



K-STATE
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Extension Agronomy

eUpdate

11/13/2025

These e-Updates are a regular weekly item from K-State Extension Agronomy and Kathy Gehl, Agronomy eUpdate Editor. All of the Research and Extension faculty in Agronomy will be involved as sources from time to time. If you have any questions or suggestions for topics you'd like to have us address in this weekly update, contact Kathy Gehl, 785-532-3354 kgehl@ksu.edu, or Dalas Peterson, Extension Agronomy State Leader and Weed Management Specialist 785-532-0405 dpeterso@ksu.edu.

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1. Fifty Years of Herbicide Resistance in Kansas

This year marks the 50th anniversary of the first documented case of herbicide resistance in Kansas. In this article, we'll look back on where we have been, where we are now, and what needs to be done in the future to combat this problem.

Understanding herbicide resistance

Herbicide resistance is defined as the ability of a weed population to survive an herbicide application that would normally kill that particular weed species. By contrast, herbicide tolerance is the natural ability of a weed species to grow and reproduce after treatment with a particular herbicide; that is, the weed was never very susceptible to that herbicide to begin with. The development of herbicide resistance is a process of selecting for naturally occurring genetic variation(s) that allow a plant to survive the herbicide application. Resistance can be broken down into two categories:

1. **Target Site Resistance (TSR).** With TSR, a mutation in the resistant weed causes a change in the enzyme that the herbicide acts upon (the target site). Often, this is the result of a change in just one gene. In many cases, the change prevents the herbicide from binding at the site of action, but in some cases, it can be the result of an increase in the amount of enzymes present in the plant.
2. **Non-Target Site Resistance (NTSR).** NTSR typically involves multiple genes, making it more challenging to control these weeds. In NTSR, the affected genes alter the herbicides' *translocation* (the herbicide is not moved to the target site), *sequestration* (the herbicide is stored away from the target site), or *metabolism* (the herbicide is changed into nontoxic compounds prior to reaching the target site). Changes in metabolism, or metabolic resistance, are more common than other kinds of NTSR and are especially troubling. Metabolic resistance was discussed in [a previous article](#).

First resistant weed in Kansas: Kochia

In 1976, kochia populations from railroad rights-of-way in Kansas were identified that were resistant to the Group 5 herbicide atrazine (Tables 1 and 2). The extensive use of atrazine likely led to this development. Resistance spread due to the tumbling nature of the weed and the extensive use of triazine herbicides in corn and sorghum fields. Today, triazine-resistant kochia is found throughout the entire state.

It took 11 years before another resistance case was confirmed, also in kochia (Figure 1). In 1987, a kochia population from Seward County was identified with resistance to the Group 2 (ALS-inhibiting) herbicide chlorsulfuron. Many Group 2 herbicides were being discovered and marketed during the 1980s, and were used extensively, especially in wheat and soybean fields. Since that time, kochia has developed resistance to two other commonly used herbicide groups in Kansas, including the synthetic auxin herbicides dicamba and fluroxypyr (Group 4) and glyphosate (Group 9).

Table 1. Herbicide groups with confirmed resistance in Kansas.

Herbicide group	Site of action
2	ALS Inhibitors
4	Synthetic Auxin

5	Photosystem II I
9	EPSP Synthase I
10	Glutamine Synt Inhibitors
14	PPO Inhibitors
27	HPPD Inhibitors

Table 2. Weed species with herbicide resistance in Kansas as of 2025, and the year first identified.

Weed species	Herbicide groups						
	Group 2	Group 4	Group 5	Group 9	Group 10	Group 14	Group 27
Bushy wallflower	2005						
Cheat	2007						
Common cocklebur	1997						
Common ragweed				2007			
Common sunflower	1996						
Flixweed	2006						
Giant ragweed				2006			
Henbit	2014						
Horseweed/ Marestail	2011			2005			
Japanese brome	2007						
Kochia	1987	2013	1976	2007			
Palmer amaranth	1993	2015	1995			2021	2009
Redroot pigweed			1995				
Shattercane	1996						
Waterhemp	1995		1995	2006	2024	2001	
Wild buckwheat	2020						

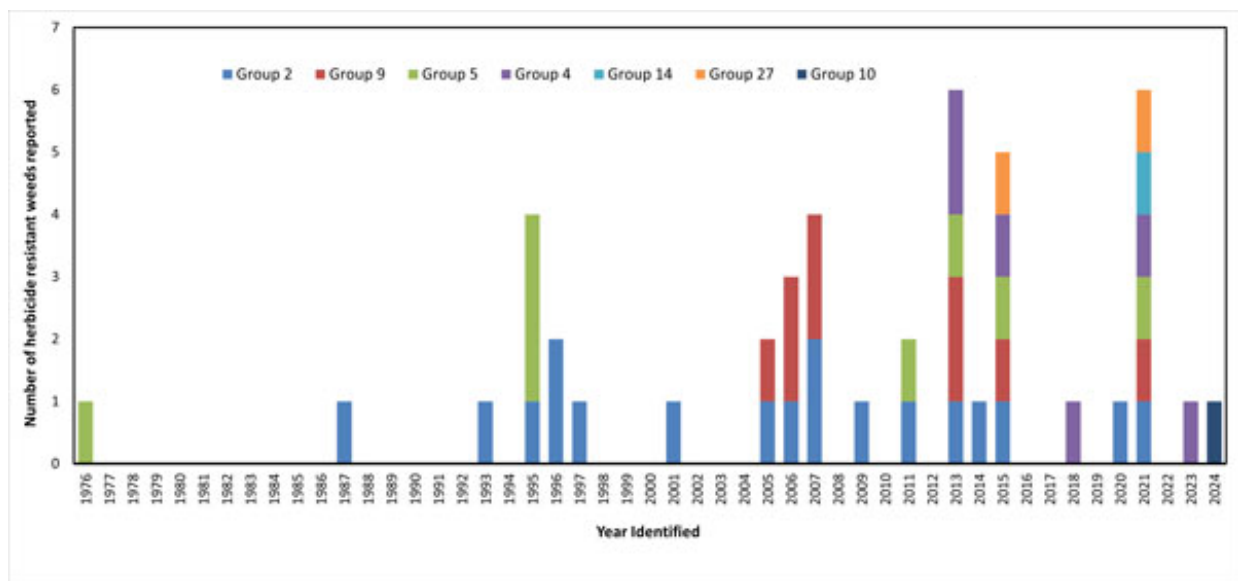


Figure 1. Number of herbicide-resistant weeds confirmed by year over the past 50 years. The different colors represent resistance to a specific herbicide group. Graph created by Yasir Parrey, Kansas State Univ.

Pigweeds: Palmer amaranth and waterhemp

The next weed to develop herbicide resistance chronologically is perhaps the worst so far. In 1993, several Palmer amaranth populations were identified that were not controlled by imazethapyr. Imazethapyr is a Group 2 herbicide commonly used in soybean, alfalfa, and (at that time) herbicide-tolerant corn.

Palmer amaranth is a large, competitive weed in which each plant is either male or female (dioecious). When seeds are formed, pollen (and genes) are transferred from one plant to another. This mixing of genetic material has led to the increased spread of herbicide-resistant plants across the state. Palmer amaranth has also been shown to develop both TSR and NTSR, discussed earlier. The presence of NTSR has been linked to cross-resistance between different herbicide groups. Because of this, a plant that has resistance to one group (for example, Group 2) may also be resistant to other groups (such as Group 4) even without herbicide applications that would select for resistance to Group 4 herbicides. As a result, switching to a different herbicide class may not be sufficient to control these populations.

In 2021, a [Palmer amaranth population](#) was identified that was resistant to six of the herbicide groups listed in Table 1. Palmer amaranth is the only species in Kansas to have developed resistance to the HPPD-inhibiting herbicides mesotrione (Callisto) and isoxaflutole (Balance) (Group 27). Furthermore, Palmer amaranth with resistance to S-metolachlor (a Group 15 herbicide), has been documented as close as Arkansas and may well spread to Kansas in the near future if it hasn't already. More recently, a Palmer amaranth population was found resistant to dicamba (a Group 4 herbicide), representing the first confirmed case for dicamba in this species.

Waterhemp, a pigweed species closely related to Palmer amaranth, is the only other species with

resistance to more than two herbicide families (Table 2). In 1995, a Kansas population of waterhemp was not controlled by imazethapyr and thifensulfuron (both Group 2), while a separate population showed resistance to atrazine (Group 5). In 2006, glyphosate-resistant waterhemp was identified in Kansas. Like Palmer amaranth, waterhemp is dioecious, and resistance can spread rapidly. Waterhemp and Palmer amaranth are currently the only species in Kansas with resistance to the PPO inhibitors (Group 14). Currently, waterhemp is most commonly found east of the Flint Hills.

Other resistant weeds

In total, 16 species have been confirmed to have herbicide resistance in Kansas (Table 2). Of those, 13 are broadleaf species and three are grasses. All are annual species, though bushy wallflower, cheat, flixweed, henbit, horseweed (maretail), Japanese brome, and wild buckwheat often emerge in the fall and overwinter to cause problems in the next growing season. The greatest number of resistant species (13) have been confirmed for Group 2 herbicides, followed by Group 9 (glyphosate) with six (Figure 2). The peak years for the identification of new resistance cases were 2013 and 2021, with 6 cases each; however, only two new cases have been documented since 2021.

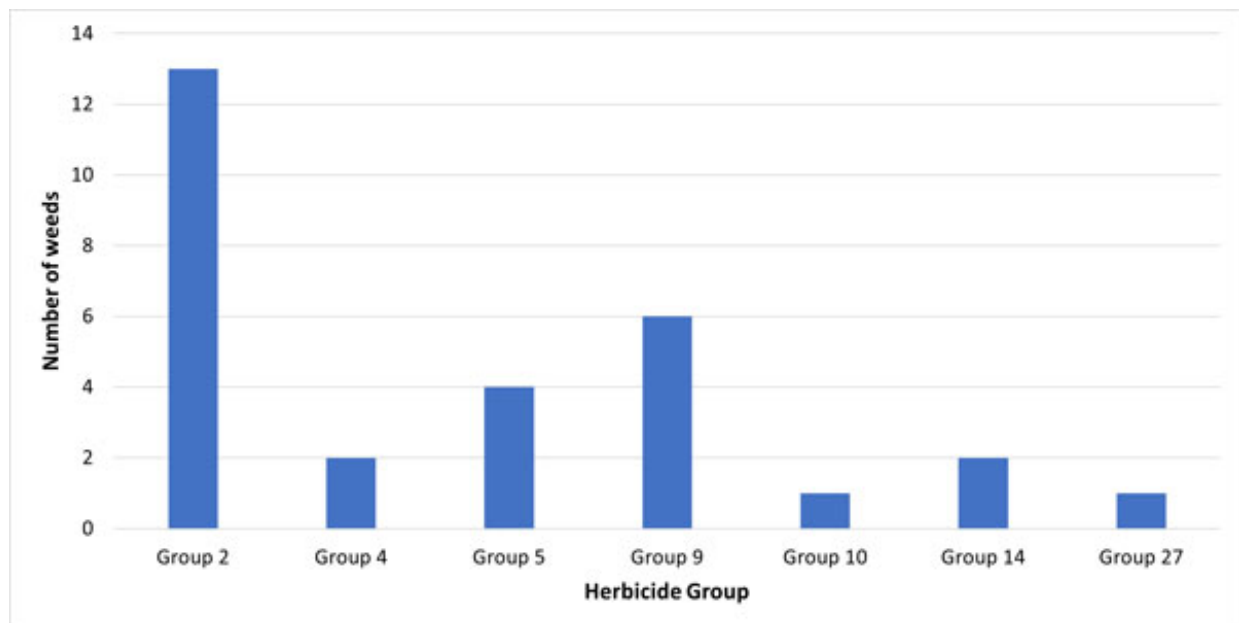


Figure 2. The number of herbicide-resistant weed species in Kansas by herbicide group. Graph created by Patrick Geier, Kansas State Univ.

Take Home Message

Herbicide resistance in Kansas has evolved over five decades, from a single case in kochia to multiple weed species resistant to several herbicide groups. Resistance is a naturally occurring phenomenon, but its spread is accelerated by repeated use of similar herbicides and limited diversity in control practices. The most effective way to manage resistant weeds and prevent new cases is to diversify control tactics through **integrated weed management**. Stay tuned for a second article that discusses integrated weed management practices and how to identify herbicide resistance in the

field.

Reference

Heap, I. 2025. The International Herbicide-Resistant Weed Database. www.weedscience.org

For additional information, see the *2025 Chemical Weed Control for Field Crops, Pastures, and Noncropland* or check with your local K-State Research and Extension office for a paper copy. https://bookstore.ksre.ksu.edu/item/2025-chemical-weed-control-for-field-crops-pastures-rangeland-and-noncropland_SRP1190

The use of trade names is for clarity to readers and does not imply endorsement of a particular product, nor does exclusion imply non-approval. Always consult the herbicide label for the most current use requirements.

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2. Using Biosolids on Agricultural Land: Agronomic, Environmental, and Safety Considerations

Publicly owned water treatment works and onsite wastewater systems generate by-products known as **biosolids**, leftover organic materials that can serve as valuable soil amendments for agricultural production. In Kansas, approximately 80% of wastewater treatment facilities recycle biosolids through land application rather than disposing of them in landfills or incinerating them. When handled properly, biosolids can provide nutrients and improve soil properties, offering both agronomic and environmental benefits.



Figure 1. Land application of biosolids is being done on cropland, which will then be incorporated with tillage. Photo by DeAnn Presley, K-State Extension.

What Are Biosolids?

Biosolids, sometimes called sewage sludge, are the organic solids separated from wastewater during treatment. They typically contain 2–15% solids and are most often applied as a liquid or semi-solid material. Depending on the treatment process, biosolids can also be dewatered, composted, or dried and sold as a soil amendment (though not for certified organic production).

Nutrient Value

The main agronomic advantage of biosolids is their nutrient and organic matter content. They supply nitrogen (N), phosphorus (P), and smaller amounts of potassium (K), along with organic carbon that enhances soil microbial activity and water-holding capacity. Biosolids also contain small amounts of

secondary nutrients (e.g., sulfur, calcium, magnesium) and micronutrients (e.g., zinc and copper) that can contribute to overall soil fertility. On average, one dry ton of biosolids contains roughly 80 pounds of N, 200 pounds of P_2O_5 , and 10 pounds of K_2O . However, much of the N is in an organic form that becomes plant-available slowly over time, a process in soil called mineralization. Proper application rates must account for mineralization, ammonia volatilization losses, and nitrate leaching. To minimize ammonia volatilization, avoid surface applications when temperatures exceed 50°F. Research shows that, depending on the treatment used to produce the sludge, about 10 to 50 percent of the organic N will be available in the first year after application. On the other hand, usually all of the P and K found in biosolids is considered plant-available during the year of application.

Regulations Governing Biosolids Application

Land application of biosolids is regulated under the **EPA 503 rules (40 CFR Part 503)**, which set limits on **pathogens, metals, and nutrient application rates** to protect public health and the environment. In Kansas, these regulations are administered by the Kansas Department of Health and Environment (KDHE).

Pathogens. EPA 503 rules classify biosolids into two categories based on pathogen reduction:

- **Class A biosolids** are essentially pathogen-free and can be used on lawns, gardens, and crops for direct human consumption.
- **Class B biosolids** meet a lower level of pathogen reduction and are typically applied to cropland or pasture, with restrictions on harvest and public access.

Vector attractions (i.e., rodents and insects). Specific standards and treatments are required to reduce the tendency of biosolids to attract rodents, flies, mosquitoes, or other vectors that may carry diseases. Class A biosolids must incorporate multiple factors that reduce vector attraction to a minimum. Class B biosolids have less stringent requirements for treatment because they are often used in less populated areas.

Metals. Biosolids applied to land must meet limits for nine metals, including cadmium, copper, lead, and zinc. Kansas biosolids rarely exceed these thresholds.

Nutrients. Application rates must not exceed the agronomic rate (the N rate required for the intended crop). Over-application can increase the risk of nitrate leaching to groundwater or phosphorus runoff to surface water. KDHE provides specific forms and guidance to help treatment facilities and haulers determine proper application rates and maintain compliance.

Emerging Contaminants in Biosolids

In addition to valuable nutrients, biosolids can also contain emerging contaminants such as **microplastics, pharmaceutical residues, and per- and polyfluoroalkyl substances (PFAS)**. These materials can persist in soil or water after land application, and researchers continue to study their long-term effects on human health and the environment. According to the [U.S. EPA](https://www.epa.gov/assessing-and-managing-pfas-contamination), certain PFAS may lead to adverse health outcomes, and ongoing efforts are focused on improving wastewater treatment and reducing PFAS sources before they reach biosolids.

Environmental and Safety Considerations

The EPA 503 standards are designed to minimize risks to human health and the environment, but additional precautions are necessary. Workers handling biosolids should wear protective gear, avoid inhaling or ingesting particles, and follow safety training protocols. Vaccinations for potential disease exposure may be recommended for frequent handlers.

To prevent soil compaction, biosolids should not be applied when soils are wet. Heavy application vehicles can negate soil health benefits provided by the organic matter. Proper timing, traffic management, and suitable access roads reduce these risks.

Nutrient losses, particularly phosphorus runoff, can harm water quality. Producers are encouraged to evaluate fields using the Phosphorus Index and adopt Best Management Practices (BMPs) such as buffer strips, incorporation of biosolids, and erosion control. Odor management is also important. Anaerobically treated sludge should be injected or incorporated into the soil, and applications near residences should maintain adequate setbacks (typically 500 feet or more).

Site Restrictions and Management Practices

The **EPA 503 regulations** outline specific management practices to ensure biosolids are applied safely and responsibly.

Biosolids must **not** be applied:

- If an adverse effect on threatened or endangered species is likely.
- To flooded, frozen, or snow-covered land where solids could enter a wetland or body of water.
- Within **33 feet (10 meters)** of any body of water.
- At rates exceeding the **agronomic nitrogen rate**, except on permitted reclamation sites.

Class B biosolids have additional restrictions:

- **Harvest delays:**
 - Food, feed, or fiber crops whose edible parts do not touch the soil (e.g., corn, wheat, soybeans, apples, peaches) may not be harvested for **30 days** after application.
 - Crops with edible parts that may contact the soil (e.g., melons, tomatoes, lettuce) require a **14-month** waiting period.
 - Root crops (e.g., potatoes, beets, carrots) require at least **38 months** if biosolids are incorporated within 4 months, or **20 months** if they remain on the surface longer.
- **Grazing restriction:** Animals must not graze on treated land for **30 days** following application.
- **Turf restriction:** Turf intended for high human-use areas cannot be harvested for **1 year** unless specifically authorized by KDHE.
- **Public access:** Sites with potential human exposure must remain closed for **1 year**, while areas with low exposure risk must restrict access for **30 days** (not including operators or employees familiar with safety precautions).

Determining Agronomic Nitrogen Rates

To ensure proper application, KDHE developed the **LA-ANR form**, based on K-State soil fertility research. This procedure helps calculate the nitrogen availability from biosolids, credits existing soil

nitrogen and previous applications, and determines a safe and effective application rate. Producers are required to maintain application records, including soil test results and field maps, for at least five years.

Summary

When properly managed, biosolids provide Kansas farmers with a cost-effective source of nutrients and organic matter. However, successful use depends on understanding nutrient content, following EPA and KDHE regulations, and adopting sound management practices to protect human health and the environment.

Producers interested in using biosolids can contact their local wastewater treatment plant or the Kansas Department of Health and Environment, Bureau of Water, for more information on availability, permitting, and application guidelines.

This article is a summarized version of the KSRE publication **“Use of Biosolids on Agricultural Land: Agronomic, Environmental, and Safety Considerations” (MF2878)**. Read the full publication online at: <https://bookstore.ksre.ksu.edu/pubs/MF2878.pdf>

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3. World of Weeds - Field Pansy

The name “pansy” might prompt pictures of hardy spring bedding plants. However, this World of Weeds feature is a wild relative of those ornamentals. Field pansy (*Viola bicolor*), also called wild pansy or Johnny-jump-up, is more noticeable in the spring, but can be found in the fall throughout Kansas (Figure 1).



Figure 1. Field pansy growing in a crop field after harvest in the fall. Photo by Sarah Lancaster, K-State Extension.

Ecology

Field pansy is a winter annual native to North America. It can be found in fields, lawns, and roadsides throughout Kansas. It prefers sunny, well-watered sites. It can germinate in fall or spring, and grows rapidly in the spring, hence the name “Johnny-jump-up”. This weed is likely to become prevalent in

fields that rely on glyphosate and 2,4-D for spring burndown applications.

Identification

Flowering stems grow upright to about 6 inches tall from a mat of basal leaves (Figure 2). Stems are angled and branch near the base. The stems of young plants are green, but they will turn purple as the plant matures (Figure 3).



Figure 2. Field pansy growing in corn stalks near Rossville, KS. Note the mat formed in the background and the upright flowering stem. Lobed stipules are seen at the base of the flowering stem on the plant in the foreground. Photo by Sarah Lancaster, K-State Extension.

Leaves are up to 2 inches long, usually smooth, and may have occasional notches in the margins. They are generally egg-shaped, becoming narrower near the flowers. Leaves are alternately arranged along the stem. Deeply lobed stipules, up to 1 inch long, occur at the base of the flowering stem.

Flowers develop on long stalks that arise from leaf axils and are protected by five light green, hairless sepals (Figure 3). When they emerge, flowers are about ½ inch across and have five petals, ranging in color from violet to cream, with the center of the flower becoming white. Petals have dark blue-violet veins. One petal has a yellow spot at the base and is surrounded by two petals that have small hairs near the base (Figure 4). Tiny, oblong, yellow-brown seeds develop in oblong capsules that are about 0.25 inch in length. The seeds are spread when they are ejected from mature capsules (a phenomenon called forced or explosive dehiscence).



Figure 3. Flowering stems become purple as they mature. Large sepals are present at the base of the flower. Photo by Sarah Lancaster, K-State Extension.



Figure 4. Field pansy flowers come in a range of colors. All flowers will have dark veins in the petals and a yellow spot near the center of the flower. Photo by Sarah Lancaster, K-State Extension.

Management

Field pansy is [easier to control in the fall](#) compared to the spring. [Including a fall application](#) of flumioxazin (Valor, others), chlorimuron (Classic), or tribenuron (Express, others) is likely to provide better control of field pansy than spring applications alone, especially late spring applications. Spring burndown applications that include dicamba will provide better control of field pansy compared to those that include 2,4-D. Products that can control field pansy in the spring include atrazine, isoxaflutole (Balance Flexx, others), mesotrione (Callisto, others), cloransulam (FirstRate, others), and thifensulfuron (Harmony, others).

For more information, see the “2025 Chemical Weed Control for Field Crops, Pastures, and Noncropland” guide available online at <https://bookstore.ksre.ksu.edu/pubs/SRP1190.pdf> or check with your local K-State Research and Extension office for a paper copy.

The use of trade names is for clarity to readers and does not imply endorsement of a particular product, nor does exclusion imply non-approval. Always consult the herbicide label for the most current use requirements.

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4. Southeast Kansas Ag Applicator Training Set for December 1 in Parsons

Kansas State University's Southeast Research and Extension Center will host a Southeast Kansas Ag Applicator Training event on **Monday, December 1, from 8:30 a.m. to 3:30 p.m.** at 25092 Ness Road, Parsons.

This one-day event offers a valuable opportunity for applicators to earn five 1A recertification credits, plus one KDA Core credit, while receiving timely updates on weed, disease, and technology topics from K-State specialists.

Featured presentations include:

- **Great Glufosinate Applications** – Dr. Sarah Lancaster
- **Managing Pasture and Range Weeds** – Dr. Molly Reichenborn
- **Upcoming Crop Diseases and Methods of Control** – Dr. Tina Sullivan
- **Spray Drone Technology: Use and Limitations** – Dr. Deepak Joshi
- **Resources for Application Decisions** – James Coover, Wendie Powell, and Lonnie Mengarelli

The cost to attend is \$20. Participants can register online by scanning the QR code in the flyer below or by calling 620-784-5337.

This event, hosted by K-State Extension, is open to all individuals interested in pesticide application management, agronomy, and integrated pest management.

James Coover, Crop Production Agent – Wildcat District
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SEK Ag Applicator Training Day

December 1, 2025

8:30 a.m. – 3:30 p.m.

Southeast Research & Extension Center

25092 Ness Road, Parsons

**Five (1A)
recertification credits +
one KDA Core credit**

Cost \$ 20
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Spray Drone Technology; Use & Limitations:

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5. Share Your Input: Digital Ag and AI Survey for Farmers

Are you a Kansas farmer working in row crops, specialty crops, or livestock/ranching? We invite you to share your perspective on Digital Agriculture and Artificial Intelligence (AI) in farming systems by completing a brief survey.

Your survey responses will help identify opportunities, challenges, and resource needs across Kansas as these technologies continue to evolve.

The information collected in this survey is strictly confidential and will be used solely for academic and educational purposes. All responses are anonymous and will not be linked to any individual. We appreciate your participation and collaboration.

The survey takes less than 10 minutes to complete and is open to all producers and growers in Kansas.

Scan the QR code in the flyer below or click the link below to participate:

https://kstate.qualtrics.com/jfe/form/SV_bwoxVYFC5t10Wge?Q_CHL=qr

ATTENTION FARMERS

Survey Participants Needed

**Inclusive
Criteria**

**Anonymous
Responses**

**10-15 Minutes
to Complete**



Help us discover the needs in Kansas Digital Ag & AI

If any of the following apply to you,
you qualify to take our survey:

- Row crop production
- Specialty crop production
- Livestock ranching/operation

Scan Here



[https://kstate.qualtrics.com/jfe/form/
SV_bwoxVYFC5t10Wge](https://kstate.qualtrics.com/jfe/form/SV_bwoxVYFC5t10Wge)

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6. Sorghum Connection Launches Second Year of Winter Educational Series

The Sorghum Connection Series, a collaboration between the Kansas Grain Sorghum Commission (KGSC), K-State Research & Extension, and the K-State Department of Plant Pathology, announces its second year of a comprehensive winter educational series focused on enhancing the profitability of sorghum producers across the state.

Following this year's field day events, which welcomed over 120 growers, Sorghum Connection offers an additional series of multiple one-day events across Central and Western Kansas. The events are scheduled for:

- **December 3** at the South Hutchinson Community Building in Hutchinson
- **December 4** at the Buffalo Bill Cultural Center in Oakley
- **December 5** at the Hy-Plains Feedyard in Montezuma

Each event will begin with registration at 9:30 a.m. and will conclude at 2:30 p.m.

Attendees will receive valuable data-driven information from industry leaders from K-State, the United Sorghum Checkoff Program, and many others on key topics for both grain and forage sorghum, including, but not limited to:

- Effectively managing forage sorghum in water-limited silage
- Enhancing sorghum digestibility for cattle
- Integrated weed management
- Strategies for optimum yield and profitability

The program also looks to the future of the sorghum crop system, covering advancements such as the application of spray drones in precision agriculture and highlighting breakthroughs in farmer-directed crop improvement.

There is no cost to attend; however, an RSVP is required. To register or learn more about these events, visit www.ksgrainsorghum.org/sorghum-connection.



2025 SORGHUM CONNECTION WINTER SERIES

Mark your calendars for local winter summits aimed to bring multi-disciplinary, data-driven information to Kansas sorghum producers to help improve on-farm productivity and profitability.



WEDNESDAY, DECEMBER 3 | HUTCHINSON
South Hutchinson Community Center
101 W. Ave. C, South Hutchinson, KS, 67505

THURSDAY, DECEMBER 4 | OAKLEY
Buffalo Bill Cultural Center
3083 US-83, Oakley, KS 67748

FRIDAY, DECEMBER 5 | MONTEZUMA
Hy-Plains Feedyard
7505 US-56, Montezuma, KS, 67867



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