VISUAL GUIDE
Winter Wheat
DEVELOPMENT AND GROWTH STAGING
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Introduction

Understanding the growth stages of cereals crops and how to identify them is key to successful cropping and pest management decisions.

Although there are several growth staging methods, this guide is based on the Feekes scale, which is a popular tool used in the field. It has eleven development stages with some stages having more detailed subdivisions.

The Zadoks scale is the standard scale used in research and has ten development stages, each stage having ten subdivisions. Both scales are useful to know, so this guide cross-references the Zadoks equivalents to the Feekes.

This guide uses winter wheat as an example. However, the methods generally apply to other cereals as well and at the back of the guide are sections that showcase barley, oats, rye and triticale.

A few notes on growth staging plants:
• Select plants that represent at least 50% of the field
• Dig plants (if possible), so you can assess the entire plant
• Start at the base of plant and work your way upward
• Use a knife to split the stems and sheaths
• Look and feel for nodes

References:


Basic wheat anatomy

This illustration shows the basic anatomy of a Feekes 2 plant; the intention of the drawing is to illustrate and annotate an ideal plant. Plants in the field are rarely ideal and are often missing leaves, tillers, etc.

During the vegetative stages, the **auricles** are often a good way to distinguish between different cereal crops.

Wheat | Auricles blunt and hairy; leaf sheath and blade always hairy; ligule medium length; leaf blades twist clockwise
### Feekes scale for cereal growth stages

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seedling growth</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>One shoot, first leaf through coleoptile</td>
</tr>
<tr>
<td><strong>Tillering</strong></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Tillering begins; main shoot and one tiller</td>
</tr>
</tbody>
</table>
| 3 | Tillers formed; leaves often twisted  
  In some varieties, plant may be prostrate in appearance |
| 4 | Leaf sheaths lengthen; beginning pseudostem erection |
| 5 | Leaf sheaths fully elongated to form strongly erect pseudostem |
| **Stem extension** | |
| 6 | First node of stem visible at base of shoot; jointing |
| 7 | Second node of stem formed; next-to-last leaf just visible |
| 8 | Flag leaf visible but still rolled up |
| 9 | Ligule of flag leaf just visible |
| 10 | Flag leaf sheath completely grown out; booting |
| **Heading** | |
| 10.1 | First awns of head just visible |
| 10.2 | 1/4 of heading process complete |
| 10.3 | 1/2 of heading process complete |
| 10.4 | 3/4 of heading process complete |
| 10.5 | All heads out of sheath |
| 10.5.1 | Beginning of flowering |
| 10.5.2 | Flowering complete to top of head |
| 10.5.3 | Flowering complete at base of head |
| 10.5.4 | Flowering complete; kernel watery ripe |
| **Flowering** | |
| 11.1 | Kernel milky ripe; milk stage |
| 11.2 | Kernel mealy ripe; soft but dry consistency; soft dough stage |
| 11.3 | Kernel hard; difficult to divide with thumbnail; hard dough stage |
| 11.4 | Kernel harvest ready; straw dead |

**Legend:**
- **Feekes scale** for cereal growth stages
- **Seedling growth**
- **Tillering**
- **Stem extension**
- **Heading**
- **Flowering**
- **Ripening**
<table>
<thead>
<tr>
<th>Zadoks scale for cereal growth stages</th>
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</thead>
<tbody>
<tr>
<td><strong>Germination</strong></td>
</tr>
<tr>
<td>00 Dry seed</td>
</tr>
<tr>
<td>01 Start of imbibition</td>
</tr>
<tr>
<td>03 Imbibition complete</td>
</tr>
<tr>
<td>05 Radicle emerged from seed</td>
</tr>
<tr>
<td>07 Coleoptile emerged from seed</td>
</tr>
<tr>
<td>09 Leaf just at coleoptile tip</td>
</tr>
<tr>
<td><strong>Seedling growth</strong></td>
</tr>
<tr>
<td>10 First leaf through coleoptile</td>
</tr>
<tr>
<td>11 First leaf unfolded</td>
</tr>
<tr>
<td>12 2 leaves unfolded</td>
</tr>
<tr>
<td>13 3 leaves unfolded</td>
</tr>
<tr>
<td>14 4 leaves unfolded</td>
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<tr>
<td>15 5 leaves unfolded</td>
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<tr>
<td>16 6 leaves unfolded</td>
</tr>
<tr>
<td>17 7 leaves unfolded</td>
</tr>
<tr>
<td>18 8 leaves unfolded</td>
</tr>
<tr>
<td>19 9 or more leaves unfolded</td>
</tr>
<tr>
<td><strong>Tillering</strong></td>
</tr>
<tr>
<td>20 Main shoot only</td>
</tr>
<tr>
<td>21 Main shoot and 1 tiller</td>
</tr>
<tr>
<td>22 Main shoot and 2 tillers</td>
</tr>
<tr>
<td>23 Main shoot and 3 tillers</td>
</tr>
<tr>
<td>24 Main shoot and 4 tillers</td>
</tr>
<tr>
<td>25 Main shoot and 5 tillers</td>
</tr>
<tr>
<td>26 Main shoot and 6 tillers</td>
</tr>
<tr>
<td>27 Main shoot and 7 tillers</td>
</tr>
<tr>
<td>28 Main shoot and 8 tillers</td>
</tr>
<tr>
<td>29 Main shoot and 9 or more tillers</td>
</tr>
<tr>
<td><strong>Stem elongation</strong></td>
</tr>
<tr>
<td>30 Pseudostem erection</td>
</tr>
<tr>
<td>31 1\textsuperscript{st} node detectable</td>
</tr>
<tr>
<td>32 2\textsuperscript{nd} node detectable</td>
</tr>
<tr>
<td>33 3\textsuperscript{rd} node detectable</td>
</tr>
<tr>
<td>34 4\textsuperscript{th} node detectable</td>
</tr>
<tr>
<td>35 5\textsuperscript{th} node detectable</td>
</tr>
<tr>
<td>36 6\textsuperscript{th} node detectable</td>
</tr>
<tr>
<td>37 Flag leaf just visible</td>
</tr>
<tr>
<td>39 Flag leaf ligule/collar just visible</td>
</tr>
</tbody>
</table>

A leaf is unfolded when its ligule is visible, or the tip of the next leaf is visible.
<table>
<thead>
<tr>
<th>Stage</th>
<th>Event</th>
<th>Code</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Booting</td>
<td>Flag leaf sheath extending</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Boot just visibly swollen</td>
<td>45</td>
<td></td>
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<tr>
<td></td>
<td>Flag leaf sheath opening</td>
<td>47</td>
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</tr>
<tr>
<td></td>
<td>First awns visible</td>
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<td></td>
</tr>
<tr>
<td>Inflorescence emergence</td>
<td>First spikelet of inflorescence visible</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>1/4 of inflorescence emerged</td>
<td>53</td>
<td></td>
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<tr>
<td></td>
<td>1/2 of inflorescence emerged</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3/4 of inflorescence emerged</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Emergence of inflorescence completed</td>
<td>59</td>
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<td>Anthesis</td>
<td>Beginning of anthesis</td>
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<td>Anthesis half-way</td>
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<td>Anthesis completed</td>
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<tr>
<td>Milk development</td>
<td>Kernel watery ripe</td>
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<td>Early milk</td>
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<td>Medium milk</td>
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<td>Late milk</td>
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<td>Dough development</td>
<td>Early dough</td>
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<td>Soft dough</td>
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<td></td>
<td>Hard dough</td>
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<tr>
<td>Ripening</td>
<td>Kernel hard (difficult to divide with thumbnail)</td>
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</tr>
<tr>
<td></td>
<td>Kernel hard (no longer dented with thumbnail)</td>
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<td>Kernel loosening in daytime</td>
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<td>Overripe, straw dead and collapsing</td>
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<td>Viable seed giving 50% germination</td>
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<td>Seed not dormant</td>
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<td>Secondary dormancy induced</td>
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<td></td>
<td>Secondary dormancy lost</td>
<td>99</td>
<td></td>
</tr>
</tbody>
</table>
Germination begins when the dry seed imbibes water and begins to expand.

**Zadoks 00**
Dry seed

**Zadoks 01**
Start of imbibition

**Radicle**
The first root

**Coleoptile**
The round sheath that protects the first leaf

**Zadoks 05**
Radicle emerged from seed

**Zadoks 07**
Coleoptile emerged from seed

*Planting depth and soil temperature* influence the duration of the germination stages.
The **first true leaf** emerges through the coleoptile’s tip

The **coleoptile** stops growth when it encounters light above the soil surface

The **seminal roots** begin developing

Seminal roots are fibrous and are produced by the seed
EMERGENCE | Feekes 1 | One shoot formed; first leaf through coleoptile
This is an important time to check plants for **uniform emergence**; planting depth and soil temperature influence the length of this stage.
TILLERING | Feekes 2 | Tiller development begins
Tillers produced in the fall will contribute more to grain yield than those produced in the spring.

The crown forms between the seed and soil surface.
The secondary root system starts developing tillers.

- **Main shoot**
- **Tiller**
- **Prophyll**: The independent sheath at the base of each tiller

The secondary root system starts developing.
Are tillers important?

Tillers are absolutely necessary for high yields

1 can produce 4–5 tillers
planted seed

The total numbers of tillers a plant produces is determined by both environmental conditions and genetic potential

KEY YIELD COMPONENT

A tiller is capable of forming a single head (spike)
The head is made up of spikelets
Each spikelet contains individual florets
Individual florets can produce a single kernel

In Wisconsin, the recommended planting date range for optimal tiller development in winter wheat is September 20 to October 10
TILLERING | Feekes 3 | Tillering completed
The secondary root system undergoes extensive development.

Tillers with 3 or more leaves will be nutritionally independent from the main shoot.
What happens during winter dormancy?

Vernalization!

When temperatures fall below 50 degrees Fahrenheit for typically 3-6 weeks, the plant initiates differentiation.

The growing point changes from vegetative or leaf producing to reproductive or spikelet producing.

The growing point is at the double ridge stage and is still protected in the crown below the soil surface.

The number of florets initiated during this stage will determine the potential number of kernels per head.

FEEKES 3 CAN OCCUR IN FALL OR SPRING because winter wheat development is dependent on both temperature and planting date.
Dig plants as soon as the soil thaws, bring inside and place in a warm (preferably moist) area for a few days, then check for root regrowth.

**FACTORS AFFECTING WINTER SURVIVAL**

- Good snow cover acts as insulator; keeps soil temperature from going below critical levels
- Cyclic freezing and thawing increases injury from ice crystal growth in tissue
- Mid-winter thaw and rain cause flooding at the base of the plants; crowns can die at warmer temperatures
- Ice encasement traps carbon dioxide and suffocates plant by inhibiting respiration
- Frost heaving can push root system out of ground, leaving plants vulnerable and weak

**regrowth**
Root regrowth will develop from the crown and appear a vibrant white compared to the older roots.
1 **V**enture out and get a general overview of the **f**ields — vibrant green patches may be interspersed with drab brown areas, but brown does not always indicate winter-killed plants.

2 **C**heck for winter survival — identify several representative plants and 1) dig plants and bring inside to check for root regrowth or 2) wait a week and revisit to check for regrowth in the field.

3 **D**o a plant count — below 12 live plants per square foot is an automatic replant; 12-15 live plants per square foot requires more consideration for a replant decision; 15-22 live plants per square foot may recover and reach maximum yield potential; over 22 live plants per square foot means you’re good to go!

4 **C**onsider a nitrogen application — the optimal time to apply nitrogen to winter wheat in Wisconsin is during green up; for recommendations and rates, consult UW-Extension publication A2809 *Nutrient Application Guidelines for Field, Vegetable and Fruit Crops in Wisconsin*. 
In Wisconsin, the growth stage at green up can be **Feekes 3** or **Feekes 4** depending on planting date and environmental conditions.

**How to do a plant count plant**

- Count the number of plants in a 3-foot length
- Do this for at least 3 areas
- Take the average of the counts
- Multiply that number by 4
- Then divide by the row width (inches)

**EXAMPLE**

The 3 counted areas have 40, 35 and 45 plants.

1. Add 40, 35 and 45 and then divide by 3, the average = 40
2. Multiply 40 x 4 = 160
3. Divide 160 by 7.5 inches = **21 plants/square foot**
TILLERING | Feekes 4 | Leaf sheaths lengthen, pseudostem erection begins
Wheat plants have a **pseudostem**, which is a false stem composed of concentric rolled leaf sheaths that surround the growing point (the developing head) During this stage, these leaf sheaths lengthen, making the plants stand more upright

This is an important time for weed control and/or nitrogen applications

Feekes 4
This is the last stage that some herbicides can be used without risk of injury!

*Always check and follow herbicide labels*
The growing point is at the **terminal spikelet stage** and about 1/4 inch above the crown. 

The **number of spikelets per head** has been determined by this stage.
As the head moves up the stem, it is vulnerable to freeze injury during low temperatures!
A node is an area of active cell division from which leaves, tillers and adventitious roots develop.
The jointing stage is when the *internodal tissue* begins to elongate and pushes the **four nodes** that are stacked in the crown upward, similar to how a telescope works.

A leaf arises from each of these nodes, with the 4th node giving rise to the flag leaf — the last leaf the plant produces.

The developing head is located above the nodes.

The stem is hollow behind the node.

The space between the nodes elongates and moves the head upward.
Feekes 6 plant shown with all leaves intact

From this growth stage forward, broken stems due to wheel traffic will result in yield loss!

The developing head is moving up the stem and needs to be protected

The number of tillers that form heads has been determined by this stage
SCOUT NOW!
THIS WILL GIVE YOU THE INFORMATION YOU NEED TO MAKE GOOD MANAGEMENT DECISIONS ABOUT PROTECTING THE FLAG LEAF AT THE NEXT STAGE.
This leaf arises from the 2nd node.

To demonstrate this, pull the leaf sheath back and downward; it will break off at the node.

Sheaths removed and stem slit to show head (about 1-1/2 inches) and nodes.

1st node

2nd node

3rd node

4th node

Location of developing head

Nutrient use increases

Water use increases

Feekes 7
This is a **critical time** to make foliar fungicide application decisions!

**FLAG LEAF FACTS**

The flag leaf accounts for over 50% of the photosynthates used for grain development, a.k.a **YIELD**

It must be protected from disease or insect damage to ensure the plant’s full yield potential.

Fungicide application decisions to protect the flag leaf should be made based on **presence** and **severity** of disease on the two leaves immediately below it.

STEM EXTENSION | **Feekes 8** | Flag leaf visible, still rolled up
HOW DO YOU KNOW IF IT’S THE FLAG LEAF?

Identify the leaf arising from the 1st node

Call this leaf #1 and count upward

The flag leaf will be leaf #4

Kernel size is determined by crop health and water/nutrient availability beginning now and continuing through grain fill
STEM EXTENSION | Feekes 8 | Flag leaf fully emerged from the whorl; ligule just visible
Continue to scout for insect pests and diseases!
At this stage, the Feekes scale subdivides:

10.1 Head emerging
10.2 Heading 1/4 complete
10.3 Heading 1/2 complete
10.4 Heading 3/4 complete
10.5 Heading complete

and then subdivides again

10.5.1 Beginning flowering
10.5.2 Flowering complete to top of spike
10.5.3 Flowering complete at base of spike
10.5.4 Kernels watery ripe

CONTINUE TO SCOUT FOR INSECT PESTS AND DISEASES!
The developing head is pushed through the flag leaf sheath as the peduncle and sheath elongate.

- **Peduncle**: The stem that supports the head.
- **Spikelets**
- **Awns**
- **Sheath** removed to show detail of developing head.

Approximately 3 inches long.

Feekes 10
During head emergence, the tiller’s development synchronizes with the main stem. The result is that flowering occurs simultaneously throughout the plant, even though the tillers may have emerged at different times.

**Awns** are the slender bristles that extend from the floret; some wheat varieties are awnless (also called beardless).

As the leaf sheath splits, the awns become visible.
When determining the growth stage of a field, **50% of the plants** must be at that stage or above.
1/4 of the head emerged from the leaf sheath
sheaths removed to show developing heads
Feekes 10.3

1/2 of the head emerged from the leaf sheath
The 5th or apical floret is sterile.

Spikelet
Subdivision of the head that contains the florets.

Glumes
The pair of husks that contain the spikelet.

Pedicel
Connects the spikelet to the rachis (the stem of the head).

Spikelet opened to show detail

Lemma
The outer, lower bract that encloses the flower in a floret: also where the awn extends from.

Palea
The inner, upper bract that encloses the flower in a floret.

Ovary
The inner, upper bract that encloses the flower in a floret.

Stigma
The stigma and ovary (female flower parts) and the three anthers (male flower parts).
3/4 of the head emerged from the leaf sheath
head lifted out of sheath to show elongating peduncle
Head completely emerged from the leaf sheath
This stage completes the heading process
Starting now and continuing 5-7 days after this stage is the optimum time for fungicide application to suppress Fusarium head blight (FHB), also called head scab.
The number of flowers pollinated determines the number of kernels that will develop.

Anthers dangle outside the florets during flowering.

This stage begins shortly after the head has completely emerged from the leaf sheath.

**KEY YIELD COMPONENT**

- **anther**: The male flower part that produces and releases pollen.
- **pollen**: The powder-like grains that enable fertilization.
The developing head is still vulnerable to freeze injury during low temperatures.

FLOWERING | Feekes 10.5.2 | Flowering complete to the top of the head
Anthers fade to white as flowering completes at the top of the head, while those toward the base are still brightly colored.

floret opened shortly after pollination to show developing kernel.
FLOWERING | Feekes 10.5.3 | Flowering complete at the base of the head
This stage signals the end of pollination.

floret outer structure removed to show developing kernel
This is the beginning of the **grain filling stages**; kernel length is established during this stage.
Kernel size increases but not dry matter accumulation

When squeezed, **clear fluid** is released from the kernel.
Feekes 11.1

RIPENING | **Feekes 11.1** | Kernel milky ripe; milk stage
Dry matter accumulates in the kernel.

When squeezed, milk-like fluid is released from the kernel.
Feekes 11.2

RIPENING | Feekes 11.2 | Kernel mealy ripe; soft but dry consistency; soft dough stage
Starch, nutrients and dry matter accumulate rapidly in the kernel.

The kernel's content is a soft-doughy material.
Ripening | Feekes 11.3 | Kernel hard; difficult to divide with a thumbnail; hard dough stage
Kernels reach their *maximum dry weight* and are *physiologically mature*. 

Kernel moisture decreases from 40% to 30%.
Kernel moisture decreases from 30% to 15%

RIPENING | **Feekes 11.4** | Kernel harvest ready; straw dead
Green plant tissue fades to \textit{straw}
To distinguish barley from wheat during the vegetative stages, check the auricles — barley auricles are long, slender and hairless, while wheat auricles are blunt and hairy.

Barley
Auricles long, slender and hairless; leaf sheath and blade usually hairless (scattered hairs on some varieties); ligule medium length; leaf blades twist clockwise
To distinguish oats from wheat during the vegetative stages, check the auricles — oats lack auricles, while wheat auricles are blunt and hairy.

Oats

Auricles absent; leaf sheath and blade hairless (scattered hair on some varieties); ligule medium length; leaf blades twist counter-clockwise.
A simple method to distinguish oats from all other cereals during the vegetative stages is to observe the twist of the leaves; when viewing from above, oat leaves will have a counter-clockwise curl, all other cereals’ leaves curl clockwise.
To distinguish rye from wheat during the vegetative stages, check the auricles — rye auricles are short and hairless, while wheat auricles are blunt and hairy.

**Rye**

Auricles very short and hairless; leaf sheath and blade have an inconsistent degree of hairiness; ligule short; leaf blades twist clockwise.
Other cereals
The auricles of both triticale and wheat are blunt and hairy, so they are difficult to distinguish from each other during the vegetative stage.

An alternative method is to remove a seedling from the soil and check the grain shell; triticale shells are oblong in shape and dark in color, while wheat grain shells are oval and lighter.

Triticale

Auricles blunt and hairy, leaf sheath and blade hairy; ligule of medium length; leaf blades twist clockwise
Other cereals

Auricles blunt and hairy, leaf sheath and blade hairy; ligule of medium length; leaf blades twist clockwise.
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