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 and 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

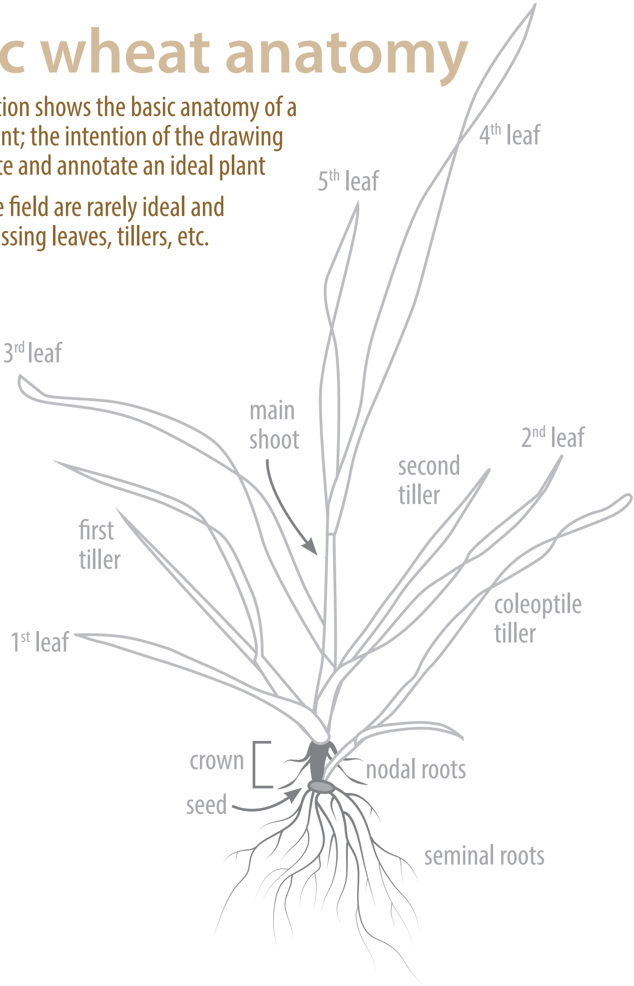
Feekes, Willem (1941). *De tarwe en haar milieu* [*Wheat and its environment*]. Verslagen van de Technische Tarwe Commissie. (in Dutch (English summary)). 17: 523–888.

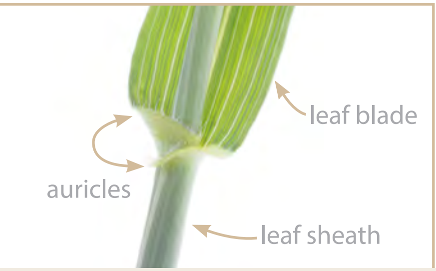
J.C. Zadoks, T.T. Chang, C.F. Konza. *A Decimal Code for the Growth Stages of Cereals.* Weed Research 1974 14:415-421.

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

Zadoks scale for cereal growth stages

Stage	Code	Description	Phase	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	TILLERING	
	13	3 leaves unfolded	TILLERING	
	14	4 leaves unfolded	TILLERING	
	15	5 leaves unfolded	TILLERING	
	16	6 leaves unfolded	TILLERING	
	17	7 leaves unfolded	TILLERING	
	18	8 leaves unfolded	TILLERING	
	19	9 or more leaves unfolded	TILLERING	
Tillering	20	Main shoot only	TILLERING	
	21	Main shoot and 1 tiller	TILLERING	2
	22	Main shoot and 2 tillers	TILLERING	
	23	Main shoot and 3 tillers	TILLERING	
	24	Main shoot and 4 tillers	TILLERING	
	25	Main shoot and 5 tillers	TILLERING	
	26	Main shoot and 6 tillers	TILLERING	3
	27	Main shoot and 7 tillers	TILLERING	
	28	Main shoot and 8 tillers	TILLERING	
	29	Main shoot and 9 or more tillers	TILLERING	
Stem elongation	30	Pseudostem erection	TILLERING	4-5
	31	1st node detectable	STEM EXTENSION	6
	32	2nd node detectable	STEM EXTENSION	7
	33	3rd node detectable	STEM EXTENSION	
	34	4th node detectable	STEM EXTENSION	
	35	5th node detectable	STEM EXTENSION	
	36	6th node detectable	STEM EXTENSION	
	37	Flag leaf just visible	STEM EXTENSION	8
	39	Flag leaf ligule/collar just visible	STEM EXTENSION	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 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

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

The ***seminal roots*** begin developing

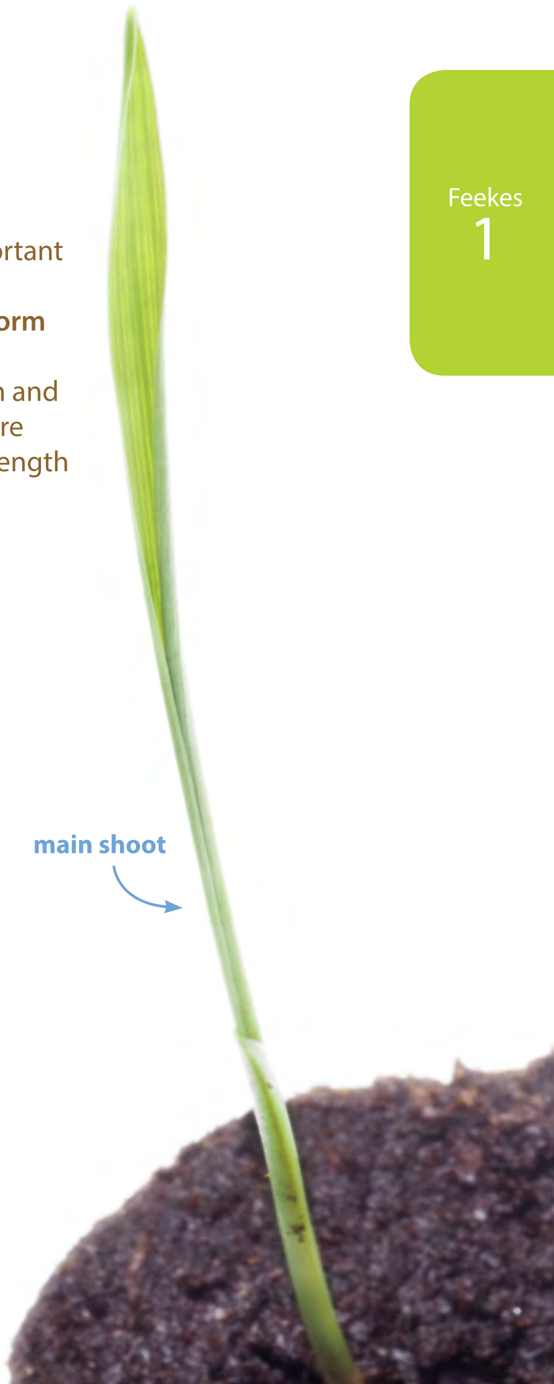
Seminal roots are fibrous and are produced by the seed

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

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; not 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

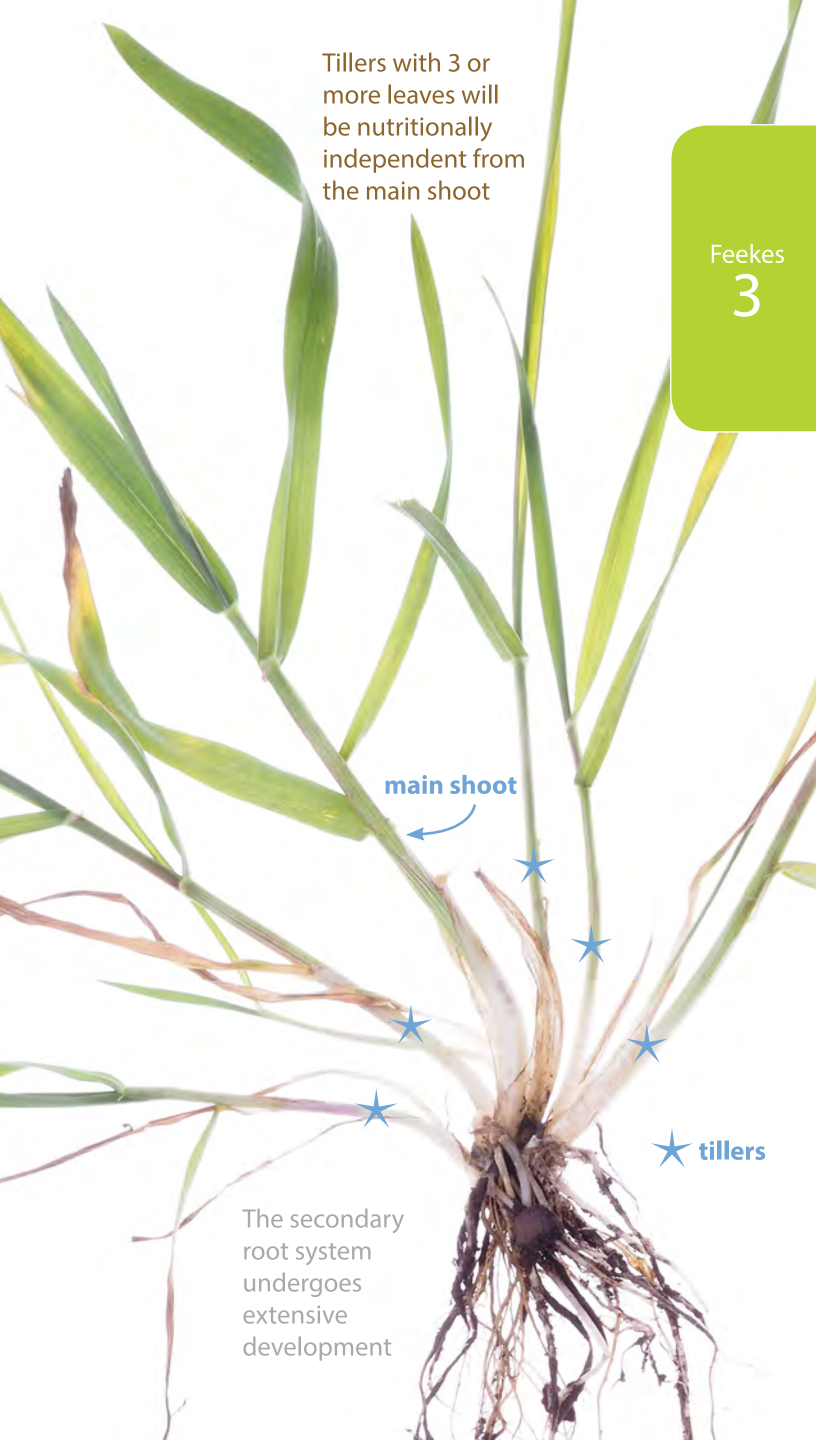
A **tiller** is capable of forming a single head (spike)
The **head** is made up of spikelets
Each **spikelet** contains individual florets
Individual **florets** can produce a single **kernel**

In Wisconsin, the recommended planting date range for optimal tiller development in winter wheat is **September 20** to **October 10**

Feekes
3

Zadoks
22-29

TILLERING | **Feekes 3** | Tillering completed


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 CAN OCCUR IN FALL OR SPRING

because winter wheat development is dependent on both temperature and planting date

Feekes 3

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 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

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

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

Always check and follow herbicide labels

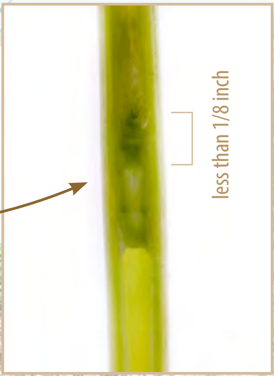
Feekes
5

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

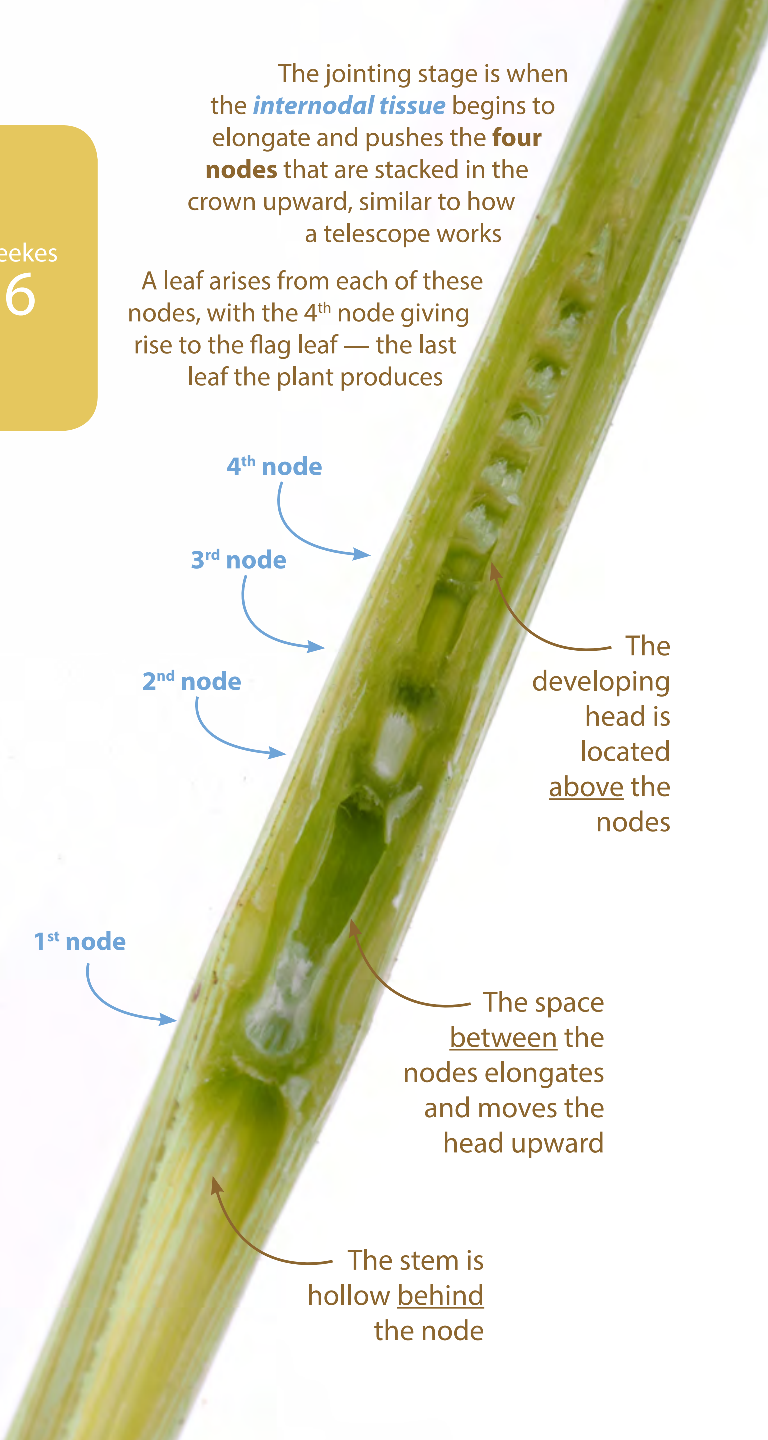
Feekes 6

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

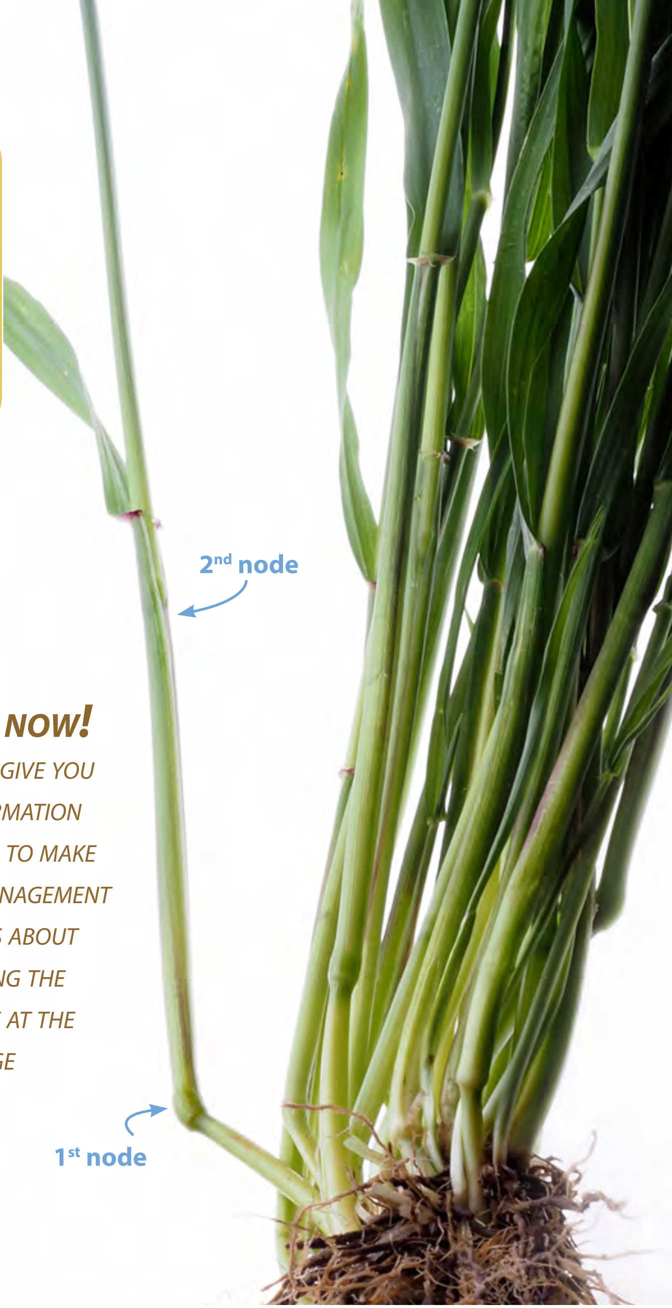
From this growth stage forward, ***broken stems due to wheel traffic will result in yield loss!***

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



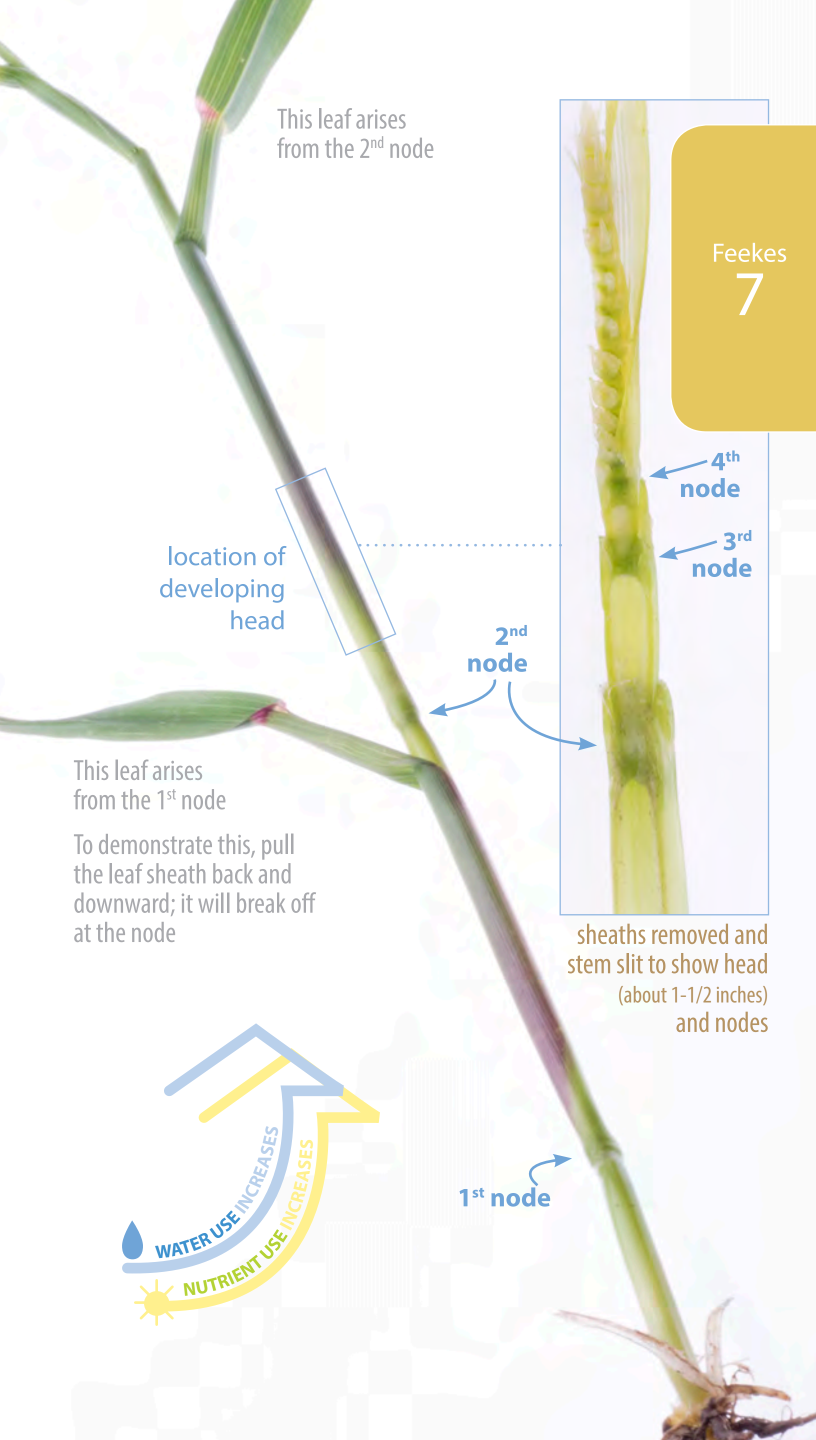
SCOUT NOW!

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
This leaf arises from the 1st 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
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**

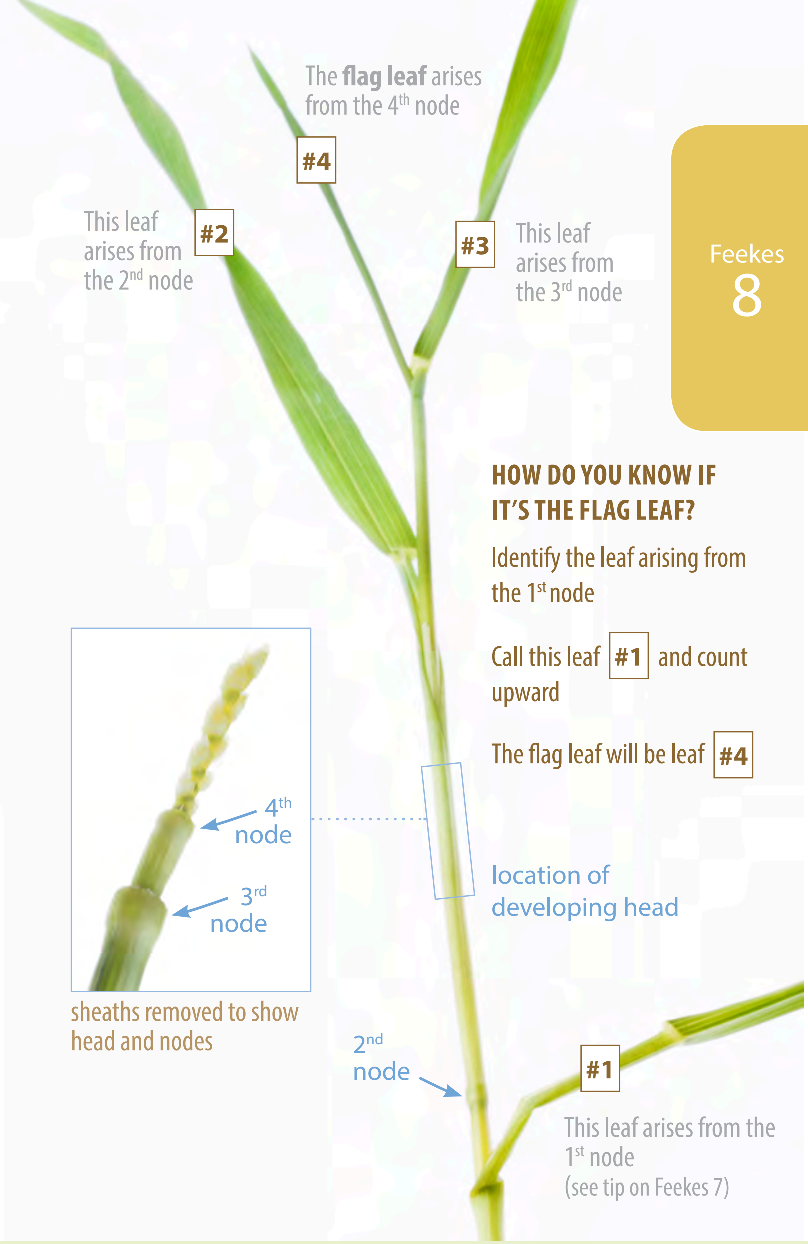
It must be protected from disease or insect damage to ensure the plant's full yield potential

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



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

sheaths removed to show head and nodes

***Kernel size** is determined by crop health and water/nutrient availability beginning now and continuing through grain fill*

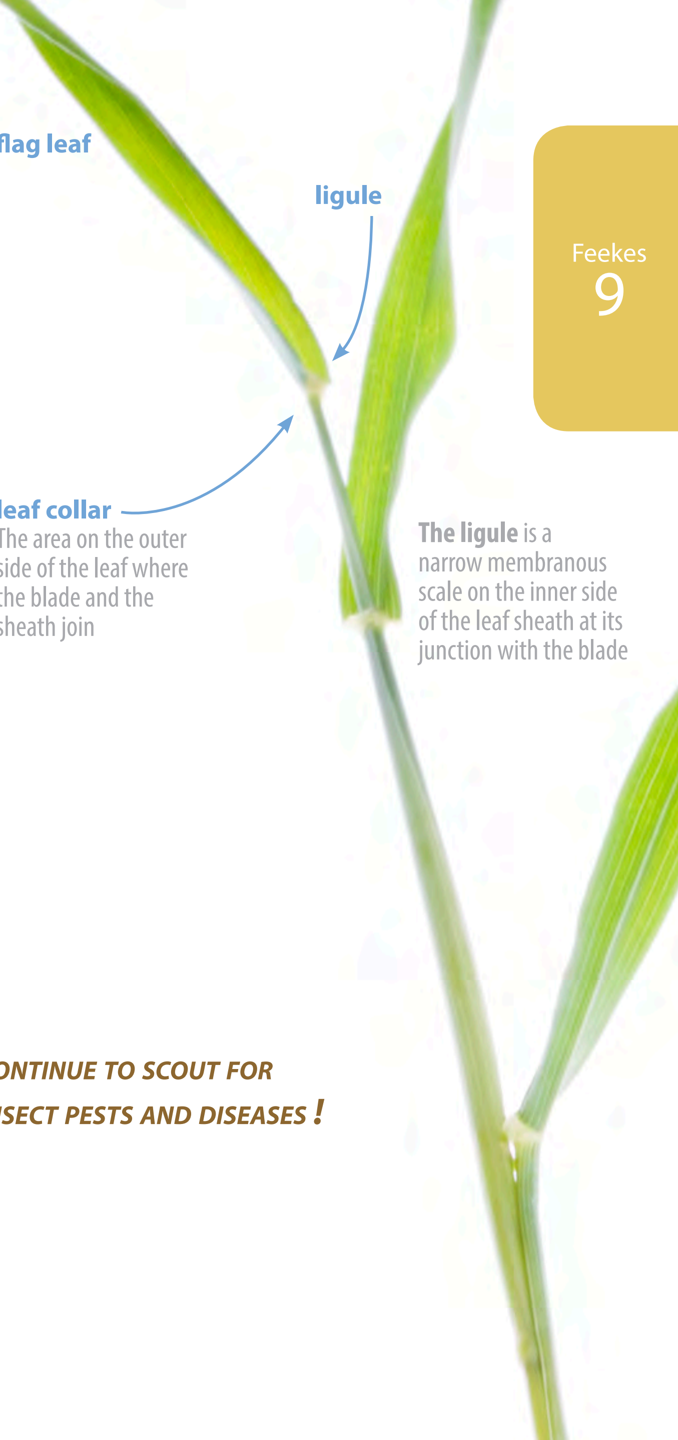
KEY YIELD COMPONENT

Feekes
9

Zadoks 39

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

Feekes 9



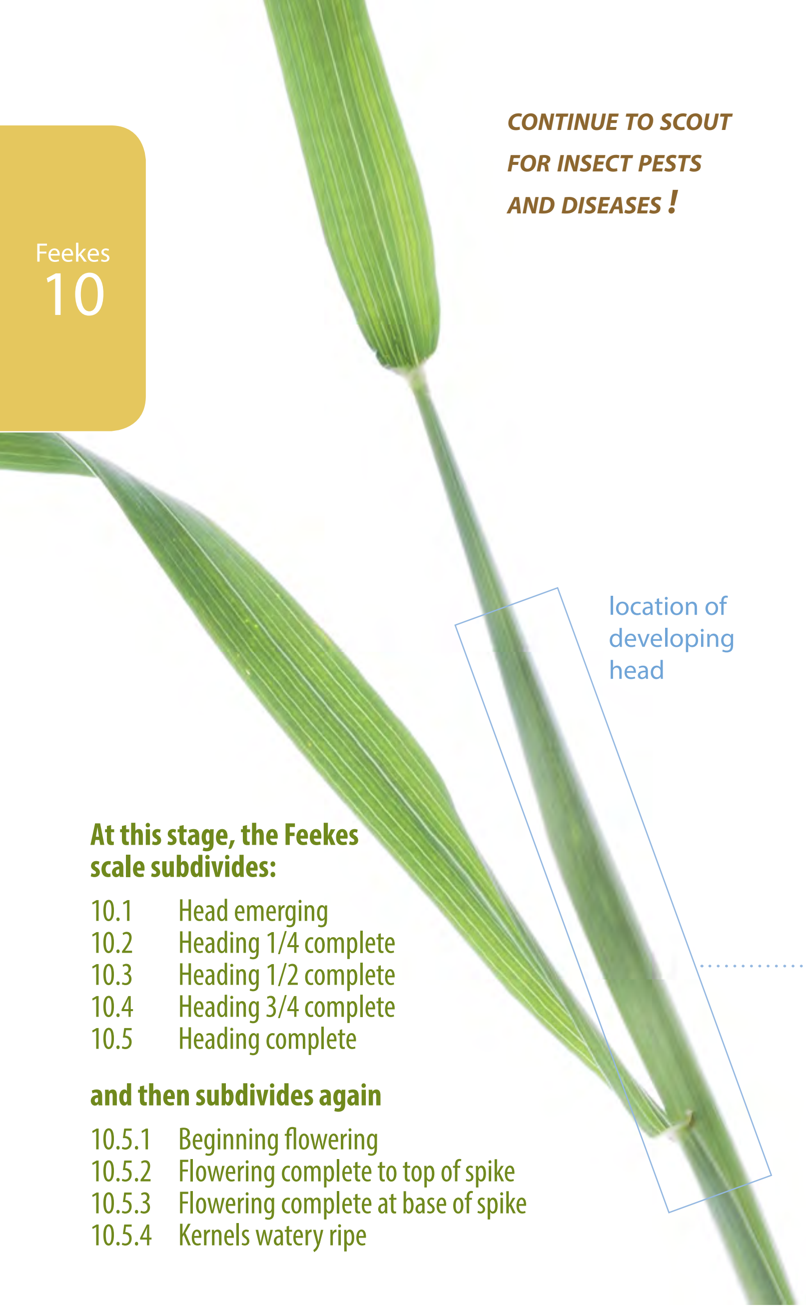
leaf collar
The area on the outer side of the leaf where the blade and the sheath join

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

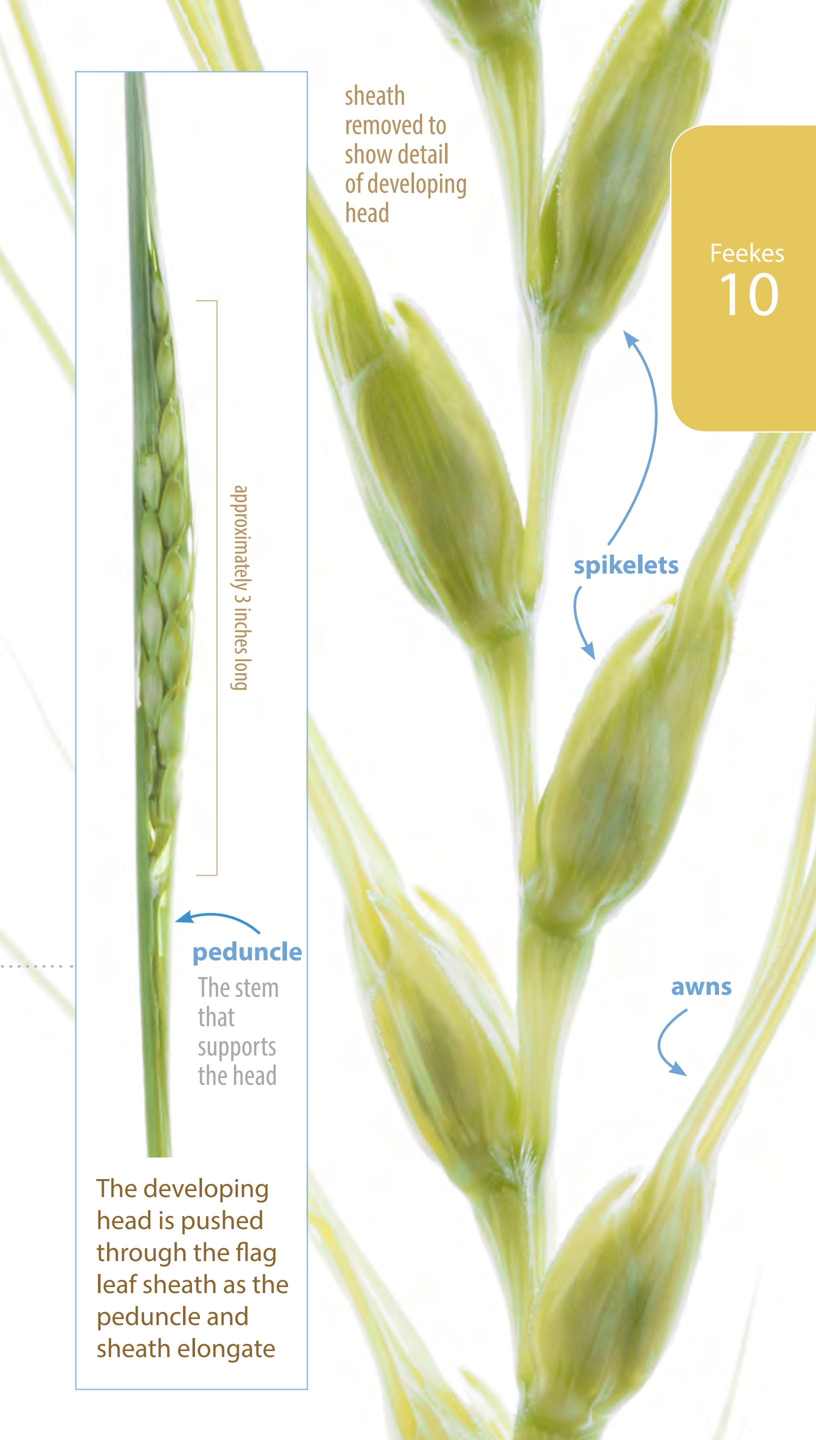
and then subdivides again

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

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

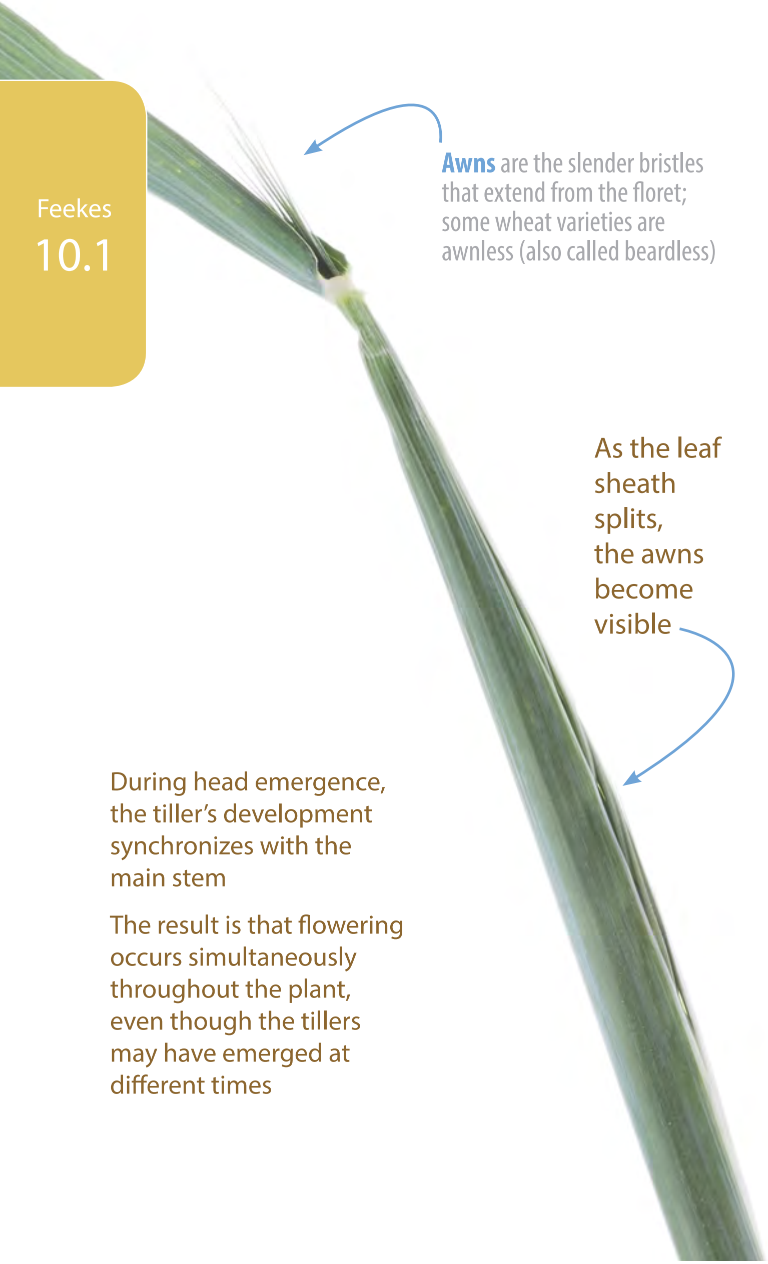
Zadoks 45

Feekes 10



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

Feekes
10.1



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

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

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

Zadoks 50

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

Feekes
10.2

Zadoks 53

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


Feekes 10.1
Feekes 10.2
sheaths removed to show developing heads

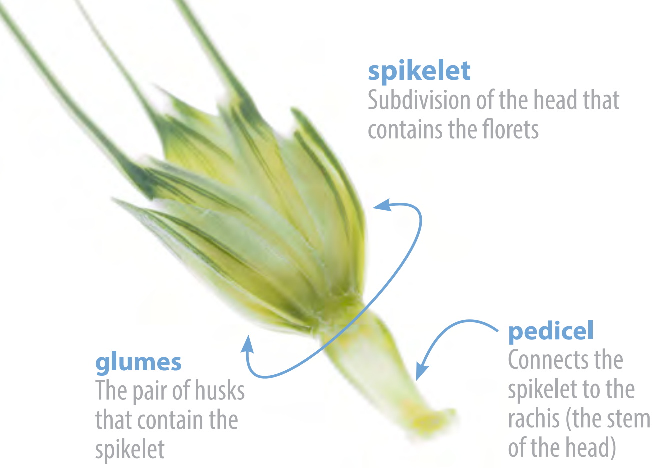
Feekes

10.3

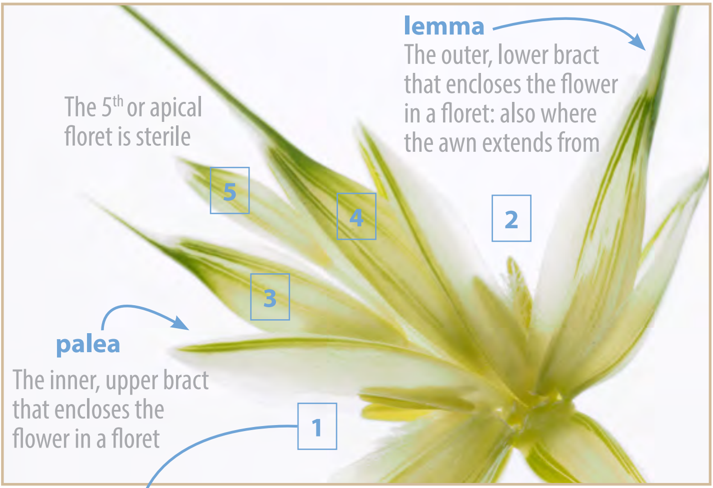
Zadoks 55

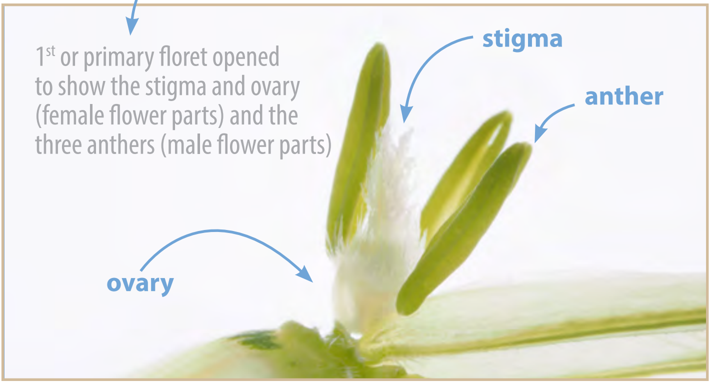
HEADING | **Feekes 10.3 |** 1/2 of the head emerged from the leaf sheath

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

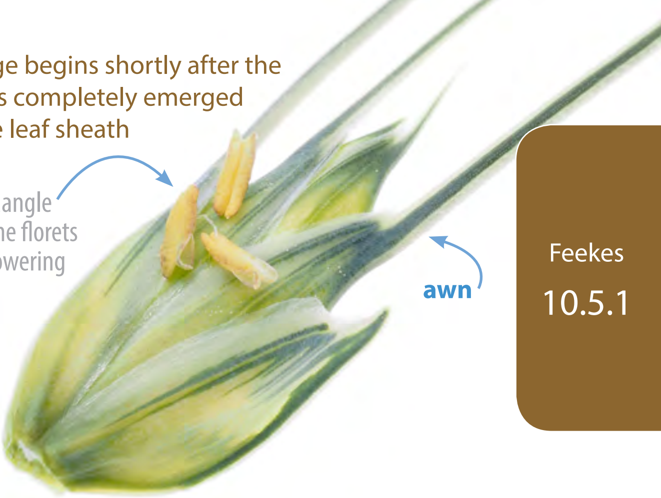
10.5.1

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

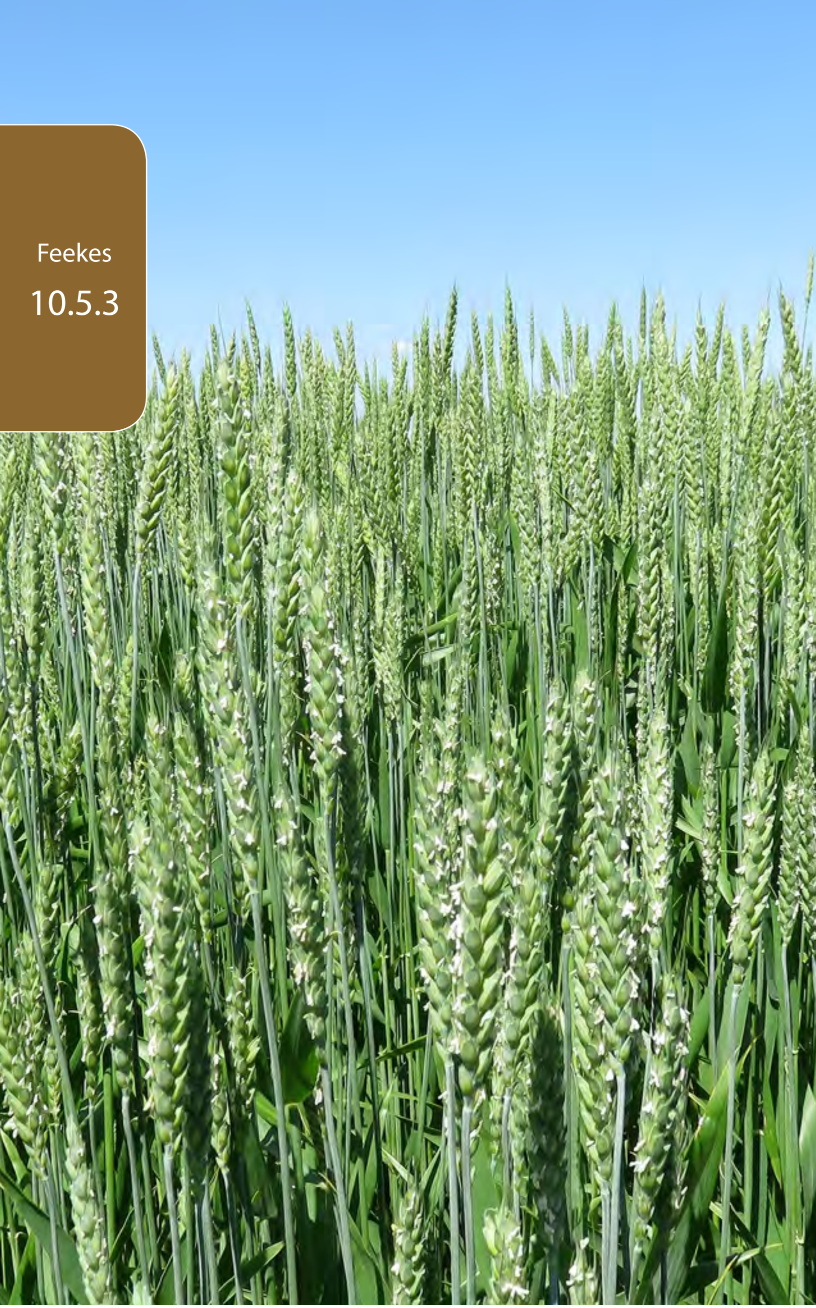
The ***developing head*** is still vulnerable to freeze injury during low temperatures

Flowering continues toward the base

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

Zadoks 65


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

Feekes

10.5.3

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

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

Feekes
11.1

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

Zadoks 91

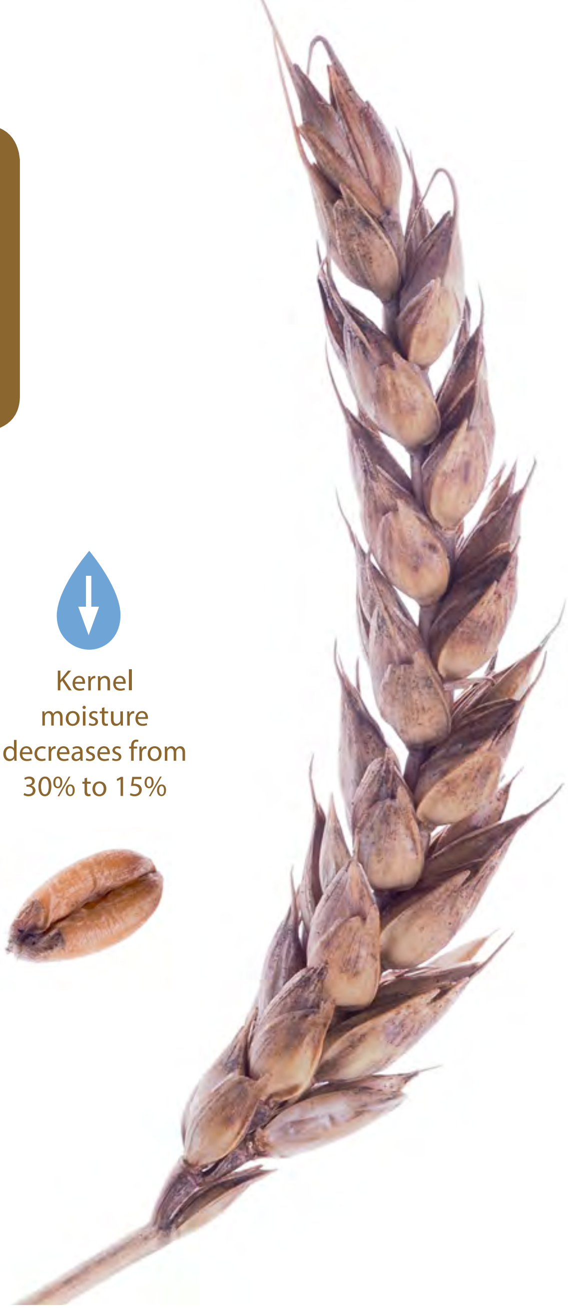
RIPENING | **Feekes 11.3** | Kernel hard; difficult to divide with a thumbnail; hard dough stage

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

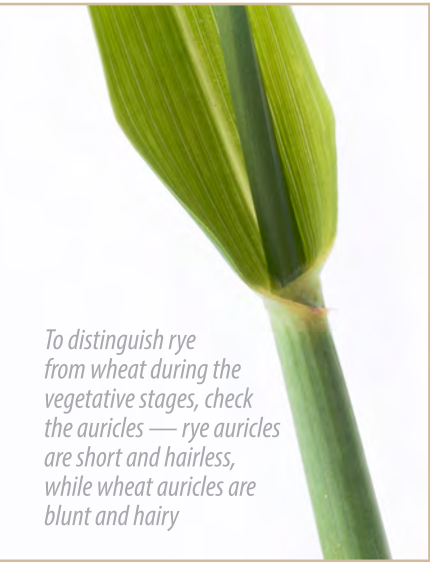
Oats

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

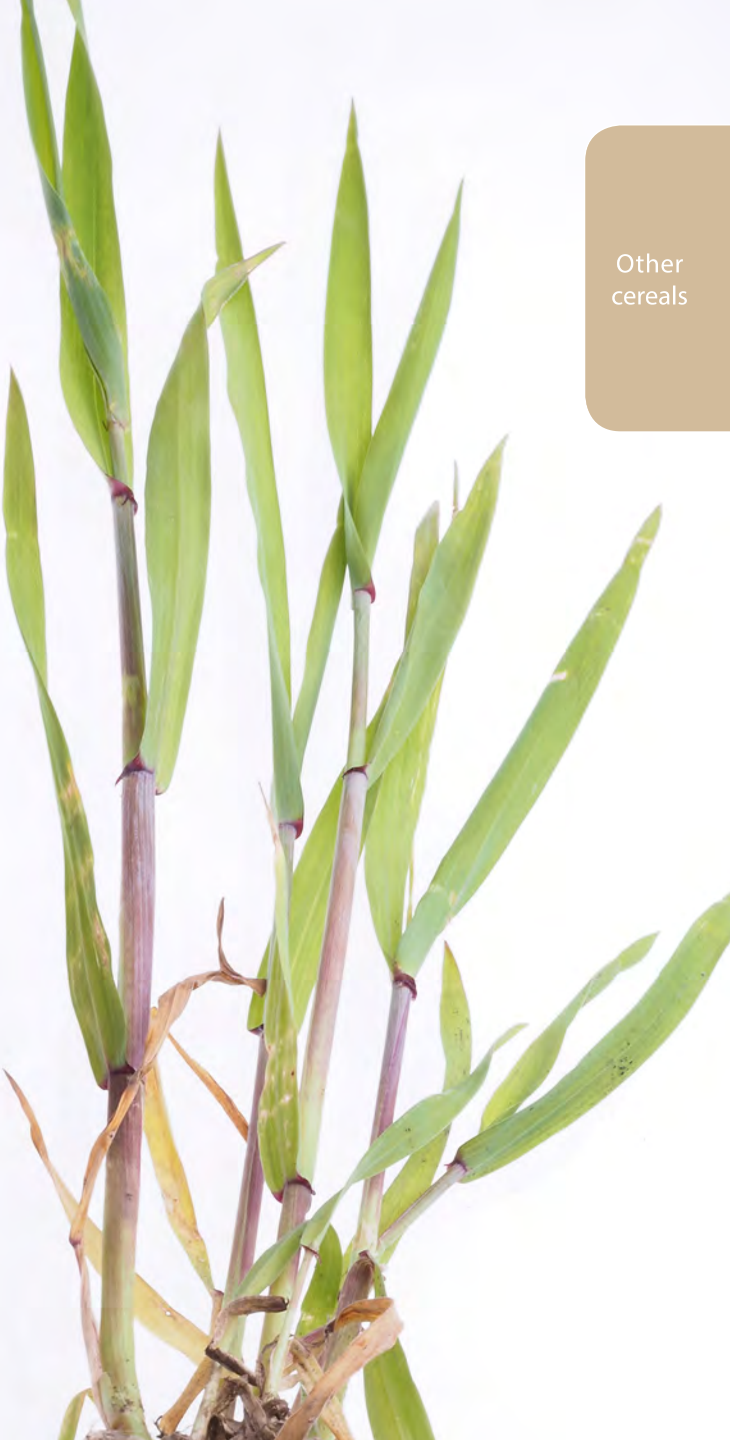
Other cereals

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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