Dec 1st, 12:00 AM

Understanding corn development: A key for successful crop management

Lori J. Abendroth
Iowa State University, labend@iastate.edu

Roger W. Elmore
Iowa State University

Matthew J. Boyer
Iowa State University

Stephanie K. Marlay
Iowa State University

Follow this and additional works at: https://lib.dr.iastate.edu/icm
Part of the Agriculture Commons, and the Agronomy and Crop Sciences Commons

This Event is brought to you for free and open access by the Conferences and Symposia at Iowa State University Digital Repository. It has been accepted for inclusion in Proceedings of the Integrated Crop Management Conference by an authorized administrator of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.
Understanding corn development: A key for successful crop management

Lori J. Abendroth, agronomy specialist, Agronomy, Iowa State University; Roger W. Elmore, professor, Agronomy, Iowa State University; Matthew J. Boyer, former graduate research assistant, Agronomy, Iowa State University; Stephanie K. Marlay, agricultural specialist, Agronomy, Iowa State University

New publication: Corn Growth and Development

The new publication, *Corn Growth and Development*, will be released January 2011 (Abendroth et al., 2011) and replaces *How a Corn Plant Develops*, Special Report 48 by Iowa State University (Ritchie et al., 1986). *Corn Growth and Development* (CGD) highlights include:

- Text based on new corn growth and development research
- Images of the plant above- and below-ground
- Timelines showcasing crop development across large periods of time
- Season-long nutrient and biomass accumulation curves derived from ISU research conducted during 2007 and 2008

Objectives

CGD is written to equip producers, agronomists, and scientists with a thorough and technical understanding of crop growth and development. The new publication not only provides the fundamentals of crop development but also material specifically useful to practitioners looking for detailed information on crop physiology applicable to field scale agriculture. Specific goals of today’s session include:

- Predicting vegetative and reproductive development
- Estimating dry matter and nutrient (N, P, and K) accumulation
- Identifying suitable plant and root development

Objective 1: Predicting vegetative and reproductive development

Vegetative development

Crop developmental stages are determined on a whole-field basis when 50% or more of the plants are at a particular stage. The Leaf Collar Method is used for determining the appropriate vegetative (V) stage although other methods do exist and are used to a lesser degree including: Horizontal Leaf also known as “Droopy” Leaf (used primarily by crop insurance adjustors), Leaf Tip and BBCH (used primarily by the international scientific community), and the method used on pesticide labels (these often reference plant height in determining proper application timing).

Crop development varies year to year if compared on a calendar date basis due to variability in planting dates, air and soil temperature, and overall environmental conditions. If crop development is evaluated based on heat unit accumulation, or thermal time, development becomes predictable within and across growing seasons. The time required for corn to progress from one developmental stage to another is based on the amount of heat accumulated. Thermal time represents the length of time the crop spends within a defined temperature range considered optimum for that crop. For corn, this range for air temperatures begins at 50° F (10° C) and ends at 86° F (30° C). Corn thermal time is determined using the following equation (Equation 1) and its end result referred to as growing degree days (GDD).
Equation 1. Fahrenheit growing degree day (GDD) calculation for one day.

\[ \text{GDD} = \left[ \frac{T_{\text{MAX}} + T_{\text{MIN}}}{2} \right] - 50, \]

with:

- \( T_{\text{MAX}} \): Maximum daily air temperature. If temperature is more than 86° F, insert 86 into the equation.
- \( T_{\text{MIN}} \): Minimum daily air temperature. If temperature is less than 50° F, insert 50 into the equation.

Leaf appearance is predictable from VE to the plant’s final leaf (Vn) based on GDD accumulation (Figure 1). From VE to V10, a new collared leaf will appear approximately every 84 GDDs whereas new leaves appear approximately every 56 GDD for V11 to Vn.

Figure 1. Following emergence (VE), vegetative development is predictable based on GDD accumulation. The approximate number of calendar days from VE to certain vegetative stages is shown. Note: Figure as shown is very similar to the figure included in Corn Growth and Development although this is not the final version. This figure cannot be reproduced for any use; if a usable version of this figure is desired it can be attained from www.extension.iastate.edu/store.

Reproductive development

Reproductive (R) stages are defined solely on grain development of the primary ear (uppermost ear). Staging criteria are based on the outer appearance and inner characteristics of the kernels located in the middle of the ear. Kernels change in several significant ways during the grain fill period, including: color change from white to a deep yellow, reduced moisture content, embryo development, and increased starch accumulation.
Reproductive development is predictable based on growing degree day accumulation although more variation exists compared to that with vegetative development. Figure 2 displays the expected developmental trend although the number of GDDs necessary to progress from one stage to the next can vary with differences from that shown most expected to occur after R4. Reproductive development does not follow a linear response (as in Figure 1) with significantly more time required between the later R stages than with the earlier.

![Graph showing reproductive development relative to growing degree day accumulation](image)

**Figure 2.** Beginning at R1 (silking), reproductive development is predictable based on GDD accumulation. The approximate number of calendar days from R1 to each later R stage is noted on the x-axis. Note: Figure as shown is very similar to the figure included in Corn Growth and Development although this is not the final version. *This figure can not be reproduced for any use; if a useable version of this figure is desired it can be attained from [www.extension.iastate.edu/store](http://www.extension.iastate.edu/store).*

Although kernels are pollinated and fertilized during R1, the ear is at the beginning of a rapid elongation period and is only 40% to 45% of its final size. By R2, the ear has reached its final size and only kernel development changes from this point forward.

The number of calendar days varies between each R stage as shown in Figure 2 and are summarized as approximately: R2 (10 to 12 days after R1), R3 (18 to 20 days after R1), R4 (24 to 26 days after R1), R5 (31 to 33 days after R1), and R6 (66 to 70 days after R1). The largest amount of time is required between R5 and R6 with over a month on average.

Kernel growth begins following pollination (R1) and moisture content changes accordingly with the peak set early. At the beginning of each stage, kernel moisture is 85% (R2), 80% (R3), 70% (R4), 60% (R5), and 30-35% (R6). As kernel moisture decreases, dry matter accumulation increases. Kernel dry matter is approximately 5% at R2, 15% at R3, 25% to 30% at R4, 45% at R5, and 100% at R6. A large increase in kernel weight occurs during R5 with substages defined based on the ‘milk line’ (Table 1). Most often, kernels are designated as ¼, ½, or ¾ milk line.
Table 1. Progression of milk line from R5 to R6 with approximate GDD and days between each substage. Note: Table as shown is very similar to the table included in Corn Growth and Development although this is not the final version. This table can not be reproduced for any use; if a useable version of this table is desired it can be attained from www.extension.iastate.edu/store.

<table>
<thead>
<tr>
<th>R Stage</th>
<th>Between Each Substage:</th>
<th>GDD</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.25 (1/4 milk line)</td>
<td></td>
<td>75</td>
<td>4</td>
</tr>
<tr>
<td>5.5 (1/2 milk line)</td>
<td></td>
<td>115</td>
<td>6</td>
</tr>
<tr>
<td>5.75 (3/4 milk line)</td>
<td></td>
<td>175</td>
<td>6</td>
</tr>
<tr>
<td>6.0</td>
<td></td>
<td>235</td>
<td>20</td>
</tr>
<tr>
<td>Total (Average)</td>
<td></td>
<td>600</td>
<td>36</td>
</tr>
</tbody>
</table>

Objective 2: Estimating dry matter and nutrient (N, P, and K) accumulation

Dry matter accumulation

Modern-day hybrids produce more than 20,000 pounds per acre of above-ground dry matter given ample sunlight, water, and fertility without competition from weeds, insects, or foliar diseases (Figure 3). The percent of grain to plant material at physiological maturity (R6) is approximately 50%:50% and has remained fairly unchanged although it has increased slightly when compared to older hybrids. Therefore, as grain produced from an acre of land increases, the amount of vegetative dry matter also increases nearly the same percent.

![Total Above-Ground Dry Matter](image)

Figure 3. Total dry matter accumulation on a percent and pound per acre basis, from VE to R6. Note: Figure as shown is different from the figure included in Corn Growth and Development. This figure can not be reproduced for any use; if a useable version of this figure is desired it can be attained from www.extension.iastate.edu/store.
**Nutrient (N, P, and K) accumulation**

Three macronutrients account for the majority of fertilizer applied to meet crop demand, nitrogen (N), phosphorus (P), and potassium (K). Other nutrients are needed by the crop although they do not regularly get applied by growers due to the small amount needed and their natural occurrence in the soil at appropriate levels. Corn nutrient accumulation patterns vary based on the nutrient examined although each nutrient follows a similar pattern of increased use as time progresses.

Nitrogen is the nutrient consumed in the largest quantity per unit area, with nearly 200 pounds per acre contained in the plant at R6 (Figure 4). Phosphorus and potassium consumption are less at R6, 40 and 140 lbs per acre respectively (Figures 5 and 6, respectively).

---

**Figure 4.** Total nitrogen (N) accumulation on a percent and pound per acre basis, from VE to R6. The decline in total N at mid-R5 is attributed to leaf loss and degradation. Note: Figure as shown is different from the figure included in Corn Growth and Development. *This figure can not be reproduced for any use; if a useable version of this figure is desired it can be attained from www.extension.iastate.edu/store.*
Figure 5. Total phosphorus (P) accumulation on a percent and pound per acre basis, from VE to R6. The decline in total P at late-R5 is attributed to leaf loss and degradation. Note: Figure as shown is different from the figure included in Corn Growth and Development. This figure can not be reproduced for any use; if a useable version of this figure is desired it can be attained from www.extension.iastate.edu/store.

Figure 6. Total potassium (K) accumulation on a percent and pound per acre basis, from VE to R6. The decline in total K at mid-R5 is attributed primarily to leaf loss and degradation. Note: Figure as shown is different from the figure included in Corn Growth and Development. This figure can not be reproduced for any use; if a useable version of this figure is desired it can be attained from www.extension.iastate.edu/store.
Objective 3: Identifying suitable plant and root development

The status of a crop's overall health is primarily evaluated by examining above-ground plant growth. Seeing and understanding normal development is critical for any practitioner to effectively assess a crop field.

Growth and development are terms often used interchangeably in crop discussions, yet each has a distinct and different meaning. Growth refers to the increase in size of an individual plant or component of the plant. Development refers to the plant's progress from earlier to later stages of maturation based on established crop criteria. Agronomists and scientists can better predict crop development (as shown in Figures 1 and 2) rather than crop growth because growth varies relative to temperature, moisture stress, weed pressure, adequate fertility, etc.

At planting, corn absorbs 30% of its weight in water and will do so nearly irrespective of temperature although enzyme activity will not occur until seedbed temperatures reach 50°F.

The two primary components within the seed are the endosperm and embryo. The endosperm interior contains starch and protein which are broken down by enzymes largely into solubilized sugars and amino acids utilized by the growing embryo.

Following germination and emergence, the seedling initiates new leaves at the growing point. The growing point remains below-ground until approximately V6 (six collared leaves) at which time it moves above the soil surface. All leaves are initiated by V6 although much growth is necessary per leaf as many of the leaves are too small to see without a microscope. Each leaf is attached to a specific stalk node and separated by internode tissue, the amount of separation increases typically with later appearing leaves.

Two distinct root systems exist in corn, the seminal root system and the nodal root system. Seminal root system growth slows following emergence and reaches maximum size at approximately V2. The nodal root system is: visible by V2, represents half of the root mass by V3, and becomes the dominant root system by V6. Nodal roots develop at the junction of the coleoptile and mesocotyl and found normally at a depth of approximately 0.75 inches. Corn planted at 1.5 inches or deeper will have the nodal root system consistently near 0.75 inches because the placement is based on the perception of incident light by the mesocotyl. Roots can elongate approximately 1 inch per day with some variation existing among hybrids. The plant's root system will reach maximum depth between approximately R2 and R3 and can extend more than 6 feet deep in unrestricted soils, although in most fields the majority of roots are located within the upper 1.5 feet.

References