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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. Soybean yield estimation: Timing, method, and accuracy

With most Kansas soybean fields already in reproductive stages, it is time to assess the yield potential. The latest USDA-NASS Kansas Crop Progress and Condition report (Aug. 18) estimates that 87% of soybeans in Kansas are blooming. Around 69% of the soybeans in the state are setting pods, which is on pace with last year and near the 5-year average of 67%.

Soybean plants can more easily compensate for stress (relative to corn), especially if the timing of the stress is before seed filling. Soybeans can compensate because of overlapping vegetative and reproductive phases due to their indeterminate nature (i.e., the plant continues to produce new nodes and leaves at the top of the plant even when flowering has begun at the bottom of the plant). Thus, flowering in soybeans can normally last between 4-6 weeks, allowing for the replacement of flowers and small pods that may have been aborted during heat or drought stress.

Since the final number of pods is not determined until the beginning of seed filling, when estimating soybean yield potential, we must remember that the estimate could change based on the timing of this estimation as well as weather conditions. For example, wet periods toward the end of the reproductive period can extend the seed-set period, promoting greater pod production and retention with heavier seed weight.

Estimating the final yield before harvest can be a very tedious task, but a simplified method using yield components can be applied to start setting yield expectations.

From a physiological perspective, the main yield components to consider are:

- Plants per acre
- Pods per area
- Seeds per pod
- Seed size

When can I start making soybean yield estimates?

There is no precise time, but we can start making soybean yield estimates as soon as the end of the R4 stage, full pod (pods are ¾-inch long on one of the top four nodes), or at the onset of the R5 stage, beginning seed (seeds are 1/8-inch long on one of the top four nodes). Keep in mind that yield prediction is less precise at these early reproductive stages since the seed number per area, as well as the seed weight, are not yet completely defined. At this early stage of seed development, it is important to only consider the pods that are at least ¾-inch long to avoid over-optimistic estimations since smaller pods can still abort under stressful conditions.

As the crop moves into the R6 stage (full seed), the seed number (main yield component) is almost fully defined. However, the conditions during seed filling will determine the final seed number as well as the size and weight of the seed. The closer to maturity (R7 stage) we make the estimation, the more accurate the expectation and overall yield prediction.

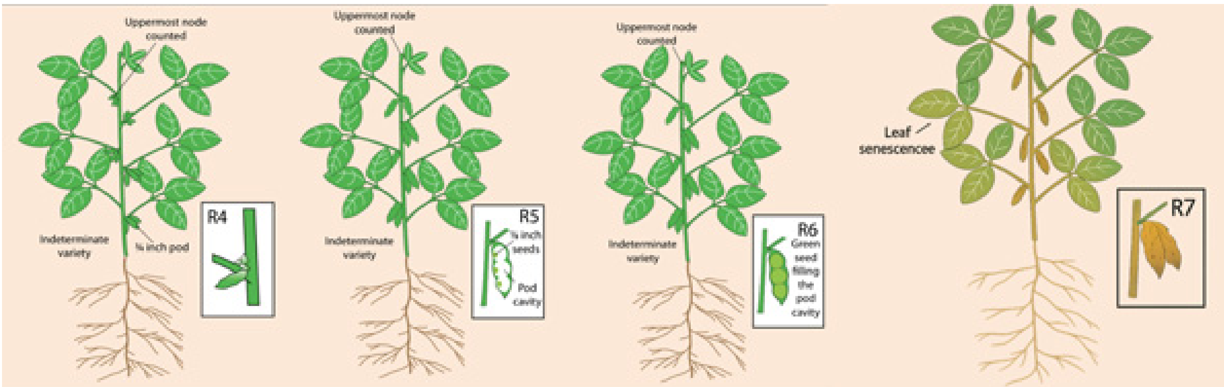

Figure 1. Soybean phenological stages to start yield prediction using the yield components method.

How many samples are needed to account for field variation?

Perform yield estimations in at least 6 and ideally 12 different areas of the field. Variability between areas within the same field also needs to be properly accounted for. Make sure to collect enough samples from the different areas to fairly represent the entire field. Within each sample section, take consecutive plants within the row to have a good representation. The variability between plants in terms of the number of pods and seed size needs to be considered when trying to get an estimation of soybean yield. The more variability to represent, the more samples needed for a proper estimation.

The yield components equation

Soybean yield estimates following the conventional approach are based on the following components (**Eq. 1**):

Eq. 1

$$\left[\left(\frac{plants}{ac.}\right) x \left(\frac{pods}{plant}\right) x \left(\frac{seeds}{pod}\right)\right] \div \left[\left(\frac{seeds}{lbs.}\right) x \left(\frac{lbs.}{bu}\right)\right]$$

where,

1. **Plants/ac. (Figure 2, step 1)**
   a. A simplified approach can be applied by using samples covering 1/10,000th of an acre. With 30-inch row widths, you would need 21 inches of row length. Thus, the average number of plants in several sections multiplied by 10,000 will give us an estimation of the number of plants per acre.
   b. If the soybean plants are arranged in 30-inch rows, we just need to sample a single row; 2 rows if the row spacing is 15 inches; and 4 rows if the row spacing is 7.5 inches.
2. **Pods/plant. (Figure 2, step 2).**
   a. Count and average the number of pods per plant from the sample.
3. **Seeds/pod. (Figure 2, step 3)**

a. Count and average the number of seeds per pod. Soybean plants have, on average, 2.5 seeds per pod (ranging from 1 to 4 seeds per pod).
b. Under severe drought and heat stress, a pessimistic expectation would be an average of 1-1.5 seeds per pod.

4. **Seeds/acre.** (Figure 2, step 4)
    a. Calculate the total number of plants/acre (1), pods/plant (2), and seeds/pod (3) to obtain the total number of seeds/acre .
5. **Pounds/bu.**
    a. For this estimation, you could use the average test weight for soybeans of 60 lbs./bu.
6. **Seeds/lbs. (Figure 2, step 5)**
    a. The number of seeds per pound will vary depending on the seed-filling conditions, which will determine the seed size. Normally, this number could range somewhere between 2,500 (bigger seeds) to 3,500 (smaller seeds) seeds per pound for optimal to unfavorable seed filling conditions.
    b. Combined with a constant test weight of 60 lbs./bu, you could see a range of seeds per bushel between 150,000 seeds per bushel to 210,000 seeds per bushel.

The final step to estimating yield is dividing seeds/acre by seeds/bu to obtain the yield estimation in bushels per acre (**Eq. 2**).

Eq. 2

$$\left(\frac{seeds}{ac.}\right) \div \left(\frac{seeds}{bu}\right) = {}^{bu}/_{ac.}$$

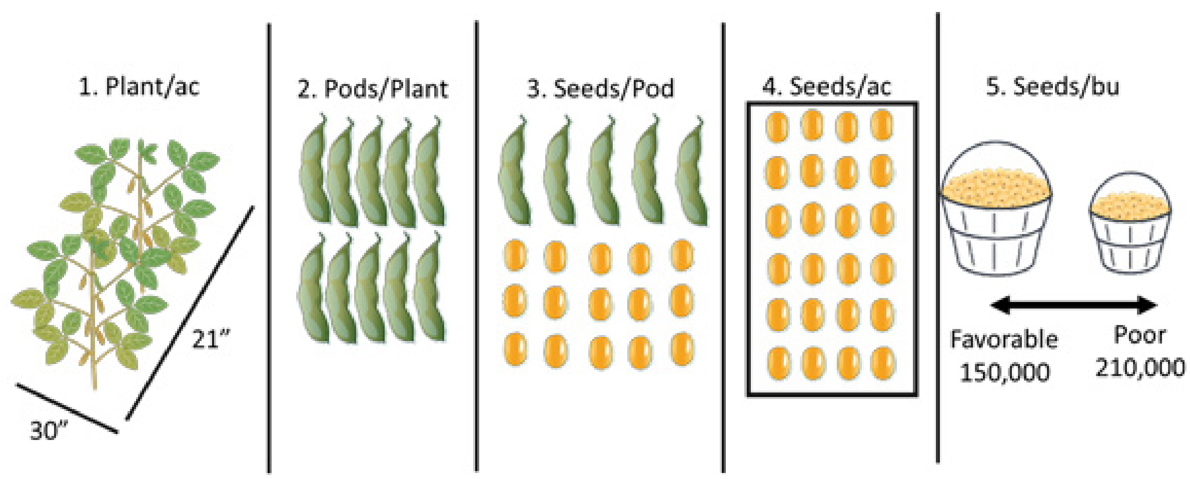

Figure 2. Example of yield estimation method using samples of 1/10,000th of an acre (21-inch x 30-inch sections) for a regular yield until seed filling, where the seed size is expected to be reduced compared to favorable seed filling conditions, increasing the #seeds/bu component.

Example representing average conditions

- Using the steps, we counted the number of plants in 10 sections of 30x21 inches and determined an average number of 12.4 plants. Since these sections are 1/10,000th of an acre, our first component, the plant density, is 124,000 plants/acre.

- Then, in those 12.4 plants, we measured, on average, 27 pods per plant. Assuming a "normal" growing season condition, we could expect to count around 2.5 seeds per pod.
- Combining these components, we obtained an expectation of 8.37 million seeds per acre.
- Finally, we have to assume or estimate the seed-filling conditions. In this case, we used regular-to-poor seed filling due to a lack of precipitation combined with heat. Thus, we divided the seeds per acre by an expectation of 200,000 seeds per bu (small seed size), giving us an estimate of roughly 42 bu/acre.

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2. Planting winter canola: Variety, site, and seedbed preparation

Winter-hardy canola varieties now make production possible across much of Kansas. When planted at the right time into good soil moisture, canola has the best chance to establish strong fall growth and survive the winter.

Deciding when to plant canola this fall may be challenging because soil moisture in the planting zone is adequate to variable across the state. High August temperatures and less frequent rainfall patterns have parts of the state lacking in topsoil moisture. The planting window for winter canola arrives in Kansas by early September. As the planting window closes, consider all the risk factors for planting winter canola too late. Getting a good fall stand is one of the most important steps to producing a successful crop.

This article covers three key areas for getting a successful start: **variety selection, site selection, and seedbed preparation**. A companion eUpdate article addresses other management considerations such as seeding date, rate, row spacing, fertility, and pest management.

Variety Selection

Choose varieties based on winter survival, yield, oil content, herbicide tolerance, disease resistance, maturity, lodging susceptibility, and shatter tolerance. Winter hardiness should be the top priority in new production areas.

Producers have the option of selecting either open-pollinated varieties or hybrids.

Open-pollinated varieties: Common in the southern Great Plains; reliable overwintering and high yield potential. Roundup Ready options are available for broad-spectrum weed control.

Hybrids: Larger seed size, vigorous growth, and high yield and oil potential when resources are not limiting. Clearfield herbicide tolerance is available in some hybrids.

Varieties tolerant to sulfonylurea (SU) herbicide carryover can be used after crops treated with products like Finesse, avoiding long plant-back intervals. Some Roundup Ready varieties also have SU carryover tolerance.

Planting two or more varieties with different maturities can spread harvest timing and reduce risk. Consider pairing a proven variety with a new one to evaluate performance.

Site Selection

Canola grows on a range of soils but performs best on well-drained, medium-textured soils with a pH between 5.5 and 7.0. Correct low pH with lime before planting. Avoid poorly drained or waterlogged sites. Liming should be considered when soil pH is less than 5.5.

Be mindful when planting canola following crops like sunflower, soybean, alfalfa, or cotton. These crops share similar diseases with canola. Continuous canola is not recommended, and it is not insurable. Rotate with grass crops (wheat, corn) to minimize disease risk.

Canola will perform best when adequate time is given after the preceding crop to allow for soil moisture recharge and weed control, and where there is adequate time to get the canola planted early enough to help the plants survive over winter.

Avoid fields with heavy winter annual broadleaf weed pressure if possible. If planting in these conditions, consider a Roundup Ready variety. Grassy winter annual weeds are easily controlled by using clethodim, quizalofop, or sethoxydim in conventional canola, or by using the Roundup Ready or Clearfield canola systems. Be aware of herbicide history - winter canola is sensitive to Group 2 and triazine herbicide carryover, which may require 18 months or more before planting. A companion eUpdate article covers herbicide carryover restrictions in more detail.

Seedbed Preparation

Because of its small seed size, a properly prepared seedbed is critical for successful canola establishment. Open-pollinated varieties typically range from 100,000 to 125,000 seeds per pound, and hybrids range from 70,000 to 100,000 seeds per pound.

A level, firm seedbed with adequate moisture within the top inch is preferred. A seedbed with many large clumps results in poor seed placement and seed-to-soil contact. An overworked seedbed may be depleted of moisture and will crust easily, potentially inhibiting emergence. In addition, this could promote deep placement of the seed.

If using tillage, perform the most aggressive tillage as early as possible, with each succeeding tillage operation being shallower than the last. Incorporate fertilizer and herbicide with the last tillage operation. Some producers perform one aggressive tillage operation as early as possible and then control newly emerged weeds chemically. Planting into this “stale” seedbed will help ensure adequate moisture for establishment.

Tips for no-till planting

No-till planting is an option, and some long-term no-till producers have grown canola successfully using this practice (Figure 1). With proper settings, no-till planting can result in very good stands. However, maintaining stands over the winter can be difficult with low soil disturbance in heavy residue cover. This challenge has been overcome by burning surface residue immediately before planting, removing the residue (i.e., baling), vertical tillage, or using a more aggressive residue manager that removes residue from the seed row. Research in south central Kansas indicates that even with good winter survival, no-till canola yields under heavy residue were lower than where residue was burned or where tillage had been performed.

Figure 1. Overwintering canola established under no-tillage in 30-inch rows in southwest Kansas. Photo by Mike Stamm, K-State Research and Extension.

Ensure that drills and planters are properly set, and consider using a setup that creates a more disturbed seed row. Using a high-disturbance opener (such as a coulter, residue manager, or hoe-type opener) in no-till can improve winter survival and result in yields comparable to those obtained in tilled fields.

Weeds must be controlled chemically, mechanically, or with a combination of both methods prior to planting because canola seedlings are not competitive with established weeds.

Additional Resources

- *2024 National Winter Canola Variety Trial:* https://bookstore.ksre.ksu.edu/item/2024-national-winter-canola-variety-trial_SRP1192
- *Great Plains Canola Production Handbook*. Contact your local Extension office for a copy or download it online: https://www.bookstore.ksre.ksu.edu/pubs/mf2734.pdf.
- *Canola Growth and Development* poster: https://www.bookstore.ksre.ksu.edu/pubs/MF3236.pdf.

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3. Planting winter canola: Seeding, fertility, and pest management

Winter canola can be a profitable rotation crop in Kansas, and success starts with strong stand establishment. This article covers seeding date, seeding rate, seeding depth, fertility, and pest management. For variety and site selection, seedbed preparation, and herbicide carryover information, see the companion eUpdate articles.

Seeding date

The general rule is to plant winter canola about six weeks before the average date of the first killing frost (28°F) in central and south-central Kansas, and six to eight weeks before in southwest and northern Kansas. This allows the crop to develop a healthy canopy and a strong root system for winter survival.

- **Planting too late** may lead to small, weak plants with a lower chance of winter survival.
- **Planting too early** may cause excessive fall growth that depletes soil moisture and raises the growing point above the soil surface, increasing the risk of winterkill.
- Heavy residue in the seed row can worsen excessive growth problems unless managed correctly.

Target dates

The planting window for winter canola starts September 1 in Kansas.

- Northern and southwest KS – by September 15
- Central KS – by September 25
- Far south-central KS (Barber, Harper, and Sumner counties) – by October 1

Monitor short-term and long-term weather forecasts to help gauge planting time decisions. The most recent 8-14 day outlook from NOAA, issued August 19, projects below-normal temperatures and near-normal to above-normal precipitation are likely. The 1-month outlook is for near-normal temperatures and moisture. These projections could make for favorable winter canola planting conditions.

Seeding rate, depth, and row spacing

Winter canola will compensate for a poor plant stand; however, it is important to obtain as uniform a stand as possible to facilitate optimum plant development, winter survival, weed control, and uniform plant maturity.

Seeding rate:

- **Open-pollinated varieties** – 3 to 4 lb/acre (~300,000 to 400,000 pure live seeds/acre at 100,000 seeds/lb) in narrow rows (7.5-inch to 15-inch)
- **Hybrid varieties** – 250,000 to 300,000 pure live seeds/acre in narrow rows (lower seeding rates than OPs due to higher seed costs and greater plant vigor)
- **30-inch rows** – Possible with row crop planters, but yields may be slightly lower under dryland conditions. Seed 1.5 to 3 lb/acre (~150,000 to 300,000 pure live seeds/acre). Use of

hybrid varieties may increase yield potential in wide rows.

Depth:

- Optimal – ½ to 1 inch
- Dry conditions – up to 1.5 inches, but this may slow emergence and reduce vigor
- Plant slower than wheat (5 mph or less) for accurate depth control
- Check depth in every field and be aware of crusting risk after heavy rain, especially where the ground has been excessively worked

Row spacing:

- **7.5 to 15-inch rows**: rapid canopy closure, better light interception, and weed suppression. Yields are similar across this range. Plant-to-plant uniformity at emergence is critical for optimum plant development and growth, overwintering, and weed control.
- **30-inch rows**: may be the best option for no-till producers, but residue must be moved from the seed row. Reduce seeding rate to limit plant-to-plant competition in the row.

Figure 1. Canola established under conventional tillage in narrow rows in south central Kansas. Photo by Mike Stamm, K-State Research and Extension.

Plant nutrition and soil fertility

Soil testing, including a profile sample for nitrogen (N) and sulfur (S), is important in determining fertilizer needs. If you have questions, contact your local Extension office. Canola fertility recommendation programs, based on soil test levels, can be found at http://www.agronomy.ksu.edu/soiltesting/

Fertility needs are similar to winter wheat; however, canola needs slightly greater N and S. Applying high rates of fertilizer in-row at planting is not recommended because canola is sensitive to ammonia and salt damage (phytotoxic effects). However, research by Oklahoma State indicates that a low rate of DAP or MAP (20 to 30 lb/acre of product) is beneficial and not detrimental to yield. The best management practice for banding fertilizer should separate the fertilizer from the seed by two inches to avoid direct contact. Pre-plant broadcast application is also acceptable.

- **Lime**: Apply lime so that pH is in the range of 5.5-7.0 and early enough so the lime has time to react in the soil.
- **Phosphorus (P):** No P should be added if the P soil test is above 30 ppm.
- **Potassium (K):** Apply when soil test levels are less than 125 ppm.
- **Sulfur**: Apply S based on the soil test recommendation. Sulfate-sulfur (SO_4-S) soil tests should be above 10 ppm, or fertilizer should be applied. If no soil test is available, an application of 20-30 lb/acre S is recommended.
    - Canola requires S because of its high content of S-containing proteins. Sulfur deficiency is more common in coarse-textured and low-organic-matter soils; however, S application is still recommended for all soil types. Sulfur can be applied at any time from pre-plant until the canola plant breaks dormancy in late winter.
- **Nitrogen**: Apply one-third to ½ of total N (based on expected yield) in the fall. 30-80 lb/acre actual N is the general rule for fall applications. Winter survival, plant vigor, and yield potential can decrease without adequate fall N.

Weed management

A clean seedbed is critical as small canola seedlings compete poorly with established weeds. However, once a good stand and canopy are established, canola suppresses and outcompetes most winter annual weeds. Regardless of your herbicide program, the most important thing to remember is to control weeds early in the fall.

- Trifluralin and ethalfluralin are effective at controlling winter annual weeds pre-plant, but each requires mechanical incorporation.
- Grass herbicides such as clethodim, quizalofop, and sethoxydim are labeled for cool-season grass control in canola.
- Roundup Ready (glyphosate-tolerant) canola varieties are available, providing excellent control of many problem weeds. Glyphosate is not labeled for application once the plant has bolted after dormancy.
- Clearfield canola varieties are available and provide another herbicide resistance option for controlling winter annual grasses.

Insect management

An insecticide seed treatment is highly recommended to control green peach aphids and turnip aphids through fall and early winter. Several products are labeled and provide good to excellent control. Monitor canola stands for the following fall insect pests: grasshoppers, diamondback moth larvae, armyworm, flea beetle, aphids, and root maggots. A post-emergence application may be necessary in the fall to control these insect pests.

Disease management

Crop rotation is the best way to minimize the introduction and reduce the potential spread of canola diseases. Do not plant canola in the same field more than once every three years, and do not plant canola continuously.

- **Blackleg** (*Leptosphaeria maculans*) is the most serious disease threat to canola. Use proper rotation intervals, disease-free seed, and fungicide seed treatments to slow the spread of blackleg.
- **Damping-off** of young seedlings resembles the pinching of the stem at or just below the soil line. This is caused by several fungi, including *Pythium*, *Fusarium*, and *Rhizoctonia*. A fungicide seed treatment can lessen the effects of these soil-borne diseases.

Additional Resources

Great Plains Canola Production Handbook. Contact your local Extension office for a copy or download it online: https://www.bookstore.ksre.ksu.edu/pubs/mf2734.pdf.

Canola Growth and Development poster is available online at: https://www.bookstore.ksre.ksu.edu/pubs/MF3236.pdf.

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4. Key herbicide carryover issues when planting winter canola

Market opportunities have generated more interest in planting winter canola in the fall of 2025. As you make seeding plans, be sure to consider the herbicides you use or have used in your winter and summer crops. Table 1 highlights some herbicides used in winter and summer crops that may or may not have rotation restrictions for canola. As you consider this information, please remember that rotation intervals required by the EPA only consider the time that is required to ensure no illegal herbicide residues are found in the second crop. However, in some cases, additional information can be provided by the herbicide registrant regarding the potential for injury. When appropriate, that information will be noted in Table 1.

Table 1. Active ingredients, field half-lives, and crop rotation intervals of some herbicides applied to winter and summer crops that may be of concern for winter canola.

Herbicide	Active ingredient	Half-life (days)	Rotation interval	Comments
Aatrex, others	Atrazine	29	one year to avoid crop injury	--
Component of Acuron, others	Bicyclopyrone	213	18 months	--
Balance Flexx, others	Isoxaflutole	1.3	18 months	Also requires 15" of precipitation
*Beyond **	Imazamox	30-60	18 months	--
Callisto, others	Mesotrione	5	10 months	--
Classic	Chlorimuron	28	9 to 18 months	See label for details
Dimetric, others	Metribuzin	19	18 months	
Dual II Magnum, others	S-metolachlor	23	12 months	--
*Finesse **	Chlorsulfuron metsulfuron	14-42	None listed	Field bioassay required
FirstRate	Cloransulam	10	18 months	--
Harmony, others	Thifensulfuron	10	45 days	--
Harness, Warrant, others	Acetochlor	12	Not listed	--
Huskie	Pyrasulfotole	30	9 months	--
Outlook, others	dimethenamid-P	16	4 to 6 months	Interval increases with increasing rate
Permit, others	Halosulfuron	14	15 months	Bioassay if drought or cool conditions
Powerflex HL	Pyroxsulam	13	9 months	--
Pursuit	Imazethapyr	51	40 months	Also requires bioassay
Python, others	Flumetsulam	45	26 months	Also requires bioassay

Reflex	fomesafen	86	18 months	--
Spartan, others	sulfentrazone	541	24 months	--
Valor, others	flumioxazin	18	6 or 12 months	6 months if tilled
Zidua, others	pyroxasulfone	22	12 to 18 months	Interval increases with increasing rate

** To avoid plant back restrictions for canola, consider planting a Clearfield® winter canola after applying Beyond in wheat, and a sulfonylurea herbicide carryover tolerant winter canola after applying Finesse or similar Group 2 herbicides in wheat.*

For producers using the CoAXium® wheat system, remember that there is no rotation restriction for canola. However, to protect the efficacy of controlling weeds in both crops, it is recommended to rotate herbicide modes of action.

For more detailed 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.

For more information on canola planting considerations, see the "Great Plains Canola Production Handbook" available at https://www.bookstore.ksre.ksu.edu/pubs/mf2734.pdf. There are also two canola planting articles in this eUpdate.

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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5. Weed management practices: Fall scouting and equipment cleaning

Weed management encompasses more than controlling actively growing weeds. Farmers can be proactive to help prevent the future spread of weeds. This article discusses two different management practices: fall scouting for weed escapes and equipment cleaning.

Fall scouting can help plan for future control

Weeds that escape control by in-season management practices can cause several problems, including the possibility of reduced harvest efficiency and crop yield. Even if these factors do not justify an herbicide application, it is important to consider the future costs of seeds produced by those escapes, particularly if those escaped weeds produce a lot of seed and/or are herbicide-resistant.

Just a few escapes of species such as waterhemp or Palmer amaranth can have a big impact (Figure 1). For example, research conducted in Georgia showed that one female plant in five acres added about two million seeds per acre to the soil. Those seeds can have an impact for multiple years. For example, 5% of Palmer amaranth seeds remained viable after three years in a study of seeds collected from five states. In some situations, scouting during the weeks leading up to harvest may provide an opportunity to remove these plants by hand to reduce the number of seeds in the soil.

Figure 1. The waterhemp plants growing between these corn rows may not have reduced grain yield, but they will produce seeds that must be controlled in future years. Photo by Sarah Lancaster, K-State Research and Extension.

Scouting for weeds at harvest, even if you simply make notes from the combine, is important for planning future weed management.

When scouting, make notes about

- which weed species are present,
- where weed escapes are present, and
- any changes in the size or location of areas with weed escapes.

Some observations might result from soil or environmental conditions, while others might suggest problems with the herbicide selection or application equipment. However, some of these escapes might indicate the presence of herbicide-resistant weeds in your field, especially if the same herbicide program has been used for several years. Two observations that might indicate herbicide resistance are 1) a growing patch of a particular species or 2) herbicide failure on a few plants of a single species that is normally controlled.

Stop spreading weed seed during harvest activities

Weeds can spread in a variety of ways, including on farm equipment. As you move harvest equipment from field to field, be aware of the potential to spread weed seed, especially if uncontrolled weeds are known or suspected to be herbicide resistant. Some steps to prevent spreading weeds when moving harvest equipment from one field to another are listed below.

- Clean new-to-you equipment so someone else's weeds are not introduced to your farm.
- If possible, harvest fields with excellent weed control first.
- Harvest fields where weeds are or might be herbicide-resistant last.
- Harvest around areas with extremely dense weed populations.
- Slow the combine to 'self-clean' between fields.
    - Run the unloading auger empty for a minute or two.
    - Open grain elevator doors, rock trap, and unloading auger sump, then run the separator with maximum airflow and suction.
- Use an air compressor to remove material remaining in the rock trap and grain auger and from the head, feeder house, and straw spreader.
- Take half a day to do a deeper clean when possible.
- Check fall-tillage equipment between fields.

It is very difficult to completely remove weed seeds from harvest equipment. However, taking a few minutes to reduce the number of seeds on your harvest equipment may save time and money in the future.

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6. Crop monitoring with drone-based remote sensing technology

As crops are actively growing, it is critical to regularly monitor fields. For example, most of the Kansas corn crops are in the tasseling (VT) to grain filling (R1-R4) stages right now, which are the critical stages for determining final yield. During the transitional phase from vegetative to reproductive development (VT), any possible stresses such as drought, flooding, disease, pests, and nutrient deficiencies during this window may lead to fewer kernels per ear, lighter test weight, and ultimately lower crop yield. Therefore, proper monitoring during this phase can help with early stress detection and crop yield estimation.

Thanks to modern precision agriculture technologies such as Unmanned Aerial Vehicles (UAVs), commonly called 'drones', fields can be monitored more rapidly, frequently, and more precisely compared to traditional visual inspection by walking the field. Visual inspection is time-consuming, labor-intensive, and potentially less precise/accurate when limited to a small area of the field, as in fields with limited accessibility, or when fields are highly variable. Moreover, crops like corn are tall, dense, and have a closed canopy when they reach tasseling and begin grain filling, which makes field scouting and visual inspection more difficult. In these scenarios, drones can be used to detect the pattern and uniformity of crop growth and identify the problem areas more quickly and precisely.

What is drone-based remote sensing?

Drone-based remote sensing involves using a drone equipped with a sensor (camera) to collect images and information by flying over your farm or field without touching the crop or ground. The camera senses light color reflectance from below across a range of wavelengths, both visible and invisible to human eyes. Visible light includes red, green, and blue light. However, it is near infrared (NIR) light, which is not visible, that can be used to detect plant growth and vigor. When the plant is green and healthy, it reflects more NIR light and absorbs red light for photosynthesis. However, when a plant is stressed or less green, the reflection pattern of NIR is just the opposite, as it reflects less NIR light. Such light reflectance values from plant canopies are also used in various equations to calculate vegetation indices (VIs) to assess plant health, greenness, biomass, etc.

One of the most common and widely used indices in precision agriculture is the Normalized Difference Vegetation Index (NDVI), which is calculated using the reflectance value of NIR and Red light as in the equation below:

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

The value for NDVI usually ranges from -1 to +1. In general,

- +0.6 to +1.0 = Very healthy, dense vegetation coverage
- +0.2 to +0.5 = Moderate crop health and canopy coverage.
- 0 to +0.2 = Stressed plants or bare soil,
- Less than 0 = Water, snow, or non-vegetated surfaces.

Using these thresholds, crop growth can be monitored, and areas of the field that need specific attention can be identified to support decision-making. However, one issue with NDVI maps at the later growth stage of the crop is 'NDVI Saturation'. This is the crop growth stage at which NDVI reaches the peak level, and it remains the same even when chlorophyll content changes. In this case, Normalized Difference Red Edge (NDRE) indices can be more reliable, as it is more sensitive than NDVI to small changes in chlorophyll content. The NDRE can be calculated using the following equation:

$$NDRE = \frac{(NIR - Red\ Edge)}{(NIR + Red\ Edge)}$$

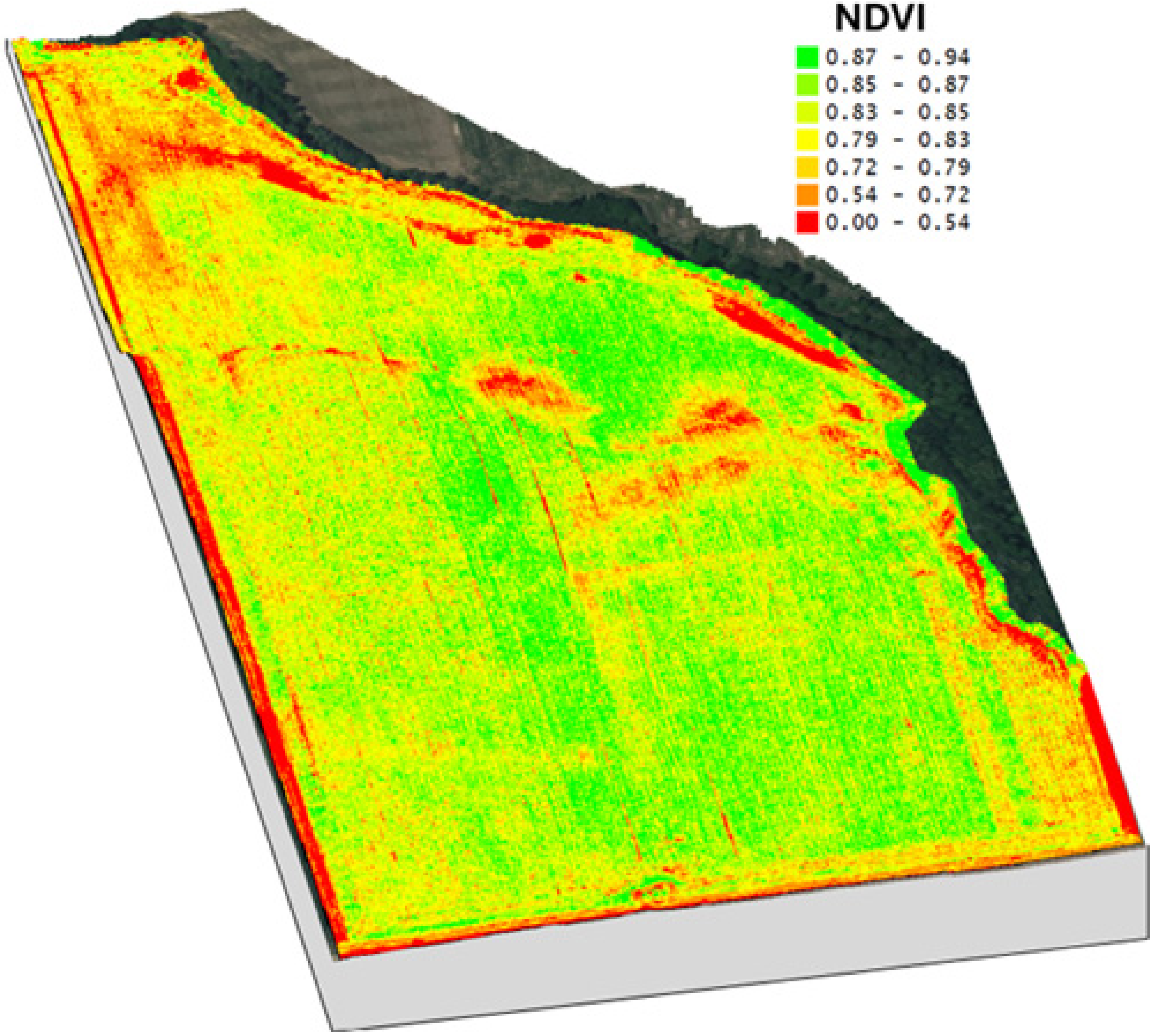
NDRE values for crops typically range from 0 to 1. Values closer to 1 indicate higher chlorophyll content in the leaves, while values closer to 0 suggest lower chlorophyll content, plant stress, or reduced canopy coverage.

Drones in crop growth monitoring: A real-world scenario

Crop growth and canopy vigor can be monitored using drone-based imagery with various vegetative indices, such as NDVI or NDRE data derived from such imagery. For example, drone imagery was collected at the silking to grain filling growth stages of corn. From this, NDVI (Figure 1a) and NDRE (Figure 1b) maps were generated for a detailed view of corn canopy conditions and variability across the field.

The NDVI values of the corn crop ranged from 0.79 to 0.94, indicating dense canopy cover and high biomass. However, some parts of the fields along the edges or certain low spots seem to have lower NDVI values, indicating the possibility of water stress, nutrient deficiency, or other issues; therefore, such areas should be prioritized for ground inspections to identify or confirm the cause of stress before taking any action. Moreover, NDVI may begin to saturate at this stage, masking subtle differences in plant health. Therefore, the NDRE map can provide a complementary perspective.

Compared to NDVI, NDRE shows a wider range of variability within the green zone and is more sensitive to chlorophyll concentration in upper leaves. Since NDRE is less prone to saturation compared to NDVI at the mid to later growth stage when there is high biomass and dense canopies, it is more effective for earlier detection of stress.



NDVI
0.87 - 0.94
0.85 - 0.87
0.83 - 0.85
0.79 - 0.83
0.72 - 0.79
0.54 - 0.72
0.00 - 0.54

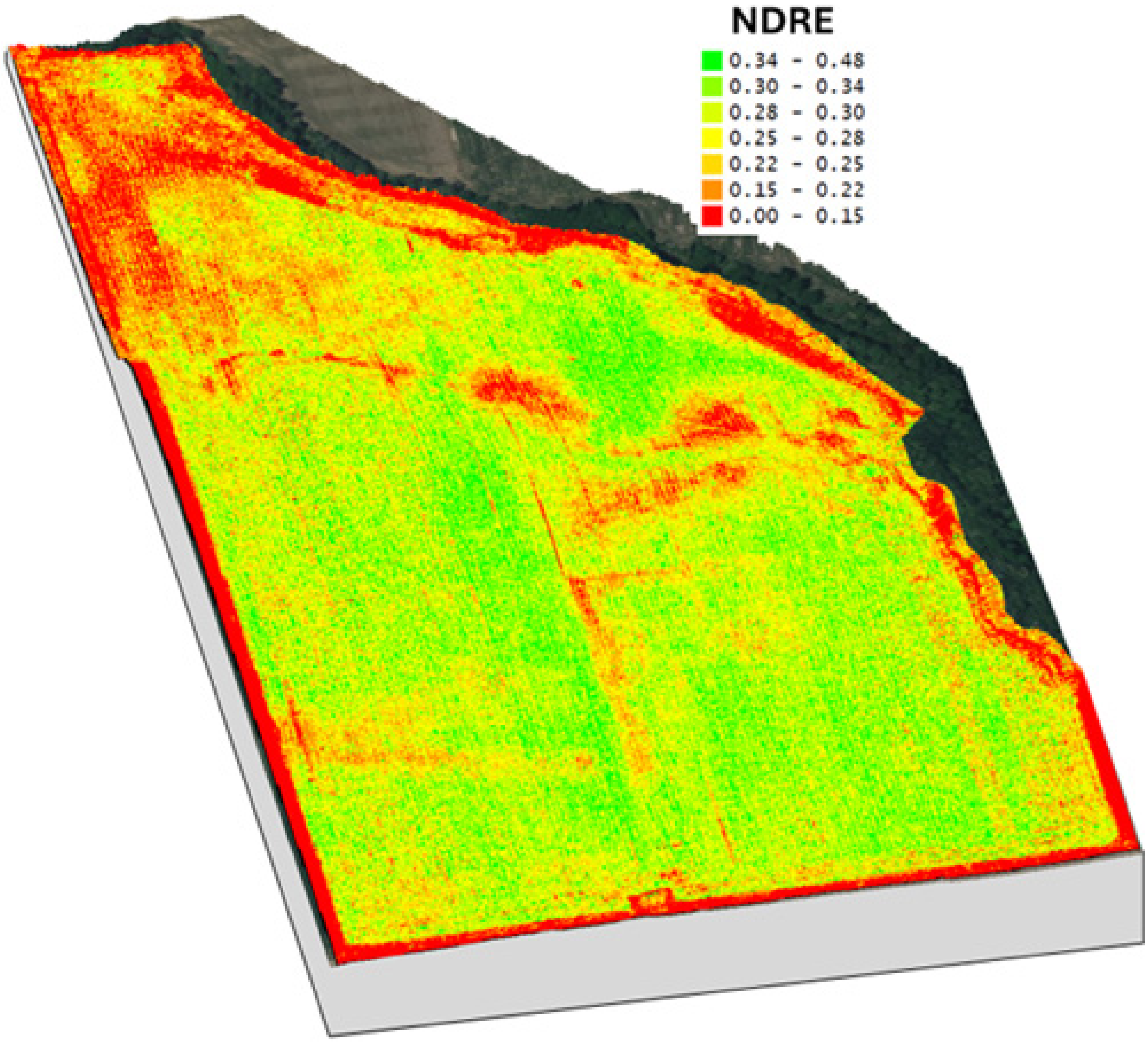


Figure 1. Spatial variability of corn canopy health as indicated by NDVI (top image) and NDRE (bottom image) maps collected on July 29, 2025. NDVI images were overlaid on a LiDAR-based digital elevation model (DEM) to visualize and analyze the spatial variability in NDVI-driven crop growth patterns. Image credit: Deepak Joshi & Flickner Innovation Farm.

Conclusion

Visual inspections by walking around the field are quite challenging as they are time-consuming, labor-intensive, and potentially less precise/accurate when limited to a small area of the field. Moreover, such visual inspection or scouting is even more impossible for crops like corn, as they are tall, dense, and have a closed canopy when they reach tasseling and begin grain filling. Therefore, drone-collected imagery at the later growth stage of the crop can help to understand the temporal and spatial variability in crop growth and vigor and yield estimation.

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7. Spray water quality and herbicide performance survey

The state of Kansas is currently facing challenges related to water quality. Limited research has been conducted within the state regarding the effects of water acidity, alkalinity, and hardness on herbicide performance. Consequently, there is an urgent need to carry out this survey to collect farmers' perspectives on spray water quality and its implications for weed control, as well as to identify ways in which research can better support them in enhancing their chemical weed management practices.

We want to learn your perspective on the impact of spray water quality on herbicide performance in your operations to allow us to provide research-based recommendations for improving your chemical weed control. This survey will gather insights from producers regarding how spray water quality affects their chemical weed control. The survey covers:

1. Demographic information (counties farmed, primary responsibilities on the farm, and acreage operated),
2. General water quality assessments,
3. Impact of spray water pH on herbicide performance
4. Influence of spray water hardness on herbicide efficacy
5. Effects of spray water turbidity on herbicide effectiveness

No identifiable information is collected, and no data will be used or shared for future research. All of the questions are voluntary, and if you do not want to answer specific questions, you can skip them. You may also withdraw your participation at any time without penalty or loss of benefits that you may otherwise be entitled.

Accessing the survey

- Click this link to access the survey or
- Scan the QR code below.

For questions about this survey, please contact any of the researchers below:

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