VISUAL GUIDE

# Winter Wheat

DEVELOPMENT AND GROWTH STAGING

COOL BEAN

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# Contents





# 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 <u>and</u> feel for nodes

**References:**

Large, E. C. (1954). *Growth Stages in Cereals Illustration of the Feekes Scale*. Plant Pathology, 3: 128–129. doi:10.1111/j.1365-3059.1954.tb00716.x

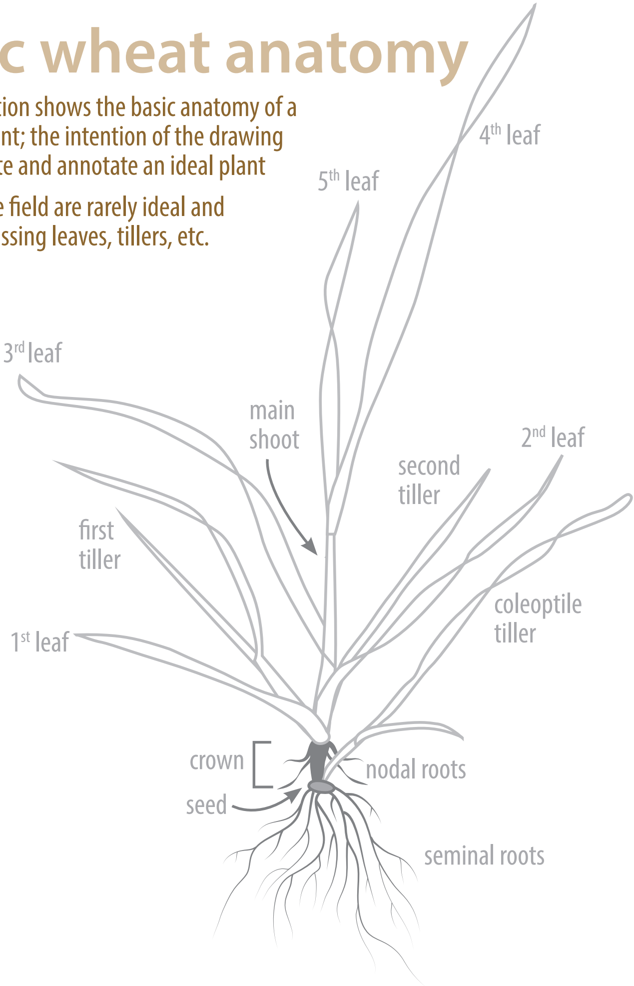
Feekes, Willem (1941). *De tarwe en haar milieu* [*Wheat and its environment*]. Verslagen van de Technische Tarwe Commissie. (in Dutch (English summary)). 17: 523–888.

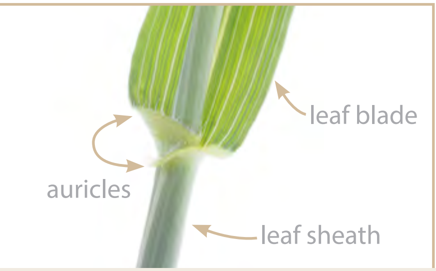
J.C. Zadoks, T.T. Chang, C.F. Konza. *A Decimal Code for the Growth Stages of Cereals.* Weed Research 1974 14:415-421.

# 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

| | | |
|---|---|---|
| SEEDLING GROWTH | 1 | One shoot, first leaf through coleoptile |
| TILLERING | 2 | Tillering begins; main shoot and one tiller |
| | 3 | Tillers formed; leaves often twisted<br>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 |
| FLOWERING | 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 |
| RIPENING | 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 |

# Zadoks scale for cereal growth stages

| Phase | Code | Description | Period | Feekes scale equivalent |
|---|---|---|---|---|
| Germination | 00 | Dry seed | | |
| | 01 | Start of imbibition | | |
| | 03 | Imbibition complete | | |
| | 05 | Radicle emerged from seed | | |
| | 07 | Coleoptile emerged from seed | | |
| | 09 | Leaf just at coleoptile tip | | |
| Seedling growth | 10 | First leaf through coleoptile | | 1 |
| | 11 | First leaf unfolded | TILLERING | |
| | 12 | 2 leaves unfolded | | |
| | 13 | 3 leaves unfolded | | |
| | 14 | 4 leaves unfolded | | |
| | 15 | 5 leaves unfolded | | |
| | 16 | 6 leaves unfolded | | |
| | 17 | 7 leaves unfolded | | |
| | 18 | 8 leaves unfolded | | |
| | 19 | 9 or more leaves unfolded | | |
| Tillering | 20 | Main shoot only | | |
| | 21 | Main shoot and 1 tiller | | 2 |
| | 22 | Main shoot and 2 tillers | | |
| | 23 | Main shoot and 3 tillers | | |
| | 24 | Main shoot and 4 tillers | | |
| | 25 | Main shoot and 5 tillers | | |
| | 26 | Main shoot and 6 tillers | | 3 |
| | 27 | Main shoot and 7 tillers | | |
| | 28 | Main shoot and 8 tillers | | |
| | 29 | Main shoot and 9 or more tillers | | |
| Stem elongation | 30 | Pseudostem erection | | 4-5 |
| | 31 | 1st node detectable | STEM EXTENSION | 6 |
| | 32 | 2nd node detectable | | 7 |
| | 33 | 3rd node detectable | | |
| | 34 | 4th node detectable | | |
| | 35 | 5th node detectable | | |
| | 36 | 6th node detectable | | |
| | 37 | Flag leaf just visible | | 8 |
| | 39 | Flag leaf ligule/collar just visible | | 9 |

A leaf is unfolded when its ligule is visible, or the tip of the next leaf is visible

| | | | | |
|---|---|---|---|---|
| Booting | 40 | --------- | STEM EXTENSION | 10 |
| | 41 | Flag leaf sheath extending | | |
| | 45 | Boot just visibly swollen | | |
| | 47 | Flag leaf sheath opening | | |
| | 49 | First awns visible | | |
| Inflorescence emergence | 50 | First spikelet of inflorescence visible | HEADING | 10.1 |
| | 53 | 1/4 of inflorescence emerged | | 10.2 |
| | 55 | 1/2 of inflorescence emerged | | 10.3 |
| | 57 | 3/4 of inflorescence emerged | | 10.4 |
| | 59 | Emergence of inflorescence completed | | 10.5 |
| Anthesis | 60 | Beginning of anthesis | FLOWERING | 10.5.1 |
| | 65 | Anthesis half-way | | 10.5.2 |
| | 69 | Anthesis completed | | 10.5.3 |
| Milk development | 70 | --------- | | |
| | 71 | Kernel watery ripe | | 10.5.4 |
| | 73 | Early milk | | |
| | 75 | Medium milk | RIPENING | 11.1 |
| | 77 | Late milk | | |
| Dough development | 80 | --------- | | |
| | 83 | Early dough | | |
| | 85 | Soft dough | | 11.2 |
| | 87 | Hard dough | | |
| Ripening | 90 | --------- | | |
| | 91 | Kernel hard (difficult to divide with thumbnail) | | 11.3 |
| | 92 | Kernel hard (no longer dented with thumbnail) | | 11.4 |
| | 93 | Kernel loosening in daytime | | |
| | 94 | Overripe, straw dead and collapsing | | |
| | 95 | Seed dormant | | |
| | 96 | Viable seed giving 50% germination | | |
| | 97 | Seed not dormant | | |
| | 98 | Secondary dormancy induced | | |
| | 99 | Secondary dormancy lost | | |

Germination

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

**Zadoks 05**
Radicle emerged from seed

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

**Zadoks 07**
Coleoptile emerged from seed

***Planting depth and soil temperature*** influence the duration of the germination stages

Zadoks
00-09


The *first true leaf* emerges through the coleoptile's tip
**Zadoks 09**
Leaf just at coleoptile tip
The *coleoptile* stops growth when it encounters light above the soil surface
seed
The *seminal roots* begin developing
Seminal roots are fibrous and are produced by the seed

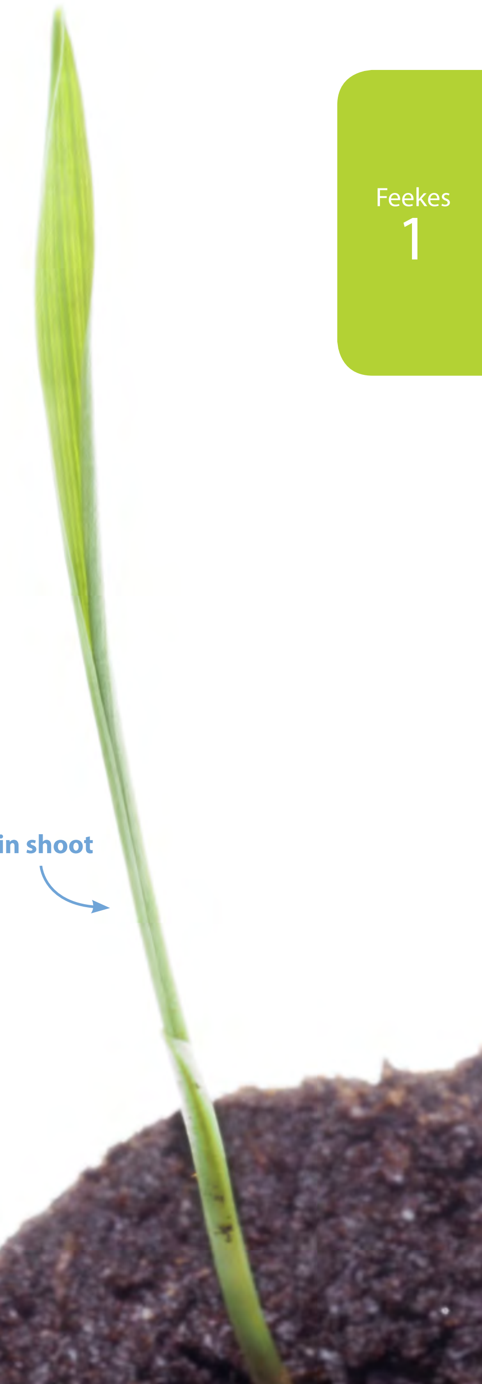
Feekes
1

Zadoks 10

EMERGENCE | **Feekes 1** | One shoot formed;
first leaf through coleoptile

## Feekes 1

This is an important time to check plants for **uniform emergence**; planting depth and soil temperature influence the length of this stage



Feekes
2

Zadoks 21

TILLERING | **Feekes 2** | Tiller development begins

# Feekes 2

Tillers produced **in the fall** will contribute more to grain yield than those produced in the spring

# Feekes 2


main shoot
tiller
tillers
prophyll
The independent sheath at the base of each tiller
tiller
The secondary root system starts developing

# *Are tillers important?*

Feekes
2

## Tillers are absolutely necessary for high yields

**1** can produce **4-5** **tillers**

**planted seed**

are also called axillary or side shoots; <u>not</u> all tillers will complete development and produce grain

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

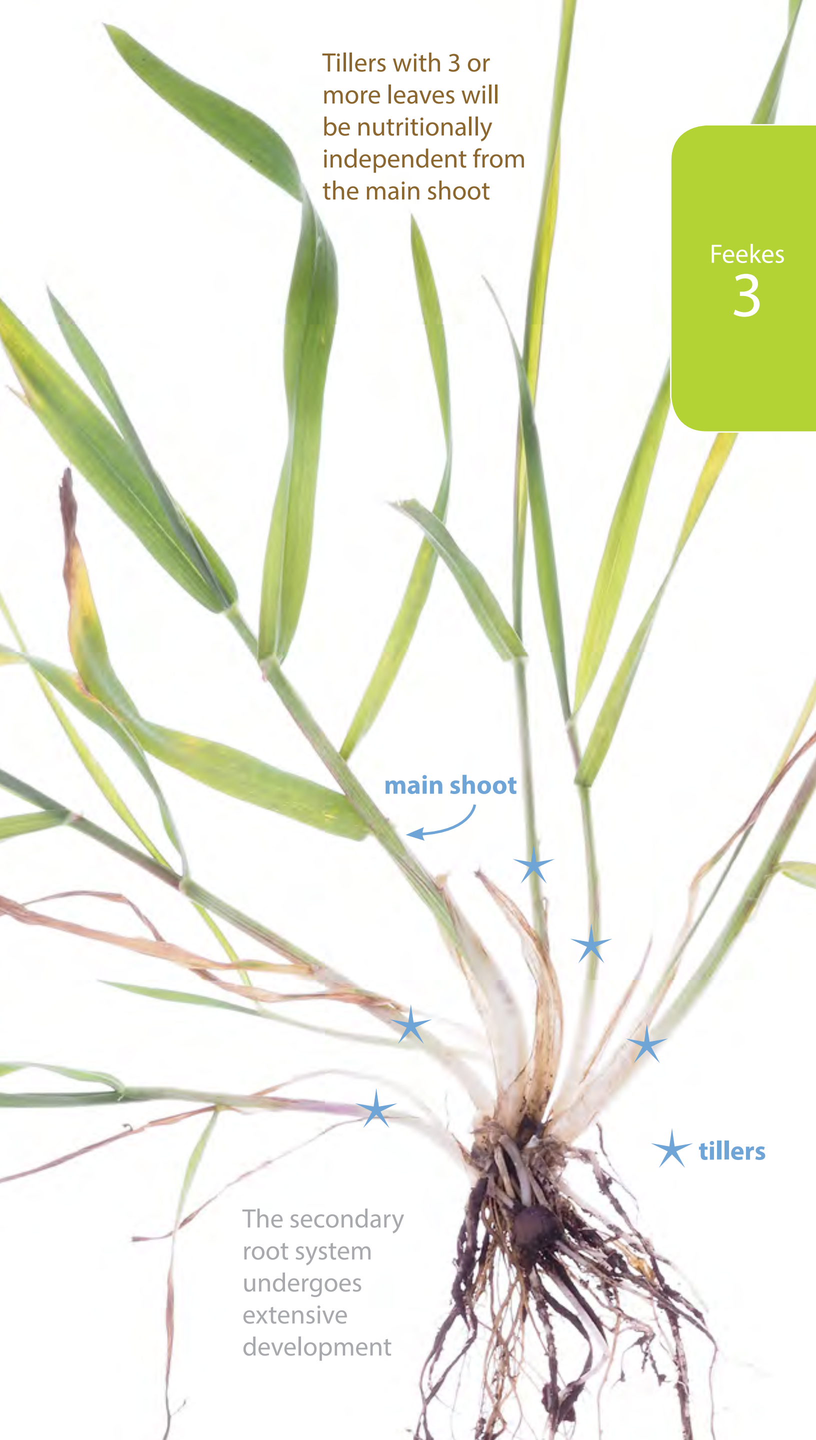
**KEY YIELD COMPONENT**

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**

# Feekes 3


Tillers with 3 or more leaves will be nutritionally independent from the main shoot
main shoot
tillers
The secondary root system undergoes extensive development

Feekes
3

**FEEKES 3 CAN OCCUR IN FALL OR SPRING**
because winter wheat development is dependent on both temperature and planting date

**FEEKES 3 FALL** Tillering completes in fall, winter dormancy occurs

**FEEKES 3 SPRING** Tillering begins in the fall, winter dormancy occurs, tillering completes in the spring

# *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*

**KEY YIELD COMPONENT**

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

GREEN UP

# 4 STEPS
## TO ASSESS STANDS IN EARLY SPRING

1 **Venture out and get a general overview of the fields** — vibrant green patches may be interspersed with drab brown areas, but brown does not always indicate winter-killed plants

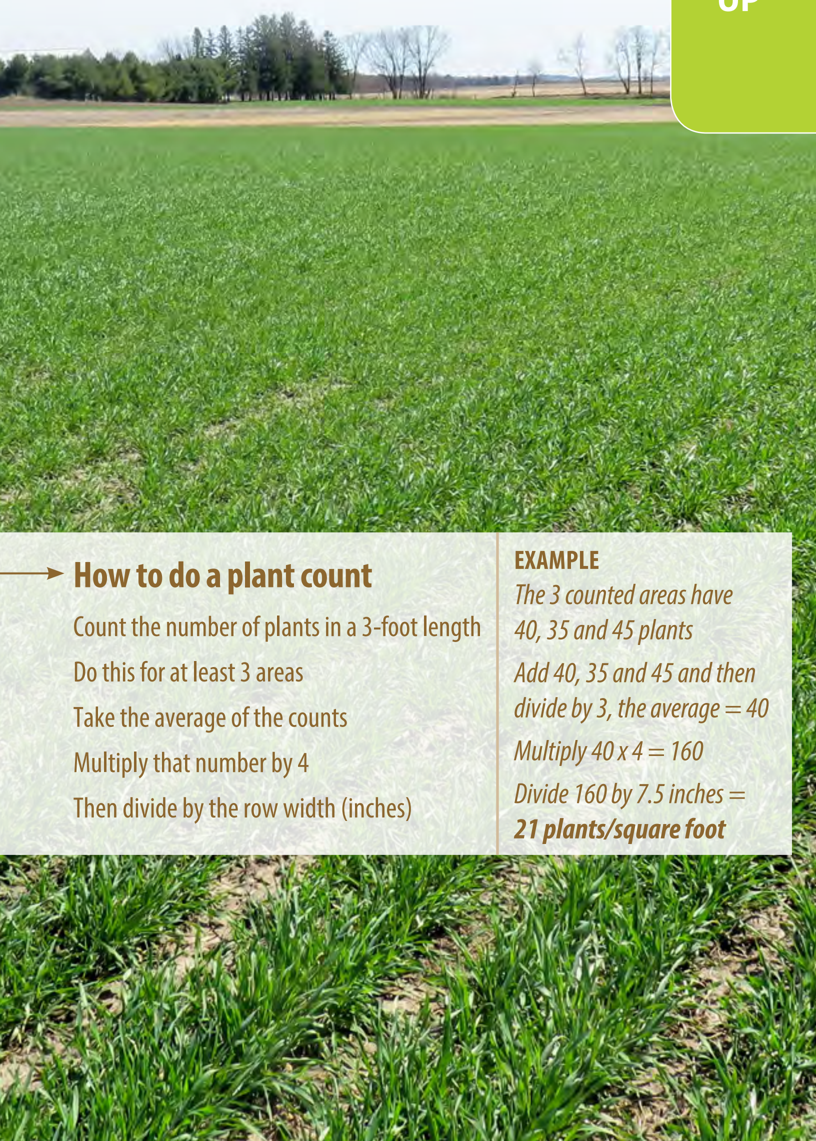
2 **Check for winter survival** — identify several representative plants and 1) dig plants and bring inside to check for root regrowth **or** 2) wait a week and revisit to check for regrowth in the field

3 **Do 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 **Consider 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

**GREEN UP**



## How to do a plant count

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*

*Add 40, 35 and 45 and then divide by 3, the average = 40*

*Multiply 40 x 4 = 160*

*Divide 160 by 7.5 inches =* ***21 plants/square foot***

Feekes
4

Zadoks 30

TILLERING | **Feekes 4 |** Leaf sheaths lengthen, pseudostem erection begins

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

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

Feekes 4

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

*Always check and follow herbicide labels*

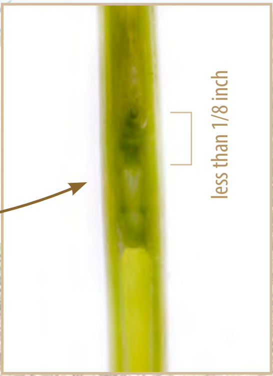
Feekes
5

Zadoks 30

TILLERING | **Feekes 5** | Leaf sheaths fully elongated, pseudostem strongly erect

# Feekes 5


As the ***developing head*** is pushed up into the pseudostem, it becomes more vulnerable to damage




*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*

**KEY YIELD COMPONENT**

Feekes
6


*As the head moves up the stem, it is vulnerable to freeze injury during low temperatures!*

Zadoks 31

STEM EXTENSION | **Feekes 6** | First node of the stem visible at the base of the shoot; jointing

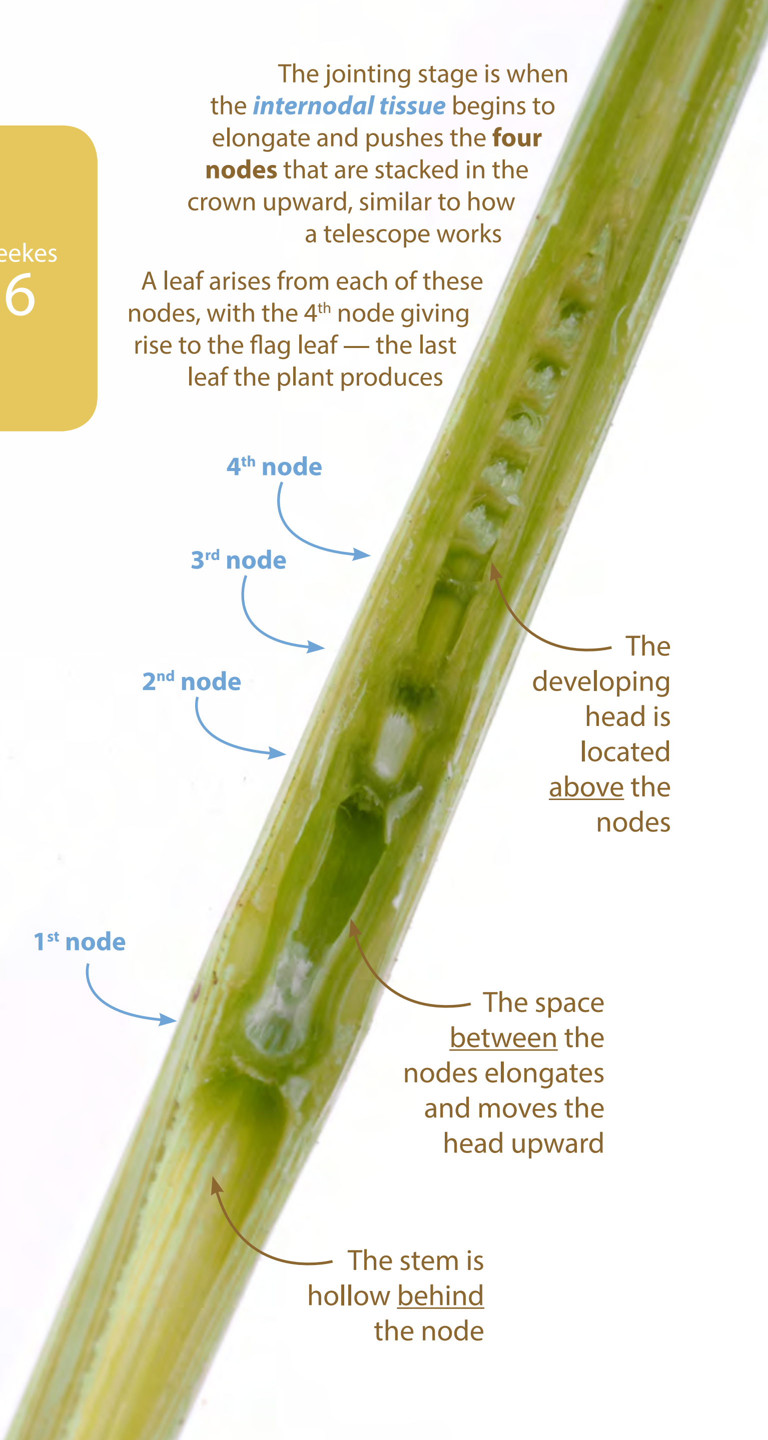
Feekes
6


**A node** is an area of active cell division from which leaves, tillers and adventitious roots develop

Feekes
6

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



## Feekes 6


Feekes 6 plant shown with all leaves intact

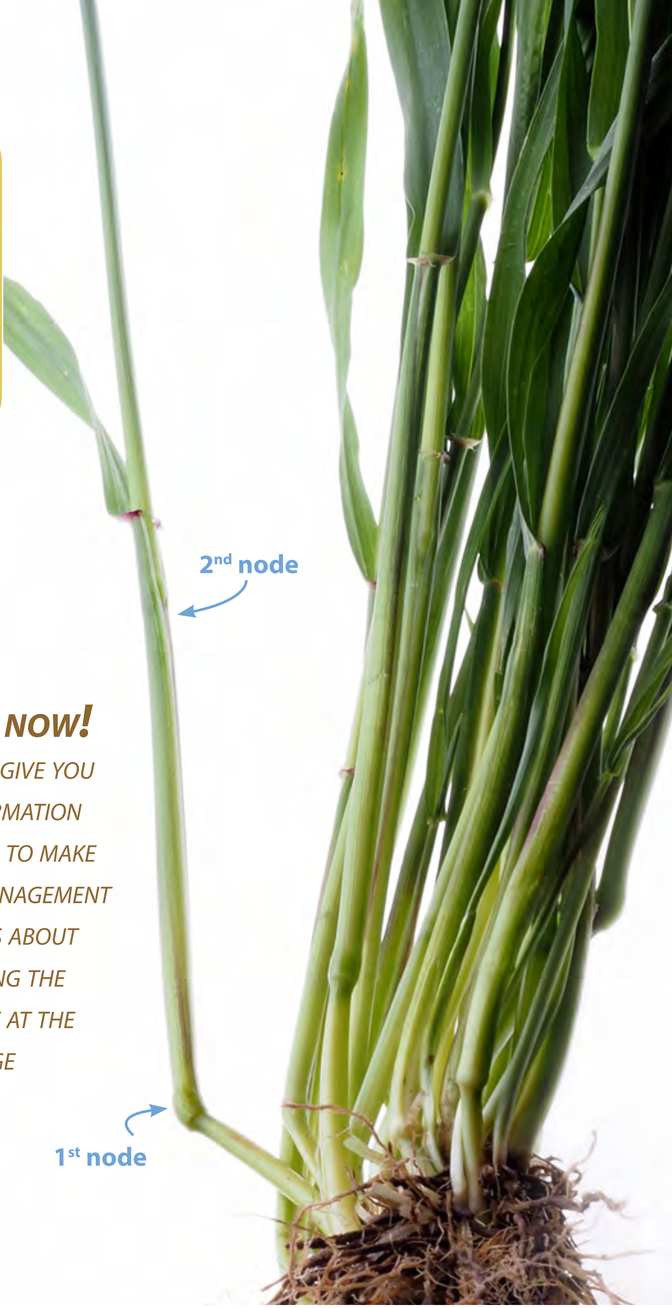
*From this growth stage forward,* ***broken stems due to wheel traffic will result in yield loss!***

*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*

**KEY YIELD COMPONENT**

Feekes
7



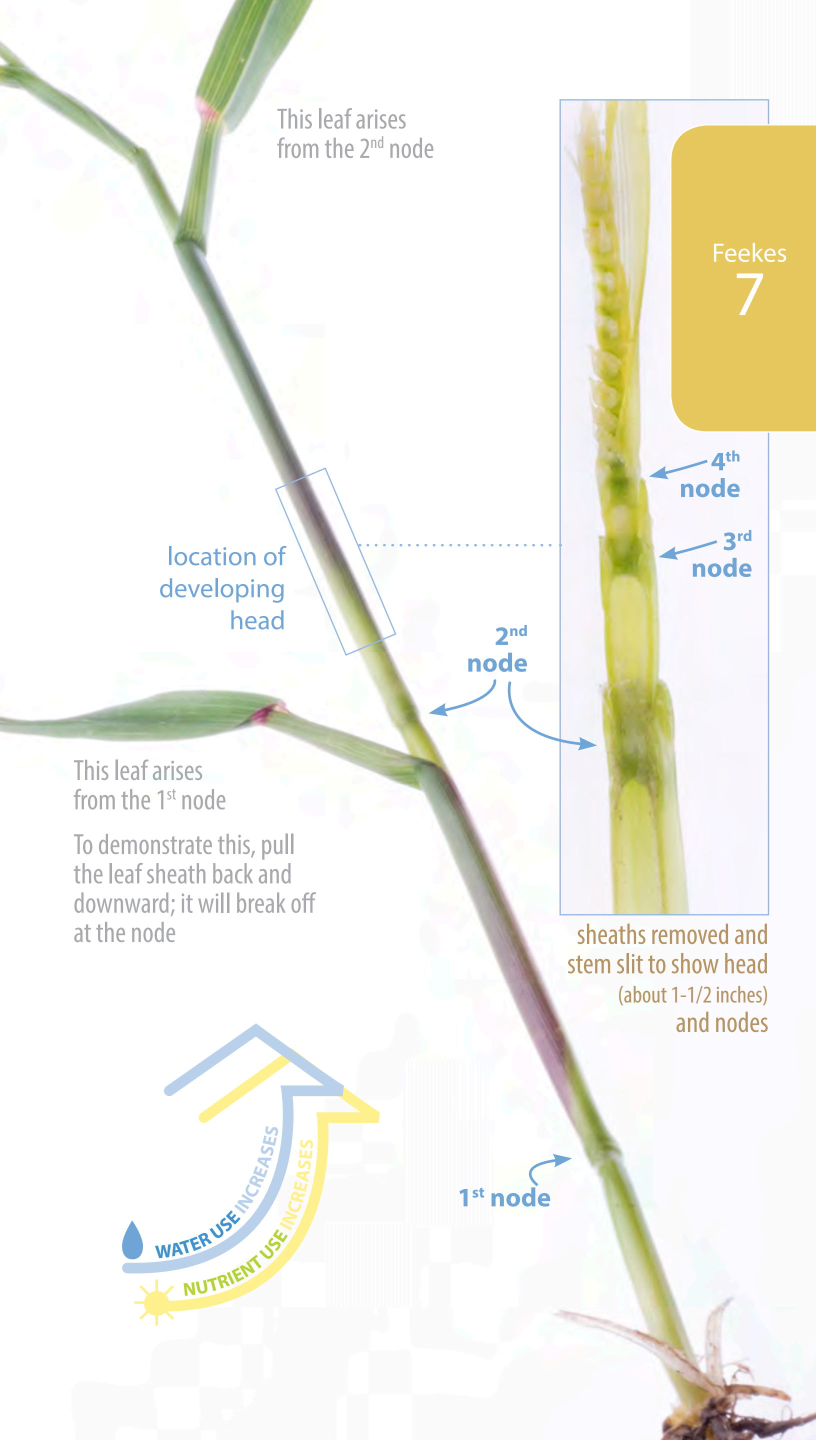

***SCOUT NOW!***

*THIS WILL GIVE YOU THE INFORMATION YOU NEED TO MAKE GOOD MANAGEMENT DECISIONS ABOUT PROTECTING THE FLAG LEAF AT THE NEXT STAGE*

Zadoks 32

STEM EXTENSION | **Feekes 7** | Two nodes visible above the soil line

# Feekes 7


This leaf arises from the 2nd node
location of developing head
4th node
3rd node
2nd node
sheaths removed and stem slit to show head (about 1-1/2 inches) and nodes
This leaf arises from the 1st node
To demonstrate this, pull the leaf sheath back and downward; it will break off at the node
1st node
WATER USE INCREASES
NUTRIENT USE INCREASES


Feekes
8

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**

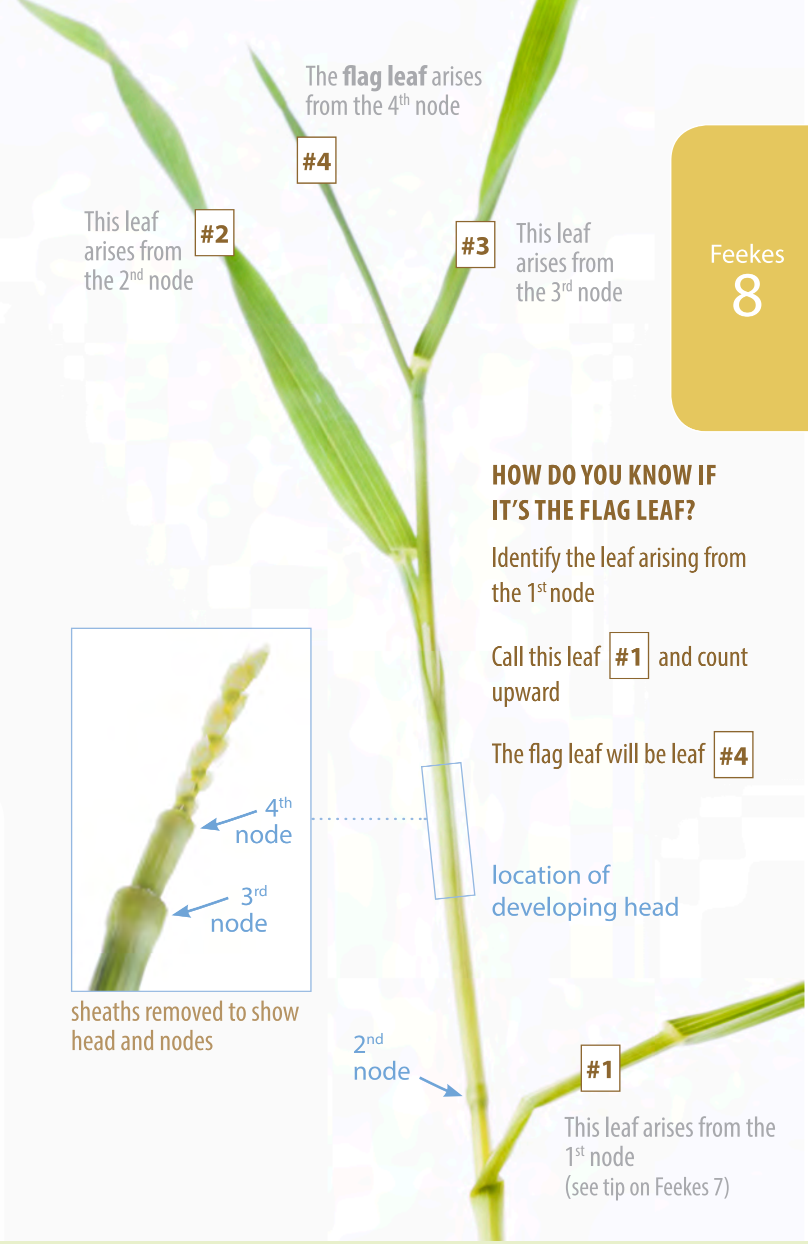
It must be protected from disease or insect damage to ensure the plant's full yield potential

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

Zadoks 37

STEM EXTENSION | **Feekes 8** | Flag leaf visible, still rolled up

# Feekes 8




sheaths removed to show head and nodes

## 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*

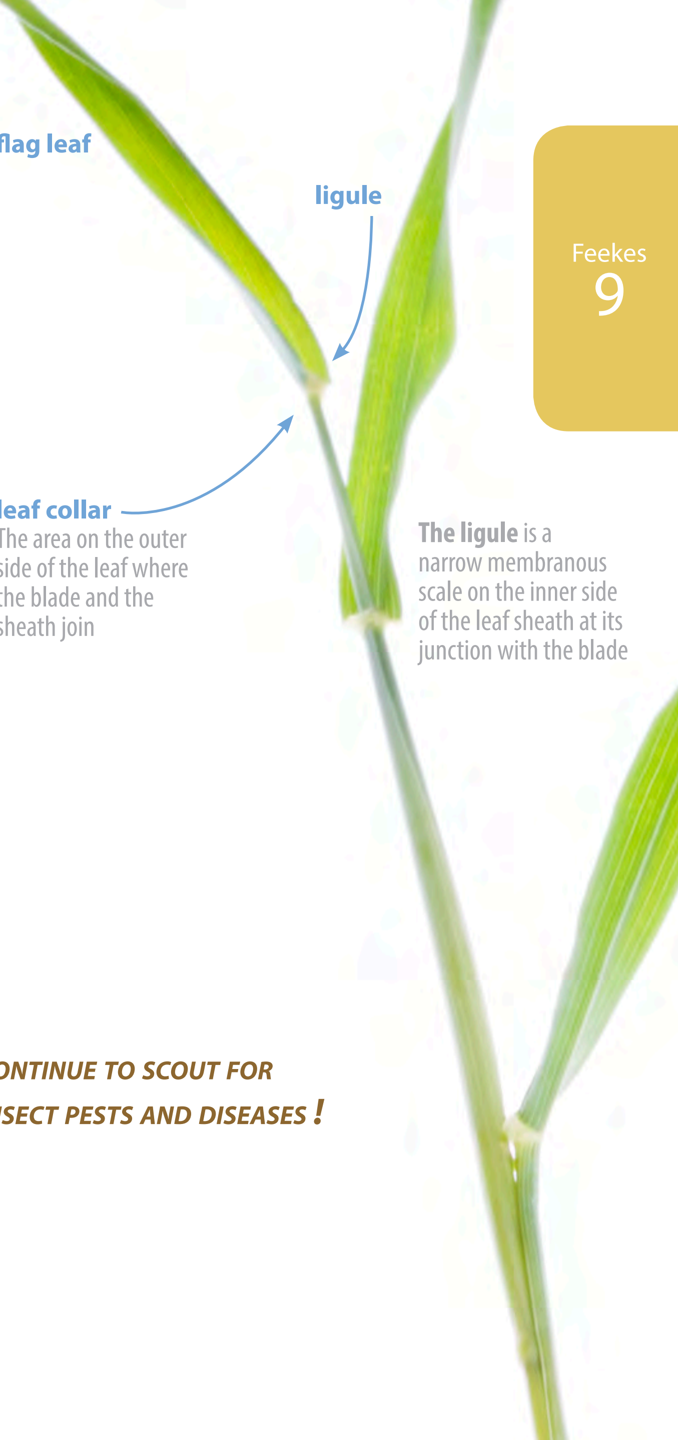
**KEY YIELD COMPONENT**

Feekes 9

Zadoks 39

STEM EXTENSION | **Feekes 8 |** Flag leaf fully emerged from the whorl; ligule just visible

Feekes 9



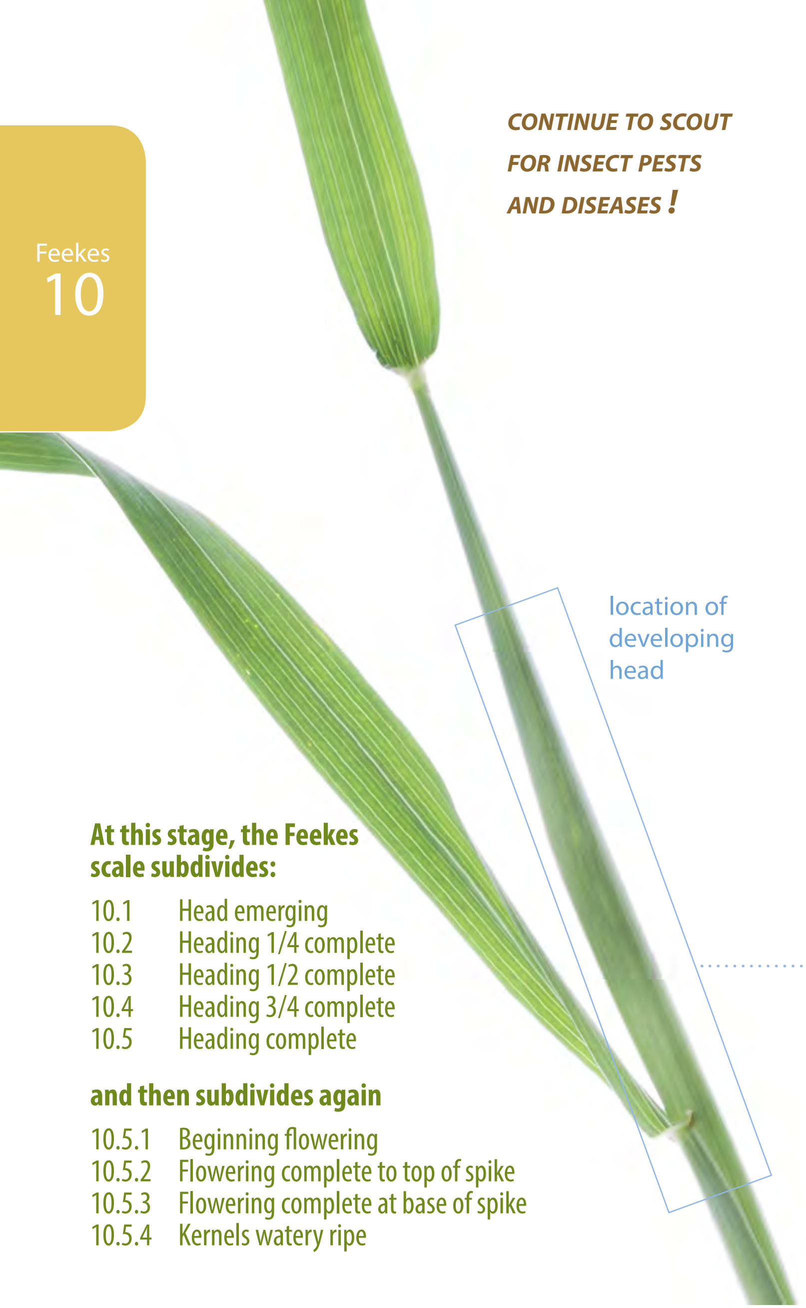

**leaf collar**
The area on the outer side of the leaf where the blade and the sheath join

**The ligule** is a narrow membranous scale on the inner side of the leaf sheath at its junction with the blade

***CONTINUE TO SCOUT FOR INSECT PESTS AND DISEASES!***

Feekes
10

***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 |

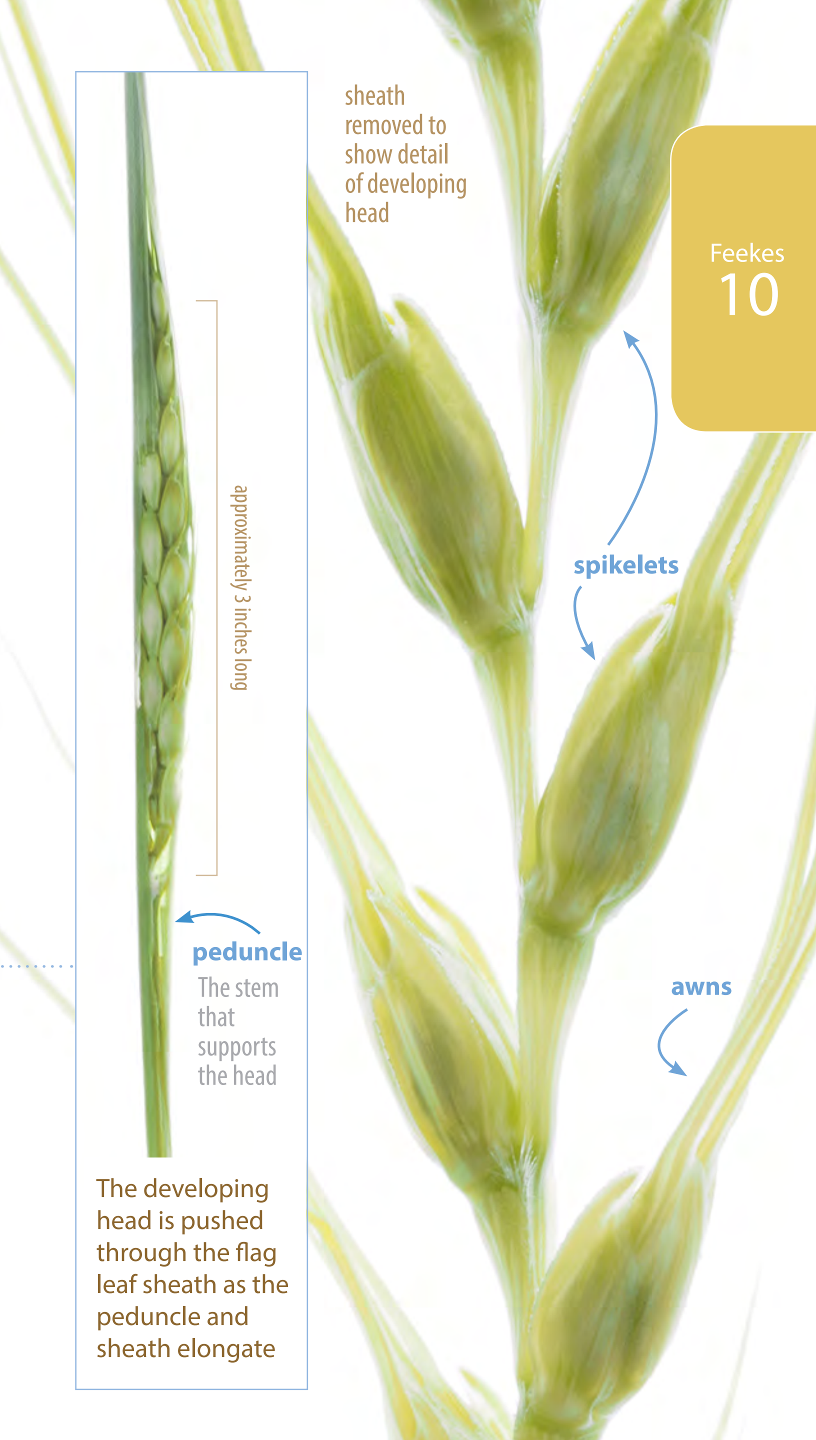
**and then subdivides again**

| | |
|---|---|
| 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 |

Zadoks 45

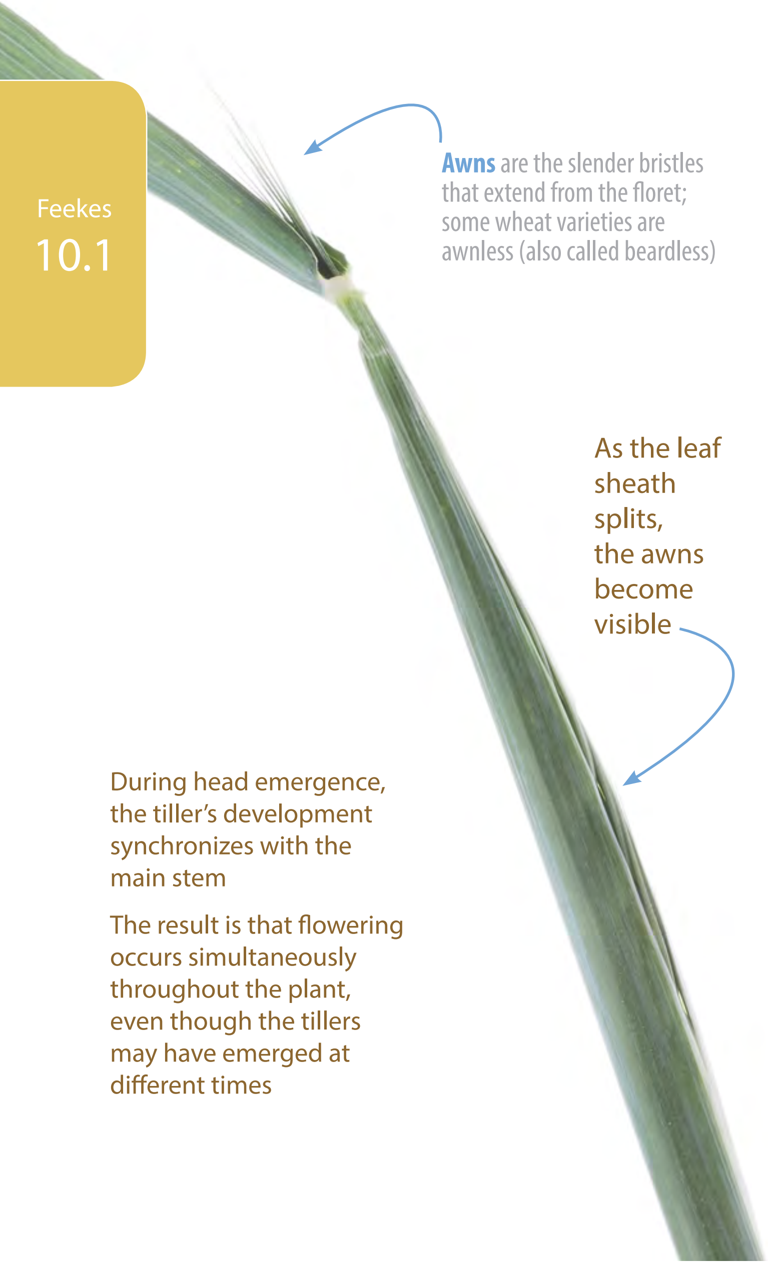
STEM EXTENSION | **Feekes 9** | Flag leaf sheath completely grown out; head visible in the leaf sheath; booting

# Feekes 10




The developing head is pushed through the flag leaf sheath as the peduncle and sheath elongate

## Feekes 10.1




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

Zadoks 50

HEADING | **Feekes 10.1** | First awns of the head just visible

When determining the growth stage of a field, ***50% of the plants*** must be at that stage or above

Feekes
10.1

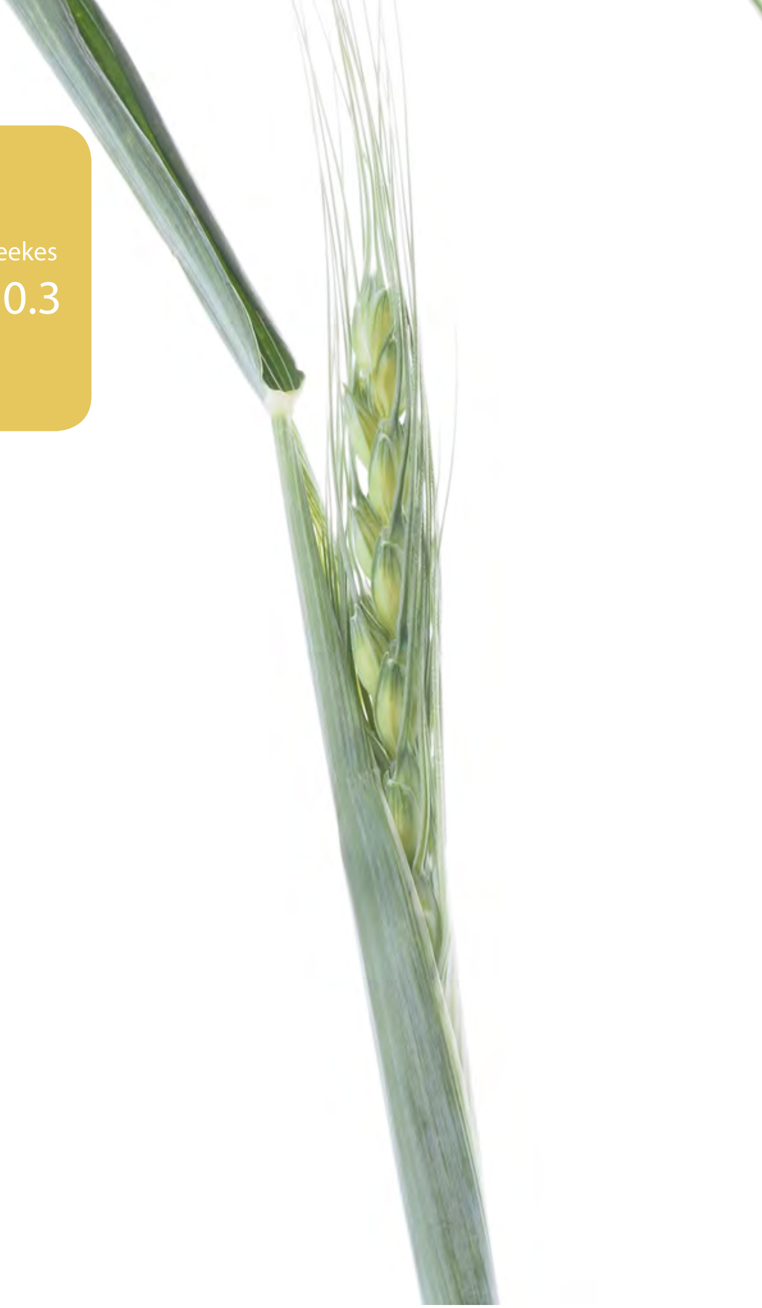

Zadoks 53

HEADING | **Feekes 10.2 |** 1/4 of the head emerged from the leaf sheath


sheaths removed to show developing heads

Feekes

10.3

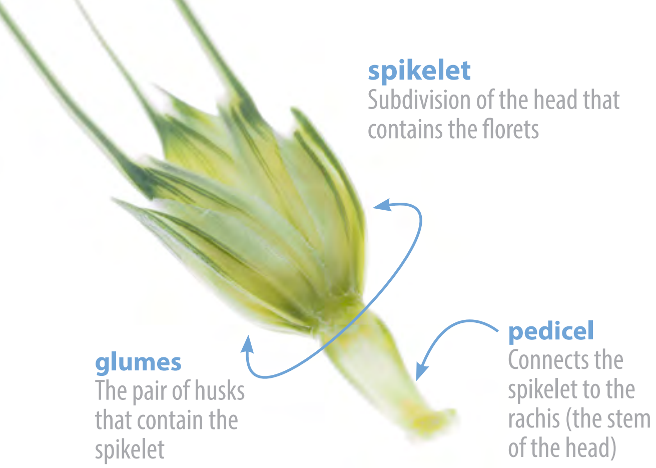


Zadoks 55

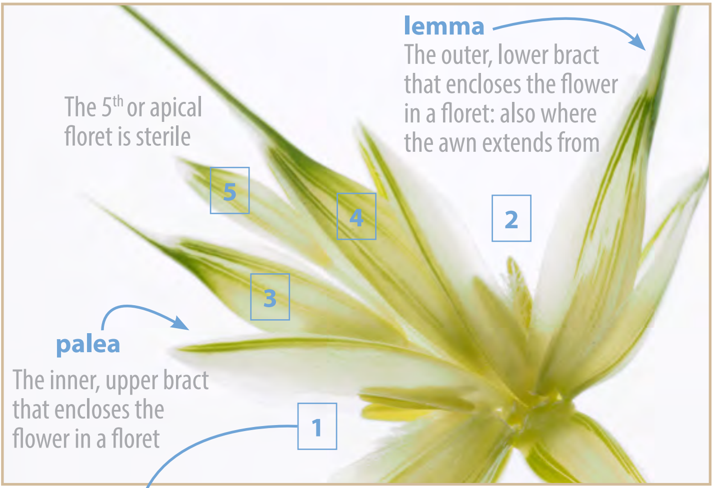
HEADING | **Feekes 10.3 |** 1/2 of the head emerged from the leaf sheath

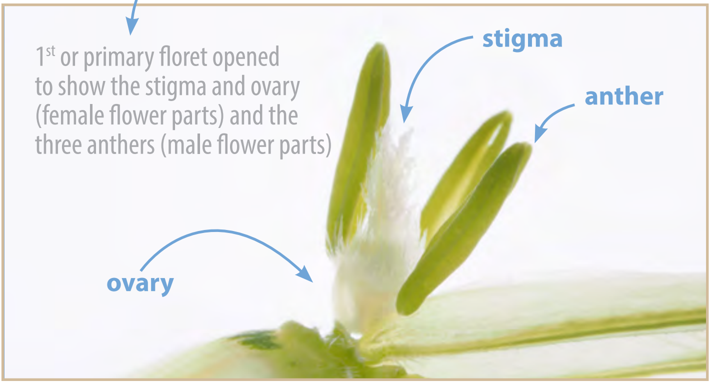
Feekes

10.3




spikelet opened to show detail



Feekes
10.4

Zadoks 57

HEADING | **Feekes 10.4** | 3/4 of the head emerged from the leaf sheath

Feekes

10.4

head lifted out of sheath to show elongating peduncle


Zadoks 59

HEADING | **Feekes 10.5** | Head completely emerged from the leaf sheath

This stage completes the heading process

Feekes

10.5

Feekes

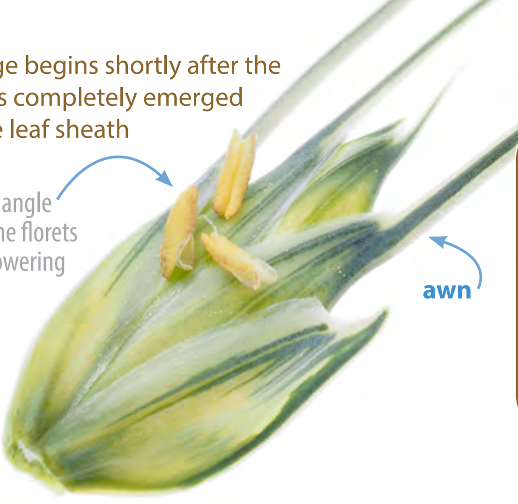
10.5.1

*Flowering begins slightly above the middle portion of the head and continues towards the top*

*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*

## Feekes 10.5.1

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




*The number of **flowers pollinated** determines the number of **kernels that will develop***

**KEY YIELD COMPONENT**

Feekes
10.5.2

The ***developing head*** is still vulnerable to freeze injury during low temperatures

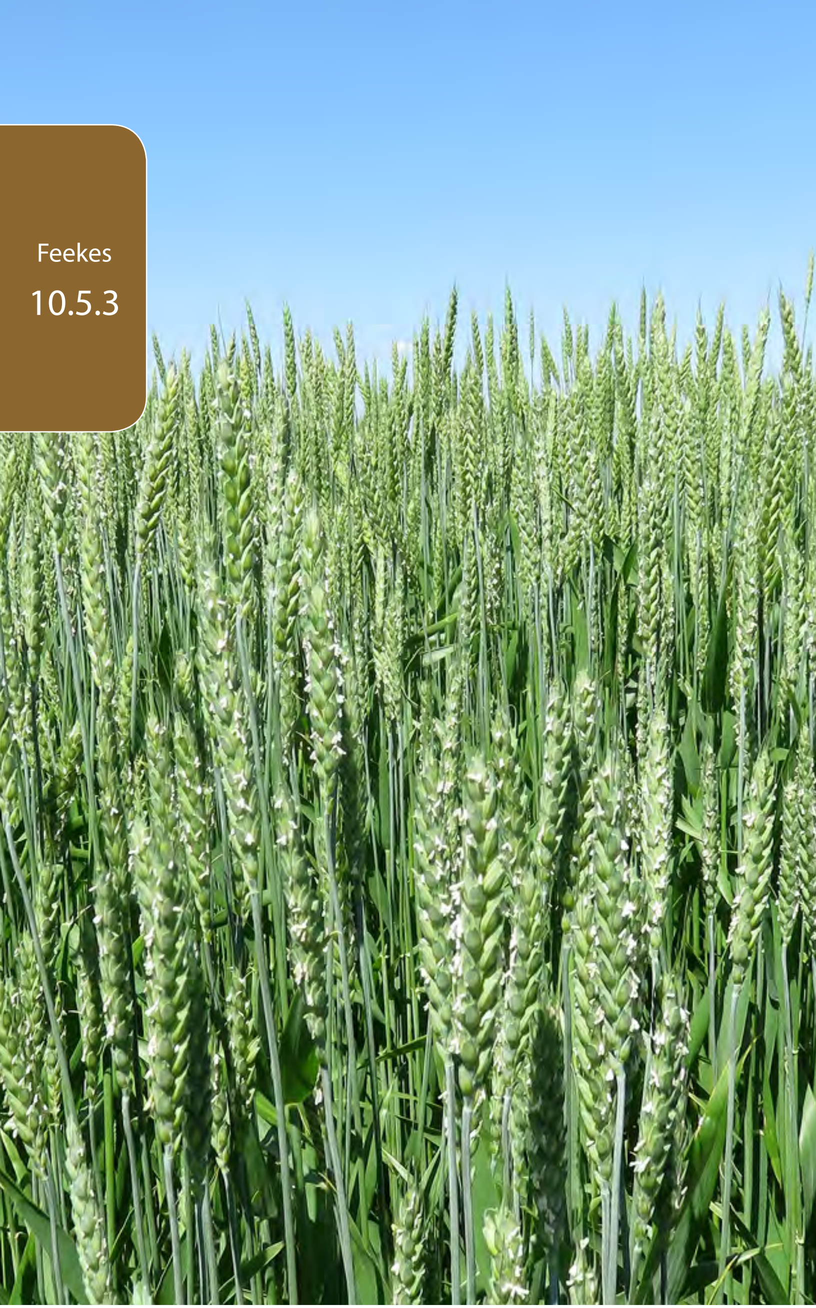
*Flowering continues toward the base*

FLOWERING | **Feekes 10.5.2 |** Flowering complete to the top of the head

Feekes 10.5.2

**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



Feekes

10.5.3

Zadoks 69

FLOWERING | **Feekes 10.5.3 |** Flowering complete at the base of the head

This stage signals the end of pollination

Feekes

10.5.3

floret outer structure removed to show developing kernel

This is the beginning of the **grain filling stages**; kernel length is established during this stage

Feekes

10.5.4

Zadoks 71

FLOWERING | **Feekes 10.5.4** | Flowering complete; kernel watery ripe

Feekes

10.5.4

When squeezed, ***clear fluid*** is released from the kernel

developing kernel with desiccated anthers still attached

***Kernel size increases*** but not dry matter accumulation


Zadoks 75

RIPENING | **Feekes 11.1 | Kernel milky ripe; milk stage**

Feekes
11.1

**Dry matter accumulates**
in the kernel

When squeezed,
***milk-like fluid***
is released from
the kernel

Feekes
11.2

Zadoks 85

RIPENING | **Feekes 11.2** | Kernel mealy ripe; soft but dry consistency; soft dough stage

# Feekes 11.2

Green color of the kernel, glume and peduncle begins to fade

## *Starch, nutrients and dry matter*

accumulate rapidly in the kernel

The kernel's content is a soft-doughy material

Feekes

11.3

Zadoks 91

RIPENING | **Feekes 11.3** | Kernel hard; difficult to divide with a thumbnail; hard dough stage

Feekes 11.3

Kernels reach their ***maximum dry weight*** and are ***physiologically mature***

Kernel moisture decreases from 40% to 30%

Feekes
11.4

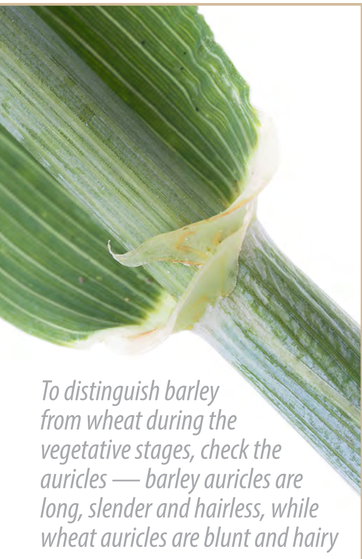
Kernel moisture decreases from 30% to 15%

Zadoks 92

RIPENING | **Feekes 11.4** | Kernel harvest ready; straw dead

Green plant tissue fades to *straw*

Feekes 11.4



*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

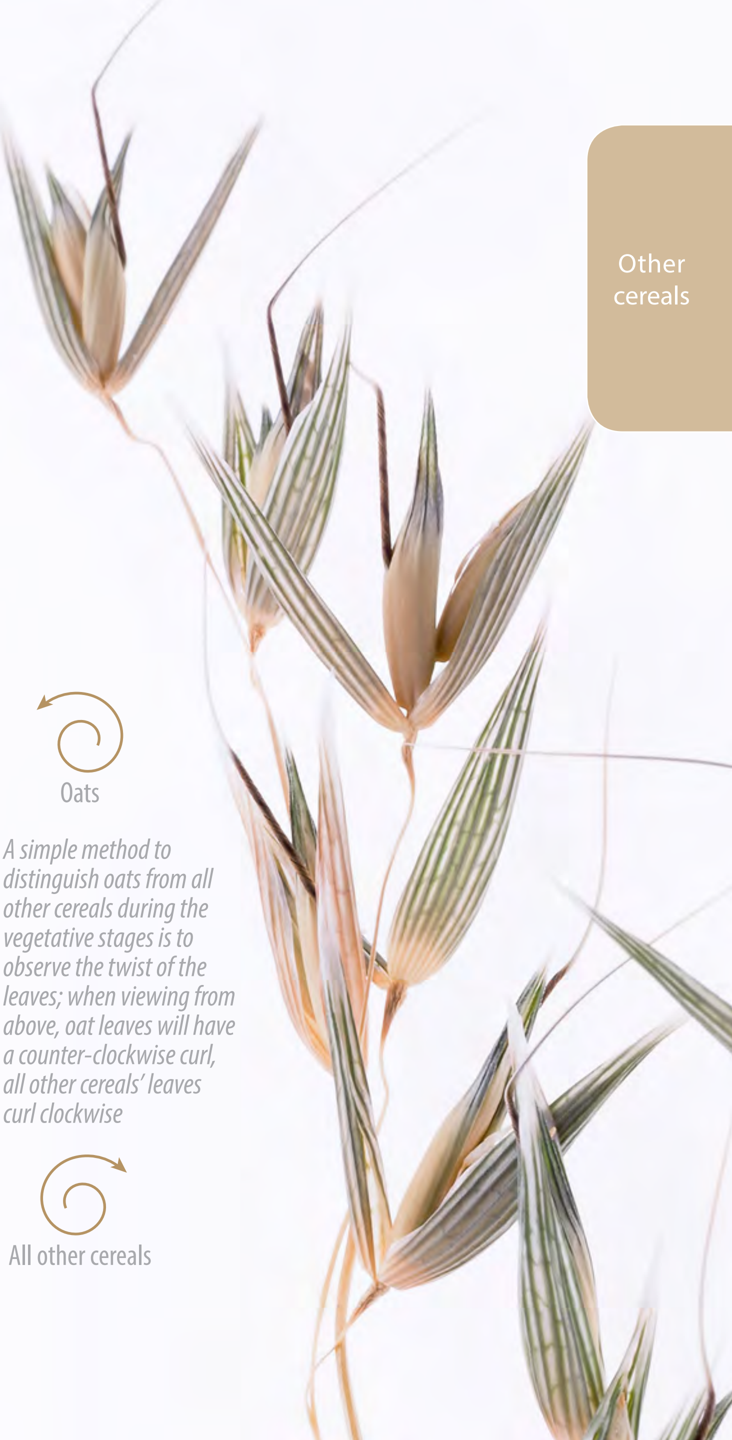
Auricles long, slender and hairless; leaf sheath and blade usually hairless (scattered hairs on some varieties); ligule medium length; leaf blades twist clockwise

# Other cereals

*To distinguish oats from wheat during the vegetative stages, check the auricles — oats lack auricles, while wheat auricles are blunt and hairy*

# Oats

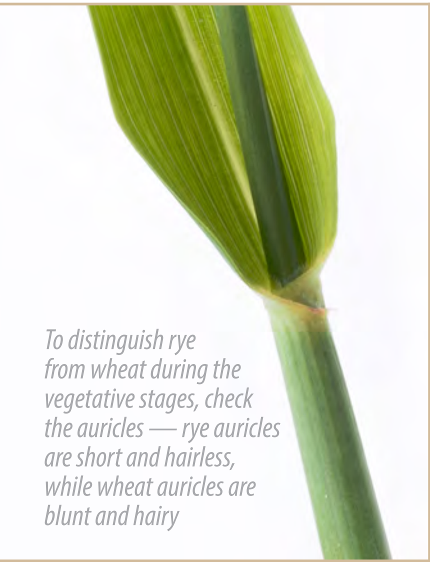
Auricles absent; leaf sheath and blade hairless (scattered hair on some varieties); ligule medium length; leaf blades twist  counter-clockwise



Oats

*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*

All other cereals



*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

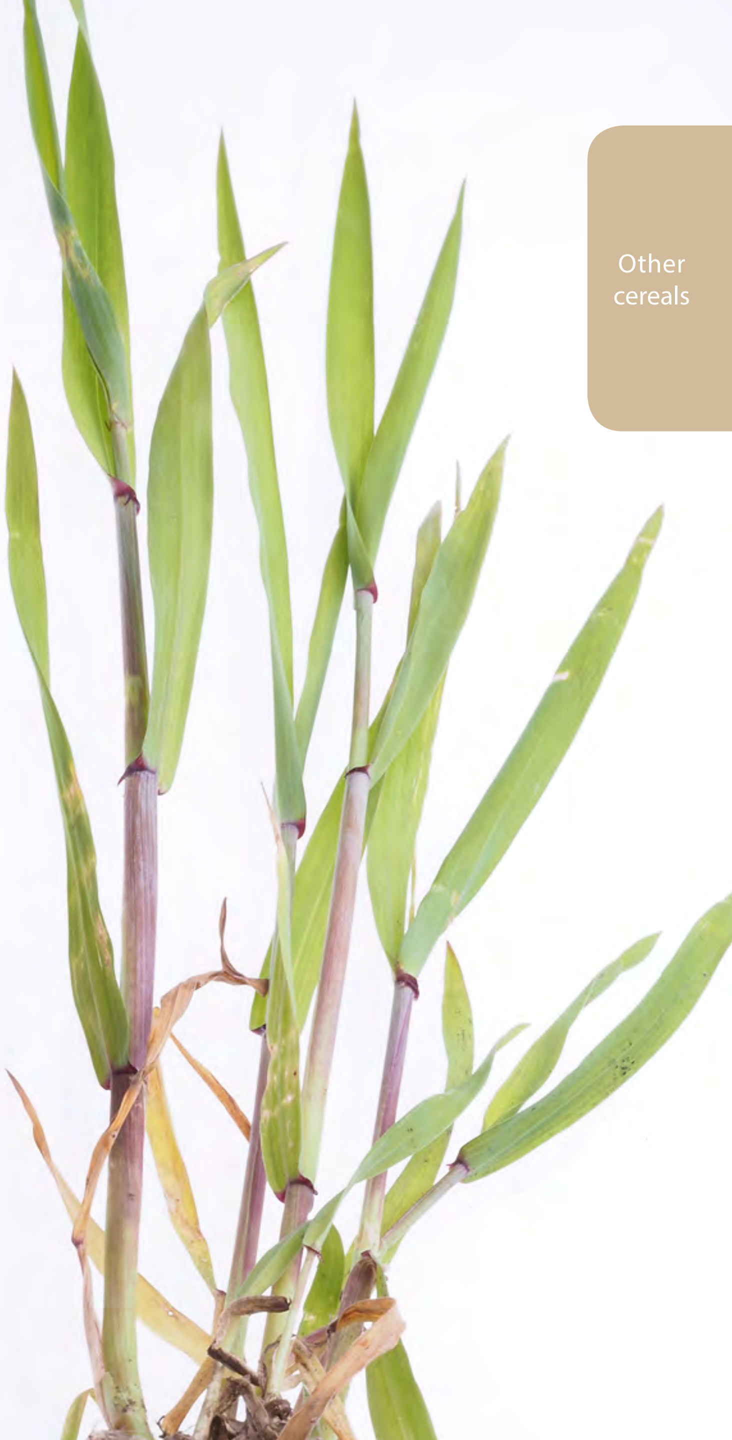
# Other cereals

*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



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