Authors
Mimi Broeske, Nutrient and Pest Management Program and Joe Lauer, Department of Agronomy, University of Wisconsin-Madison

Acknowledgements
The authors would like to thank our reviewers:
Dr. Roger Elmore, University of Nebraska-Lincoln
Dr. Lori J. Abendroth, Iowa State University
Doug Rebout, Wisconsin Corn Growers Association
Additional thanks to Teal Potter, Zach Zalewski, Thierno Diallo, Kent Kohn, Griffin Broeske, Janet Hedtcke and the Wisconsin CCA Board!

The Wisconsin Corn Promotion Board provided initial funding for development of this publication.

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

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>4</td>
</tr>
<tr>
<td>Corn basics</td>
<td>6</td>
</tr>
<tr>
<td>Terminology</td>
<td>9</td>
</tr>
<tr>
<td>Pre germination</td>
<td>10</td>
</tr>
<tr>
<td>Germination</td>
<td>12</td>
</tr>
<tr>
<td>Vegetative stages</td>
<td>14</td>
</tr>
<tr>
<td>VE – Emergence</td>
<td>14</td>
</tr>
<tr>
<td>V1 – First leaf collar</td>
<td>16</td>
</tr>
<tr>
<td>V2 – Second leaf collar</td>
<td>18</td>
</tr>
<tr>
<td>V3 – Third leaf collar</td>
<td>20</td>
</tr>
<tr>
<td>V4 – Fourth leaf collar</td>
<td>22</td>
</tr>
<tr>
<td>V5 – Fifth leaf collar</td>
<td>24</td>
</tr>
<tr>
<td>Staging – Internode method</td>
<td>26</td>
</tr>
<tr>
<td>Staging – Sixth leaf method</td>
<td>27</td>
</tr>
<tr>
<td>V6 – Sixth leaf collar</td>
<td>28</td>
</tr>
<tr>
<td>V7 – Seventh leaf collar</td>
<td>30</td>
</tr>
<tr>
<td>V8 – Eighth leaf collar</td>
<td>32</td>
</tr>
<tr>
<td>V9 – Ninth leaf collar</td>
<td>34</td>
</tr>
<tr>
<td>V10 – Tenth leaf collar</td>
<td>36</td>
</tr>
<tr>
<td>V11 – Eleventh leaf collar</td>
<td>37</td>
</tr>
<tr>
<td>V12 – Twelfth leaf collar</td>
<td>38</td>
</tr>
<tr>
<td>V13 – Thirteenth leaf collar</td>
<td>40</td>
</tr>
<tr>
<td>V14 – Fourteenth leaf collar</td>
<td>41</td>
</tr>
<tr>
<td>V15 – Fifteenth leaf collar</td>
<td>42</td>
</tr>
<tr>
<td>V16 – Sixteenth leaf collar</td>
<td>44</td>
</tr>
<tr>
<td>V17 – Seventeenth leaf collar</td>
<td>45</td>
</tr>
<tr>
<td>V18 – Eighteenth leaf collar</td>
<td>46</td>
</tr>
<tr>
<td>Vn – (n)th leaf collar</td>
<td>48</td>
</tr>
<tr>
<td>V to R transition</td>
<td>49</td>
</tr>
<tr>
<td>VT – Tassel</td>
<td>50</td>
</tr>
<tr>
<td>Pollination notes</td>
<td>52</td>
</tr>
<tr>
<td>R stages overview</td>
<td>53</td>
</tr>
<tr>
<td>R1 – Silk</td>
<td>54</td>
</tr>
<tr>
<td>R2 – Blister</td>
<td>56</td>
</tr>
<tr>
<td>R3 – Milk</td>
<td>58</td>
</tr>
<tr>
<td>R4 – Dough</td>
<td>60</td>
</tr>
<tr>
<td>R5 – Dent</td>
<td>62</td>
</tr>
<tr>
<td>R6 – Maturity</td>
<td>64</td>
</tr>
<tr>
<td>Grain yield</td>
<td>66</td>
</tr>
<tr>
<td>The right RM hybrid</td>
<td>67</td>
</tr>
<tr>
<td>Final notes</td>
<td>68</td>
</tr>
<tr>
<td>Glossary</td>
<td>69</td>
</tr>
</tbody>
</table>
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:

\[
GDU = \left[\left(\frac{T_{\text{min}} + T_{\text{max}}}{2}\right) - 50^\circ\right]
\]

\[T_{\text{min}} = \text{the minimum daily temperature (° F), if temperature is <50°, use 50°}\]

\[T_{\text{max}} = \text{the maximum daily temperature (° F), if temperature is >86°, use 86°}\]

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 cygenic (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

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

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.

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). The endosperm is the nutritive tissue of the kernel. 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.

Along with oxygen, the kernel imbibes 30–35% of its weight in water.

Minimum ~50°F soil temperature required for germination.

The coleoptile emerges and elongates upward.

The radicle emerges and elongates downward.

Lateral seminal roots arise from the mesocotyl.

GERMINATION
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.

**coleoptile**

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

**embryonic leaves**

**mesocotyl**

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

**coleorhiza**

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

**lateral seminal roots**

**seminal root system**

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

**radicle**

**seminal (adjective)**

1: of, relating to, or consisting of seed
Emergence occurs when the **coleoptile tip** breaks through the soil surface.

Sunlight softens the coleoptile’s sharp tip, allowing the **first true leaf** to break through.

** coleoptile tip **

**Exposure to sunlight softens the coleoptile’s sharp tip, allowing the first true leaf to break through.**

Sunlight disrupts the elongation of the mesocotyl, which fixes the depth of the stem’s growing point at ~3/4 inch below 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.
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.

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.
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.

The first leaf collar is visible.
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.
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.

**The growing point is below the soil surface**
Watch for floppy corn!
Poor seed furrow closure due to planting in wet soils or shallow planting followed by excessively dry soil conditions may result in plants with poor nodal root development.

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.
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.
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.
The fourth leaf collar is visible; stalk tissue begins elongating. Lower leaf sheaths removed to show nodes

The first stem internode is above the 4th stem node; it is ~¼ to ½ inch in length.

The first four stem nodes are compressed with no visible internodes.

V4 – FOURTH LEAF COLLAR
If you must cultivate, do it carefully!
Nodal roots can be damaged.
The fifth leaf collar is visible; tassel begins to form; leaf and ear shoot initiation complete.

The microscopically small tassel is located at the growing point’s tip just below the soil surface and is protected by the leaf sheaths.
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.
STAGING – INTERNODE METHOD

The internode method

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

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

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. **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*

---

---
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
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.

As the internode above the 5th stem node elongates, the growing point is pushed above the soil surface; a healthy growing point is creamy to light yellow (brown to reddish brown indicates ill health).

The nodal root system is established and is now the major functional root system for the plant.

V6 — SIXTH LEAF COLLAR
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.
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 *before* the internodes above them.

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

*Shoots emerge just above the leaf that grew from the same node*

*The tassel is visible but very small*
Canopy closure usually occurs between V8 and V10.

The eighth leaf collar is visible.
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.
Shoots that emerge from the above-ground nodes may develop into ears.

A total of 6–8 ear shoots forms on the stalk; each new ear shoot develops faster than the one above it, but growth of the lower ear shoots eventually slows. Only the top 1–2 shoots will fully develop into harvestable ear(s).

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

Shoots that emerge from below-ground nodes may develop into tillers.

Leaf sheaths removed to show nodes and shoots.
The tenth leaf collar is visible.
The eleventh leaf collar is visible.
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.

**At this stage, this ear shoot is still smaller than those below it**

10th stem node

Leaf sheaths and husk removed to show shoot and ear shank
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.

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.
Male flowers are on the tassel.

The thirteenth leaf collar is visible.
The **fourteenth leaf collar** is visible.

Female flowers are on the ear.
The fifteenth leaf collar is visible; uppermost ear now more developed than those below it.

Silks are beginning to emerge on the upper ear.

Each silk is attached to a single ovule.

The ovule is part of the female flower along with the silk. When fertilized with pollen, the embryo is formed.

Ear shoot from 10th stem node.

Leaf sheaths and husk removed to show ear.
Approximately 10–12 days until R1 stage!

2 weeks before and 2 weeks after R1 is a critical time for adequate moisture; Water stress and hail damage will reduce yield!
V16 The sixteenth leaf collar is visible.
The seventeenth leaf collar is visible.

V17 – SEVENTEENTH LEAF COLLAR
The eighteenth leaf collar is visible; ear development is rapid; upper ear is developing faster than lower ears.

Silks emerge from the butt of the ear first, then the middle and the tip.

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.
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!

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Yield Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frost causes plant death</td>
<td>100%</td>
</tr>
<tr>
<td>Completely defoliated by hail</td>
<td>100%</td>
</tr>
<tr>
<td>Lodging occurs</td>
<td>12–31%</td>
</tr>
<tr>
<td>Drought or heat (leaf rolling by mid-morning)</td>
<td>4%</td>
</tr>
<tr>
<td>Flooding less than 48 hours</td>
<td>No loss</td>
</tr>
</tbody>
</table>

1160 GDUs ~ 56 days after emergence

V18
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.
Each male flower (spikelet) is composed of 2 florets with 3 anthers each; the anthers produce pollen.

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

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, and a pollen grain must land on the ovule and fertilize it for a kernel to develop!
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 will not develop.
There are 6 reproductive stages. With the exception of R1, stages are characterized by kernel development.

<table>
<thead>
<tr>
<th>Stage</th>
<th>GDUs</th>
<th>Days After</th>
<th>Maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>1400</td>
<td>~60–65</td>
<td>Silk</td>
</tr>
<tr>
<td>R2</td>
<td>1600</td>
<td>~10–14</td>
<td>Blister</td>
</tr>
<tr>
<td>R3</td>
<td>1800</td>
<td>~18–22</td>
<td>Milk</td>
</tr>
<tr>
<td>R4</td>
<td>2000</td>
<td>~24–28</td>
<td>Dough</td>
</tr>
<tr>
<td>R5</td>
<td>2100</td>
<td>~35–42</td>
<td>Dent</td>
</tr>
<tr>
<td>R6</td>
<td>2350</td>
<td>~55–60</td>
<td>Maturity</td>
</tr>
</tbody>
</table>

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.

**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.

---

**R STAGES OVERVIEW**

prolific (adjective)

1: more than one harvestable ear on the main stalk, tendency increases with lower plant densities.
Stresses that reduce pollination can result in an ear with a barren tip called a nubbin.

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!
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.

The plant has reached its maximum height.
As the kernels expand, the surrounding glumes become less visible.

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.

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!
Plant is utilizing 0.26 inch of water per day.

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

Fertilized kernel silks are now dry and brown; unfertilized silks may still be visible.
Kernels begin to display final coloring; inner fluid is milky white; moisture is ~80%.

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.

Stress during this stage can reduce final kernel weight and size; kernels may still abort; as kernels mature, potential yield reduction from stress decreases.
Plant is utilizing 0.24 inch of water per day.

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.
As the lemmas and paleas dry, the cob begins to attain its final coloring — white, pink, light red or dark red.

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

The embryo has increased in size and will continue to develop rapidly during this stage. Kernels are about half of their mature weight.

Kernels display final coloring; inner fluid thickens to a dough-like consistency; moisture is ~70%.
Plant is utilizing 0.20 inch of water per day.

Lower leaves often die back when nutrients are being relocated within the plant during the reproductive stages.

2000 GDUs ~24–28 days after silking (R1)

R4
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.
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 be 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.
Kernels reach maximum dry matter weight and are physiologically mature; moisture is ~30–35%; black layer forms.

**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.
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.

---

**Number**

- **Ears per area**
- **Kernels per ear**

**Size**

- **Weight per kernel**

**Grain Yield**

\[ \text{Grain Yield} = \text{Number} \times \text{Size} \]

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

- 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.

---

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**.

---

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

<table>
<thead>
<tr>
<th>Stage</th>
<th>GDUs</th>
<th>Approximate Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>V12</td>
<td>815</td>
<td>~ Jun 26</td>
</tr>
<tr>
<td>V18</td>
<td>1160</td>
<td>~ Jul 13</td>
</tr>
<tr>
<td>R1</td>
<td>1250</td>
<td>~ Jul 17</td>
</tr>
<tr>
<td>R6</td>
<td>2350</td>
<td>~ Sep 11</td>
</tr>
</tbody>
</table>

~GDUs per day ~ May 12

THE RIGHT RM HYBRID
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.