Cover Your Acres
Winter Conference

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Oberlin, KS

A cooperative effort between:

K·STATE
Research and Extension

Northwest Kansas Crop Residue Alliance

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Herbicide Resistant Weeds: Lessons Learned and the Need for Diversity: Herbicide resistance is a growing challenge. The progression of resistance in Kochia and Palmer Amaranth, what the future holds, and how to manage for it will be discussed.

Economics of Soil Fertility Management: With thinning margins, there are opportunities to manage crop nutrients in order to gain the best possible financial return to your bottom line.

Forage Sorghum and Cover Crop Management: Take a look at how some management options can maximize your potential economic returns to growing forage sorghum or cover crops for livestock use.

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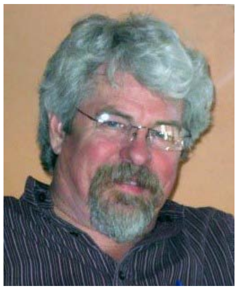
Proceedings from prior years of the Cover Your Acres
Winter Conference can be found online:
www.northwest.ksu.edu/coveryouracres

Presenters



Charlie Griffin- Charlie Griffin is a Research Assistant Professor in the School for Family Studies and Human Services, College of Human Ecology, at Kansas State University. He began his career assisting with the impact of the 80's farm crisis and has continued to support agricultural families as they work together, make decisions together, and nurture their families and businesses.

Lucas Haag- Lucas Haag was raised on a diversified dryland farming and ranching operation near Lebanon, Nebraska along the Kansas/Nebraska line. He received his B.S. in Agricultural Technology Management in 2005 and a M.S. in Agronomy (crop ecophysiology) in 2008 from K-State. Lucas completed his Ph.D. in Agronomy in 2013. He is an assistant professor of agronomy and Northwest Area Agronomist stationed at the Northwest Research-Extension Center, Colby, Kansas. He has extension agronomy responsibilities for 26 counties in northwest and north-central Kansas. He conducts research and extension activities in a variety of areas but specializes in precision ag and dryland cropping systems. Lucas remains actively tied to production ag as a partner with his brothers in Haag Land and Cattle Co.

John Holman-Cropping Systems Agronomist at Kansas State University. John received his B.S. degree in plant science and agriculture business and his M.S. degree in weed science from Montana State University. His Ph.D. was from the University of Idaho. He joined Kansas State University in 2006 and is currently an Associate Professor with a 70% Research and 30% Extension appointment. His research is primarily on dryland cropping systems of western Kansas, with an emphasis in soil-water, crop rotations, integrated weed management, and annual forages. He manages the state-wide forage variety testing program. In addition, he and his wife Marcella, operate a 4th generation cow/calf and farming enterprise near Dodge City, KS.

Kevin Moore- Kevin Moore is a Research Engineer and PhD candidate in Biosystems and Agricultural Engineering at Oklahoma State University (OSU). He received his BS degree in Chemical Engineering and his MBA from OSU. Kevin worked for eight years as an Applications Engineer at Sulzer Chemtech in Tulsa, OK before returning to OSU as Manager of Proposal Services for the College of Engineering, Architecture, and Technology. He later became the Director of Student Academic Services, leading the recruiting, academic advising, and career services activities of the college for six years. Since returning to graduate school, Kevin's research topics have included post-harvest grain storage, agricultural safety, and electronic sensing of grain quality.

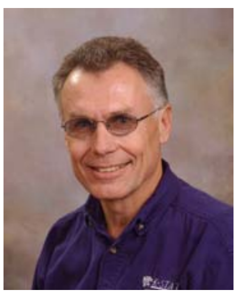
Daniel O'Brien– Extension Agricultural Economist. Dr. Daniel O'Brien received his B.S. in Agricultural Economics from the University of Nebraska and his Ph.D from Iowa State University. The focus of Daniel O'Brien's extension and applied research efforts have been in the areas of grain and bioenergy 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.

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.

Presenters

Alan Schlegel- Alan Schlegel joined Kansas State University in 1986. He is a Professor and Agronomist-in-Charge 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 program is to develop cropping strategies that reduce tillage, increase capture of precipitation, reduce evaporation and erosion potential while enhancing crop yields. The focus his nutrient management research is to optimize fertilizer use efficiency, crop production, and profitability while maintaining environmental quality. Current irrigation research is focusing on limited irrigated cropping systems to reduce groundwater depletion while maintaining profitability.

Phil Stahlman– Phil was raised on his family's small grains and dairy farm in northwest Oklahoma. He received his B.S. in Agronomy from Panhandle State College, M.S. at NDSU, and Ph.D. and Univ. of Wyoming. He is a Professor and Weed Scientist at the K-State Agricultural Research Center-Hays where he has directed weed management research in dryland cropping systems for the past 39 years. Previously he was Agronomist-in-Charge of the Harvey County Experiment Field in Hesston and Assistant Agronomist at the North Central Branch Experiment Station at Minot, ND. His research focuses on crop weed interactions and integrated weed management with recent emphasis on herbicide-induced weed spectrum shifts and the ecology and management of glyphosate resistant kochia.



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.

Peter Tomlinson- Peter Tomlinson - Peter Tomlinson is an Assistant Professor and Extension Environmental Quality Specialist for Kansas State University. He received B.S. degrees in Animal Science and Agronomy from the University of Connecticut and M.S and Ph.D. degrees in Crop, Soil and Environmental Sciences from the University of Arkansas. Peter's passion for agriculture began as a 4-Her and motivates his current research and extension programs addressing the complex environmental challenges facing agriculture. Drawing on his diverse background in animal science, manure management, agronomy, soil science and ecology Peter conducts applied research and extension programing in the areas of soil biology, nutrient management, and soil, water and air quality.

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.

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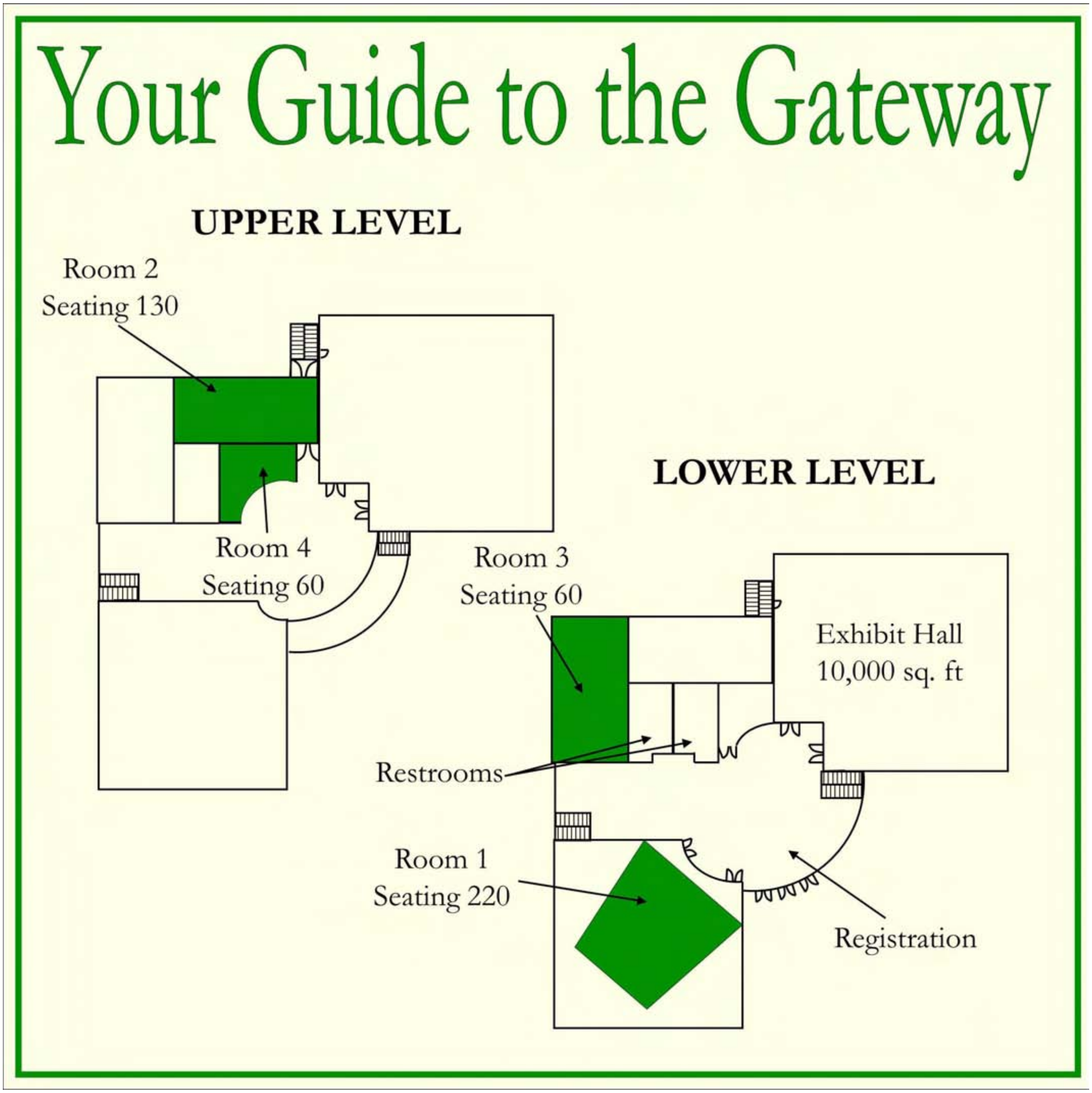

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Building Strong Business Dynamics in Tough Times

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Building Strong Business Dynamics in Farm and Ranch Families

Strong successful businesses do not just happen. They grow and develop because of the application of very specific practices and strategies over time. These practices are based in strong core values that guide the development of the business over time coupled with careful, thoughtful planning, and rely at the everyday level on successful communication, teamwork, and the satisfaction of life goals of every member of the team.

These practices are challenging and difficult in the best of times, but become essential during "tough times." Those tough times may be financial/economic in nature, but they may well arise from the unforeseeable life crises that may befall anyone…..health crises, weather and other natural disasters, relationship changes, and simply the development of lives as times go by. During those tough times, careful attention must especially be paid to the basics of good management, communication and decision making.

Agricultural families and businesses are traditionally rooted in intergenerational relationships and continuity of those relationships with the land itself. Tough times highlight the need for families to learn and utilize successful coping strategies, both on a day to day basis and in regard to intergenerational farm transfer.

Understanding Farm Family and Small Business Dynamics

Small business and farm family businesses are challenging for a number of reasons. They combine, much more than other businesses, three spheres, (1) the family/personal relationships where we have fun, find security, nurturance, and support, (2) the management system which is how we get things done day by day and maintain productivity, and (3) the ownership system, who actually owns the business assets and gains the return on investments. Those three spheres are not easily nor naturally compatible on a day to day basis. But they are woven together throughout the day, with the "factory work floor" and the family recreational area and even the child rearing and day care all rolled together in a way that other workplaces simply do not do. And our team relationships must shift from one role to another as we move from one role to another. Not a simple thing to do. These business dynamics bring their own unique challenges, stressors, and sources of conflict for farm and ranch families to manage. At the heart of that successful management is good effective communication, which is likely to be the last farm management skill that gets attention in a busy operation.

Successful farm businesses must carefully plan for the future at the same time as they negotiate the day to day challenges of making a living. In the larger picture, it is essential that those businesses recognize the need to weave together the Career Development of younger entering members of the family with the Professional Development of all members while looking ahead to the Retirement Process for the older generation. Just as farmers and ranchers understand the yearly seasonal cycles and life cycles of crops and animals, they need to understand how their Family Life Cycles and Business Cycles intertwine, sometimes with 3 generations all at different points in those cycles.

The key point is that all these decisions regarding the structure and practice at the family and business level will be made simultaneously, not one at a time. And it‘s best if they are made at an early point in the business planning process, knowing that they may well need to be re-examined and perhaps changed at major transition points throughout life.

Business Planning in a Nut Shell
Given the points made above, there are clear practices that support successful businesses.

Step 1: Have a Vision, a clear Mission! This provides the long term orientation. It's what holds a team together so that they are all working in tandem toward a common outcome and not fighting against each other at a basic level. The business needs to have a commonly understood and motivating mission that all team members care about! Understand that each individual member may well have their own goals, motivations, vision, passions which provide their satisfaction with their life. It's vital that they do! But the individual visions should mesh together and complement each other in support of the primary vision. So, developing a clearly motivating Vision and Mission is the first step of business planning, and generally the most over looked.

Step 2: Develop a carefully thought out strategy as to how to accomplish the Vision. What is the path that the family/business is going to pursue to make their vision real? For example, will they raise cattle, cow-calf, backgrounding, feedlot finishing, hogs, only raise crops, irrigate or dry land, develop niche markets for farmers markets, organic outlets, do value added processing, put land in CRP, lease the land and work off farm? Each strategy may depend on understanding the resources available, the skills and competencies of the team members, the motivation and inclinations of each person, and external market realities, etc. And strategies need to be reevaluated on a regular basis. Is it working successfully, are there new and better strategies, have the external realities changed? Most farm and ranch families have pursued many different strategies at different times in their life, due at times to their own choices, at other times to the realities of the changing world around them.

Step 3: Execution….this term really points to how we work together every day to get things done in light of the first two steps. It points to the daily decision making, coordination, and communication necessary to keep the show moving to a successful outcome.

These three steps offer a self-evaluation outline for each business to determine where their strengths and weaknesses lie and to work on improvement of their management skills. But often, the failure is at the level of Step 1. Most farm and ranch business management advisors will recommend at least a yearly business planning meeting to re-examine at a broad level Vision, Mission, Guiding Principles and Values and to give all members of the team on opportunity for input, re-thinking and adjustment. Some families find a meeting of this sort is helpful every six months. Communication about Execution is ongoing every day!

Finally, it's worth pointing out that these business management practices are essential for successful businesses at all levels. But when times get tough, due to difficult financial times or unexpected life crises, they are essential. And yet it's very challenging in the midst of daily stressors and crises to find the space to pull back and attend to the larger picture. Below is a 'tip sheet' from the Kansas Agricultural Mediation Service for steps to take with our own families as well as with friends and neighbors who may be experiencing those hard times, focusing on the hardest part of the equation, the communications!

Tips to Help Others

Listen

- Take time.
- Listen to what is being said and NOT being said.
- Give time to share thoughts – Silence is okay.
- Tears are okay, not something that needs to be fixed.

Starting the conversation

- Get acquainted.
- "Tell me about your farming operation."
- Start slow, don't jump into the heavy stuff.

Keep them focused

- "Why did you call us today?"
- "What is your biggest concern?"
- "If today you could change ONE thing, what would it be?"
- Take time to listen to the tough stuff and acknowledge the emotions, then…..
- Focus on the present—things that CAN be changed not on what can't be changed

Encourage connection. Don't be alone.

- "Who's your best friend?", "Who do you talk to?" –then say, "Talk to them."
- Those closest may not be aware of what's happening
- A support system may include family member, friends, pastors, hired man, employer, accountant, attorney, etc. Professionals are often the "helper of last resort."
- Encourage them not to face stressful situations alone.

Empower them

- Help them learn how to help themselves.
- Encourage them. It's OK to ask for help.
- Pride is important for every farmer. Support them in asking for help.
- Give homework to do and ask for a report. Make a follow up call, if for no other reason to just to say "How are you doing?"

Confidentiality

- Assure that what is shared is confidential.
- It requires a lot of trust on the producer's part to share their whole story.
- Transparency is vital to be able to help them.
- Gaining respect and trust is vital.

Elephant in the room

- "So what else is going on?" "Tell me what's going on?" often uncovers real issues.
- These kinds of statements sometimes gives permission to open up.
- It is often more than loan delinquency at the bank. i.e. no money for family living expenses, depression, guilt, domestic violence, substance abuse, addictions, health issues etc.
- Be ready when you ask these questions. You may learn more than what you expect.

Include the whole team

- Talk with all the members of the operation (family, intergenerational, etc.) when appropriate.

Don't try to solve every problem

- Assure the person that there is help and support.
- May require a different approach, you are helping them find a solution.

Making a referral

- **Know SAFE places to call.**
- Remember a bad referral is worse than no referral.
- Know the resources that are available.
- Network with helping agencies.
- Include a contact person when making the referral.
- Encourage them to report back about how the referral went.

Show that you care

- Be as "non-judgmental as your dog."

"Your most important gift to your clients is your listening, your acceptance and your sincere interest in them. To know that you are not alone gives courage."

Kansas Agricultural Mediation Service 1-800-321-3276

Herbicide Resistant Weeds: Lessons Learned and the Need for Diversity

Phillip W. Stahlman
Research Weed Scientist
KSU Agricultural Research Center-Hays

Weed management through the ages. From the beginning of organized farming by ancient man through the mid-20th century, weeds in agroecosystems were mostly pulled by hand or removed using specialized tools. Romans were known to apply salt to fields of enemies to prevent crop growth and by the mid-19th century it was learned how to use lime and salts to control weeds in crops and orchards.

The modern era of chemical weed control began with the discovery of chlorophenoxy acetic herbicides in the early 1940's. This family of herbicides, especially 2,4-D and MCPA, not only transformed agriculture by revolutionizing weed control, but also gave rise to the scientific disciple of weed science and an entire new crop protection industry. During the next three decades, many new broad-spectrum herbicides were developed that were simple to use and typically provided exceptionally good weed control with far less need for labor compared to mechanical weed control. Over time farmers increasingly relied on intensive herbicide use for cropland weed management. Crop yields and production efficiency increased and allowed many farmers to increase the size of their farming operations. Life was good!

Prior to the first commercialization of glyphosate-resistant (GR) crops in 1996, glyphosate was already to top selling global crop protection chemical. The introduction of GR crops arguably began the fastest adoption of new technology in American agriculture. Declining glyphosate costs helped fuel the rate of adoption. Benefits included simple and cost-effective weed control with "over-the-top" glyphosate without need for other herbicides, lower production costs, greater flexibility in farm management, and improved soil and water conservation. Within only a few years a large majority of the corn, cotton, soybean and eventually sugarbeet acreage in the United States was planted to GR varieties. In many instances multiple applications of glyphosate alone were made to these crops every year, in addition to preplant and fallow applications. Use of pre-emergent herbicides was nearly abandoned in GR crops. All this was good for farmers, or so many believed, but was not good for the crop protection industry!

Evolved weed resistance to herbicides. An unintended consequence of intensive herbicide use, especially in monoculture and limited rotational cropping systems, is shifts in species composition and selection for rare existing resistant biotypes within weed populations. Frequent, repeated use of any herbicide mode of action over large areas without use of other alternative control tactics will eventually eliminate susceptible biotypes and allow resistant biotypes to increase in proportion to the point of weed control failure. Using multiple herbicide modes of action will delay but will not prevent selection processes leading to enhanced metabolism or stacked (multiple) resistant traits within the same species.

Species with high genetic diversity, prolific production of seeds that readily germinate, and short seed-life (e.g., kochia and Palmer amaranth) are more prone to evolved herbicide resistance than species with low genetic diversity and long seed-life. The dramatic increase in glyphosate use over vast areas increased selection pressure on weed populations at an unprecedented rate. Herbicide resistance (HR) is widely recognized as the adaptive evolution of weed populations to intensive herbicide selection pressure.

The first confirmed case of GR weeds in the United States was in horseweed in Delaware in 2000. Horseweed also was the first weed species in Kansas to evolve resistance to glyphosate in 2005, followed by tall waterhemp, common and giant ragweed, and kochia in 2006 and 2007. Within only 5 years, GR kochia had spread or evolved independently throughout the entire North American Great Plains and into the Pacific Northwest. GR Palmer amaranth was first confirmed in Kansas in 2011, and is now present throughout most of central and western Kansas and into Nebraska and Colorado.

Some impacts of HR. One of the first realized impacts of HR weeds is unacceptable weed control following use of a previously effective herbicide program. Depending on extent of the control failure, this could result in negative economic and environmental impacts of reduced crop yields and lower grain and/or forage quality, lower short- and long-term profitability, and if severe, possibly lower land value. Social impacts include damages to self-esteem of being a good farmer, possible strained relationships with neighbors and landlords, and perceived or actual affected reputation within the community.

Human behavior and decision-making is driving resistance evolution. Farmers are very aware of HR problems, but few are proactive in adopting recommended integrated weed management practices. The dilemma is that farmers are faced with a complex mix of interacting operational, economic and social considerations affecting weed management decisions. HR fits the sociological definition of a "wicked" problem lacking simple solutions. Indeed, there are no simple solutions to HR weeds.

What have we learned? Dale Shaner, retired USDA-ARS scientist, recently reviewed the history of HR and documented lessons learned over the past 45 years (Shaner 2014). Here is a brief summary of his learnings.

1. Reliance on herbicides alone for weed management is not sustainable long-term.
2. Simple weed management systems are not sustainable long-term because of the selection pressure exerted on weed populations.
3. Diversity is the key to weed management, meaning using multiple tactics and tools.
4. Time constraints will limit farmer adoption of HR weed management programs that cannot be easily implemented.
5. HR will never be eliminated but can only be managed.

Managing HR weeds. Because of the mobile nature of resistance through pollen flow and seed movement by multiple means, HR weed management solutions will require a shift in thinking and practice and will involve multiple integrated tactics implemented on community-wide or regional scales. The latter likely will challenge and threaten the independence of some individuals for the benefit of the community. Yet, there are successful examples of community-based programs for insect pest eradication and control of invasive species that can be used to help design and implement "bottom-up" community-based programs. Most successful community-based programs usually involve incentives as well as regulations.

Simple or singly effective solutions are unlikely in most situations. Rather, solutions will involve adopting diverse practices in a more holistic and longer-term approach to weed management than from year to year. For many, this will require a change in mind-set that cost-effective weed management involves only herbicides. This can be a hard sell unless there are clear and immediate economic rewards associated with change in weed management practices. Unfortunately, integrated weed management systems involving multiple tactics are more complex and time consuming to implement than herbicide-only reliant management systems, and they may require greater short-term input costs. Return on investment is uncertain and may not be realized the same year of implementation.

Much has already been written elsewhere about proactive vs. reactive weed management and the benefits of implementing a diverse tactile approach to HR weed management. Here I will address some supplemental tactics to be used in combination with herbicides, which likely will continue to be the main weed management tools well into the future.

Alternative weed management tactics. Many farmers report that the cost-effectiveness of herbicides and operational issues, such as time and labor constraints, are greater barriers to adoption of diverse or alternative weed management tactics than are higher associated costs. Avid no-tillers strongly resist the idea of tillage, believing even occasional or strategic tillage will destroy gains in soil and water conservation and improved soil productivity that took years to achieve. Whereas this may be true for deep inversion tillage, research indicates that infrequent, shallow tillage does not substantially negate those accrued benefits. In certain instances, tillage may be the most effective and reasonable way to prevent HR species from producing seed and renewing the soil seedbank. Consequently, tillage should not be a disregarded component of integrated weed management, but should be used judiciously after considering possible environmental, economic, and regulatory implications.

Cultural practices can aid in weed suppression and help crop plants attain a competitive advantage over weeds. Any practice that favors crop plants while shading or otherwise inhibiting weed growth shifts the competitive advantage to the crop. Such cultural practices include rotations of crops having different seasonal growth patterns, adjusted planting dates, higher seeding rates for some crops, narrow row spacing and direction orientation, planting configurations, crop plant architecture, fertilizer placement, and others. Admittedly, no one of these tactics is as effective as herbicides and they are most effective when used in combinations to supplement and improve herbicidal weed control. When possible, choose crop varieties known to be more competitive with weeds.

Cover crops for weed control. An area receiving considerable research attention and considerable farmer interest in recent years is that of cover crops. Recent and current research in Kansas has shown that cover crops can increase soil quality, reduce soil compaction, and suppress weed growth, thus requiring fewer herbicide applications during non-crop phases of crop rotations. Though uniform stands of cover crops can inhibit weed establishment and subsequent growth, that's just one aspect producers should consider in deciding whether to use cover crops and which cover crops are best for their situation. Effects of cover crops on yields of succeeding crops have been highly variable, largely depending on seasonal rainfall quantity and timeliness, when the cover crops were terminated, and the extent of biomass removal by livestock grazing. Ongoing research and experience should help determine how best to use cover crops for weed management and whether cover crops should be part of the crop rotation.

Concluding comments. HR weeds are not a new problem; they are becoming more prevalent throughout the world. The first confirmed case of HR in Kansas was atrazine resistance in kochia in 1976. And weed resistance to ALS-inhibiting herbicides was first confirmed in Kansas, Idaho, and North Dakota in 1987. Though inconvenient, those problems have largely been overcome and are not now major issues. The problem with GR weeds, however, is considerably more serious because of the importance of glyphosate for weed management in fallow and multiple cropping systems and because of the lack of similarly cost-effective alternative herbicides.

In a recent call to action, Coble and Schroeder (2016) noted that farmers and pest management practitioners are key to weed management because they decide the practices to be used. However, many other individuals, organizations and federal programs influence those decisions. The crop protection industry, retail suppliers, university and government scientists, and regulatory agencies influence decisions through retail promotions, research, extension, and outreach education, and government agencies through regulatory and incentive programs. It is critically important that all groups work together and communicate the same message that is based on credible science.

There is general agreement among plant biologists and weed scientists that diversity of weed management tactics is needed to manage existing HR populations and delay/prevent the selection of additional cases of resistance to additional mechanisms of action. The time to implement more diverse weed management strategies is now.

Online information and resources. Those seeking additional information on the internet are encouraged to visit the Herbicide Resistance section on the Weed Science Society of America website at http://wssa.net/wssa/weed/resistance/ This website contains a wealth of information on herbicide resistance, including links to fact sheets, infographics, control modules, and numerous other credible resources.

Greater in-depth information on the contents of this paper can be found in the following print publications; most are accessible online.

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Managing crop nutrients to maximize your return on investment

Dorivar Ruiz Diaz, Soil Fertility, Kansas State University

Low grain prices require improved efficiency in the use of production inputs to maximize profits. Fertilizer is one of the key inputs for optimum production, and require a combination of economic and agronomic considerations for any adjustments in the short and long term. Reduced application rates may not necessarily be the right decision for all fields. However, some fields with high levels of soil nutrients (based on soil test) can reduce fertilizer application rates and may increase profits in the short term.

For nitrogen management consider the value of soil profile nitrogen testing

Soil testing to determine the available nutrients in the soil is the first step in developing an effective crop fertilization program. Nitrogen, unlike phosphorus and potassium, is very mobile in the soil, and as result a profile soil test is recommended to determine the amount of available nitrogen in the soil.

Using profile soil nitrogen test to verify nitrogen credits can provide valuable information to farmers. Most farmers are unaware of the amount of nitrogen already present in their soils from the previous season. Plant available nitrogen can be present in the soil from fertilizer carryover, previous manure applications or legume plowdowns. Fertilizer nitrogen is applied based on production conditions and estimated yield potential for that particular year. When the actual crop yield is lower than expected or fertilizer nitrogen was simply over-applied, there is a high probability of some residual nitrogen present in the soil. Under conditions of high rainfall this nitrogen is prone to loses by leaching or denitrification. However, under conditions of low precipitation such as the high plains this nitrogen will likely stay in the soil and become available for following crops.

Deep nitrate-nitrogen soil testing (0- to 24- inch profile nitrate test) can provide information regarding the level of carryover nitrogen. Soil nitrate testing can be especially important after a crop failure due to drought conditions. Crop growth can be extremely limited during a drought and therefore the applied fertilizer nitrogen as well as mineralized soil nitrogen is typically not fully utilized. This carryover nitrogen would be available for the next crop and some farmers will find that fertilizer nitrogen needs can be significantly reduced. The relative “value” of the profile nitrate test will depend on several factors affecting nitrogen carryover. Some of these factors can be related to soil and climate such as soil texture, rainfall, and air/soil temperature, while management practice like crop rotation and manure application history will also affect the value of this test (Table 1). Yield levels in recent years across Kansas varied, and some very good yield levels were reported. Fields with recent history of high yields will likely have very low levels of residual nitrate. This information is equality important, and may result in higher N fertilizer requirements for this year’s crop.

When taking samples for nitrate analysis, late fall or early spring is a good time to sample. Nitrate levels will fluctuate somewhat through the year, depending on soil temperatures and soil mineralization rates. The best time to take the sample is considered to be during cool periods after the previous crop has been harvested but before the soil warms up too much the following spring. This will give producers a good reading on how much nitrogen remains from the previous crop, before mineralization begins to increase nitrate levels the following spring.
Profile nitrate testing for residual nitrogen provides valuable information for precise fertilizer recommendations and provides producers season-end information regarding crop N use and N remaining for next year’s crop.

Table 1. Likelihood of significant profile nitrogen carryover

Higher probability of significant profile n (profile nitrogen test more valuable)	Lower probability of significant profile n (profile nitrogen test less valuable)

• Medium-fine textured soils
• Recent history of excessive N rates
• Previous crop
  o Lower than expected yield
  o Drought affected
  o Fallow
  o Previously destroyed stands of alfalfa/clovers
• History of manure application
• Warm, late falls and/or early, warm springs
	• Sandy soils
	• Appropriate N rate history
	• Previous crop
	  o Soybeans (immediately preceding)
	  o Higher than expected yield history
	  o Expected yields history
	• Excessive precipitation
	• No manure or biosolids application history
	• Increased rotation intensity

Adapted from: Leikam D. and D. Mengel, 2007. Nutrient Management *in* Corn Production Handbook, Kansas State University.

Proper soil sampling and testing for immobile nutrients.

In addition to residual profile nitrate, in Kansas, mineralized nitrogen from soil organic matter is also credited. For warm season crops is expected approximately 20 lbs of available nitrogen per acre during the crop year for each one percent of soil organic matter. For cool season crops (e.g. wheat) is expected approximately 10 lbs of available nitrogen for each one percent of soil organic matter. Information regarding the level of soil organic matter would significantly improve the efficiency in nitrogen management. Sampling depth for organic matter is established at the 0- to 6- inch.

Proper soil sampling and testing is very important for a good assessment of nutrient status in the soil. Nitrate testing require yearly sampling of each field for accurate residual nitrogen estimations. For immobile nutrients including OM, pH, P, K, and Zn samples should be collected at least every 3-4 years. During years with a tight budget soil sampling every 2 years may be beneficial for optimum fertilizer rates and management. Keep in mind the investment on soil sampling and testing is relatively low compared to the economic implications of inaccurate fertilizer application rates (Fig. 1)

Using soil test information producers can decide if fertilizer rates can be reduced for a given year and crop. However, producers should not reduce fertilizer application in soils testing very low. May slightly reduce the rate in soils testing medium or high, and consider using a low starter rate in high-testing soils. The KSU publication “Soil Test Interpretations and Fertilizer Recommendations” (MF2586) provide the recommended rates for each soil test level.

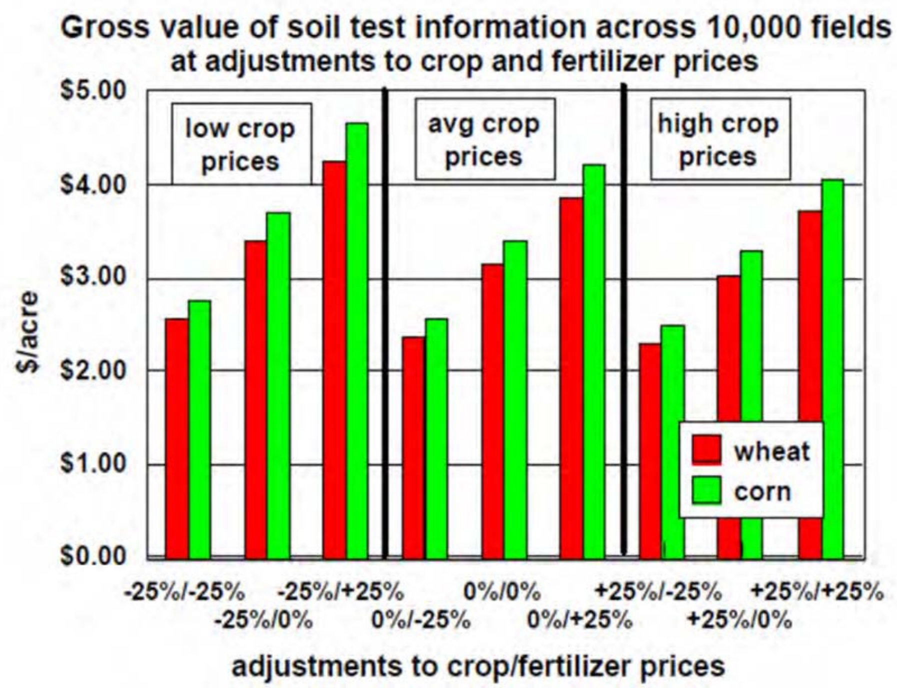

Figure 1. Simulated relative economic return to soil test information given crop and fertilizer prices (T. Kastens and K. Dhuyvetter, 2004)

Grain nutrient removal and soil test levels in the medium and long term

The yield level and P or K removal should be used to determine the application rate needed to maintain soil-test levels. Table 2 show the average removal rates by crop, is important to keep in mind the effect of crop removal may not be evident in one year due to year to year variability. Fields with high testing soils can decrease application rates and likely increase profits in the short-term, however higher nutrient rates will be needed in the future because soil-test values will decline. Total nutrient removal rates is a key information that should be considered along with good soil test data.

Table 2. Phosphorus and potassium crop removal

Crop	Unit	P2O5	K2O
Alfalfa & Clover	ton	12	60
Corn	bushel	0.33	0.26
Grain sorghum	bushel	0.4	0.26
Sorghum silage	ton	3.2	8.7
Wheat	bushel	0.5	0.3
Sunflowers	pound	0.015	0.006
Soybeans	bushel	0.8	1.4

From KSU publication MF2586

The use of sensors and variable-rate technology application

Sensors (NDVI) provide a good alternative for accurate nitrogen management particularly for wheat and sorghum. This technology can help to adjust N rates based on in season N status of the crop. On the other hand, the use of variable-rate lime, P and K fertilization is a good option to improve efficiency in fields that have significant variation in soil-test or yield levels.

The use of sensors and variable rate fertilizer application can help to identify parts of a field that could respond to higher rates of fertilizer; provide savings from reduced fertilizer application if non-responsive areas of a field are identified. The benefits can only be determined on a field-by-field basis (Fig 2). The challenge is to identify opportunities for increased net income with sufficient precision without excessive cost.

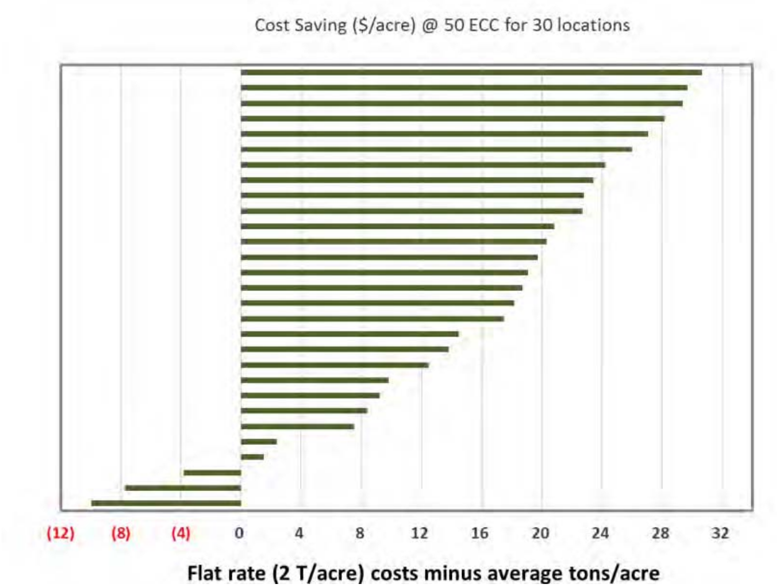

Figure 2. Cost savings with the use of variable rate application of lime.

Fertilizer placement and application rates

Banding fertilizer can be considered as more efficient than broadcasting including reduced risk for surface loses. However multiple studies in KS seldom show an increased efficiency in crop response with band application of phosphorus. Therefore, reducing the P fertilizer rate for low-testing soils when banding will increase the risk of yield loss, may reduce profits from crop production, and future fertilization rates will need to be increased.

However, for nitrogen application, particularly under heavy residue cover (no-till), subsurface band applications can increase efficiency significantly by reducing N immobilization and volatilization loses.

Summary

- Use good soil test information to make the right decision.
- Don’t reduce rate in low testing fields, profits are very likely.
- Return to fertilizer in high testing soils may be limited with current conditions (use “reserve soil nutrients”).
- Low grain prices may require more soil sampling.
- Consider variable rate application.
- Placement can improve efficient for N under some conditions.

NINE YEARS OF COVER CROP RESEARCH IN THE HIGH PLAINS

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ABSTRACT

Producers are interested in growing cover crops in place of fallow. Growing a cover crop during the fallow period would increase system profit if the benefits of growing the cover crop exceed the expense of growing the cover crop plus the potential negative yield impacts on the following cash crop. Benefits of growing a cover crop were shown in high precipitation regions, but limited information is available on growing cover crops in the semiarid Great Plains. A study from 2007–2016 evaluated cover crops, annual forages, and short season grain crops grown in place of fallow. In the first experiment (2007-2012) the crop rotation was no-till wheat-fallow, and in the second experiment (2012-2016) the rotation was no-till wheat-grain sorghum-fallow. This report presents results from both experiments. Wheat yield was affected by growing a crop in place of fallow, but there was no difference in wheat yield whether the crop was grown for forage or cover. Wheat yield following crops grown in place of fallow was dependent on the amount of precipitation received during the fallow period and the winter wheat growing season. In dry years (2011-2014), growing a crop in place of fallow reduced wheat yields up to 75%, yet growing a crop in place of fallow had little impact on wheat yield in wet years (2008-2010). The length of the fallow period between cover crop termination and wheat planting also affected wheat yields. Fallow periods less than 120 days between cover crop termination and wheat planting tended to reduce wheat yield greater. Cover crops did not improve wheat or grain sorghum yields compared to fallow. Cover crops always resulted in less profit than fallow, while annual forages increased profit compared to fallow in wet years. In dry years fallow was the most profitable. The negative effects of annual forages on wheat yields and profit might be minimized by using flex-fallow. Flex-fallow is the concept of only growing a crop in place of fallow in years when soil moisture at the time of annual forage planting and precipitation outlook for the coming year are favorable. This determination is made at the time of making the decision of whether or not to plant a forage crop within the traditional fallow period. In years that soil moisture and precipitation outlook are not favorable, then a forage crop is not planted and fallow should be practiced.

INTRODUCTION

Interest in replacing fallow with a cash crop or cover crop has necessitated research on soil water and wheat yields following a shortened fallow period. Fallow stores moisture, which helps stabilize crop yields and reduces the risk of crop failure; however, only 25 to 30% of the precipitation received during the fallow period of a no-till wheat-fallow rotation is stored. The remaining 85 to 70% precipitation is lost, primarily due to evaporation. Moisture storage in fallow is more efficient earlier in the fallow period, when the soil is dry, and during the winter months when the evaporation rate is lower. It may be possible to increase cropping intensity without reducing winter wheat yield. This study evaluated replacing part of the fallow period with a cover, annual forage, or short-season grain crop on plant-available water at wheat planting and winter wheat yield.

MATERIALS AND METHODS

A study from 2007–2016 evaluated cover crops, annual forages, and grain peas grown in place of fallow in a no-till cropping system. In the first experiment (2007-2012) the rotation was wheat-fallow, beginning in 2012, the crop rotation was modified to wheat-grain sorghum-fallow. Treatments that stayed the same between experiments 1 and 2 were maintained in the same plots so that long-term treatment impacts could be determined. Fallow replacement crops (cover crop, annual forage, or short-season grain crop) were either grown as standing cover, harvested for forage (annual forage crop), or harvested for grain and changed slightly over time to identify the best crops for the environment (Table 1).

In experiment 1 (2007-2012) both winter and spring crop species were evaluated. Winter species included yellow sweet clover (*Melilotus officinalis* (L.) Lam.) hairy vetch (*Vicia villosa* Roth ssp.), lentil (*Lens culinaris* Medik.), Austrian winter forage pea (*Pisum sativum* L. ssp.), Austrian winter grain pea (*Pisum sativum* L. ssp.), and triticale (×*Triticosecale* Wittm.). Spring species included lentil (*Lens culinaris* Medik.), forage pea (*Pisum sativum* L. ssp.), grain pea (*Pisum sativum* L. ssp.), and triticale (×*Triticosecale* Wittm.). Crops were grown in monoculture and in two-species mixtures of each legume plus triticale. Crops grown for grain were grown in monoculture only. Winter lentil was grown in place of yellow sweet clover beginning in 2008. Crops grown in place of fallow were compared with a wheat-fallow and continuous wheat rotation for a total of 16 treatments. The study design was a split-split-plot randomized complete block design with four replications; crop phase (wheat-fallow) was the main plot, fallow replacement was the split-plot, and fallow replacement method (forage, grain, or cover) was the split-split-plot. The main plot was 480 ft wide and 120 ft long, the split-plot was 30 ft wide and 120 ft long, and the split-split plot was 15 ft wide and 120 ft long.

In experiment 2 (2012-2016) spring crops were grown the year following grain sorghum. Grain sorghum is harvested late in the year and in most years does not allow growing a winter crop during the fallow period. Spring planted treatments included spring grain pea, spring pea plus spring oat (*Avena sativa* L.), spring pea plus spring triticale and spring oat, spring oat, spring triticale, and a six species "cocktail" mixture of spring oat, spring triticale, spring pea, buckwheat var. Mancan (*Fagopyrum esculentum* Moench), purple top turnip (*Brassica campestris* L.), and forage radish (*Raphanus sativus* L.). In addition, spring pea, oat, and triticale were grown for grain. Additional treatments initiated in 2013 was spring oats planted in a "flex-fallow" system and in 2014 was cocktail planted in a "flex-fallow" system (Table 1). The flex-fallow treatment was planted when a minimum of 1.5ft of PAW was determined using a Paul Brown moisture probe at spring planting; otherwise the treatment was left fallow. The flex-fallow treatment was intended to take advantage of growing a crop during the fallow period in wet years and fallowing in dry years. Crops grown in place of fallow were compared with a wheat-grain sorghum-fallow rotation for a total of 12 treatments (Table 1). The study design was a split-split-plot randomized complete block design with four replications; crop phase (wheat-grain sorghum-fallow) was the main plot, fallow replacement was the split-plot, and fallow replacement method (forage, grain, or cover) was the split-split-plot. The main plot was 330 ft wide and 120 ft long, the split-plot was 30 ft wide and 120 ft long, and the split-split plot was 15 ft wide and 120 ft long.

Winter wheat was planted approximately October 1. Spring crops were planted as early as soil conditions allowed, ranging from the end of February through the middle of March. Spring cover and forage crops were chemically terminated or forage-harvested approximately June 1. Biomass yields for both cover crops and forage crops were determined from a 3-ft × 120-ft area cut 3 in. high using a small plot Carter forage harvester from within the split-split-plot managed for forage. Winter and spring grain peas and winter wheat were harvested with a small plot Wintersteiger combine from a 6.5-ft × 120-ft area at grain maturity, which occurred approximately the first week of July.

Volumetric soil moisture content was measured at planting and harvest of winter wheat, grain sorghum, and fallow using a Giddings Soil Probe by 1-foot increments to a 6-ft soil depth. In addition, volumetric soil content was measured in the 0–3-in. soil depth at wheat planting to quantify moisture in the seed planting depth. Grain yield was adjusted to 13.5% moisture content, and test weight was measured using a grain analysis computer. Grain samples were analyzed for nitrogen content.

RESULTS AND DISCUSSION

Winter Wheat Yield in Wheat-Grain Sorghum-Fallow

In 2013, 6.25 inches of precipitation occurred during the growing season between planting and harvest. This was about 50% of normal (12.5 inches) for this time period, and was the third consecutive year of drought. The 30 year average precipitation during the fallow period (Nov-Oct) of a wheat-grain sorghum-fallow rotation averaged 18.03 inches, and 12.88 inches of precipitation occurred during fallow between November 1, 2011 and October 1, 2012. Below normal precipitation during fallow and the winter wheat growing season resulted in any treatment other than fallow significantly reducing wheat yield 50% or more. The cover crop cocktail treatment yielded 79% less than fallow. Wheat following fallow yielded 14 bu/a and all other treatments yielded between 2 to 7 bu/a (Figure 1).

In 2014, 14.57 inches of precipitation occurred during the growing season between planting and harvest. This was above average, but most of the rain came in June (10.5 inches) which was too late to benefit the wheat crop. Therefore wheat yields were significantly reduced by 40-80% by any treatment other than fallow (Figure 2).

In 2015, 12.18 inches of precipitation occurred during the growing season between planting and harvest. This was about average, but most of the rain came in May (6.38 inches) which benefited the crop but not before early season moisture stress reduced the crop's yield potential. The late precipitation resulted in most of the cover crop treatments yielding similar to fallow. Except oats grown for hay or grain and peat/triticale, which reduced wheat yield 47% (Figure 3).

The 2016 crop was lost due to a combination of dry conditions at planting with a severe rabbit infestation feeding newly emerging plants that resulted in stand loss.

Grain Sorghum Yield in Wheat-Grain Sorghum-Fallow

In 2015, 12.9 inches of precipitation occurred during the growing season between planting and harvest. The 30 year average precipitation during this time period (Jun-Nov) averaged 11.61 inches. The high rainfall in 2015 during the growing season plus 6.38 inches in May before planting resulted in good sorghum yields ranging from 84 to 109 bu/acre (Figure 4). Interestingly enough, an effect of the cover crop grown two years previous was found on sorghum yields, which was caused by differences in water use efficiency or in-season moisture use. Those cover crops that reduced 2014 wheat yield resulted in almost an exact proportional yield reduction of 2015 grain sorghum. In fact, the only treatment that did not fit the same response over two years was peas grown for grain, which ranked has the 7th highest wheat yield treatment in 2014, but the 2nd highest grain sorghum yield treatment in 2015. Grain sorghum's yield response may have been in part due to less wheat stubble in those cover crop treatments that reduced wheat yield. More years of data are necessary to see if this is a consistent response across years.

In 2016, 11.7 inches of precipitation occurred during the growing season between planting and harvest. The 30 year average precipitation during this time period (Jun-Nov) averaged 11.61 inches. The high rainfall in 2016 during the growing season plus 4.6 inches in April before planting resulted in good sorghum yields averaging 63 bu/acre. Unlike the previous year, there were no differences between treatments. Grain sorghum was likely not affected due to better wheat yields in 2015. Wheat averaged 13 bu/acre in 2015 and only 2 bu/acre wheat in 2014. The very low wheat yields in 2014 effected the next year's grain sorghum in-season water use efficiency, but this was not observed in 2016.

Cover vs. Annual Forage

Similar to the first experiment, there was no difference in wheat or grain sorghum yields whether the previous crop was left as cover or harvested for forage. Despite slightly more plant available water following cover than forage harvest. This indicates the previous crop can be harvested for forage rather than left standing as a cover crop without negatively affecting wheat or grain sorghum yields.

SUMMARY

Fallow helps stabilize crops in dry years. Annual precipitation in this study has ranged from 12.1 to 23.3 inches. The 30 year average precipitation was 19.24 inches. In dry years (2011-2014), growing a crop during the fallow period reduced wheat yields, but in wet years (2008-2010), growing a crop during the fallow period had little impact on wheat yield. The length of the fallow period also affected yields of the following wheat crop. Growing a cover or hay crop until June 1 affected wheat less than if continuous wheat, grain peas, oat, or triticale were grown until grain harvest, which was approximately the first week of July.

Forages can provide an economic return, whereas cover crops left standing were less profitable than fallow. The cropping system can be intensified by replacing part of the fallow period with annual forages or spring grain crop to increase profit and improve soil quality; however, in semiarid environments, wheat yields will be reduced, particularly in dry years. The risk of reducing wheat yield is greater when a spring crop is grown for grain rather than hay. Winter wheat yield reduction in part, can be compensated for by the sale of a forage or grain crop in years with above normal precipitation, but not with a cover crop. The negative impacts on wheat yields might be minimized with flex-fallow. Flex-fallow is the concept of only planting a spring forage or grain crop when soil moisture levels are adequate and the precipitation outlook is favorable. Under drought conditions such as 2011-2013, using flex-fallow, a crop would have not been grown in place of fallow. Implementing flex-fallow may help minimize the negative impacts of reduced fallow. However flex-fallow will not prevent reduced yield in years that growing season precipitation levels are below normal. Additional years of data are required to determine the effects of replacing fallow in a wheat-summer crop-fallow rotation.

Table 1. Fallow treatments 2007-2016.

Season	Crop	Cover	Hay	Grain	Year produced									
					2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Spring	Fallow				x	x	x	x	x	x	x	x	x	x
""	Cocktail mix†	x	x		-	-	-	-	-	x	x	x	x	x
""	Cocktail mix† (flex)††	x	x		-	-	-	-	-	-	-	-	N	?
""	Spring oat (flex)		x		-	-	-	-	-	-	-	Y	N	?
""	Spring oat		x		-	-	-	-	-	x	x	x	x	x
""	Spring oat (grain)			x	-	-	-	-	-	-	x	x	x	x
""	Spring pea	x	x		x	x	x	x	x	x	-	-	-	-
""	Spring pea (grain)			x	-	-	-	x	x	x	x	x	x	x
""	Spring pea/Spring oat	x	x		-	-	-	-	-	x	x	x	-	-
""	Spring pea/Spring triticale	x	x		-	-	-	-	-	x	x	x	-	-
""	Spring triticale	x	x		-	-	-	-	-	x	x	x	-	-
	Spring triticale		x		-	x	x	x	x	-	-	-	x	x
	Spring triticale (grain)			x	-	-	-	-	-	-	-	-	x	x
	Spring oat/triticale/pea		x		-	-	-	-	-	-	-	-	x	x
	Spring triticale/oat		x		-	-	-	-	-	-	-	-	x	x
	Spring triticale/pea		x		-	x	x	x	x	-	-	-	-	-
	Spring triticale/lentil				-	x	x	x	x	-	-	-	-	-
	Spring lentil				x	x	x	x	x	-	-	-	-	-

† oat, triticale, pea, buckwheat, forage brassica and forage radish

†† Flex: Plant when soil moisture is 1.5' or > and precipitation outlook is neutral or favorable

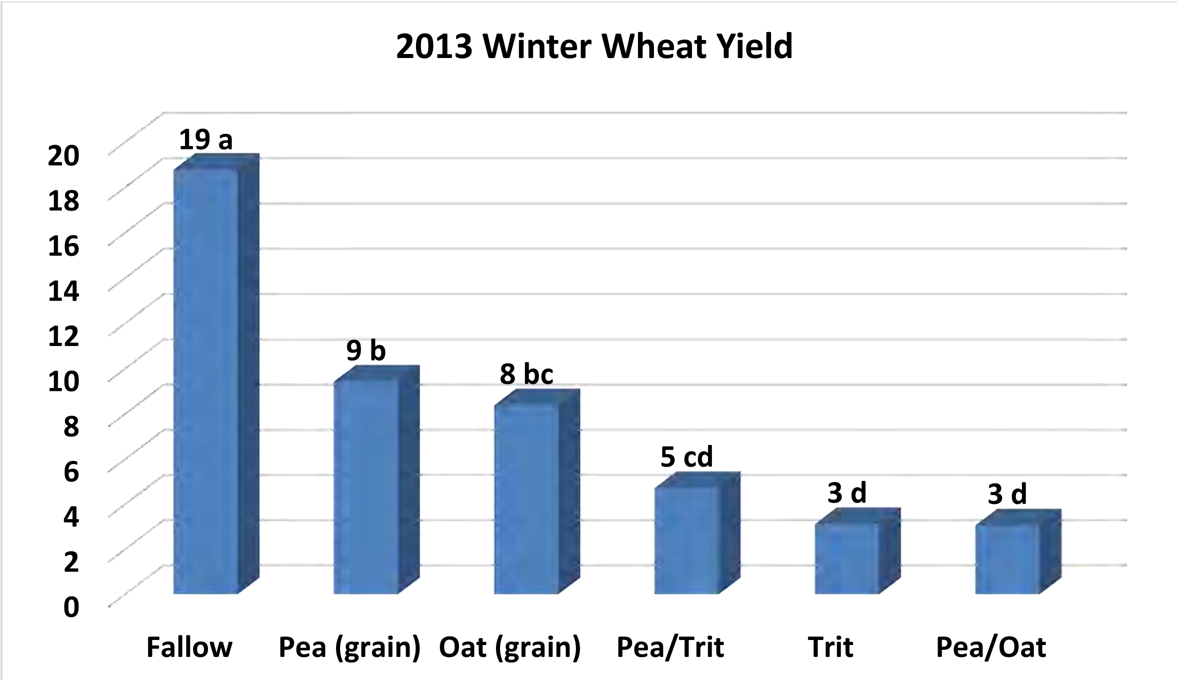

Figure 1. Wheat grain yields following fallow or cover/hay crops. Garden City, KS. 2013.

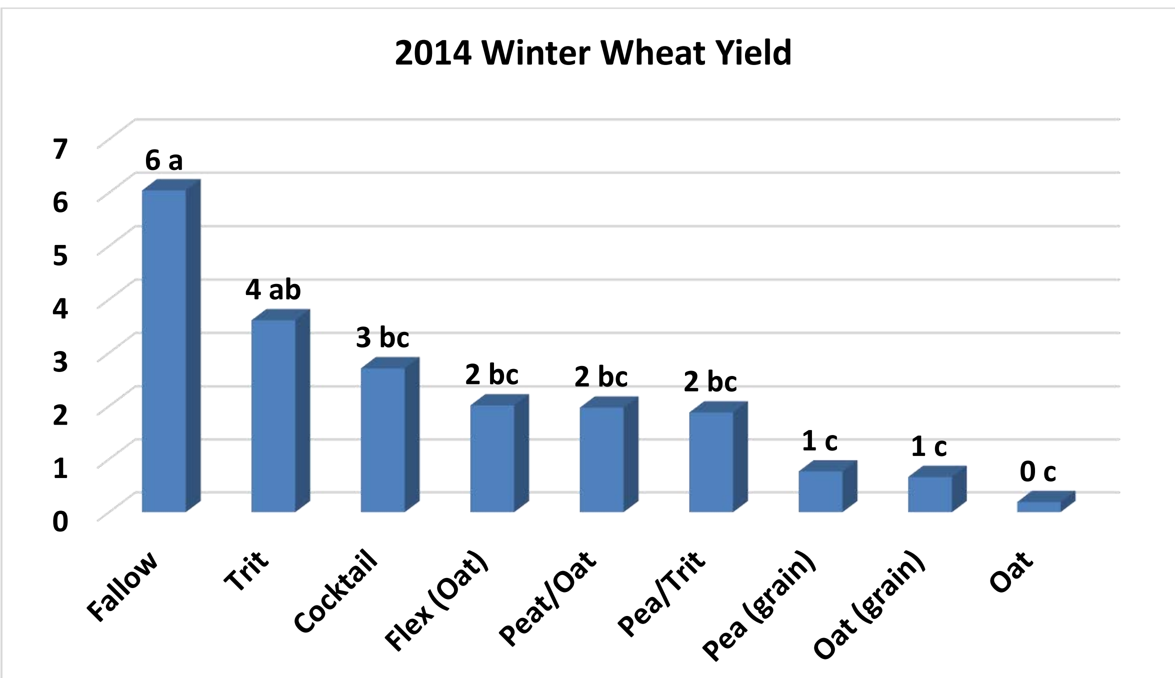

Figure 2. Wheat grain yields following fallow or cover/hay crops. Garden City, KS. 2014.

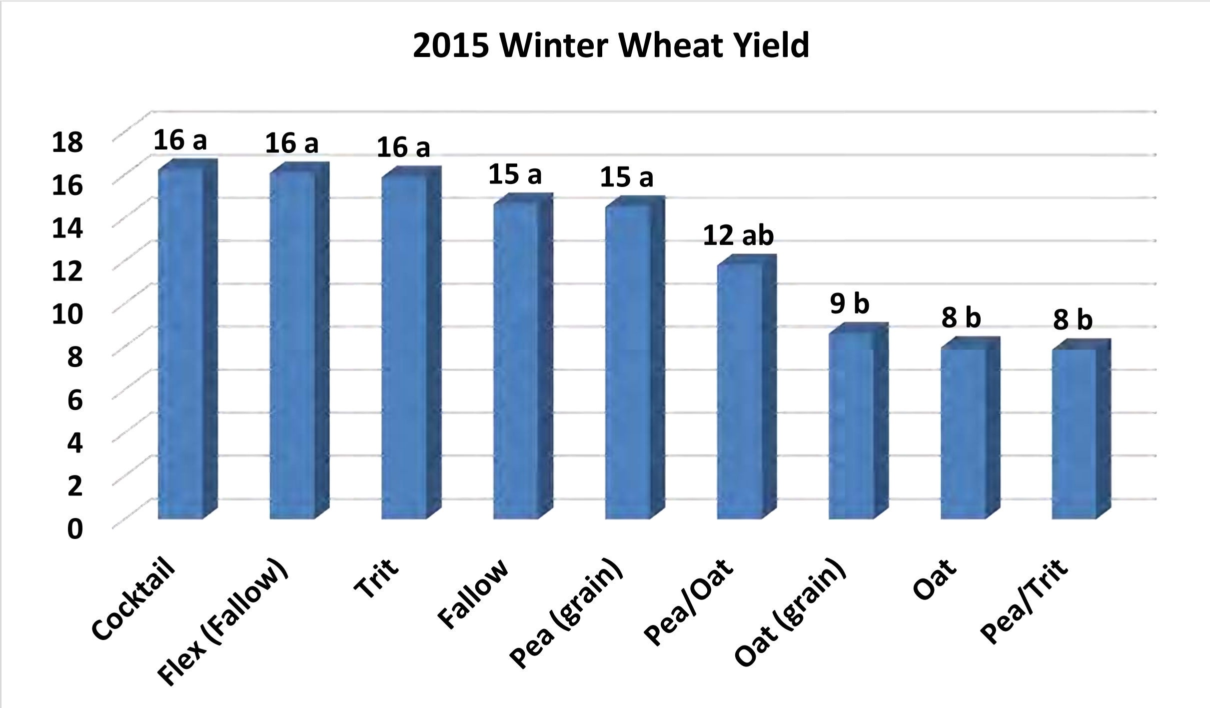

Figure 3. Wheat yields following fallow or cover/hay crops. Garden City, KS. 2015.

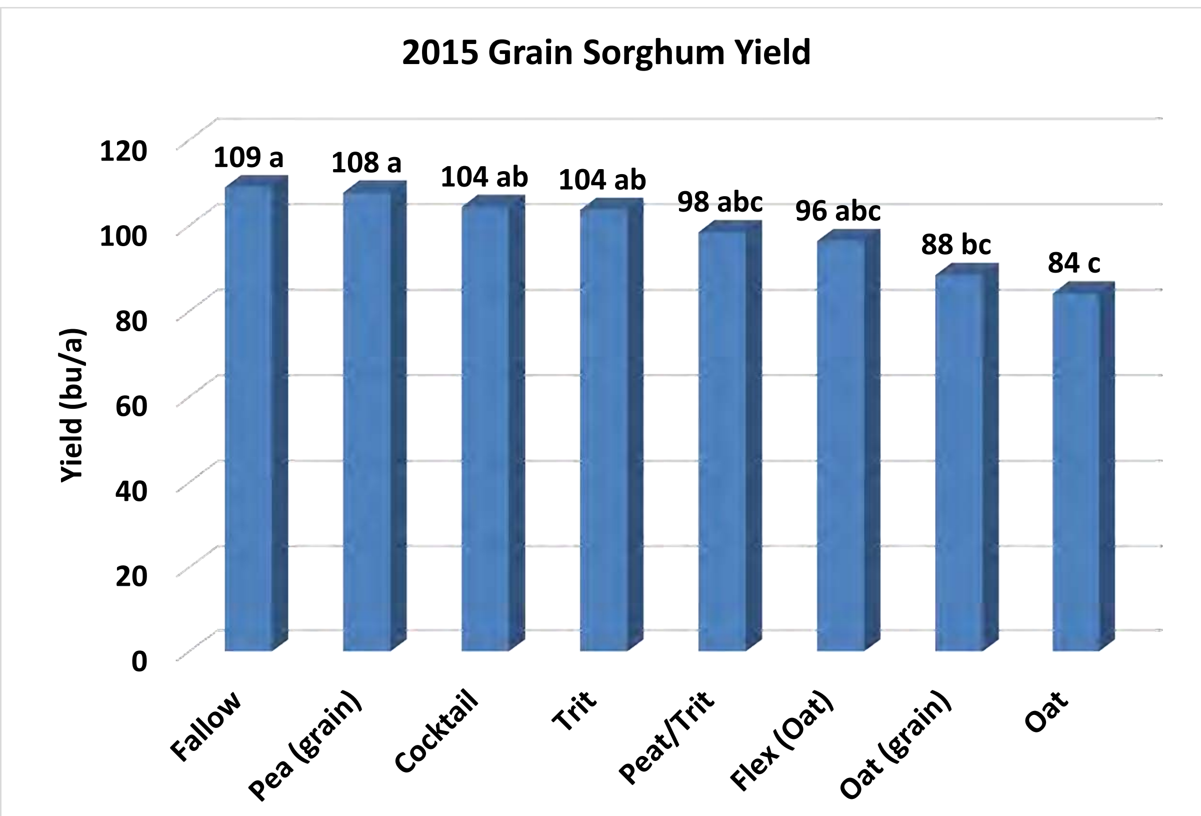

Figure 4.Grain sorghum yields in a W-S-F rotation with either fallow or cover/hay crops during the fallow period. Garden City, KS. 2015.

FORAGE SORGHUM IN ROTATION

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ABSTRACT

Producers are interested in growing annual forages, yet the region lacks proven recommended crop rotations such as those for grain crops. Forage production is important to the region's livestock and dairy industries and is becoming increasingly important as irrigation well capacity declines. Forages require less water than grain crops and may allow for increased cropping intensity and opportunistic cropping. Two forage rotation experiments were established.

The first study compared several 1-, 3-, and 4-year annual forage rotations with no-till and minimum-till (min-till). Data presented are from 2013 through 2016. Winter triticale yields were increased by tillage. Double-crop forage sorghum yielded 23% less than full-season forage sorghum across years. Oats failed to make a crop in 2013 and do not appear to be as drought tolerant as spring triticale or forage sorghum. Subsequent years will be used to compare forage rotations and profitability.

The second study evaluated forage sorghum grown in rotation with winter wheat and grain sorghum. Grain crops were more sensitive to moisture stress than forage crops. Growing a double-crop forage sorghum after wheat reduced grain sorghum yield the second year, but never reduced second-year forage sorghum yield in the years of this study. As long as double-crop forage sorghum is profitable, it appears the cropping system can be intensified by growing second year forage sorghum. Caution should be used when planting double-crop forage sorghum by evaluating soil moisture condition and precipitation outlook, since other research has found cropping intensity should be reduced in dry years. The "flex-fallow" concept could be used to make a decision on whether or not to plant double-crop forage sorghum to increase the chance of success. Of important note, this research showed forages are more tolerant to moisture stress than grain crops and the potential exists to increase cropping intensity by integrating forages into the rotation.

MATERIAL AND METHODS-STUDY 1 (ANNUAL FORAGES)

An annual forage rotation experiment was initiated in 2012 at the Southwest Research- Extension Center in Garden City, Kansas. All crop phases were in place by 2013, with the exception of T-S-O (oats), which had all crop phases in place by 2015. The study design was a randomized complete block design with four replications. Treatment was crop phase (with all crop phases present every year) and tillage (no-till or min-till). Plots were 30 ft wide and 30 ft long. Crop rotations were one-, three-, and four-year rotations (see treatment list below). Crops grown were winter triticale (×*Triticosecale* Wittm.), forage sorghum (*Sorghum bicolo*r L.), and spring oat (*Avena sativa* L.). Spring triticale was grown in place of spring oat beginning in 2015. Tillage was implemented after spring oat/triticale was harvested in treatments 3 and 5, using a single tillage with a sweep plow with 6-ft blades and trailing rolling pickers.

Treatments included:

1. Continuous forage sorghum (no-till): (S-S)
2. Year 1: winter triticale/double crop forage sorghum; Year 2: forage sorghum; Year 3: spring oat/triticale (no-till): (T/S-S-O no-till)
3. Year 1: winter triticale/double crop forage sorghum; Year 2: forage sorghum; Year 3: spring oat/triticale (single tillage after spring oat, min-till): (T/S-S-O min-till)

4. Year 1: winter triticale/double crop forage sorghum; Year 2: forage sorghum; Year 3: forage sorghum; Year 4: spring oat/triticale (no-till): (T/S-S-S-O no-till)
5. Year 1: winter triticale/double crop forage sorghum; Year 2: forage sorghum; Year 3: forage sorghum; Year 4: spring oat/triticale (single tillage after spring oat, min-till): (T/S-S-S-O min-till)
6. Year 1: winter triticale; Year 2: forage sorghum; Year 3: spring oat/triticale (no-till): (T-S-O)

Winter triticale was planted the end of September, spring oat/triticale was planted the beginning of March, and forage sorghum was planted the beginning of June. Crops were harvested at early heading to optimize forage yield and quality (Haun scale 9.5). Winter triticale was harvested approximately May 15, spring oat/triticale was harvested approximately June 1, and forage sorghum was harvested approximately the end of August. Forage yields were determined from a 3 × 30 ft area (from each plot) cut 3 in. high using a small plot Carter forage harvester. Forage yield and quality (protein, fiber, and digestibility) were measured at each harvest. Gravimetric soil moisture content was measured at planting and harvest to a depth of 6 ft using 1-ft increments. Precipitation storage efficiency (% of precipitation stored during the fallow period) was quantified for each fallow period, and crop water use efficiency (forage yield divided by soil water used plus precipitation) was determined for each crop harvest. Crop yield response to plant available water at planting is being used to estimate yield and develop a yield prediction model based on historical or expected weather conditions. Most producers use a soil probe rather than gravimetric sampling to determine soil moisture status, so soil penetration with a Paul Brown soil probe was used four times per plot at planting to estimate soil water availability. Previous studies found a soil moisture probe provided an accurate and easy way to determine soil moisture level and crop yield potential.

MATERIAL AND METHODS-STUDY 2 (ANNUAL FORAGE AND GRAIN ROTATIONS)

A study beginning in 2013 evaluated various integrated grain and forage rotations compared to a no-till wheat-grain sorghum-fallow rotation. Crop phases were in rotation beginning in 2014. A total of 11 crop rotations were evaluated. The study design was a split-plot randomized complete block design with four replications; crop phase (wheat-sorghum-fallow) was the main plot and alternative crop choices were the split-plot. Each split-plot was 30 ft wide and 120 ft long.

Treatments included:

1. Wheat-Grain Sorghum-Flex Fallow (ww-gs-fx)
2. Wheat-Grain Sorghum-Fallow (ww-gs-fl)
3. Wheat/Forage Sorghum-Forage Sorghum-Oat (ww/fs-fs-o)
4. Wheat-Forage Sorghum-Oat (ww-fs-sg)
5. Wheat/Forage Sorghum-Grain Sorghum-Oat (ww/fs-gs-o)
6. Wheat-Grain Sorghum-Oat (ww-gs-o)
7. Wheat-Forage Sorghum-Oat (tilled) (ww-fs-o(T))
8. Wheat-Forage Sorghum-Fallow (ww-fs-fl)
9. Wheat-Forage Sorghum-Flex Fallow (ww-fs-fx)
10. Wheat/Forage Sorghum-Forage Sorghum-Flex Fallow (ww/fs-fs-fx)
11. Wheat/Forage Sorghum-Grain Sorghum-Flex Fallow (ww/fs-gs-fx)

“Flex-fallow” is a spring planting decision based on current soil moisture condition and seasonal outlook. Spring oats were planted when 14 inches or more plant available water (PAW) was determined available by using a Paul Brown moisture probe and seasonal precipitation forecasted outlook was neutral or favorable; otherwise the treatment was left fallow. The flex-fallow treatment was intended to take advantage of growing a crop during the fallow period in wet years and fallowing in dry years. A flex-fallow crop was planted in 2013 and 2016, but not 2014 or 2015.

Winter triticale was planted approximately October 1 in all years. Spring crops were planted as early as soil conditions allowed, ranging from the end of February through the middle of March. Spring forage crops were harvested approximately June 1 in all years. Forage sorghum was either planted around June 1 for full-season or following wheat harvest around July 1 for double-crop. Forage biomass yields were determined from a 3-ft × 120-ft area cut 3 in. high using a small plot Carter forage harvester. Winter wheat and grain sorghum were harvested with a small plot Wintersteiger combine from a 6.5-ft × 120-ft area at grain maturity.

RESULTS AND DISCUSSION
STUDY 1: ANNUAL FORAGE
ROTATION YIELD
Annual rotation yield was determined by measuring total yield for the rotation and dividing by the number of years in the rotation. This method allows for comparing rotations of different years to each other for annual forage production (Fig. 1). Low crop yields and no spring oat yield were the results of a very dry year in 2013. In 2014, annualized yield was comparable across treatments except for T/S-S-O (no-till), which had lower yield than T/S-S-S-O (min-till) and was comparable to all other treatments. The crop rotation of T-S-O was not in phase until 2015, so no comparison was made to that rotation until 2015. In 2015, T/S-S-O (no-till) yielded less than S-S, but more than T-S-O and comparable to all other treatments. T-S-O annual yield was less than all other treatments in 2015. Tillage increased the yield of triticale and thus the yield of T/S-S-O and T/S-S-S-O were improved with tillage, and annual yield of the three-year rotation was improved more than the four-year rotation due to triticale occurring more frequently in the rotation. In 2016, S-S produced the greatest yield. Rotations that grew oats more frequently yielded less total forage, and no-till triticale yielded less then min-till triticale.

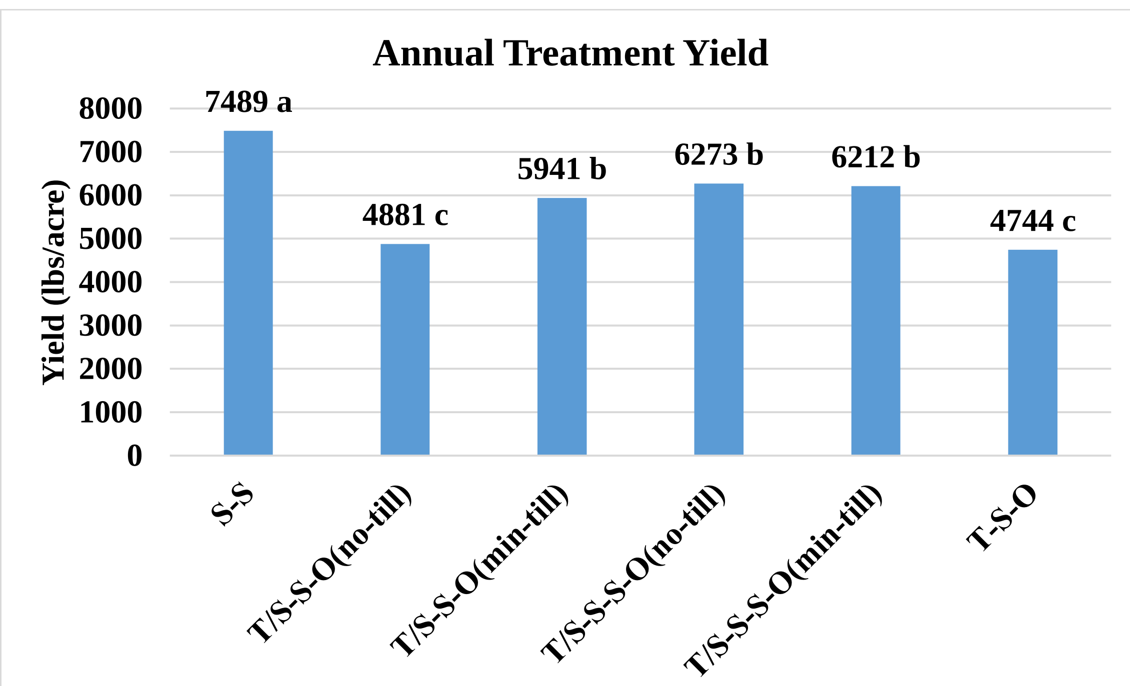


Figure 1. Annual Forage Rotation Yields.

RESULTS AND DISCUSSION
STUDY 2: ANNUAL FORAGE AND GRAIN ROTATIONS
FORAGE SORGHUM YIELD

Forage sorghum yield was highly correlated with plant available moisture at planting (Fig. 2), but not as high as grain sorghum. Plant available moisture at planting explained approximately 40% of the variability in forage yield. Approximately 530 lbs of forage was grown for every inch of plant available water at planting.

Forage sorghum yields were not different across treatments in 2014, except ww/FS-fs-o which yielded 2,200 lb/acre less than ww/fs-FS-o (Fig. 3). This lower yield was most likely due to less plant available water at planting, 1.3 versus 2.1 inches. In 2014 plant available water averaged 1.0 inch ahead of double-crop forage sorghum and 4.1 inches ahead of full season forage sorghum. In 2014 most of the annual precipitation occurred later in the year (Jun-Sep), which likely helped improve the yield of double-crop forage sorghum relative to full-season forage sorghum. In 2014, double-crop forage sorghum yielded on average 17% less than full-season forage sorghum (3,300 versus 3,900 lbs/acre). In 2015 most of the precipitation occurred earlier in the year (May-Aug) than 2014, which helped increase wheat yields but also resulted in comparatively less moisture at planting double-crop forage sorghum, 1.6 versus 7.2 inches. As a result, in 2015 double-crop forage sorghum yields were reduced 70% compared to full-season forage sorghum (2,400 versus 8,000 lbs/acre).

Surprisingly, second year forage sorghum yields following double-crop forage sorghum were similar to full-season forage sorghum following wheat with fallow between wheat harvest and sorghum planting. Yet forage sorghum following double-crop forage sorghum had an average of 3 inches less soil moisture compared to fallow ahead of forage sorghum. In dry years this difference in plant available soil water may result in yield differences, but did not affect yield in this study. These results suggest that as long as the benefits of growing a double-crop forage sorghum crop exceeded costs, an extra crop could be grown in the rotation without adversely affecting full-season forage sorghum yield in a wheat/forage sorghum-forage sorghum rotation under favorable moisture conditions. A partial enterprise analysis of this phase of the rotation only, indicated double-crop forage sorghum needs to yield at least 30% of full-season forage sorghum or at least 2,000 lbs/acre, for a double-crop forage sorghum crop that is grazed to be profitable. The additional variable expenses of growing double-crop forage sorghum would be around $25.00/acre.

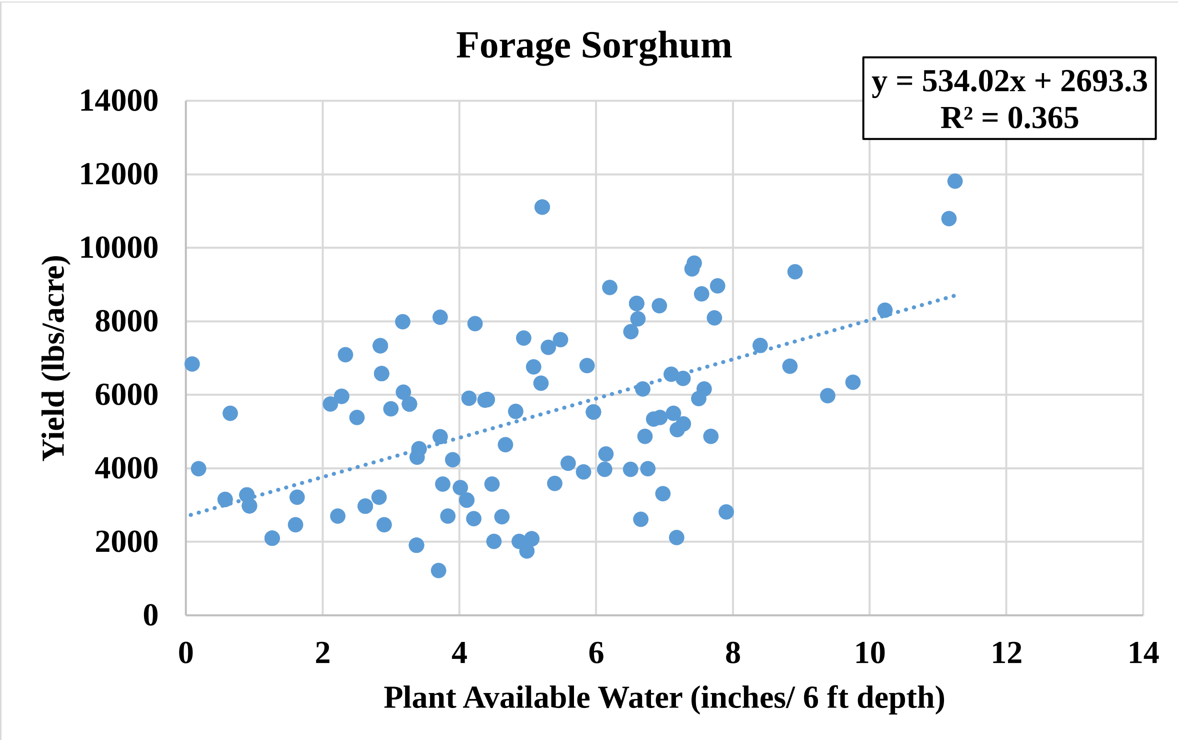


Figure 2. Forage Sorghum Yield Relationship to Plant Available Water at Planting (2014-2016).

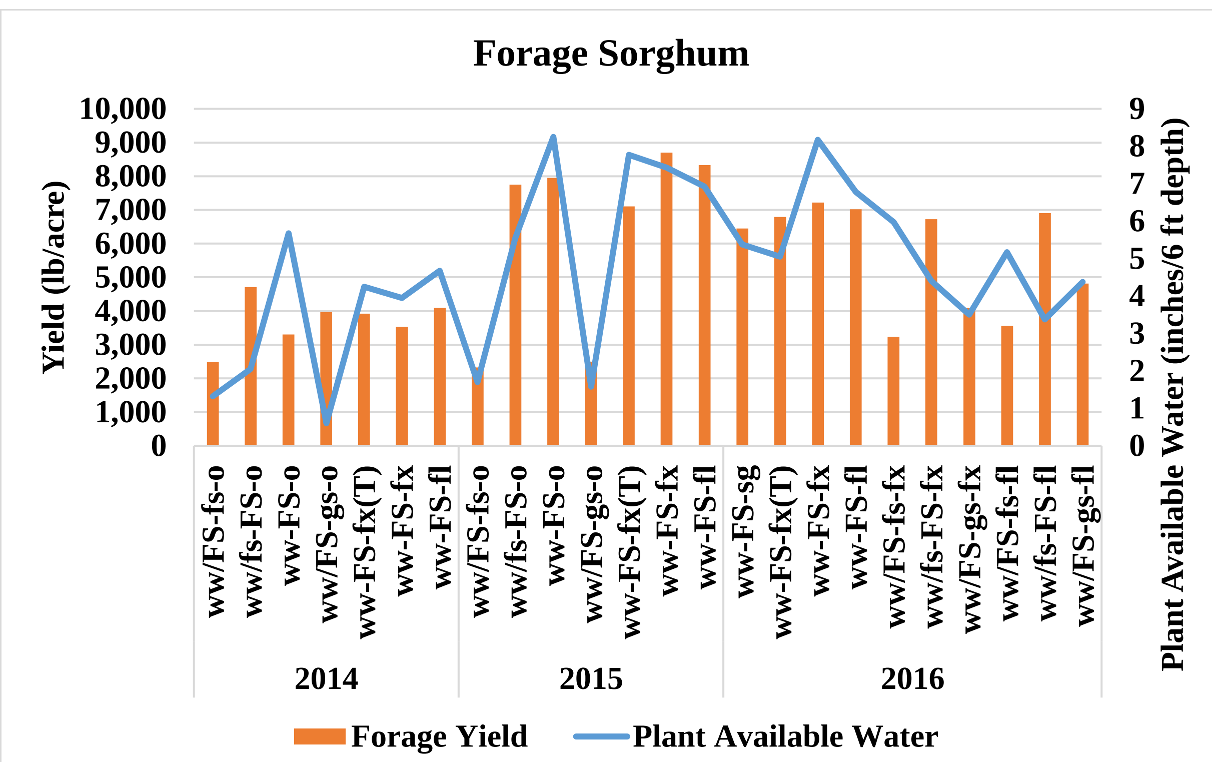


Figure 3. Forage Sorghum Yield and Plant Available Water at Planting Across Rotations (2014-2016).

Long –Term Tillage Intensity in a Wheat-Sorghum-Fallow Rotation[1]

A. Schlegel and L. Haag

Summary

Grain yields of wheat and grain sorghum increased with decreased tillage intensity in a wheat-sorghum-fallow (WSF) rotation. In 2016, available soil water at wheat and sorghum planting was greater for reduced till (RT) than no-till (NT) and least for conventional till (CT). Averaged across the 16-yr study, available soil water at wheat and sorghum planting was similar for RT and NT and about 1 inch greater than CT. Averaged across the past 16 years, NT wheat yields were 4 bu/a greater than RT and 7 bu/a greater than CT. Grain sorghum yields in 2016 were 15 bu/a greater with long-term NT than short-term NT. Averaged across the past 16 years, sorghum yields with long-term NT have been 70% greater than with short-term NT (68 vs. 40 bu/a).

Procedures

Research on different tillage intensities in a WSF rotation at the Tribune unit of the Southwest Research-Extension Center was initiated in 1991. The three tillage intensities in this study are conventional (CT), reduced (RT), and no-till (NT). The CT system was tilled as needed to control weed growth during the fallow period. On average, this resulted in four to five tillage operations per year, usually with a blade plow or field cultivator. The RT system originally used a combination of herbicides (one to two spray operations) and tillage (two to three tillage operations) to control weed growth during the fallow period; however, in 2001, the RT system was changed to using NT from wheat harvest through sorghum planting (short-term NT) and CT from sorghum harvest through wheat planting. The NT system exclusively used herbicides to control weed growth during the fallow period. All tillage systems used herbicides for in-crop weed control.

Results and Discussion

Soil Water

The amount of available water in the soil profile (0 to 8 ft.) at wheat planting varied greatly from year to year (Figure 1). In 2016, available soil water at wheat planting was greater RT than NT and least with CT. Averaged across the 16-yr study, available soil water at wheat planting was similar for RT and NT (about 7 inches) and about 1 inch greater than CT.

Similar to wheat, the amount of available water in the soil profile at sorghum planting varied greatly from year to year (Figure 2). In 2016, available soil water at sorghum planting was greater with RT than NT and least with CT. On average, available soil water at sorghum planting was similar for RT and NT and about 1 inch more than CT.

Grain Yields

Wheat yields in 2016 were 55 to 65 bu/a greater than the long-term average (Table 1). Since 2001, wheat yields have been depressed in 10 of 16 years, primarily because of lack of precipitation, while winterkill reduced yields in 2015. Reduced tillage and NT increased wheat yields. On average, wheat yields were 7 bu/a higher for NT (24 bu/a) than CT (17 bu/a). Wheat yields for RT were 3 bu/a greater than CT even though both systems had tillage prior to wheat. NT yields were significantly less than CT or RT in only 1 of the 16 years.

The yield benefit from RT was greater for grain sorghum than wheat. Grain sorghum yields for RT averaged 16 bu/a more than CT, whereas NT averaged 28 bu/a more than RT (Table 2). For sorghum, both RT and NT used herbicides for weed control during fallow, so the difference in yield could be attributed to short-term compared with long-term NT. In 2016, sorghum yields were 15 bu/a greater with long-term NT than short-term NT. This consistent yield benefit with long-term vs. short-term NT has

[1] This research project was partially supported by the USDA-ARS Ogallala Aquifer Program.

been observed since the RT system was changed in 2001. Averaged across the past 16 years, sorghum yields with long-term NT have been 70% greater than with short-term NT (68 vs. 40 bu/a).

Table 1. Wheat response to tillage in a wheat-sorghum-fallow rotation, Tribune, Kansas, 2001–2016.

Year	Tillage			LSD (0.05)	ANOVA ($P > F$)		
	Conventional	Reduced	No-till		Tillage	Year	Tillage × year
	- - - - - - - - - - bu/a - - - - - - - - - -						
2001	17	40	31	8	0.002		
2002	0	0	0	- - -	- - -		
2003	22	15	30	7	0.007		
2004	1	2	4	2	0.001		
2005	32	32	39	12	0.360		
2006	0	2	16	6	0.001		
2007	26	36	51	15	0.017		
2008	21	19	9	14	0.142		
2009	8	10	22	9	0.018		
2010	29	35	50	8	0.002		
2011	22	20	20	7	0.649		
2012	0	1	5	1	0.001		
2013	0	0	0	- - -	- - -		
2014	10	11	18	12	0.336		
2015	10	9	9	9	0.966		
2016	72	85	82	18	0.239		
Mean	17c	20b	24a	2	0.001	0.001	0.001

Table 2. Grain sorghum response to tillage in a wheat-sorghum-fallow rotation, Tribune, Kansas, 2001–2016.

Year	Tillage			LSD (0.05)	ANOVA ($P > F$)		
	Conventional	Reduced	No-till		Tillage	Year	Tillage × year
	- - - - - - - - - - bu/a - - - - - - - - - -						
2001	6	43	64	7	0.001		
2002	0	0	0	- - -	- - -		
2003	7	7	37	8	0.001		
2004	44	67	118	14	0.001		
2005	28	38	61	35	0.130		
2006	4	3	29	10	0.001		
2007	26	43	62	42	0.196		
2008	16	25	40	20	0.071		
2009	19	5	72	31	0.004		
2010	10	26	84	9	0.001		
2011	37	78	113	10	0.001		
2012	0	0	0	- - -	- - -		
2013	37	51	78	32	0.053		
2014	38	72	94	28	0.008		
2015	56	60	102	55	0.153		
2016	55	124	139	47	0.010		
Mean	24c	40b	68a	6	0.001	0.001	0.001

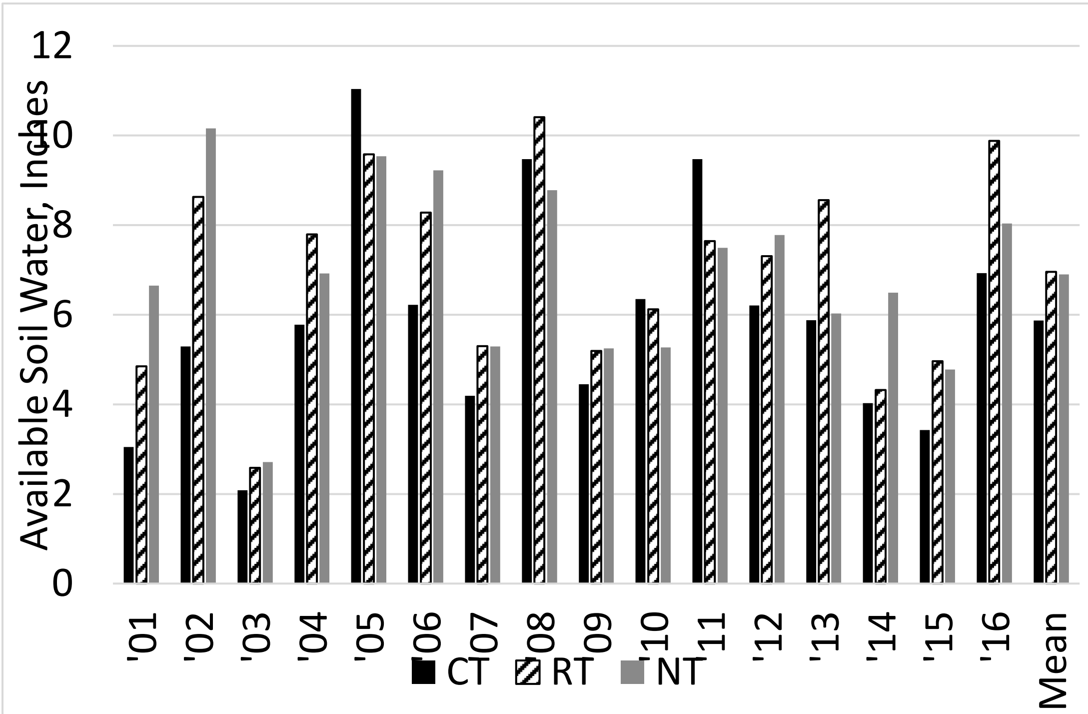


Figure 1. Available soil water in 8-ft profile at planting of wheat in a WSF rotation as affected by tillage intensity, Tribune, Kansas, 2001–2016.
The last set of bars (Mean) is the average across years.

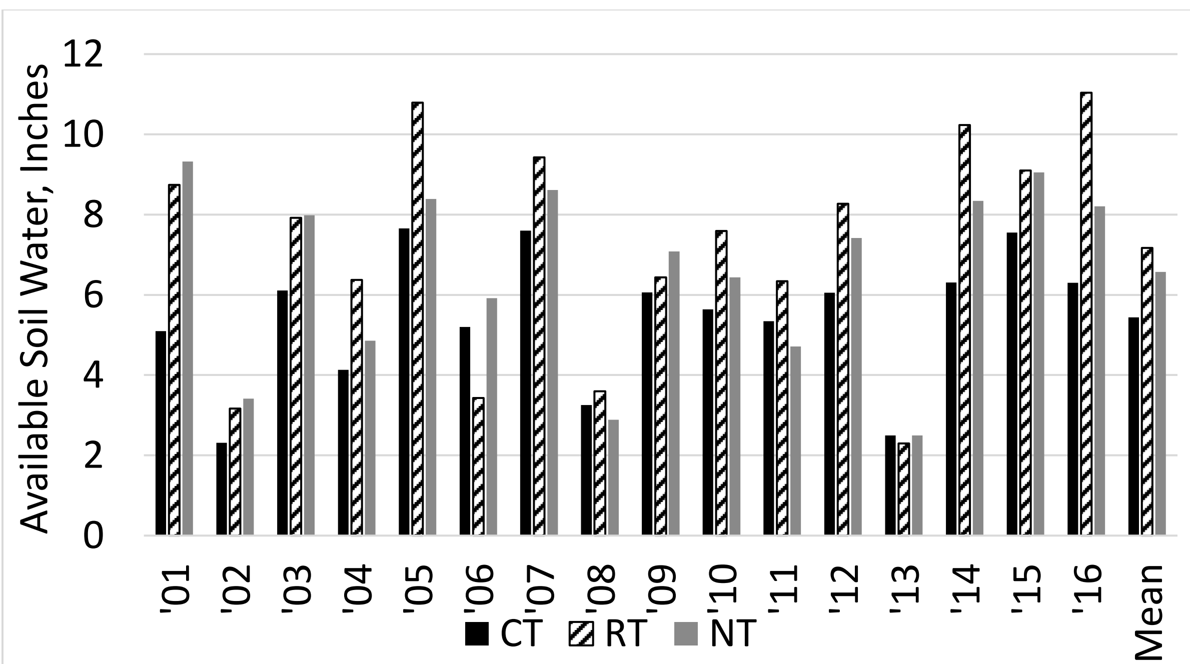
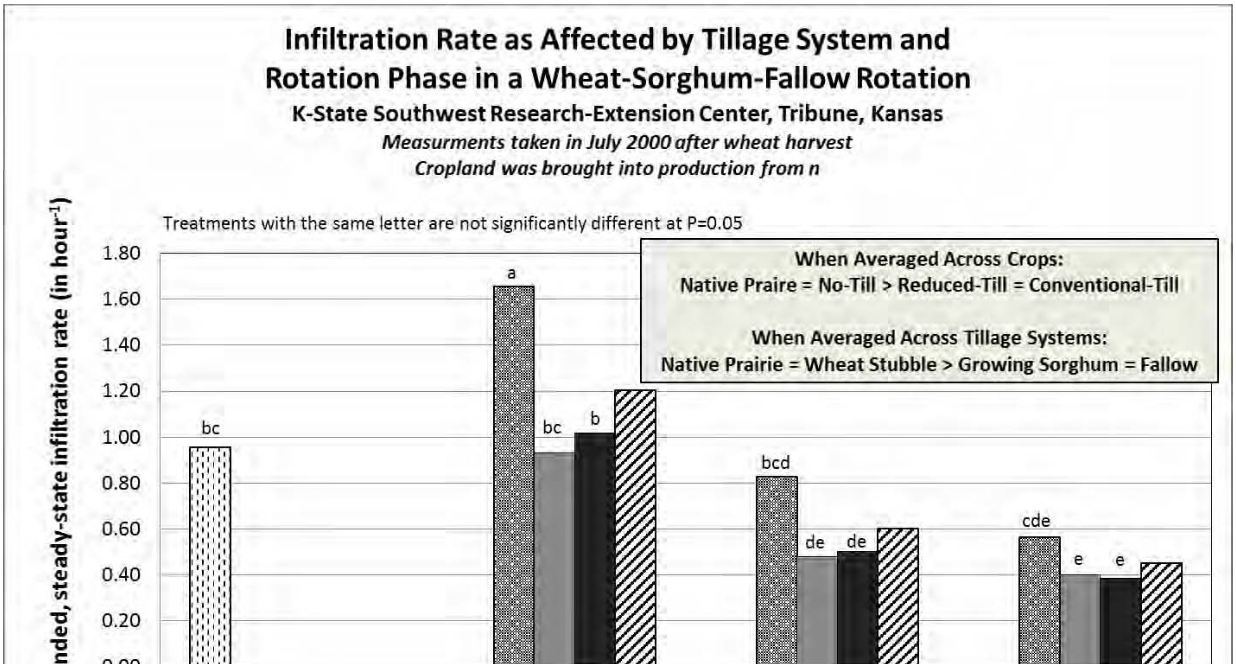


Figure 2. Available soil water in 8-ft profile at planting of grain sorghum in a WSF rotation as affected by tillage intensity, Tribune, Kansas, 2001–2016.
The last set of bars (Mean) is the average across years.

Water Infiltration

A common question relating to no-till adoption and other soil health initiatives is the effect of farming practices on water infiltration. Research from a long-term study in western Kansas offers some insight into this.

In July of 2000, 10 years into the study, infiltration measurements we obtained. Infiltration was measured using large dual-ring infiltrometers with diameters of 36 and 48 inches. The ponded, steady-state infiltration rates, measured in inches per hour, are shown in Figure 1.



	Native Prairie	No-Till	Reduced-Till	Conventional Tillage
Sod	0.96			
Wheat		1.66	0.83	0.56
Sorghum		0.93	0.48	0.40
Fallow		1.02	0.50	0.39
Average		1.20	0.60	0.45

Infiltration rates were significantly higher in the freshly harvested no-till wheat stubble than any other treatment, including native prairie. Infiltration in the no-till wheat stubble was significantly higher than in the growing no-till sorghum or chem-fallow. Infiltration also tended to be numerically higher in wheat stubble than in growing sorghum or fallow for the reduced-till and conventional-till systems as well. Even though the sorghum was always no-till planted into wheat stubble in all tillage systems, the effect of tillage during the fallow period prior to wheat resulted in lower infiltration rates in the sorghum.

When averaged across crops, infiltration in the no-till system was 1.2 in hr^{-1}, significantly higher than the reduced-till (0.60 in hr^{-1}) or conventional till systems (0.45 in hr^{-1}) and not statistically different from native sod (0.96 in hr^{-1}).

Long-Term Dryland Rotations with Wheat and Grain Sorghum

A. Schlegel and L. Haag

Summary

Research on 4-year crop rotations with wheat and grain sorghum was initiated at the Southwest Research-Extension Center near Tribune, Kansas, in 1996. Rotations were wheat-wheat-sorghum-fallow (WWSF), wheat-sorghum-sorghum-fallow (WSSF), and continuous wheat (WW). Soil water at wheat planting averaged about 9 in. following sorghum, which is about 3 in. more than the average for the second wheat crop in a WWSF rotation. Soil water at sorghum planting was only about 1 in. less for the second sorghum crop compared with sorghum following wheat. Grain yield of recrop wheat averaged about 80% of the yield of wheat following sorghum. Grain yield of continuous wheat averaged about 65% of the yield of wheat grown in a 4-year rotation following sorghum. Generally, wheat yields were similar following one or two sorghum crops. Similarly, average sorghum yields were the same following one or two wheat crops. Yield of the second sorghum crop in a WSSF rotation averages ~65% of the yield of the first sorghum crop.

Introduction

In recent years, cropping intensity has increased in dryland systems in western Kansas. The traditional wheat-fallow system is being replaced by wheat-summer crop-fallow rotations. Is more intensive cropping feasible with concurrent increases in no-till? Objectives of this research were to quantify soil water storage, crop water use, and crop productivity of 4-year and continuous cropping systems.

Procedures

Research on 4-year crop rotations with wheat and grain sorghum was initiated in 1996 at the Tribune unit of the Southwest Research-Extension Center. Rotations were WWSF, WSSF, and WW. No-till was used for all rotations except for the first two years where reduced tillage was used for wheat following sorghum. Available water was measured in the soil profile (0 to 6 ft) at planting and harvest of each crop. The center of each plot was machine harvested after physiological maturity, and yields were adjusted to 12.5% moisture.

Results and Discussion

Soil Water

The amount of available water in the soil profile (0 to 6 ft) at wheat planting varied greatly from year to year (Figure 1). In 2016, available soil water was slightly greater for wheat following sorghum and slightly less for wheat following wheat compared to the long-term average. Soil water was similar following fallow after either one or two sorghum crops and averaged about 9 in. across the 20-year study period. Water at planting of the second wheat crop in a WWSF rotation was generally less than at planting of the first wheat crop, except in 1997 and 2003. Soil water for the second wheat crop averaged more than 3 in. (or about 40%) less than that for the first wheat crop in the rotation. Continuous wheat averaged about 0.8 in. less water at planting than the second wheat crop in a WWSF rotation.

Similar to wheat, the amount of available water in the soil profile at sorghum planting varied greatly from year to year (Figure 2). Soil water was similar following fallow after either one or two wheat crops and averaged about 8 in. over 21 years. Water at planting of the second sorghum crop in a WSSF rotation was generally less than that at planting of the first sorghum crop. Averaged across the entire study period, the first sorghum crop had about 1.3 in. more available water at planting than the second crop.

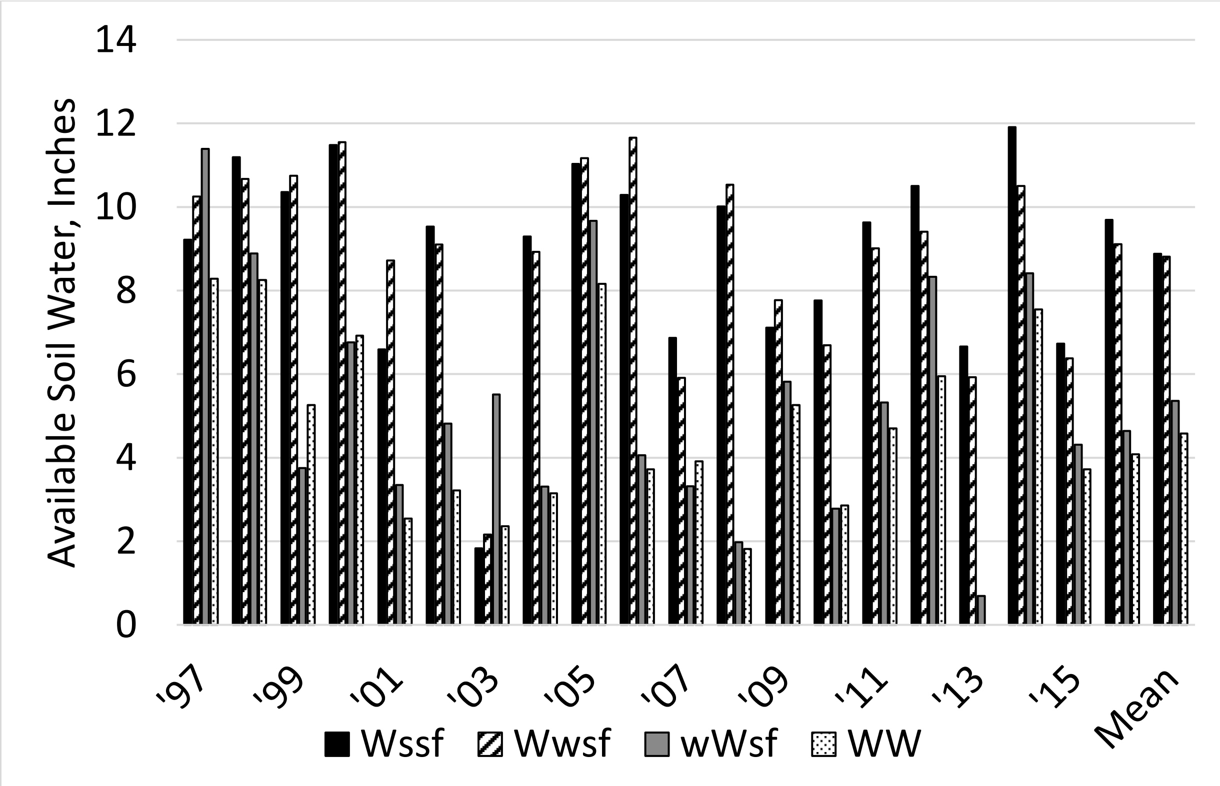


Figure 1. Available soil water in 6-ft profile at planting of wheat in several rotations, Tribune, Kansas, 1997–2016. Capital letter denotes current crop in rotation (W, wheat; S, sorghum). The last set of bars (Mean) is the average across years.

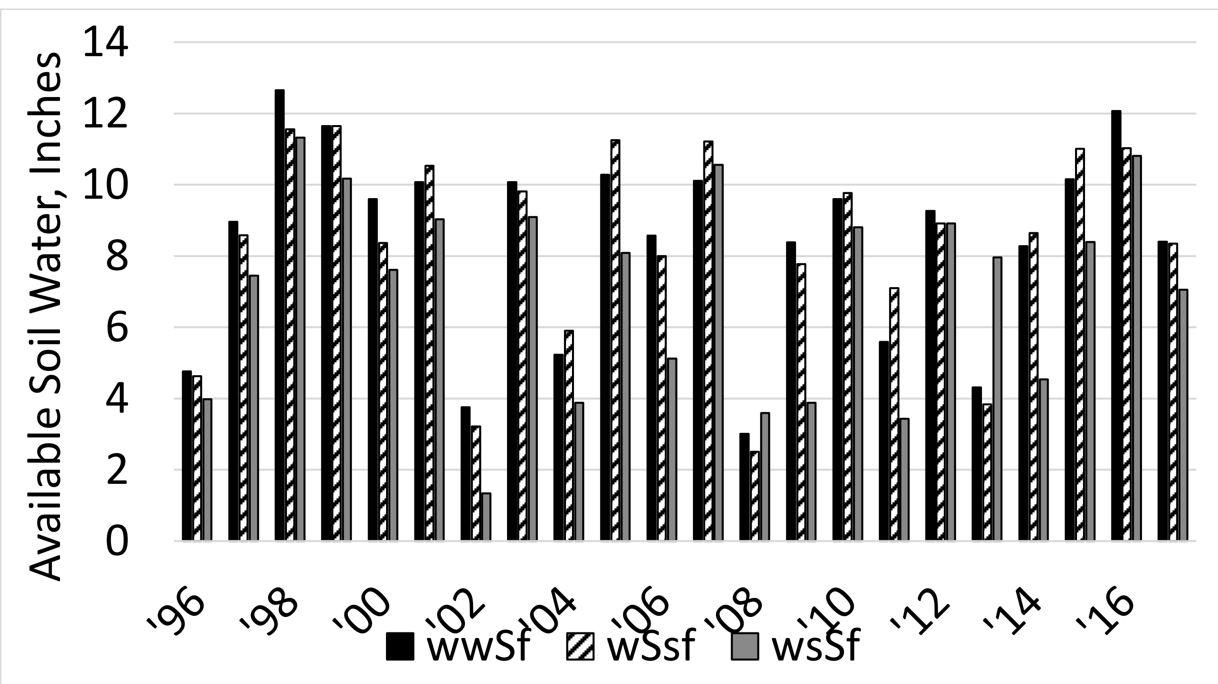


Figure 2. Available soil water in 6-ft profile at planting of sorghum in several rotations, Tribune, Kansas, 1996–2016. Capital letter denotes current crop in rotation (W, wheat; S, sorghum). The last set of bars (Mean) is the average across years.

Table 1. Wheat response to dryland crop rotation, Tribune, Kansas, 1997–2016.

	Rotation					ANOVA (P>F)
Year	Wssf[1]	Wwsf	wWsf	WW	LSD 0.05	Rotation
	- - - - - - - - - - bu/a - - - - - - - - - -					
1997	57	55	48	43	8	0.017
1998	70	64	63	60	12	0.391
1999	74	80	41	43	14	0.001
2000	46	35	18	18	10	0.001
2001	22	29	27	34	14	0.335
2002	0	0	0	0	- - -	- - -
2003	29	27	66	30	14	0.001
2004	5.7	6.1	0.4	0.5	1.6	0.001
2005	45	40	41	44	10	0.690
2006	28	26	7	2	8	0.001
2007	75	61	63	41	14	0.004
2008	40	40	5	6	5	0.001
2009	37	39	50	24	15	0.029
2010	63	60	29	23	9	0.001
2011	25	22	25	17	8	0.152
2012	14	20	10	9	15	0.380
2013	0	0	0	0	- - -	- - -
2014	51	45	31	12	18	0.004
2015	49	36	24	24	12	0.001
2016	78	77	58	52	12	0.001
Mean	40a	38b	30c	24d	2	0.001

[1] W, wheat; S, sorghum; capital letters denote current year's crop

Table 2. Grain sorghum response to crop rotation, Tribune, Kansas, 1996–2016.

	Rotation				ANOVA (P>F)
Year	wSsf[1]	wsSf	wwSf	LSD 0.05	Rotation
	- - - - - - - - bu/a - - - - - - - -				
1996	58	35	54	24	0.117
1997	88	45	80	13	0.001
1998	117	100	109	12	0.026
1999	99	74	90	11	0.004
2000	63	23	67	16	0.001
2001	68	66	73	18	0.673
2002	0	0	0	- - -	- - -
2003	60	41	76	18	0.009
2004	91	79	82	17	0.295
2005	81	69	85	20	0.188
2006	55	13	71	15	0.001
2007	101	86	101	9	0.008
2008	50	30	57	12	0.005
2009	89	44	103	53	0.080
2010	98	52	105	24	0.004
2011	119	47	105	34	0.005
2012	0	0	0	- - -	- - -
2013	105	98	100	23	0.742
2014	91	5	84	29	0.001
2015	125	82	124	22	0.005
2016	134	98	139	10	0.001
Mean	81a	52b	81a	4	0.001

[1] W, wheat; S, sorghum; capital letters denote current year's crop

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Grain Yields

In 2016, wheat yields were greater than the long-term average for all rotations (Table 1). Averaged across 20 years, recrop wheat (the second wheat crop in a WWSF rotation) yielded about 80% of first-year wheat crop in WWSF. Before 2003, recrop wheat yielded about 70% of first-year wheat. Wheat yields following two sorghum crops are 2 bu/a greater than following one sorghum crop. In most years, continuous wheat yields have been similar to recrop wheat yields, but in several years (2003, 2007, 2009, and 2014), recrop wheat yields were considerably greater than continuous wheat yields.

Sorghum yields in 2016 for all rotations were 46 to58 bu/a greater than the long-term average (Table 2). Sorghum yields were similar following one or two wheat crops, which is consistent with the long-term average. The second sorghum crop yields were 73% of the first sorghum crop in 2016 which is slightly greater than the long term average of about 65%.

Aeration and Cooling of Stored Grain

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Many stored grain problems, such as mold, insects, fungi and spoilage, start with or are worsened by improper grain moisture and temperature. Internal air currents driven by temperature differentials in the grain cause moisture to migrate to the top and center of the grain mass; molds develop, and insects feed and reproduce. Aeration is used to cool and maintain uniform temperatures and moisture in masses of stored grain. In aeration, a fan is used to pump outside air through grain in a storage facility. The grain temperature eventually attains the temperature of air traveling through void spaces in the grain mass. Without aeration, stored grain develops wide temperature differentials, increasing the chances of mold and insect development.

Each type of grain has different storage requirements for temperature and moisture and thus has a unique aeration protocol. In Oklahoma early summer crops such as wheat can be cooled during relatively frequent cool nights soon after harvest. Crops harvested later in summer may have limited cooling opportunities immediately after harvest. Oil seeds generally require cooler and dryer storage conditions than wheat or corn to prevent development of rancidity and spoilage.

This document discusses design and operation of aeration systems for grain storage structures.

Aeration is an Integral Part of Integrated Pest Management Practices

Stored grain insects thrive at 75 F to 85 F. Aeration systems should be operated immediately after binning when nighttime temperatures allow to lower temperature to unfavorable levels for insect feeding, growth, and reproduction. Later in September aeration systems should be used to lower temperatures to the lower 60s. If the grain will remain in storage through the winter into summer, another cooling cycle is needed in mid-winter to lower the grain mass to 30 F to 35 F to reduce insect activity and equalize grain mass temperatures.

The bin's doors, unloading auger, under floor spaces, and aeration fan openings should be cleaned and sprayed with a residual insecticide. Openings should be sealed before harvest to keep insects from inhabiting or entering lower bin areas from the outside, to keep cool air from flowing out of the bin, and to keep winds from blowing into fan openings. Keep these openings sealed year round, except when aeration fans are operating.

Aeration System Design Considerations

The design procedure for an aeration system involves first determining the airflow rate and direction needed to achieve specific aeration goals. After the aeration rate is determined the air distribution system can be designed and fans selected to deliver the required air volume. For specific design information see the following OSU Fact Sheets:
BAE-1102 Aeration Systems for Flat-Bottom Round Bins
BAE-1103 Aeration Systems for Cone-Bottom Round Bins

Choosing Airflow Rate

Airflow used for aeration is usually expressed as CFM/bu (cubic feet of air per minute, per bushel of stored grain). Aeration rates start at about 0.05 CFM/bu and increase as shown in Table 1.

Table 1. Aeration time required to cool wheat and corn versus CFM/bu.

	Time (hours) *Grain Condition*		
CFM/Bu.	*Clean*	*High F.M.*	*Aeration Classification*
0.05	240	300-350	Light
0.1	120	150-175	Light
0.2	60	75-85	Medium
0.3	40	50-60	Medium
0.4	30	35-40	Fast
0.5	24	30-35	Fast
0.6	20	25-30	Fast
0.8	15	18-20	Fast
1.0	12	14-16	High speed
2.0	6	8-10	High speed
3.0	4	5-6	High speed
5.0	2.5	3-4	High speed

Light aeration systems, 0.1 CFM/bu or less, require long operation times to lower grain temperatures and are best suited to cooler climates.

Medium and Fast aeration systems, 0.2 CFM/bu through 0.8 CFM/bu, are operated periodically to lower grain temperature and equalize temperatures in stored grain. Just a few nights of operation will lower grain temperature to nighttime air temperature. In Oklahoma a minimum 0.2 CFM/bu is recommended.

For high speed grain cooling, 1 CFM/bu or greater is required. In this case, grain can be cooled in one or two nights of fan operation.

Grain cooling should not be confused with natural air grain drying, which requires high speed airflows greater than 1 CFM/bu. For natural air grain drying, damp grain is placed in a bin and the fan is operated continuously for several weeks until all the grain has dried to a safe moisture content. Grain cooling involves an initial period of fan operation to cool grain followed by periodic operation to maintain even temperatures throughout the grain mass.

The airflow rate should be chosen according to how the aeration system will be used. If grain will be stored with safe moisture content and the aeration system will be used to prevent moisture migration, a light aeration system may be chosen. When storage will be attempted with moisture contents one or two percent above safe moisture levels, grain temperature must be controlled more closely and a fast aeration system is desirable. In general, if grain must be cooled quickly, a faster airflow should be chosen.

Time Required for Cooling

The time required to cool grain to the approximate temperature of the ambient air depends largely on airflow rate, foreign material in the grain, and the amount of evaporative cooling (drying) that takes place. For dry grain, where evaporative cooling is negligible, approximate cooling times are given in Table 1. Doubling the airflow rate will cut cooling time in half.

Many on-farm aeration fans are sized for about 0.1 CFM/bushel airflow which then require about 120 hours (five days) of continuous operation for clean grain or 150 hours to 175 hours (six to seven days) for grain containing high levels of foreign materials (f.m.).

Figure 1 shows temperature data with the number of hours for the months of September and October where the air is below 55 F. Cooling grain to 55 F or lower causes insects to become dormant or die. It also eliminates grain temperature differentials that cause moisture migration, top crusting, and major mold problems.

To take maximum advantage of short duration cool weather in early fall it is advised to use automatic aeration controllers and higher capacity fans that deliver at least 0.2 CFM/bushel to cool grain in less than 60 hours to 85 hours. The additional cost may be recovered in one or two seasons from savings in grain damage, moisture losses, protectant, and fumigation expenses.

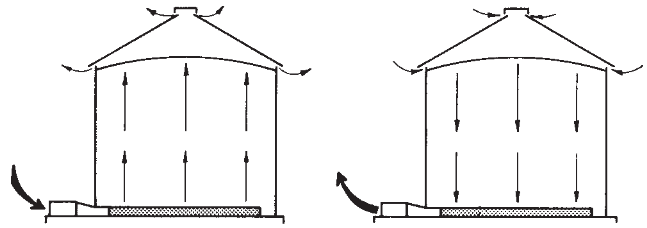


Figure 2. Direction of airflow in aeration systems.

Airflow Direction: Pressure vs. Suction

Pressure (upward) airflow is preferred by many grain storage managers over suction (downward) airflow (Figure 2) because: (1) aeration fans are designed to deliver maximum airflow against pressure; fans push more mass of cool dense air than warm light air; (2) pressure fans develop more uniform airflow through the grain mass than suction systems; (3) with pressure airflow, condensation on top of the grain is visible and usually dries up by the end of the aeration cycle; the problem is visible and solvable, whereas bottom condensation damage caused by suction fans cannot be seen until the bin is unloaded; (4) pressure fans eliminate winter bin roof collapse (roof vents may freeze over during suction cooling). NOTE: Axial (Propeller) fans can usually be reversed simply by turning the fan housing around and rebolting.

Selecting Fans

Aeration fans may be either axial (propeller) type or centrifugal (squirrel-cage) type as illustrated in Figure 3. Axial type fans are less expensive and are normally used when static pressure will not exceed 4 or 5 inches of water.

Centrifugal type fans with backward-inclined blades give more consistent air delivery over a range of pressures than

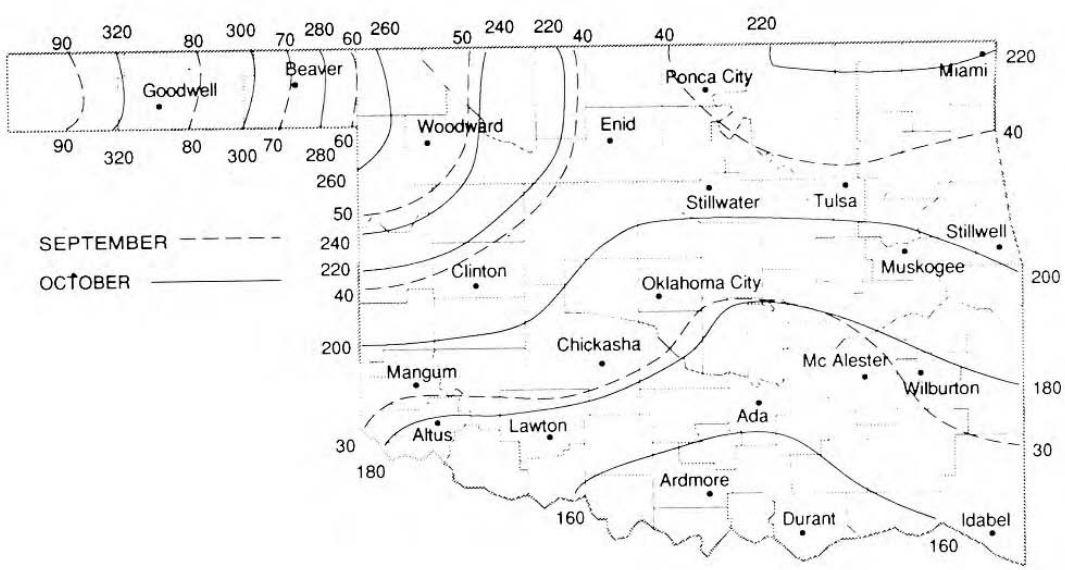
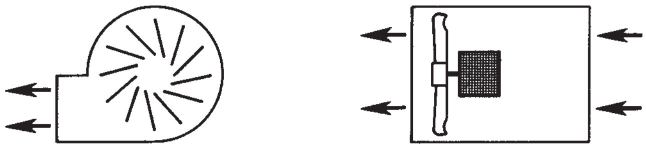


Figure 1. Hours during September and October where temperature is less than 55 F in Oklahoma (30-year weather data).



Centrifugal Fan **Axial Fan**

Figure 3. Centrifugal fan with backward-inclined blades and an axial fan.

most axial type fans and, in special designs, can operate at 20 or more inches of static pressure.

The power required for aeration increases rapidly as airflow rate and grain depth increase. A doubling of airflow rate or grain depth causes about a four-fold increase in power required. Different grain types have different resistance to airflow. For these reasons aeration fans vary greatly in horsepower. With light aeration systems in farm-size storage, fractional horsepower fans are often used. As airflow rates increase to 0.5 CFM/bu or more with grain depths of 20 feet or more, the power requirement may exceed 1 horsepower for every 1,000 bu of bin capacity. In large bins, multiple fans of 20 or 25 horsepower may be required. An estimate of fan power can be obtained from the fan power calculator located at: http://storedproducts.okstate.edu/aerationcalc/aerationfan.aspx

Fans should not be selected by type or by horsepower. Fans for aeration should be selected from the manufacturer's rating tables or curves to deliver the required air volume at the expected static pressure.

Grain Bin Construction and Other Considerations

Grain bins with fully perforated drying floors are ideal for aeration, but cleaning under the floor can be difficult and erection costs can be higher. Removable floor ducts are an alternative to drying floors and can be obtained in large square, cross, "Y," or "U" patterns.

Cross-flow aeration systems can be used to reduce the resistance to airflow encountered in aeration of tall grain bins. The lower power requirements reduce operating expense and capital costs.

Bins must have adequate roof exhaust vents to minimize roof condensation and maximize airflow. There should be a minimum of one square foot of roof vent opening for every 1500 CFM of airflow. A temporary alternative to installing roof openings during aeration fan operation is to open roof fill caps and access doors to allow air to escape. Roof vents that are designed to open under pressure or vacuum can remain closed between aerations to help reduce insect infiltration.

Aeration fans can suck rain and snow into a grain bin. Rain or snow storms of short duration (three hours to six hours) usually do not create a moisture problem. During storms of longer duration or continuous foggy weather, stop aeration until weather improves.

Controls for Aeration

Aeration fans may be controlled by manual, semiautomatic or automatic controls. Manual control requires only a single on-off switch. Controls which can be used with aeration fans include time clock or electric eye for night operation, high- or low-limit thermostats and high- or low-limit humidistats. Several commercial control packages are available, ranging from simple temperature and humidity controls for a single bin to elaborate controls for multiple fan operation.

When semiautomatic or automatic controls are used, an elapsed-time clock should be placed in the circuit. If the aeration system is not operating long enough to achieve temperature equalization within the stored grain, then the control settings should be changed to allow longer or more frequent operation. Aeration systems often must be operated several times during cooling seasons, each time long enough to equalize temperatures throughout the entire grain mass (Table 1).

Small motors can be started and run by temperature and humidity control switches if the contacts are rated for these loads. Magnetic motor starters should be used for all motors of 0.5 horsepower or larger. Automatic aeration temperature controllers using time-delay relays to minimize inrush current and peak power loads can control two or more large fan motor starters in sequence. Both thermostats and humidistats should be carefully adjusted and maintained according to manufacturer's recommendations. Controls should be cleaned at least once a year and more often if operated in dusty surroundings.

An OSU-designed automatic aeration temperature controller for controlling one to three small fans costs about $200-500 for component parts and can be assembled and wired by a local electrician. Schematics and a listing of suggested parts can be found at http://storedproducts.okstate.edu. This basic design can be adapted to operate any number of larger fans.

Aeration Procedures

Filling the Bin and Managing Foreign Material

A level grain surface is an important part of controlling grain temperature and insect activity. Temperatures and insects in grain peaks are difficult to control. Level grain does not vary as much in temperature as peaked grain, which follows outside air temperatures because air blows against grain slopes through roof eave openings.

Grain managers can reduce storage risks from insects and mold by cleaning grain and/or using grain spreaders to distribute foreign material (f.m.) and level the grain surface. Level surfaces improve temperature uniformity and allow easy bin entry for inspection. Grain fines, weed seeds, and other f.m. tend to accumulate in a column under the bin fill point. This accumulation of f.m. restricts airflow and increases the problems of insect and mold development, resulting in grain heating and spoilage.

Coring is a simple method of leveling a peaked bin and removing part of the center column of trash and foreign material. Remove 10 bushels to 20 bushels from each 3- to 4-foot layer of grain during bin filling (Figure 4). The peak is then hand leveled at the end of filling. An alternate coring plan after a bin is full is to unload 100 bushels to 200 bushels of grain and fines with the unload auger a week or two after harvest, reseal the auger, and hand level the surface. (WARNING!! DO NOT enter grain bins while unload augers are running and grain is being unloaded!) Since the removed grain contains a high percentage of fines, it may be marketed, fed to livestock, or cleaned.

Drying and Rewetting Grain During Aeration

Aeration is used to lower grain temperature and to equalize temperatures in stored grain. It is not intended as a drying system; yet minor changes to moisture content can occur. The air surrounding stored grain has an equilibrium moisture content (EMC) which is the point at which grain and air don't exchange moisture. The EMC changes with temperature and moisture content of grain. If grain is aerated with air having relative humidity above the EMC, the grain will slowly gain moisture by absorbing water from the air. Conversely is the air's relative humidity is below the EMC, the grain will dry by transferring water to the air.

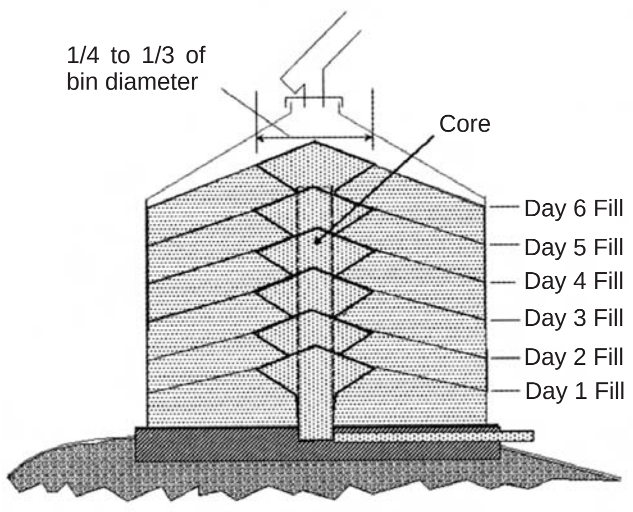


Figure 4. Coring a grain bin to distribute foreign material.

The amount of drying or rewetting that takes place during aeration depends on how dry the grain is when placed in storage, the airflow rate, how long the aeration system is operated, and, of course, the air's humidity. At low airflow, drying is a slow process. Light aeration systems (less than 0.1 CFM/bu) will rarely reduce average moisture content more than 1.0 percent, even when operated for long periods.

Fast aeration systems can cause greater moisture loss if operated continuously. This moisture loss might be desirable if grain moisture content is above safe levels. It can also be undesirable if the grain dries below the market standard moisture content and the owner suffers additional shrinkage when the grain is sold. If some drying is desired, fast aeration systems can be operated continuously while periodically sampling grain moisture. If drying is not desired, fast aeration systems can be operated at night only as needed for cooling and temperature equalization. Systems with grain cooling and grain drying airflows are generally operated at night only when used for aeration.

Rewetting of grain by aeration with humid air is a very slow process. Operation of light or medium speed aeration systems in humid weather will have little effect on moisture content. However, if airflow rates above 0.5 CFM/bu are used for aeration, fans should not be operated for more than a few hours when humidity is extremely high. Because the higher airflow will cool grain rapidly, it is practical to wait for lower humidity before cooling.

Normal aeration rates are much too low for effectively drying grain and can't keep wet grain safe in warm weather. If harvested grain moisture is too high (13 percent for wheat), solve the moisture problem before putting it in storage.

Aeration costs

The cost of installing an aeration system varies widely and depends on the specific installation. Availability of electricity, existing bin equipment such as a drying floor and roof vents, level of automation desired, and bin configuration all affect the total capital cost.

Total annual operating costs to aerate three times (summer, fall and winter) at 8 ¢/KWH to 10 ¢/KWH is approximately 0.7¢/bu to 0.9¢/bu, based on minimum aeration times from Table 1.

The cost of grain moisture removed by aeration (0.3 to 0.5 Ibs/bu/yr) at $5.00 to $5.50/bu wheat price is 2.5 to 4.5 ¢/bu/yr; for $7.00 to $7.50/bu wheat, moisture losses would be 3.5 to 6.3 ¢/bu/yr.

Aeration generally costs less than grain fumigants or protectants, or losses from mold and insect damage, and maintains grain quality.

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Other Grain Storage Resources

Emergency Storage of Grain: Outdoor Piling. Kansas State University.
Extension Publication MF-2363
http://www.bookstore.ksre.ksu.edu/pubs/mf2363.pdf

Aeration Systems for Flat-Bottom Round Bins. Oklahoma State University
Extension Publication BAE-1102.
http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Rendition-6318/unknown

OSHA Fact Sheet – Worker Entry into Grain Storage Bins.
https://www.osha.gov/Publications/grainstorageFACTSHEET.pdf

Aeration System Design for Cone-Bottom Round Bins.
Oklahoma State University Extension Publication BAE-1103.
http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Rendition-6320/unknown

Use of Silo Bags for Commodity Grain Storage in Indiana. Purdue Extension.
https://extension.purdue.edu/pages/article.aspx?intItemID=6963

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http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-10349/BAE-1290web.pdf

Oklahoma State University Stored Product and Research Education Center
http://oaes.okstate.edu/frsu/sprec

Corn, Sorghum, & Wheat Market Outlook Plus Storage Returns

Daniel O'Brien – Extension Agricultural Economist, K-State Research and Extension

Prepared on January 3, 2017

I. 2017 Kansas Corn Market Outlook

Since the USDA's December 9th **World Agricultural Supply and Demand Estimates (WASDE) report**, MARCH 2016 CME corn futures have moved sideways in a varying trend. On the day of the report, MARCH 2016 corn futures closed at $3.59 ½ per bushel, and then moved to a high of $3.63 on December 15th, before closing at $3.55 ¾ on Tuesday, January 3, 2017. The USDA's forecast of a record large 2016 U.S. corn crop 15.226 billion bushels (bb) and large 2016/17 marketing year ending stocks of 2.403 bb have continued to be the primary limiting focus of U.S. corn market prices.

Cash corn prices at major grain elevators in central and western Kansas on January 3rd ranged from $2.86 to $3.09 in Western KS, from $2.78 to $3.11 in Central KS, and from $3.38 to $3.41 in selected per Eastern KS terminals. Kansas ethanol plant bids for corn ranged from $3.27 to $3.52, with basis at $0.25-$0.00 under MARCH 2017 Corn futures. Although the "large supply and tight storage availability" situation predominates in local Kansas grain markets, it is a positive sign that corn usage has provided enough market support that Kansas cash corn prices have not fallen down to USDA loan rate – price support levels near $2.05 (Central KS) to $2.19 (Western KS) per bushel.

Other market factors to consider that could affect the U.S. corn market in 2017 include: 1) the pace and timing of U.S. farmer marketing of the 2016 corn crop – much of which had been placed in storage after fall harvest and likely will be held for sale through the winter into at least early spring 2017, 2) anticipation of continued strong use of 2016 crop U.S. corn for domestic U.S. ethanol production and livestock feeding, 3) at least moderate strength in U.S. corn exports – driven partly by a poor harvest and lack of exportable supplies in Brazil in 2016 as well as other World corn market factors, and 4) the always present possibility of broader U.S. and Foreign economic and/or financial system disruptions impacting grain, energy, and other commodity markets in 2017.

For example, U.S. financial policy announcements by the U.S. Federal Reserve in 2017 could lead to increases in U.S. interest rates and the value of the U.S. dollar relative to other World currencies, which could in turn have a negative impact on U.S. corn exports.

USDA Supply-Demand Forecast for "Current" MY 2016/17: With USDA projections of 2016 U.S. corn plantings of 94.490 ma, harvested acres of 86.836 ma, record high projected yields of 175.1 bu/ac (vs 168.4 bu/ac in 2015 and the previous record high of 171.0 bu/ac in 2014), 2016 U.S. corn production is forecast to be a record high 15.226 bb – up from 13.601 bb in 2015, the previous record of 14.216 bb in 2014, and 13.829 bb in 2013.

With forecast "current" MY 2016/17 total supplies of 17.031 bb (record high), total use of 14.610 bb (record high), and projected ending stocks of 2.403 bb (16.45% S/U) – up from 1.738 bb (12.72% S/U) in MY 2015/16 and the highest since 4.259 bb (54.90% S/U) in MY 2004/05 – U.S. corn prices are projected by the USDA to be in the range of $3.05-$3.65 (midpoint = $3.35 /bu) – being down from $3.61 /bu for MY 2015/16. *(continued)*

<u>USDA Supply-Demand Forecast for "Next Crop" MY 2017/18</u>: With early USDA projections of 2017 <u>U.S. corn plantings</u> of 90.000 ma (down 4.490 ma), <u>harvested acres</u> of 82.300 ma (down 4.536 ma), projected <u>yields</u> of 170.8 bu/ac (vs the record high of 175.3 in 2016), <u>2017 U.S. corn production</u> is forecast to be 14.060 bb – down from the record high of 15.226 bb in 2016.

With forecast "next crop" MY 2017/18 <u>total supplies</u> of 16.513 bb (down 500 mb from last year's record high), <u>total use</u> of 14.215 bb (down 395 mb from last year's record high), and projected <u>ending stocks</u> of 2.298 bb (16.17% S/U) – down from 2.403 bb (16.45% S/U) in "current" MY 2016/17 – <u>U.S. corn prices</u> are projected by the USDA to average $3.30 /bu. ***This scenario is given a 55% likelihood of occurring by KSU Extension Ag Economist D. O'Brien***.

<u>Alternative KSU Forecasts for "Next Crop" MY 2017/18</u>: Three alternative **KSU-Scenarios** for U.S. corn supply-demand and prices are presented for "next crop" MY 2017/18. Each forecast scenario presents the likelihood of lower U.S. corn yields and production than projected by the USDA in the **December 1st USDA early supply-demand estimate** for "next crop" MY 2017/18.

KSU "Next Crop" MY 2017/18 Scenario #1) <u>"167.4 bu/ac – 13.777 bb" Scenario *(25% probability)*</u> assumes: 90.000 ma planted, 82.300 ma harvested, 167.4 bu/ac trend yield, 13.777 bb production, 16.230 bb total supplies, 14.215 bb total use, 2.015 bb ending stocks, 14.18% S/U, & $3.55 /bu U.S. corn average price for "next crop" MY 2017/18;

KSU "Next Crop" MY 2017/18 Scenario 2) <u>"165.0 bu/ac – 13.580 bb" Scenario *(15% probability)*</u> assumes: 90.000 ma planted, 82.300 ma harvested, 165.0 bu/ac yield, 13.580 bb production, 16.033 bb total supplies, 14.215 bb total use, 1.818 bb ending stocks, 12.79% S/U, & $3.70 /bu U.S. corn average price for "next crop" MY 2017/18;

KSU "Next Crop" MY 2017/18 Scenario #3) <u>"150.0 bu/ac – 12.345 bb" Scenario *(5% probability)*</u> assumes: 90.000 ma planted, 82.300 ma harvested, 150.0 bu/ac yield, 12.345 bb production, 14.798 bb total supplies, 13.460 bb total use, 1.338 bb ending stocks, 9.94% S/U, & $4.30 /bu U.S. corn average price for "next crop" MY 2017/18;

<u>World Corn Supply-Demand</u>: Record high <u>World corn production</u> of 1,039.7 million metric tons (mmt) is projected for "current" MY 2016/17, up 8.2% from 961.1 mmt in MY 2015/16, and up 2.5% from 1,014.0 mmt in MY 2014/15. Record high <u>World corn total supplies</u> of 1,248.7 mmt are projected for "new crop" MY 2016/17, up from 1,169.3 mmt in MY 2015/16, and from 1,188.8 mmt in MY 2014/15.

<u>World corn exports</u> of 147.7 mmt are projected for "new crop" MY 2016/17, up 21.8% from 121.2 mmt in MY 2015/16, and up 3.9% from 142.2 mmt in MY 2014/15. Projected record high <u>World corn ending stocks</u> of 222.25 mmt (21.7% S/U) in "new crop" MY 2016/17 are up from 208.95 mmt (21.8% S/U) in MY 2015/16, and from 208.3 mmt (21.2% S/U) in MY 2014/15.

Although <u>World corn ending stocks</u> are projected to be a record high in "new crop" MY 2016/17 at 222.25 mmt, <u>World corn percent ending stocks-to-use</u> in "new crop" MY 2016/17 are forecast to actually decline marginally to 21.7% - indicative that strong World demand for corn at low prices is expected to continue – especially in Europe where grain production has been hampered by extreme weather conditions in the last year.

II. 2017 Kansas Grain Sorghum Market Outlook

The USDA's forecast of a 462 million bushel (mb) 2016 U.S. grain sorghum crop along with record large 2016 U.S. corn crop of 15.226 billion bushels (bb), together with large 2016/17 marketing year U.S. feedgrain ending stocks of 64.8 million metric tons (mmt) – up 35%-38% from the previous two marketing years – and have continued to pressure both U.S. grain sorghum and corn market prices.

Cash grain sorghum prices in Kansas: At major grain elevators in western Kansas, cash grain sorghum prices were in the range of $2.56 - $2.61 /bu on January 3rd with basis levels $0.95 to $1.10 under CME MARCH 2017 Corn futures. As low as these prices were, they were still markedly *higher* than county FSA marketing loan rates of $1.76-$1.90 per bushel. Similarly, central Kansas cash grain sorghum prices were in the range of $2.41 - $2.91 /bu with basis levels $1.00 to $0.65 under MARCH 2017 Corn, but still above local FSA loan rates of $1.85-$1.93 /bu.. At Topeka in east central Kansas, a higher bid was reported of $3.11 /bu (basis = $0.45 under). Kansas ethanol plant bids for grain sorghum ranged from $2.87 to $2.92, with basis at $$0.65-$0.60 under MARCH 2017 Corn futures. Just as with corn, wheat, and soybeans, current cash bids for grain sorghum are below full economic cost of production in most instances – although to a degree high yields in 2016 has helped to mitigating this factor.

Although the existing "*large supply and tight storage availability*" situation predominates in local Kansas grain sorghum and corn markets in early January 2017, it is a positive sign that usage of these crops has provided enough market support so that Kansas cash prices have not fallen down to USDA loan rate – price support levels during the 2016 harvest and immediate post-harvest period.

Other market factors to consider that could affect the U.S. feedgrain markets in 2017 include: 1) the pace and timing of U.S. farmer marketing of the 2016 grain sorghum and corn crops during 2017 – much of which had been placed in storage after the 2016 fall harvest and likely will be held for sale through the winter into at least early spring 2017, 2) anticipation of continued strong use of 2016 crop U.S. feedgrains for domestic U.S. ethanol production and livestock feeding, 3) at least moderate strength in U.S. grain sorghum exports – driven partly by a poor Brazilian feedgrain harvest and lack of exportable supplies in earlier in 2016, as well as other World coarse grain market factors, and 4) the always present possibility of broader U.S. and Foreign economic and/or financial system disruptions impacting grain, energy, and other commodity markets in 2017.

USDA Supply-Demand Forecast for "Current" MY 2016/17: The USDA has projected of 2016 U.S. sorghum plantings of 6.761 ma, harvested acres of 6.045 ma, record high yields of 76.5 bu/ac (vs 76.0 bu/ac in 2015 and 67.6 bu/ac in 2014), resulting in a 2016 U.S. grain sorghum production is forecast to be 462 mb – down from 597 mb in 2015, but above 433 mb in 2014, and 392 mb in 2013.

With forecast "current" MY 2016/17 total supplies of 500 mb, total use of 465 mb, and projected ending stocks of 35 mb (7.48% S/U), U.S. grain sorghum prices are projected by the USDA to be in the range of $2.80-$3.30 (midpoint = $3.05 /bu). Ending stocks of 35 mb (7.48% S/U) in "current" MY 2016/17 compare to 37 mb (6.28% S/U) in MY 2015/16, and 18 mb (4.10% S/U) in MY 2004/05. United States grain sorghum prices of $3.05 /bu in "current" MY 2016/17 continue the downward trend from $3.31 /bu in MY 2015/16, $4.03 in MY 2014/15, $4.28 in MY 2013/14, and the record high of $6.33 /bu in the drought year of MY 2012/13.

<u>USDA Supply-Demand Forecast for "Next Crop" MY 2017/18</u>: With early USDA projections of 2017 <u>U.S. sorghum plantings</u> of 6.300 ma (down 461,000 acres), <u>harvested acres</u> of 5.400 ma (down 645,000 acres), projected <u>yields</u> of 67.1 bu/ac (vs the record high of 76.5 bu in 2016), <u>2017 U.S. grain sorghum production</u> is forecast to be 362 mb – down from 462 mb in 2016, and 597 mb in 2015.

With forecast "next crop" MY 2017/18 <u>total supplies</u> of 397 mb (down from 500 mb last year and 620 mb the year before), <u>total use</u> of 365 mb (down from 465 mb last year and 583 the year before), and projected <u>ending stocks</u> of 32 mb (8.76% S/U) – down from 35 mb (7.48% S/U) in "current" MY 2016/17 – <u>U.S. sorghum prices</u> are projected by the USDA to average $3.10 /bu.

<u>Note</u>: This is a "large U.S. feedgrain crop" – "no major U.S. or Foreign crop problem" scenario. Emerging production threats and the actual outcome of 2017 U.S. grain sorghum and corn production will drive the U.S. grain sorghum market in "next crop" MY 2017/18.

<u>World Coarse Grain Supply-Demand</u>: Record high <u>World coarse grain production</u> of 1,329.35 million metric tons (mmt) is projected for "current" MY 2016/17, up 6.4% from 1,249.65 mmt in MY 2015/16, and up 1.8% from 1,306.1 mmt in MY 2014/15. Record high <u>World coarse grain total supplies</u> of 1,574.15 mmt are projected for "new crop" MY 2016/17, up from 1,495.0 mmt in MY 2015/16, and from 1,517.2 mmt in MY 2014/15. **"Coarse grains"** include grain sorghum, corn, barley, oats, rye, millet, and mixed grains.

<u>World coarse grain exports</u> of 185.2 mmt are projected for "new crop" MY 2016/17, up 12.4% from 164.8 mmt in MY 2015/16, and down 0.5% from 186.1 mmt in MY 2014/15. Projected record high <u>World coarse grain ending stocks</u> of 254.9 mmt (19.3% S/U) in "new crop" MY 2016/17 are up from 244.8 mmt (19.6% S/U) in MY 2015/16, but down from 245.4 mmt (19.3% S/U) in MY 2014/15.

Although <u>World coarse grain ending stocks</u> are projected to be a record high in "new crop" MY 2016/17 at 254.9 mmt, <u>World coarse grain percent ending stocks-to-use</u> in "new crop" MY 2016/17 are forecast to actually decline marginally to 19.3% - indicative that strong World demand for coarse grains at low prices is expected to continue – especially in Europe where grain production has been hampered by extreme weather conditions in the last year.

III. 2017 Kansas Wheat Market Outlook

Since the USDA's December 9th **<u>World Agricultural Supply and Demand Estimates (WASDE)</u> report**, U.S. and World wheat futures market prices have traded in a sideways and volatile – with **CME MARCH 2017 Kansas HRW Wheat futures** gaining $0.08 ¾ /bu to close at $4.13 ½ on 12/9/2016 – the day of the report – and trading as high as $4.20 ¾ per bushel through Wednesday, December 28th before closing down to $4.14 on January 3, 2017.

<u>Cash wheat prices in Kansas</u>: At major grain elevators in <u>western Kansas</u>, cash wheat prices were in the range of $2.84 - $3.04 /bu on January 3rd with basis levels $1.30 to $1.10 unden CME MARCH 2017 KS HRW wheat futures. These prices just below or equal to than county FSA marketing loan rates of $3.03-$3.08 per bushel. Similarly, <u>central Kansas</u> cash wheat prices were in the range of $2.97 - $3.27 /bu with basis levels $1.17 to $0.87 under CME MARCH 2017 KS HRW wheat futures, compared to local FSA loan rates of $3.19-$3.23 /bu.. At Topeka and Atchison in <u>east central and northeast Kansas</u>, higher bids were reported of $3.19-$3.39 /bu (basis = $0.95-$0.75 under). <u>Kansas wheat processor 11% protein</u>

wheat bids in Wichita ranged were \$3.69 /bu, with basis at \$0.45 under CME MARCH 2017 KS HRW wheat futures, compared to 12% protein bids of \$4.04 /bu at \$0.10 under. Just as with corn, sorghum, and soybeans (to a lesser degree), current cash bids for wheat in Kansas are below full economic cost of production in most instances – although to a high yields in 2016 has helped to mitigating this factor as with other crops.

Supply-Demand Trends: For the "current crop" 2016/17 marketing year (MY), the USDA projected: 1) World wheat total supplies of 991.9 million metric tons (mmt) and total use of 739.8 mmt – both at record high levels, 2) that World wheat exports are continuing to trend higher to 176.8 mmt in the "current" marketing year – up from 172.5 mmt last year, and up from 164.4 mmt two years ago, 3) World wheat ending stocks at a record high 252.1 mmt up from 240.65 mmt last year, and 217.2 mmt two years ago, and 4) World wheat percent ending stocks-to-use (S/U) of 34.1% - up from 33.8% last year, and from 30.8% two years ago – up to the highest level since MY 2005/06.

For a perspective on how historically large World total wheat stocks and World wheat percent stocks-to-use now are, in MY 2007/08 the 34-year low in World wheat ending stocks of 128.1 mmt and at least a 57-year low in percent ending stocks-to-use of 20.75% stocks/use both occurred – the last major World wheat "short crop" marketing year. The situation in MY 2007/08 compares to projections of 252.1 mmt ending stocks and 34.1% ending stocks-to-use projected for "current" MY 2016/17. The "large crop-over supply" situation that now exists in World and U.S. wheat markets continues to have a strong prevailing negative influence on U.S. and World wheat prices.

However, the broader large crop-over supply-low price" situation in the World wheat market may be "hiding" at least a couple of other important market issues. First, while the quantity of wheat available in the World is plentiful, the available supply of high protein milling wheat is less so. This factor may eventually help exports of both U.S. Hard Red Spring (HRS) wheat (higher protein – good quality) and U.S. Hard Red Winter (HRW) wheat (moderate protein – good quality) relative to World wheat export competitors. As evidence of this, exports of U.S. HRW wheat have been occurring at the pace needed to meet USDA projections – helped by both low purchase prices and acceptable protein and quality. This raises the outside possibility of improved U.S. HRW prices in coming months. Second, while the supply of wheat in World markets overall has grown, the supply of wheat in the "*World Less China*" is projected to have actually "contracted" or "diminished" in "current crop" MY 2016/17 compared to a year ago – down to the tightest supply-balances situation since MY 2013/14. If this "China factor" eventually leads to noticeably tighter available global supplies of exportable wheat to occur in coming months, it could have a positive impact U.S. wheat market prices in Spring 2017.

Even so, given the broader World wheat market's current focus – it is likely that significant World wheat production problems and/or trade disruptions would need to occur in year 2017 in order to have wheat prices recover significantly by spring-summer 2017. Ongoing strength in the U.S. dollar exchange rate is a serious negative factor that is limiting the competitive affordability of U.S. wheat exports. These factors have resulted in higher U.S. wheat ending stocks and % ending stocks-to-use, and have caused U.S. and Kansas wheat cash prices to fall sharply – down to and below the marketing loan rate in most of Kansas in fall / early winter 2016.

USDA U.S. Wheat Supply/Demand Forecast for "Next Crop" MY 2017/18: On December 1, 2016 the USDA released their preliminary **Long Term Agricultural Projections to 2026**, in which they projected

2017 U.S. wheat plantings of 48.500 million acres (ma) – down from 50.154 ma in 2015. The USDA also forecast 2016 harvested acres of 41.100 ma which would be down from 43.890 ma a year ago. Trendline 2017 wheat yields for 2017 are projected at 47.1 bu/a, down from the 2016 record of 52.6 bu/ac, while 2017 U.S. wheat production is forecast to be 1.936 billion bushels (bb), down from 2.310 bb in 2015. Projected "next crop" MY 2017/18 total supplies are 3.199 bb (down from 3.410 bb in "current" MY 2016/17), with total use of 2.206 bb (down from 2.267 bb in "current" MY 2016/17).

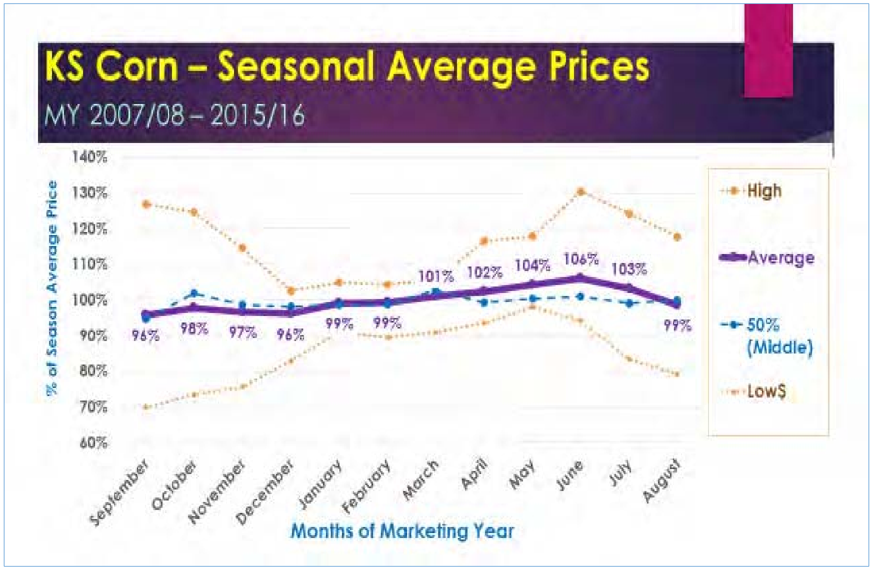
Given these numbers, the USDA projected "next crop" MY 2017/18 ending stocks of 933 million bushels (mb) (vs 1.143 bb a year ago), with percent ending stocks-to-use of 45.0% S/U (vs 50.4% last year and 50.0% the previous year). United States wheat average prices are projected to average $4.00 /bu – up from $3.70 in "current" MY 2016/17, but down from $4.89 /bu in MY 2015/16 and $5.99 /bu in MY 2014/15. It is assumed by Kansas State University that these **USDA projections** for "next crop" MY 2016/17 have a **50% probability of occurring**.

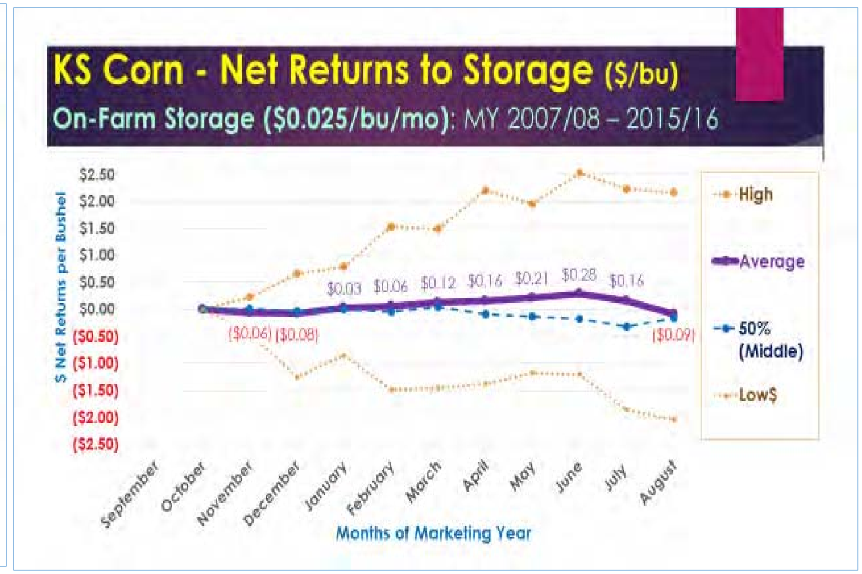
Three Alternative KSU U.S. Wheat S/D Forecast for "Next Crop" MY 2017/18: As an alternative to the USDA's projection, three potential **KSU-Scenarios** for U.S. wheat supply-demand and prices are presented for "next crop" MY 2017/18. These scenarios assume lower 2017 U.S. planted (47.624 ma) and harvested (38.385 ma) wheat acres than the USDA – due to larger than normal amounts of "graze out" and "crop switching" in 2017.

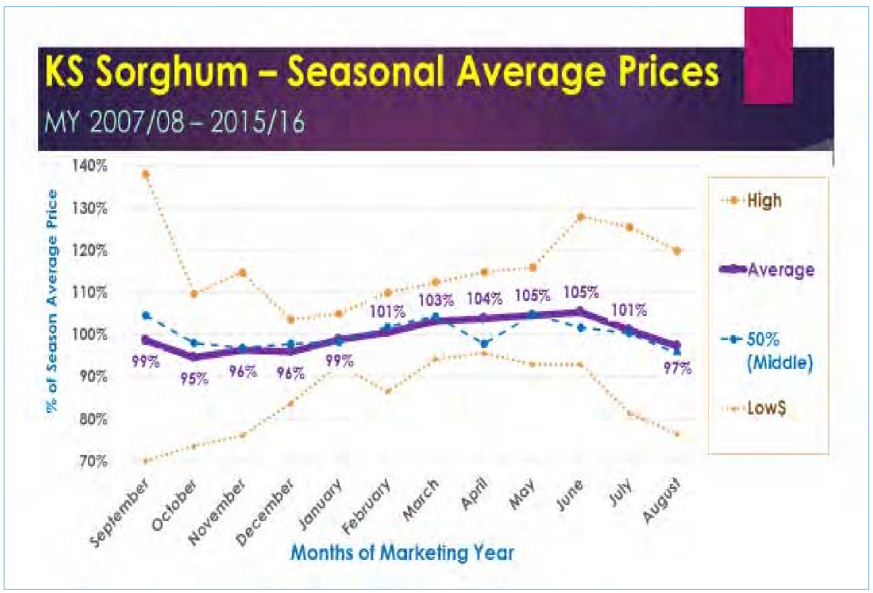
KSU Scenario 1) "Lower Acres, Trend Yield" Scenario (30% probability) assumes for "next crop" MY 2017/18: 47.624 ma planted, 38.385 ma harvested, 47.0 bu/ac trend yield, 1.804 bb production, 3.067 bb total supplies, 960 mb exports, 200 mb feed & residual use, 2.191 bb total use, 876 mb ending stocks, 39.98% S/U, & $4.00-$4.50 /bu U.S. wheat average price;

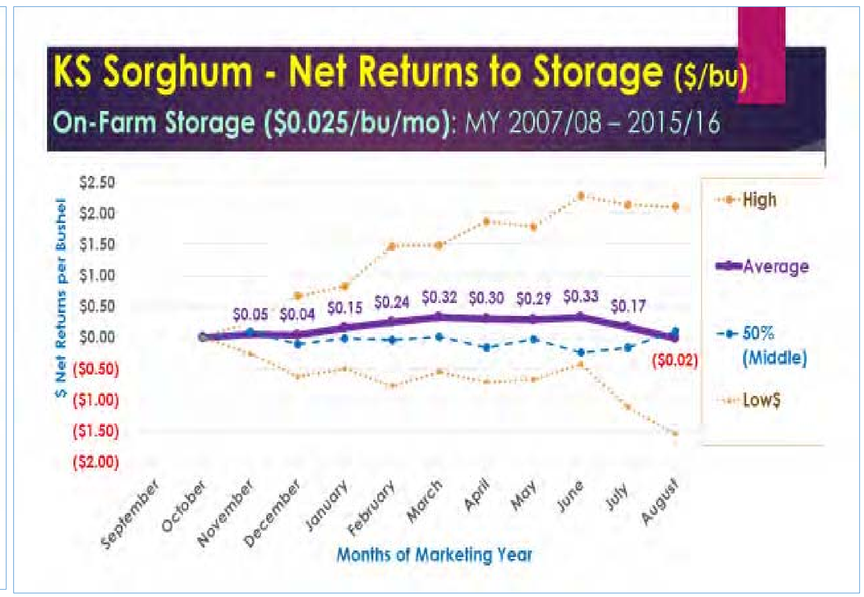
KSU Scenario 2) "Lower Acres, Trend Yield, +20% Exports" Scenario (10% probability) assumes for "next crop" MY 2017/18: 47.624 ma planted, 38.385 ma harvested, 47.0 bu/ac trend yield, 1.804 bb production, 3.067 bb total supplies, 1.152 bb exports***, 200 mb feed & residual use, 2.383 bb total use, 684 mb ending stocks, 24.10% S/U, & $5.25-$5.75 /bu U.S. wheat average price;

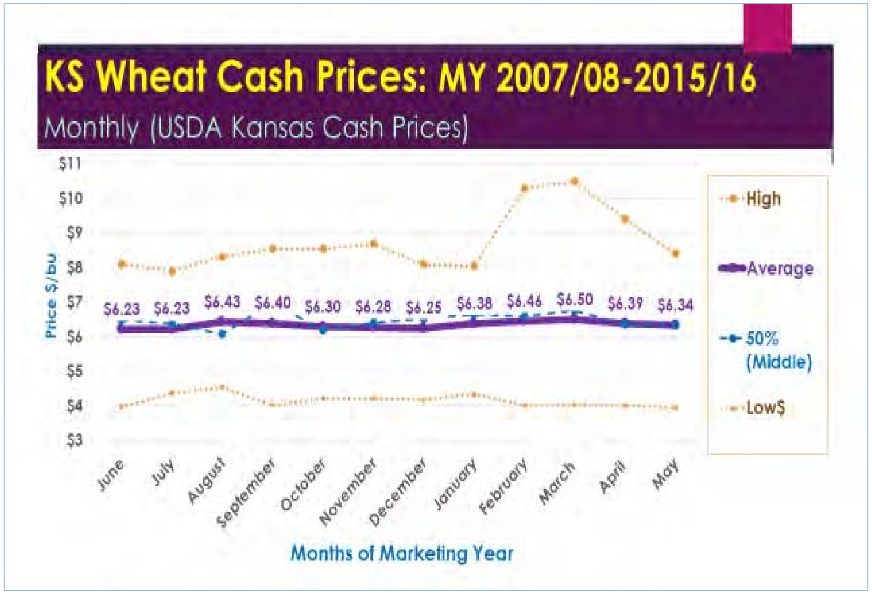
KSU Scenario 3) "Lower Acres, Short Crop Yield" Scenario (10% probability) assumes for "next crop" MY 2017/18: 47.624 ma planted, 38.385 ma harvested, 43.6 bu/ac low yield***, 1.674 bb production, 2.937 bb total supplies, 925 mb exports, 200 mb feed & residual use, 2.156 bb total use, 781 mb ending stocks, 36.22% S/U, & $4.40-$4.90 /bu U.S. wheat average price.

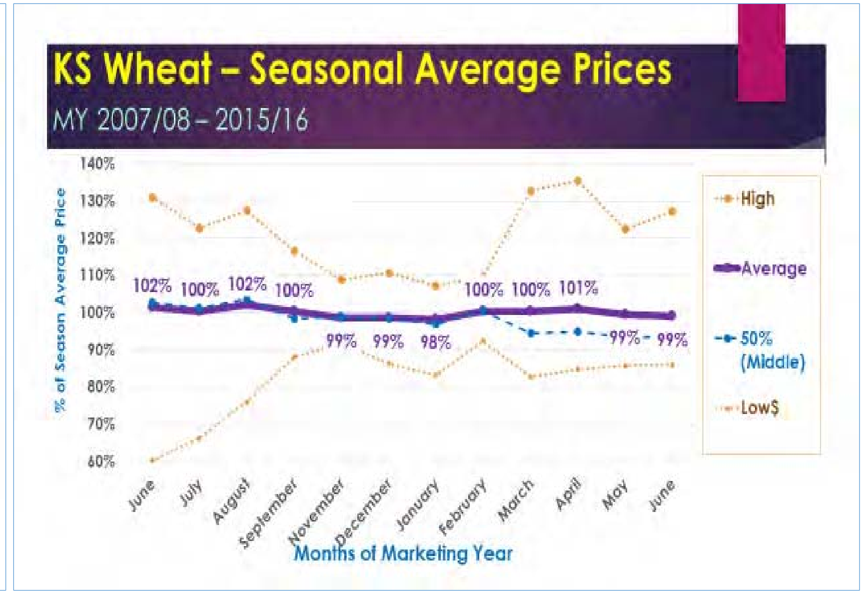

KS Corn – Seasonal Average Prices
MY 2007/08 – 2015/16
% of Season Average Price
140%
130%
120%
110%
100%
90%
80%
70%
60%
96% 98% 97% 96% 99% 99% 101% 102% 104% 106% 103% 99%
September October November December January February March April May June July August
Months of Marketing Year
High
Average
50% (Middle)
Low$

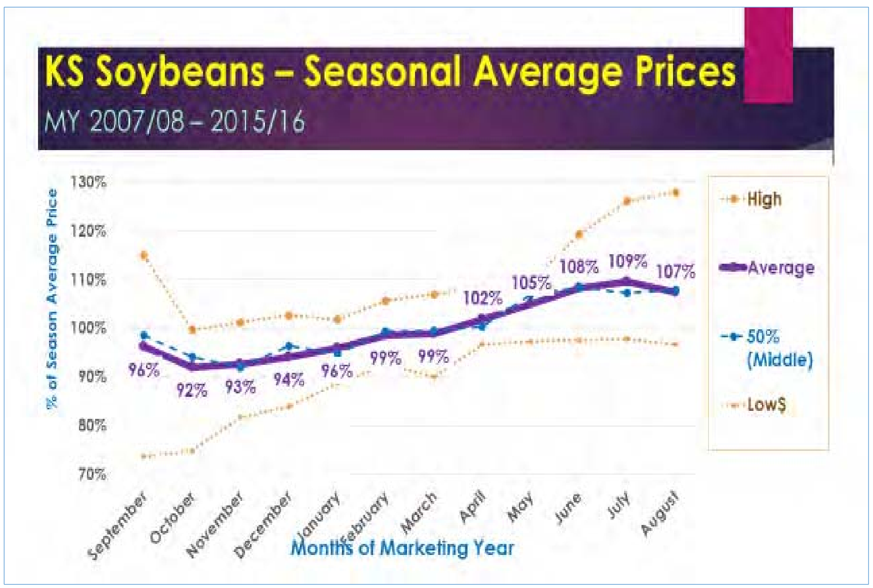

KS Corn - Net Returns to Storage ($/bu)
On-Farm Storage ($0.025/bu/mo): MY 2007/08 – 2015/16
$ Net Returns per Bushel
$2.50
$2.00
$1.50
$1.00
$0.50
$0.00
($0.50)
($1.00)
($1.50)
($2.00)
($2.50)
($0.06) ($0.08) $0.03 $0.06 $0.12 $0.16 $0.21 $0.28 $0.16 ($0.09)
September October November December January February March April May June July August
Months of Marketing Year
High
Average
50% (Middle)
Low$

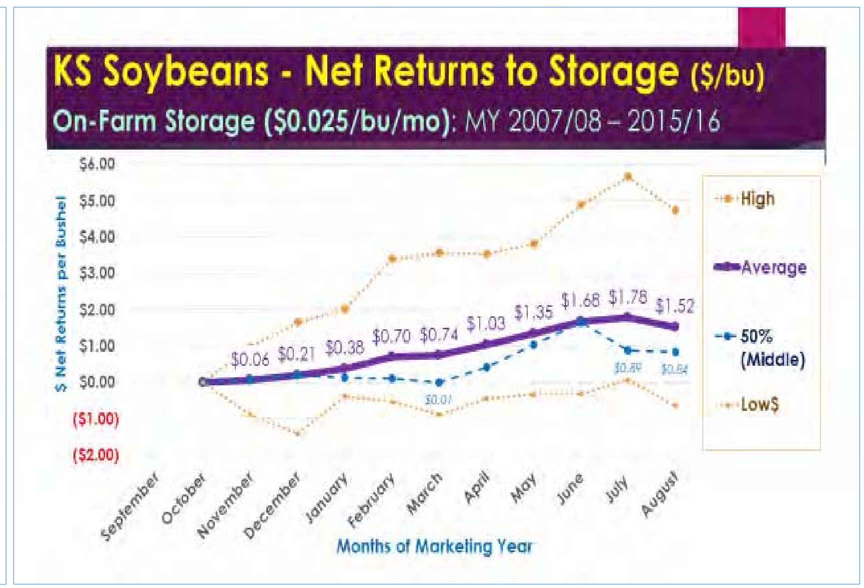

KS Sorghum – Seasonal Average Prices
MY 2007/08 – 2015/16
% of Season Average Price
140%
130%
120%
110%
100%
90%
80%
70%
99% 95% 96% 96% 99% 101% 103% 104% 105% 105% 101% 97%
September October November December January February March April May June July August
Months of Marketing Year
High
Average
50% (Middle)
Low$


KS Sorghum - Net Returns to Storage ($/bu)
On-Farm Storage ($0.025/bu/mo): MY 2007/08 – 2015/16
$ Net Returns per Bushel
$2.50
$2.00
$1.50
$1.00
$0.50
$0.00
($0.50)
($1.00)
($1.50)
($2.00)
$0.05 $0.04 $0.15 $0.24 $0.32 $0.30 $0.29 $0.33 $0.17 ($0.02)
September October November December January February March April May June July August
Months of Marketing Year
High
Average
50% (Middle)
Low$


KS Wheat Cash Prices: MY 2007/08-2015/16
Monthly (USDA Kansas Cash Prices)
Price $/bu
$11
$10
$9
$8
$7
$6
$5
$4
$3
$6.23 $6.23 $6.43 $6.40 $6.30 $6.28 $6.25 $6.38 $6.46 $6.50 $6.39 $6.34
June July August September October November December January February March April May
Months of Marketing Year
High
Average
50% (Middle)
Low$


KS Wheat – Seasonal Average Prices
MY 2007/08 – 2015/16
% of Season Average Price
140%
130%
120%
110%
100%
90%
80%
70%
60%
102% 100% 102% 100%
99% 99% 98%
100% 100% 101%
99% 99%
June July August September November December January February March April May June
Months of Marketing Year
High
Average
50% (Middle)
Low$


KS Soybeans – Seasonal Average Prices
MY 2007/08 – 2015/16
% of Season Average Price
130%
120%
110%
100%
90%
80%
70%
96% 92% 93% 94% 96% 99% 99% 102% 105% 108% 109% 107%
September October November December January February March April May June July August
Months of Marketing Year
High
Average
50% (Middle)
Low$


KS Soybeans - Net Returns to Storage ($/bu)
On-Farm Storage ($0.025/bu/mo): MY 2007/08 – 2015/16
$ Net Returns per Bushel
$6.00
$5.00
$4.00
$3.00
$2.00
$1.00
$0.00
($1.00)
($2.00)
$0.06 $0.21 $0.38 $0.70 $0.74 $1.03 $1.35 $1.68 $1.78 $1.52
September October November December January February March April May June July August
Months of Marketing Year
High
Average
50% (Middle)
Low$

Profitability in Northwest Kansas Operations

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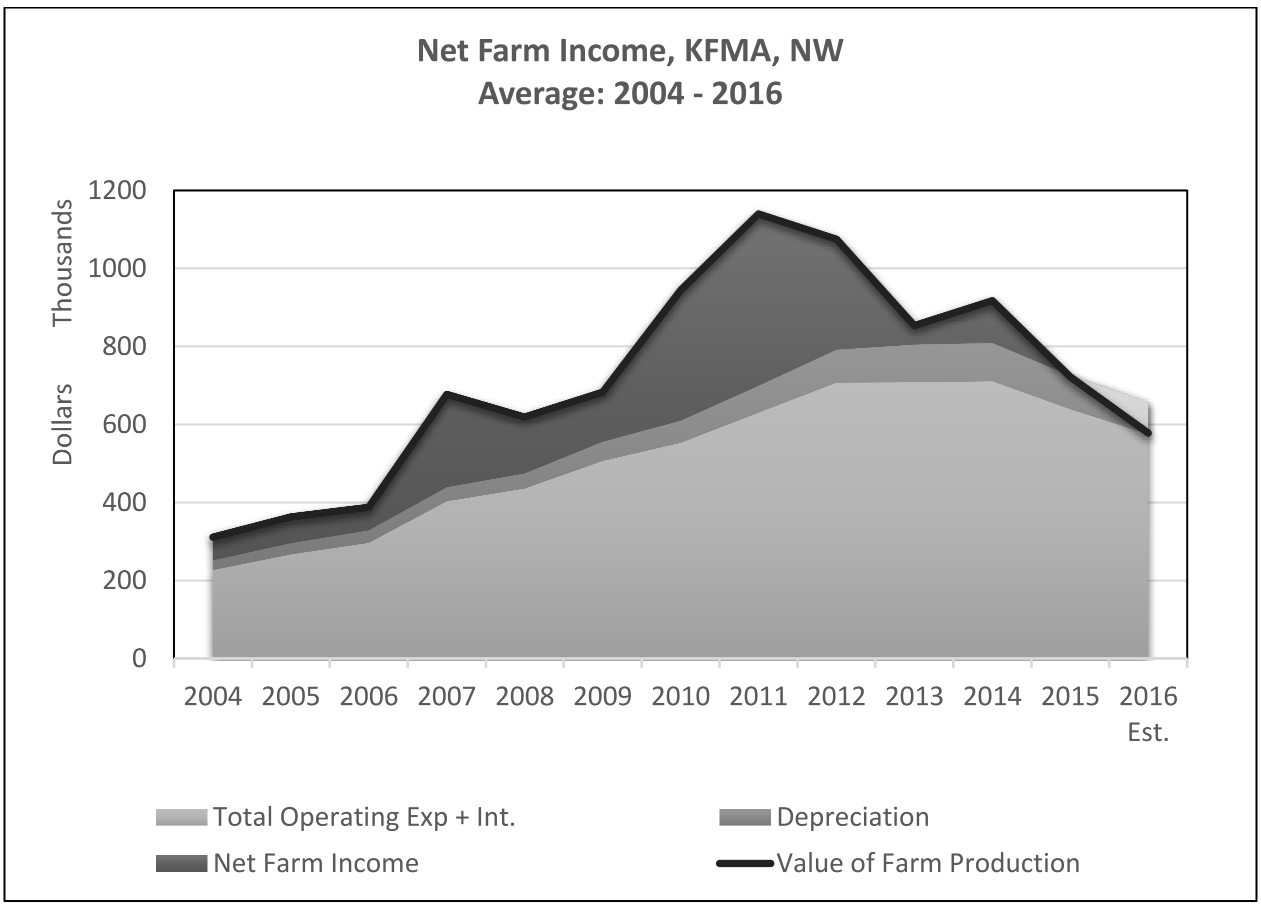
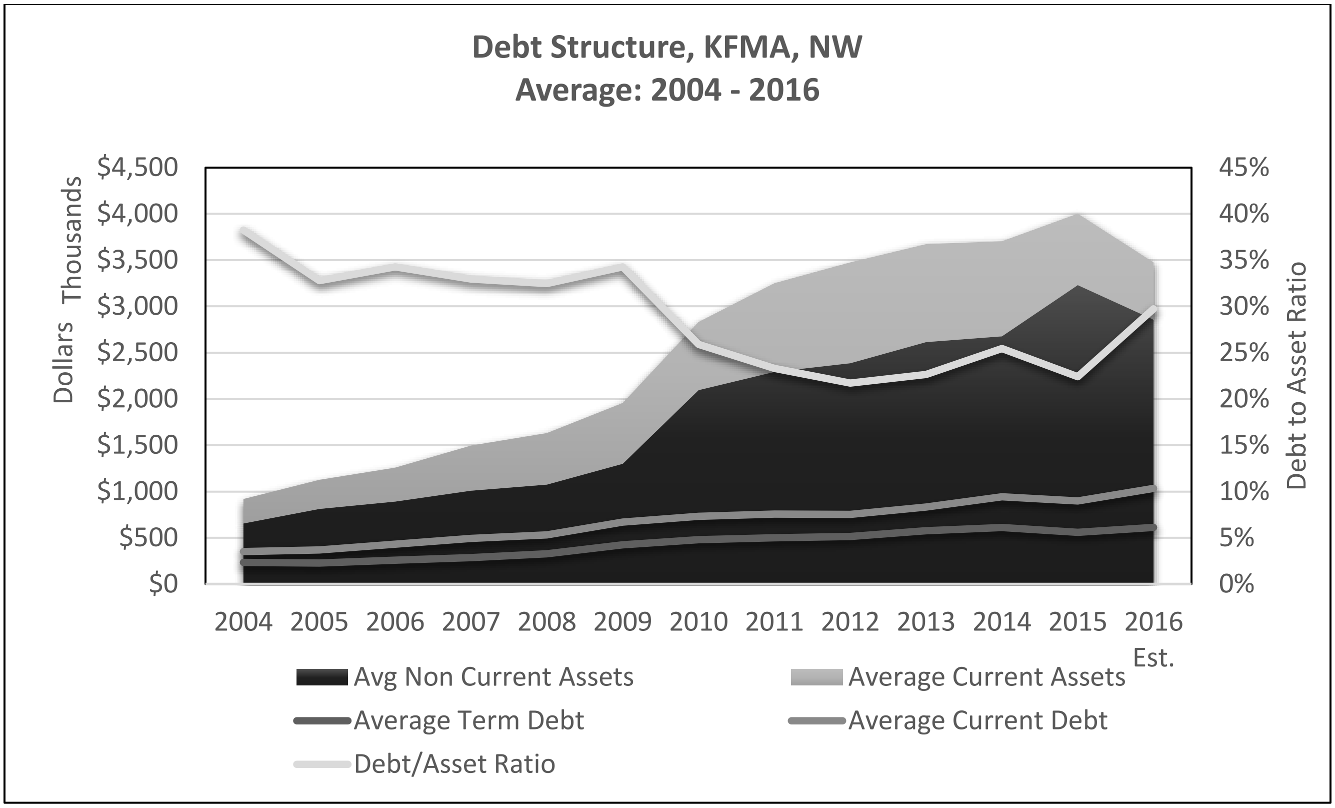
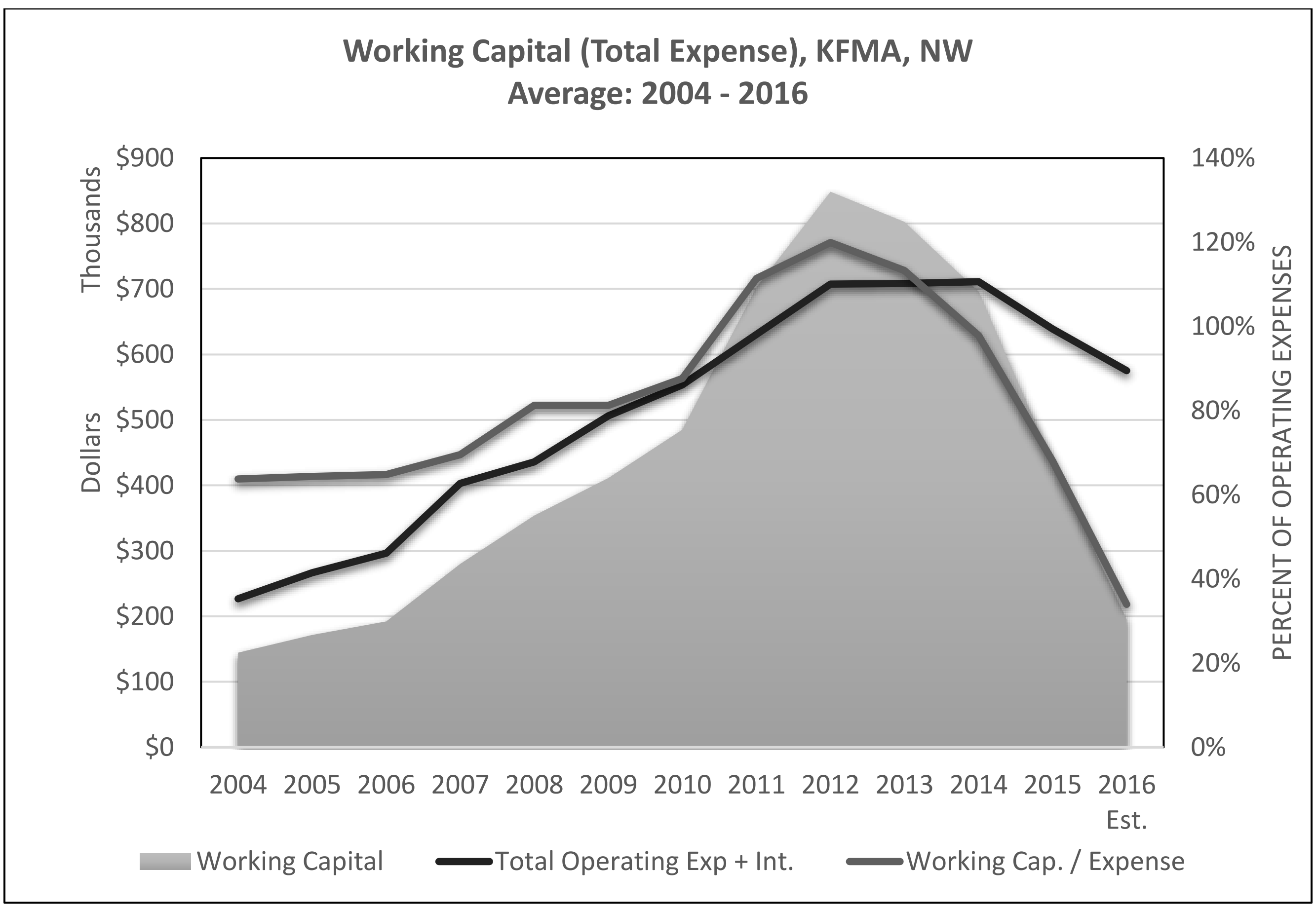
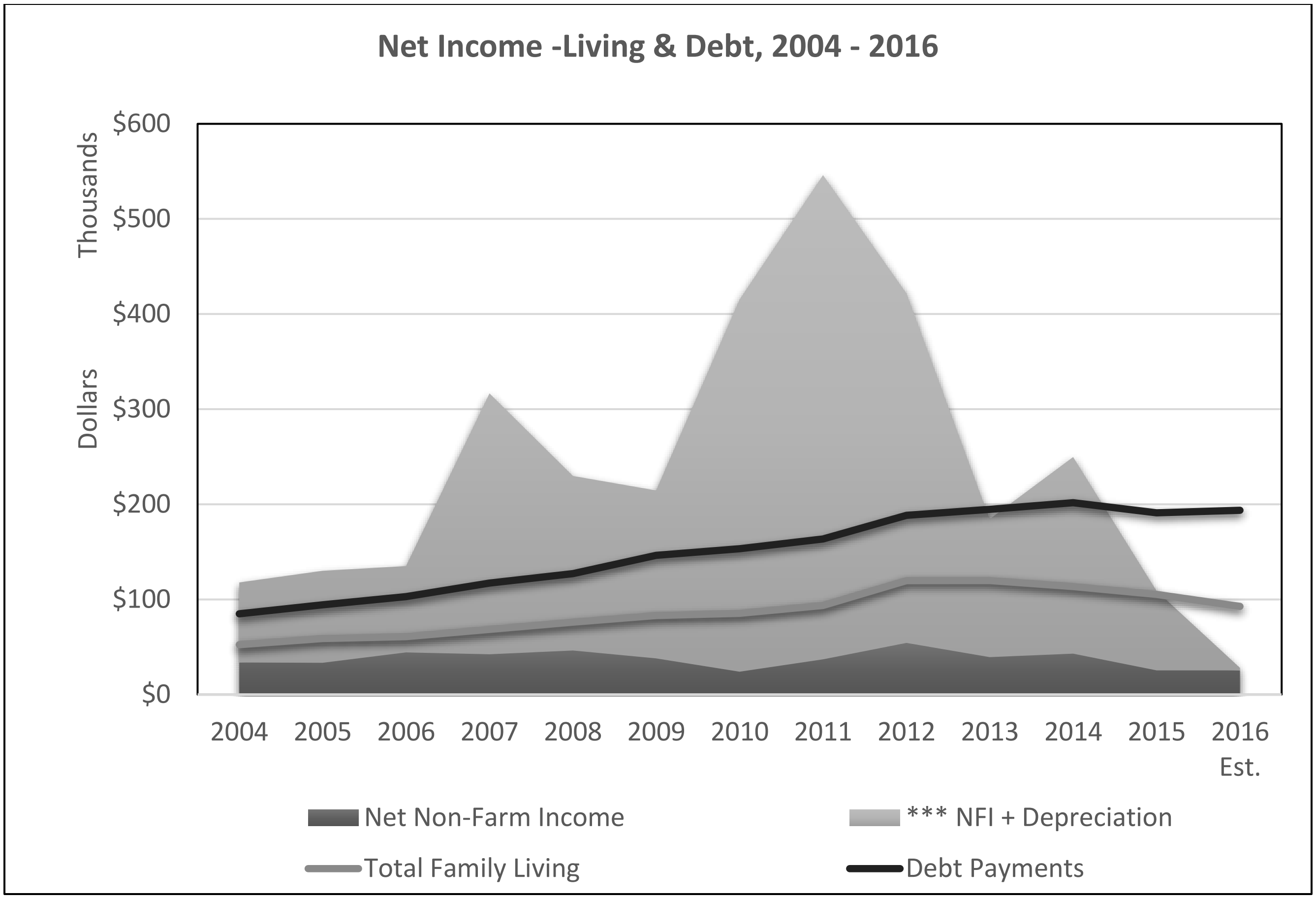
The following are examples of charts and tables that are the basis for my presentation at the 2017 Cover Your Acres conference in Oberlin, KS. I'll begin with a review of the average financial performance of the Kansas Farm Management Association, Northwest membership from 2004 through an estimate of 2016. The value of history can be the benefit of perspective. The 2007 through 2012 analysis years demonstrate income and equity accumulation beyond historic proportions. The recent and projected declines simply return producers to a more typical, longer term income and financial situation. Unfortunately, the excessive income (and equity accumulation) will have to be "worked out" of the system like all business cycles. What can you do in your operation that could enable your operation to fare better than the average or will you simply hold on until better times return? The pressures of limited or negative returns will challenge us to become better, sharper, stronger managers. These questions and more will be discussed in this presentation.

I look forward to visiting with many of you at the Cover Your Acres Conference. Let's keep focused on making sound financial decisions and not let the discouragement distract us. That's what successful people do….




Debt Structure, KFMA, NW
Average: 2004 - 2016
Dollars Thousands
$4,500
$4,000
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
Debt to Asset Ratio
2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 Est.
Avg Non Current Assets
Average Current Assets
Average Term Debt
Average Current Debt
Debt/Asset Ratio


Working Capital (Total Expense), KFMA, NW
Average: 2004 - 2016
Dollars Thousands
$900
$800
$700
$600
$500
$400
$300
$200
$100
$0
140%
120%
100%
80%
60%
40%
20%
0%
PERCENT OF OPERATING EXPENSES
2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 Est.
Working Capital
Total Operating Exp + Int.
Working Cap. / Expense


Net Income -Living & Debt, 2004 - 2016
Dollars Thousands
$600
$500
$400
$300
$200
$100
$0
2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 Est.
Net Non-Farm Income
*** NFI + Depreciation
Total Family Living
Debt Payments

Historic, Estimated and Projected Yields, Price, Revenue, Costs, and Net Returns to Selected Irrigated KFMA, NW Enterprises

Irrigated Corn	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016 est	2017 proj
Yield per Acre	197.5	192.7	189.9	205.9	175.9	192.0	202.0	203.2	190.5	178.8	194.9	213.5	195.0	195.0
$/bushel	$ 2.19	$ 2.08	$ 3.15	$ 3.88	$ 4.21	$ 3.68	$ 4.78	$ 4.77	$ 6.12	$ 7.01	$ 4.70	$ 3.64	$ 3.25	$ 3.75
Gross Revenue/Acre	$ 420.77	$ 453.26	$ 594.50	$ 721.19	$ 653.46	$ 667.88	$ 874.87	$ 878.64	$ 1,104.93	$ 1,197.73	$ 897.75	$ 694.62	$ 570.64	$ 656.43
Variable Cost/Acre	$ 338.44	$ 367.72	$ 380.79	$ 424.35	$ 535.68	$ 475.02	$ 471.11	$ 475.13	$ 578.87	$ 654.93	$ 677.87	$ 575.63	$ 547.58	$ 534.33
Fixed Cost/Acre	$ 88.14	$ 87.65	$ 105.29	$ 137.83	$ 117.76	$ 127.86	$ 155.42	$ 156.50	$ 189.97	$ 217.28	$ 226.12	$ 181.77	$ 174.77	$ 176.80
Net Ret Mgt/Acre	$ (5.81)	$ (2.11)	$ 108.42	$ 159.01	$ 0.02	$ 65.00	$ 248.34	$ 247.01	$ 336.09	$ 325.52	$ (6.24)	$ (62.78)	$ (151.71)	$ (54.70)
Equitable Cash Rent 15%	$ 64.01	$ 59.81	$ 105.99	$ 143.69	$ 111.06	$ 115.73	$ 182.09	$ 182.47	$ 225.25	$ 236.85	$ 136.48	$ 107.27	$ 72.31	$ 101.48
Accumulated NRM/Acre	**$ (5.81)**	**$ (7.92)**	**$ 100.50**	**$ 259.51**	**$ 259.53**	**$ 324.53**	**$ 572.87**	**$ 819.88**	**$ 1,155.97**	**$ 1,481.49**	**$ 1,475.25**	**$ 1,412.47**	**$ 1,260.76**	**$ 1,206.06**

Irrigated Soybeans	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016 est	2017 proj
Yield per Acre	47.8	57.4	50.3	67.3	56.8	61.0	62.8	63.5	55.0	56.1	62.5	62.9	60.0	60.0
$/bushel	$ 5.20	$ 5.33	$ 5.52	$ 9.53	$ 8.75	$ 8.66	$ 10.09	$ 10.92	$ 13.04	$ 12.18	$ 9.29	$ 7.96	$ 8.50	$ 8.75
Gross Revenue/Acre	$ 266.10	$ 320.76	$ 329.07	$ 601.11	$ 472.88	$ 562.41	$ 608.44	$ 667.58	$ 724.19	$ 665.29	$ 531.50	$ 476.10	$ 481.07	$ 494.48
Variable Cost/Acre	$ 217.50	$ 270.36	$ 257.87	$ 269.27	$ 362.29	$ 363.00	$ 346.42	$ 369.13	$ 451.35	$ 453.44	$ 380.82	$ 400.76	$ 423.40	$ 430.07
Fixed Cost/Acre	$ 55.43	$ 66.52	$ 61.04	$ 90.78	$ 88.81	$ 102.79	$ 103.35	$ 130.72	$ 154.04	$ 153.27	$ 148.45	$ 126.20	$ 127.12	$ 124.89
Net Ret Mgt/Acre	$ (6.83)	$ (16.12)	$ 10.16	$ 241.06	$ 21.78	$ 96.62	$ 158.67	$ 167.73	$ 118.80	$ 58.58	$ 2.23	$ (50.86)	$ (69.45)	$ (60.48)
Equitable Cash Rent 15%	$ 36.26	$ 43.47	$ 43.17	$ 132.36	$ 77.82	$ 93.73	$ 118.83	$ 129.16	$ 125.40	$ 111.34	$ 87.43	$ 67.52	$ 66.08	$ 69.68
Accumulated NRM/Acre	**$ (6.83)**	**$ (22.95)**	**$ (12.79)**	**$ 228.27**	**$ 250.05**	**$ 346.67**	**$ 505.34**	**$ 673.07**	**$ 791.87**	**$ 850.45**	**$ 852.68**	**$ 801.82**	**$ 732.37**	**$ 671.89**

Irrigated Wheat	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016 est	2017 proj
Yield per Acre	30.3	46.2	41.3	67.1	59.7	54.0	61.5	58.4	52.7	29.7	51.9	65.1	80.0	60.0
$/bushel	$ 3.08	$ 3.39	$ 4.23	$ 5.92	$ 6.66	$ 5.06	$ 5.52	$ 6.62	$ 7.62	$ 7.27	$ 5.94	$ 5.13	$ 3.00	$ 3.85
Gross Revenue/Acre	$ 143.37	$ 188.10	$ 25.52	$ 390.86	$ 414.62	$ 295.38	$ 348.88	$ 404.55	$ 429.41	$ 275.26	$ 285.95	$ 301.91	$ 215.89	$ 208.05
Variable Cost/Acre	$ 142.15	$ 146.50	$ 157.67	$ 203.30	$ 249.81	$ 243.62	$ 218.75	$ 281.74	$ 323.21	$ 286.65	$ 221.20	$ 307.24	$ 299.10	$ 298.23
Fixed Cost/Acre	$ 50.10	$ 67.16	$ 55.30	$ 90.74	$ 94.93	$ 83.07	$ 86.19	$ 113.85	$ 130.98	$ 106.42	$ 114.73	$ 116.15	$ 111.30	$ 109.20
Net Ret Mgt/Acre	$ (48.88)	$ (25.56)	$ (187.45)	$ 96.82	$ 69.88	$ (31.31)	$ 43.94	$ 8.96	$ (24.78)	$ (117.81)	$ (49.98)	$ (121.48)	$ (194.51)	$ (199.38)
Equitable Cash Rent 15%	$ 14.00	$ 23.49	$ 26.20	$ 59.58	$ 59.60	$ 40.99	$ 50.93	$ 58.01	$ 60.24	$ 32.36	$ 46.26	$ 50.10	$ 36.00	$ 34.65
Accumulated NRM/Acre	**$ (48.88)**	**$ (74.44)**	**$ (261.89)**	**$ (165.07)**	**$ (95.19)**	**$ (126.50)**	**$ (82.56)**	**$ (73.60)**	**$ (98.38)**	**$ (216.19)**	**$ (266.17)**	**$ (387.65)**	**$ (582.16)**	**$ (781.54)**

Equitable Cash Rent by Rotations:														
Corn	$ 64.01	$ 59.81	$ 105.99	$ 143.69	$ 111.06	$ 115.73	$ 182.09	$ 182.47	$ 225.25	$ 236.85	$ 136.48	$ 107.27	$ 72.31	$ 101.48
C-SB	$ 71.79	$ 77.09	$ 83.17	$ 114.31	$ 103.29	$ 115.33	$ 129.39	$ 143.61	$ 172.01	$ 185.28	$ 187.29	$ 153.99	$ 150.94	$ 150.84
W-C-SB	$ 38	$ 42	$ 58	$ 112	$ 83	$ 83	$ 117	$ 123	$ 137	$ 127	$ 90	$ 75	$ 58	$ 69

Historic, Estimated and Projected Yields, Price, Revenue, Costs, and Net Returns to Selected Non-Irrigated KFMA, NW Enterprises

Non-Irrigated Wheat	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016 est	2017 proj
Yield per Acre	7.2	30.8	20.0	50.0	37.6	51.0	53.4	43.7	49.5	19.8	29.2	31.0	70.0	40.0
$/bushel	$ 3.03	$ 3.29	$ 4.22	$ 5.62	$ 6.56	$ 4.64	$ 5.00	$ 6.73	$ 7.38	$ 6.56	$ 5.87	$ 4.41	$ 3.00	$ 3.85
Gross Revenue/Acre	$ 94.90	$ 114.39	$ 114.96	$ 251.17	$ 235.20	$ 220.87	$ 242.24	$ 267.86	$ 325.76	$ 215.91	$ 166.94	$ 154.23	$ 183.63	$ 139.06
Variable Cost/Acre	$ 65.21	$ 84.57	$ 82.10	$ 108.22	$ 135.89	$ 153.23	$ 146.64	$ 156.05	$ 177.96	$ 165.11	$ 130.98	$ 168.48	$ 172.69	$ 170.10
Fixed Cost/Acre	$ 30.12	$ 37.98	$ 66.41	$ 72.25	$ 62.63	$ 66.03	$ 68.97	$ 71.46	$ 88.38	$ 74.92	$ 80.68	$ 81.21	$ 81.92	$ 82.50
Net Ret Mgt/Acre	$ (0.43)	$ (8.16)	$ (33.55)	$ 70.70	$ 36.68	$ 1.61	$ 26.63	$ 40.35	$ 59.42	$ (24.12)	$ (44.72)	$ (95.46)	$ (70.98)	$ (113.54)
Equitable Cash Rent 25%	$ 23.73	$ 28.60	$ 28.74	$ 62.79	$ 58.80	$ 55.22	$ 60.56	$ 66.97	$ 81.44	$ 53.98	$ 41.74	$ 38.56	$ 45.91	$ 34.77
Accumulated NRM/Acre	**$ (0.43)**	**$ (8.59)**	**$ (42.14)**	**$ 28.56**	**$ 65.24**	**$ 66.85**	**$ 93.48**	**$ 133.83**	**$ 193.25**	**$ 169.13**	**$ 124.41**	**$ 28.95**	**$ (42.03)**	**$ (155.57)**
Non-Irr, NT Wheat	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016 est	2017 proj
Yield per Acre	5.5	34.9	14.9	47.0	34.8	53.0	55.8	36.9	44.6	22.4	31.6	41.4	70.0	40.0
$/bushel	$ 2.91	$ 3.17	$ 3.87	$ 5.83	$ 6.50	$ 4.96	$ 5.38	$ 6.66	$ 7.87	$ 6.78	$ 5.97	$ 4.99	$ 3.00	$ 3.85
Gross Revenue/Acre	$ 88.00	$ 113.86	$ 16.30	$ 231.55	$ 232.61	$ 245.05	$ 264.75	$ 241.29	$ 344.16	$ 227.08	$ 184.22	$ 186.65	$ 178.30	$ 133.51
Variable Cost/Acre	$ 63.04	$ 79.89	$ 83.89	$ 109.87	$ 139.54	$ 159.26	$ 143.76	$ 155.78	$ 188.60	$ 196.98	$ 167.19	$ 186.29	$ 192.72	$ 190.32
Fixed Cost/Acre	$ 21.64	$ 40.73	$ 27.19	$ 63.63	$ 56.23	$ 58.18	$ 64.48	$ 64.09	$ 86.60	$ 70.16	$ 67.98	$ 66.55	$ 68.81	$ 63.65
Net Ret Mgt/Acre	$ 3.32	$ (6.76)	$ (94.78)	$ 58.05	$ 36.84	$ 27.61	$ 56.51	$ 21.42	$ 68.96	$ (40.06)	$ (50.95)	$ (66.19)	$ (83.23)	$ (120.46)
Equitable Cash Rent 25%	$ 22.00	$ 28.47	$ 4.08	$ 57.89	$ 58.15	$ 61.26	$ 66.19	$ 60.32	$ 86.04	$ 56.77	$ 46.06	$ 46.66	$ 44.58	$ 33.38
Accumulated NRM/Acre	**$ 3.32**	**$ (3.44)**	**$ (98.22)**	**$ (40.17)**	**$ (3.33)**	**$ 24.28**	**$ 80.79**	**$ 102.21**	**$ 171.17**	**$ 131.11**	**$ 80.16**	**$ 13.97**	**$ (69.26)**	**$ (189.72)**
Non-Irr, NT Corn	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016 est	2017 proj
Yield per Acre	43.7	48.9	28.5	80.2	64.2	112.0	93.8	75.9	15.7	30.2	71.4	89.4	100.0	70.0
$/bushel	$ 2.03	$ 1.93	$ 3.06	$ 3.97	$ 3.99	$ 3.57	$ 4.74	$ 6.18	$ 7.05	$ 4.88	$ 3.93	$ 3.50	$ 2.90	$ 3.50
Gross Revenue/Acre	$ 148.01	$ 138.93	$ 153.69	$ 279.80	$ 281.12	$ 382.54	$ 400.52	$ 451.71	$ 326.19	$ 261.66	$ 276.19	$ 271.84	$ 253.30	$ 215.28
Variable Cost/Acre	$ 104.54	$ 136.24	$ 132.70	$ 152.93	$ 209.30	$ 221.66	$ 208.88	$ 248.71	$ 245.79	$ 229.07	$ 230.68	$ 257.12	$ 258.81	$ 257.28
Fixed Cost/Acre	$ 28.91	$ 37.88	$ 36.11	$ 65.04	$ 55.34	$ 78.82	$ 82.64	$ 90.20	$ 69.17	$ 74.93	$ 82.04	$ 83.88	$ 81.89	$ 77.65
Net Ret Mgt/Acre	$ 14.56	$ (35.19)	$ (15.12)	$ 61.83	$ 16.48	$ 82.06	$ 109.00	$ 112.80	$ 11.23	$ (42.34)	$ (36.53)	$ (69.16)	$ (87.40)	$ (119.65)
Equitable Cash Rent 25%	$ 37.00	$ 34.73	$ 38.42	$ 69.95	$ 70.28	$ 95.64	$ 100.13	$ 112.93	$ 81.55	$ 65.42	$ 69.05	$ 67.96	$ 63.33	$ 53.82
Accumulated NRM/Acre	**$ 14.56**	**$ (20.63)**	**$ (35.75)**	**$ 26.08**	**$ 42.56**	**$ 124.62**	**$ 233.62**	**$ 346.42**	**$ 357.65**	**$ 315.31**	**$ 278.78**	**$ 209.62**	**$ 122.22**	**$ 2.57**
Non-Irr, NT Milo	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016 est	2017 proj
Yield per Acre	32.4	68.0	42.9	92.0	77.2	75.0	89.0	76.7	28.0	30.1	53.6	82.1	110.0	70.0
$/bushel	$ 1.80	$ 1.62	$ 3.18	$ 3.72	$ 3.22	$ 3.13	$ 4.74	$ 5.95	$ 6.73	$ 4.12	$ 3.85	$ 3.10	$ 2.45	$ 3.00
Gross Revenue/Acre	$ 117.32	$ 148.47	$ 155.47	$ 298.52	$ 241.18	$ 224.08	$ 376.30	$ 425.49	$ 291.85	$ 212.76	$ 189.61	$ 217.32	$ 229.80	$ 180.53
Variable Cost/Acre	$ 89.31	$ 122.66	$ 112.70	$ 144.14	$ 166.45	$ 176.68	$ 171.39	$ 201.75	$ 208.51	$ 193.51	$ 196.52	$ 184.99	$ 187.51	$ 186.90
Fixed Cost/Acre	$ 29.36	$ 39.45	$ 30.58	$ 61.07	$ 54.11	$ 58.64	$ 73.89	$ 84.00	$ 68.20	$ 71.31	$ 75.25	$ 75.15	$ 76.36	$ 71.13
Net Ret Mgt/Acre	$ (1.35)	$ (13.64)	$ 12.19	$ 93.31	$ 20.62	$ (11.24)	$ 131.02	$ 139.74	$ 15.14	$ (52.06)	$ (82.16)	$ (42.82)	$ (34.07)	$ (77.50)
Equitable Cash Rent 25%	$ 29.33	$ 37.12	$ 38.87	$ 74.63	$ 60.30	$ 56.02	$ 94.08	$ 106.37	$ 72.96	$ 53.19	$ 47.40	$ 54.33	$ 57.45	$ 45.13
Accumulated NRM/Acre	**$ (1.35)**	**$ (14.99)**	**$ (2.80)**	**$ 90.51**	**$ 111.13**	**$ 99.89**	**$ 230.91**	**$ 370.65**	**$ 385.79**	**$ 333.73**	**$ 251.57**	**$ 208.75**	**$ 174.68**	**$ 97.18**
Non-Irr, NT Soybeans	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016 est	2017 proj
Yield per Acre		22.4	9.4	24.0	32.5	45.0	24.3	24.1	6.2	6.3	13.7	12.7	45.0	25.0
$/bushel		$ 5.15	$ 5.52	$ 10.50	$ 8.37	$ 8.99	$ 10.02	$ 10.85	$ 13.12	$ 12.29	$ 9.15	$ 7.35	$ 8.50	$ 8.75
Gross Revenue/Acre		$ 150.47	$ 99.53	$ 195.10	$ 301.95	$ 399.56	$ 245.94	$ 280.36	$ 220.69	$ 206.91	$ 134.17	$ 122.04	$ 350.75	$ 214.79
Variable Cost/Acre		$ 115.08	$ 106.43	$ 132.52	$ 176.62	$ 196.76	$ 153.41	$ 187.89	$ 197.78	$ 212.05	$ 220.19	$ 207.62	$ 211.59	$ 211.89
Fixed Cost/Acre		$ 43.94	$ 34.00	$ 81.65	$ 80.30	$ 77.93	$ 74.10	$ 86.63	$ 67.11	$ 82.32	$ 89.65	$ 81.74	$ 104.22	$ 92.68
Net Ret Mgt/Acre		$ (8.55)	$ (40.90)	$ (19.07)	$ 45.03	$ 124.87	$ 18.43	$ 5.84	$ (44.20)	$ (87.46)	$ (175.67)	$ (167.32)	$ 34.94	$ (89.78)
Equitable Cash Rent 25%		$ 37.62	$ 24.88	$ 48.78	$ 75.49	$ 99.89	$ 61.49	$ 70.09	$ 55.17	$ 51.73	$ 33.54	$ 30.51	$ 87.69	$ 53.70
Accumulated NRM/Acre		**$ (8.55)**	**$ (49.45)**	**$ (68.52)**	**$ (23.49)**	**$ 101.38**	**$ 119.81**	**$ 125.65**	**$ 81.45**	**$ (6.01)**	**$ (181.68)**	**$ (349.00)**	**$ (314.06)**	**$ (403.84)**
Equitable Cash Rent by Rotations:														
W-NtC-F	$ 20.24	$ 21.11	$ 22.39	$ 44.25	$ 43.03	$ 50.28	$ 53.56	$ 59.96	$ 54.33	$ 39.80	$ 36.93	$ 35.51	$ 36.41	$ 29.53
NtW-NtC-F	$ 19.67	$ 21.07	$ 14.17	$ 42.61	$ 42.81	$ 52.30	$ 55.44	$ 57.75	$ 55.86	$ 40.73	$ 38.37	$ 38.21	$ 35.97	$ 29.07
NtW-NtM-F	$ 17.11	$ 21.86	$ 14.31	$ 44.17	$ 39.48	$ 39.09	$ 53.42	$ 55.57	$ 53.00	$ 36.65	$ 31.15	$ 33.66	$ 34.01	$ 26.17
NtW-NtC (no fallow)	$ 25.63	$ 27.57	$ 18.16	$ 55.78	$ 56.04	$ 68.21	$ 72.34	$ 75.14	$ 73.38	$ 53.35	$ 50.07	$ 49.88	$ 46.97	$ 37.89
NtW-NtC-NtM-NtSB		$ 30.68	$ 23.85	$ 55.81	$ 58.72	$ 69.62	$ 71.60	$ 77.93	$ 65.46	$ 50.39	$ 43.54	$ 44.30	$ 56.38	$ 41.44

Soil Biology: Who and What is Living in Our Soils

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The unique interaction of soil's physical, chemical, and biological properties has led to the diversity of soils found around the world. Any given soil has intrinsic properties (i.e. mineralogy and texture), that are not easily altered and dynamic properties (i.e. pH, N, P, K, S, micro nutrients, organic matter, and the biological community), that are responsive to changes in the environment and our management of the soil. The association of organisms in the soil biological community has a diverse and intricate arrangement that result in processes such as crop residue decomposition and nutrient cycling. The arrangement and interaction of these organisms can be depicted in a food web (Fig. 1) that diagrams the conversion and movement of energy and nutrients as organisms consume their respective food sources (Tugel et al. 2000).

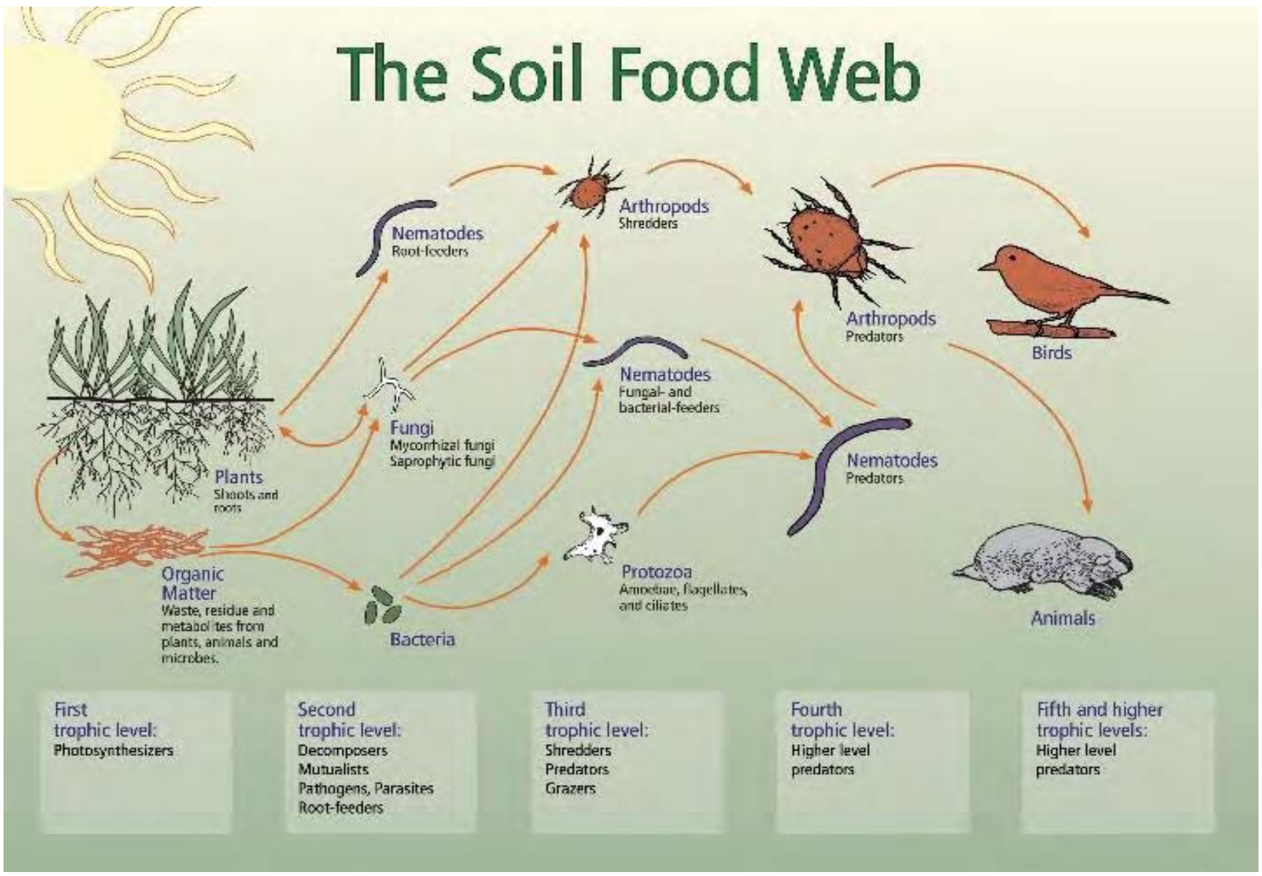

Fig. 1. The soil food web.
Source: https://www.nrcs.usda.gov/Internet/FSE_MEDIA/nrcs142p2_049822.jpg

Soil Biological Community Members:

Bacteria: Bacteria are the smallest of the cellular microorganisms found in soil, are single celled, and have a wider range of metabolic capabilities than the other soil microorganisms. Many of the soil bacteria obtain carbon from organic compounds (heterotrophic organisms) while others obtain carbon from carbon dioxide (autotrophic organisms), and others shift their metabolism in response to environmental triggers. Additionally, within each of these groups are organisms that derive energy from organic, inorganic, or photochemical reactions in aerobic conditions and others that require anaerobic conditions. Bacteria have many difference shapes. The common cell shapes observed in soil bacteria include rod, spherical, twisted or spiral, and slender branching filaments. In addition to the shape, the composition of the cell wall distinguishes different bacteria. Four groupings based on cell wall composition are recognized these include the gram positive (no outer membrane and thick cell wall), gram negative (outer membrane surrounding a thin cell wall), acid-fast (outer membrane containing long-chain fatty acids surrounding a thin cell wall), and mycoplasma (no outer membrane and no cell wall) (Alexander, 2005).

The primary role of soil bacteria in the soil food web is as decomposers (Fig. 1) of organic matter. Bacteria also play critical roles in the transformation of inorganic nutrients such as nitrogen and sulfur. Other bacteria are pathogenic and cause disease in plants or other organisms (Tugel et al. 2000 and Alexander, 2005).

Fungi: Fungi are distinct within the soil biological community because of the extent and the filamentous nature of their structure. The filamentous structures are called hyphae and can extend from a few cells to yards in length releasing a diverse range of enzymes that facilitate decomposition of complex substrates to simple compounds that are subsequently taken up by the hyphae. Fungi can be grouped into three functional groups based on how they obtain energy. Decomposers (saprophitic fungi) breakdown organic materials such as lignin and cellulose into fungal biomass, carbon dioxide, and small molecules like organic acids. Mutualists (mycorrhizal fungi) colonize plant roots increasing the effective surface area of the plant roots to absorb nutrients such as N, P, and micro nutrients; in exchange for carbon in the form of root exudates. Some mycorrhizal fungi have also been found to release P solubilizing compounds. Mycorrhizal fungi are further differentiated based on how the hyphae interact with the plant roots. Ectomycorrhizal fungi colonize the surface layer of the root, while endomycorrhizal fungi grow within the root cells. The third group of fungi are pathogens, or parasites that negatively impact the organism they infect and may cause death. While there are examples for pathogenic fungi that negatively impact agriculture such as *Pithium* and *Rhizoctonia* other fungi in this group are beneficial to agriculture such as nematode trapping fungi (Tugel et al. 2000 and Morton, 2005).

Protozoa: Protozoa are aquatic soil organisms that live within the water filled pores of soil aggregates. They are single-celled and range in size from 1/5000 to 1/50 of an inch (5 to 500 µm) in diameter and are classified into three groups based on shape and motility. The flagellates utilize one or more long wipe-like structures called flagella to move. The flagellates tend to be the smallest and most numerous of the protozoa, feeding primarily on bacteria. The Amoebae move by extending and contracting a temporary foot like structure called a pseudopodia and are further divided based on the presence (testate amoebae) or absence (naked amoebae) of a siliceous or chitin-based shell. The ability of naked amoebae to change shape allows them to explore smaller soil pores than other protozoa. Amoebae like flagellates are bacterial feeders and are common in the soil near roots. Ciliates move by beating short hair-like cilia that cover the cell surface. The largest of the three groups, the ciliates consume protozoa in the other two groups as well as bacteria.

Protozoa are abundant in cultivated land and play an important role in nutrient mineralization. Protozoa have a C:N ratio of 10:1 or higher and thus excrete excess nitrogen as they consume nitrogen rich bacteria (C:N ratio from 3:1 to 10:1). Protozoa release nitrogen in the form of ammonium and can be taken up by bacteria, other soil organisms, and plants. Protozoa number vary widely and are affected by soil fertility, bacterial populations, and soil moisture. Protozoa tend to proliferate in the rhizosphere and can reach numbers in millions per teaspoon (Tugel et al. 2000 and Amador and Görres, 2005).

<u>Nematodes:</u> Nematodes are non-segmented worms with tapered ends ranging in diameter from 1/5000 to 1/250 of an inch (5 to 100 µm) and in length from 1/250 to 1/25 of an inch (100 to 1000 µm) allowing them to move within the existing pore structure of the soil and soil aggregates. Similar to protozoa nematodes are aquatic organisms and inhabit water films and water filled pores thus nematodes are sensitive to changes in the soil microenvironment. Nematodes function at multiple levels in the soil food web (Fig. 1) from feeding on plants (first trophic level) to grazing on bacteria and fungi (second trophic level) and other higher organisms. Free-living Nematodes are categorized into four general groups based on their esophagus, mouthparts, and food source. Bacterial-feeders (Bacteriovores) have a stoma (mouth) and open channel. Predatory nematodes have a large stoma and tooth-like structure and pray on nematodes and protozoa consuming their pray whole or attaching themselves to larger nematodes. Fungal-feeders (Fungivores) have a small tooth –like structure to puncture the fungal hyphae. Omnivores are less specialized eating a variety of organisms. Plant parasitic nematodes (Plant and root-feeders) are not considered free-living although during certain life stages they can be free-living in the soil such as the infectious larval stage.

Nematodes similar to protozoa facilitate nutrient cycling as they require less nitrogen than the bacteria and fungi they consume. Nematode feeding is thought to play an important role in regulating and stimulating the growth of pray ranging from bacteria to plants and even nematodes. Nematodes tend to be found in association with their prey and numbers can range from less than 100 in a teaspoon of agricultural soil to several hundred in a grassland or forest soil (Tugel et al. 2000 and Amador and Görres, 2005).

<u>Earthworms:</u> Earthworm species are generally grouped into three functional categories (epigeic, endogeic, and anecic) based on habitat, feeding, and behavior. Epigeic species live at the interface of plant residue and the mineral soil, do not form permanent burrows, and consuming plant residue. Endogeic species inhabit mineral soil, do not form permanent burrows and consume organic matter associated with the mineral soil. Anecic species form and inhabit permanent burrow structures that extend from the soil surface into the mineral soil

(Fig. 2) and feed on both plant residue and organic matter. The basic physical structure of an earthworm is a tube within a tube. The outer tube is the segmented muscular body wall. A characteristic feature of adult earthworms is the thickened saddle-shaped structure called the clitellum and its location is used in earthworm identification (Fig. 3) and the inner tube is the digestive track. The general organization of the digestive track is mouth, pharynx, esophagus, gizzard, and intestine. Ingested material moves through the digestive track and is mixed and ground in the gizzard before it enters the intestine.

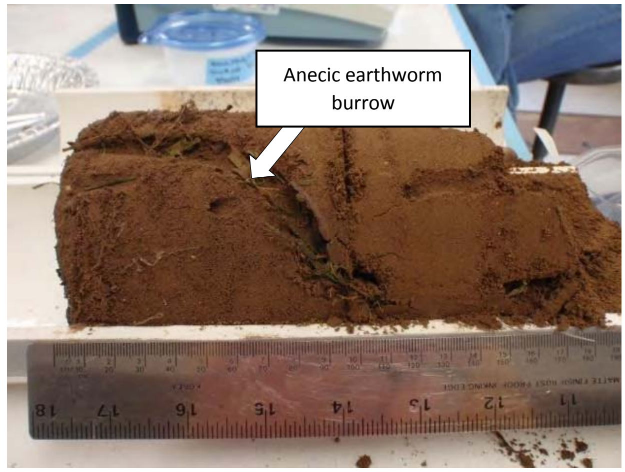

Fig. 2. Anecic earthworm burrow lined with plant residue extending from the soil surface into the mineral soil (Photo by Peter Tomlinson, Kansas State University).

The activity of earthworms accelerates decomposition of plant material and mineralization of soil organic matter increasing the availability of plant available nutrients. A complex relationship exists between earthworms and microorganisms. Microorganism can be transported either through physical attachment or ingestion in one location and subsequent excretion in another location. Fungi and protozoa and to a lesser extent algae are reported to be an important source of nutrition in the earthworm diet. Bacteria are thought to be a minor source of nutrition but have been found to proliferate in the earthworm gut and be excreted in cast material. Thus, enhanced microbial decomposition of organic matter fueled by the presence of nutrient rich secretions begins in the earthworm gut and continues in earthworm casts. Earthworm populations decrease with disturbance such as tillage and harmful chemicals and increase with increasing soil

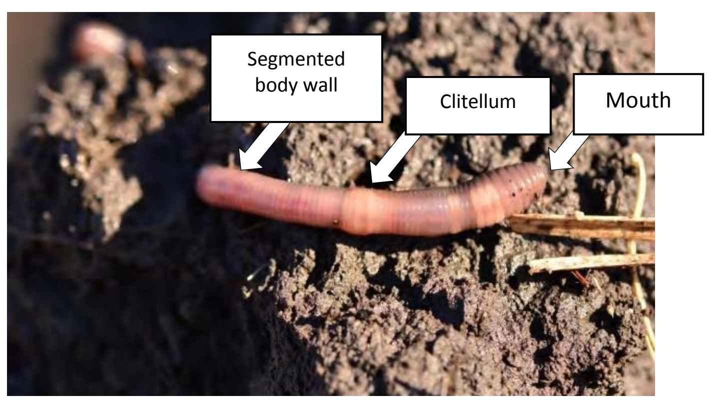

Fig. 3. Adult non-native earthworm in a clump of soil from a no-till field in Northeastern Kansas
(Photo by DeAnn Presley, Kansas State University).

organic matter. Earthworm populations in US cropland can range from 50 to 300 in square yard or more depending on management (Tugel et al. 2000 and Amador and Görres, 2005)

Other Soil Organisms: In addition to earthworms a diverse array of soil fauna exists in the soil ranging from potworms (enchytraeids) to arthropods. Potworms serve a similar function to earthworms but are smaller in size, lighter in color and the soil pore size and structure that they influence are smaller. Arthropods are a diverse group of invertebrate organisms that derives their name from jointed (arthros) legs (podos). Arthropods are grouped by their function in the soil ecosystem. The four broad groupings are shredders, predators, herbivores and fungal-feeders. Arthropods generally carry out beneficial functions in the soil food web but some plant-feeding arthropods are considered parasites (Tugel et al. 2000).

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Chemistry in Premixes.

Resistance Management: Using multiple effective modes of action is a strategy to success.

Herbicide Premixes

Product (Manufacturer)	Ingredients (Tradename, herbicide site of action number)
Accurate Extra (Cheminova)	37.5% thifensulfuron (Harmony, 2), 18.8% tribenuron (Express, 2), and 15% metsulfuron (Ally, 2)
Acuron (Syngenta)	2.14 lb S-metolachlor (Dual II Magnum, 15), 0.24 lb mesotrione (Callisto, 27), 0.06 lb bicyclopyrone (27), and 1.0 lb atrazine (5) per gal
Acuron Flexi (Syngenta)	2.86 lb S-metolachlor (Dual II Magnum, 15), 0.32 lb mesotrione (Callisto, 27), and 0.08 lb bicyclopyrone (27) per gal
Affinity BroadSpec (DuPont)	25% thifensulfuron (Harmony, 2) and 25% tribenuron (Express, 2)
Affinity TankMix (DuPont)	40% thifensulfuron (Harmony, 2) and 10% tribenuron (Express, 2)
Afforia (DuPont)	41% flumioxazin (Valor, 14), 5% thifensulfuron (Harmony, 2), and 5% tribenuron (Express, 2)

Chemistry in Premixes

Searching for program table.

Selecting an herbicide program

Herbicide(s)	Crop tolerance	Annual grasses: Barnyardgrass	Crabgrass	Fall panicum	Foxtail	Johnsongrass seedlings	Longspine sandbur	Shattercane	Witchgrass	Annual broadleaf weeds: Eastern black nightshade	Cocklebur	Devilsclaw	Jimsonweed	Kochia	Lambsquarters	Morningglory	Pigweed + waterhemp	Common ragweed	Sunflower	Velvetleaf	Venice mallow	Perennials: Field bindweed	Established johnsongrass
Preplant Incorporated or Preemergence																							
Resicore	G	E	E	E	E	F	F	F	E	G	G	G	G	G	E	G	E	G-E	E	G-E	—	—	—
SureStart II, Triple-FLEX II, Trisidual	F	E	E	E	E	—	P	P	E	G	G	—	—	G	E	F	E	G	E	F-G	—	—	—
Verdict	G-E	E	E	E	E	P	F-G	P	E	G	G	P-F	G	G	G	G	G	G	G	G	G	—	—
Zemax	E	E	E	E	E	F	F-G	P	E	G	G	G	G	G	G	F	E	G	F	G	G	—	—
Preemergence Only																							
Fierce	G	G-E	E	G-E	E	P	—	P	—	E	—	—	G-E	F	E	F-G	E	G	—	G	G-E	—	—
Prowl, Pendimax, Acumen	G	G-E	G	G	G	G	G	F	G-E	—	—	—	—	F-G	F-G	—	F-G	—	—	P-F	—	—	—
Valor, Rowel, Outflank, Panther, Tuscany	G-E	F	F	F-G	F-G	P	P	P	F	E	F	F-G	G-E	F	G-E	F-G	E	F	P	F	G-E	—	—
Zidua	E	E	E	E	E	F	F-G	F	E	G-E	P	—	G	F-G	G	F	E	F	P	F-G	F	—	—
Postemergence																							
Accent Q, NIC-IT	G-E	G-E	F	G	G-E	E	G	E	—	—	—	—	G	—	—	F	G'	—	—	—	—	—	G
Aim	G-E	—	—	—	—	—	—	—	—	E	F	F	E	F-G	E	E	F-G	F	F	E	G	—	—

Herbicide discussion in guide

Herbicides for Corn

Herbicide* and lb active ingredient needed/acre	Formulated product/acre*	Comments and limitations
BURNDOWN, PREPLANT, AND/OR PREEMERGENCE		
Acetochlor (15) + Clopyralid (4) + Mesotrione (27) 1.6 to 2.1 + 0.107 to 0.142 + 0.169 to 0.225	2.25 to 3.0 qt **Resicore**	Resicore may be used on all field corn, grain, silage, or seed, and yellow popcorn from 28 days before planting prior to emergence. Resicore may be applied early postemergence to all field corn. See postemergence section for further discussion. When organic matter is less than 3% use Resicore at 2.25 qt on coarse soils, 2.5 qt on medium soils, and 2.75 qt on fine soils. When soils are 3% or more organic matter, use Resicore at 2.5 qt on coarse soils, 2.75 on medium soils, and 3 qt on fine soils. When applying Resicore as a split application, both pre and post, see label for restrictions and rates. A maximum of 3.25 qt can be used in the entire season. Weed control with Resicore will be enhanced when applied with atrazine. Rotational restrictions: wheat 4 months, alfalfa, barley, millet, oats rye, sorghum soybean, and sunflower 10.5 months. If applied with atrazine, restrictions to soybean is 18 months. If Resicore is applied after June 1, only corn or grain sorghum can be planted the following year.

* Numbers in parentheses indicate herbicide site of action; see p. 3 for more information. Products often are available in several formulations or brand names, and label information may vary. Refer to the Names, Toxicities, and Persistence table, p. 12.

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Herbicide discussion in guide

Herbicides for Corn

Herbicide* and lb active ingredient needed/acre	Formulated product/acre*	Comments and limitations
POSTEMERGENCE		
Acetochlor (15) + Clopyralid (4) + Mesotrione (27) 0.88 to 2.1 + 0.059 to 0.142 + 0.094 to 0.225	1.25 to 3.0 qt **Resicore**	Resicore may be applied to all field corn, grain, silage, or seed, early postemergence up to 11 inches tall and weeds less than 3 inches. When organic matter is less than 3% use Resicore at 2.25 qt on coarse soils, 2.5 qt on medium soils, and 2.75 qt on fine soils. When soils are 3% or more organic matter, use Resicore at 2.5 qt on coarse soils, 2.75 on medium soils, and 3 qt on fine soils. Include with these rates, NIS 0.25% v/v or COC not to exceed 1% v/v. Do not mix with MSO or adjuvants containing nitrogen. An exception is the 1.25 qt rate of Resicore may be applied postemergence when tank mixed with glyphosate or glufosinate to 1 to 2 inch weeds and corn 11 inches tall or less. In this tankmix, add 0.25% v/v NIS and AMS at 8.5 lb / 100 gallon spray solution. Do not use UAN or MSO. Rotational restrictions: wheat 4 months, alfalfa, barley, millet, oats rye, sorghum soybean, and sunflower 10.5 months. If applied with atrazine, restrictions to soybean is 18 months. If Resicore is applied after June 1, only corn or grain sorghum can be planted the following year.

Herbicide price?

Approximate 2017 Retail Costs of Herbicides, Harvest Aids, and Adjuvants

Realm Q	DuPont	38.8 DF	5.18/oz
Reflex	Syngenta	2	53.35/gal
Reglone/Diquat	Syngenta	2	80.85/gal
Remedy Ultra	Dow AS	4	74.80/gal
Resicore	Dow AS	3.29	70.90/gal
Resolve Q	DuPont	22.4 DF	9.45/oz
Resource	Valent	0.86	242.00/gal
Revulin Q	DuPont	51.2 WDG	5.94/oz
Roundup PowerMax	Monsanto	4.5 ae	22.80/gal

Atrazine issues AGAIN!

- **Complete EPA review, Timeline 3 yrs! Outcomes?**
  - **Cancel registration, very unlikely**
  - **Change labeled rates and total annual rates, likely**
  - **Alter current uses, very possible**
  - **Add additional restrictions, very possible**
  - **For 2017 production, likely no changes!**
- **Off target movement**
  - **Atrazine is safe but finding atrazine in ground and surface water, increases the overall problem!**
  - **Need to be good stewards with atrazine use**

Best Management Practices for Atrazine

KSU publication MF-2182

- **Incorporation reduces losses 67%**
- **Applying atrazine prior to April 15, reduces loss by 50%**
- **Split applications, 2/3 rate in March and remainder after planting, reduces loss by 33%**
- **Use to low atrazine rate PREmixes. Ie "Lite" formulations**
- **Use POST vs PRE applications of atrazine. Lower rates used POST. Can reduce losses by 67%**
- **Reduce PRE atrazine rates to 1 pound or less followed by POST 0.5 lb if needed. Combined applications improve control.**
- **Use other herbicides without atrazine. Can reduce losses by 100%**
- **Vegetative filter strips reduce flow rate and reduce losses by 50%**
- **Buffer zones. Avoid applications near water sources and environmentally sensitive areas.**

What's new for 2017?

- **Enlist Duo????????**
- **Resicore**
- **Acuron Flexi**
- **DiFlexx Duo**
- **Kochiavore for fallow**
  - **also registered in corn & sorghum**
- **Inzen sorghum – Zest WDG**

Herbicide registered for corn and soybean, but cotton pending (anticipate by spring 2017)

Dow AgroSciences

Enlist Duo™ Herbicide

GROUP 4 9 HERBICIDES

Continue to wait for foreign trade approvals for corn and soybean. Will contribute to Palmer amaranth management!

Resicore (Dow AgroSciences) for all Corn

- Acetochlor (15) 2.8 lb/gal + mesotrione (27) 0.30 lb/gal + clopyralid (4) 0.19 lb ae/gal
  - Rates are 2.25 to 3.0 qt/a PRE to field, silage, seed, and popcorn 28 days before planting up to emergence
  - Used at 1.5 to 3.0 qts/acre to field, silage or seed corn early post up to corn 11 inches tall
- Add NIS at 0.25% v/v or COC up to 1% v/v to enhance postemergence activity. Do not use MSO or adjuvants containing nitrogen if corn has emerged. The exception is 1.5 qts of Resicore may be applied postemergence with glyphosate (on glyphosate resistant corn) or glufosinate (on Liberty Link corn) and AMS at 8.5 lb/100 gallon + NIS at 0.25% v/v.

For corn (grain, silage, seed, sweet, and yellow pop), Syngenta

- Bicyclopyrone 0.08 + mesotrione 0.32 + S-metolachlor 2.86 lb/gallon
- Use rate 2.0 qt on soils < 3% OM and 2.25 qt on soils with 3% OM or more with a maximum of 2.25 qt / year.
- Apply from 28 days prior to planting postemergence from emerged to 30 inches tall or up to the 8-leaf stage on field, silage, and seed corn only.
- If applied POST to corn and weeds, used NIS at 0.25% v/v. COC can be used up to 1% v/v but will increase the risk of crop injury. DO NOT use MSO, AMS, or UAN. Do not apply postemergence to sweet or pop corn!

Weed management in corn with PRE herbicides, Ashland Bottoms, Manhattan KS, 2016, 1605corn, Thompson and Peterson

Treatment	Timing	Rate	Herb. Cost	Yield	Palmer	Vele	Mogy
		Prod. / acre	$/a	Bu/a	% control, July 14, 70 DAA		
Acuron*	Pre	2.5 qt	46.50	157	98	100	96
Acuron Flexi	Pre	2 qt	46.40	159	95	98	80
Zemax	Pre	2 qt		151	93	97	71
Resicore	Pre	2.5 qt	44.30	151	98	98	92
Resicore+atrazine	Pre	2.5 + 0.63 qt	46.50	168	94	100	96
SureStart II	Pre	1.25 qt	34.25	146	95	38	69
SureStart II +atrazine	Pre	1.25 +0.63 qt	36.45	148	98	35	76
Degree Xtra*	Pre	3 qts	37.00	138	97	47	82
Corvus	Pre	5.6 fl oz	42.40	140	97	100	56
Corvus+atrazine	Pre	5.6 fl oz + 0.63 qt	44.60	148	96	100	64
Verdict	Pre	15 fl oz	28.40	158	96	81	88
Verdict+atrazine	Pre	15 fl oz + 0.63 qt	30.60	154	97	83	84
Untreated				22	-	-	-
		LSD (0.05)		24	7	16	8

* Contain atrazine   Pre's = Applied May 5

DiFlexx Duo (Bayer Crop) for all Corn and in fallow

- Diglycolamine salt of dicamba 1.86 lb ae/gal + Laudis 0.27 lb/gal+ Safener - This CSA safener has soil and foliar activity
- Use 24 to 49 fl oz/A may be applied preplant, preemergence to field, silage, seed, and pop corn up through V7 stage. With drop nozzles can be applied up to corn at the V10 stage or 36 inch tall.
- At MSO or COC at 1% v/v when applied alone or tankmixed with atrazine.
- AMS or UAN is recommended in the label.
- NOTE the addition of AMS or UAN will increase the risk of dicamba volatility!

Weed management in Irrigated corn with DiFlexx Duo, 2016, 1609cornTR, Thompson and Schlegel. ALL POST!

Treatment	Rate	Herb $/a	Yield	PAAM	KOCZ	VELE	LSSB
	Prod. / acre		Bu/a	% control 7 wks after POST			
DiFlexx Duo (DD) + atra +Destiny HC+AMS	24 fl oz+ 1 pt + 1% v/v + 8.5 lb	$23.90	192	96	100	99	35
DD+atra+Destiny HC+AMS	32 fl oz + 1pt + 1% v/v+8.5 lb	$31.15	195	96	100	99	39
DD+RPM+atra+ Destiny HC+AMS	24+32 fl oz+ 1pt+ 1%v/v + 8.5 lb	$29.60	203	91	98	100	86
DD+Liberty280+atra+ Destiny HC+AMS	24+22 fl oz+ 1pt+ 1%v/v + 8.5 lb	$37.30	198	96	100	100	41
Capreno+RPM+atra+ Superb HC + AMS	3 fl oz + 32 oz +1pt +0.5% + 8.5 lb	$29.90	211	96	99	100	90
Halex GT + atraz + NIS + AMS	3.6 pt + 1 pt + .25% + 8.5 lb	$31.00	208	100	98	100	92
Armezon + atra +Status + NIS + AMS	0.57 oz + 1 pt + 3 oz + .25% + 8.5 lb	$24.15	198	94	90	100	51
Armezon + atra +Status + RPM+ NIS + AMS	0.57 oz + 1 pt + 3 oz + 32 +.25% + 8.5 lb	$29.90	204	95	96	100	96
Armezon + atra + RPM + Outlook + RPM+ NIS + AMS	0.57 oz + 1 pt + 32 + 14oz +.25% + 8.5 lb	$45.65	209	98	97	99	94
LSD 0.05			16	4	3	1	14

Weed management in conventionally tilled irrigated Corn, Tribune KS, 2014 1410cornTR, Thompson and Schlegel.

Treatment	Time	Rate	Herbicide	Yield	KOCZ	PAAM
	App.	Prod. / acre	2017 Cost/A	Bu/a	% control	
Corvus+atrazine	PRE	3 oz + 1 qt	22.70+4.50	114	85	81
Anthem ATZ	PRE	2 pt	28.5	106	84	90
Anthem ATZ/ Solstice+RPM+atra	PRE POST	2 pt 3.15+32+1 pt	28.50/ 16.40+5.70+2.25	142	90	85
Harness Xtra/ Roundup Pmax	PRE POST	3.2 pt 32 oz	26.18/ 5.70	131	91	83
Harness Xtra RPM+Imact+Atra	PRE POST	3.2 pt/ 32+1.0oz+1pt	26.18/ 5.70+25.55+2.25	158	100	92
Harness Xtra Impact+At+Status	PRE POST	3.2 pt/ 1.0+1pt+3 oz	26.18/ 25.55+2.25+12.57	160	100	90
Solstice+RPM+atra	POST	3.15+32+16 oz	16.40+5.70+2.25	99	78	74
Status+RPM	POST	5 oz + 32 oz	20.95+5.70	84	48	59
Halex GT	POST	3.6 pt	28.70	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 corn, Ashland Bottoms, Manhattan KS, 2015, 1506corn, Thompson and Peterson

Treatment	Timing	Rate	Herbicide Cost	Yield	Palmer	Vele	Mogy
		Prod. / acre	2017 $/a	Bu/a	% control, June 22		
SureStart II + Atazine	PRE	2.5 pt + 1 qt	34.25+4.50	151	97	93	83
SureStartII+atrazine Durango+AMS	Pre fb Post	2.5 pt+ 1 qt 1 qt	34.25+4.50 4.95	163	100	98	89
SureStartII+atrazine+ Durango	EPost	2pt+1+1q+8.5	27.40+4.50+ 4.95	148	98	95	88
Resicore+atra Durango+AMS	Pre fb Post	2.5qt+1 qt 1 qt + 8.5 lb	44.30+4.50	153	100	97	92
Resicore+atra Res+atra+Dur+AMS	Pre fb Post	1.5qt+1 qt 1.5+.5+1+8.5	26.60+4.50 26.60+2.25+4.95	159	100	100	95
Corvus+atra RPM+atr+Diflexx+Adj	PRE fb Post	3.3 oz + 1 qt 22oz+1+8oz	25+4.50 5.70+4.50+16.25	142	100	97	88
HalexGT+Atra+ Diflexx + NIS+AMS	Epost	3.6+1 qt + 8oz+.25+8.5 lb	28.70+4.50+ 16.25	165	99	95	91
Untreated		0 LSD (0.05)	0	114 26	- 3	- 12	- 8

Pre's = Apr 22, Epost = May 12 at V2, Post= June 6 at V7

Weed management in Liberty Link Corn, Manhattan KS, 2016 1606corn, Thompson and Peterson.

Treatment	Time	Rate	Yield	Palmer	VELE	MOGY	SUNF
	App.	Prod. / acre	Bu/a	% control 6 wks after POST			
Balance Flexx+Atra	PRE	3 fl oz + 1 pt	130	85	100	87	23
Balance Flexx+Atra Liberty 280+AMS	PRE POST	3 fl oz + 1 pt 22 fl oz + 8.5 lb	164	95	100	93	100
Balance Flexx+Atra Liberty 280+AMS	PRE POST	3 fl oz + 1 pt 29 fl oz + 8.5 lb	163	92	100	83	100
Balance Flexx+Atra Liberty 280+atra+AMS	PRE POST	3 fl oz + 1 pt 22 oz + 1 pt+8.5	154	97	100	95	100
Balance Flexx+Atra Liberty 280+atra+AMS	PRE POST	3 fl oz + 1 pt 29 oz+ 1pt + 8.5	150	96	100	94	100
Balance Flexx+Atra Lib+atra+Diflexx+AMS	PRE POST	3 fl oz + 1 pt 22+1pt+10oz+8.5	150	100	100	93	100
Balance Flexx+Atra Lib+atra+Diflexx+AMS	PRE POST	3 fl oz + 1 pt 29+1pt+10oz+8.5	161	100	100	91	100
Balance Flexx+Atra Lib+atra+Laudis+AMS	PRE POST	3 fl oz + 1 pt 22oz+1pt+3oz+8.5	163	100	100	86	100
Balance Flexx+Atra Lib+atra+Capreno+AM	PRE POST	3 fl oz + 1 pt 22oz+1pt+3oz+8.5	153	98	100	93	100
Untreated/LSD 0.05		LSD 0.05	22/46	3	1	7	1

Balance Flexx+atrazine = $17, Liberty 280 at 22 fl oz = $13.40, DiFlexx, Laudis, Capreno $/oz = 2.03, 6.08, 7.32

Weed management in corn, Ashland Bottoms, Manhattan KS, 2015, 1506corn, Thompson and Peterson

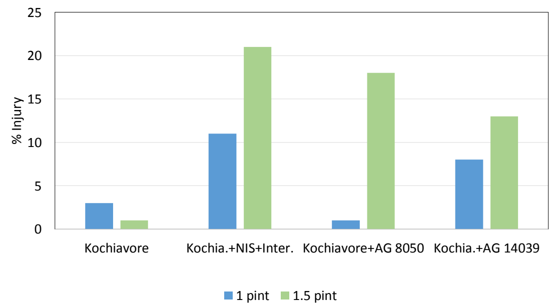
Treatment	Timing	Rate	Herb Cost	Yield	Palmer	Vele	Mogy
		Prod. / acre	$/a	Bu/a	% control, June 22		
Acuron	Pre	2.5 qt	46.50	161	100	97	88
Acuron+atrazine	Pre	2.5 + 1 qt	46.50+4.50	164	99	98	84
Acuron HalexGT+NIS+AMS	Pre fb Post	1.25 qt fb 3.6p+.25+2.5	23.25 28.70	173	100	99	97
Acuron Acuron+NIS+AMS	Pre fb Post	1.25 qt 1.25+.25+ 8.5	23.25 23.25	150	99	100	95
Acuron Callisto GT+AMS	Pre fb Post	1.25 qt 2 pt + 8.5 lb	23.25 23.40	164	100	100	89
Degree Xtra	PRE	3 qts	37	155	100	40	85
Harness Xtra 5.6L Impact+At+MSO+AMS	Pre fb Post	3.2 pt .75oz+.5+.5+8.5	37 19.15+2.25	151	100	97	92
Untreated				114	-	-	-
		LSD (0.05)		26	3	12	8

Pre's = Apr 22, Epost = May 12 at V2, Post= June 6 at V7

Kochiavore, Winfield Solutions

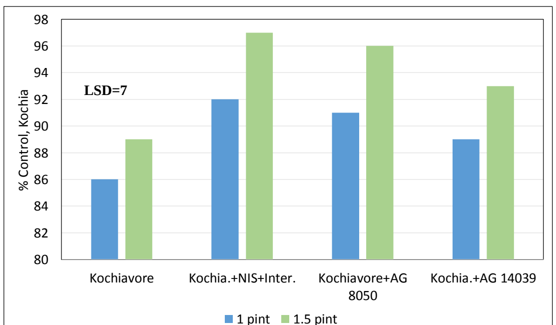
- 2,4-D LV 1.67 ae lb, bromoxynil 1.67 lb, & Fluroxypyr 0.67 ae lb/gallon
- Broadleaf weed control including kochia.
- Use 1 to 1.5 pints in corn Preplant, minimum of 7 days ahead of planting, or post plant preemergence to notill planted corn, or postemergence, v3 to v5. Postemergence to grain and forage sorghum v4 to the pre-boot stage. Kochiavore will cause crop injury. Can be applied up to 2.5 pints on fallow. Maximum is 3 pints/a for growing season.
- Do not feed or graze corn for 47 days following application or harvest grain for 90 days of application. Do not harvest grain within 70 days of application or allow meat or dairy animals to consume fodder, forage, or graze for 45 days following application to sorghum. Do not allow livestock to grazed fallow that has been treated with Kochiavore.

Crop injury 4 weeks after post applications, Tribune KS. Thompson, Schlegel, and Peterson. 1613cornTR.



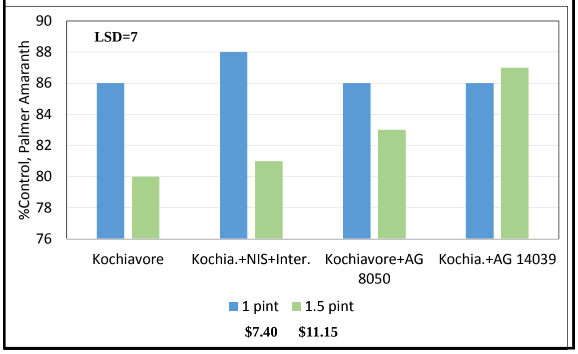
$7.40 $11.15

Kochia control 4 weeks after post applications, Tribune KS. Thompson, Schlegel, and Peterson. 1613cornTR.

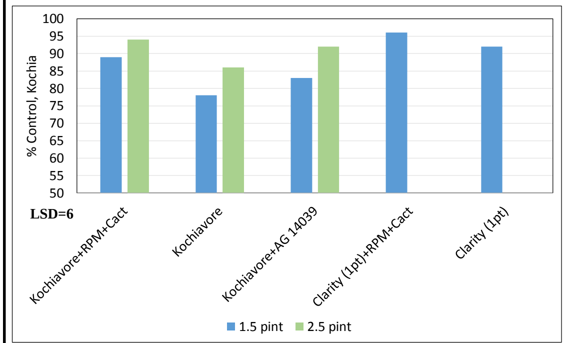


$7.40 $11.15

Palmer amaranth control 4 weeks after post applications, Tribune KS. Thompson, Schlegel, and Peterson. 1613cornTR.

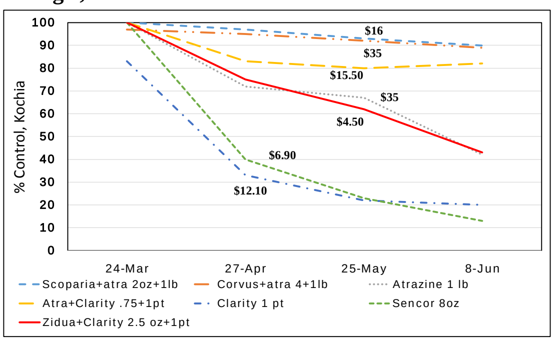


Kochia control in fallow 5 weeks after post applications, Tribune KS. Thompson, Schlegel, and Peterson. 1515koczTR.

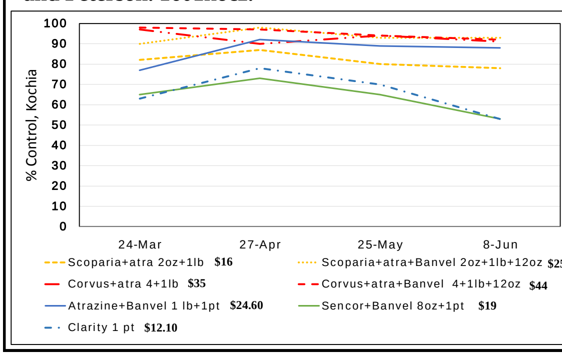


Application was made to 2 to 6" kochia on May 6, 2016.

Kochia control with Dec 20th applied herbicide treatments. Tribune, KS 2015-16. Thompson, Schlegel, and Peterson. 1601kocz.



Kochia control with Feb 15th applied herbicide treatments. Tribune KS 2016. Thompson, Schlegel, and Peterson. 1601kocz.



Inzen Z sorghum development

- ALS resistant sorghum lines were developed at KSU
- ALS resistant shattercane from SW Kansas was crossed with grain sorghum lines (Tuinstra and Al-Khatib)
- Several ALS resistant lines were distributed by K-State to all sorghum breeding programs
- Currently Pioneer and Advanta have agreements signed with DuPont (Owner of this new technology) and will produce & market hybrid Inzen Z sorghum

Zest WDG (DuPont) for Inzen sorghum

- Nicosulfuron 75% WDG, 0.67 to 1.33 oz prod./a
- 0.25 to 0.5% v/v NIS or 1% v/v COC
- 2 qt/a UAN or 2 lb/a AMS
- Apply to sorghum 5 collar to flagleaf visible, 4 to 20 inch sorghum.
- Annual grass control varies with species and size of the grass at application.
- Start with an effective PRE applied herbicides.
  - Zest should be the second part of a two pass system.

Maximum grass species height

WEEDS CONTROLLED IN INZEN™ GRAIN SORGHUM

Weeds controlled with 0.67ounces (0.032 pounds of nicosulfuron active ingredient) ZEST™ WDG herbicide.

Grasses	Maximum Height or Diameter
Barnyardgrass†	4"
Broadleaf signalgrass	2"
Crabgrass (large)*	2"
Foxtails (bristly, giant†, green†, yellow†)	4"
Itchgrass	6"
Panicum (Texas, browntop)	3"
fall	4"
Ryegrass (Italian, perennial) †	6"
Sandbur (field, longspine)*	3"
Wild oats†	4"
Wild proso millet	4"
Witchgrass	6"

† Naturally occurring resistant biotypes are known to occur. If weed escapes occur, treat with an herbicide having a mode of action other than Group 2 and/or use non-chemical methods to remove escapes, as practicable, with the goal of preventing further seed production.

* Refer to Specific Weed Instructions Section of this Label

Zest WDG Restrictions

- Can be tankmixed with 2,4-D LV, dicamba, atrazine, Starane Ultra, and Ally XP, 1/20 oz.
- DO NOT USE COC when tankmixing 2,4-D or dicamba.
- DO NOT tankmix with Huskie herbicide as significant grass antagonism may result.
- Rotation back to sorghum is 18 months
  - NOT CONTINUOUS SORGHUM!

Zest WDG Rotation Restrictions

The following rotational intervals should be observed when using ZEST™ WDG at a maximum of 1.33 ounces:

ZEST™ WDG ROTATIONAL CROP GUIDELINE - 1

No soil pH restrictions

Rotational Crop	Interval in Months
Corn (field, seed)	Anytime
Corn (pop, sweet)*	10
Soybeans	0.5 (15 days)
Cereals, spring (barley, oats, rye, wheat)	8
Cereals, winter (barley, oats, rye, wheat)	4
Cotton	10
Dry Beans, Peas, Snap Beans	10
Alfalfa**	12
Red Clover**	12
Sorghum (All types including hybrids containing the INZEN™ trait)	18
Other Crops	See Rotational Crop Guidelines 2 and 3

* Except the sweet corn varieties "Merit", "Carnival", and "Sweet Success", for which the minimum time interval is 15 months.

**Except for the state of Kansas east of Highway 75, for Minnesota east and south of the Red River Valley and for the states east of the line formed by the western borders of Iowa, Missouri, Arkansas, and Louisiana, where the minimum time interval is 10 months.

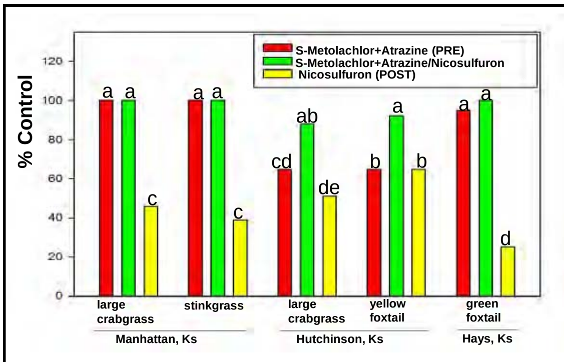
ZEST™ WDG ROTATIONAL CROP GUIDELINE - 2

With soil pH ≤7.5 restrictions

	Rotational Interval in Months	
Crop	pH 7.5	pH > 7.5
Sunflowers	11**	18
All other crops not listed in Rotational Guidelines 1 or 2	See Rotational Guideline 3	

* Except in Texas and Oklahoma east of Highway 281, where the rotational interval is 10 months, regardless of pH.

**Precipitation following application must exceed 14" prior to planting sunflowers.



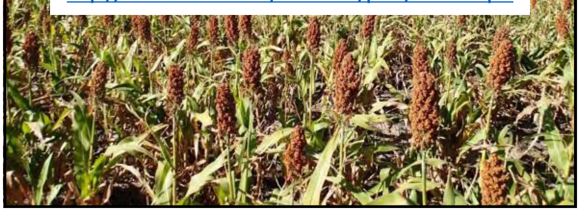
Annual grass control with 3 herbicide programs at 3 locations, Vanloenen etal 2015.

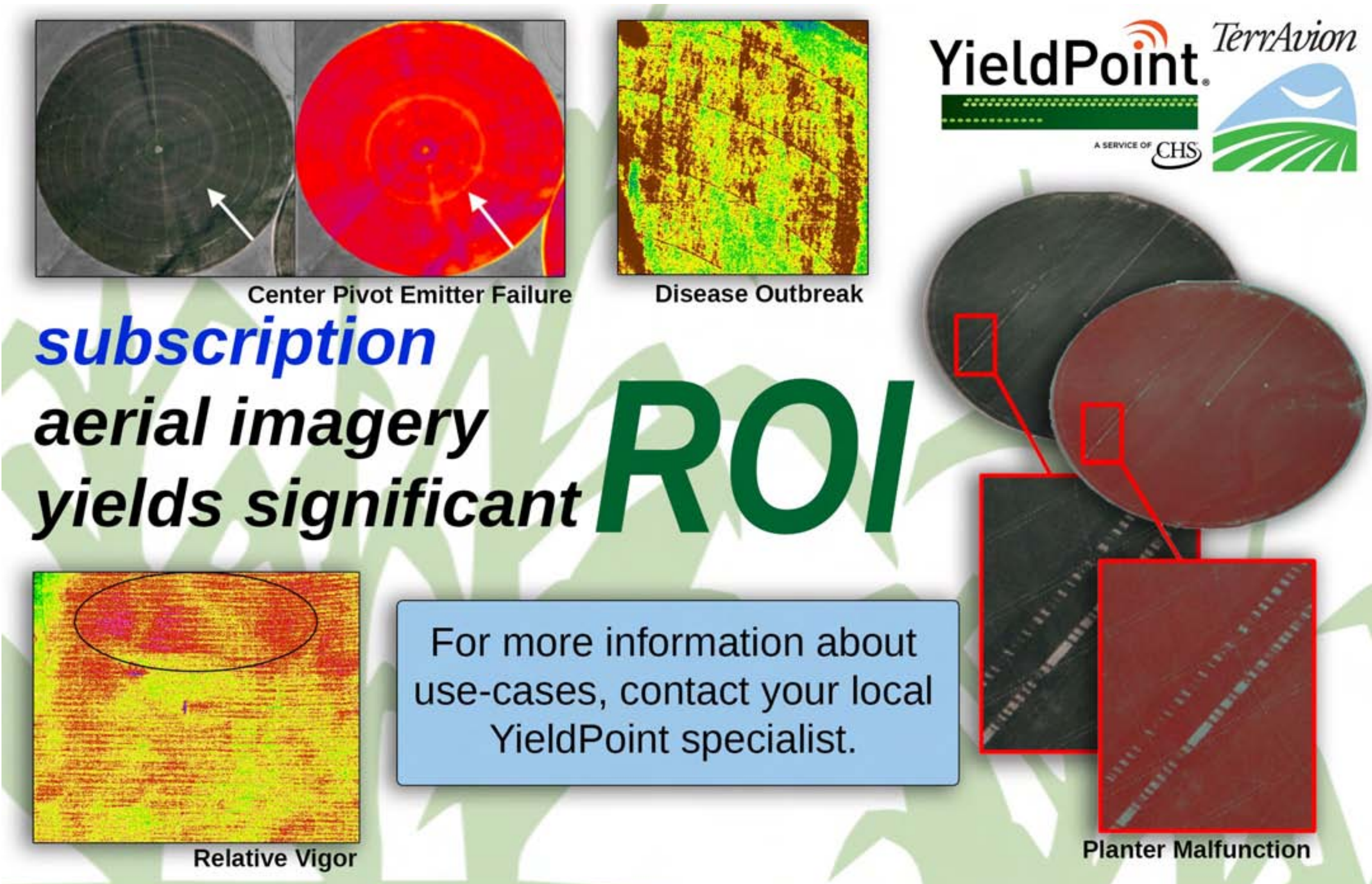
Yield potential of test cross hybrids resistant to ALS inhibitor herbicides as compared to commercial checks, 2015. Tesfaye Tesso and his group, Agronomy Department, K-State.

Entry	bu/acre	Yield as % of the top check
PR14/15-119 × PR14/15-199	132	101
PR14/15-143 × PR14/15-241	122	93
PR14/15-103 × PR14/15-175	134	103
PR14/15-149 × PR14/15-190	128	98
PR14/15-105 × PR14/15-181	134	103
PR14/15-119 × PR14/15-199	131	100
PR14/15-121 × PR14/15-190	122	93
PR14/15-121 × PR14/15-197	126	97
PR14/15-157 × PR14/15-217	119	91
Pioneer 84G62	130	-
Dekalb 54 00	129	-

Questions?

Curtis Robert Thompson
Extension Weed Specialist
K-State Agronomy, @KStateAgron
Cell (785) 532-3444 Office (785) 477-4639
http://www.ksre.ksu.edu/bookstore/pubs/SRP1132.pdf

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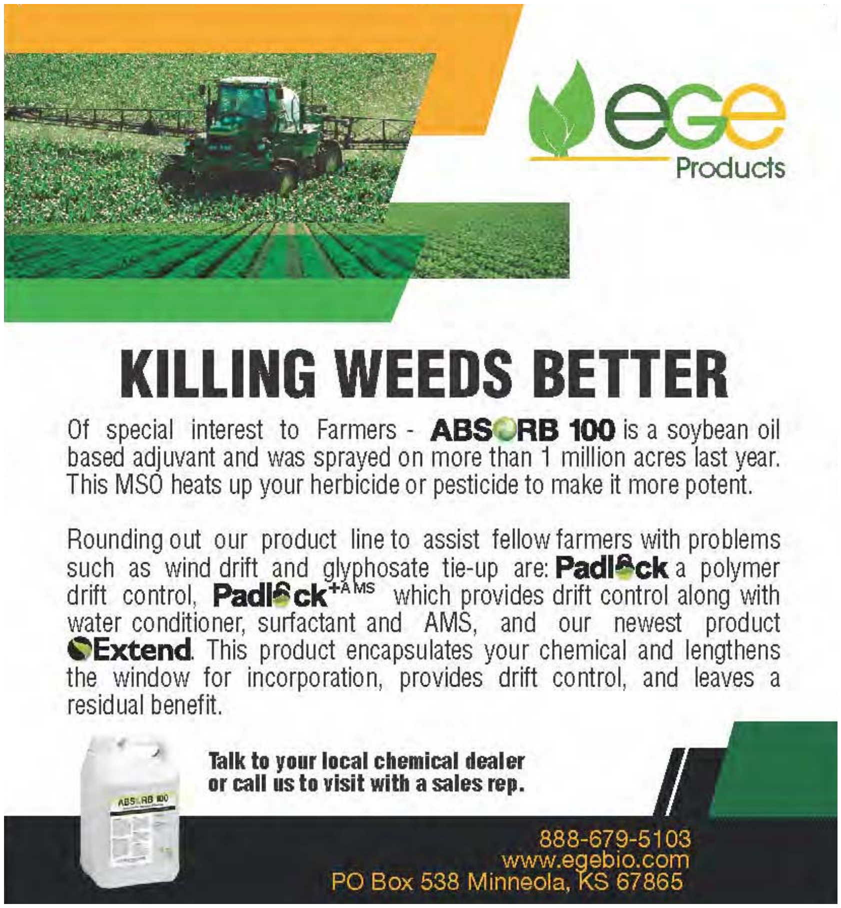
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K-State Mobile Irrigation Lab	www.mobileirrigationlab.com
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Herbicide Labels:

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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	Profitability in NWKS Operations[1] *(M. Wood)*	Current State of Weed Resistance[1,2] *(P. Stahlman)*	Forage Sorghum and Cover Crops[1] *(J. Holman)*	*Sunflower Update (Natl. Sunflower Assoc.) (I)*
9:30	10:20	Marketing Grain and Storage Economics[1] *(D. O'Brien)*	Managing Bin Stored Grain[1] *(K. Moore)*	Learning from Long-Term Tillage/Rotation Studies[1] *(A. Schlegel & L. Haag)*	*Rootworm Beetle and Sugarcane Aphid Management (Dupont Pioneer) (I)*
10:20	10:50	*View Exhibits*			
10:50	11:40	Weed Management Strategies[1,2] *(C. Thompson)*	Soil Biology: Who and What is Living In Our Soil *(P. Tomlinson)*[1]	Building Strong Business Dynamics in Tough Times[1] *(C. Griffin)*	*Plant Nutrition (CPS) (I)*
11:50	12:40	Economics of Soil Fertility[1] *(D. Ruiz-Diaz)*	Forage Sorghum Cover Crops[1] *(J. Holman)*	*Lunch*	
12:50	1:40	Current State of Weed Resistance[1,2] *(P. Stahlman)*	Marketing Grain and Storage Economics[1] *(D. O'Brien)*	*Lunch*	
1:50	2:40	Learning from Long-Term Tillage/Rotation Studies[1] *(A. Schlegel & L. Haag)*	Weed Management Strategies[1,2] *(C. Thompson)*	Economics of Soil Fertility[1] *(D. Ruiz-Diaz)*	*High Resolution Imagery (CHS) (I)*
2:40	3:10	*View Exhibits*			
3:10	4:00	Producer Discussion Panel On-Farm Grain Storage	Building Strong Business Dynamics in Tough Times[1] *(C. Griffin)*	Soil Biology: Who and What is Living in Our Soil *(P. Tomlinson)*[1]	*Improve Your Bottom Line (Sims Fertilizer) (I)*
4:10	5:00	Managing Bin Stored Grain[1] *(K. Moore)*	Profitability in NWKS Operations[1] *(M. Wood)*	*A Radical New Vision for Dryland Agriculture (Green Cover Seed) (I)*	*The Importance of Adjuvants (EGE Products) (I)*

(I) indicate industry sessions.

[1] Indicate Certified Crop Advisor CEUs applied for.

[2] Indicate Commercial Applicator CEUs applied for.

This conference is organized by a committee of producers and K-State Research & Extension personnel. Lucas Haag, K-State Northwest Area Agronomist is the conference coordinator and proceedings editor. Please send your feedback to lhaag@ksu.edu

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