UNIVERSITY OF WISCONSIN

VISUAL GUIDE TO CORN DEVELOPMENT

Extension
UNIVERSITY OF WISCONSIN–MADISON

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The Wisconsin Corn Growers Association (WCGA) works to create opportunities for Wisconsin corn growers' long-term profitability. It is an independent association that provides leadership development, grower education and lobbying efforts. With just over 750 members, the WCGA has a strong voice in Congress and the State Capitol, where it supports sound policy development and pro-farmer legislation.

The Wisconsin Corn Promotion Board is funded by a ½-cent-per-bushel assessment on all corn sold into commercial channels. It funds market development programs (promotion and education efforts, research initiatives and strategic initiatives to build corn demand), trade missions, U.S. Grains Council efforts and university research projects.

CONTENTS

This guide to corn development hopes to make the stages easy to understand by using clear, annotated images that highlight the details of what is happening in the plant and potentially make the connection to sound management practices. Toss it in the glovebox and use it when scouting fields!

The corn plants used were both greenhouse and field grown in south central Wisconsin using a 100–110 day relative maturity yellow dent hybrid with 20–21 leaves, silking at ~65 days after emergence and reaching maturity at ~60 days after silking.

Important note: *Although there are different types of corn (dent, flint, flour, popcorn, waxy, high-oil, pod and sweet), this guide focuses on dent hybrids. Much of the information can be applied to other types of corn, however, if you are considering growing other types, it is best to seek out information that takes into account their specific characteristics.*

Are development and growth the same thing?

Development and growth are often used interchangeably when staging plants, but they actually describe different processes.

Development is simply the progression of the plant through distinct stages, basically from a seed to the production of seed.

How this happens is through growth. **Growth** describes an increase in size and mass, which can be enhanced by favorable conditions or decreased by stressful ones. Conditions that favor corn growth include adequate moisture, nutrients, heat and sunlight.

When favorable growth conditions are lacking, development can be delayed or inhibited. Each development stage responds to stress in a predictable way so understanding development stages can provide insight into not only what's happening but what might happen.

What are the developmental stages?

The development stages used in this guide are those from the Leaf Collar Method, which starts with vegetative (V) stages and concludes with reproductive (R) stages.

During the **vegetative stages**, the plant maximizes the ability to absorb sunlight and therefore produce energy (carbohydrates) through photosynthesis. These carbohydrates are then utilized by the plant. Vegetative stages are noted with an uppercase V, starting with V1 and going sequentially with whole numbers up to Vn (where n will vary with hybrid and region). The vegetative stages end with VT (where T stands for tassel).

Reproductive stages allocate carbohydrate energy toward the development of seed, the ultimate goal of the plant (and the farmer). Reproductive stages are noted with an uppercase R and sequentially by whole numbers 1–6.

How do you estimate the time needed for the development stages?

The time it takes for a plant to move from one developmental stage to another can be estimated by the number of calendar days, but a more accurate method is to use a measurement of accumulated heat.

This guide uses **growing degree units** (GDUs) with a base temperature of 50° F. Sometimes these are called growing degree days (GDDs) or heat units (HUs) depending on where you live. You can usually find out what these are in your area by doing an internet search or contacting your local extension agent or agronomist.

For GDUs used in this guide, the following formula is used:

$$\mathbf{GDU = [(T_{min} + T_{max})/2] - 50^\circ}$$

T_{min} = the minimum daily temperature (° F), if temperature is $<50^\circ$, use 50°

T_{max} = the maximum daily temperature (° F), if temperature is $>86^\circ$, use 86°

With this method, 0–36 GDUs per day is possible. Keep in mind that GDUs are also used to predict insect pest development, which may use different minimums/maximums, temperature systems or base level.

Corn botany

Corn is a **monocot** (short for monocotyledon) — a flowering plant with an embryo that bears a single cotyledon (seed leaf) and typically has elongated leaves with parallel veins. It is also **monoecious** — producing separate male and female flowers on the same plant.

Corn hybrids and genetics

Hybrids are developed by carefully controlled cross-pollination between two "parent" lines called inbreds. Inbreds take several years of self-pollination to develop and are selected for desirable characteristics. Seed production for hybrids uses controlled pollination of two inbred parents to produce seed with agronomic performance that is superior to that of its parents and open-pollinated varieties.

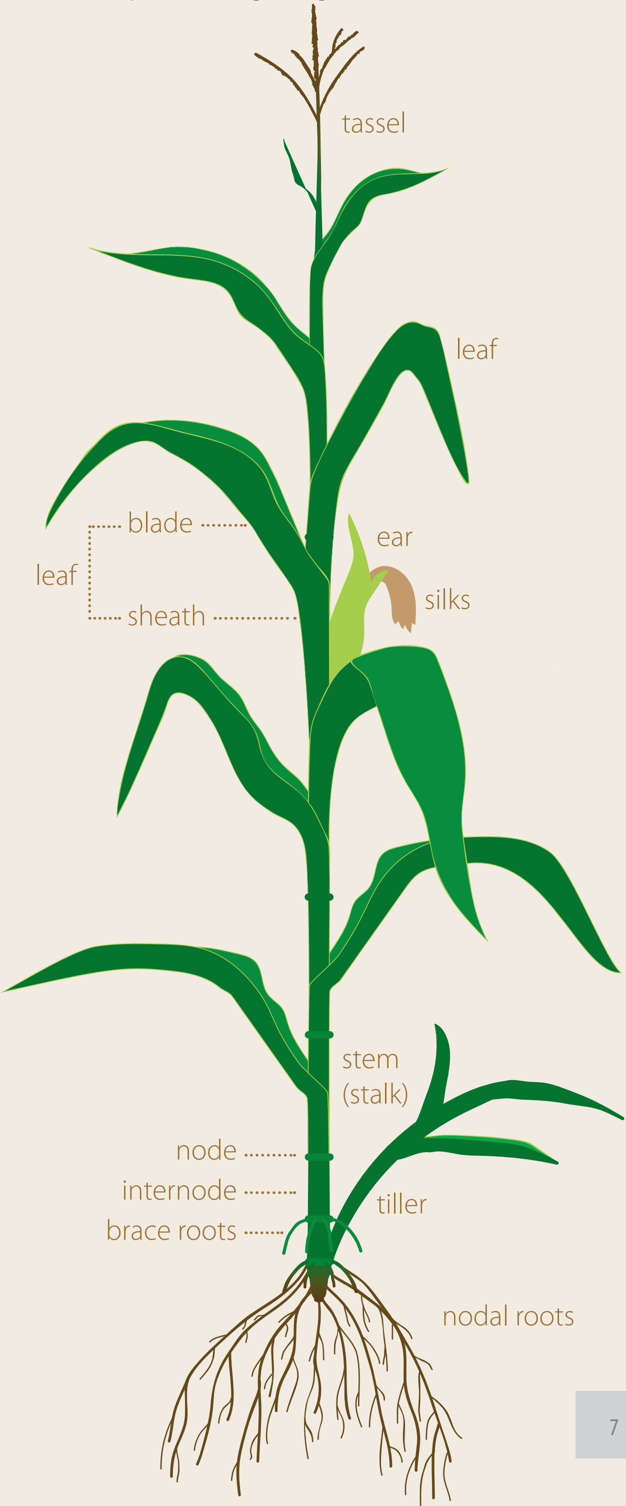
Bio-engineered hybrids include both transgenic (transferred from a different biological organism) and cysgenic (manipulated within the plant’s own genetics) traits. These may include improved control of insects and weeds, better disease resistance, increased tolerance to drought and improved production efficiencies.

Quick note about relative maturity

Relative maturity (RM) — e.g. 105-day corn — is a familiar component of many seed descriptions. This is somewhat misleading since the days do not refer to calendar days but rather to an index defined relative to a standard hybrid, and since there is **no set standard** in the seed industry, comparing RMs is challenging and warrants caution. Seek out information from non-biased sources (e.g. university trials, demonstration plots, etc.) and pay attention to planting dates. See **THE RIGHT RM HYBRID** on page 67 for more information.

Corn anatomy

Although each development stage will be clearly annotated and the terms defined, being familiar with the corn plant in this simplified illustration will be helpful in using this guide.



Nutrient uptake, fertilizer and corn

Like most plants, corn is made of organic carbon-based materials that result from photosynthesis and subsequent metabolic processes. It all starts with the seed.

The seed needs adequate heat, moisture and sunlight (once the plant emerges from soil) along with 13 elemental nutrients that are essential for optimum growth and development. Corn plants need substantial amounts of nitrogen, phosphorus and potassium, relatively smaller amounts of secondary nutrients (calcium, magnesium and sulfur) and only trace amounts of micronutrients (zinc, manganese, copper, boron, iron, molybdenum and chlorine). Availability of nutrients to the plant is dependent on soil pH.

Adequate nutrients are needed throughout the season for corn, but the amounts needed will vary based on the development stage. Some nutrients can even be translocated from the vegetative plant parts to the developing grain later in the season if necessary. But keep in mind that nutrient deficiencies at any time can result in developmental delays and reduced growth.

During harvest, nutrients are removed from the field. What's leftover — the nutrients in the leaves, stalks and other residue — can be recycled back into the soil.

This is why soil testing is important for corn production. It is imperative to have an accurate measure of soil pH and nutrient levels for potassium, phosphorus, calcium, magnesium and sulfur. Micronutrients are rarely lacking but consider testing for them if the field has a history of deficiency.

Nitrogen fertilizer recommendations should be based on soil type, tillage, irrigation and yield goal, and also take into account any credits from manure or previous legumes. Considerations for timing, placement and type of nitrogen should be based on multiple factors, such as minimizing potential loss to the environment, working within the production system and cost.

During the very early stages, only small amounts of nutrients are needed but concentrations near the root zone need to be sufficient since the root system is small. Many plant parts are being initiated and having an adequate supply that the roots can access is vital! Once the root systems have grown, precise fertilizer placement is less critical.

Later stages require much larger amounts of nutrients as the plant accumulates dry matter. Soil moisture plays a key role in effective root nutrient uptake.

Terms used in this guide

There are a lot of terms used in growing guides — some originate from the world of botany, some from the local cooperative. And many are used interchangeably, even though they have slightly different meanings!

For simplicity sake, the terms used in this guide will remain as consistent as possible. This does not imply that the term chosen is the only correct one, only that it was selected for its ease of use and clarity.

The list below shows the term used in this guide in bold followed by others with meanings that are the same, similar or used in other guides. Definitions of terms are spread throughout the guide and also defined in the GLOSSARY starting on page 69.

Brace roots | anchor roots | aerial roots | prop roots

Coleoptile | spike

Cotyledon | scutellum | seed leaf

Ear | ear shoot

Endosperm | starch

Embryo | germ

Growing degree units (GDUs) | heat units (HUs) | growing degree days (GDDs)

Growing point | apical meristem | stem apex

Kernel | seed | grain | ovule

Nodal root system | secondary roots | crown roots | adventitious roots | stem roots

Pollen shed | pollen drop | anthesis

Radicle | primary root | seed root

Seed coat | pericarp

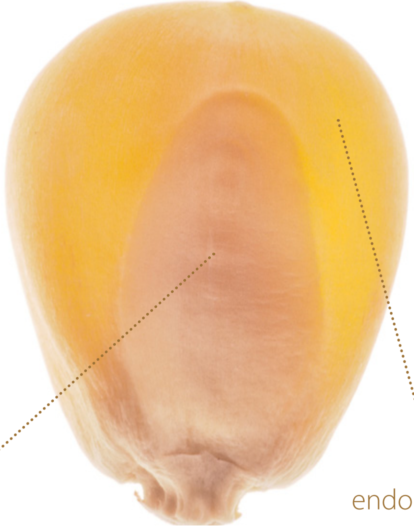
Seminal root system | primary root system | seed roots

Tiller | shoot | sucker

Stem | main stem | stalk

Protected in the kernel is an embryonic plant that will remain dormant until germination is initiated.

FRONT VIEW



The **embryo** contains the embryonic plant and oil-rich cotyledon along with vitamins, minerals and enzymes.

The **endosperm** is the main energy source for the young seedling. It is mainly composed of starch but also some protein.

BACK VIEW

The embryo is not visible from the back view.

The **tip** is the point of attachment to the cob where water and nutrients are acquired from the plant.

The ***endosperm*** *is composed of two types of starch: a soft inner core (floury) and a hard outer layer (vitreous)*

vitreous (adjective)
1: like glass in appearance

CROSS SECTION VIEW

Varying the amount of the endosperm's soft and hard starches results in different physical/chemical properties of the kernel; this is an important component of many corn breeding programs and processing mills.

The **seed coat** is the hard protective outer cover of the kernel. It resists water and protects the embryo from attack by bacteria, fungi and other pests.

The tip is the only area of the kernel not covered by the seed coat

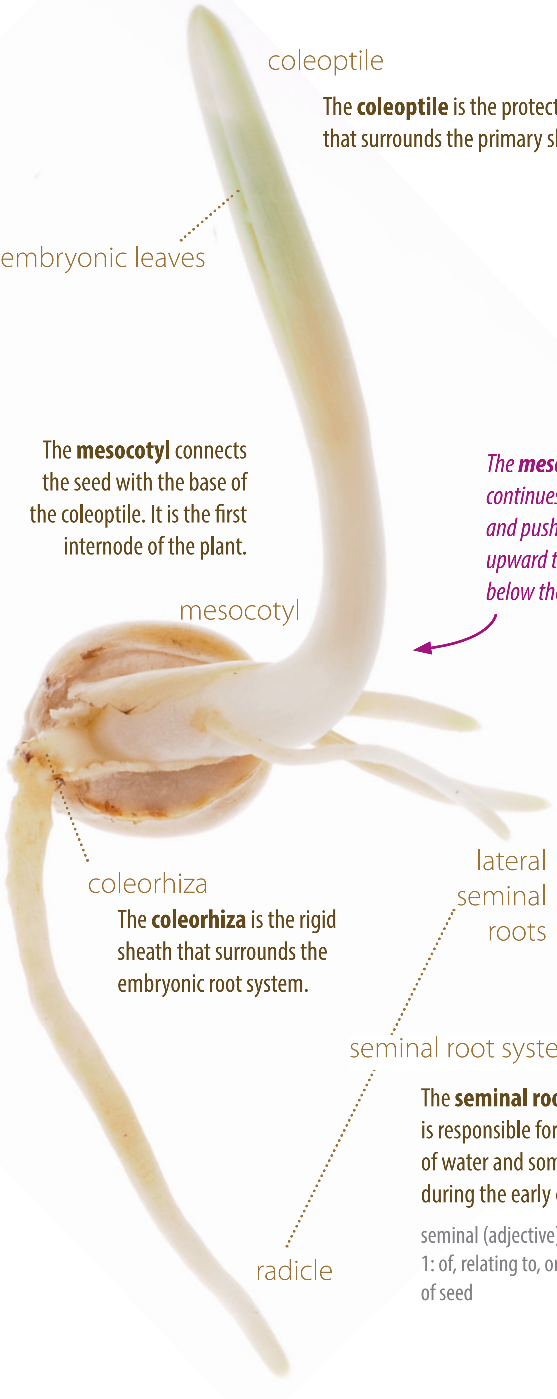
Quick note about the embryonic plant

Within the embryo is a miniature corn plant that already has a primary shoot with embryonic leaves and a seminal root system. Both are protected by rigid tubular sheaths: the coleoptile encloses the above-ground parts, and the coleorhiza encloses the below-ground parts.

Germination is initiated when water is absorbed (imbibition) through the seed coat.

minimum ~50° F soil temperature required for germination

GERMINATION



The **coleoptile** is the protective sheath that surrounds the primary shoot.

The **mesocotyl** connects the seed with the base of the coleoptile. It is the first internode of the plant.

*The **mesocotyl** continues to elongate and pushes the coleoptile upward to within ¾ inch below the soil surface*

The **coleorhiza** is the rigid sheath that surrounds the embryonic root system.

The **seminal root system** is responsible for the uptake of water and some nutrients during the early growth stages.

seminal (adjective)
1: of, relating to, or consisting of seed

Cold or dry conditions can delay emergence for several days!

Planting in cloddy/crusted or cold soils can result in the first leaves unfurling below-ground and may reduce yield potential.

Emergence occurs when the **coleoptile tip** breaks through the soil surface.

The growing point is fixed closer to the soil surface when seeds are planted at shallow depths (less than 1 inch); this may result in floppy corn syndrome (V2–V4).

Let's talk growing point and nodes

A plant's growing point is a compressed stem consisting of stacked nodes and internodes. Similar to how a telescope works, the internodes elongate between the nodes, lengthening the stem.

Nodes are regions where cells can differentiate into different plant parts. In corn, a leaf develops from each node. Root whorls also develop at five of the below-ground nodes, one at the soil surface and potentially one or more at above-ground nodes.

Also at each leaf axil (between the stem and leaf at the node), a shoot can be initiated. Below-ground, shoots can develop into tillers, and above-ground into ears. Most shoots do not fully develop.

VE

125 GDUs ~7–10 days after planting

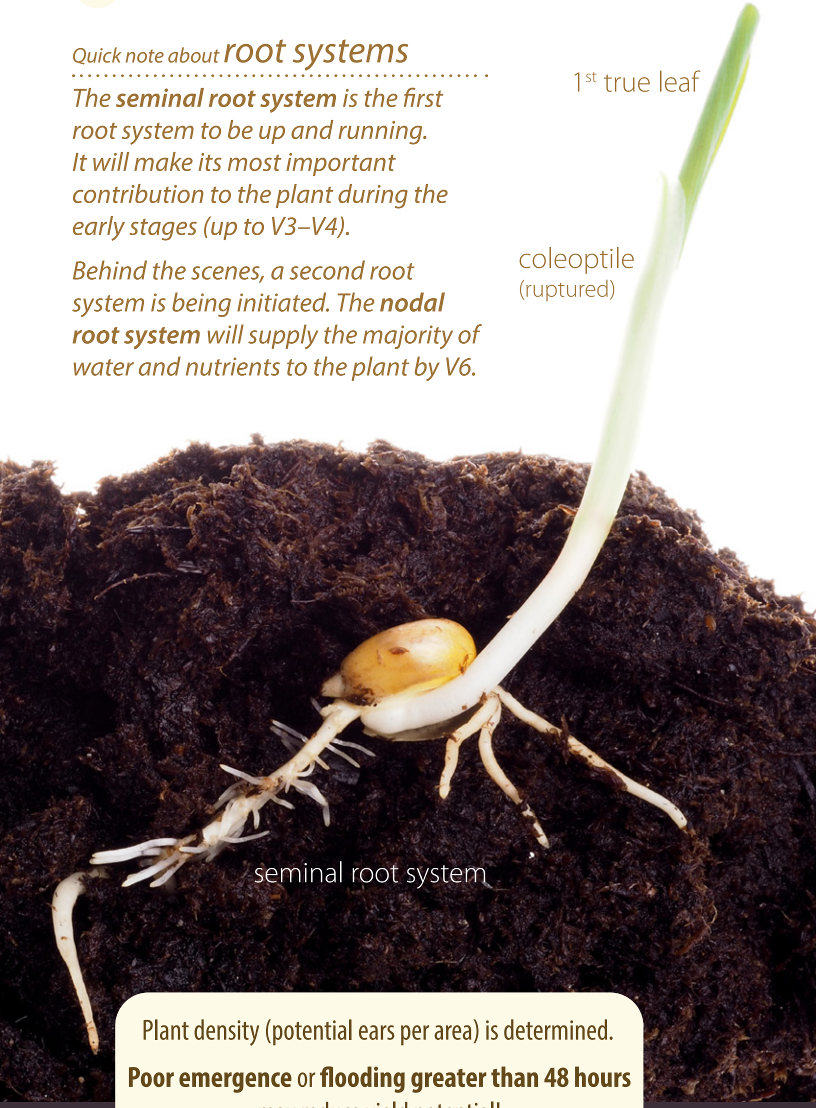
Emergence GDUs may need to be adjusted:

If conservation tillage is implemented, add 30–60 GDUs
If planting date is before April 25, add 10–25 GDUs
If planting date is after May 15, subtract 50–70 GDUs
If seeding depth is below 2 inches, add 15 GDUs for each inch below
If seed-bed condition has soil crusting or massive clods, add 30 GDUs
If seed-zone soil moisture is below optimum, add 30 GDUs

Quick note about ***root systems***

*The **seminal root system** is the first root system to be up and running. It will make its most important contribution to the plant during the early stages (up to V3–V4).*

*Behind the scenes, a second root system is being initiated. The **nodal root system** will supply the majority of water and nutrients to the plant by V6.*



Plant density (potential ears per area) is determined.

Poor emergence or **flooding greater than 48 hours** may reduce yield potential!

Frost or hail will not affect yield.

V1 The **first leaf collar** is visible.

Let's talk leaf collars

Development stages are defined by the uppermost leaf whose collar is visible.

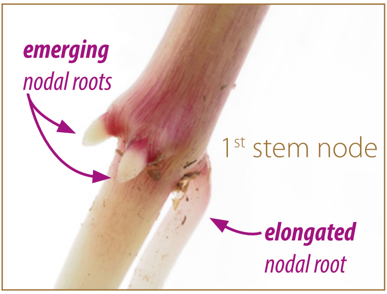
The first sign of the leaf collar is on the underside of the leaf sheath; it looks like a discolored line. Eventually, it will separate from the stem, and the collar will be more pronounced.

V1 – FIRST LEAF COLLAR

Quick note about the first true leaf

Below-ground, the first true leaf arises from the first stem node along with the first whorl of nodal roots.

Why is it called the first true leaf?
It is the first leaf of the plant to use photosynthesis to produce energy.



V2

The **second leaf collar** is visible.

Let's talk

growing point

The stem's growing point is located ~½ to ¾ inch below the soil surface where it is normally protected from above-soil threats like hail, wind or frost.

It is still vulnerable to below-ground threats like excessive moisture, insect feeding or extreme cold temperatures.

With protection and favorable environmental conditions, this growing point will result in a flowering stem that will push up through the stalk.

V2 – SECOND LEAF COLLAR

Quick note about ***nodal roots***

Nodal roots will continue to appear sequentially from each progressively higher stem node until the stem's growing point switches from vegetative to reproductive growth (when the tassel is initiated).

Nodal roots that grow above-ground and reach the soil are called brace roots; they can scavenge water and nutrients from the top layer of soil and stabilize the plant.

Watch for floppy corn!
Poor seed furrow closure due to planting in wet soils <u>or</u> shallow planting followed by excessively dry soil conditions may result in plants with poor nodal root development.

V3

The **third leaf collar** is visible; ear shoots begin forming.

Cold air and soil temperatures can increase the time between development stages.

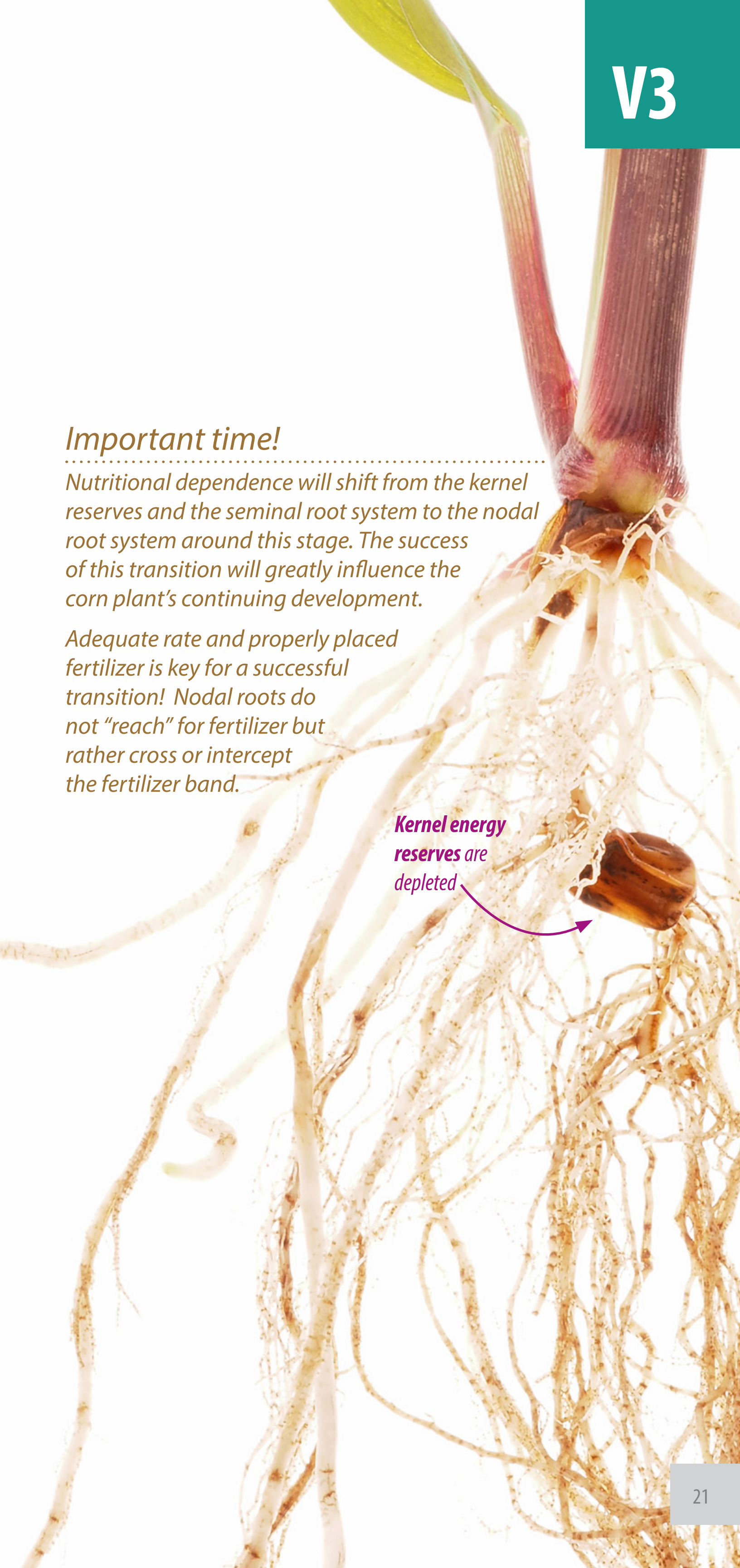
The growing point is still located below the soil surface and protected from above-ground threats.

V3 – THIRD LEAF COLLAR

Important time!

Nutritional dependence will shift from the kernel reserves and the seminal root system to the nodal root system around this stage. The success of this transition will greatly influence the corn plant's continuing development.

Adequate rate and properly placed fertilizer is key for a successful transition! Nodal roots do not "reach" for fertilizer but rather cross or intercept the fertilizer band.



V4

The **fourth leaf collar** is visible; stalk tissue begins elongating.

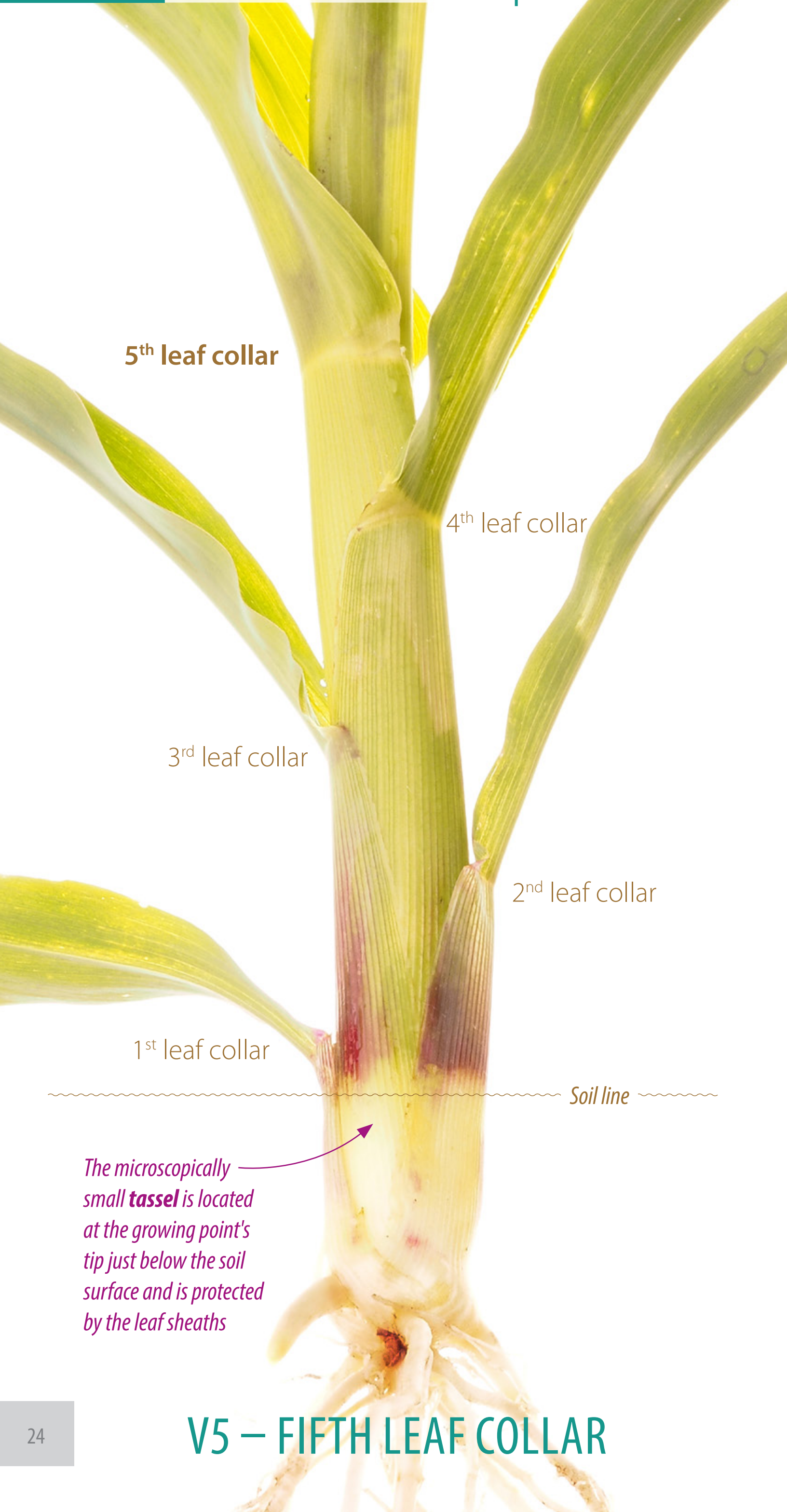
V4 – FOURTH LEAF COLLAR

V4

If you must cultivate, do it carefully!
Nodal roots can be damaged.

V5

The **fifth leaf collar** is visible; tassel begins to form; leaf and ear shoot initiation complete.



V5 – FIFTH LEAF COLLAR

Quick note about ***staging plants***

Rapid growth can cause the lower 3–4 leaves to detach from the stalk and decompose. ***How do you stage a plant if the leaves and respective leaf collars are missing?***

There are two methods that you can use: the internode method and the sixth leaf method (described on the following pages).

Remember when staging a field of corn, each specific stage is reached when 50% or more of the plants in the field are at or beyond that stage.

The internode method

If the lower leaves and respective leaf collars are missing from the plant, try using this staging method.

1

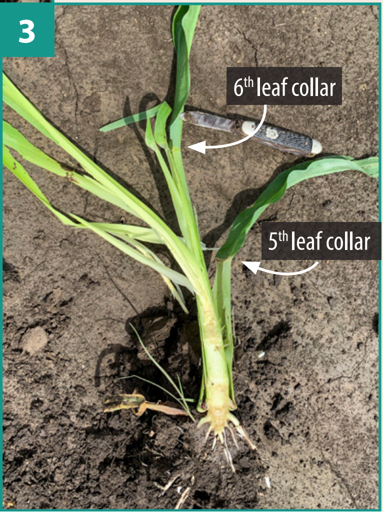
1. **Dig** a representative* plant and **split** the stalk with a knife down through the nodal roots.

2

2. **Identify** the 5th stem node.

   Tip! The internode between the 4th and 5th stem nodes will be noticeable at ~1/4 inch in length. The internodes below the 4th are compressed.

3



3. **Count** upward from the 5th stem node to determine the highest visible leaf collar.

   For example, if the 5th and 6th leaf collars are visible but not the 7th, then the plant is at V6.

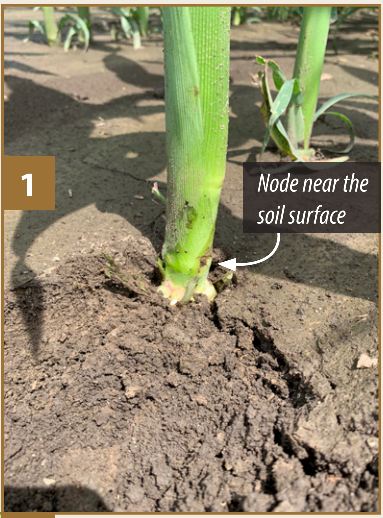
** 50% or more of the plants in the field are at or beyond it in size/development*

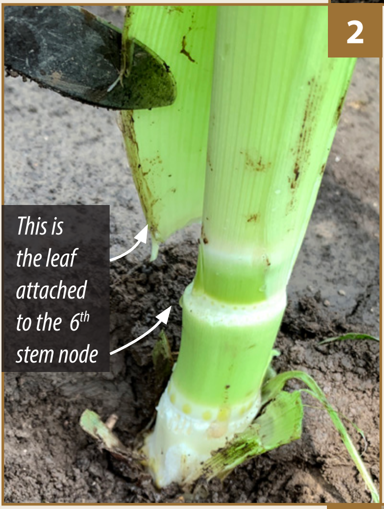
STAGING – INTERNODE METHOD

The sixth leaf method

If the lower leaves and respective leaf collars are missing from the plant, try using this staging method.

1. **Remove** the soil near the base of a representative* plant and **identify** the stem node near the soil surface.



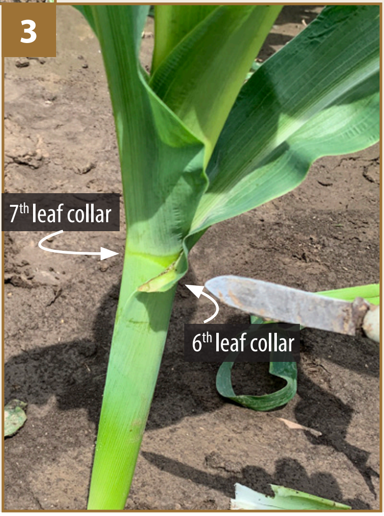


2. This node is typically the 6th stem node. **Expose** the leaf attached to the 6th stem node.

Tip! You may need to remove leaves or partial leaves from lower stem nodes.

3. **Count** upward from the 6th stem node to determine the highest visible leaf collar.

For example, if the 6th and 7th leaf collars are visible but not the 8th, then the plant is at V7.



** 50% or more of the plants in the field are at or beyond it in size/development*

V6

The **sixth leaf collar** is visible; rapid internode elongation and determination of the number of rows around the cob begin; all potential plants parts are present.

V6 – SIXTH LEAF COLLAR

V6

475 GDUs ~24–30 days after emergence

The growing point is above the soil surface and is now susceptible to both environmental and mechanical injury.

100% yield loss if frost causes plant death

Severe yield loss if flooding greater than 48 hours

Apply nitrogen (up to V8) **before rapid uptake period begins!**

Precise fertilizer placement is less critical now.

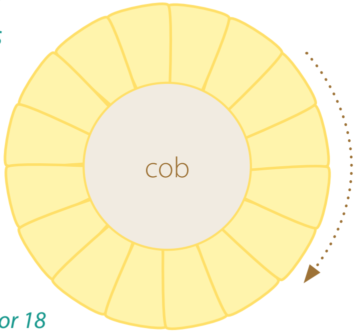
V7

The **seventh leaf collar** is visible; shoots and tassel are visible; number of rows around the cob is being established.

Let's talk rows around the cob

*By the V7 stage, the number of **kernel rows around the cob** is being established.*

Hybrid genetics, stress and timing of some herbicide applications can influence the number of rows, which ultimately affects yield.



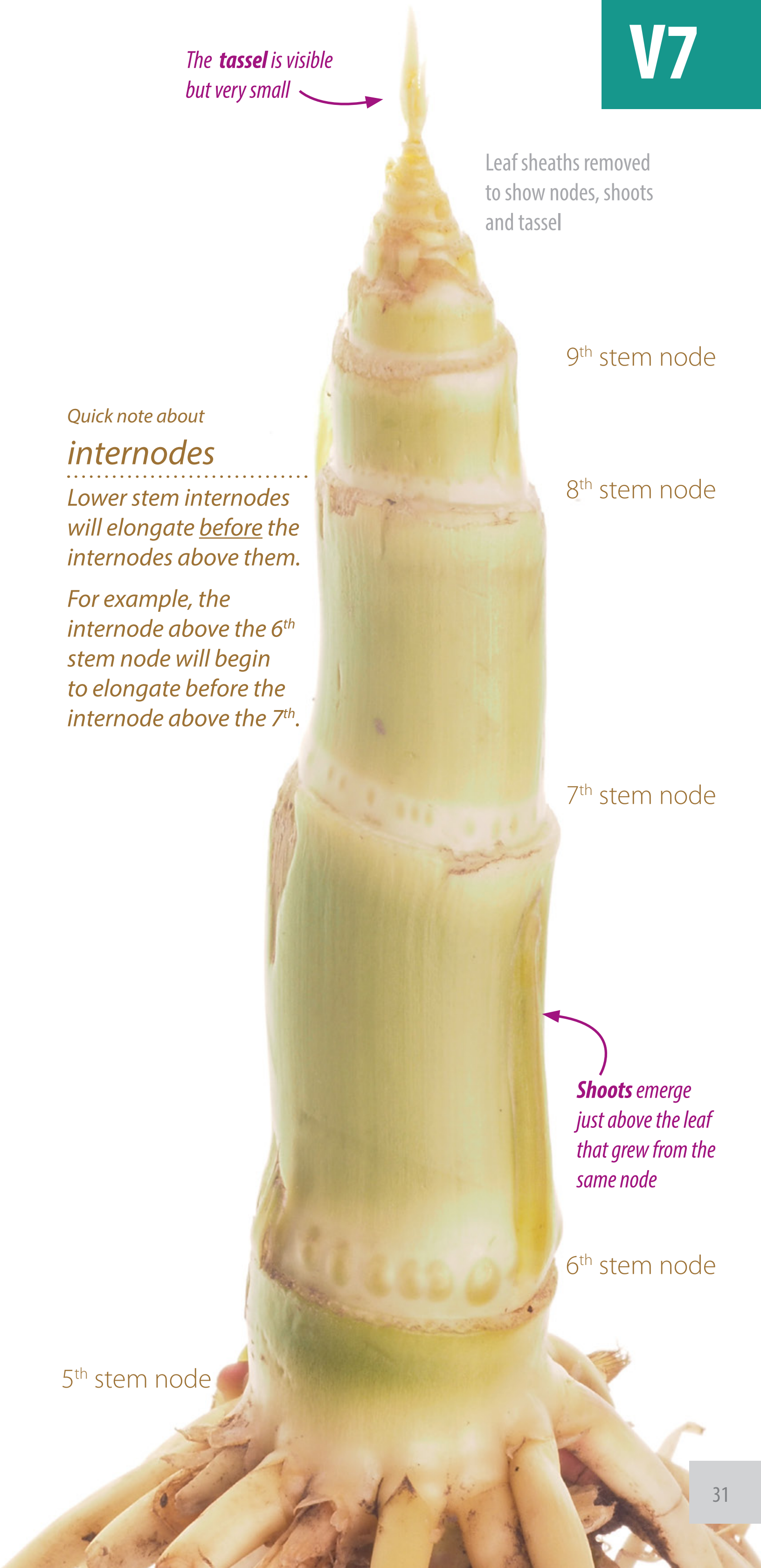
Mid-maturity hybrids average 14, 16 or 18 rows of kernels or less; it is always an even number of rows due to cell division.

Quick note about

internodes

Lower stem internodes will elongate <u>before</u> the internodes above them.

For example, the internode above the 6th stem node will begin to elongate before the internode above the 7th.



V8

The **eighth leaf collar** is visible.

Canopy closure usually occurs between V8 and V10.

Quick note about **tillers**

Tillers develop from below-ground nodes; their presence varies with hybrid, plant density, fertility and other environmental conditions. Widespread presence of tillers indicates a low population for a field during the growing season they occur; most tillers do not fully develop.

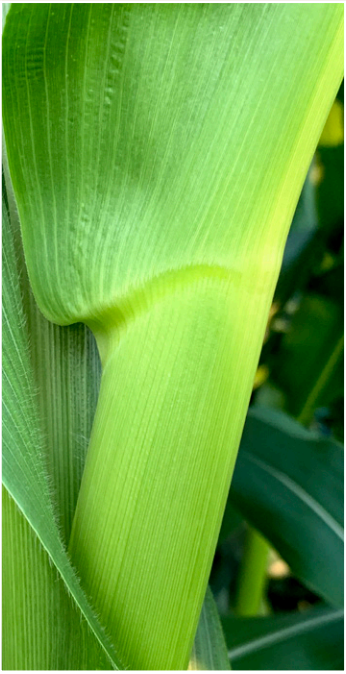
V9

The **ninth leaf collar** is visible; the tassel begins to rapidly develop; the stalk continues to elongate.

V9 – NINTH LEAF COLLAR

V10

The **tenth leaf collar** is visible.



V10 – TENTH LEAF COLLAR

The **eleventh leaf collar** is visible.

V11

tassel flowers

V11 – ELEVENTH LEAF COLLAR

V12

The **twelfth leaf collar** is visible; potential number of kernels per row and ear size are being determined; new V stage about every 2 days.

Let's talk

kernel number & ear size

*The potential number of **kernels per row** is strongly affected by two main factors: availability of moisture and nutrients, and the length of time available for ovule development.*

Since early maturing hybrids progress through the development stages in a shorter amount of time, the ears will be smaller than those of later maturing hybrids.

Keep in mind that the potential number of kernels per row is being determined. What occurs during pollination and afterwards will ultimately determine the final number of kernels and thus, yield.

V12

815 GDUs ~42–46 days after emergence

Quick note about

brace roots

Brace roots begin to stabilize the plant.

Brace roots can develop from the above-ground stem nodes and scavenge moisture and nutrients from the top layer of soil.

Brace root formation will vary based on genetics and environmental conditions.

Plant is utilizing 0.25 inch of water per day.
Moisture and nutrient deficiencies will reduce potential number of kernels and ear size!

100% yield loss if frost causes plant death

56–72% yield loss if completely defoliated by hail

3% yield loss if drought or heat (leaf rolling by mid-morning)

No yield loss if flooding less than 48 hours

Plant is utilizing large amounts of nitrogen, phosphorous and potassium.

V13

The **thirteenth leaf collar** is visible.

tassel

V13 – THIRTEENTH LEAF COLLAR

V14

The **fourteenth leaf collar** is visible.

ear shoot in husk

Female flowers are on the ear.

V14 – FOURTEENTH LEAF COLLAR

V15

The **fifteenth leaf collar** is visible; uppermost ear now more developed than those below it.

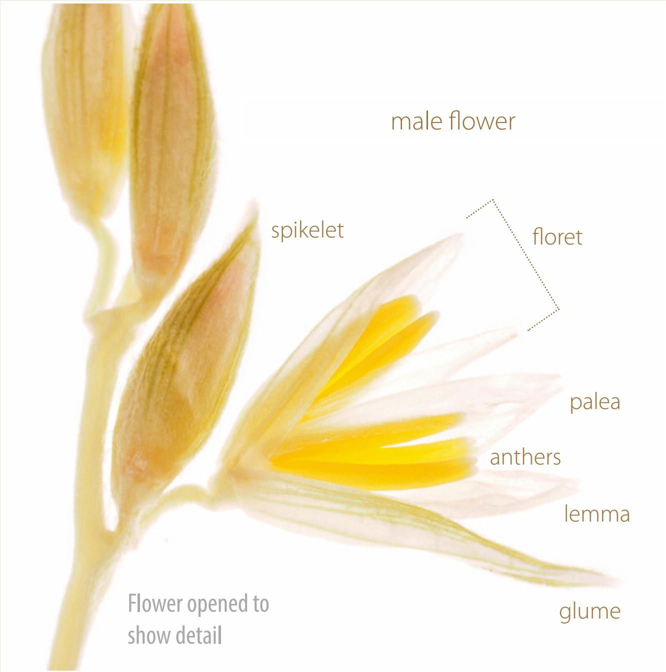
V15 – FIFTEENTH LEAF COLLAR

V15

Approximately 10–12 days until R1 stage!

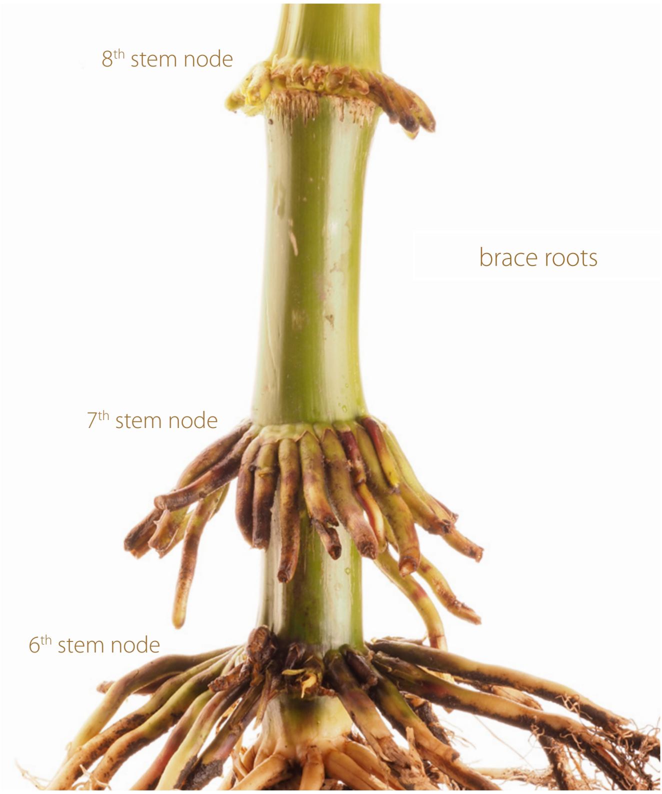
2 weeks <u>before</u> and 2 weeks <u>after</u> R1
is a critical time for adequate moisture;
Water stress and hail damage <u>will reduce</u> yield!

V16 The **sixteenth leaf collar** is visible.



V17

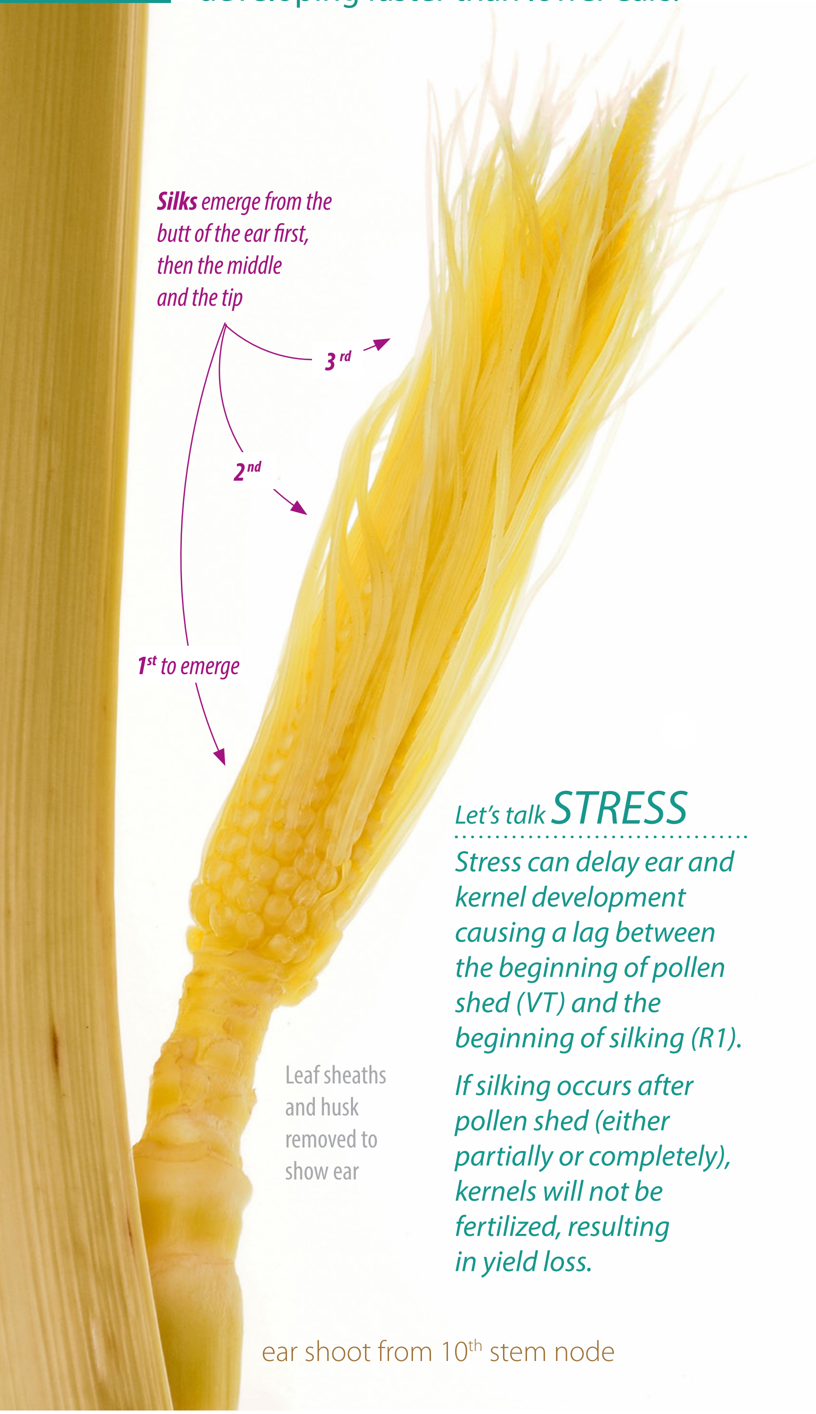
The **seventeenth leaf collar** is visible.



V17 – SEVENTEENTH LEAF COLLAR

V18

The **eighteenth leaf collar** is visible; ear development is rapid; upper ear is developing faster than lower ears.



Let's talk STRESS

Stress can delay ear and kernel development causing a lag between the beginning of pollen shed (VT) and the beginning of silking (R1).

If silking occurs after pollen shed (either partially or completely), kernels will not be fertilized, resulting in yield loss.

V18

1160 GDUs ~ 56 days after emergence

Plant is utilizing 0.30 inch of water per day. **Moisture deficiency now may cause lag between pollen shed and beginning silk, resulting in yield loss!**

100% yield loss if frost causes plant death

100% yield loss if completely defoliated by hail

12–31% yield loss if lodging occurs

4% yield loss if drought or heat (leaf rolling by mid-morning)

No yield loss if flooding less than 48 hours

Vn The **(n)th leaf collar** is visible.

Let's talk *final number of leaves*

The final number of leaves a corn plant will produce varies greatly by the growing region, relative maturity of the hybrid (see page 6) *and environmental conditions.*

For example, some early maturing varieties develop only 15–17 leaves at full maturity, while tropical varieties can have 30+ leaves.

In Wisconsin, corn grown in the southern part of state (110–115 day RM hybrid) will develop 21–23 leaves, while corn grown in the northern part (~80 day RM hybrid) will only develop 15–17 leaves.

Corn plants that have a shorter time to maturity will move through vegetative stages quicker, resulting in fewer leaves and shorter plants.

Quick note about **stage overlap**

The last vegetative stage (VT) is reached when the tassel is fully extended. Sometimes the first reproductive stage can come before VT; the silks are visible outside the husk (R1) before the tassel is visible. Occurrence and timing of this transition can vary depending on the hybrid and environmental conditions.

VT

The last branch of the tassel is completely extended; silks have not emerged from the ear sheaths.

Each male flower (spikelet) is composed of 2 florets with 3 anthers each; the anthers produce pollen

Let's talk ***pollen shed***

Pollen shed begins near VT and is essential for grain development!

During this 1–2 week period, each silk must emerge from the ear husk, <u>and</u> a pollen grain must land on the ovule and fertilize it for a kernel to develop!

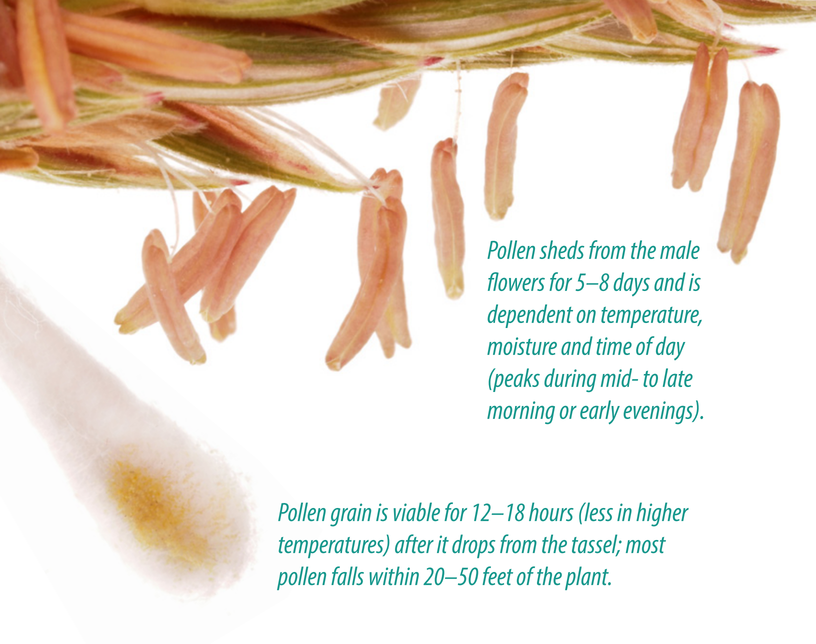
VT – TASSEL

VT

Plant is utilizing 0.28 inch of water per day.

Moisture deficiency may cause lag between pollen shed and beginning silk, resulting in yield loss!

100% yield loss if completely defoliated by hail



Pollen sheds from the male flowers for 5–8 days and is dependent on temperature, moisture and time of day (peaks during mid- to late morning or early evenings).

Pollen grain is viable for 12–18 hours (less in higher temperatures) after it drops from the tassel; most pollen falls within 20–50 feet of the plant.

Let's talk fertilization

*When a pollen grain lands on a silk, a pollen tube is initiated. The pollen tube grows within the silk to the ovule where fertilization occurs and the **kernel embryo** is formed.*

*A second fertilization also takes place that results in the formation of the **endosperm**.*

Immediately following fertilization, an abscission layer forms at the base of the silk, restricting entry of genetic material from other pollen grains.

To check for pollination

1. Carefully remove the husks from an ear 2–3 days after pollen shed ceases.
2. Gently shake the ear.
3. If the silks easily drop off, those ovules have been successfully fertilized.
4. If the silks are retained, those ovules have not been fertilized, and kernels <u>will not</u> develop.

There are 6 reproductive stages. With the exception of R1, stages are characterized by kernel development.

R1	**1400 GDUs**	~60–65 days after emergence	Silk
R2	**1600 GDUs**	~10–14 days after silk	Blister
R3	**1800 GDUs**	~18–22 days after silk	Milk
R4	**2000 GDUs**	~24–28 days after silk	Dough
R5	**2100 GDUs**	~35–42 days after silk	Dent
R6	**2350 GDUs**	~55–60 days after silk	Maturity

For staging a **prolific** plant, use the top ear unless otherwise indicated.

For R2–R4, stage using kernels from the middle of the ear.

For R5–R6, stage using kernels that represent 50% or more of the ear.

prolific (adjective)
1 : more than one harvestable ear on the main stalk, tendency increases with lower plant densities

What does the term "nick" mean?

It is simply the period when pollen shed (VT) coincides with silk receptivity (R1).

Poor nick can result from hot and dry weather; silks can be delayed and dehydrated, which hastens pollen shed and causes the plant to miss the window for pollination.

R1

Silks are visible outside the husks; final kernel number and potential kernel size is being determined.

***Silks** will grow for 3–5 days or until pollination occurs.*

***Silks** will turn brown once outside husk.*

Stresses that reduce pollination can result in an ear with a barren tip called a nubbin.

Each kernel has a noticeable point where the silk was attached; the kernel is surrounded by paleas, lemmas and glumes

Let's talk fertilized kernels

Cell division occurs within the kernel for ~7–10 days after fertilization. After cell division is complete, the cells fill — the outer part of the kernel is white, and the inner part is clear with very little fluid. The embryo is not yet visible.

*The kernel endosperm fills with photosynthate, most of which is produced by the leaf on the same node as the ear shank; **this ear leaf provides 60% of the total grain yield!***

R1

1250 GDUs ~69–75 days after emergence

The plant has reached its maximum height.

Plant is utilizing 0.30 inch of water per day.
Hot and dry weather can result in poor pollination and seed set!

100% yield loss if completely defoliated by hail

100% yield loss if frost causes plant death

7% yield loss per day if drought or heat (leaf rolling by mid-morning)

No yield loss if flooding less than 48 hours

Rapid uptake of nitrogen and phosphorus continues; potassium uptake is essentially complete.

R2

Kernels are ~85% moisture and have a blister-like appearance; endosperm and inner fluid are clear.

Kernels may abort during this stage due to stress with highest risk during the first 10–14 days after pollination; kernels fertilized last (near the tip) often abort first.

*As the kernels expand, the surrounding **glumes** become less visible*

Let's talk kernel fill

Starch fills the watery endosperm, beginning a period of rapid dry matter accumulation that will continue steadily until close to R6.

Although relocation of nutrients from the vegetative to reproductive parts has started, the plant continues uptake of nitrogen and phosphorus from the soil.

Upon careful dissection, a tiny embryo can be seen; the radicle, coleoptile and the first embryonic leaf have already formed a miniature corn plant!

R2 – BLISTER

R2

1600 GDUs ~10–14 days after silking (R1)

Fertilized kernel silks are now dry and brown; unfertilized silks may still be visible.

Plant is utilizing 0.26 inch of water per day.

R3

Kernels begin to display final coloring; inner fluid is milky white; moisture is ~80%.

The space between the kernel rows is filled

Stress during this stage can reduce final kernel weight and size; kernels may still abort; as kernels mature, potential yield reduction from stress decreases.

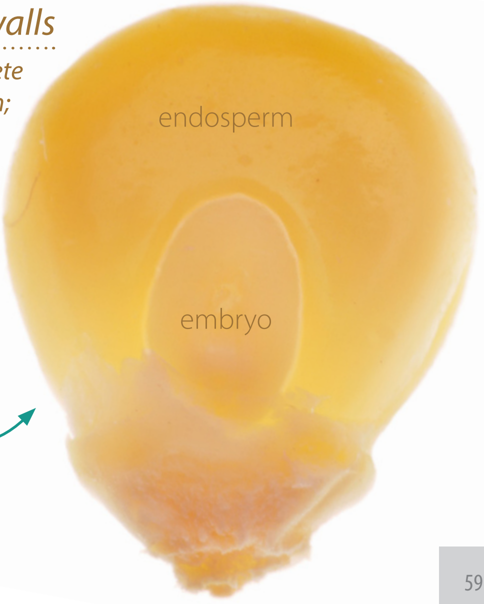
Let's talk kernel color

Final coloring of field corn can range from yellow to white for most dent hybrids, white to yellow to reddish-orange for flint hybrids.

R3

Quick note about ***cell walls***

Cell division is complete within the endosperm; the focus is now on expansion and filling of the cell walls with starch.



With the seed coat removed, the embryo can be easily seen

R4

Kernels display final coloring; inner fluid thickens to a dough-like consistency; moisture is ~70%.

The embryo has increased in size and will continue to develop rapidly during this stage.

Kernels are about half of their mature weight.

Stress at this stage can reduce starch accumulation, resulting in lower kernel weight.


R4
2000 GDUs ~24–28 days after silking (R1)
Lower leaves often die back when nutrients are being relocated within the plant during the reproductive stages.
Plant is utilizing 0.20 inch of water per day.

R5

Most kernels have dented; kernel milk begins to disappear; milk line moves toward the kernel tip; moisture is ~55%.

Quick note about ***dent***

When the soft starch core begins to lose moisture, it shrinks and causes a dent to form on the top of the kernel; hybrid genetics and growing conditions determine dent size.

Let's talk ***kernel milk***

Kernel milk *is the white starchy fluid that disappears as the kernel matures. Starting at the top and moving towards the tip, the endosperm loses moisture and rapidly accumulates dry matter. This process starts now and concludes early in R6.*

To determine its progress, press the kernel with a pencil tip; it will be soft where the kernel milk remains and hard where it has disappeared.

Don't confuse it! *Another commonly used term is milk line, which describes the separation between the soft and hardened starch. Both terms describe similar phenomenon but in slightly different ways.*

Kernel milk and the milk line will be visible on the side opposite of the embryo ~one week after R5 begins.

Early R5

1/4 *milk line*

3/4 *kernel milk*

45% *of total dry matter*

Mid- R5

1/2 *milk line*

1/2 *kernel milk*

90% *of total dry matter*

Late R5

3/4 *milk line*

1/4 *kernel milk*

97% *of total dry matter*

This process takes 3–4 weeks depending on temperature, moisture and hybrid genetics

R5

2100 GDUs ~35–42 days after silking (R1)

Plant is utilizing 0.20 inch of water per day.

Stress at this stage can still reduce starch accumulation and result in lower kernel weight.

Hard early frost can:

Cause premature black layer formation

Halt dry matter accumulation

Corn has two peaks for high quality forage value during its development: the first is during pollination and the second (higher value) is during R5; the value declines greatly between the peaks.

To ensure proper fermentation and preservation of silage taken during R5, harvest should occur when whole plant moisture is optimal for the intended storage structure. The kernel milk location can be a useful indicator of when to begin sampling fields to measure plant dry matter, which can then used to time harvest to ensure fermentation and preservation of the forage.

Once the kernel milk begins to move, sample fields to measure the percent dry matter of whole plants and combine this with average whole plant drydown rates for the geographic region. Many factors can affect drydown rate, including hybrid, planting date, general health of the crop, landscape position, soil type and weather conditions. In general, corn silage that is slightly too wet is better for storage than corn silage that is too dry; so harvesting a little early is better than waiting too long.

R6

Kernels reach maximum dry matter weight and are physiologically mature; moisture is ~30–35%; black layer forms.

*Cells at the kernel tip collapse to form the **black layer***

Kernel milk has completely disappeared; milk line has reached the cob.

Tip removed to show the single black layer of cells

Quick note about ***black layer***

Formation of the black abscission layer signals that starch and moisture are no longer moving in or out of the kernel. Moisture loss is now solely from evaporation through the seed coat.

The black layer forms on kernels beginning at the ear tip and progressing to the butt →

R6

2350 GDUs ~55–60 days after silking (R1)

Plant is utilizing 0.18 inch of water per day.

If the plant dies before it reaches physiological maturity, **yield may be reduced!**

Lodging can result in yield loss.

Stress and frost have no impact on yield.

Let's talk drydown

Physiologically mature grain is not ready for storage yet! *For long-term storage, shelled grain needs to be down to 13–15% moisture. This period between physiological and harvest maturity is called drydown.*

Grain drydown is dependent on hybrid and air variables. Air variables include temperature, relative humidity and air movement, while hybrid variables include ear orientation, tightness and length of husks, and kernel hardness.

Mechanically drying grain can be costly so if possible, let nature do the drying. Sunny days dry corn faster than cloudy days, even if the heat units are the same!

To drop 1% moisture:	***~30 GDUs** for grain @ 25–30%*
	***~45 GDUs** for grain @ 20–25%*

For highest forage quality, harvest silage prior to R6!

Let's talk grain yield

There are three main components that determine grain yield in corn:

1) *Ears per area*
2) *Kernels per ear*
3) *Kernel weight*

The potential of each yield component is determined at different developmental stages and is influenced by environmental factors like weather and pests.

Keep in mind that these stages determine the potential number, the actual number will be influenced by other environmental factors.

NUMBER x **SIZE** = **GRAIN YIELD**

$$\frac{\text{ears}}{\text{area}} \times \frac{\text{kernels}}{\text{ear}} \times \frac{\text{weight}}{\text{kernel}} = \frac{\text{weight}}{\text{area}} \times \frac{\text{volume}}{\text{weight}} = \frac{\text{volume}}{\text{area}}$$

$$\frac{\text{bu}}{\text{acre}}$$

VE – **V6**

*Potential **ears per area** are determined at planting and VE. The actual **number of ears** per plant are determined by V6.*

V6 – **V11** – **VT** – **R3**

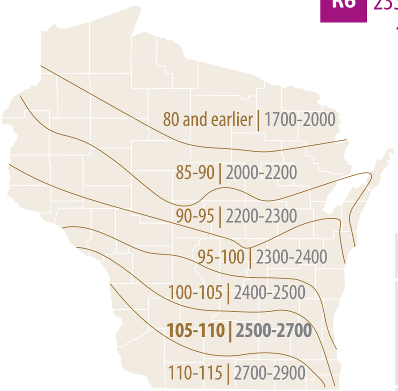
*The potential **number of rows around the cob** are being determined between V6–V11. The potential **number of kernels per row** are determined by VT and will be influenced by the events prior to and after pollination with the final number by R3.*

R6

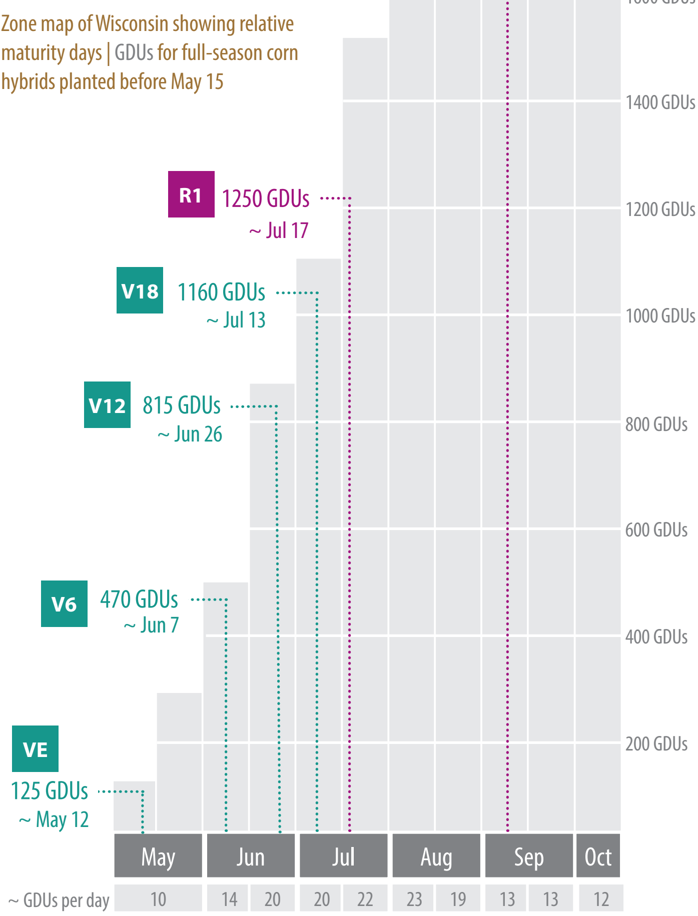
*The final **weight per kernel** is determined by R6.*

Grain yield is commonly measured in bushels/acre. A bushel is a dry measure of volume equal to 64 US pints. One bushel of shelled corn weighs ~56 pounds.

Planting the right relative maturity (RM) hybrid is imperative for a successful harvest! Seek out information that provides geographic zone maps, GDUs (or other thermal units) and planting dates. ***This example*** *shows the approximate dates that a 105-day RM hybrid planted May 1 in south central Wisconsin will reach key developmental stages.*



Zone map of Wisconsin showing relative maturity days | GDUs for full-season corn hybrids planted before May 15



THE RIGHT RM HYBRID

Tassel ears may look odd but do not indicate any health problems

One last note tassel ears

It is not uncommon to see a few tassel ears in a field. Usually found on tillers or edge-of-field plants, these structures do not interfere with yield or indicate any health problems.

Tassel ears are the result of a physiological abnormality — male flowers retain their female structures and develop kernels; these female structures are usually aborted on the tassel during normal development.

Tips for profitable and sustainable corn production

Analyze your costs, economic goals and potential risks

Match relative maturity hybrids to your region with realistic yield goals

Reduce tillage when possible

Understand your soil fertility levels, subsoil moisture and crop fertility needs

Utilize seed treatments

Optimize seeding rates, planting date and row spacing

Maximize economic optimum management practices rather than those that only maximize yield

Minimize or eliminate pest pressure (insects, weeds, diseases)

Harvest and store carefully

Get a handle on information management!

Abiotic: Non-living chemical and physical aspects of the environment that affect living organisms and the functioning of ecosystems

Aerial roots: Adventitious roots that grow above-ground

Anchor roots: See brace roots

Anthers: Part of the male flower; tiny double-barrelled structures that contain pollen grains

Adventitious roots: Roots that arise from an organ other than the plant's root (e.g. brace roots form from stem nodes)

Apical meristem: The growth region of tissue found within the root tips and the tips of the new shoots and leaves

Axillary bud: An embryonic shoot at the junction of the stem and petiole; each bud has the potential to form vegetative shoots (stems and branches) or reproductive shoots (flowers); also called lateral bud

Black layer: A single layer of cells at the tip (base) of the kernel that die, collapse, and turn black once the kernel has matured

Blade: The broad portion of a leaf; also called the leaf blade

Brace roots: Roots that form from above-ground stem nodes that provide physical support for the stem; also called anchor roots, aerial roots or prop roots

Coleoptile: The protective sheath that covers the primary shoot

Coleorhiza: The protective sheath that covers the radicle

Collar: The outer side of the leaf where the leaf blade and the sheath join

Cotyledon: Part of the embryo that is an oil-rich storehouse of food important for the germination process; the 1st leaf to emerge from the seed

Ear: Although not botanically correct, ears often refers to kernels and cob of the corn plant; for silage, the ear also includes the silks, shanks and husk leaves; see spike

Embryo: One of the three key parts of the corn kernel (the other two being the endosperm and seed coat); contains a miniature plant (the primary shoot with 4–5 preformed leaves, coleoptile, radicle, lateral seminal roots and coleorhiza)

Embryonic plant: The miniature plant contained in the embryo; see embryo

Endosperm: One of the three key parts of the corn kernel (the other two being the embryo and seed coat); occupies the bulk of the kernel; main energy reserve for the young seedling; primary component is starch

GDUs: Growing degree units; see definition

GDDs: Growing degree days; see definition

Growing degree days: A measure of heat accumulation used to predict plant development rates; also called GDDs, growing degree units (GDUs) or heat units (HUs)

Growing degree units: A measure of heat accumulation used to predict plant development rates; also called GDUs, growing degree days (GDDs) or heat units (HUs)

Glumes: A pair of bract-like structures at the base of the flower

Grasses: Monocotyledons (mostly herbaceous) with jointed stems, slender sheathing leaves and flowers borne in spikelets

Growing point: An area of active cell division and elongation at the tip of the young stalk or root

Heat units: A measure of heat accumulation used to predict plant development rates; also called HUs, growing degree days (GDDs) or growing degree units (GDUs)

HUs: Heat units; see definition

Hybrid: Seed corn production involving the crossing of two inbred lines

Inbred line: A self-pollinated strain of corn; all progeny are genetically identical to each other and to the inbred parent

Internode: The area between two nodes on the plant stem

Lateral bud: see axillary bud

Leaf: A typically green and blade-like flattened structure that is attached to a stem directly; main organs of photosynthesis and transpiration

Leaf axil: The angled area between the upper side of a leaf and the stem where the buds or shoots can develop

Leaf blade: see blade

Leaf collar: Area on the outer side of the leaf where the blade and sheath join

Leaf sheath: The basal part of leaf that encircles the stem; connects the vascular system of the leaf blade to the rest of the plant

Lemma: The lowermost of two chaff-like bracts enclosing the grass floret

Main stalk: see main stem

Main stem: Main structural axes of a vascular plant; normally divided into nodes and internodes

Meristem: Growth tissue; area of active cell division and elongation

Mesocotyl: A tubular, white, stem-like tissue that connects the seed and the base of the coleoptile

Monocotyledon: A flowering plant with an embryo that bears a single cotyledon (seed leaf)

Monoecious plant: Separate male and female flowers on the same plant

Nodal root system: Main root system of the corn plant; originates from lower stem nodes, usually from five nodes below the soil surface

Node: A place on the stem where leaves, roots, ears and tassels emerge from; nodes are often raised and noticeable by feel

Ovule: Part of the female flower; potential kernel on the cob

Palea: The uppermost of the two chaff-like bracts enclosing the grass floret

Pericarp: The layer that develops around the seed of a plant after it is fertilized and protects the enclosed endosperm and embryo from attack by fungi and bacteria; also called the seed coat

Plumule: The part of the seed embryo that develops into the shoot bearing the first true leaves of a plant

Pollen: Fine to coarse powder made of pollen grains; microgametophytes that produce male gametes (sperm cells)

Pollen tube: A hollow tube that develops from the pollen grain when it is deposited on the stigma (female); acts as a conduit to transport the male gamete cells (sperm) to the ovules at the base of the pistil

Prolific: More than one harvestable ear on the main stalk, tendency increases with lower plant densities

Radicle: The embryonic root of the plant

Relative maturity: A method for comparing corn hybrids in regards to length of season necessary to reach maturity

Scutellum: see cotyledon

Seed leaf: see cotyledon

Seminal root system: Composed of the radicle and up to three pairs of seminal roots; contained within the seed; of greatest importance during early seedling growth

Shank: Small, stalk-like structure on a leaf node from which the ear develops from

Sheath: see leaf sheath

Shoots: A stem along with its leaves, stems and flowers; functionally responsible for food production (photosynthesis) and reproduction

Silk: Part of the female flower that traps pollen; the stigma; elongates towards the tip of the ear shoot

Spike: An unbranched inflorescence bearing flowers that are directly attached without stalks; in corn, spike is the ear; a central stem on which tightly packed rows of flowers develop into fruits containing seeds; see ear

Stalk: One of two main structural axes of a vascular plant, the other being the root; divided into nodes and internodes; also called the stem

Stem: The main structural plant axis that bears buds and shoots with leaves; normally divided into nodes and internodes

Stem apex: see apical meristem

Stem node: Areas on the stem from which leaves and shoots and roots can develop

Stigma: Part of the female flower that traps pollen

Tiller: Branches that develop from axillary buds at the lower 5–7 stem nodes; morphologically identical to the main stalk; capable of forming their own root system, nodes, internodes, leaves, ears and tassels

Tassel: The male flowering part that contains the anthers and pollen; also called the flowering stalk or flowering stem

Whorl: An arrangement of at least three leaves that radiate from a single point and surround or wrap around the stem

During maturity, cell walls breakdown within the ear shank and in some hybrids, result in upside-down ears. This can be beneficial — the husks act like umbrellas, shedding precipitation and protecting the grain.

Husk opened to show kernels

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