
Cover Your Acres

Winter Conference

January 20 & 21, 2015

Gateway Civic Center
Oberlin, KS

A cooperative effort between:



K-STATE
Research and Extension

**Northwest Kansas
Crop Residue Alliance**

2015 Proceedings, Vol. 12



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To provide a positive experience for presenters and attendees please silence your wireless device.

Session Summaries

Characteristics of the Ogallala Aquifer-Facts and fiction of the Ogallala Aquifer relating to geology, recharge, water movement, changes in water levels and modeling efforts.

Cover Crop Research in the Central Great Plains-Cover crop biomass yield, water use, crop yield, and soil microbiology results from a multi-year cover crop study using both single species and mixes at Akron, CO and Sidney, NE.

Environmental Effects on Weed Control-Time of day, temperature, soil organic matter and pH and how all of these factors influence the efficacy of herbicides.

Fallow and Row-Crop Weed Control Options-The latest data on strategies, products, and rates to control troublesome weeds.

Growing Yield: Key Points in Wheat Growth and Development-Take a fresh look at how we grow yield. Plant responses at key developmental stages throughout the season play a role in determining our yield potential.

Integrating Farm Bill and Crop Insurance Decisions - Take a look at how various farm bill choices, along with crop insurance, might perform in Northwest Kansas scenarios at minimizing your risk.

Management of Drought Tolerant Corn-What's important in selecting a DT hybrid? An overview of DT corn results from multiple years of dryland and limited irrigation conditions at Tribune.

Phosphorus Management-Understanding P availability, tie-up, specialty products, and both short-term and long-term management strategies.

Sampling 101-Good decisions require good data. A quick refresher on the proper procedures for collecting soil, plant tissue, and forage samples to ensure your lab results are as accurate as possible.

Soil Microbiology and Carbon in High Plains Dryland Agriculture - A look at the basics of soil microbiology and soil carbon, in the context of dryland cropping systems.

Producer Panel-Tips and tricks for efficiency and efficacy in spraying operations.

Proceedings from prior years of the Cover Your Acres
Winter Conference can be found online:
www.northwest.ksu.edu/coveryouracres

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Presenters



Francisco Calderon— Research Soil Scientist. Mr. Calderon was born in Puerto Rico. He obtained a B.S. and M.S. degrees in biology from the University of Puerto Rico. The Master's thesis subject was the role of mycorrhizal fungi on landslide revegetation. Mr. Calderon went on to obtain his Ph.D. at Michigan State University studying the effects of mycorrhizae on growth and Carbon cycling in Sorghum. He now works as a Research Soil Scientist for the USDA Agricultural Research Service at Akron, Colorado.



Greg McMaster- Dr. Greg McMaster is a Research Agronomist with the USDA-Agricultural Research Service. Greg has been with the Agricultural Systems Research Unit (formerly the Great Plains Systems Research Unit) in Fort Collins, CO since 1982. Greg earned his B.S. at Michigan State University, M.S. at San Diego State University, & Ph.D. at Colorado State University with emphasis on plant physiology, agronomy, and ecology. His research combines field experiments with crop simulation modeling (and other digital technology tools), and span scales from the gene to the watershed.



David Nielsen- Dr. David C. Nielsen is a Research Agronomist employed by the USDA-ARS, Central Great Plains Research Station at Akron, CO for the past 31 years. He grew up on a farm in north-central Iowa. He holds degrees in Meteorology and Agronomy/Agricultural Climatology from Iowa State University, and received his Ph.D. in Agricultural Meteorology/Bioenvironmental Engineering from the University of Nebraska. He is a Fellow of the American Society of Agronomy, the Crop Science Society of America, and the Soil Science Society of America. His research involves crop water use and precipitation storage in dryland and irrigated cropping systems in the central Great Plains.



Daniel O'Brien— Extension Agricultural Economist. Dr. Daniel O'Brien received his B.S. in Agricultural Economics from the University of Nebraska and his Ph.D. from Iowa State University. The focus of Daniel O'Brien's extension and applied research efforts have been in the areas of grain and bioenergy market analysis - with emphasis on of wheat, feed grain, oilseed, and ethanol supply-demand and prices. He also has been working in the areas of irrigated and dryland cropping systems and natural resource-related issues in western Kansas. He also works extensively with agricultural audiences on issues such as farmland leasing and crop enterprise profitability.



Dallas Peterson- Dallas Peterson is a Professor and Extension Weed Specialist at Kansas State University. He grew up on a small diversified crop and livestock farm in north central Kansas and received his B.S. and M.S. degrees in Agronomy from Kansas State University. Dallas completed his Ph.D. degree at North Dakota State University and worked as an Assistant Professor and Extension Weed Specialist in North Dakota from 1987 to 1989 before returning to Kansas State in a similar capacity. Dr. Peterson conducts applied weed management research and provides educational programming and weed management information to Kansas farmers and crop advisors. Dallas currently is serving as President-Elect for the Weed Science Society of America.

Presenters



Dorivar Ruiz-Diaz-Dr. Dorivar Ruiz Diaz is a soil fertility and nutrient management specialist at Kansas State University. He holds a Ph.D. in soil fertility from Iowa State University and MS in soil fertility from the University of Illinois at Urbana-Champaign. He does research and extension work on the efficient use of fertilizers, phosphorus and micronutrient management, and land application of by-products with an emphasis on crop-available nitrogen.



Alan Schlegel- Alan Schlegel joined Kansas State University in 1986. He is Research Agronomist and Professor at the Southwest Research-Extension Center in Tribune. His primary research efforts have been with water and nutrient management strategies for cropping systems in a semi-arid environment. The objectives for the dryland cropping systems research is to develop cropping strategies that reduce tillage, increase capture of precipitation, reduce evaporation and erosion potential while enhancing crop yields. The focus of the nutrient management research is to optimize fertilizer use efficiency, crop production, and profitability while maintaining environmental quality. Current research is focusing on limited irrigated cropping systems to reduce groundwater depletion while maintaining profitability.



Curtis Thompson-Curtis Thompson is a Professor and Extension Weed Science Specialist for Kansas State University, Agronomy. Native of North Dakota, he received his BS and MS and NDSU and a Ph.D. at the University of Idaho. His area of focus includes weed management in field crops emphasizing sorghum, corn, sunflower, and resistant weed management. Thompson continues to focus on glyphosate resistant kochia management in western Kansas and has worked extensively on HPPD resistant Palmer amaranth in the central part of the State. Efforts to manage glyphosate resistant Palmer amaranth are intensifying.



Brownie Wilson- Brownie Wilson graduated from Kansas State University with a Bachelor and Masters Degree in Geography. He started his working career with the Kansas Department of Agriculture's Division of Water Resources in 1993 as a Geographic Information Systems (GIS) Analyst. In 1999, Mr. Wilson accepted an Environmental Scientist IV position with the Kansas Water Office and in 2001 moved to the Kansas Geological Survey where he holds his current appointment as the Geohydrology Section's GIS/Support Services Manager.



Mark Wood-Mark Wood is an Extension Agricultural Economist with the Farm Management Association in Northwest Kansas. He has been assisting Association member families with record keeping, analysis, management and generational transfer issues in Northwest Kansas for over 28 years. He graduated from North Dakota State University with a Master's degree in Agriculture Economics in 1986 and Kansas State University with a Bachelor's degree in Agricultural Economics in 1982. Mark grew up on a farm near Wakefield, Kansas.

The Gateway

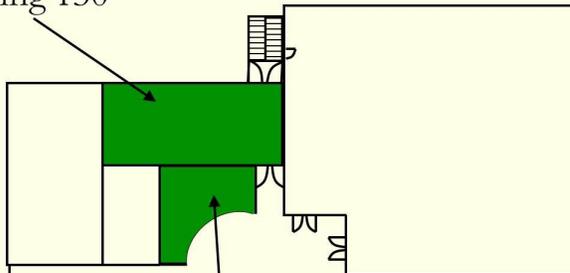
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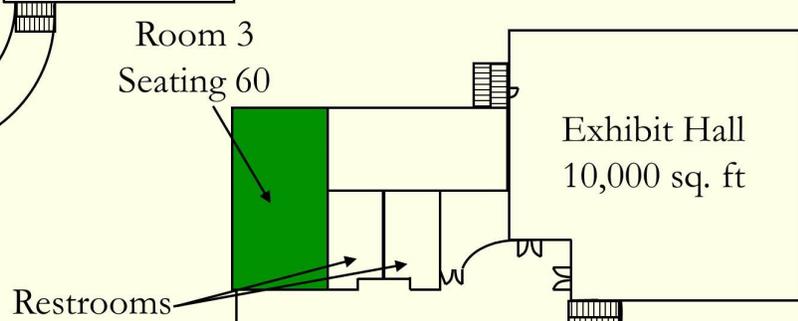
Room 2
Seating 130



Room 4
Seating 60

LOWER LEVEL

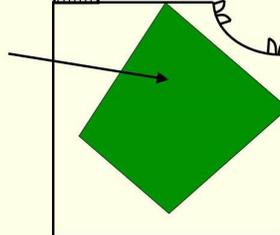
Room 3
Seating 60



Restrooms

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10,000 sq. ft

Room 1
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Registration

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The High Plains Aquifer

Rex C. Buchanan, Robert R. Buddemeier, and B. Brownie Wilson
Kansas Geological Survey

Introduction

The High Plains aquifer, which includes the well-known Ogallala aquifer, is the most important water source for much of western and central Kansas (fig. 1), supplying 70% of the water used by Kansans each day. Water from the High Plains aquifer supports the region's cities, industry, and much of its agriculture.

However, large-volume pumping from this aquifer has led to steadily declining water levels in the western portion of the region, and the area faces several critical water-related issues. This Public Information Circular describes the High Plains aquifer, the effect of decades of large-volume pumping, and some responses to water issues in central and western Kansas.

The High Plains Aquifer Defined

Aquifers are underground deposits containing permeable rock or sediments (silts, sands, and gravels) from which water can be pumped in usable quantities. The High Plains aquifer is a regional aquifer system composed of several smaller units that are geologically similar and hydrologically connected—that is, water can move from one aquifer to the other. The High Plains aquifer system lies beneath parts of eight states in the Great Plains, including about 30,500 square miles of western and central Kansas (fig. 1).

Aquifer characteristics are determined in large part by geology. The High Plains aquifer is composed mainly of silt, sand, gravel, and clay—rock debris that washed off the face of the Rocky Mountains and other more local sources over the past several million years. The aquifer varies greatly from place to place: thick in some places, thin in others; permeable (able

to transmit water easily) in some places, less so in others. Where the deposits are thick and permeable, water is easily removed and the aquifer can support large volumes of pumping for long periods. In most areas, this water is of good quality.

The most important component of the High Plains aquifer is the Ogallala aquifer, generally the western half of the High Plains aquifer in Kansas. In some locations (such as Lake Scott State Park in Scott County), the Ogallala Formation crops out at the surface, forming a naturally cemented rock layer called mortarbeds. In the subsurface, the Ogallala largely consists of silt and clay beds that are interlayered with sand and gravel that is mostly unconsolidated, or not naturally cemented together.

The south-central extension of the High Plains aquifer is composed of younger sediments that are similar to the Ogallala. These younger sediments,

The High Plains aquifer system lies beneath parts of eight states in the Great Plains, including about 30,500 square miles of western and central Kansas

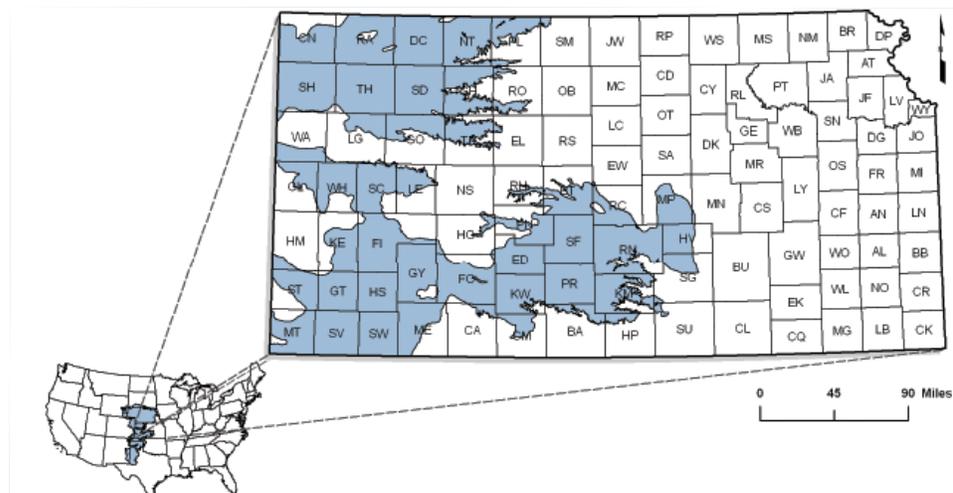
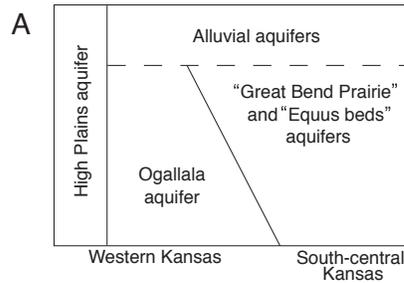


Figure 1—Saturated extent of High Plains aquifer in Kansas.

In the year 2000, about 21 million acre-feet of ground water was removed from the High Plains aquifer across the eight-state region

deposited during the Pleistocene Epoch, or Ice Ages, include the “Equus beds” aquifer (in McPherson, Reno, Harvey, and Sedgwick counties) and the “Great Bend Prairie aquifer” (in Stafford, Edwards, Pratt, Kiowa, and other counties). Also lying above the Ogallala Formation are other Pleistocene deposits and other younger deposits in the valleys of modern streams. Where these stream deposits (known as alluvium) are connected to the Ogallala or Pleistocene aquifers, the alluvial aquifers are considered part of the High Plains aquifer (fig. 2).



Beneath the High Plains aquifer is much older, consolidated bedrock, usually limestone, sandstone, or shale (fig. 3). In some places this bedrock holds enough water to be called an aquifer, and it may be connected to the overlying aquifer. Layers of permeable sandstone in the Dakota Formation, for example, are connected to the High Plains aquifer in parts of southwestern or south-central Kansas. Some layers of the underlying bedrock contain saltwater; where these are directly connected to the High Plains aquifer, they pose a threat to water quality.

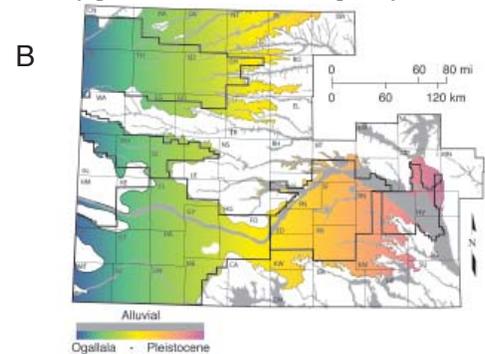


Figure 2—Schematic (A) and map (B) showing aquifers that make up the High Plains aquifer.

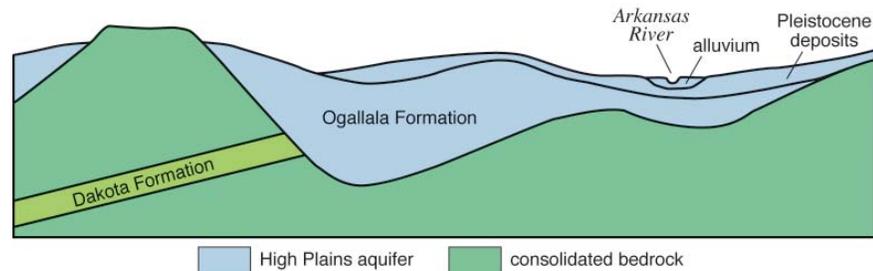


Figure 3—Generalized cross section showing the High Plains aquifer and underlying bedrock. The Ogallala Formation, Pleistocene deposits, and alluvium combine to form the High Plains aquifer.

Water Resources in the High Plains Aquifer

Usable water in the High Plains aquifer is in the pore spaces between particles of sand and gravel. This water (called ground water) accumulated slowly—in some of the deeper parts of the aquifer, over tens of thousands of years. In the subsurface, water in the aquifer generally moves slowly from west to east, usually at the rate of tens of feet per year.

Recharge is the natural movement of water into an aquifer, usually from precipitation. Natural recharge to the High Plains aquifer from precipitation is low, in part because much of the rain falls during the growing season, when plant roots intercept the soil moisture. In western Kansas, where precipitation is scant and the water table is relatively deep (several hundred feet) in many places, recharge occurs infrequently and the long-term average is less than an inch per year. In central Kansas, where the aquifer is closer to the land surface, where soils are sandier, and precipitation amounts greater, recharge can be significant, as much as 4 to 6 inches per year.

Water volumes and use are measured in various ways. One measure is an acre-foot, or the amount of water necessary to cover an acre of ground (a parcel about the size of a football field) with a foot of water.

An acre-foot equals 325,851 gallons of water. In the year 2000, about 21 million acre-feet of ground water was removed from the High Plains aquifer eight-state region (McGuire, 2009). In Kansas, the High Plains aquifer yielded 4.4 million acre-feet, of which 2.4 million acre-feet came from the Ogallala aquifer in 2007. Estimated average annual natural recharge to the Ogallala in Kansas is 0.72 million acre-feet.

Another measure of ground water is saturated thickness—the thickness of the sands, gravels, and other materials that are saturated with water. Saturated thickness is commonly measured in feet, but “feet of saturated thickness” is not the same as feet of actual water. Only about 10 to 25% of the aquifer volume is pore space that can yield extractable water. Therefore, in an aquifer with 17% pore space, removing 1 acre-foot of water causes the water table to drop by about 6 feet. In Kansas, saturated thickness in the High Plains aquifer is generally greatest in the southwestern part of the state (see fig. 4). There, saturated thicknesses of 300 feet and greater were common before the onset of large-scale irrigation, a time that is often called “pre-development.”

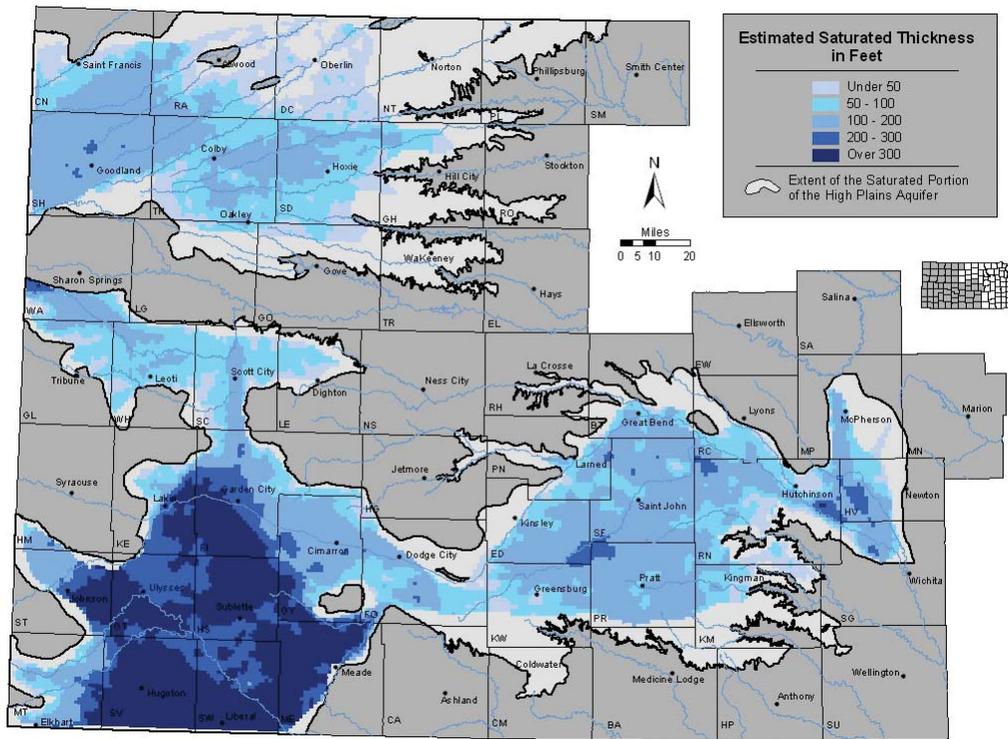


Figure 4—Predevelopment saturated thickness for the High Plains aquifer in Kansas.

Ground water can also be measured in terms of its availability: how much water can be removed by a well over short periods. Large volumes of water can be pumped rapidly (1,000 gallons or more per minute) from the High Plains aquifer in many locations. This

contrasts with much of the rest of the state, where wells generally produce smaller amounts (less than 100 gallons per minute). By way of comparison, a good household well produces 5 to 10 gallons per minute, although many household wells produce less.

Water-level Declines in the Aquifer

Large-scale irrigation began in western Kansas in the late 1800's, with the use of ditches to divert water from the Arkansas River. As technology improved, ground water became the major irrigation source because surface water (lakes, rivers, and streams) is relatively scarce in western Kansas. With the advent of large-capacity pumps that were capable of drawing several hundred gallons of water per minute, people began to develop that ground water. Using a technique called flood irrigation, water was pumped through long pipes or ditches along the edges of a field, then out onto rows of crops (fig. 5A).

In the 1950's and 1960's, technological developments led to a dramatic increase in large-scale pumping. In particular, center-pivot irrigation systems—large sprinklers that roll across the land on wheels—allowed people to irrigate uneven terrain, thus opening up large new areas for irrigation (fig. 5B). These irrigation methods led to the cultivation of crops, such as corn, that could not previously be grown reliably in the area. That grain production led, in turn, to large feedlots and packing plants and a boom in the economy of much of western Kansas, all largely dependent on ground water. One study in 2001 estimated that the economic



Figure 5—Aerial photos of (A) flood and (B) center-pivot irrigation (photos courtesy of Tom Schmiedeler, Washburn University).

impact of irrigation in southwestern Kansas alone amounts to more than \$188 million annually (Gilson et al., 2001).

For many years, people believed that the High Plains aquifer contained an inexhaustible amount of water. However, large-volume pumping (mostly for irrigation) eventually led to substantial declines in the water table, and people realized that the amount of water in the aquifer was finite and could be exhausted. Much of the Ogallala portion of the High Plains aquifer has declined since predevelopment, with some areas having declines of more than 60% (fig. 6).

When Will the Aquifer Run Dry?

Perhaps the most common and important question about the High Plains aquifer is: How much longer can it support large-scale pumping? It's a simple question with a complicated answer. First, the aquifer will probably be able to support small, domestic wells far into the future. With proper planning, most cities and towns should be able to provide for their water needs. Second, the future of agricultural use of the aquifer depends on a variety of factors, including the price of irrigated crops, the price and availability of energy (the deeper the water table, the more energy it takes to pump water), climate, and how the water is managed. Third, it is important to remember that the aquifer is not one consistent, homogeneous unit. Rather, it varies considerably from place to place. In places, the aquifer consists of less than 50 feet of saturated thickness and receives little recharge. In other places, the aquifer is far thicker or receives considerably more recharge.

Nonetheless, in much of the aquifer, considerable amounts of water remain. For example, declines of 100 feet or more may have occurred in parts of southwestern Kansas, but that represents less than half of the original saturated thickness, and 100 to 200 feet (or more) of saturated thickness may remain. On the other hand, in parts of west-central Kansas—such as Greeley, Wichita, Scott, and northern Finney counties—the original saturated thickness was much less, often less than 100 feet. In these places, where early flood-irrigation systems were prevalent, less than 50 feet of saturated thickness remains.

With those qualifications in mind, researchers at the Kansas Geological Survey have made projections about the aquifer, based on past trends in water-level declines. Obviously, the actual future use of water will be affected by commodity prices, energy prices, climate, and management policies. Relatively little data are available for some parts of the aquifer, and projections are not practical in those areas. Assuming saturated thickness sufficient to support pumping of at least 400 gallons per minute, researchers concluded that parts of the aquifer are effectively exhausted in Greeley, Wichita, and Scott counties (fig. 7). Other parts of the aquifer, in areas such as southwestern Thomas County, are projected to have a lifespan of less than 25 years, based on past decline trends. However, the biggest share of the aquifer in southwest Kansas would not be depleted for 50 to 200 years. It is important to remember that these projections are based solely on past water-level trends, and future changes could alter the actual depletion rate.

Much of the Ogallala portion of the High Plains aquifer has declined since predevelopment, with some areas having declines of more than 60%

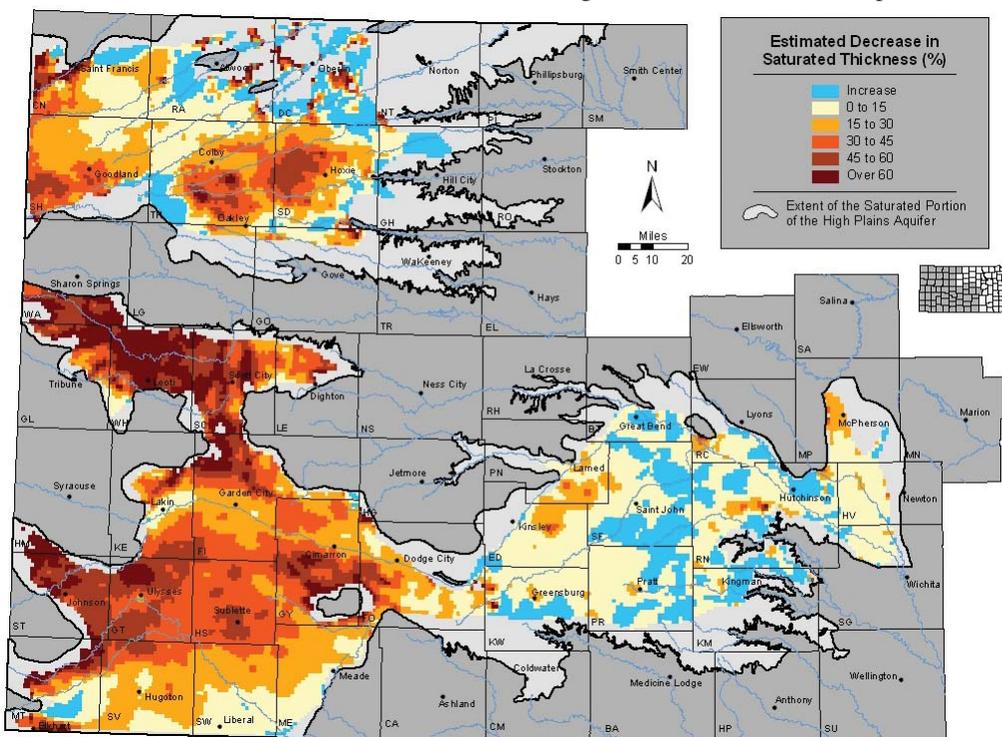


Figure 6—Percent change in saturated thickness for the High Plains aquifer in Kansas, predevelopment to 2007–09.

By Kansas law, water is a public resource that is dedicated to the people of the state

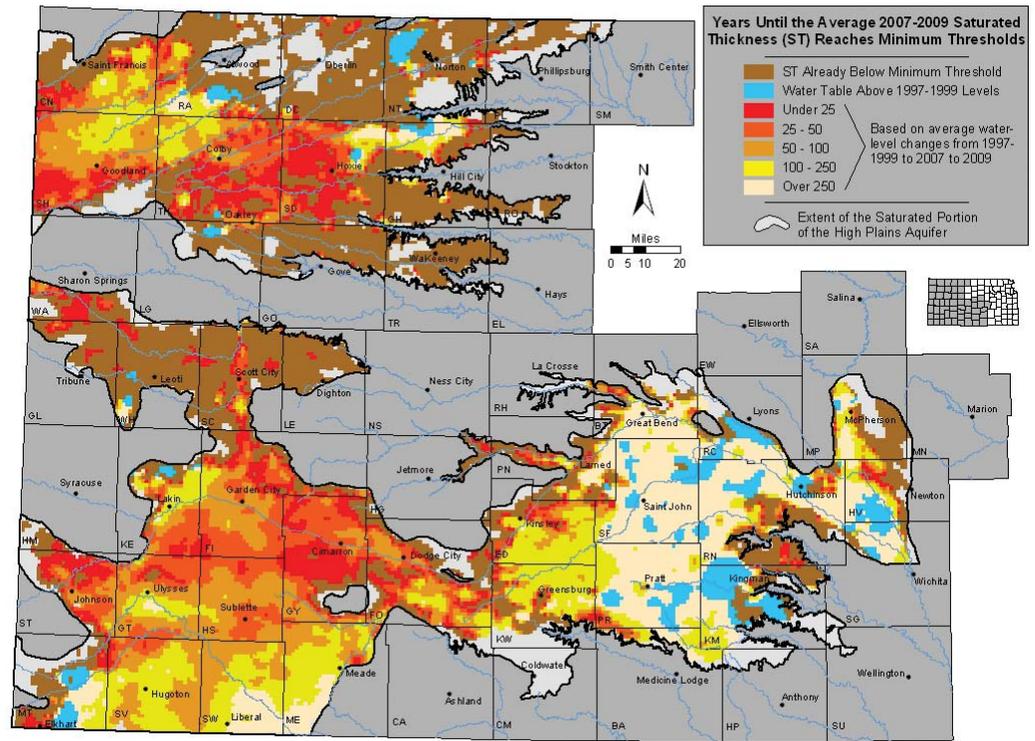


Figure 7—Estimated usable lifetime (1998–2008) trend for the High Plains aquifer in Kansas.

Managing Water in the Aquifer

By Kansas law, water is a public resource that is dedicated to the use of the people of the state. Individuals, companies, municipalities, and other entities can obtain permission to use water for beneficial purposes by obtaining a water right, either new or existing. In general, all beneficial uses of water, except most domestic use, require a water right. Kansas water law is based on the doctrine of prior appropriation. That is, when there is insufficient water to meet all water rights, the date of the water right determines who has the right to use the water. This doctrine is commonly expressed as “First in time, first in right.”

Responsibility for managing water use in Kansas is spread over several agencies. The Division

of Water Resources of the Kansas Department of Agriculture is responsible for administering water rights, and thus is primarily responsible for regulation related to the quantity of water used. Water issues also are subject to local control and management. Five groundwater management districts have been created in Kansas to provide local management of the resource within the framework of the State’s water laws. Together, they cover nearly all of the state underlain by the High Plains aquifer (fig. 8). Groundwater management districts, through staff and an elected board, develop and implement policies and rules and regulations to manage and protect the quality of water, undertake educational activities,

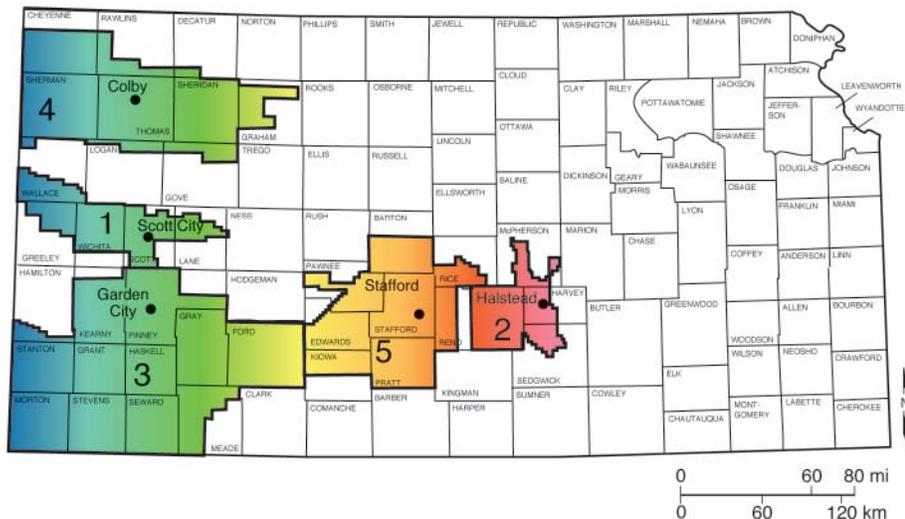


Figure 8—Groundwater management district boundaries in Kansas.

and work with State and Federal water-related agencies to regulate and manage the High Plains aquifer.

A variety of other agencies deal with other aspects of water in the state. The Kansas Geological Survey, for example, a research and service division of the University of Kansas, undertakes a variety of water-related activities, but has no regulatory responsibility. The Kansas Department of Health and Environment monitors water-quality issues. The Kansas Water Office, working with the Kansas Water Authority, is

responsible for water planning. That planning is according to drainage basins, or areas that are drained by a common stream, such as the Cimarron River or Neosho River. Each of those basins is represented by a volunteer basin-advisory committee. The Kansas Department of Wildlife and Parks, Kansas State University's Extension program, the Kansas Biological Survey, the U.S. Geological Survey, and other State and Federal agencies have various responsibilities for water.

Where Do We Go From Here?

Individuals, governmental agencies, and private organizations are all attempting to address issues related to the High Plains aquifer. In addition, several new institutions have recently been proposed to deal with issues concerning the aquifer on a regional basis. Irrigators have implemented a number of techniques that have improved the efficiency with which they use water—using low-pressure application methods on center-pivot systems, for example, instead of spraying water high into the air.

Among the more far-reaching proposals for extending the life of the aquifer is the idea of sustainable development. This is the concept of limiting the amount of water taken from the aquifer to no more than the amount of recharge, and perhaps less, depending on the impact on water quality and minimum streamflows. This level of use is the target of the safe-yield management policies currently in effect in the Big Bend and Equus Beds Groundwater Management

Districts in the eastern part of the High Plains aquifer. Adoption of a similar policy in other areas of the High Plains aquifer would require a substantial decrease in the amount of water currently used. This would have an impact on the type and amount of crops grown in western Kansas and, in turn, on a variety of economic activities. Because many of the water rights in the High Plains aquifer were established long ago and thus have priority, the implementation of sustainable-development approaches to water resources has serious legal implications. Other methods for dealing with the High Plains aquifer are being proposed, discussed, and implemented. All are aimed at extending the life of this crucial resource.

[The authors thank Dave Young, formerly of the Kansas Geological Survey, and Bob Sawin, Kansas Geological Survey, for their help in the preparation of this circular.]

Additional Reading

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Web Sites

Kansas Geological Survey — <http://www.kgs.ku.edu/>
Information about water-levels in specific wells is available at <http://www.kgs.ku.edu/Magellan/WaterLevels/> and can be searched by legal description or county.
More information on the High Plains Aquifer is available at <http://www.kgs.ku.edu/HighPlains/index.shtml>

Kansas Department of Agriculture, Division of Water Resources — <http://www.ksda.gov/dwr/>

Kansas Water Office — <http://www.kwo.org/>

U.S. Geological Survey's Water Resources Division Office, Lawrence — <http://ks.water.usgs.gov/>
This site includes current streamflow information.

The mission of the Kansas Geological Survey, operated by the University of Kansas in connection with its research and service program, is to conduct geological studies and research and to collect, correlate, preserve, and disseminate information leading to a better understanding of the geology of Kansas, with special emphasis on natural resources of economic value, water quality and quantity, and geological hazards.

The Geology Extension program furthers the mission of the KGS by developing materials, projects, and services that communicate information about the geology of Kansas, the state's earth resources, and the products of the Kansas Geological Survey to the people of the state.



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High Plains Cover Crop Research

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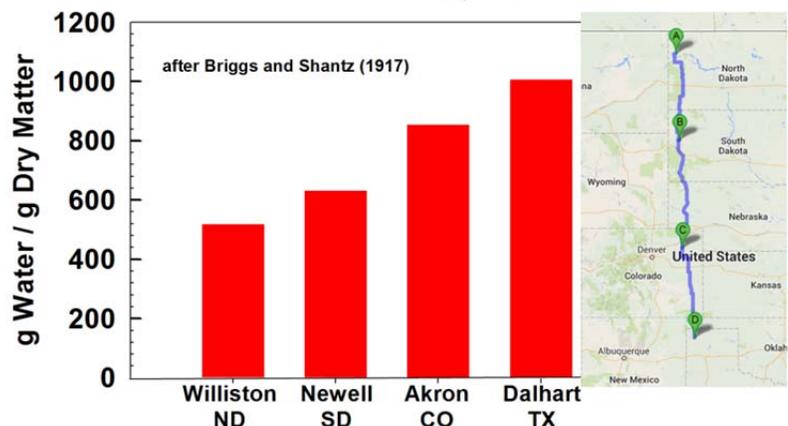
The past few years have seen a greatly renewed interest in adding cover crops to agricultural production systems. Unger et al. (2006) defined cover crops as “close-growing crops such as grasses, legumes, or small grains that are used primarily to provide seasonal protection against soil erosion and for soil improvement.” Some of the benefits reported for cover crop use include increased organic matter, improved soil structure, improved infiltration, reduced evaporation, increased erosion protection, greater snow catch, greater nitrogen fixation, increased soil biological activity, increased nutrient availability, reduced nutrient loss, reduced excess soil water, and weed suppression (Snapp et al., 2005). Much of the literature documenting these benefits associated with cover crop use come from studies conducted in regions with less evaporative demand and/or more precipitation than the semi-arid region of the central High Plains of the United States. A press release about cover crop mixtures from the USDA-Natural Resources Conservation Service in Champaign, IL

(<http://www.nrcs.usda.gov/wps/portal/nrcs/detail/il/newsroom/releases/?cid=STELPRDB1117185>) stated that “...cover crops don’t interfere or compete with the production of grain and commodity crops.”

While that statement may be true in humid and sub-humid regions, Unger et al. (2006) cautioned that cover crop use in semi-arid dryland regions (annual precipitation of 10-20 inches) could be detrimental to yields of subsequent crops because of the water that the cover crop used that was not replenished by precipitation between the time of cover crop termination and planting the next crop. Unger and Vigil (1998) made the definitive statement that “Specific reasons for growing cover crops vary among sites and regions, but a consequence in all cases is that they use soil water, which can positively, neutrally, or negatively affect the soil water supply for the next crop.” Wortman et al. (2012)

indicated that a major farmer concern related to cover crop use was the amount of soil water used by the cover crop that could potentially reduce available soil water for the subsequent cash crop. Recent presentations by individuals from North Dakota and South Dakota have indicated that successful cover crop implementation into farming systems in those regions are proof of future successful implementation in the central High Plains, which has a similar precipitation pattern. Unfortunately, that reasoning ignores the well documented fact that greater evaporation potential in the central High Plains results in more water required to produce a unit of biomass in this region compared with the Dakotas (Briggs and Shantz, 1917; see figure

Water Requirement of Second Crop of Grimm Alfalfa, 1912



to the right). Simply put, an inch of crop water use in Texas will not produce as much biomass as an inch of water in North Dakota. As a consequence research results and farmer experiences with cover crops grown in the Dakotas may not be directly transferrable to more southern regions with higher evaporative demand.

Recent recommendations advocating the use of cover crop mixtures in semi-arid environments have not been derived from the results of rigorous scientific studies. In particular, the results from a single-year, unreplicated demonstration plot in south-central Nebraska (average annual precipitation of 27 inches) indicated that cover crops grown in mixtures of 9 to 14 species and seeded in mid-July did not show declines in soil water content during the August through November growth period, while single-species plantings of cover crops planted at the same time and location did use significant amounts of soil water (Berns and Berns, 2009). The authors, however, wisely noted that “...we acknowledge that these results are from one trial in one year. We think that this question of yield response to cover crop mixes needs to be studied further.” Nevertheless, these results have been widely disseminated as authoritative evidence that cover crops grown in mixtures may use much less water than crops grown in single-species plantings (R. Archuleta, NRCS, Greensboro, NC, personal communication, 2013; Berns and Berns, 2009). While the mechanism for the reduced water use from cover crop mixtures has not been identified, it has been hypothesized that such a reduction could be possible as the result of soil fungal and bacterial associations that

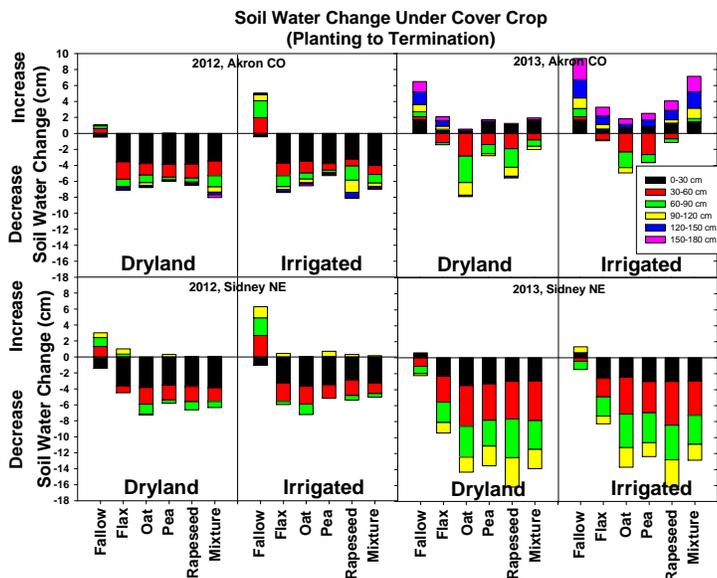
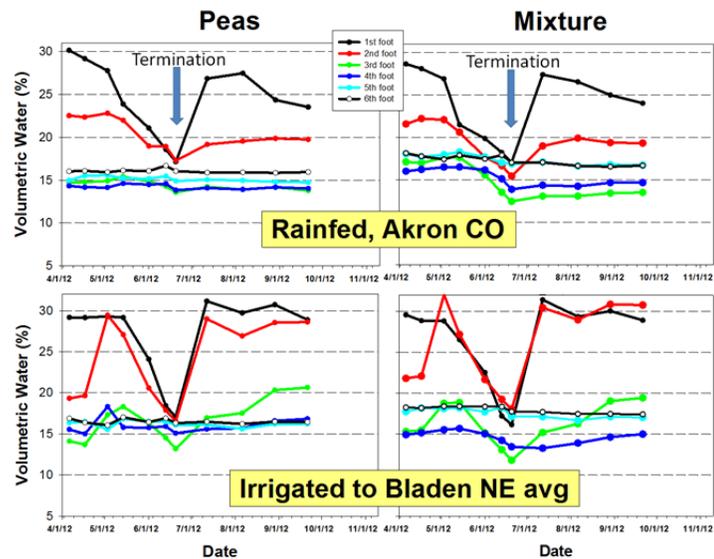
improve drought tolerance through access to greater soil volume (Dr. K Nichols, formerly USDA-ARS, Mandan, ND, now Rodale Institute, Kutztown, PA, personal communication, 2012).

After inspecting the soil water figures presented by Berns and Berns (2009) it appears evident that some instrument problems may have resulted in field observations that led them to conclude that cover crop mixtures used much less water than single-species plantings of cover crops. For example, there are a number of instances when the soil water sensors did not show a response to precipitation events, and other times when precipitation events caused sensor responses to occur at lower soil depths before responses were observed at depths closer to the soil surface. The following results presented in this paper will more clearly define the water use of cover crops grown in a 10-species mixture and as single-species plantings as well as effects of cover crop water use on subsequent wheat yields at two central High Plains locations (Akron, CO and Sidney, NE) over a three-year period. The mixture included barley, oat, flax, rapeseed, pea, clover, safflower, phacelia, lentil, and vetch. For comparison purposes data were also collected on a no-till fallow plot with proso millet stubble.

Cover Crop Water Use – Do Mixtures Use Less Water Than Single Species?

The figure to the right (from Akron) is a typical example of the cover crop water use data collected at both Akron and Sidney. The volumetric soil water contents as recorded by a neutron probe used at six soil depths in the 6-foot soil profile clearly show that there is soil water extraction happening under the cover crop mixture that is not greatly different from the pattern of soil water extraction under the single-species planting of pea (which is typical of all of the single-species plantings).

The next figure shows the change in soil water content between cover crop planting and termination for each of the six soil layers.

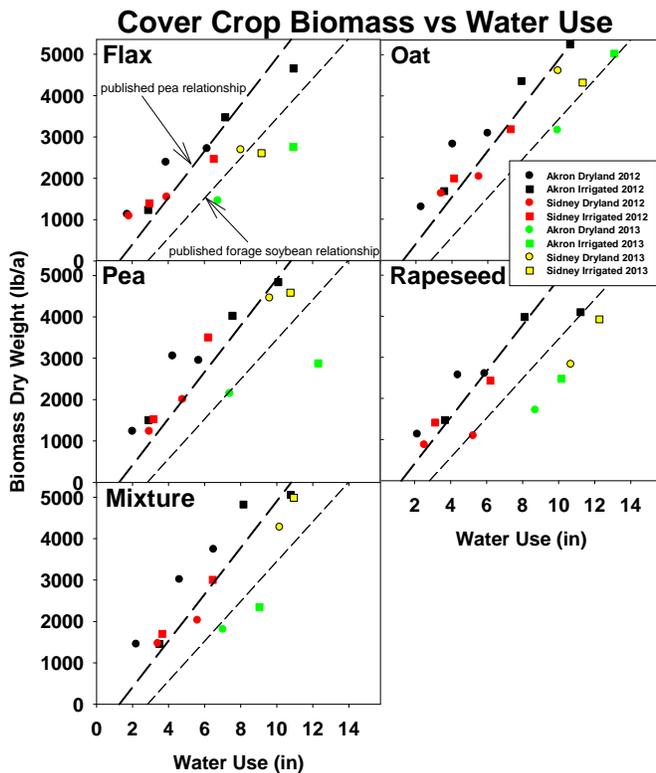


and termination for each of the six soil layers. For the data observed at Akron in 2012 and at Sidney in 2012 and 2013, soil water extraction is seen for all single-species plantings and for the cover crop mixture. The cover crop mixture did not exhibit less soil water extraction than the single-species plantings. The different pattern seen at Akron in 2013 (particularly the soil water recharge observed for the irrigated mixture, and to a lesser degree the single crops of rapeseed and flax) is due primarily to very thin plant stands in 2013 due to very cool April temperatures. These cool temperatures resulted in very slow germination and emergence and seed predation. For example the plant stand in the irrigated mixture was only 9% of the 2012 irrigated mixture stand.

The cover crop water use from planting to termination, comprised of both soil water extraction and use of growing season precipitation and irrigation is shown to the right for the data collected at Sidney. For all four data sets we observed similar water use by the mixture compared with the single-species plantings, in contrast to the previously reported result of less water use by cover crops grown in mixtures (Berns and Berns, 2009). Averaged over all of the cover crop plantings, locations, and rainfall regimes, cover crops used 1.78 times more water than was lost by evaporation from the no-till fallow treatment.

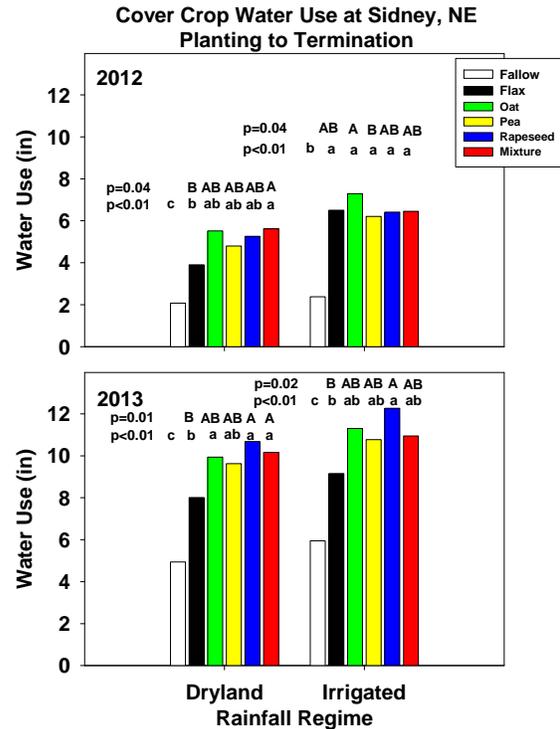
Cover Crop Biomass Production – Do Mixtures Produce Biomass More Efficiently Than Single Species?

Some people have claimed that cover crops grown in mixtures will produce biomass much more efficiently than cover crops grown as single species because of enhanced soil microbiological activity stimulated by the diversity of plant roots. An easy way to look for that enhanced productivity is to plot cover crop biomass against cover crop



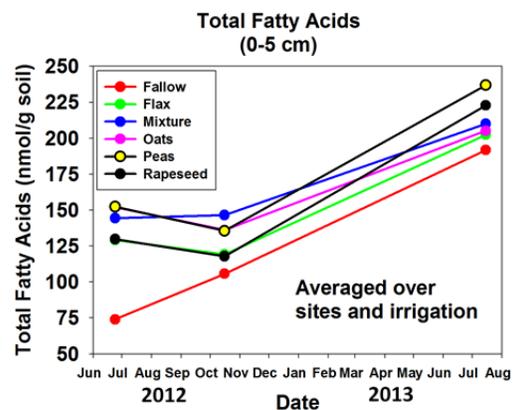
Soil Microbiological Community Composition – Do Cover Crop Mixtures Produce Greater Concentrations of Microbiological Organisms Than Single Species?

We measured soil microbiological community composition through the use of fatty acid methyl ester (EL-FAME) analysis. Measurements were made at cover crop termination (mid-June), following wheat planting (mid-October), and following wheat harvest (mid-July). The results of the analysis of two of the fatty acid markers shown here are representative of all of the analyses performed. The total fatty acids can be seen as an index of the total amount of microbial biomass in soil, while the mycorrhizal markers indicates the abundance of arbuscular



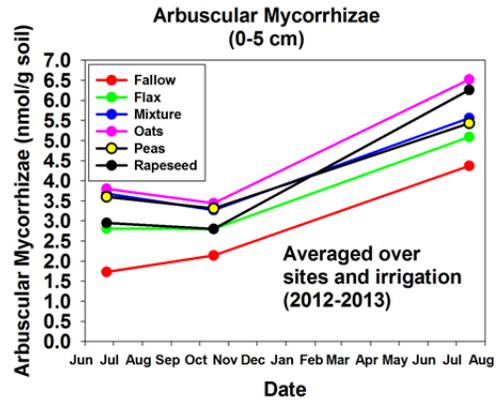
water use. Most crop species exhibit a linear relationship between biomass produced and water used to produce the biomass. The slope of the linear relationship is an indication of the water use efficiency of biomass production. The figures to the right show that relationship for four single-species plantings of cover crops and for the 10-species mixture. Two lines are shown for reference to previously published relationships for pea and forage soybean. The green points on the figures can be ignored as they come from the Akron 2013 data set which, as previously mentioned, had extremely low stand counts due to very cold April temperatures and delayed emergence.

For the most part these data indicate that there is not an enhanced water use/biomass production relationship for the mixture compared with the single-species plantings. In other words, growing cover crops in mixtures does not increase water use efficiency of cover crop biomass production.



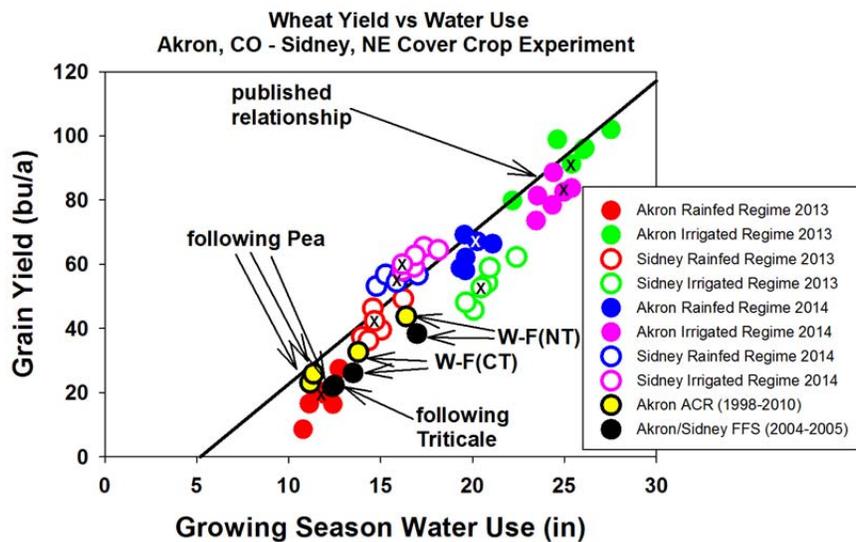
mycorrhizal fungi, which are thought to help plants reach into the bulk soil to procure water and phosphorus.

At cover crop termination (first set of data points) the fallow plots had been without a growing plant for nearly nine months and show much reduced concentrations of Total Fatty Acids and Arbuscular Mycorrhizae in the top two inches of soil (0-5 cm) compared with where cover crops were being grown. As the wheat started growing (second set of data points) the concentrations of total Fatty Acids and Arbuscular Mycorrhizae increased in the previously fallowed plots while small declines were evident where the cover crops had been terminated and not been growing for about four months. At the end of the wheat growing period (third set of data points) the concentrations of Total Fatty Acids and Arbuscular Mycorrhizae had continued to increase in all of the treatments (fallow plots and cover crop plots), but remained lowest in the plots that had been fallowed. There was no clear evidence of increased microbial concentrations under the cover crop mixture for any of the three sampling dates compared with the single-species plantings.



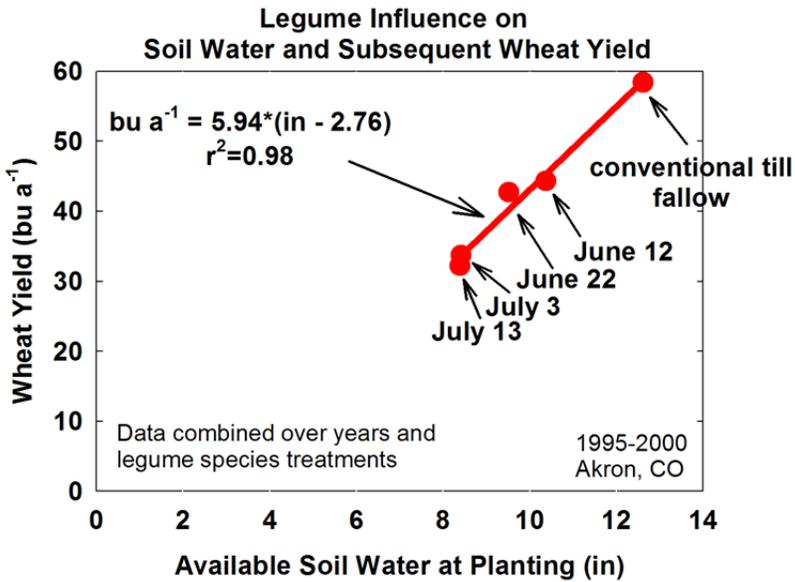
Effect of Cover Crop on Subsequent Wheat Yield – Do Mixtures Change the Wheat Water Use-Yield Relationship?

It stands to reason that any water that a cover crop uses that is not replaced by precipitation during the time between cover crop termination and planting of the next crop will result in a depression in the subsequent crop yield. The figure to the right shows a previously published relationship between winter wheat yield and growing season water use (black line) that was determined at Akron, CO and indicates that as water use decreases due to less available water at planting,



wheat yield decreases at a rate of 4.7 bu/a per inch of water use. In the figure the data points from the recent cover crop study conducted at Akron and Sidney are represented by the red, green, blue, and pink circles. Those data points exhibit a slope similar to the previously published relationship. Similar data sets are shown for the average (1998-2010) data collected from the long-term Alternative Crop Rotation (ACR) experiment at Akron (yellow points) and another previously conducted 2-year study conducted at Akron and Sidney (black points). These other two data sets confirm the slope of the water use/yield relationship (about 4.7 bu/a per inch). These other data sets also show the typical winter wheat yield reduction due to having wheat following pea or triticale in a rotational sequence and confirm that the observed yield reduction is attributable to the water use of those previous crops that was not replaced prior to planting.

The data points in the figure associated with the 10-species cover crop mixture are indicated with an “X”. If enhanced microbiological activity from the mixture were improving the water use efficiency of crop production, then we would see these points above and/or to the left of the other points in their color groups. Since we do not see that separation we can assume that photosynthesis is happening with the same relative efficiency for the wheat plants following the mixture cover crop as seen for the wheat plants following fallow or single-species plantings.



Conclusions

Because we have seen no evidence in the studies that we have conducted to indicate that cover crops grown in mixtures use water differently or use less water than cover crops grown as single species, we are confident in presenting some older data collected at Akron in 1995-2000 (Nielsen and Vigil, 2005) showing the effects of legume cover crops in single-species plantings to predict the effects of cover crops on winter wheat yields (figure to right).

This data set shows that growing the legume cover crop from about April 1 to June 12 reduced available soil water at wheat planting by about 2.2 inches and subsequent wheat yield by

about 13 bu/a. As termination of the legume cover crop was delayed from June 12 to July 13, the soil water at wheat planting was reduced another 2.0 inches and wheat yield another 12 bu/a. Even when cover crop termination occurred on June 12 (100 days prior to planting the next wheat crop), the 6-year average yield depression compared with wheat on fallow was 13 bu/a because of the water that the legume cover crop used that was not replenished prior to wheat planting. This result is in stark contrast to the NRCS cover crop termination guidelines for northeastern Colorado which indicate cover crops can be terminated 35 days prior to planting the subsequent crop and not have any effect on the yields of the next crop (see <http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=34072.wba>).

As we stated at the beginning of this paper, there are many reported benefits of growing cover crops. But research data to support the existence of those benefits for dryland crop production in the semi-arid environment of the High Plains is not easily found. Perhaps the most important benefit of growing a cover crop in this environment is for increasing surface cover for erosion protection and evaporation suppression. But it is difficult to justify the expenses associated with planting a cover crop for these two purposes when existing crop residues may be present in a no-till system that will adequately protect the soil surface and suppress evaporation without having the water demands of a cover crop (see table of seed costs below). Planting cover crops into such residue will have the effect of destroying some of the residue.

Single Species				Mixture (planted at 52 lb/a) [Mixing cost of \$0.05 per pound]	
Species	Seed Cost \$/lb	Target Rate lb/a	Total \$/a		\$/a
Pea	\$0.40	100	\$40.00	Seed	\$34.29
Lentil	\$0.65	50	\$32.50	Mixing	\$2.60
Vetch	\$0.80	50	\$40.00	Total	\$36.89
Clover	\$2.15	15	\$32.25		
Oat	\$0.29	90	\$26.10		
Barley	\$0.31	90	\$27.90		
Rapeseed	\$1.00	6	\$6.00		
Flax	\$0.65	35	\$22.75		
Safflower	\$0.70	30	\$21.00		
Phacelia	\$4.45	5	\$22.25		

The results of this research have shown that cover crop mixtures do not use water differently, do not increase soil microbiological concentrations, do not produce more biomass per unit of water used, and do not improve the wheat water use/yield relationship compared with single-species plantings of cover crops. Yet the seed costs associated with growing cover crop mixtures can be greater than for single-species plantings. Therefore, we would not recommend the planting of cover crop mixtures over single-species plantings unless there are some specific use

goals for the cover crop that the producer has (such as obtaining a specific forage composition from the cover crop if it is to be fed to livestock).

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Environmental Effects on Weed Control

Dallas Peterson, Extension Weed Specialist
K-State Research & Extension



Requirements for Herbicide Activity

- ☛ Contact with the target weed
- ☛ Absorption into the plant
- ☛ Accumulation of toxic levels at the site of action



Factors Affecting Herbicide Performance

- ☛ Soil Active Herbicides
 - Soil Properties, Herbicide Properties, Precipitation, Weed Seedbank
- ☛ Postemergence Herbicides
 - Herbicide Properties, Application Technique, Adjuvants, Environmental conditions, and Weed Factors
- ☛ Complex interactions unique to each herbicide



Factors Affecting Performance of Soil-Applied Herbicides

- ☛ Soil environment
- ☛ Herbicide properties
- ☛ Activation
- ☛ Weed seedbank

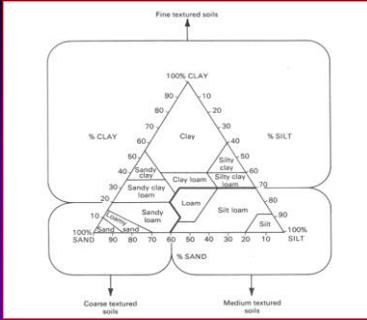


The Soil Environment

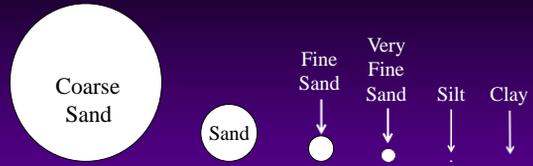
- ☛ Soil texture
- ☛ Organic matter
- ☛ pH
- ☛ Moisture



Soil Texture Triangle



Soil Particle Size



Clay is too small to see without electron microscope ~30,000X

Largest particle about the size of pencil lead (1 millimeter)



Organic Matter

Organic matter has a greater effect than soil texture on herbicide activity because of its high Cation Exchange Capacity (CEC) and the broad spectrum of herbicides it can adsorb.



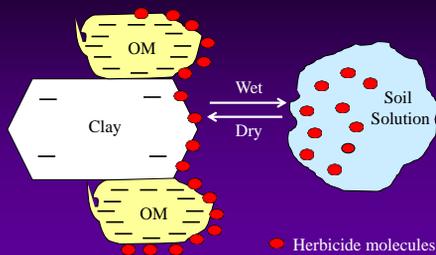
Soil Factors

Cation Exchange Capacity (CEC)

- soils ability to adsorb positively charged compounds
- fine-textured, high-organic matter soils have larger CEC's than coarse, low-organic matter soils



Herbicide Interactions in Soils



Bicep II Magnum Rates based on soil texture and organic matter.

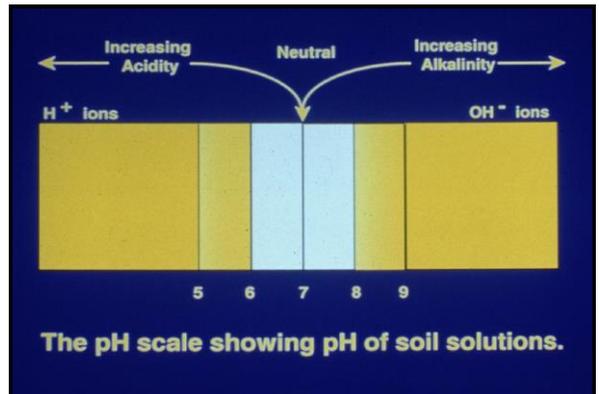
Table 3: Bicep II Magnum – Preplant Surface, Preplant Incorporated, or Preemergence – Corn

Soil Texture	Broadcast Rate Per Acre	
	Less Than 3% Organic Matter	3% Organic Matter or Greater
COARSE Sand, loamy sand, sandy loam	1.3 qts.	1.6 qts.
MEDIUM Loam, silt loam, silt	1.6 qts.	2.1 qts.
FINE Sandy clay loam, silty clay loam, clay loam, sandy clay, silty clay, clay	2.1 qts.	A. 2.1 qts. B. 2.1-2.58 qts.*
Muck or peat soils (more than 20% organic matter)	DO NOT USE	



Soil Texture & OM Restrictions

- ☞ Atrazine: For all soil applications to sorghum, do not apply to coarse textured soils or to medium and fine textured soils having less than 1% OM or crop injury may occur.
- ☞ Lumax EZ: Do not apply Lumax EZ to sorghum grown on sandy soils.
- ☞ Spartan: Do not use on soils classified as sand which have less than 1% OM.

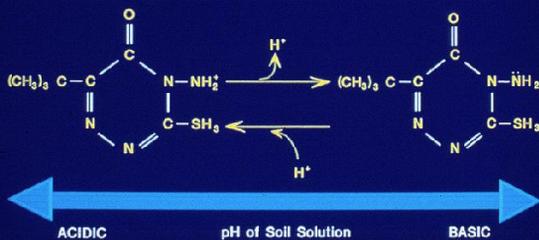


Protonated Metribuzin

- positive charge
- sticks to organic matter and clay
- unavailable for plant uptake

Nonprotonated Metribuzin

- no electrical charge
- moves freely in soil solution
- available for plant uptake



Spartan Rates in Sunflowers based on soil texture, organic matter, and pH.

SUNFLOWERS (22.0)

Table 8

Broadcast Rate	Spartan 4F Use Rate Table (Sunflowers) Fall, Early Spring Preplant, Preemergence, and Preplant Incorporated Applications		
	Fluid Ounces Spartan 4F per acre		
	Soil Texture		
% Organic Matter	Coarse	Medium	Fine
<1.5	3.0 - 3.75	3.0 - 4.5	3.75 - 5.25
1.5-3.0	3.0 - 4.5	3.75 - 6.0	4.5 - 6.75
>3	3.75 - 6.0	4.5 - 6.75	6.0 - 8.0

Refer to the previous information on soil types under the COARSE, MEDIUM, and FINE categories
Use higher rates for soils of pH less than 7.0 and lower rates for pH greater than 7.0 within the rate range.



Herbicide Characteristics

- ☞ Solubility in water
- ☞ Adsorption properties
- ☞ Response to soil pH
- ☞ Persistence



Herbicide Solubility

- ☞ Capacity of a pesticide to dissolve in water
- ☞ Expressed as parts per million (ppm), or mg/l



Herbicide Solubility

The higher a herbicide solubility, the greater the potential for it to move into, through, and over the soil in water.

EPA has designated herbicides with a water solubility of 730 ppm to have significant risk for water contamination problems.



Adsorption

The degree to which a pesticide sticks to, or “adheres” to soil particles.

Expressed as the Adsorption Coefficient or Soil Sorption Index.



Herbicide Solubility and Adsorption

Herbicide (charge status)	Solubility	Koc
Paraquat (+)	620,000	1,000,000
Roundup (+)	15,700	24,000
2,4-D amine(-)/ester	796,000/900	20/100
Dicamba(-)	720,000	2
Glean (pH)	31,800	40
Classic (pH)	1,200	110
Spartan (pH)	780	43
Atrazine (pH)	33	100
Metribuzin (pH)	1,100	60
Dual	488	200
Outlook	1174	155
Treflan	0.3	7,000
Prowl	0.3	17,200



The Influence of pH on Solubility

Herbicide	5 pH	7 pH
Glean	587	31,800
Classic	11	1,200
Spartan	110*	780

* pH = 6



Herbicide Activation

- Availability for uptake by plants.
 - Soil solution
 - Vapor phase (minor for most herbicides)
- Distribution in the soil.
 - Mechanical incorporation
 - Movement with water



Effect of Precipitation Amount After Application on Herbicide Performance



Simmons et al. 1997



Weed Factors

- ☛ Species composition and susceptibility
- ☛ Seedbank
- ☛ Seed distribution in the soil
 - depth



Factors Affecting Postemergence Herbicide Performance

- ☛ Weeds
 - Species, Size/Growth Stage, Density
- ☛ Application Technique
 - Spray volume, droplet size, deposition and coverage
- ☛ Herbicide Properties and Adjuvants
- ☛ Environmental Conditions
 - Temperature, humidity, wind, rain, soil moisture
- ☛ Time of Day/light intensity



Weed Size Guidelines on Labels

- ☛ Herbicides generally recommended when weeds are small and actively growing, less than 3 to 4 inches.
- ☛ Application rates often based on weed size.



Effect of application stage on broadleaf weed control (Peterson & Regehr).

Herbicide	Timing*	Palmer Amaranth	Velvetleaf	Copperleaf	Ivyleaf morningglory
		(% control)			
Cobra	EP	93	50	95	70
	P	67	50	88	62
Synchrony	EP	93	98	0	94
	P	97	98	0	70
Roundup	EP	92	90	70	83
	P	95	83	83	87

* EP = early postemergence: 16 DAP, weeds < 4 inches
 P = postemergence: 23 DAP, weeds 2 to 12 inches



Preemergence Palmer Amaranth Control in Soybeans
10 DAP



Preemergence Palmer Amaranth Control in Soybeans
14 DAP



Preemergence Palmer Amaranth Control in Soybeans
20 DAP



Roundup PowerMax at 32 oz/A



Cobra at 12.5 oz/A applied 20 DAP



Temperature

- ☛ Influences rate of plant growth and development.
- ☛ Influences the rate of herbicide translocation and metabolism.
- ☛ Herbicides generally most effective with optimal temperatures for plant growth.
- ☛ The speed of herbicide activity is greatly influenced by prevailing temperatures.



Temperature

- ☛ Roundup absorption in johnsongrass doubled as temperature was increased from 75^o to 95^o. (McWhorter et al. 1980)

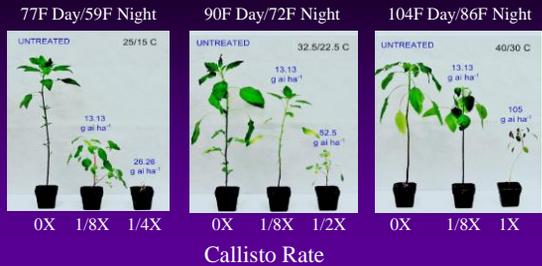


Temperature

- ☛ Glyphosate resistant marestalk was controlled similar to susceptible marestalk when sprayed and grown at low temperatures vs higher temperatures (Ge et al).
- ☛ Difference due to more rapid sequestration of glyphosate in the vacuole at higher temperatures.



Palmer amaranth response to Callisto at low, moderate and high temperature regimes (Jugulam et al).



Callisto metabolized more rapidly at higher than lower temperatures.



Relative Humidity

- ☛ Influences rate of droplet drying on the leaf surface. Higher RH = Slower drying and better absorption.
- ☛ Influences cuticle hydration. Higher RH = hydrated cuticle and enhanced absorption of water soluble herbicides.



Morningglory control as influenced by relative humidity (Wichert et al).

Herbicide	Relative Humidity	
	50%	85%
	(% control)	
Blazer	52	93
Cobra	56	91
Reflex	49	86



Amaranthus species control with Liberty as influenced by relative humidity (Coetzer et al).

Relative Humidity	Redroot Pigweed	Waterhemp	Palmer Amaranth
	(% control)		
35%	73	70	71
90%	100	81	88

Liberty provided 100% control of green foxtail with 95% relative humidity compared to 30% control with 40% relative humidity (Anderson et al)



Drought Stress

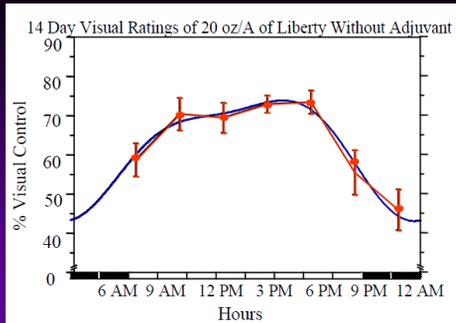
- ☛ Results in thicker leaf cuticles
- ☛ Reduces herbicide absorption, translocation, and metabolic interactions.
- ☛ Dramatically reduces herbicide performance.
- ☛ Do not spray if plants showing visible wilting symptoms.



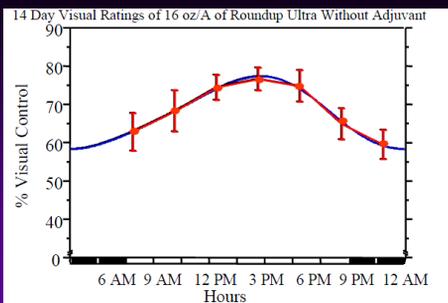
Application Time of Day

- ☛ Varying environmental conditions.
 - Temperature, humidity, wind
- ☛ Different light intensity.
- ☛ Influences plant physiological reactions
 - Photosynthesis, respiration, translocation etc.





Martinson et al



Martinson et al



The influence of application time of day on Roundup performance, Manhattan, KS, 1999.

Application Time of Day	Palmer Amaranth		Velvetleaf	
	Post	Late P	Post	Late P
	(% control)			
6:00 am	96	85	96	47
10:00 am	99	100	99	99
1:30 pm	100	100	99	99
5:00 pm	100	99	97	97
9:00 pm	99	88	95	47
Lsd (5%)	3		9	



Late Postemergence - 6 am



Late Postemergence - 10 am



Late Postemergence - 9 pm



Application Time of Day

- ☛ Weed control with Roundup was less when applied pre-dawn or post sundown than during the middle of the day.
- ☛ Possible reasons:
 - presence of dew
 - light influence on physiological interactions
 - plant leaf orientation



Leaf Orientation During the day and at Night

Velvetleaf

Palmer amaranth

Day:



Night:



Light mediated herbicides probably work best with bright sunny days.

- ☛ Paraquat
- ☛ PPO herbicides
 - Cobra
 - Aim
 - Flextar
 - Blazer



Summary

- ☛ Many factors interact to influence herbicide performance.
- ☛ Herbicides generally work best with good growing conditions.
- ☛ Follow individual label guidelines as closely as possible.

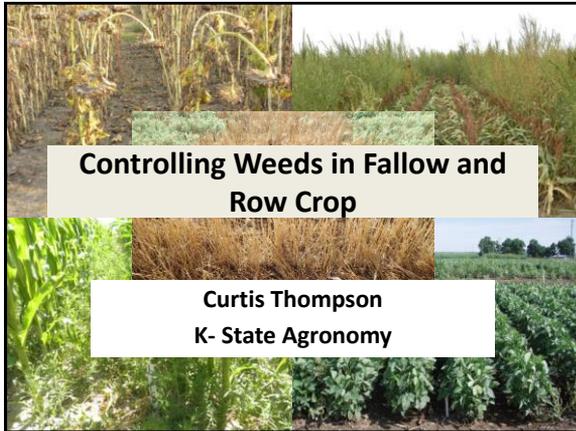


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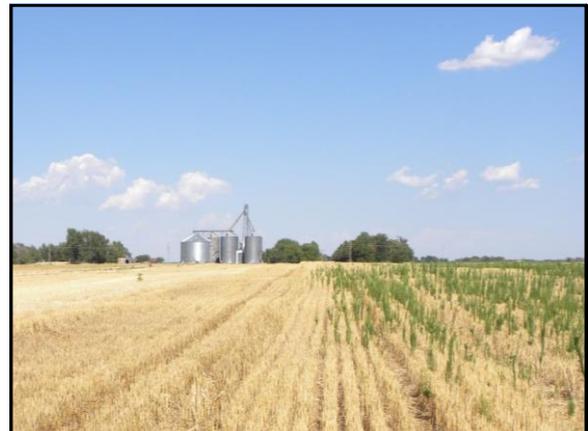
Knowledge
in Life



Topics in presentation

Weed management: Kochia and Palmer amaranth

- Weed Management in fallow
- Weed Management in Corn and Sorghum
- Weed Management in Soybean
- Weed Management in Sunflower

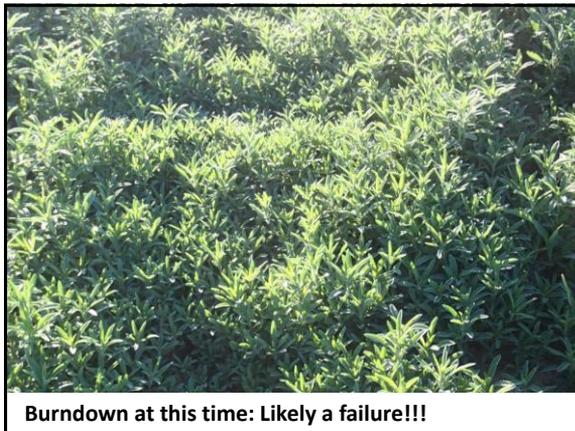


Weed control in Wheat and wheat stubble following harvest, SWREC Tribune 2014. Thompson, Schlegel, and Peterson. 1403whtTR

Treatment	Product Rate Lb / acre	Appl. time	Kochia in crop		Kochia in fallow	
			May 15	PreHarv	15 DAT	30 DAT
Clarity + 2,4-D/ Clarity+2,4-D+NIS+AMS	0.125+0.375/ 0.5+0.5+0.125%+2.5	Prejnt Fallow	63	51	55	64
Clarity+2,4-D+Zidua/ Clarity+2,4-D+NIS+AMS	0.125+0.375+0.106/ 0.5+0.5+0.125%+2.5	Prejnt Fallow	100	100	98	98
Clarity+Zidua/ Clarity+atra+Sharpen+MSO+UAN	0.125+0.106/ 0.5+1.0+.045+1%+2.5%w/v	Prejnt Fallow	100	96	100	100
Clarity+Huskie-NIS/ Atrazine+Sharpen+MSO+UAN	0.125+0.23+0.25%w/v / 1.0+.045+1%+2.5%w/v	Prejnt Fallow	93	83	99	95
Rave+NIS/ Atrazine+Sharpen+MSO+UAN	0.147+0.5% w/v / 1.0+.045+1%+2.5%w/v	Prejnt Fallow	68	65	100	93
Widematch/ Atrazine+Sharpen+MSO+UAN	0.25/ 1.0+.045+1%+2.5%w/v	Prejnt Fallow		94	100	100
LSO (0.05)			9	11	7	8

Kochia control in wheat stubble with no in wheat crop treatment, SWREC Tribune 2014. Thompson, Schlegel, and Peterson. 1403whtTR

Treatment	Product Rate Lb / acre	Appl. time	Kochia in fallow	
			15 DAT	30 DAT
Clarity+Sharpen+Linex+MSO+UAN	0.5+0.045+0.75+1%+2.5% v/v	Fallow	93	88
Clarity+Atrazine+COC	0.5+1.0+0.5%	Fallow	71	65
Clarity+atra+Sharpen+MSO+UAN	0.5+1.0+.045+1%+2.5%v/v	Fallow	98	94
Clarity+atra+Impact+MSO+UAN	0.5+1.0+.022+1%+2.5%v/v	Fallow	86	86
Atrazine+Impact+MSO+UAN	1.0+.022+1%+2.5%v/v	Fallow	84	78
Gramoxone SL+atra+COC	0.75+0.25+1% v/v	Fallow	99	85
Gramoxone SL+Linex+COC	0.75+0.75+1%	Fallow	100	88
Clarity+2,4-D+NIS+AMS	0.5+0.5+0.125%+2.5	Fallow	46	68
LSD (0.05)			7	8



Postemergence control of kochia in fallow, Tribune 2011.

Treatment	Product rate	Prod. Cost \$	Kochia control (%)	
			May 30, 16DAT	June 11, 28DAT
Distinct+AMS+NIS	4+17lb+.5%	9.48+1.82+1.05	61	68
Distinct+2,4-D LV4+AMS+MSO	4+8+ 17lb+.5%	9.48+1.38+ 0.82+3.15	55	73
Sharpen+2,4-D LV4+AMS+MSO	1+16+ 17+1%	6.24+2.76+ 0.82+3.15	79	68
Sharpen+atrazine +AMS+MSO	1+12+ 17+1%	6.24+1.77+ 0.82+3.15	86	76
Starane NXT	14	8.45	79	75
Huskie+AMS+NIS	15+8.5 +0.5%	13.27+0.41+ 2.10	76	65
Huskie+atrazine+ AMS+NIS	15+8FL oz +8.5 lb+.5%	13.27+1.18+ 0.41+2.10	87	80

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

Treatment	Product rate	Prod. Cost \$	Kochia control (%)	
			May 30, 16DAT	June 11, 28DAT
Laudis+atrazine+ AMS+MSO	3+8+ 8.5+1%	17.85+1.18+ 0.41+3.15	76	60
Callisto+atrazine+ AMS+MSO	3+8+ 8.5+1%	18.06+1.18+ 0.41+3.15	80	60
Impact*+atrazine +AMS+MSO	0.75+8+ 8.5+1%	**,**+1.18+ 0.41+3.15	76	66
Impact*+atrazine +UAN+MSO	0.75+8+ 2.5%+1%	**,**+1.18+ 0.30+3.15	82	79
Impact*+atrazine +UAN+MSO	1.0+8+ 2.5% +1%	23.25+0.97+ 0.30+77	85	84
Rup Wmax+AMS	32 oz + 17 lb	8.90+0.82	85	85

* Impact (Amvac) \$25.20/oz = Armezon (BASF) \$18.40/oz

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

Treatment	Product rate	Prod. Cost \$	Kochia control (%)	
			May 30, 16DAT	June 11, 28DAT
Gramoxone SL + atrazine+COC	48 + 16+1%v/v	15.37+ 2.36+ 2.25	94	91

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

In rowcrop or wheat stubble ahead of wheat planting the following fall!

- Aatrex – Do NOT apply following sorghum or corn harvest when rotating to wheat!
- Metribuzin 75 – wheat can be planted following 120 days after spring application of 1/2 to 2/3 lb of product.

Scoparia (Bayer Crop) for fallow, eco-fallow

- Scoparia contains 4 lb ai isoxaflutole /gallon. This formulation does NOT contain the safener found in Balance Flexx.
- Recommended rates are 1.5 to 2.5 oz/a for controlling kochia and Russian thistle in fallow. This may be fall or spring applied.
- Apply with COC, MSO, or HSOC and UAN or AMS.
- Ahead of corn, apply with atrazine. Ahead of fall wheat planting, apply with metribuzin.
- Fall applications are limited to areas west of the North/South interstates I-35 and I135. Spring applications can be state wide.
- Do NOT apply to frozen soil.

– This is a Section 24 (c) Special local need label valid through December 31, 2019.

Scoparia plantback restrictions.

<u>Crop</u>	<u>Months</u>	<u>Precip Required</u>
Field corn	4	0 inches
Wheat, triticale	4	4 inches
Soyb, Pop & Sweet		
Corn, grain sorghum,		
Oats, Rye, Sunflower	9	15 inches
Alfalfa, cotton, rice	10	15 inches
Peanuts	11	15 inches
Drybeans	18	15 inches
All other crops	18	15 inches

Corvus (Bayer Crop) for fallow, eco-fallow

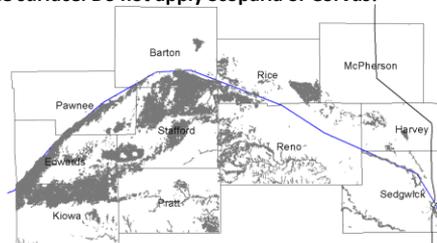
- Corvus is a mixture of Balance Flexx and thien carbazono-methyl. Contains safener.
- Recommended rates are 3 to 4 oz/a for controlling kochia and Russian thistle in fallow. This may be fall or spring applied.
- Apply with COC, MSO, or HSOC and UAN or AMS.
- Ahead of corn, apply with atrazine. Ahead of fall wheat planting, apply with metribuzin.
- Fall applications are limited to areas west of the North/South interstates I-35 and I135. Spring applications can be state wide.
- Do not apply to frozen soil.

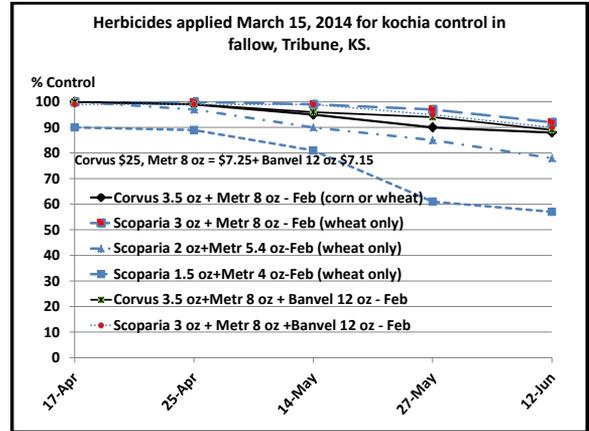
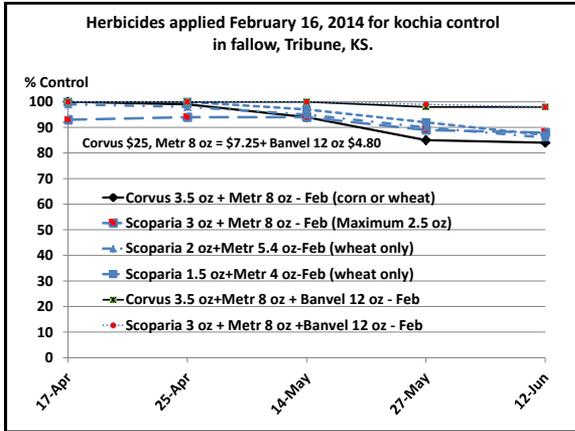
– This is a Section 24 (c) Special local need label valid through December 31, 2019.

Corvus plantback restrictions.

<u>Crop</u>	<u>Months</u>	<u>Precip Required</u>
Field corn	0	0 inches
Wheat, triticale	4	4 inches
Soyb, Pop & Sweet	9	15 inches
Cotton, rice	10	15 inches
Peanuts	11	15 inches
Alfalfa, drybeans,		
Oats, sorghum, sunflower		
Canola, Potato,		
All other crops	17	30 inches

Scoparia and Corvus herbicides – In Kansas and especially in this area, restrictions apply when Loamy sands or sandy soils occur over a water table that is less than 25 ft below the surface. Do not apply Scoparia or Corvus!





Authority MTZ (FMC) for fallow, eco-fallow

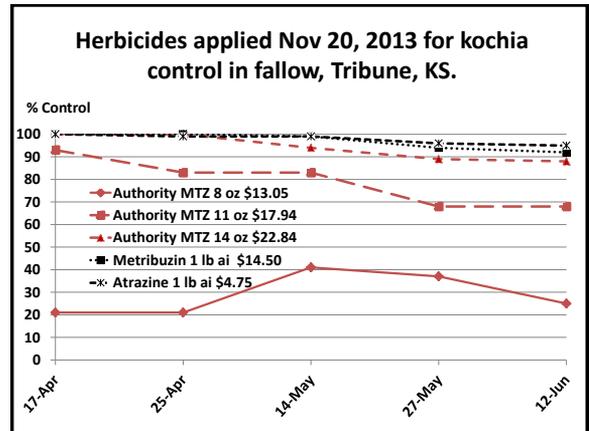
May be Tank mixed with burn down herbicides labeled for fallow.

Crop	Weed	% OM	Use Rate oz Product / acre		
			Coarse	Med	Fine
Fallow,Ecofallow	Kochia, COLQ	1-2	8-10	8-12	10-12
	Russian Thistle	2-4	8-12	10-14	12-16

Plant back restrictions:

Crop	Recropping interval (months)
Wheat, Barley	4
Field corn	4 (if 14 oz or Less), 10
Sorghum, sunflower	12 if less than 20 oz
Soybean	anytime

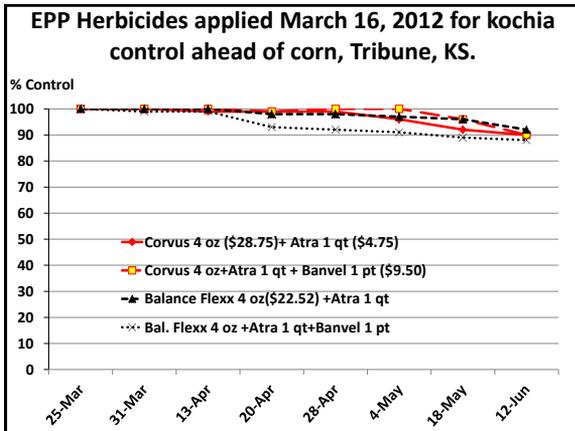
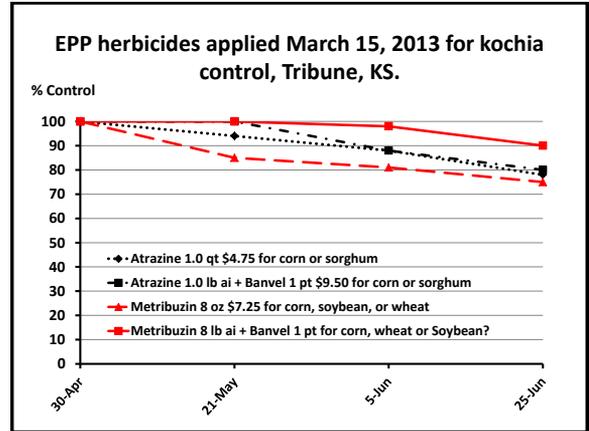
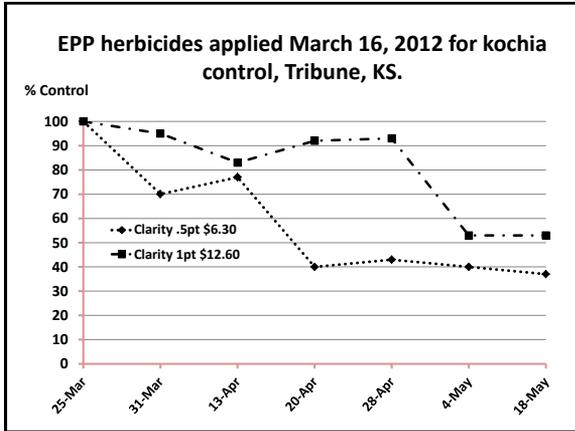
- This is a Section 24 (c) Special local need label valid through December 31, 2019.
- 16, 14, 12, 10, 8 oz of Authority MTZ = approximately \$26, 23, 19.50, 16, 13



Palmer amaranth in fallow?

- Glyphosate resistance increases the problem!!
- Wet weather during wheat maturation will likely allow rapid growth on Palmer amaranth.
- In crop spring wheat treatments may have inadequate residual for good Palmer control.
- Glyphosate (see label) + 2,4-D ester or Aim can be used on wheat pre-harvest when wheat is hard dough, 30% moisture or less, and a 7 day PHI has been observed.
- Implement control strategies immediately following harvest if Palmer is present and good growing conditions exist. Leave stubble height as tall as possible to allow herbicide coverage on Palmer.





Weed management in conventionally tilled irrigated Corn, Tribune KS, 2014

Treatment	Time	Rate	Herbicide	Yield	% control	
					Kochia	Palmer
Corvus+atrazine	PRE	3 oz + 1 qt	21.57+4.75	114	85	81
Anthem ATZ	PRE	2 pt	27.5	106	84	90
Anthem ATZ/ Solstice+RPM+atra	PRE POST	2 pt 3.15+32+16 pt	27.50/ 16.79+7.25+2.38	142	90	85
Harness Xtra/ Roundup Pmax	PRE POST	3.2 pt 32 oz	22.88/ 7.25	131	91	83
Harness Xtra RPM+Imact+Atra	PRE POST	3.2 pt/ 32+1.0oz+1pt	22.88/ 7.25+25.20+2.38	158	100	92
Harness Xtra Impact+At+Status	PRE POST	3.2 pt/ 1.0+1pt+3 oz	22.88/ 25.20+2.38+11.5	160	100	90
Solstice+RPM+atra	POST	3.15+32+16 oz	16.75+7.25+2.40	99	78	74
Status+RPM	POST	5 oz + 32 oz	19.25+7.25	84	48	59
Halex GT	POST	3.6 pt	26.08	103	60	91
Untreated/LSD 0.05		LSD 0.05		40/31	9	9

POST trts applied with 1.0% COC (Solstice) or MSO (Impact) + 17 lb AMS/100 gal



Weed management in sorghum, Ashland Bottoms, Manhattan KS, 2014, 1428sorg, Thompson and Peterson

Treatment	Timing	Rate	Herbicide	Yield	Palmer	VELE
		Prod. / acre	Cost/A	Bu/a	% control	
Lumax EZ	Pre	2.7 qt	\$50	110	99	100
Huskie+atrazine	POST	13oz + 1 pt	\$13.88	100	84	100
H+A+2,4-D LV4	POST	13+1+4 oz	\$14.57	88	89	100
H+A+Starane Ultra	POST	13+1+6.4 oz	\$28	105	93	100
H+A+Clarity	POST	13+1+4 oz	\$17	108	90	100
Starane NXT+Atra	POST	14 fl oz+1pt	\$10.83	76	77	87
Dual II Magnum/ Huskie+atrazine	Pre POST	1.3 pt 13+1 pt	\$20 \$13.88	105	100	100
Dual II Magnum/ Clarity+atrazine	Pre POST	1.3 pt/ 8 oz+ 1 pt	\$20 \$8.67	105	89	85
Dual II Magnum/ Aim EC+atrazine	Pre POST	1.3 pt/ 0.5 oz+1 pt	\$20 \$5.88	103	97	94
Untreated				5	--	--
		LSD (0.05)		16	8	4
Huskie trts applied with 0.25% NIS + 1 lb / a of dry AMS (\$1.05+\$0.40/acre)						

Kochia And Palmer control PRE in sorghum

- Preemergence products – Highly recommended!
 - Lumax EZ 2.7 qts \$50
 - Lexar EZ 3.0 qts \$46.80
 - Degree Xtra 2.0 to 3.7 qts \$23.95-44.30
 - Bicep II Mag/Bicep Lite II Mag 1.6to2.1 qt \$18.60-24.40, 1.1 to 1.5 qt \$16.90-23.06
 - Sharpen 2 oz \$12.48 (Add to chloracetamide+atrazine)
 - Verdict 10 oz \$18.40 (8.3 oz Outlook + 2 oz Sharpen) (Add to chloracetamide+atrazine)
 - Outlook 12 to 21 oz \$13.23-23.16 (add atrazine)

Kochia and Palmer control POST in sorghum

- Treat kochia and Palmer early!!!!!! Small weeds are easier to kill!!!!!!
- Banvel, Clarity, or generics or Starane products are a key component of a post program. Starane less active on Palmer. Adding 0.5 lb atrazine could be very beneficial.
 - atrazine \$4.75 / lb ai
 - Clarity 0.5 pt \$6.30, Banvel 0.5 pt \$4.78
 - Starane Ultra 0.4 pt \$14.10
 - Starane NXT 21 oz \$12.67
 - Starane Ultra 0.4 pt \$14.60
 - Huskie 12.8 to 16 oz \$11.32 to 14.15

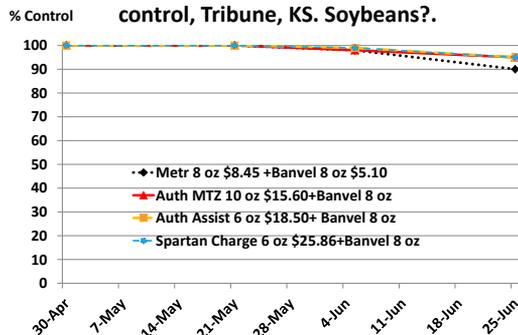
Weed Management in Soybeans and Sunflower



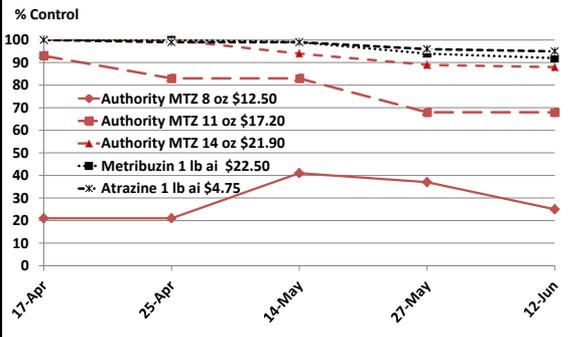
Soybeans and Sunflower

- Planting into clean seed bed is essential!
 - Marestail, kochia, and Palmer amaranth are concerns if not controlled well in advance of planting.
 - EPP's may likely be required if dealing with glyphosate resistance with fall trts for marestail and possibly kochia.
 - POST options are minimal to none.

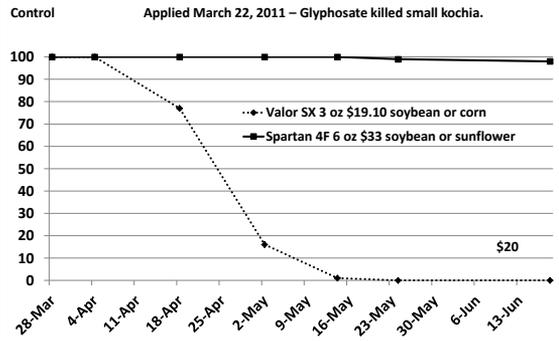
Herbicides applied March 15, 2013 for kochia control, Tribune, KS. Soybeans?.



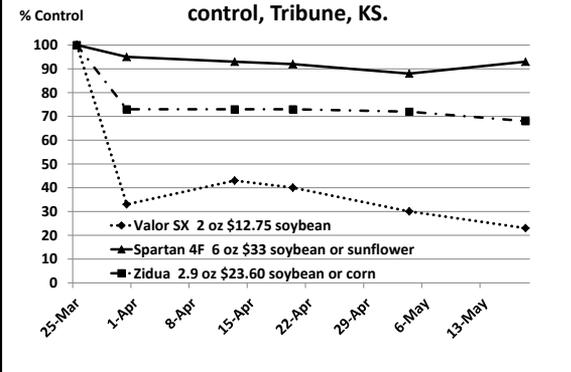
Herbicides applied Nov 20, 2013 for kochia control in fallow or ahead of soybean and corn, Tribune, KS.



EPP herbicides for kochia control, Tribune 2011.



PRE herbicides Applied March 16, 2012 for kochia control, Tribune, KS.



Kochia Control with Selected Herbicides in Soybeans, 2009-10. Brandon Hulse et al



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

Herbicide	Rate g ai/ha	WAP		Cost \$/acre
		4 WAP % control	8 WAP % control	
Valor	2 oz	83	98	13.56
Valor	3 oz	99	98	20.36
Spartan 4F	6 oz	100	100	33.00
Spartan 4F	9 oz	100	100	49.50
Authority First*	6 oz	100	100	32.85
Authority MTZ	16 oz	100	100	26.10
Valor XLT*	4 oz	100	100	20.35
Prowl H2O + Valor	3 pt + 2 oz	95	100	18.15+13.56
Prowl H2O + Spartan	3 pt + 6 oz	100	100	18.15+33
Prefix+ Dimetric or Tricor	1 qt+ 1 lb	100	99	13.0+14.5
Roundup Powermax + AMS	22 oz		95	5.87
Roundup Powermax + AMS	44 oz		95	10.85
LSD		9	5	

All PRE herbicide treatments were followed by POST applied Roundup Powermax at 22 fl oz/a + AMS at 17 lb/100 gal.

*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.

Herbicide treatment	Rate/A	Cost/A ¹	Kochia ³	Pigw spp ²	Bu/A ²
Authority First PRE fb	3 oz	\$16.43	83 ab	85 a	24 a
Liberty + Cadet + AMS ⁴ POST	29 oz + 0.9 oz	\$33.02			
Authority MTZ PRE fb	10 oz	\$16.30	90 a	94 a	27 a
Liberty + Cadet + AMS ⁴ POST	29 oz + 0.9 oz	\$33.02			
OpTill PRE fb	2 oz	\$14.75	84 ab	96 a	25 a
Liberty + Cadet + AMS ⁴ POST	29 oz + 0.9 oz	\$33.02			
Verdict PRE fb	5 oz	\$9.20	73 abc	95 a	24 a
Liberty + Cadet + AMS ⁴ POST	29 oz + 0.9 oz	\$33.02			
Dual II Magnum PRE fb	1.25 pt	\$19.23	63 bc	90 a	22 a
Liberty + Cadet + AMS ⁴ POST	29 oz + 0.9 oz	\$33.02			
Prefix PRE fb	2 pt	\$13.00	71 abc	97 a	20 a
Liberty + Cadet + AMS ⁴ POST	29 oz + 0.9 oz	\$33.02			
Boundary PRE fb	2 pt	\$21.60	85 a	99 a	25 a
Liberty + Cadet + AMS ⁴ POST	29 oz + 0.9 oz	\$33.02			
Raptor + MSO POST	4 oz + 1% v/v	\$21.15	64 bc	53 b	19 a
Liberty + Cadet + AMS ⁴ POST	29 oz + 0.9 oz	\$33.02	59 c	66 b	22 a

¹Application not included ²# of trials ³17 lb/100 gal Phil Stahlman et al

Summary of kochia control in soybean

- Control kochia early before planting!
- Soil applied herbicides are essential.
- Authority/Spartan (sulfentrazone) based products are 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 Liberty for post kochia control in Liberty-Link beans is very risky!

Controlling kochia and Palmer in a sunflower crop.



Kochia control in sunflower

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

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

Herbicide	Product	Cost	Kochia	RUTH	RRPW	PUVI
	Rate/acre	\$/acre	-----% control -----			
Dual Mag.	1.5 pt	23.40	28	64	76	74
Prowl H2O	2.6 pt	15.50	46	65	64	80
Dual Mag.+ Prowl H2O	1.3 pt + 2.6 pt	20.30 + 15.50	63	80	70	79
Dual Mag. + Spartan	1.3 pt + 4 fl oz	20.30 + 22	94	98	90	87
Prowl H2O + Spartan	2.6 pt + 4 fl oz	15.50 + 22	95	97	82	66

Evaluations were made 40 days after PRE herbicide application.
RUTH = Russian thistle, RRPW = redroot pigweed, PUVI = Puncturevine

Summary

- Managing kochia and Palmer 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 and Palmer requires extended residual.
- Implementing strategies that control the huge early flushes of kochia may be critical to a successful kochia management program, regardless of crop planted, however does not adequately control Palmer.
- Timeliness of POST herbicide applications is essential!!
- Frequency of glyphosate resistant kochia and Palmer likely is going to increase.

Questions?

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- Cell 785 532-3444 or Of 785 477-4639
- <http://www.ksre.ksu.edu/bookstore/pubs/SRP1117.pdf> - new one to printer Nov 25

Wheat Yield and Development
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Final grain yield is the result of developmental and growth processes of the wheat plant from seed germination to grain maturity. Knowing the sequence and timing of events during wheat canopy development helps understanding how yield potential is determined, assess how the plant “perceives” its environment, and improve management practices. Wilting and tissue color change are common signals indicating water or nutrient stress. Combined with knowledge of how the wheat plant develops, signals such as these provide ways to estimate the outcome of yield-impacting situations and guide the selection and application of management tools to minimize the negative effects. This handout provides a general discussion of the yield potential and yield components of winter wheat, and summarizes the considerable research covering winter wheat development that leads to determining the yield potential as background material for the talk. The basic premise is that better understanding of how the wheat plant develops will provide a solid foundation for solving production and environmental problems, including maximizing yield.

Yield Potential, Yield Components, and Final Yield

The wheat plant is remarkably resilient and flexible in forming final yield because the plant can take alternative paths in reaching final yield. Five yield components determine yield potential:

- 1) Number of plants per acre,
- 2) Number of heads (spikes) per plant,
- 3) Number of spikelets per head,
- 4) Number of kernels per spikelet, and
- 5) Kernel size.

Number of plants per acre and number of heads per plant can be combined as number of heads per acre, and number of spikelets per head and number of kernels per spikelet can be combined to create kernels per head.

A yield triangle is a useful representation of how yield components interact to achieve a given yield (Figure 1). The triangles shown in Figure 1 represent the yield potential at the beginning of grain filling for two different growing conditions. The actual yield is determined by the kernel number per unit area and the size of the kernels. Grain filling can be thought of as a pipe (the process of) delivering material (carbohydrate) to fill the triangle (kernels). Under desirable conditions all kernels fill to their potential and yield is high. Under stressful conditions, kernel filling is limited (the flow of carbohydrate to the kernels is reduced) and yield is less than the potential.

Research usually shows that yield components related to number of plant parts (number of tillers per acre, number of kernels per head) are more important in determining yield than size of the parts (kernel size) in semi-arid production systems such as the Great Plains. Though this statement may seem counter intuitive, it reflects the fact that kernels tend to be more similar in size across years and varieties than number of heads or kernels. It follows that the number of

heads per acre is the most important yield component in that it is most affected by environmental conditions (weather, management, etc.).

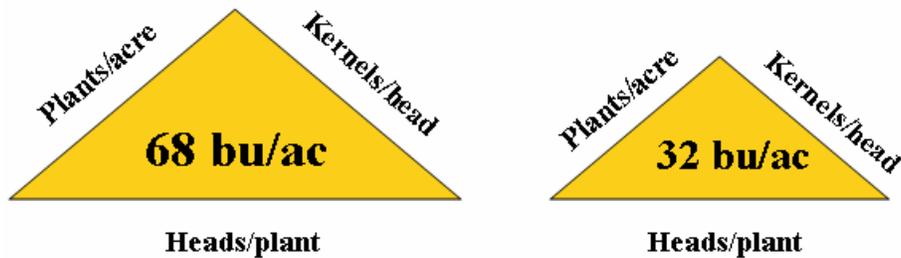


Figure 1. Yield components and grain yield. Yield components define the potential yield for the environmental conditions created during various dynamic developmental stages. Grain filling rate and duration ultimately define yield by determining kernel weight.

Wheat Development

*So nature glories in her highest growth,
Showing her endless forms in orderly array.
None but must marvel as the blossom stirs
Above the slender framework of its leaves.*

Johann Wolfgang Goethe
(*Metamorphosis of Plants*, 1791)

Although J.W. Goethe is most commonly known for his literary works (e.g., *Faust*), he also is considered the father of plant morphology. This quote illustrates that it has been long-recognized that plants develop in an orderly manner, and much subsequent research has extended this viewpoint to include that plant development is also predictable. While there are always exceptions, this applies to all crop plants and there are certain commonalities among crop plants. For a particular species, genes provide the blueprint for building the canopy, and the environment adjusts the blueprint to what is finally built.

The phytomer concept presented by Gray in 1879 has provided a sound botanical basis for understanding plant development, canopy architecture, and the dynamic nature of plant canopies in the field. The concept is simple in its basic conceptualization of canopy development, as canopies are built by the addition, growth, and abortion/senescence of basic building blocks (i.e., phytomers) that are repeated within and among all shoots on a plant. The phytomer, usually considered a vegetative unit of a leaf, node, internode, axillary bud, and occasionally nodal roots, has been extended to the inflorescence with units repeated within and among shoots (see Figure 2). Each shoot on a plant is built with the sequential addition of phytomers, and each particular phytomer may vary in the size of each of the component parts. The axillary bud can develop further into either another shoot (= tiller in wheat) or an inflorescence structure (= tiller in the first few leaves of corn, or the ear in later leaves).

The canopy architecture can be viewed as the orderly appearance of phytomers and this leads to being able to uniquely identify each leaf, shoot, and inflorescence. This is important not only in communicating what part of the plant we are interested in, but provides us with other signals from the plant about the effect of the environment it was/is growing in. Each leaf is named based on the order of appearance from the earliest to latest (see Figure 3). Tillers are

named based on which leaf on the shoot it appears from (see Figure 4). Similarly, each spikelet and floret/kernel within a spikelet can be named (see Figure 5). One important use of understanding and naming the parts of the canopy is that this can tell us about how the plant perceives its environment. For instance, since each individual tiller can only appear within a specific window of time based on the number of leaves of the shoot, if the tiller is missing from the plant then there were insufficient resources to have the axillary bud grow into a tiller. Or since successive leaves on a shoot increase in size, if one leaf is smaller than the preceding leaf then insufficient resources limited its growth from its potential.

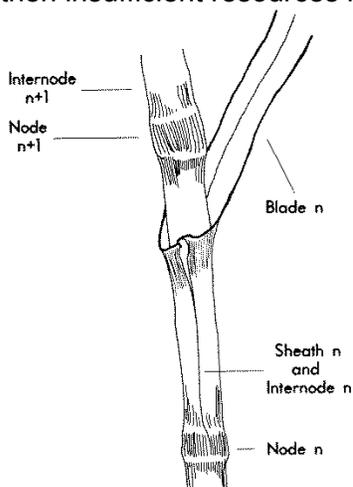


Figure 2. The most common definition of a phytomer consists of the leaf, node, internode, and axillary bud (located just above the node).

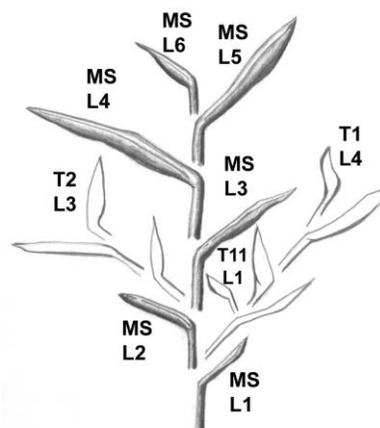


Figure 3. Leaf naming convention is to use "L" followed by a number, beginning with the first leaf to appear on the shoot

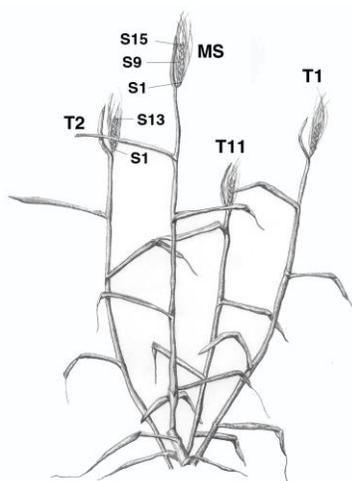


Figure 4. Tiller naming convention is to use a "T" followed by a digit(s). Primary tillers are those formed from the main stem, secondary tillers are formed from leaves on the primary tillers, etc.

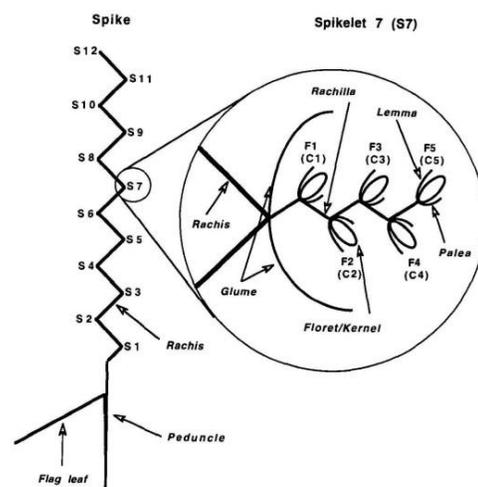


Figure 5. Each spikelet within a spike/head on a shoot is sequentially numbered from the most basic spikelet. Each floret/kernel is sequentially numbered from the base of the spikelet.

Although the phytomer concept and morphological naming of plant parts on wheat development can provide useful insights in understanding the creation of yield potential and yield components, taking an alternative approach to viewing wheat development might be more helpful. Most of us are more familiar with viewing wheat development by looking at the progression of readily discernible growth stages such as that shown in Figure 6. However, other important developmental events occurring at the shoot apex (or meristem or growing point) are not readily visible (and some of these are noted at the top of Figure 6).

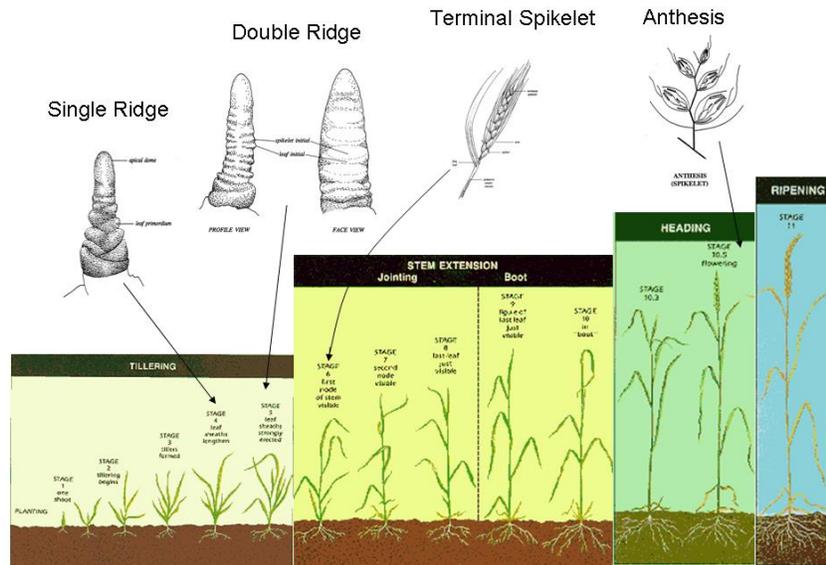


Figure 6. Sequence of general development of the wheat canopy. The bottom portion of the figure shows readily visible growth stages, and drawings above this note the timing of developmental events occurring at the shoot apex that are visible only by magnification.

A finer resolution of Figure 6 is shown in Figure 7. Figure 7 depicts the sequence of developmental events from seed germination to plant maturity. Many of these events normally occur at the shoot apex, and their correlation with growth stage indicates when they occur. This time line or developmental sequence can be used to understand which yield components are affected at any specific time. All cultivars follow this developmental sequence, but they can vary in the rates and duration of developmental events. These variations are an important consideration in cultivar selection, such as using late maturing cultivars for locations with a high probability spring freeze injury to the developing head. The overall development sequence also is important in understanding why management practices frequently target certain growth stages for maximum efficacy.

After plants emerge, two linked processes occur simultaneously: leaf and tiller appearance. Tillering usually begins about 2 weeks after emergence, if temperatures are adequate. Leaves and tillers are formed at the growing point of each stem during the fall, winter, and early spring until the single ridge growth stage, usually in March. The double ridge stage signals the shift from only vegetative growth to the beginning of the initiation of the wheat head. This important growth stage is only visible under magnification, but is protected from low temperatures because it is underground. The double ridge stage is when spikelets are being initiated, which strongly influences the number of kernels per head. Spikelets and florets (i.e., flowers) within spikelets form from double ridge through booting. Booting marks the completion

of the flag leaf, which is the most important leaf for supplying carbohydrates to kernels during grain filling. Different parts of the flower are initiated from booting until heading or flowering, which usually occurs in early June. Heading and flowering occur in very rapid succession. The maximum kernel number per head is determined during flowering. Subsequent stress-induced abortion may reduce kernel number per head slightly, however, only those flowers that are fertilized at flowering can develop into kernels and contribute to yield. All yield components related to number (i.e., number of plants, tillers, heads, spikelets, and florets/kernels) have been determined by flowering. The final developmental stages relate to kernel growth, where kernels increase in size and yield is created (Figure 1). The last stage is maturity, the process of finalizing yield and drying of grain to harvest water content. Kernel size is set during this stage, with maximum size determined by mid-July. Jointing (or the beginning of stem elongation and growth) is one growth stage of particular importance often not recognized. This is for a number of reasons including 1) many important developmental events that influence yield potential are just beginning or ending near this growth stage, this is the time that many of the tillers begin to abort, and often the only indication that this is happening is the youngest leaf turns brown, and 3) the canopy has nearly reached its maximum leaf area index and photosynthetic capacity and this is the time that the major sink for carbohydrates is for stem growth (leaf and head sinks are very low) so carbohydrate reserves for later grain filling can occur.

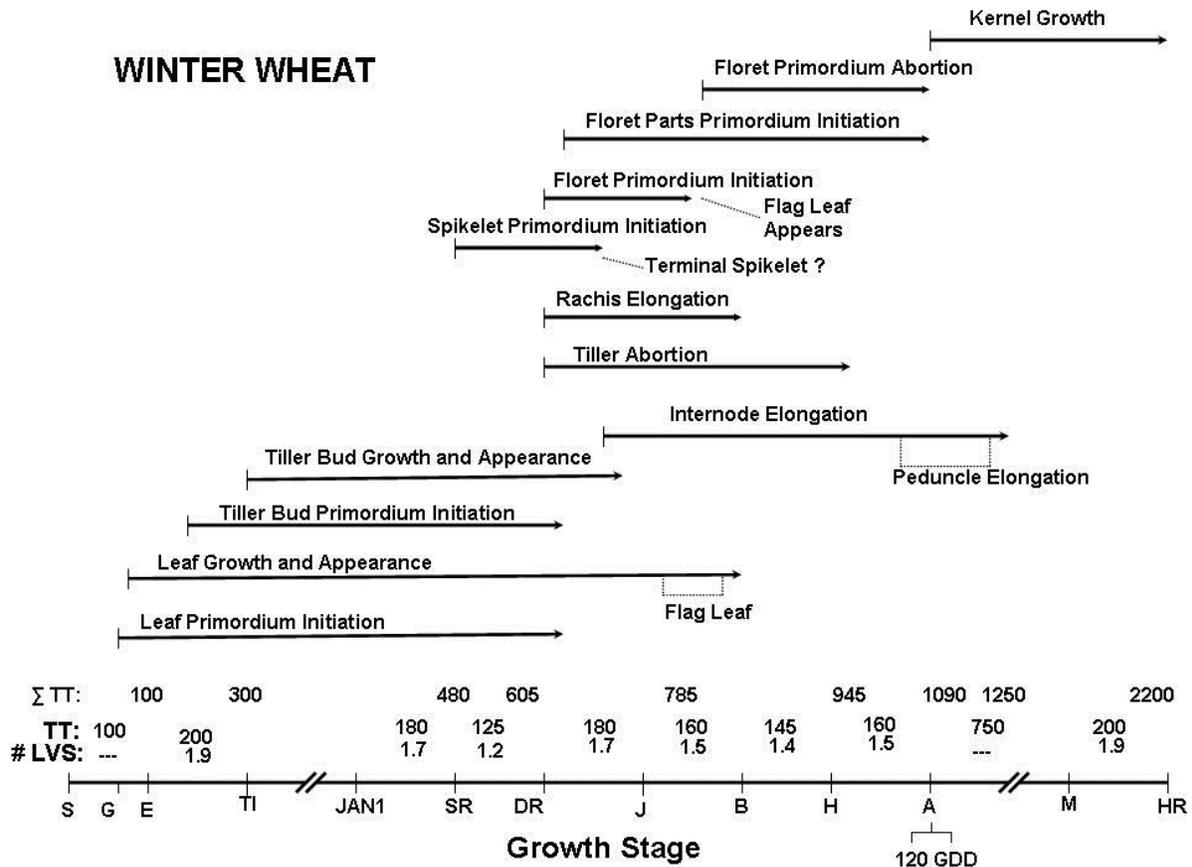


Figure 7. Developmental sequence of the winter wheat shoot apex correlated with growth stages. (PD = planting date, E = emergence, TI = initiation of tillering, SR = single ridge, DR = double ridge, J = jointing, B = booting, H = heading, A = anthesis/flowering, M = maturity.) Growing degree-days (GDD in °C) are included as an approximation for a generic cultivar and vary with cultivars and conditions.

Wheat Phenology

Phenology (the study of influence of the environment on the timing of growth stages) is an important component of wheat development and merits some more detailed comments than presented above, particularly since management is increasingly being tied to specific developmental stages. For wheat, as with all crops, temperature is the most important environmental variable influencing the time when nearly all developmental stage occurs (remember, there are always exceptions!). Certainly for specific developmental stages other environmental variables such as water, nutrients, and sunlight can influence the timing as well. Given the primary importance of temperature, much research has focused on how to use temperature in predicting phenology. In 1735, Reaumur first proposed what is now known as thermal time, or heat units, or growing degree-days (GDD). Since then many way of calculating thermal have been used, but the most basic form is:

$$\text{GDD} = \frac{(\text{Tmax} + \text{Tmin})}{2} - \text{Tbase}, \quad (\text{GDD cannot be negative.})$$

with Tmax being the maximum temperature of the day, and Tmin being the minimum. Tbase is lowermost temperature for which growth can occur. Tbase for wheat is often set to 0°C or 32 °F.

GDD are commonly used to predict when a growth stage will be reached, and for a generic winter wheat plant the number of GDD between growth stages are shown in Figure 8 for two conditions: well-watered/optimal and very dry, but non-lethal. For crops such as corn where the initial “V” growth stages referring to number of leaves that have appeared, GDD are used to estimate the rate of leaf appearance (called the phyllochron). This approach is commonly used both in detailed crop simulation models and more general computer programs such as PhenologyMMS for predicting crop phenology. If long-term weather data are available, the average expected date specific growth stages would occur can be predicted and used for guiding management practices.

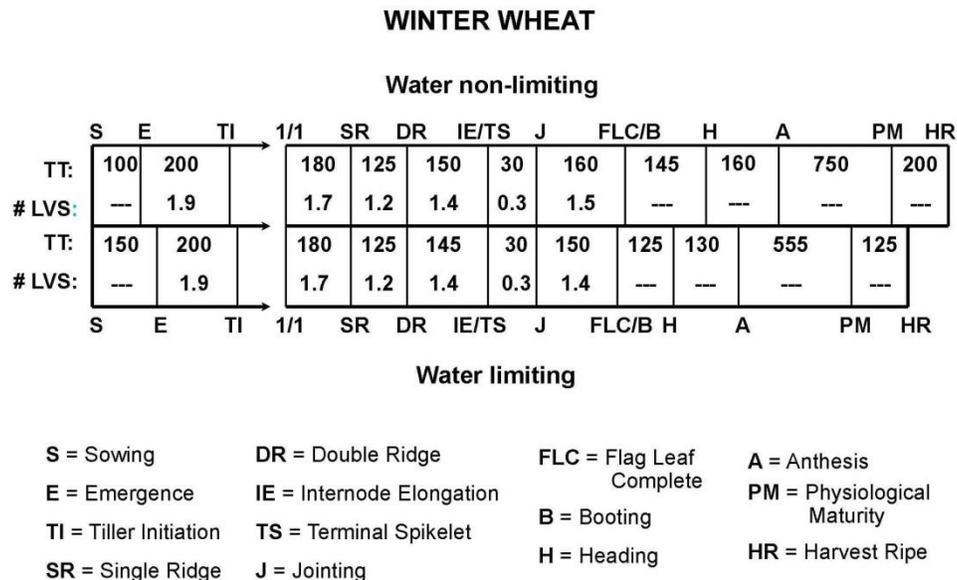


Figure 8. Winter wheat phenology for both water non-limiting and limiting conditions for a generic winter wheat. Intervals between stages are shown as both the thermal time (TT in growing degree-days, GDD, using 0°C base) and the number of leaves (# lvs) for a generic cultivar. Individual cultivars will vary in the actual numbers.

Farm Bill Choices in 2015

Daniel O'Brien – Extension Agricultural Economist, Kansas State University

Mark Wood – Extension Agricultural Economist, KSU Northwest Kansas Farm Management Association

Summary

As Kansas farmers consider which USDA farm program option to select for the next five years, they need to consider the coverage provided by revenue protection (RP) insurance available from private industry along with the “shallow loss” and price coverage options available from the USDA Farm Service Agency.

The author's intent in this presentation is to examine a number of issues related to the choice or “election” of farm program options that farmers will make in a unique and thought provoking manner. This will involve both a look into the past with regard to how the current farm program would have performed over the 2000-2014 time period. An effort will also be made to anticipate what the future may hold in terms of farm income coverage under alternative U.S. production and price scenarios for this program. In this presentation, ARC-CO will refer to “Agricultural Risk Coverage – County Option”, whereas PLC will refer to “Price Loss Coverage”. The Supplemental Coverage Option (SCO) available in tandem with PLC will be discussed in more detail in the Cover Your Acres Conference presentation.

Regarding how this program would have performed over the 2000-2014 period if it had been instituted, a number of calculations for major crop enterprises in Thomas County in Northwest Kansas have been developed, and are represented in the following sets of figures:

Figures 1a & 1b: Irrigated Corn in Thomas County

Figures 2a & 2b: Non-irrigated Corn in Thomas County

Figures 3a & 3b: Non-irrigated Grain Sorghum in Thomas County

Figures 4a & 4b: Non-irrigated Wheat in Thomas County

Figures 5a & 5b: Irrigated Soybeans in Thomas County

Several key assumptions are made in this analysis, including “scaling” of PLC Reference Prices downward representing a percentage of a moving average of past historical marketing year average prices. If left unchanged, the current set of reference prices would “dominate” the lower U.S. grain prices that occurred during the 2000-2007 time period.

These analyses provide several key findings. First, as likely expected irrigated corn and soybeans in Thomas County showed markedly fewer incidences of payouts from either revenue insurance, ARC-CO, and PLC than for non-irrigated cropping alternatives. Second, estimated insurance and ARC-CO payments for non-irrigated grain sorghum and corn were very similar during the 2000-2014 period, with payments being made a number of times to farmers during the drought-affected years of 2000-2006, and also in 2012-2014. Few payments of from crop revenue insurance and ARC-CO were made during the 2007-2011 time period. Third, payments to crop producers from price-only based PLC coverage were made less frequently than under ARC-CO coverage. Fourth, when crop losses were incurred by farmers, revenue insurance payments were usually markedly larger than those from either ARC-CO or PLC – reinforcing the idea that the USDA “shallow loss” coverage tools were designed to work best as a supplement for more traditional crop revenue coverage tools than a complete replacement.

Figure 1a. Irrigated Corn Revenue, Insurance Payouts, & Benchmark Revenue for Thomas County, Kansas (2000-2014)

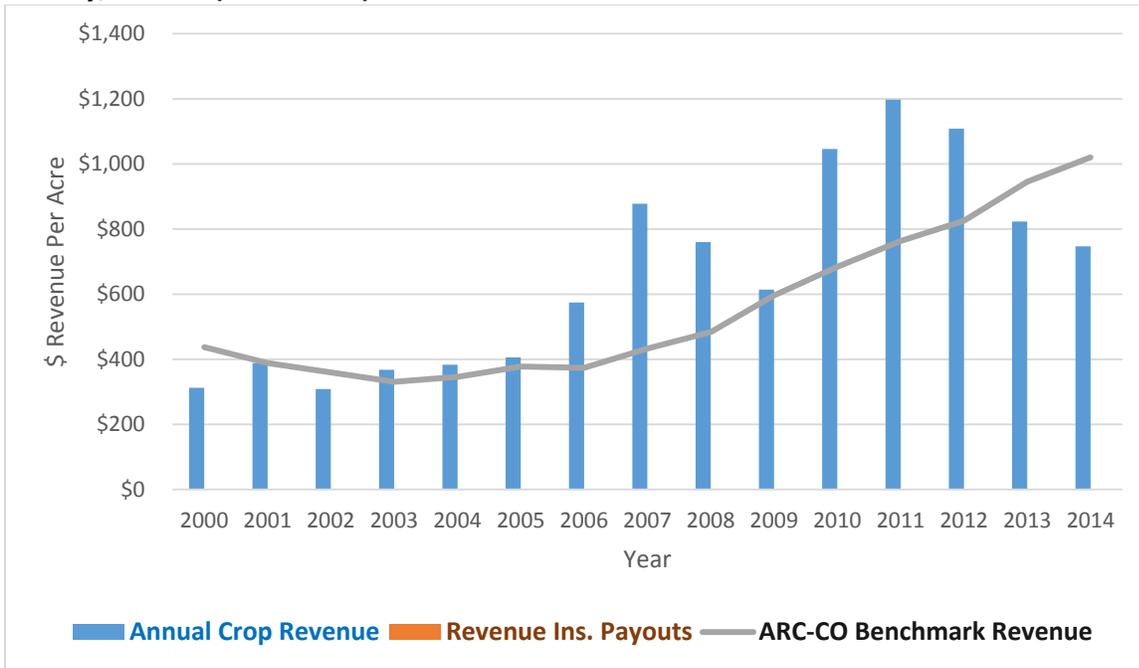


Figure 1b. Irrigated Corn Revenue Insurance, ARC-CO & PLC Payments for Thomas County, Kansas (2000-2014)

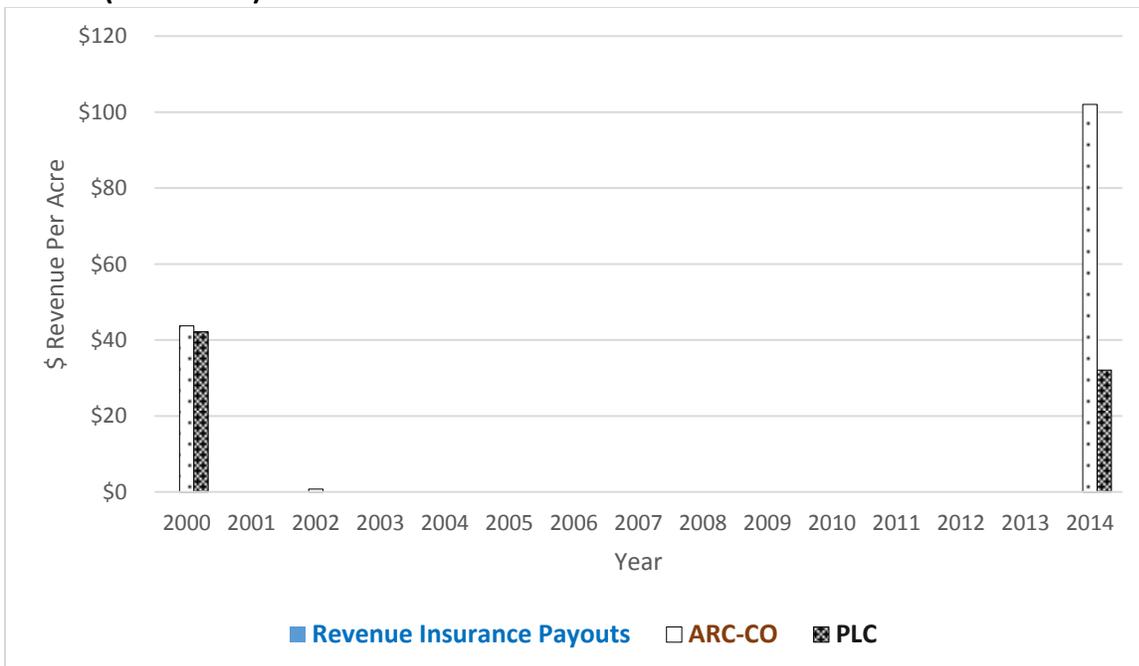


Figure 2a. Non-irrigated Corn Revenue, Insurance Payments, & Benchmark Revenue for Thomas County, Kansas (2000-2014)

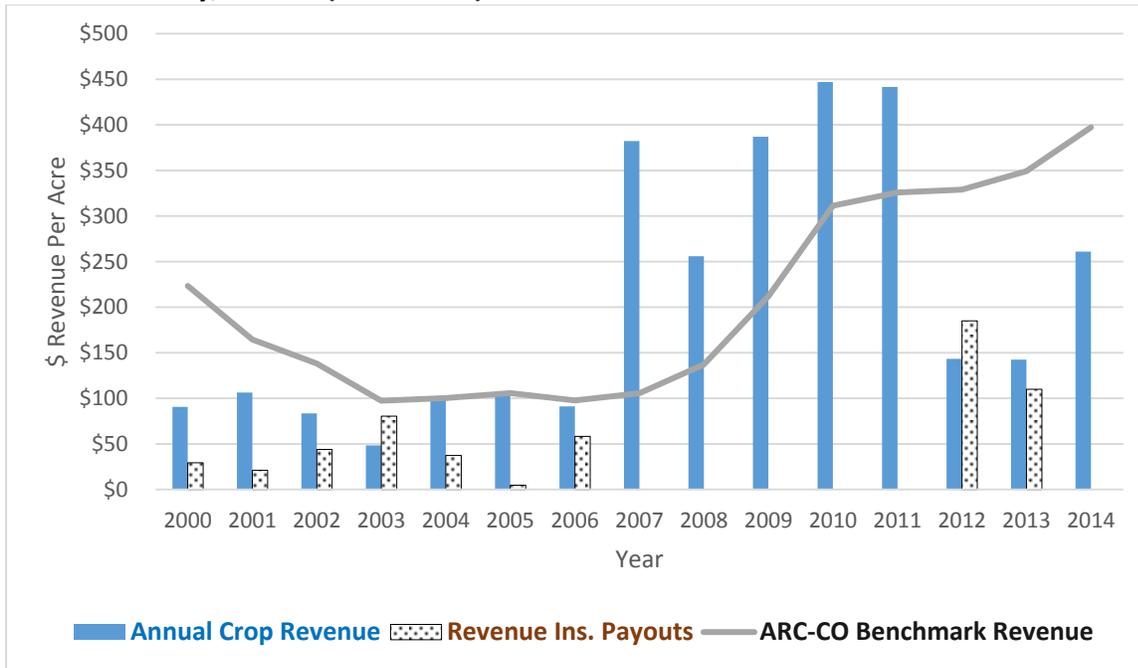


Figure 2b. Non-irrigated Corn Revenue Insurance, ARC-CO & PLC Payments for Thomas County, Kansas (2000-2014)

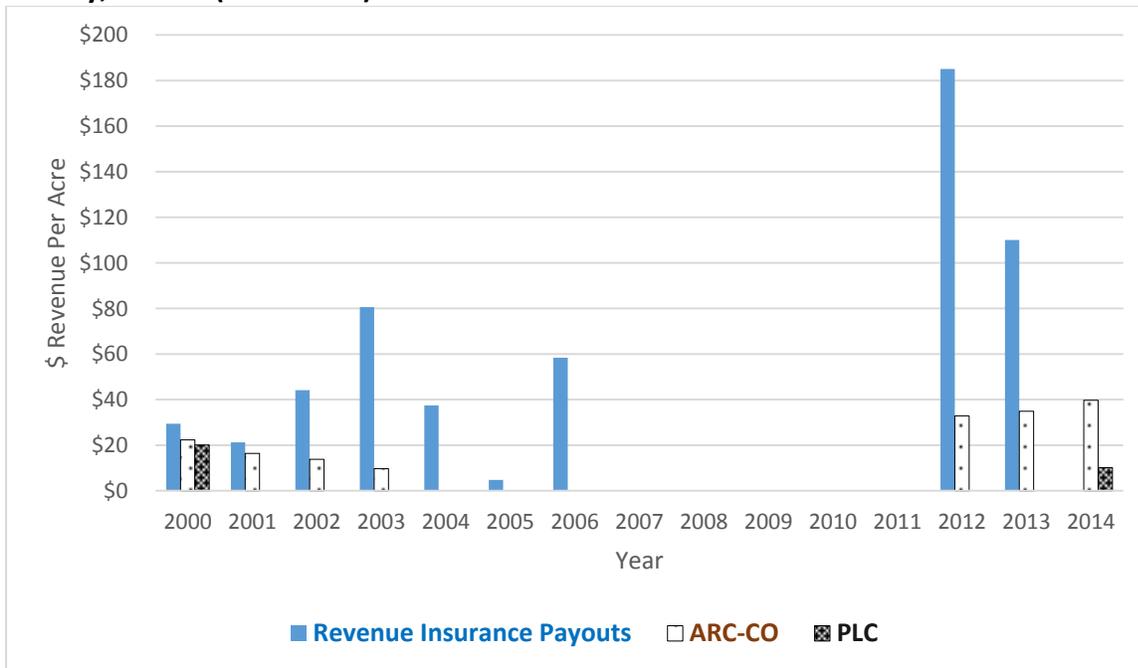


Figure 3a. Non-irrigated Grain Sorghum Revenue, Insurance Payments, & Benchmark Revenue for Thomas County, Kansas (2000-2014)

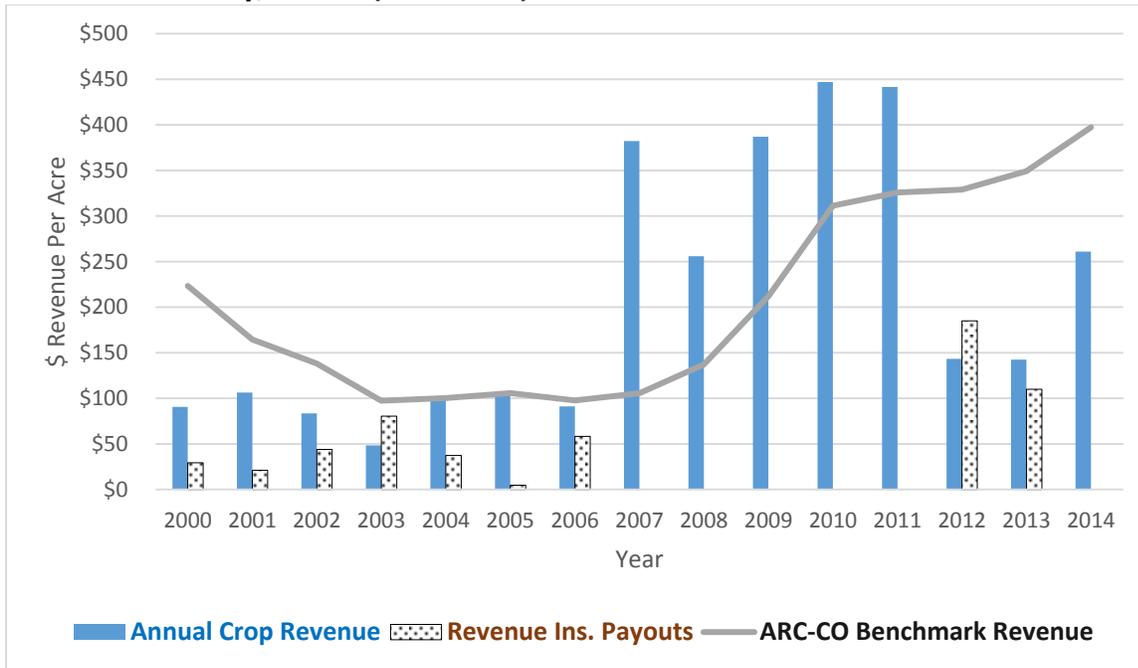


Figure 3b. Non-irrigated Grain Sorghum Revenue Insurance, ARC-CO & PLC Payments for Thomas County, Kansas (2000-2014)

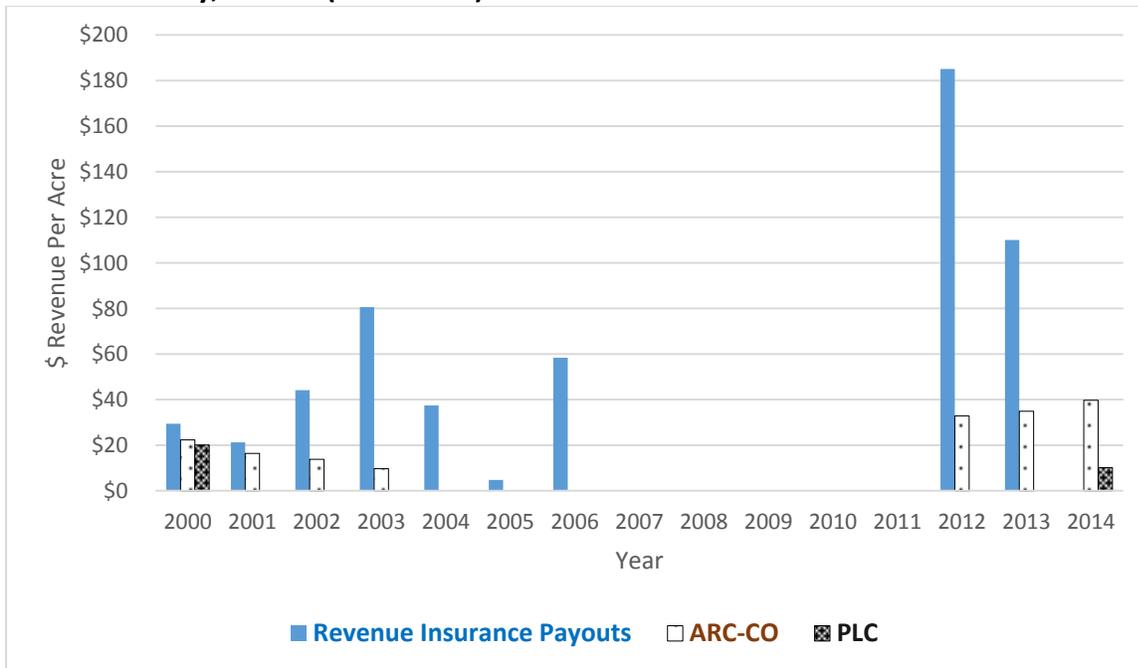


Figure 4a. Non-irrigated Wheat Revenue, Insurance Payments, & Benchmark Revenue for Thomas County, Kansas (2000-2014)

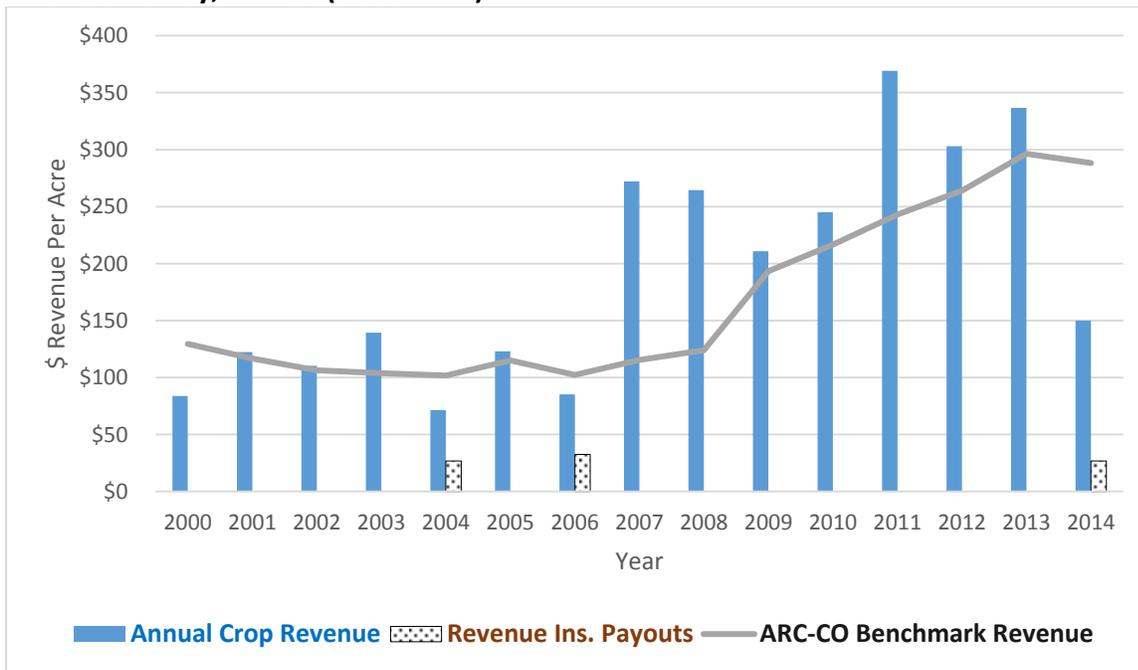


Figure 4b. Non-irrigated Wheat Revenue Insurance, ARC-CO & PLC Payments for Thomas County, Kansas (2000-2014)

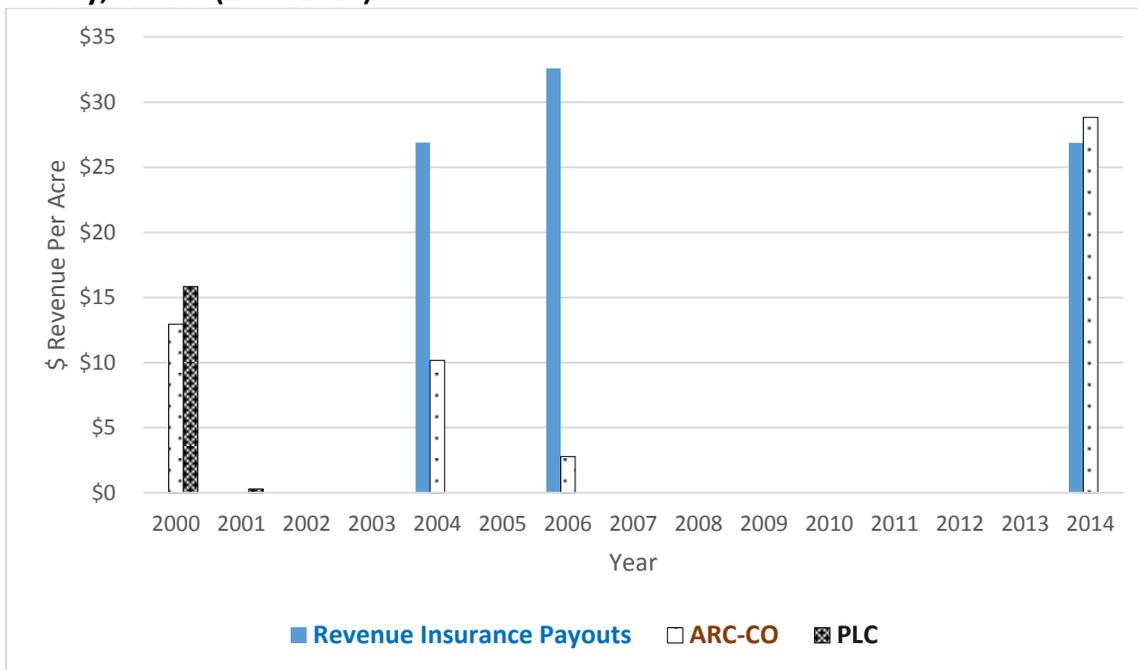


Figure 5a. Irrigated Soybean Revenue, Insurance Payments, & Benchmark Revenue for Thomas County, Kansas (2000-2014)

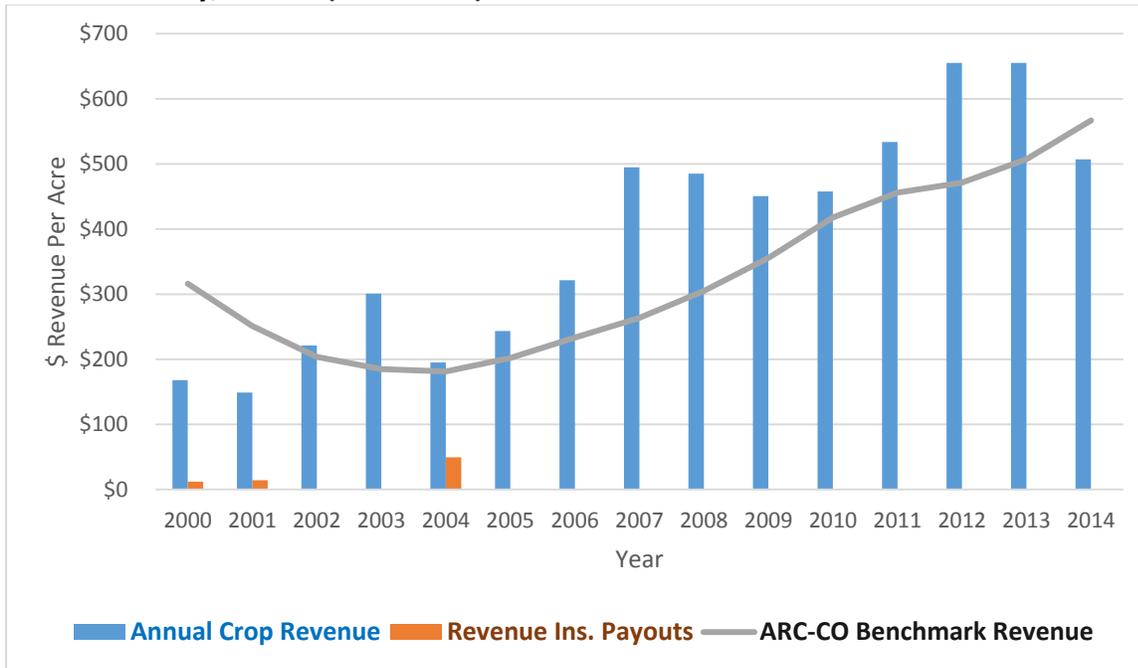
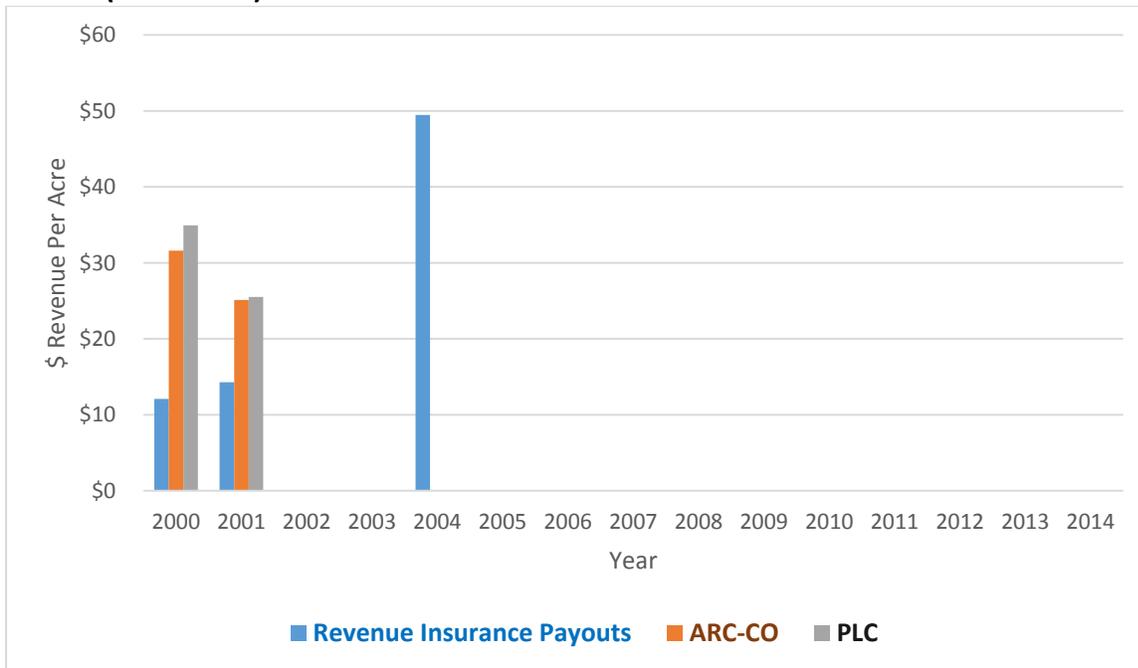


Figure 5b. Irrigated Soybean Revenue Insurance, ARC-CO & PLC Payments for Thomas County, Kansas (2000-2014)



Management of Drought Tolerant Corn

Alan Schlegel
KSU-SWREC
Tribune, KS



Knowledge
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“Drought Tolerant” Corn

- Monsanto Genuity® DroughtGard®
- Pioneer Optimum® AQUAmax®
- Syngenta Agrisure Artesian™



Knowledge
for Life

Water x Hybrid x Population Syngenta Agrisure Artesian™ Tribune, KS



Knowledge
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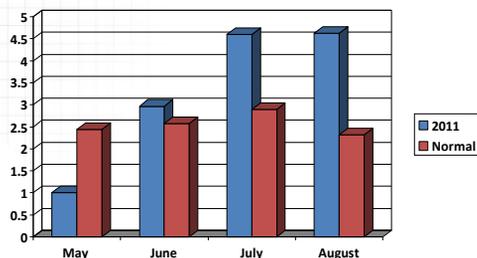
Treatments – 2011 – Tribune, KS

- Water regimes
50% of ET
75% of ET
100% of ET
- Population (target plants/acre)
24,000 plants/acre
32,000 plants/acre
40,000 plants/acre
- Hybrid
Agrisure Artesian (1)
Commercial checks (3)



Knowledge
for Life

Precipitation – Tribune, KS



Knowledge
for Life

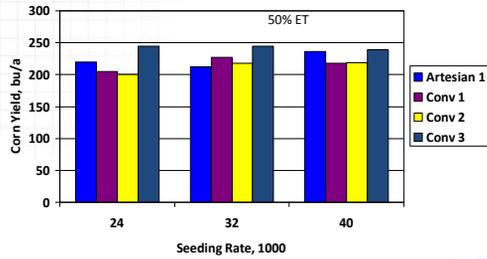
2011 Irrigation – Tribune, KS

Month	ET Level		
	50%	75%	100%
	----- inches -----		
May	0	0	0
June	1.47	2.39	2.91
July	3.16	5.96	9.69
August	0	3.11	7.15
Total	4.63	11.46	19.75



Knowledge
for Life

Water x Hybrid x Population 2011 Agrisure Artesian, Tribune, KS



Knowledge ^{for} Life

Water x Hybrid x Population 2011 Agrisure Artesian, Tribune, KS

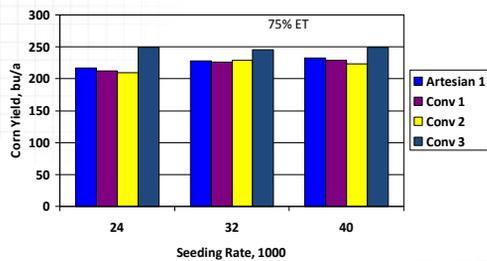
50% ET

Hybrid	% Yield Advantage	% Win
Artesian 1	-1 bu/a	44



Knowledge ^{for} Life

Water x Hybrid x Population 2011 Agrisure Artesian, Tribune, KS



Knowledge ^{for} Life

Water x Hybrid x Population 2011 Agrisure Artesian, Tribune, KS

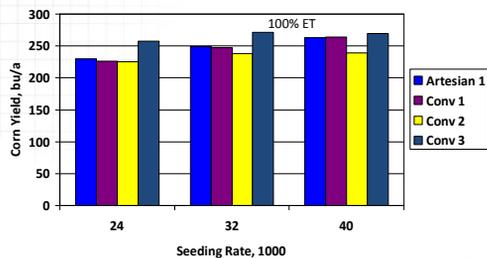
75% ET

Hybrid	% Yield Advantage	% Win
Artesian 1	-4 bu/a	56



Knowledge ^{for} Life

Water x Hybrid x Population 2011 Agrisure Artesian, Tribune, KS



Knowledge ^{for} Life

Water x Hybrid x Population 2011 Agrisure Artesian, Tribune, KS

100% ET

Hybrid	% Yield Advantage	% Win
Artesian 1	-2 bu/a	56



Knowledge ^{for} Life

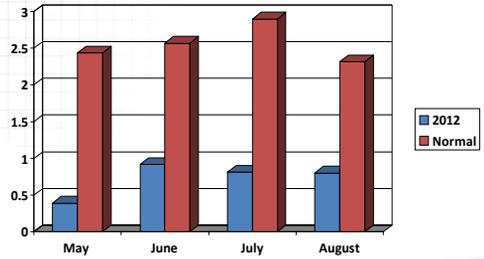
Treatments – 2012 – Tribune, KS

- Water regimes
 - 50% of ET
 - 75% of ET
 - 100% of ET
- Population (target plants/acre)
 - 24,000 plants/acre
 - 32,000 plants/acre
 - 40,000 plants/acre
- Hybrid
 - Agrisure Artesian (1)
 - Commercial checks (2)



Knowledge for Life

Precipitation – Tribune, KS



Knowledge for Life

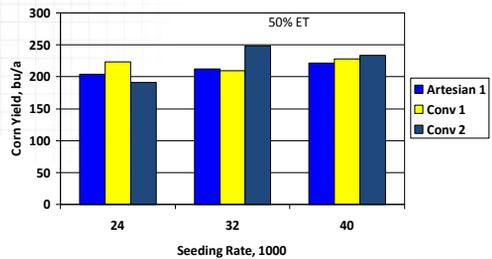
2012 Irrigation – Tribune, KS

Month	ET Level		
	50%	75%	100%
	----- inches -----		
May	0	0	1.44
June	5.56	8.38	9.79
July	5.05	9.51	9.51
August	4.83	6.49	12.80
Total	15.44	24.38	33.54



Knowledge for Life

Water x Hybrid x Population 2012 Agrisure Artesian, Tribune, KS



Knowledge for Life

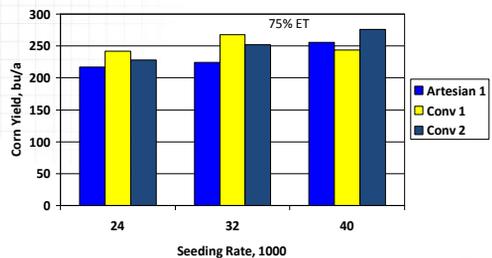
Water x Hybrid x Population 2012 Agrisure Artesian, Tribune, KS

Hybrid	50% ET	
	% Yield Advantage	% Win
Artesian 1	-9 bu/a	33



Knowledge for Life

Water x Hybrid x Population 2012 Agrisure Artesian, Tribune, KS



Knowledge for Life

Water x Hybrid x Population 2012

Agrisure Artesian, Tribune, KS

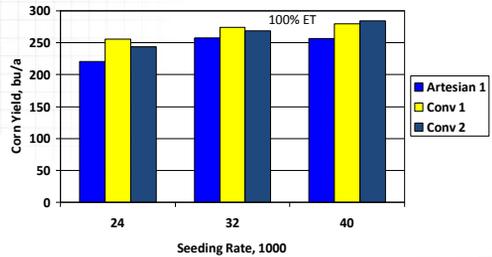
Hybrid	75% ET	
	% Yield Advantage	% Win
Artesian 1	-20 bu/a	17



Knowledge for Life

Water x Hybrid x Population 2012

Agrisure Artesian, Tribune, KS



Knowledge for Life

Water x Hybrid x Population 2012

Agrisure Artesian, Tribune, KS

Hybrid	100% ET	
	% Yield Advantage	% Win
Artesian 1	-23 bu/a	0



Knowledge for Life

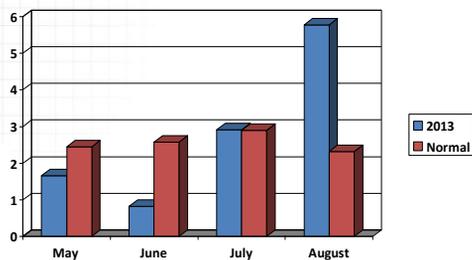
Treatments – 2013 – Tribune, KS

- Water regimes
 - 50% of ET
 - 75% of ET
 - 100% of ET
- Population (target plants/acre)
 - 24,000 plants/acre
 - 32,000 plants/acre
 - 40,000 plants/acre
- Hybrid
 - Agrisure Artesian (2)
 - Commercial checks (4)



Knowledge for Life

Precipitation – Tribune, KS



Knowledge for Life

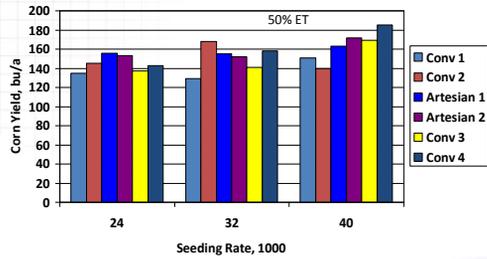
2013 Irrigation – Tribune, KS

Month	ET Level		
	50%	75%	100%
	----- inches -----		
May	1.31	1.31	1.31
June	4.82	4.85	6.33
July	1.48	4.55	6.02
August	0	1.40	2.67
Total	7.61	12.11	16.33



Knowledge for Life

Water x Hybrid x Population 2013 Agrisure Artesian, Tribune, KS



Knowledge ^{for} Life

Water x Hybrid x Population 2013 Agrisure Artesian, Tribune, KS

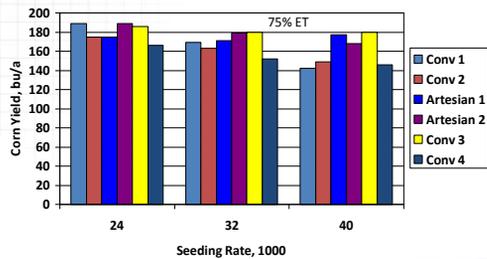
50% ET

Hybrid	% Yield Advantage	% Win
Artesian 1	8 bu/a	67
Artesian 2	9 bu/a	75



Knowledge ^{for} Life

Water x Hybrid x Population 2013 Agrisure Artesian, Tribune, KS



Knowledge ^{for} Life

Water x Hybrid x Population 2013 Agrisure Artesian, Tribune, KS

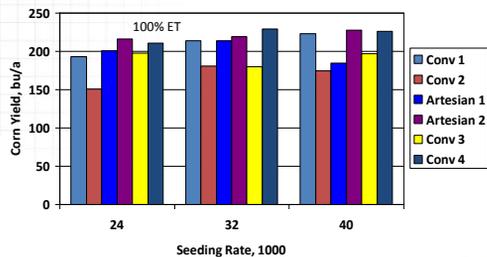
75% ET

Hybrid	% Yield Advantage	% Win
Artesian 1	8 bu/a	64
Artesian 2	13 bu/a	82



Knowledge ^{for} Life

Water x Hybrid x Population 2013 Agrisure Artesian, Tribune, KS



Knowledge ^{for} Life

Water x Hybrid x Population 2013 Agrisure Artesian, Tribune, KS

100% ET

Hybrid	% Yield Advantage	% Win
Artesian 1	2 bu/a	55
Artesian 2	23 bu/a	92



Knowledge ^{for} Life

Water x Hybrid x Population Tribune, KS 2013 Corn Commission



Knowledge
for Life

Objectives

- Assess performance of Pioneer AQUAmax and Monsanto DroughtGard hybrids relative to commercial check under varying water management regimes.
- Assess population density response of drought tolerant hybrids compared to commercial checks.



Knowledge
for Life

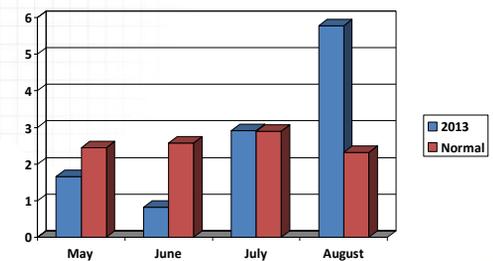
Treatments – 2013 – Tribune, KS

- Water regimes
50% of ET
100% of ET
- Population (seeds/acre)
25,000 seeds/acre
30,000 seeds/acre
35,000 seeds/acre
40,000 seeds/acre
- Hybrid
Monsanto DroughtGard (1)
Pioneer AQUAmax (1)
Commercial checks (2)



Knowledge
for Life

Precipitation – Tribune, KS



Knowledge
for Life

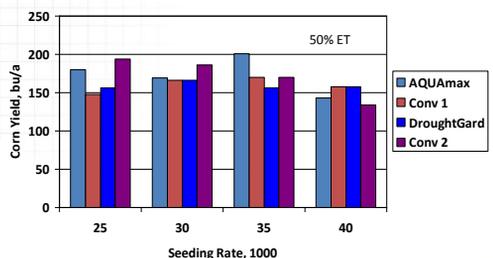
2013 Irrigation – Tribune, KS

Month	ET Level	
	50%	100%
	----- inches -----	
May	1.31	1.31
June	4.82	6.33
July	1.48	6.02
August	0	2.67
Total	7.61	16.33



Knowledge
for Life

Water x Hybrid x Population 2013 Corn Commission Study, Tribune, KS



Knowledge
for Life

Water x Hybrid x Population 2013

Corn Commission, Tribune, KS

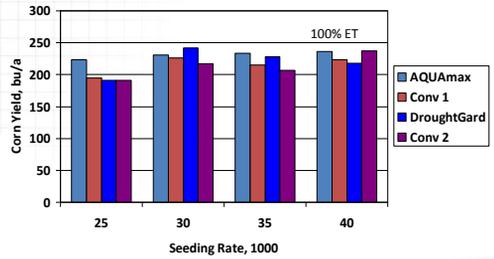
Hybrid	50% ET	
	% Yield Advantage	% Win
AQUAmax	7 bu/a	63
DroughtGard	-7 bu/a	33



Knowledge for Life

Water x Hybrid x Population 2013

Corn Commission Study, Tribune, KS



Knowledge for Life

Water x Hybrid x Population 2013

Corn Commission, Tribune, KS

Hybrid	100% ET	
	% Yield Advantage	% Win
AQUAmax	17 bu/a	88
DroughtGard	6 bu/a	57



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Summary

- Results have been variable
- “Drought tolerant” technology must be placed in adapted hybrids
- Continued improvement



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Considerations for phosphorus management under minimum tillage

Dorivar Ruiz Diaz, Soil Fertility, Kansas State University

Optimum phosphorus (P) fertility management is key for optimum crop production, and P is generally one of the most limiting nutrients for crop production in Kansas. Soil test level is usually the most important parameter for proper management of P. However, tillage system and fertilizer placement can affect P availability significantly, and should be considered especially under lower soil test P conditions.

Phosphorus broadcast and starter fertilizer for corn

Broadcast application of P fertilizer is considered an effective application under no-till with good agronomic crop response under low soil test P. Typically higher residue and higher soil moisture near the surface can promote more shallow root growth and therefore access to the fertilizer P under no-till systems. Furthermore, conditions of very low soil test P may require a combination of broadcast and band application to improve root access to the fertilizer P source and increase plant response.

Many producers in Kansas could benefit by using starter fertilizer phosphorus. Starter fertilizer is simply the placement of some fertilizer, usually nitrogen (N) and phosphorus (P), near the seed -- which "jump starts" growth in the spring. It is very unusual for a farmer not to see an early season growth response to starter fertilizer application. But whether that increase in early growth translates to an economic yield response is not a sure thing in Kansas. How the crop responds to starter fertilizer depends on soil P fertility levels, tillage system, and placement method.

Soil fertility levels. The lower the soil test level, the greater the chance of economic responses to starter fertilizers. A routine soil test will reveal available P levels. If soils test low or very low in P (below 20 ppm), there is a very good chance that producers will get an economic yield response to applying a starter fertilizer containing P, even in some low-yield environments. If the soil test shows a medium level of P, 20-30 ppm, it's still possible to get a yield response to P fertilizer. But the yield response will not occur as frequently, and may not be large enough to cover the full cost of the practice. The chances of an economic return at higher soil test levels are greatest when planting corn early in cold soils. If the soil test is high, above 30 ppm, economic responses to starter P fertilizers are rare.

All of the recommended P does not need to be applied as starter. Generally, plants respond best to a combination of starter and broadcast applications. Banding the first 15-20 pounds of P as starter, and broadcasting the balance of the fertilizer seems to result in the best performance.

Tillage system. No-till corn will almost always respond to a starter fertilizer that includes N -- along with P -- regardless of soil fertility levels or yield environment. This is especially so when preplant N is applied as deep-banded anhydrous ammonia or where most of the N is sidedressed in-season. That's because no-till soils are almost always colder and wetter at corn planting time than soils that have been tilled, and N mineralization from organic matter tends to be slower at

the start of the season in no-till environments. Furthermore, corn can benefit from close placement of P under colder soil conditions often associated with no-till.

In reduced-till systems, the situation becomes less clear. The planting/germination zone in strip-till or ridge-till corn is typically not as cold and wet as no-till, despite the high levels of crop residue in the row middles. Still, N and P starter fertilizer is often beneficial for corn planted in reduced-till conditions, especially where soil test levels are very low, or low, and where the yield environment is high.

Conventional- or clean-tilled corn is unlikely to give an economic response to an N and P starter unless the P soil test is low.

Placement method. Producers should be very cautious about applying starter fertilizer that includes N and/or K, or some micronutrients such as boron, in direct seed contact. It is best to have some soil separation between the starter fertilizer and the seed. The safest placement methods for starter fertilizer are either:

- A band application 2 to 3 inches to the side and 2 to 3 inches below the seed, or
- A surface-band application to the side of the seed row at planting time, especially in conventional tillage or where farmers are using row cleaners or trash movers in no-till.

If producers apply starter fertilizer with the corn seed, they run an increased risk of seed injury when applying more than 7 to 8 pounds per acre of N and K combined in direct seed contact on a 30 inch row spacing. Nitrogen and K fertilizer can produce salt injuries at high application rates if seeds are in contact with the fertilizer. Furthermore, if the N source is urea or UAN, in-furrow application is not recommended, urea converts to ammonia, which is very toxic to seedlings and can significantly reduce final stands.

Previous work at KSU compared in-furrow, 2x2, and surface band placement of different starter fertilizer rates in a multi-year study on irrigated corn. Excellent responses from up to 30 pounds of N combined with 15 pounds of P were obtained with both the 2x2 and surface-band placement (see chart below). In-furrow placement was not nearly as effective. This was due to stand reduction from salt injury to the germinating seedlings. Where no starter, or the 2x2 and surface band placement, was used, final stands were approximately 30-31,000 plants per acre. However, with the 5-15-5 in furrow treatment, the final stand was approximately 25,000. The final stand was just over 20,000 with the in-furrow 60-15-5 treatment.

Effect of Starter Fertilizer Placement on Corn Yield at North Central Irrigation Experiment Field

Fertilizer Applied (lbs/acre, N-P ₂ O ₅ - K ₂ O)	In-Furrow Placement	2x2 Band Placement	Surface Band Placement
----- Yield (bu/acre) -----			
Check: 159 bu	--	--	--
5-15-5	172	194	190
15-15-5	177	197	198
30-15-5	174	216	212
45-15-5	171	215	213
60-15-15	163	214	213

Is there any value to P starter fertilizer on soybeans?

Soybean is a crop that can remove significant amounts of nutrients per bushel of grain harvested. Respond to starter fertilizer application in soybeans can occur, but it depends on several factors. The most important factor is the fertility level of the soil. Soybeans will respond to direct fertilizer application on low-testing soils, particularly phosphorus. Generally warmer soils at planting time of soybean, compared to corn may also contribute to typically lower response to starter fertilizers in soybean. If fertilizer P is recommended by soil test results, then fertilizer should either be applied directly to the soybeans or applied indirectly by increasing fertilizer rates to another crop in the rotation by the amount needed for the soybeans.

Banding fertilizer to the side and below the seed at planting is an efficient application method for soybeans. This method is especially useful in reduced-till or no-till soybeans because P have only limited mobility into the soil from surface broadcast applications. However, with narrow row soybeans, it may not be possible to install fertilizer units for deep banding. In that situation, producers can surface-apply the fertilizer. Fertilizer should not be placed in direct seed contact with soybeans because the seed is very sensitive to salt injury.

Soybean seldom response to nitrogen in the starter fertilizer, however some research under irrigated, high yield environments suggest a potential benefit of small amounts of N and also for double crop soybean after wheat, especially after good wheat yields. The most consistent response to starter fertilizer with soybeans would be on soils very deficient in P, or in very high-yield-potential situations where soils have low or medium fertility levels.

Phosphorus from manure applications to soil

Manure can provide a good source of phosphorus and can be used to build up soil test P. The total phosphorus content in manure varies depending on the animal species, age, diet, and how the manure has been stored. Concentration of phosphorus in some manures may be up to 80 to 90 lbs P₂O₅ per ton (some poultry manures, for example), whereas other manure may contain as little as 4 lbs P₂O₅ per ton. It will require a laboratory analysis to know for sure.

A large fraction of the phosphorus in manure is considered to be plant available during the first year after application. The fraction that is not plant available shortly after application will

become potentially available over time. Estimated values of phosphorus availability are from 50 to 100%. This range accounts for variation in sampling and analysis, and for phosphorus requirements with different soil test levels. Use the lower end of the range of phosphorus availability values (50%) for soils testing “Very Low” and “Low” (below 20 ppm) in soil phosphorus test. In these situations, significant yield loss could occur if insufficient phosphorus is applied and soil phosphorus buildup is desirable.

On the other hand use 100% availability when manure is applied to maintain soil test phosphorus in the Optimum soil test category, and when the probability of a yield response is small. Several studies have shown that manure P is a valuable resource, comparable to inorganic fertilizer P for crop production. These two P sources are similarly effective when the manure P concentration is known and the manure is applied properly.

For maximum efficiency of manure use, is essential to know the nutrient content of the manure. Using a manure lab analysis will help in determining the actual nutrient rates applied to a particular field. Producers should ideally think in terms of actual phosphorus application rates and not just gallons or tons per acre of manure being applied.

Uniform application of manure at precise rates can also be difficult. Careful calibration of manure applicators is needed. If these aspects are not considered, the efficiency of manure P compared with inorganic fertilizer P may be reduced. However with careful management, manure not only provides the needed P, but also additional macro and micronutrient that may contribute to the overall plant nutrition.

Soil Sampling



- What tools?
- Where to sample?
- What does it take to make a good sample?
 - Sample depth, proper and consistent
 - Number of cores per sample
- How do I properly handle samples?




Soil Sampling Tools

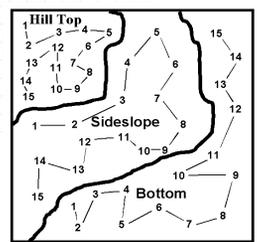
- Hand probes
 - Tip designs for wet/dry soils, clay soils
 - Different designs for core extraction
 - Telescoping models for deep sampling
- Cordless Drill, Bit, and Collection Bucket
 - Useful for deep profile samples
- Mechanized Sampling
 - ATV or pickup mounted
 - Can find both probe and auger types on the market




*All of these methods can result in high quality sample
All of these methods can result in a poor quality sample
The key is in how they are used*




Where to sample? Dividing the Field Based on Soils or Topography



Topography makes good 'management zones' in many areas.

In many cases represents soils also

Sampling areas should represent a "treatable" area, 5-20 acres in size.



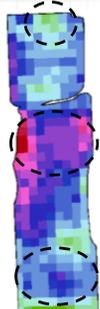

Where to sample? Dividing the Field Based on Soil series



142 acres




Where to sample? Sampling Based on Historical Yield Data

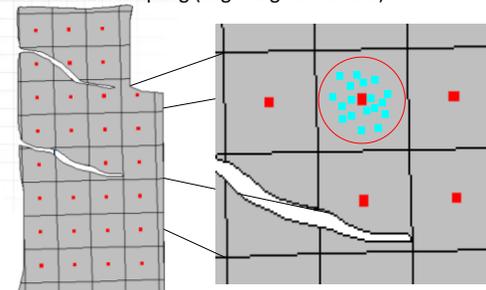


Sample areas of the field based upon their past yield

- Consistently high yield areas will often test low for nutrients such as Phosphorus, (i.e. we're removing more than we're applying, mining soil test P)
- Consistently low yielding areas will often have high soil test values for nutrients such as Phosphorus, (i.e. we're applying more than removal, building soil test P)
- Field with wide ranges in soil test values typically are better candidates for variable rate nutrient management




Where to sample? Grid Sampling (aligned grid method)



Uniform Grid
K-STATE (68 A @ 2 A)




Soil Sampling Depth

- Immobile nutrients accumulate in the top few inches of soil. Their availability should be measured using a 0 to 6" surface soil sample.
 - Shallower samples give high test results, over estimate nutrient supply, and under estimate fertilizer needs.
 - Deeper samples give low test results, under estimate nutrient supply and over estimate fertilizer needs.

Nutrient Stratification

Effect of tillage on soil P and K distribution

Depth	Plow		Chisel		No-till	
	P	K	P	K	P	K
	-----ppm-----					
0-4	30	191	43	242	49	270
4-8	28	188	31	178	35	197
8-12	22	189	13	162	19	185

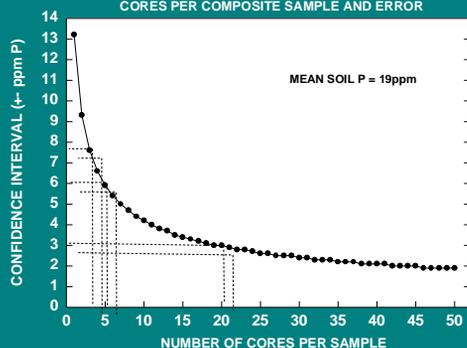
Sampling Depths for Mobile Nutrients

- While P and K are relatively immobile in soils and accumulate in the surface few inches, Nitrate-N, Sulfur (S) and Chloride (Cl) are mobile and move through the soil profile.
- We recommend a 24" Profile Soil Sample to test for mobile nutrients such as nitrate-N in the soil. 10-15 cores are still needed to give a high quality sample

Number of Cores to Make a Good Sample

- Soils vary across very short distances in nutrient supply due to many factors including:
 - Position on the landscape
 - Past erosion
 - Parent material of the soil
- We also induce variability on the soil
 - Band applications
 - Livestock grazing
- To account for this variation you should take 10-20 cores per sample

EXAMPLE OF THE RELATIONSHIP BETWEEN NUMBER OF SOIL CORES PER COMPOSITE SAMPLE AND ERROR



When to Take Soil Samples

- P, K, Zn and pH always the same time.
- Focus on times when soil conditions are good, long enough before planting to really use the information.
- Be consistent.
- Late fall, winter and early spring-November through March are good.

When to Take Soil Samples

- For N, S and Cl
- **Summer crops:** after harvest in the fall, but before the soil warms in the spring.
- **Fall crops:** before planting in the fall.
 - Spring or winter samples to predict topdress N needs don't work real well.



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Handling samples before sending to lab

- Avoid contamination with dirty buckets, galvanized buckets, etc.
- Never oven dry soil samples! High temperatures can alter test results, especially K.
- Critical for nitrate-N samples to air dry if the sample won't be shipped for a few days.



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Soil Test Interpretation



Soil Test Interpretations and Fertilizer Recommendations

Department of Agronomy MF-2586

Development of sound nutrient management program involves knowledge of a wide range of information. Soil test records are an important piece of required information, but other factors such as soil moisture conditions, land ownership tenure, crop and cropping sequence, pest management, cultural practices, environmental issues, and other management items are vital for developing sound nutrient management program. It is beyond the scope of this publication to detail the ramifications of all these factors, but they should not be overlooked when finalizing nutrient application programs.

The following tables, equations and accompanying information are the most recent soil test interpretations for major crops for the most commonly deficient plant nutrients in Kansas. These interpretations are valid for

items are based on surface soil samples collected to a depth of six inches. We suggest collecting a sample from the 0 to 2.4 inch depth for N, S and Cl recommendations and a separate 0- to 6-inch sample for pH, P, K, Zn, Fe and D soil test determinations.

For lime, the recommended lime rate should be adjusted to reflect the depth of lime incorporation while no-till and preemial crops should assume a depth of 2 inches.

Appropriate Soil Test Procedures

The K-State soil test interpretations are based on the following soil test procedures:

Soil pH - 1:1 Water pH

0-6" depth 0-6" depth

Available at:

<http://www.ksre.ksu.edu/bookstore/pubs/mf2586.pdf>

or your local extension office



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Useful soil tests in Kansas

- Mehlich III Extractable P
- Profile Nitrate-N
- Bray P-1 Extractable P
- Olsen Extractable P
- Exchangeable K
- DTPA Extractable Zn
- Chloride
- Soil pH
- Lime Requirement / Buffer pH
- Soil Organic Matter



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Where should I focus my attention in soil test?

- In Kansas the greatest return to fertilization is from N, P, and Zn.
 - Sulfur and chloride responses can be seen on cereals
 - Iron chlorosis is also common, but pH and OM may be more useful than the soil test



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Conclusions

- For immobile nutrients and lime, use a surface 0-6" sample
 - In long-term no-till or forages, 0-3 for pH and lime
- For mobile nutrients use a 0-24" profile sample before planting.
- Take lots of cores
- Be consistent



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Using Plant Analysis as a Nutrient Management Tool

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Plant analysis is an excellent "quality control" tool for growers interested in high yield crop production. It can be especially valuable for managing secondary and micronutrients which don't have high quality, reliable soil tests available, and providing insight into how efficiently you are using applied nutrients.

There are two basic ways plant analysis can be used by Kansas farmers, monitoring nutrient levels at a common growth stage and for diagnostic purposes. Monitoring is generally done at a common growth stage, the beginning of reproductive growth, while diagnostics can be done any time.

Plant analysis for nutrient monitoring. For general monitoring or quality control purposes, plant leaves should be collected as the plant enters reproductive growth. Sampling under stress conditions for monitoring purposes can give misleading results, and is not recommended.

In the case of **corn**, 15-20 ear leaves, or first leaf below and opposite the ear should be collected at random from the field at silk emergence, before pollination, and before the silks turning brown.

In **sorghum**, the first or second leaf below the flag leaf at heading should be collected. Again 15-20 individual leaves should be collected from the field at random.

In **soybeans**, the top, fully developed trifoliolate leaflets should be collected when the first pods are $\frac{3}{4}$ to one inch long. The top fully developed trifoliolate leaflets are normally the third set of leaves below the terminal bud on the main stem of the plant. They should be a dark green, and will likely be positioned at the top of the canopy, while developing/growing leaves will be a lighter green color and generally be below the fully developed leaves in the canopy. Collect 25-30 sets of leaflets at random, removing the petiole, or stem connecting the leaflets to the stem.

In **wheat**, the flag leaf is normally collected at heading. Since the flag leaves are small, 40-50 individual leaves will be needed to have enough dry plant material to have adequate plant material for analysis. Again, collect the leaves at random from the field or area which is being monitored.

Diagnostic sampling. Plant analysis is also an excellent diagnostic tool to help understand some of the variation seen in the field. When using plant analysis to diagnose field problems, try to take comparison samples from both good/normal areas of the field, and problem spots. Also

collect soil samples from the same good and bad areas since physical problems such as soil compaction or poor drainage often limits the uptake of nutrients present in adequate amounts. Don't wait for the optimum growth stages for routine monitoring.

When sampling for diagnostic purposes, collecting specific plant parts is less important than obtaining comparison samples from good and bad areas of the field. As a rule of thumb, if plants are less than 12 inches tall, collect the whole plant, cut off at ground level. If above 12 inches tall, and until reproductive growth begins (heading or tasseling), collect the top fully developed leaves. Once reproductive growth starts, collect the same plant parts indicated for monitoring purposes.

When doing diagnostics, it is also helpful to collect a soil sample from both good and bad areas. Define your areas, and collect both soil and plant tissue from areas which represent good and bad areas of plant growth.

Shipping and handling plant samples. How do I handle samples, and where should I send the samples? The collected leaves should be allowed to wilt over night to remove excess moisture, placed in a paper bag or mailing envelope, and shipped to a lab for analysis. Do not place the leaves in a plastic bag or other tightly sealed container, as they will begin to rot and decompose during transport, and the sample won't be usable. Most of the soil testing labs working in the region provide plant analysis services, including the K-State lab. Make sure to label things clearly for the lab, and if they have an input form use it and fill it out completely.

What nutrients should you analyze for? In Kansas nitrogen (N), phosphorus (P), potassium (K), sulfur (S), zinc (Zn), chloride (Cl) and iron (Fe) are the nutrients most likely to be deficient. Recently questions have been raised by consultants and others concerning copper (Cu), manganese (Mn) and molybdenum (Mo). Most labs can analyze for most of these. Normally the best values are the "bundles" or "packages" of tests offered through many of the labs. They can be as simple as N, P and K, or can be all of the 14 mineral elements considered essential to plants. K-State offers a package which includes N, P, K, Ca, Mg, S, Fe, Cu, Zn, and Mn for \$23.75.

What will I get back from the lab? The data returned from the lab will be reported as the concentration of nutrient elements, or potentially toxic elements in the plants. Units reported will normally be in percent for the primary and secondary nutrients (N, P, K, Ca, Mg, S, and Cl) and ppm or parts per million, for the micronutrients (Zn, Cu, Fe, Mn, B, Mo, and Al). Most labs/agronomists compare plant nutrient concentrations to published sufficiency ranges. A sufficiency range is simply the range of concentrations normally found in healthy, productive plants during surveys. It can be thought of as the range of values optimum for plant growth. The medical profession uses a similar range of normal values to evaluate blood work. The sufficiency ranges change with plant age (generally being higher in young plants), vary between plant parts, and can differ between hybrids. So a value slightly below the sufficiency range does not always mean the plant is deficient in that nutrient, but it is just an indication that the nutrient is relatively low. Values on the low end of the range are common in extremely high yielding crops. However, if that nutrient is significantly below the sufficiency range, then one should ask some serious questions about the availability and supply of that nutrient.

Keep in mind also that any plant stress (drought, heat, soil compaction etc) can have a serious impact on nutrient uptake and plant tissue nutrient concentrations. So a low value in the plant doesn't always mean the nutrient is low in the soil and the plant will respond to fertilizer, rather than the nutrient may not be available to the plant.

Levels above sufficiency can also indicate problems. High values might indicate over fertilization and luxury consumption of nutrients. Plants will also sometimes try to compensate for a shortage of one nutrient by loading up on another. This occurs at times with nutrients such as iron, zinc and manganese. Plants will load up on iron at times, in an attempt to compensate for low zinc. In some situations very high levels of a required nutrient can lead to toxicity. Manganese is an example of an essential nutrient which can be toxic when present in excess. This can occur at very low soil pH, generally well below 5.

The following table gives the range of nutrient content considered to be "normal" or "sufficient" for corn at silking, soybeans at pod set and wheat at heading. Keep in mind that these are the ranges normally found in healthy, productive crops.

Nutrient	Units	Crop		
		Corn Ear leaf at green silk	Soybeans top leaves pod set	Wheat flag leaf at boot to heading
Nitrogen	%	2.75-3.50	4.25-5.50	3.5-4.5
Phosphorus	%	0.25-0.45	0.25-0.50	0.3-0.5
Potassium	%	1.75-2.25	1.70-2.50	2.0-3.0
Calcium	%	0.25-0.50	0.35-2.00	0.3-0.5
Magnesium	%	0.16-0.60	0.26-1.00	0.2-0.6
Sulfur	%	0.15-0.50	0.15-0.50	0.15-0.55
Chloride	%	0.18-0.60	-	0.18-0.60
Copper	ppm	5-25	10-30	5-25
Iron	ppm	20-200	50-350	30-200
Manganese	ppm	20-150	20-100	20-150
Zinc	ppm	15-70	20-50	15-70
Boron	ppm	4.0-25	20-55	1.5-4.0
Molybdenum	ppm	0.1-3.0	1.0-5.0	-
Aluminum	ppm	<200	<200	<200

In summary, plant analysis is a good tool to monitor the effectiveness of your fertilizer and lime program, and a very effective diagnostic tool. Consider adding this to your toolbox.

Forage Sampling Procedures and Equipment

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Lyle W. Lomas, head and animal scientist, Southeast Agricultural Research Center, Kansas State University



Forage sampling is used to gather information about hay or silage to determine its market value and ration formulation for livestock. To be useful, the sample must be representative of a particular lot, capturing properties of hundreds of thousands of pounds of a wide variety of plant material in a single, thumbnail-sized sample. The sample should accurately reflect leaf-stem ratio, legume/grass mix, and weeds present in a particular location within the same cutting.

Sampling variation can be costly when forage is undervalued. Forage analysis results are only as good as the sample provided to the laboratory. Most of the time, variation is the result of hay sampling procedures rather than lab errors. Proper sampling procedures are necessary to accurately assess forage quality.

Although some variation between samples is normal, for consistent, representative samples, researchers recommend the following forage sampling procedure.

1. Sample by forage lot.

The forage from every field and cutting is different. When sampling, divide hay into lots based on known differences. Identify your forage inventory and sample by lots. A forage lot is hay or silage taken from the same location, field, or farm, the same cutting (within a 48-hour period) at the same plant maturity,

with similar amounts of grass, weeds, rain damage, or preservative treatment. A lot may range from several bales to several tons of hay. Do not combine hays of different qualities or cuttings into one composite sample. Test results will not be useful for making feeding decisions. Keep a record of quantity and location of each lot sampled.

2. Sample at the optimum time.

Collect hay or silage samples as close to the time of feeding or sale as possible. Sampling immediately before feeding accounts for any heating or weathering losses that may have occurred during storage. This is impractical when marketing hay out of the field, for lots moving through marketing channels, or where individual lots of hay are hard to access. For silage, some producers sample and test the forage as it is going into storage, while others collect grab samples during the first few days of feeding from a new silage source. A sample taken at feeding time better represents the nutritional quality of what is being fed. Allow sufficient time for delivery to the lab, laboratory analysis, and ration formulation. This may take a week or more.

3. Select a sharp, well-designed coring device.

Forage tests are based on small samples that may represent several tons of forage. Several grab samples

from a windrow or bale or a single flake from a small rectangular bale are not sufficient. Use a sharp core sampler or hay probe to collect the forage sample from bales or stacks after harvest. A core sampler is a sharp tube used to collect an accurate cross section that represents the proportions of leaves and stems as they exist in the bale. The sampler tube should be 12 to 24 inches long. Probes longer than 24 inches generate very large samples, which may be difficult to analyze in the lab.

A greater number of small samples is more representative than fewer large samples. A core sampler should have an inside diameter of $\frac{3}{8}$ to 1 inch. A coring device with an extremely small-diameter may not cut or represent the leaf-stem ratio properly, and a very large-diameter probe may produce too large a sample for efficient shipping and laboratory processing. A sharp cutting tip improves the efficiency of sampling and helps to collect a more representative sample. Sharpen or replace cutting tips regularly. Using larger probes requires considerably more effort, an important consideration if sampling with a brace or a low-powered electric drill.

Core samplers may be available for loan from K-State Research and Extension specialists, nutrition consultants, or other producers. While the cost of owning a core sampler may seem high, it may be economical compared to livestock production losses from improperly balanced rations or feeding supplements when not needed.

4. Sampling bales and stacks of hay.

To sample bales and stacks of hay, take at least 20 cores, one each from widely separated bales or stacks representative of the lot being sampled. Sample large and small rectangular bales by taking cores (12 to 15 inches deep) from the center of the end of the bales. Sample large round bales by taking cores (also 12 to 15 inches deep) at waist height on the rounded, tight side. If only a few large square or round bales make up the lot, take multiple cores from each bale to equal at least 20 cores. Sample stacks and chopped hay 18 inches deep. Avoid sampling spoiled or weathered portions of bales or stacks that will not be fed. If using a hand brace or low-powered portable electric drill, you may be tempted to collect fewer than 20 cores. But sampling error and inadequate representation of the lot variability



Cattle are fed hay from a feeding bin.

increases if fewer than 20 cores are collected. Consider using an electric corded drill powered by a portable generator or charged battery if bale storage is at a remote location.

The 20 core samples from the lot should result in 1 pint to 2 quarts in volume — or about $\frac{1}{2}$ pound of material — and represent several tons of forage. Mix the hay cores in a clean, plastic pail and place the entire sample (all 20 core samples) into a clean, heavyweight plastic bag. Seal the bag tightly to maintain moisture.

5. Sampling chopped silage crops and baleage.

Producers can either sample chopped silage crops as they are stored or as they are removed from storage for feeding. For sampling silage to be stored, collect a representative handful or two of chopped forage from each of several loads coming from a particular field at harvest. Mix the samples thoroughly and place in a sealable plastic bag, squeezing out excess air. Store the samples in a freezer, and submit the frozen composite sample to the laboratory.

A more accurate representation of silage quality being fed occurs when samples are taken at the time of feeding. Collect grab samples at both morning and evening feeding when feeding a new silage lot. Avoid sampling spoiled silage from the top of a bunker or from the transition layer between lots in an upright or bunker silo.

When sampling from the face of a bunker silo or from a plastic silage bag, mechanically remove the forage as it will be fed and collect grab samples from that volume and freeze. The accumulated grab samples (amounting to several quarts weighing 2 to

4 pounds) should be mixed thoroughly, sealed in a plastic bag, and frozen for shipment or delivery to the testing laboratory.

It may be more practical to sample when filling the silo. Although some nutritional changes occur during normal fermentation, they are usually small. If forage is excessively moist at harvest and the silo seeps, or if it is harvested too dry and the silage heats excessively during ensiling, consider sampling again at time of feeding by taking several grab samples to account for nutritional changes during ensiling.

Sampling wet or wilted forage being stored as baled silage can be done either by core sampling bales before wrapping or sampling the wrapped bales closer to the time of feeding. If sampling plastic-wrapped bales that will not be fed immediately, reseal quickly to prevent spoilage.

6. Keep good records.

Record name, date the crop was harvested, date sampled, and an identifier code or number for the lot on the bag in permanent marker. When you receive the test results, this helps you identify the proper lot for correct feeding or marketing. The lot identification should match your records of lot locations. It is also a good practice to write a brief description of the type of forage included in the sample. Some laboratories use this information in the analysis procedures. Keep a record of similar information for reference.

7. Ship samples immediately.

Hay and silage samples are perishable. Ship or deliver samples to the laboratory as soon as possible to prevent moisture loss and microbial deterioration of the sample. Mail samples early in the week to minimize the shipping time to the lab. Avoid sending samples over a weekend or holiday.

Types and Sources of Forage Sampling Equipment

Below are names, addresses, and descriptions of many of the hay sampling probes available. This list is not intended to be exhaustive and is not an endorsement of these probes or a disparagement of other probes by omission.

Sierra Hay Probe. Sierra Testing Service, 9450 E. Collier Road, Acampo, CA 95220. Telephone: (209) 333-3337. www.sierratestingservice.com

Penn State Forage Probe. NASCO-Ft. Atkinson, 901 Janesville Avenue, Box 901, Fort Atkinson, WI 53538-0901. Telephone: (800) 558-9595. www.enasco.com

Oakfield Sampler. Oakfield Apparatus, Inc., 971 S. Main Street, Fond du Lac, WI 53065. Telephone: (920)933-3604. www.soilsamplers.com/hay_samplers.html

Colorado Hay Probe. UDY Corp., 201 Rome Court, Ft. Collins, CO 80524. Telephone: (970)482-2060. www.udyone.com/hayprobeinfo.htm

Frontier Mills Sampler. Frontier Mills, Inc., 2002 SD Highway 314, Yankton, SD 57078. Telephone: (605) 665-2441. www.frontiermills.com

Star Quality Samplers. Star Quality Samplers, 5719 114A Street, Edmonton, AB Canada T6H 3M8. Telephone: (780) 434-3367. www.starqualitysamplers.com/forage.php

HMC Hay Probe. Hart Machine Co., 1216 SW Hart Street, Madras, OR 97741. Telephone: (541) 475-3107.

Hay Chec Hay Sampler. Hodge Products, Inc., P.O. Box 1326, El Cajon, CA 92022. Telephone: (800) 854-3565. www.haychec.com

AMS Hay and Forage Probes. AMS, Inc., 105 Harrison St., American Falls, ID 83211. Telephone: (800) 635-7330. www.ams-samplers.com/itemgroup.cfm

Best Harvest Hay Sampler. Best Harvest Inc., P.O. Box 20428, Saint Petersburg, FL 33742. Telephone: (888) 947-6226. www.bestharveststore.com/Bale-Hay-Sampler-Probes-c10

Forageurs Hay Probe. Forageurs Corp., P.O. Box 564, Lakeville, MN 55044. Telephone: (952) 469-2596.

Soil Microbiology and Carbon in High Plains Dryland Agriculture

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There is a vast amount of diversity of soil microbes that perform a number of very important services to mankind. Soil microbes are responsible for producing the enzymes that decompose crop residues and cycle the nutrients back to plant-available forms. Thanks to microbes, soil can be regarded as a global bioreactor that digests and cycles a vast amount of materials so that humankind can grow their food efficiently.

One important group of soil microbes are fungi. While several fungi are known to cause plant diseases such as root rot and leaf rusts, good soils are known to foster a relatively high amount of fungal biomass. Soils that accumulate organic matter have been shown to contain a relatively high fungi:bacteria ratio. Fungi are important because they can decompose lignins, which are tough plant components. Fungi are also known to bind together soil aggregates and thus improve soil structure and soil water retention. Mycorrhizae are formed by a particularly important group of fungi because they form a mutually beneficial symbiosis with plants, and they can have a profound effect on the carbon cycling of agricultural systems.

The word mycorrhizae means literally “fungus root”, and as the word implies, these are associations between the roots of most land plants with soil fungi (Figure 1). The association is often beneficial to the plant, and the formation of mycorrhizae by crop plants can have positive effects on yields and biomass production. Mycorrhizae are described as a mutualistic symbiosis, implying that both the fungus and the plant are benefitted by the association. In general, plants support the mycorrhizal fungus directly



Figure 1. A mycorrhizal Sorghum root. Note that despite the large amount of fungal infection (the darker stained structures), this root is healthy.

with the contribution of photosynthesis products. This is essential for the fungus because it has been shown that mycorrhizal fungi are unable to grow well on their own without being associated with a plant. In return for the food that the plant provides, the fungus reaches out into hard to reach regions of the soil and obtains phosphorus and N for the plant. The mycorrhizal fungi are also able to bring some moisture to the roots, and it has been demonstrated that mycorrhizal plants tend to have a lower propensity to wilt compared to non-mycorrhizal plants. There are different types of mycorrhizal fungi. Some are specialized to associate exclusively with pine trees, for example. Arbuscular mycorrhizae are the type important to row crops, and they are named that way because of the formation of tree-like structures inside root cells that facilitate the transfer of nutrients from plant to fungus and vice versa. It is thought that mycorrhizal fungi had a role in the colonization of land by vascular plants more than 400 million years ago.

While mycorrhizae are largely good to the host plants, there are certain circumstances of mycorrhizal-induced plant growth decreases in cases where the fungus acts a bit like a “parasite”. Never the less, mycorrhizae are an integral part of terrestrial ecosystems, and they have multiple roles that help plants, not just the nutritional aspects. Because of this, the benefits of mycorrhizae are not straightforward to quantify and short term decreases in plant growth may not show the full picture of the mycorrhizal relationship. For example, mycorrhizal fungi can protect plants from root depredation, reduce fungal diseases, increase carbon flow to the soil, and foster healthy microbial populations around the roots.

The infection with mycorrhizae profoundly changes how a plant takes up and distributes its carbon. In a recent study, it was shown that sorghum plants infected with mycorrhizal fungi lose more C by root respiration, but also acquire more C via photosynthesis. At a point in time near sorghum maturity, it was shown that, mycorrhizal sorghum can absorb 21% more C from the atmosphere than plants without mycorrhizae (Calderon et al., 2012). However, the mycorrhizal plants also send more of the C to the roots and soil, which can result in slower growth and smaller biomass despite the higher photosynthesis. For example, about 6.3 % of the C taken up by the mycorrhizal sorghum plants was sent to the soil, compared to only 2.4% in the non-mycorrhizal plants. Figure 2 is a micrograph showing how fungi spread from the root to the surroundings by forming hyphae (fiber-like structures) and spores. These hyphae carry plant

carbon into the soil thus resulting in a net loss of carbon by the plant. However, these hyphae also tie up soil particles to form aggregates and improve soil structure, so the plants will benefit in the long run.

Different crops species require mycorrhizae to different extents. There are plants like some orchids and some palms which do not survive or thrive without mycorrhizal fungus infection. On the other end of the spectrum there are plants that do not form mycorrhizae at all, such as brassica crops (broccoli, cauliflower, and canola are examples). Most row crops fall in the middle of this spectrum, forming mycorrhizae only when it is beneficial, such as when P is limiting. This type of mycorrhizal relationship is called facultatively mycorrhizal. This allows the plant to optimize benefits and minimize the nutrient costs associated with feeding the fungus.

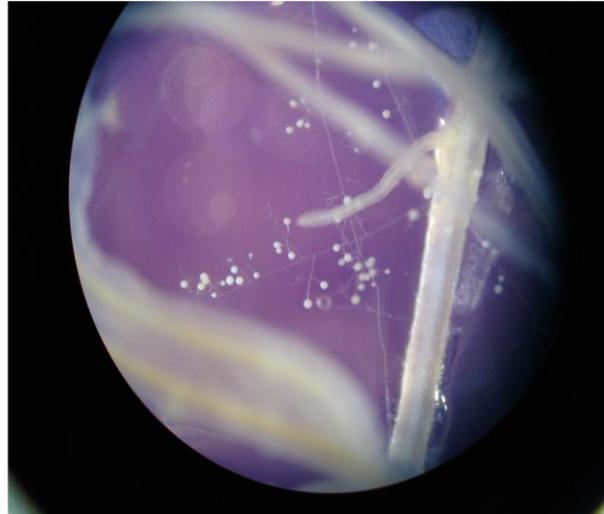


Figure 2. Mycorrhizal carrot roots and their associated mycorrhizal fungus. The fungal hypha (small filaments) and fungal spores are seen growing outside the roots.

A greenhouse study carried out in our laboratory using Proso millet as the host plant illustrates the effects of having or not having mycorrhizae on plant growth and yields (Table 1). Two varieties of Proso millet (Huntsman and Sunup) were grown in the greenhouse with four types of *Glomus occultum* fungal inoculant: An Arizona isolate (AZ), an Iowa isolate (IA), and a Wyoming (WY) isolate, as well as a killed inoculum control (C). *Glomus occultum* is interesting because it is considered a widespread fungal species, kind of a “weedy” mycorrhizal fungus, that is prevalent at the Central Great Plains Research Station (Dr. David Douds, personal comm.). All the treatments were in combination with two soil P treatments: Soils with added P (equivalent to 60 lbs per acre application), and soils without. Plants sampled for the data in Table 1 had reached reproductive stage with head formation, but not yet senesced.

Results show that mycorrhizae caused a large increase in the above-ground biomass of Proso millet, a 29-41% increase in shoot plus head dry weight relative to the controls, depending on the isolate. There was no P x inoculum treatment interaction, indicating that mycorrhizae

enhanced millet biomass regardless of the added P. Likewise, mycorrhizae increased the weight of millet heads, suggesting a potentially large effect on grain yields. While mycorrhizae did not have an effect on root biomass, the data shows that the addition of P fertilizer favored root growth. Mycorrhizal fungi are known to increase the concentration of fatty acids in root tissues (Calderon et al., 2009). Our data from the millet roots suggests that the higher root growth in the added P treatment resulted in less fungal infection compared to roots with no added P (not shown). This is a good example of a facultatively mycorrhizal relationship in which the plant fosters more mycorrhizae when it needs it most, namely when P is less available. It has to be kept in mind, however, that mycorrhizae are the natural way that plants grow in nature, and that the non-mycorrhizal condition shown in this experiment is not likely to be common in agricultural fields.

Table 1. Average values for the isolate, P, and variety treatments. Different letter suffixes within a column are significantly different according to Duncan's Multiple Range Test ($p < 0.05$).

By isolate (n=20):

	Shoot + head (g)	Heads number	Head (g)	Root (g)	Shoot to root ratio
AZ	4.16a	2.70a	2.77a	0.33a	13.2a
IA	4.31a	2.75a	2.78a	0.36a	13.0a
WY	3.95a	3.20a	2.61a	0.34a	12.4a
C	3.05b	2.90a	1.98b	0.37a	9.2b

By P treatment (n=40):

Added P	4.3a	2.8a	2.8a	0.40a	12.3a
No P	3.4b	3.0a	2.2b	0.30b	11.6a

By plant variety (n=40):

Huntsman	4.2a	2.6a	2.8a	0.40a	11.6b
Sunup	3.4b	3.1a	2.2b	0.30b	12.3a

Deployment of mycorrhizae in dryland agricultural systems is dependent on the availability of inoculum. Mycorrhizal fungi can grow only when attached to a host plant, so the production of fungal inoculum offers challenges to large-scale operations. This means that

inoculum is not usually cheap. There is an argument that inoculum application makes economic sense when high value cash crops are the target. Otherwise, it is thought that the best way to increase mycorrhizal populations is through management practices that favor the proliferation of mycorrhizal fungi. It has to be taken into account that agricultural soils have different amounts of mycorrhizal fungi in them, and that any inoculants will have to compete with the resident fungal species. Never the less, future research should address both how inoculating fields or changing the management practices affect the diversity of mycorrhizal fungi and the associated beneficial responses in crop yields.

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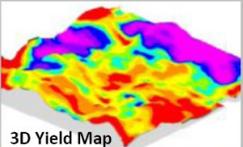
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The plan for the day...

	Room 1	Room 2	Room 3	Room 4
7:45 8:15	Registration			
8:15 8:20	Welcome			
8:30 9:20	Soil Microbiology and Carbon ¹ (F. Calderon)	Environmental Effects on Weed Control ^{1,2} (D. Peterson)	Farm Bill Decisions ¹ (D. O'Brien / M. Wood)	Maximizing w/NextField System (Cargill AgHorizons) (I)
9:30 10:20	High Plains Cover Crop Research ¹ (D. Nielsen)	Management of Drought Tolerant Corn ¹ (A. Schlegel)	Sampling 101 ¹ (NW Ag Agents)	Managing the Precision Data Matrix (Simplot) (I)
10:20 10:50	View Exhibits			
10:50 11:40	Fallow/Row-Crop Weed Control ^{1,2} (C. Thompson)	Wheat Yield and Development ¹ (G. McMaster)	High Plains Cover Crop Research ¹ (D. Nielsen)	Sunflower Production Update (Nat'l Sunflower Assoc) (I)
11:50 12:40	Phosphorus Management ¹ (D. Ruiz-Diaz)	Soil Microbiology and Carbon ¹ (F. Calderon)	Lunch	
12:50 1:40	Environmental Effects on Weed Control ^{1,2} (D. Peterson)	Management of Drought Tolerant Corn ¹ (A. Schlegel)		
1:50 2:40	Wheat Yield and Development ¹ (G. McMaster)	Ogallala Overview ¹ (B. Wilson)	Phosphorus Management ¹ (D. Ruiz-Diaz)	High Perf. Test with Variable Rate Irrig (Monsanto) (I)
2:40 3:10	View Exhibits			
3:10 4:00	Producer Discussion Panel	Fallow/Row-Crop Weed Control ^{1,2} (C. Thompson)	Sampling 101 ¹ (NW Ag Agents)	Fallow, Wheat, Row-Crop Weed Mgmt. (Bayer CS)(I)
4:10 5:00	Ogallala Overview ¹ (B. Wilson)	Farm Bill Decisions ¹ (D. O'Brien / M. Wood)	Delivering Quality Solutions (Frontier Ag) (I)	Tackling Tough Weeds (Sims Fertilizer) (I)

(I) indicate industry sessions.

¹ Indicate Certified Crop Advisor CEUs applied for.

² Indicate Commercial Applicator CEUs applied for.

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