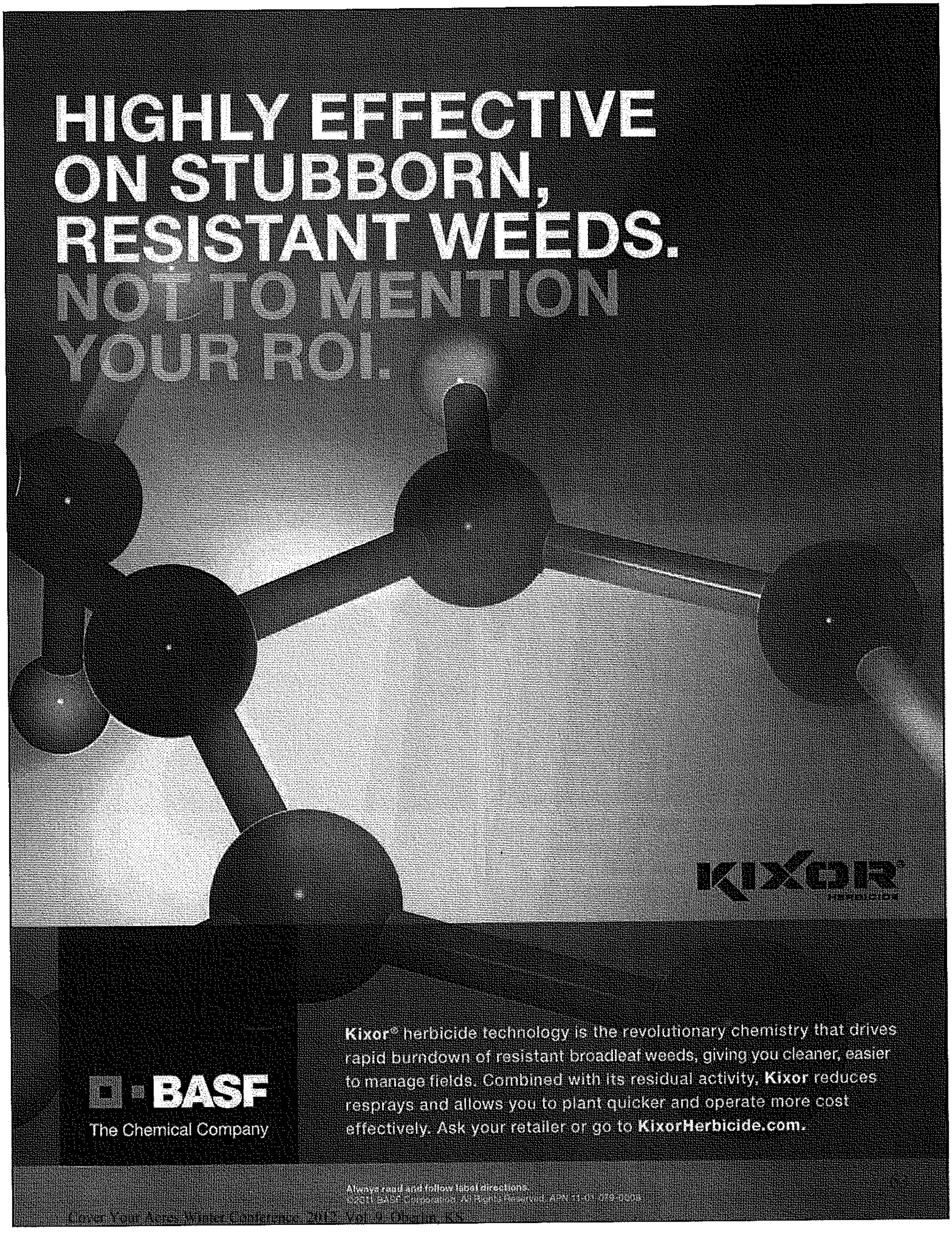
News:	
Ag Web (Farm Journal)	www.agweb.com
Agriculture.com (Successful Farming)	www.agriculture.com
Farm Progress (Kansas Farmer)	www.farmprogress.com
Grass and Grain	www.grassandgrain.com
High Plains Journal	www.hpj.com
University:	
K-State Research and Extension	www.ksre.ksu.edu
K-State Department of Agronomy	www.agronomy.ksu.edu
K-State Ag Economics Extension	www.agmanager.info
K-State Department of Entomology	www.entomology.ksu.edu
K-State Department of Plant Pathology	www.plantpath.ksu.edu
K-State Department of Bio and Ag Engineering	www.bae.ksu.edu
Commodity Groups:	
Kansas Corn Commission	www.ksgrains.com/kcc
Kansas Grain Sorghum Producers Association	www.ksgrains.com/sorghum
Kansas Soybean Commission & Kansas Soybean Assoc	www.kansassoybeans.com
Kansas Sunflower Commission	www.kssunflower.com
Kansas Wheat (Kansas Wheat Commission & Kansas Assoc of Wheat Growers)	www.kswheat.com
Herbicide Labels:	
Greenbook	www.greenbook.net
CDMS	www.cdms.net
Discussion Boards:	
Ag Talk	www.newagtalk.com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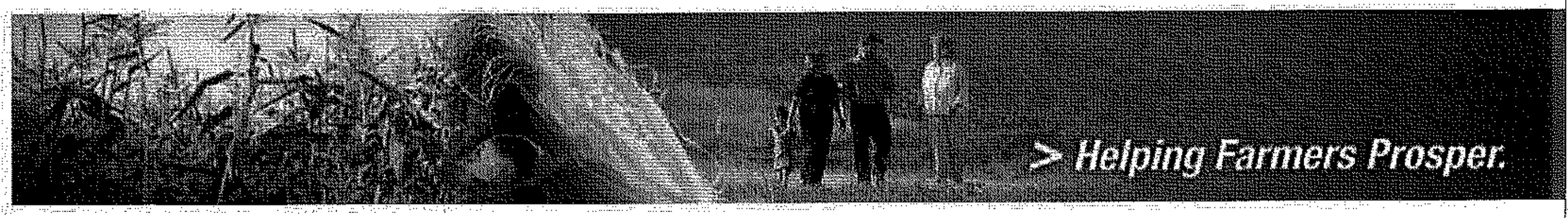

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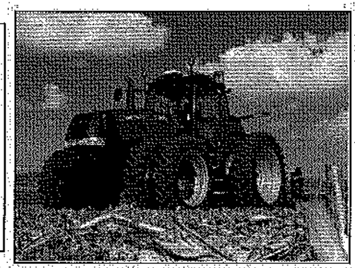

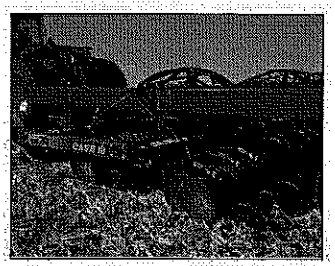

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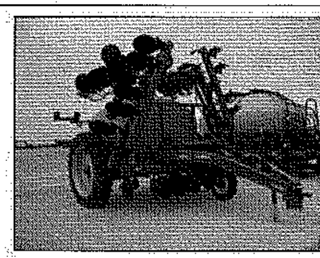

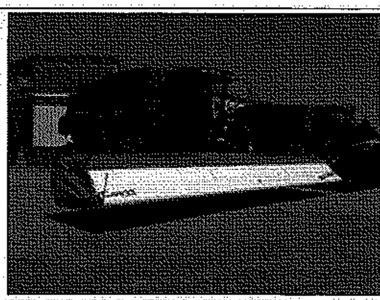

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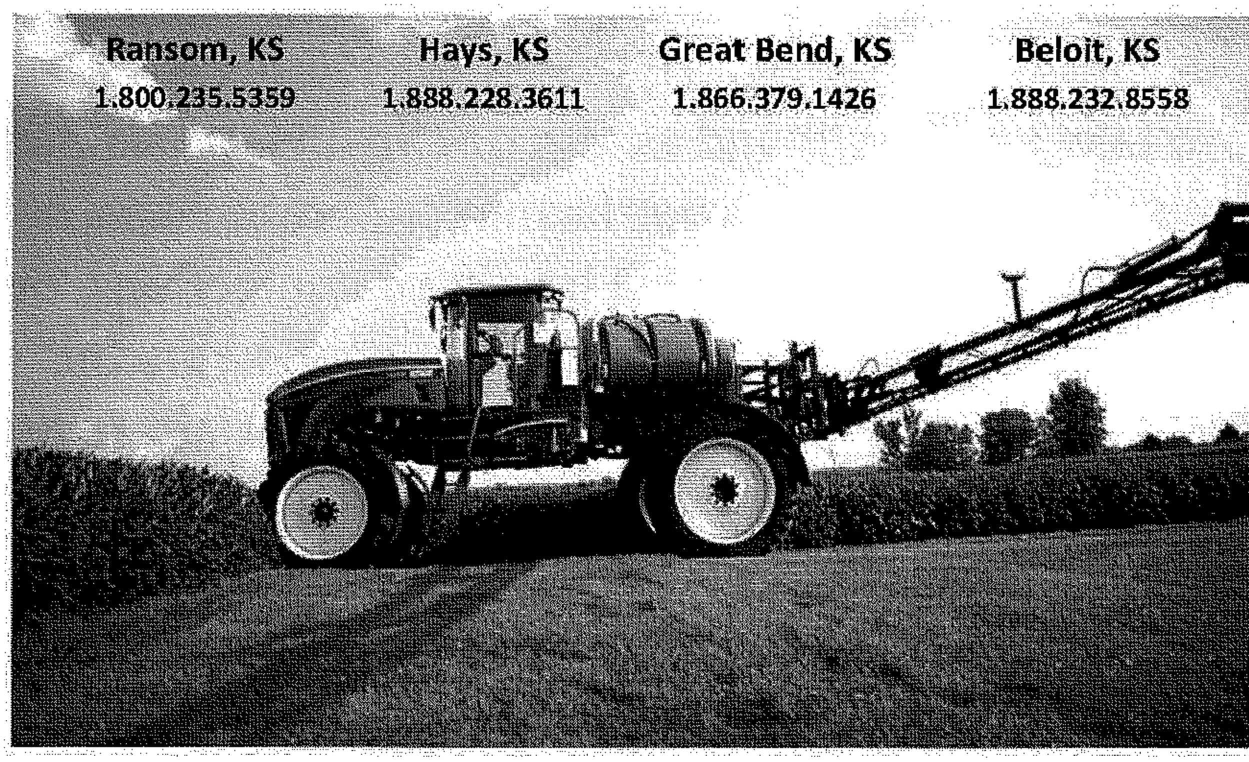

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www.bioag.novozymes.com

NuTech Seed
1-800-942-6748
www.nutechseed.com

Olsen's Ag Laboratory
(308) 345-3670
www.olsenlab.com/

Pioneer
www.pioneer.com
(785) 675-1302

Producer Hybrids
(785) 656-0467
www.producershybrids.com

ProGreen Ag
(785) 249-5528
www.progreenag.com/

Red Willow Aviation
(308) 345-3635
www.rwaviation.com/

Schaffert Manufacturing Co Inc
1-800-382-2607
www.schaffert.com/

SFP
1-800-446-GROW (4769)
www.sfp.com/

Sharp Brothers Seed
1-800-462-8483
www.sharpseed.com/

United Sorghum Checkoff
1-877-643-USCP (8727)
www.sorghumcheckoff.com/

Sorghum Partners
1-800-645-7478
www.sorghum-partners.com/

Star Seed
www.gostarseed.com/
1-800-782-7311

Triumph Seed Company
(806) 253-2585
www.triumphseed.com/

The plan for the day...

		Room 1	Room 2	Room 3	Room 4
7:45	8:15	*Registration*			
8:15	8:20	*Welcome*			
8:30	9:20	Kochia History, Bio & Glyph Resistance *(P. Stahlman)*[12]	Utility of Cover Crops *(J. Holman)*[1]	Enhanced Fertilizer Products *(K. Martin)*[1]	Chloride: Wheat & Row Crops- *Evans Enterprises (I)*
9:30	10:20	Kochia Recom for Row Crops *(C. Thompson)*[12]	Crop Rotations with Limited Irrigation *(A. Schlegel)*[1]	Vertical Tillage & Corn Production *(D. Presley)*[1]	Add Profit w/ SoilBuilder Cover Crops- *Arrow Seed (I)*
10:20	10:50	*View Exhibits*			
10:50	11:40	Kochia Recom for Wheat & Fallow *(P. Stahlman)*[12]	Sprayer Set-up *(B. Klein)*[12]	Palmer and Marestail Control *(D. Peterson)*[12]	Ag Estate Planning -KS *Community Foundations (I)*
11:50	12:40	Kochia: Growth Regulator Resistance *(P. Westra)*[12]	Utilizing Yield Monitor Data *(L. Haag)*[1]	*Lunch*	
12:50	1:40	Trends in Crop Leases *(T. Dumler)*[1]	Enhanced Fertilizer Products *(K. Martin)*[1]		
1:50	2:40	Palmer and Marestail Control *(D. Peterson)*[12]	Kochia History, Bio & Glyph Resistance *(P. Stahlman)*[12]	Sprayer Set-up *(B. Klein)*[12]	Monsanto Product Update *Monsanto (I)*
2:50	3:40	Farmer Panel: Attacking Weeds	Kochia Recom for Row Crops *(C. Thompson)*[12]	Ag Estate Planning -KS *Community Foundations (I)*	Strip-till: Seedbed Prep & Fertilizer-*Brothers Equip (I)*
3:40	4:10	*View Exhibits*			
4:10	5:00	Vertical Tillage & Corn Production *(D. Presley)*[1]	Kochia Recom for Wheat & Fallow *(P. Stahlman)*[12]	Solutions for Managing Weed Resistance - *BASF (I)*	Maximizing Your Yield w/ Solutions - *Cargill (I)*
5:10	6:00	Utilizing Yield Monitor Data *(L. Haag)*[1]	Trends in Crop Leases *(T. Dumler)*[1]	Max Yields w/ KQ-XRN and KS Fert - *Kugler Co (I)*	Strategies for Weed Control - *Sims Fertilizer (I)*
6:00		*Bull Session*			

(I) indicate industry sessions.

[1] Indicate Certified Crop Advisor CEUs applied for.

[2] Indicate Commercial Applicator CEUs applied for.

This conference is organized by a committee of producers and K-State Extension personnel. Chair of this committee is Jeanne Falk, K-State Agronomist.

Please send your feedback to jfalk@k-state.edu

www.northwest.ksu.edu/coveryouracres