BEST MANAGEMENT PRACTICES

Chapter 5:
Corn Growth and Development

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As the corn plant develops, it undergoes physical and biochemical changes, which impact its response to different management decisions. By understanding these changes, management inputs can be made more efficient. The purpose of this chapter is to highlight corn growth stages.

Introduction

The rate that corn grows and develops changes during the season. Young corn plants increase in weight slowly, but as more and more leaves are produced, the rate of dry-matter accumulation increases (Fig. 5.1). Under normal growing conditions, the rate of plant development is largely dependent on temperature. Environmental factors, such as water and nutrient deficiencies, can alter the relationship between plant growth and temperature. In South Dakota, water and nitrogen (N) are important resources that limit corn growth and development, and ultimately influence yield. If water, nitrogen, or other resources become limiting, especially when the plant is rapidly growing, yield is often reduced. Other factors can also stress corn plants, thereby limiting growth and reducing yield. Disease and insect infestations can interfere with water and nutrient uptake or severely damage the plant to the point of yield loss. Weeds have many effects on corn growth, including causing the down regulation (nonexpression) of many genes during the weed-free period and creating direct competition for water, nutrients, and light (Moriles et al., 2012). Stress from temperature and water impacts nutrient availability and susceptibility to pests.

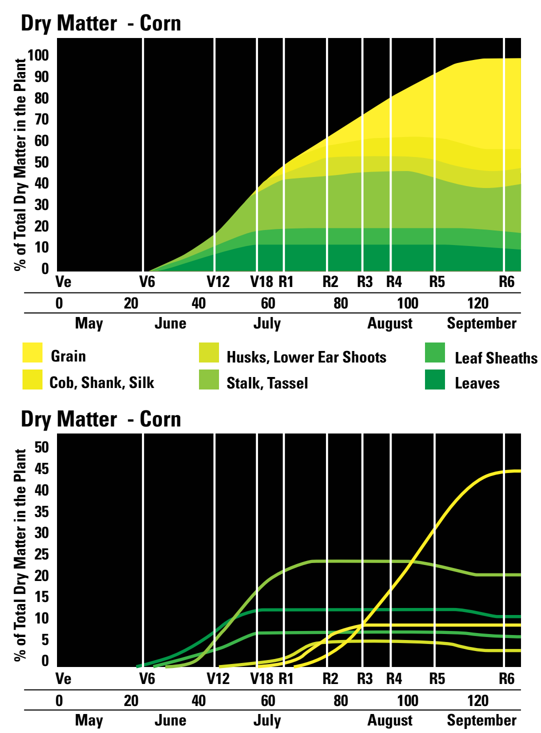

Figure 5.1 Dry-matter accumulation in corn plant over time. (Courtesy: Iowa State)

Many management decisions consider the stage of growth and development of the crop. For example, some pesticide products are labeled for use only at certain stages because of potential for crop damage or other undesirable effects. Fertilizer applied at the right time can provide a greater crop response; however, if fertilizer is applied at the wrong growth stage, benefits can be reduced or negative responses can occur. Water stress at certain stages is more critical than at other stages. Management efficiency can be improved by matching the crop's need to the treatment. Understanding how a corn plant grows and develops is important for maximizing efficiency.

Corn Growth Stages

A number of classification approaches can be used to identify a corn plant's growth stage. However, in South Dakota the most widely used system is the Iowa State classification approach (Ritchie et al., 1993). This system divides corn growth and development into vegetative (V) and reproductive (R) stages (Table 5.1). The VE (emergence) occurs when the coleoptile pushes through the soil surface. After emergence, the vegetative stages are designated numerical subdivisions as V1, V2, V3; through Vn where n is the number of leaves with collar visible until the tassel emerges (VT). The collar is where the leaf blade visually breaks away from the sheath and the stalk of the corn plant (Fig. 5.2), and vegetative growth stages are based upon the number of visible leaf collars. Leaves within the whorl, not

Figure 5.2 Corn 1st, 2nd, and 3rd leaf collars. (Courtesy: Iowa State)

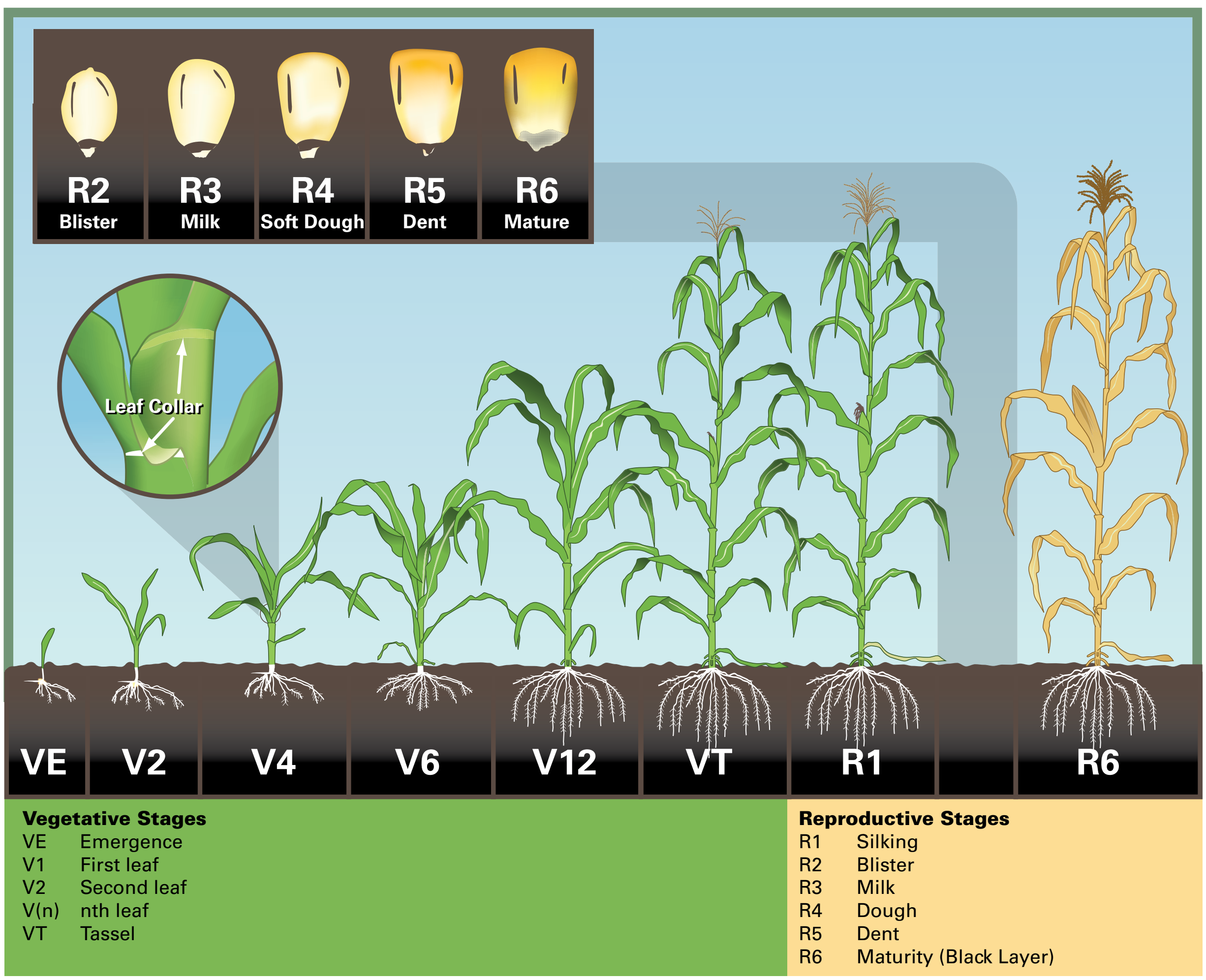

Figure 5.3 Corn growth stages typically observed in South Dakota.

Table 5.1 Growth and development stages in corn. (Adapted from Ritchie et al., 1993)

Vegetative Stages		Reproductive Stages	
VE	Emergence	R1	Silking - silks visible outside the husks
V1	First leaf collar	R2	Blister - kernels are white and resemble a blister in shape
V2	Second leaf collar	R3	Milk - kernels are yellow on the outside with a milky inner fluid
V3	Third leaf collar	R4	Dough - milky inner fluid thickens to a pasty consistency
V(n)	nth leaf collars visible	R5	Dent - nearly all kernels are denting
VT	Tasseling - last branch of tassel is completely visible	R6	Physiological maturity - the black abscission layer has formed

fully expanded and with no visible leaf collar are not included. For example, a plant with 3 collars would be called a V3 plant, although more than 3 leaves may be showing on a plant (Fig. 5.3). It is important to note that the number of leaves vary depending on the corn hybrid and environmental conditions. In South Dakota, early season (maturity rating < 95 d) can begin reproductive development after the V12 stage. It is not uncommon for late maturing hybrids (RM > 100 d) to develop more leaves after the V12 growth stage. At about V6 stage, the small lower leaves are torn from the plant due to increasing stalk and nodal root growth. This loss of lower leaves needs to be taken into consideration when determining the vegetative stage. Reproductive stages begin at silking (R1) and end at maturity or "black layer" (R6).

Under warm, moist conditions, corn will germinate and emerge 4 to 6 days after planting. Optimal temperature and soil water are critical at this time. Germination and emergence are delayed when soil water is limiting because the seed needs to imbibe water to germinate. Alternatively, too much water also delays emergence and root development. In residue-covered soils or if spring air temperatures are low, germination may be slow due to cool soil temperature. Temperatures below 50°F may delay seed germination. Ideally, corn should be planted at a depth of 1.5 to 2.0 inches. Shallow planting (< 1.5 inches) into warmer soil can accelerate emergence but may result in poor root development. Planting deeper than 2 inches may result in first leaves emerging below the soil surface.

The first leafy structure that appears aboveground is the coleoptile ("spike"), followed by true leaves (Fig. 5.4). Warm, moist, and well-aerated soil conditions promote vigorous growth and development. New leaves are produced at a single "growing point" near the tip of the stem. The "growing point" is below the soil surface for up to 4 weeks after planting. When the growing point is below the soil surface, the crop usually survives light frost or minor hail. However, corn plants are most susceptible to flood damage during this stage and flooding can results in severe yield losses.

Figure 5.4 Corn seedling showing seminal and nodal roots. (Modified from Ritchie et al., 1993, courtesy Iowa State)

Corn roots do not explore a significant volume of soil during early growth stages but develop rapidly as the plant develops. Corn has seminal and nodal roots. Seminal roots emerge immediately after germination, cease growth at V3, but continue to function throughout the life of the plant. Nodal roots are initiated at formation of the first node (V1) and continue to develop until kernel blister. By the V6 growth stage, nodal roots become the major supplier of water and nutrients.

Nutrient deficiencies, especially phosphorus (P), are common early in the growing season if soil is cool and wet. The application of starter fertilizer will usually prevent this problem. If fertility levels are sufficient, early season nutrient deficiencies often disappear and usually do not reduce yield. Scouting fields for weeds are crucial during early growth.

Six-Leaf (V6) to Seven-Leaf (V7) Stage

In South Dakota, corn is usually at V6 in early to mid-June. At the V6 stage, rapid stem elongation begins and ear shoots begin to develop. A new leaf emerges about every three days, while lower leaves begin to degenerate. The growing point is above the soil surface and frost or hail can cause significant damage. The root system is well-developed and distributed in the soil, and the plant has an improved capacity to absorb nutrients. Scouting to determine whether additional fertilizer is needed is critical at the V6 growth stage. Sidedressing nitrogen (N) is most effective when applied between V6 and V8. In addition, scouting for corn rootworm and other root-pruning insects is also critical. Because control options for these insects are limited, the best option is to plant resistant or genetically modified hybrids.

Eight-Leaf (V8) to Eleven-Leaf (V11) Stage

At this stage many ear shoots, which are potential ears, are present. Eventually, only one or two upper shoots form harvestable ears. The number of ears formed depends on the corn hybrid, with prolific hybrids forming more than one ear when planted at low plant populations. At this stage, deficiencies in macronutrients and micronutrients can start to show. If not corrected, nutrient deficiencies can seriously restrict leaf growth. By V10, the plant is growing rapidly, with new leaves appearing every 2 to 3 days. The plant requires substantial amounts of water and nutrients to maintain this growth rate. Stress from pests, heat, lack of nutrients, and/or water can slow development.

Twelve-Leaf (V12) to more leaves

The number of leaves on a plant is dependent on the plant's maturity rating and the type of corn. For example, silage corn may have more leaves than corn designed to produce grain. The higher the maturity rating, the higher the number of leaves. The potential number of kernels per ear and ear size are determined at the V12 growth stage. The rate of corn plant development at the V12 stage is influenced by hybrid maturity. Earlier-maturing hybrids progress through these stages in a shorter time, resulting in smaller ears compared to later-maturing hybrids. If water and nutrient availability can support a higher population, yield differences between early and late hybrids can be equalized by increasing plant density or population. Stress at the V12 stage can reduce kernel numbers and ear size. The plant has a peak water demand during this growth stage and it can use one-quarter of an inch per day. The corn plant also needs and utilizes large amounts of nitrogen, phosphorus, and potassium at this stage. Severe hailstorms that strip leaves and break tassels can result in complete crop loss.

Tasseling (VT)

The tasseling stage occurs 2 to 3 days before silking (Fig. 5.5). At this stage, the plant has reached full height and the last branch of the tassel is fully visible, but silks have not yet emerged from the ear shoot. The length of time between VT and R1 (silk stage) varies depending on the corn hybrid and environmental conditions. Pollen shed usually takes place from late morning to early evening. At this stage, the impact of a hailstorm can be very severe compared to any other corn growth stage, since all leaves have emerged. Any damage to or complete loss of the tassel may result in very poor to no grain formation.

Figure 5.5 Corn at the VT (Tasseling) growth stage. Courtesy: Howard F. Schwartz, Colorado State University, Bugwood.org

Silk (R1) Stage

The emergence of silk (R1) marks the first stage of the reproductive period (Fig. 5.6). Every potential kernel (ovule) on the ear grows its own silk. Silks begin to elongate soon after the V12 stage. At the R1 stage, the silks emerge and capture pollen shed from the tassel. Pollen captured by the silks fertilizes ovules on the cob within 24 hours, which then develop into kernels. Pollen shed typically occurs during early or mid-morning, when moisture and temperature conditions are favorable. This stage is one of the most crucial reproductive stages and unfavorable environmental conditions can severely reduce yield. Dry (low humidity) and hot (> 95°F) conditions result in reduced fertilization because of the drying of the exposed silks and killed pollen. With no fertilization, ears are barren. Silks grow at a rate of approximately 1.5 inches a day. The silks continue to grow until pollen is captured and germinate or until they degrade as they mature. Environmental conditions such as drought stress can result in delayed silk elongation and emergence. Generally, silks remain receptive to pollen for up to 10 days after silk emergence, though they start to deteriorate only five days after emergence. Under favorable environmental conditions, there is synchrony between pollen-shed and silk emergence making silk receptivity of little concern. Insect pests, such as corn rootworm destroy silks through feeding and can produce reduced yields. To minimize losses, fields should be scouted for corn rootworm beetles at silking (R1) and controlled if populations exceed the economic threshold.

Figure 5.6 Corn shortly after silk emergence. This growth stage is called R1 or silking. Courtesy: Howard F. Schwartz, Colorado State University, Bugwood.org

Potassium (K) uptake is complete at silking, but nitrogen (N) and phosphorus (P) uptake continues. If N and P are limiting, the plant will attempt to compensate by moving these nutrients from older leaves into upper leaves or the developing grain. At this stage, N- and P-deficiency symptoms can be observed in lower leaves. Unfortunately, nutrient application either at this time or later in development will not make up for these deficiencies.

Kernel Blister Stage (R2)

After pollination, kernel formation begins. The kernels at the R2 stage are whitish and shaped like blisters. They appear approximately 10 to 14 days after silking. At this stage, silks turn brown and dry rapidly. Starch begins to accumulate in the kernel as the plant initiates a period of kernel fill. At the R2 growth stage, the radicle, coleoptile, and the first embryonic leaf have formed in the embryo. The kernel moisture content at the R2 stage is about 85%. Any severe stress at pre-blister and blister stage can result in aborted kernels and reduce the number of kernels on the cob. At this stage, the plant will need 960 growing-degree days (GDD), also called growing-degree units, to reach physiological maturity. Additional water at or after R2 does not enhance yield, slows dry-down, and may encourage stalk and grain diseases.

Kernel Milk Stage (R3)

The kernel milk stage occurs approximately 22 days after silking (Figure 5.7). At this stage, kernels are mostly yellow on the outside, starch accumulation occurs rapidly, kernels contain a milky white fluid, and cell division in the endosperm is complete. Observable kernel growth is mainly due to cell expansion and starch accumulation, severe stress can cause kernel abortion. The kernel moisture content is about 80%, and approximately 880 GDD are required to reach physiological maturity. Although not as critical as the R1 growth stage, stress at this time can reduce kernel size and weight.

Figure 5.7 The milk stage stage. Courtesy: Howard F. Schwartz, Colorado State University, Bugwood.org

Kernel Dough Stage (R4)

As the kernels mature to the dough (R4) stage, they change from a milky consistency to soft and sticky. At R4, the kernels have accumulated nearly half of their mature weight and the cob has a color ranging from light red to pink. At this stage, four embryonic leaves are formed and the kernel moisture content is approximately 70%. Unfavorable environmental conditions or nutrient deficiencies can reduce kernel weight.

Kernel Dent Stage (R5)

At the R5 growth stage, nearly all of the kernel crowns are denting, the moisture content is approximately 55% (Fig. 5.8), and a distinct horizontal line called the milky line can be seen between the yellow (starchysolid) and white (milky-liquid) areas on the kernel. As the kernel matures and starch hardens, this line slowly progresses to the tip end of the kernel. A hard frost at R5 can kill the plant, thus reducing yield and kernel development. Corn plants killed at this stage generally have low test weight and a slower dry-down rate. Selecting a hybrid that matures 2 to 3 weeks before fall frost reduces these risks. If early frost kills the plant, the crop can be harvested and ensiled as high-moisture grain for animal feed.

Figure 5.8 The R5 growth stage in corn. Courtesy: Howard F. Schwartz, Colorado State University, Bugwood.org

Physiological Maturity (R6)

The corn plant is at physiological maturity (R6) about 55 to 65 days after silking. At this stage, kernel dry-weight has reached its maximum, the kernels are physiologically mature and safe from frost damage, the moisture content ranges from 30% to 35%, the starch line has advanced to the kernel tip, and a black layer has formed at the base of the mature kernels. The black layer forms from the tip of the kernels to the basal kernels. Severe stress after this stage has little effect on grain yield, unless the integrity of the stalk or ear is compromised by disease such as stalk rots or insect feeding. At this time, allowing the crop to dry in the field reduces drying costs if the crop is to be harvested for grain. Moisture content of 15% allows corn to be stored safely for less than six months. For long-term storage, corn should be dried to 12% moisture to avoid spoilage. Hybrids have subtle differences in growth and development (with respect to number of leaves, ears, maturity, dry-down, and other traits). Early harvest is rarely profitable because of drying costs or dockage. Corn can be left in the field if stalks maintain strength, ear drop is not a problem, and there is limited risk of ear and kernel rots ¬– especially under hot, dry conditions. Harvest loss from lodging and ear drop can be significant in fields damaged by European corn borer or Western bean cutworm. In these situations, early harvesting to reduce harvest losses should be weighed against drying costs. Scouting to assess stalk condition, ear retention, ear rots, and grain moisture is recommended.

Growing-degree Days: Rating Corn Hybrids

Regional differences in the corn growing season have resulted in multiple methods to match hybrid characteristics to environmental conditions. Corn growth rate is controlled primarily by temperature, and this is often characterized by a calculation called growing-degree days (GDD). Most seed corn companies rate hybrid maturity based on GDD or heat units (HU).

The GDD accumulation for a single day is the average of the low and high temperature, minus 50°F. The calculation subtracts 50°F because corn plants have limited growth below 50°F. If the low temperature for any given day is < 50°F, the low temperature is defined as 50°F, and if the temperature is > 86°F, the high temperature is defined as 86°F. This method of calculating GDD is often referred to as the (86,50) system. Different pests or crops have different critical values. Example calculations are provided in Chapter 10.

GDD are calculated for each day beginning with the day after planting. The GDD accumulation for the growing season varies depending on the location and year. The number of GDD required for the corn plants to reach a particular stage of development is fairly consistent. Tables 5.2 and 5.3 show the GDD needed for a plant to reach a certain vegetative or reproductive stage. The duration of the growing season for corn hybrids is directly related to their GDD requirements, with late-maturing hybrids or long-season hybrids requiring more GDD than shorter-season hybrids. The U2U (Usable to Useful) Project website can be used to calculate the date of different growth stages based on the hybrid and planting date.

Table 5.2 Comparison between leaf collar and FCIC[1] corn growth staging systems for a 120-day (RM[2]) hybrid

FCIC	Leaf Collar	Description	Days/Stage	GDUs/Stage	Days after Seeding	GDUs after Seeding
---Emergence – Vegetative Stages---						
-	V0	Seeding to Germination	5 – 10	100 – 150	5 – 10	100 – 150
-	VE	Coleoptile Opens	2 – 4	66	7 – 14	166 – 216
V2	V1	1st Leaf Collar	3	66	10 – 17	232 – 282
V3						
	V2	2nd Leaf Collar	3	66	13 – 20	298 – 348
V4	V3	3rd Leaf Collar	3	66	16 – 23	364 – 414
V5	V4	4th Leaf Collar	3	66	19 – 26	430 – 480
V6	V4	4th Leaf Collar	3	66	19 – 26	430 – 480
V7	V5	5th Leaf Collar	3	66	22 – 29	496 – 546
V8	V6	6th Leaf Collar	3	66	25 – 32	562 – 612
V9	V7	7th Leaf Collar	3	66	28 – 35	628 – 678
V10	V7	7th Leaf Collar	-	-	-	-
V11	V8	8th Leaf Collar	3	66	31 – 38	694 – 744
V12	V9	9th Leaf Collar	3	66	34 – 41	760 – 810
V13	V10	10th Leaf Collar	3	66	37 – 44	826 – 876
V14	V11	11th Leaf Collar	3	66	40 – 47	892 – 942
V15	V12	12th Leaf Collar	3	66	43 – 50	958 – 1,008
V16	V13	13th Leaf Collar	3	66	46 – 53	1,024 – 1,074
V17	V14	14th Leaf Collar	3	66	49 – 56	1,090 – 1,140
V18	V15	15th Leaf Collar	2	48	51 – 58	1,138 – 1,188
	V17	17th Leaf Collar	2	48	55 – 62	1,234 – 1,284
	V18	18th Leaf Collar	2	48	57 – 64	1,282 – 1,332
	V19	19th Leaf Collar	2	48	59 – 66	1,330 – 1,380
	V20	20th Leaf Collar	2	48	61 – 68	1,378 – 1,428
	V(n)	nth Leaf Collar	-	-	-	-
	VT	Tassel Extended – No Silks	4	100	65 – 72	1,478 – 1,528

All values are approximations, as the values may vary over years, production environments, and locations. (Adapted from USDA-FCIC, Corn Loss Adjustment Standard Handbook, 2007)

[1] Federal Crop Insurance Corporation (FCIC), operated by the United States Department of Agriculture, Risk Management Agency

[2] Relative maturity (RM)

Table 5.3 Comparison between leaf collar and FCIC1 corn growth staging systems for a 120-day (RM2) hybrid

---Reproductive Stages---						
Silked	R1	Silked – Pollen Shed	4	100	69 – 76	1,578 – 1,628
Silks Brown		Silks 75% Brown	5	125	74 – 79	1,703 – 1,753
Pre-Blister		No Fluid in Kernels	4	100	78 – 85	1,803 – 1,853
Blister	R2	Kernels are watery	4	100	82 – 89	1,903 – 1,953
Early Milk		Kernels Begin to Yellow	4	100	86 – 93	2,003 – 2,053
Milk	R3	Kernels Yellow, No Solids	5	100	91 – 98	2,103 – 2,153
Late Milk		Kernels Contain Semi-Solids	4	100	95 – 102	2,203 – 2,253
Soft Dough	R4	Kernels Pasty	5	100	100 – 107	2,303 – 2,353
Early Dent		Kernels Begin to Dent	5	100	108 – 115	2,403 – 2,453
Dent	R5	Kernels Soft but Dented	5	125	113 – 120	2,528 – 2,578
Late Dent		Kernels Dented but Drying	5	125	118 – 125	2,653 – 2,703
Nearly Mature		Kernel Embryo not Hard	5	125	123 – 130	2,778 – 2,828
Mature	R6	Black Layer	5	125	128 – 135	2,903 – 2,953

All values are approximations, as the values may vary over years, production environments, and locations. (Adapted from USDA-FCIC, Corn Loss Adjustment Standard Handbook, 2007)

[1] Federal Crop Insurance Corporation (FCIC), operated by the United States Department of Agriculture, Risk Management Agency

[2] Relative maturity (RM)

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THE U2U PROJECT: Useful to usable (U2U): Transforming climate variability and change information for cereal crop producer.

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