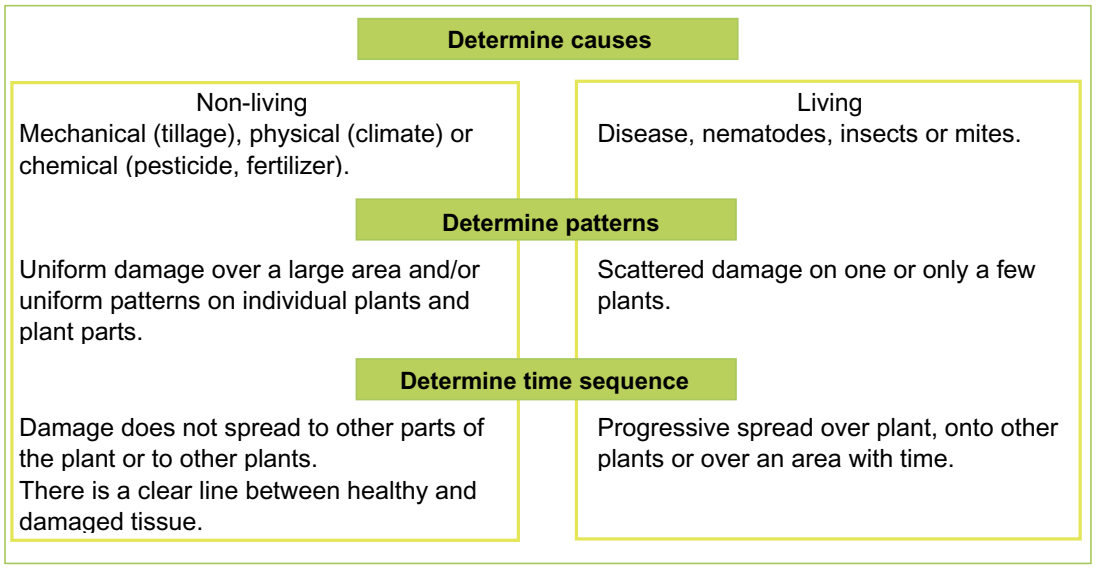
Diagnosing Corn Health

Top corn yields are achieved by providing optimum inputs to match growing conditions and by avoiding yield losses from pests and other abiotic stresses. Weeds, diseases, insects, nematodes, water stress, cultivator damage, wind, compaction, salinity and herbicide damage are only a few of the routine problems growers may encounter in any given year.

While good management can help to avoid some of these problems, the best way to avoid yield loss is to scout corn fields regularly and correctly diagnose problems. Early and correct diagnosis of problems allows producers to manage problems before they cause economic losses. This section is intended to help growers determine the actual cause of problems at certain growth stages to manage pests and other yield limiting factors.

Figure 6. Flowchart for identifying crop problems and defining crop needs.



Supplemental information to determine corn health

- Collect tissue samples (sample both affected and healthy plants).
- Sample soil for salinity, nematodes and other potential problems.
- Probe soil for compaction layers and moisture level.
- Photograph affected and healthy plants.
- Sample irrigation water if suspect salinity or toxins.

Growth Stage Determination

From the moment a corn seed is planted, it undergoes continuous biochemical and physiological changes until harvest. Understanding corn growth and development is valuable for making correct management decisions at specific growth stages throughout the growing season.

This book uses the "leaf collar" system to describe growth stages. This method divides growth stages between vegetative and reproductive stages (Table 3). The reproductive stages are identified by the development of the kernel and its parts. Due to variability in soil type, moisture, and even planting date, all plants in a given field will not be at the same stage at the same time. A field is considered at a given stage when 50% or more of the plants are at or beyond a given stage.

Table 3. Leaf collar system for corn growth stages.

Vegetative stages	Reproductive stages
VE emergence	R1 silking
V1 first leaf	R2 blister
V2 second leaf	R3 milk
V(n) nth leaf	R4 dough
VT tassel	R5 dent
	R6 maturity or blacklayer

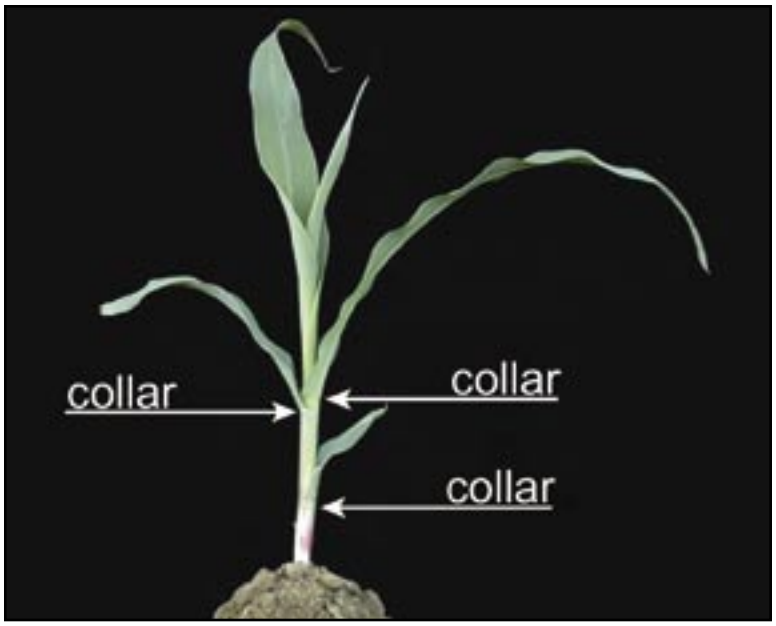


Figure 7. A three-leaf corn plant. The vegetative stages are based upon the number of fully exposed leaves with collars. The collar appears as a light green line on the back of the leaf between the leaf blade and the sheath. Normally a plant at a given growth stage will have additional leaves partially visible, but without distinct collars. The leaf collar system is different from the "hail adjustor's horizontal leaf method" developed by the National Crop Insurance Service. The hail adjustor's method typically will be 1 to 2 leaf stages greater than the collar method. The leaf collar method counts the seed leaf as the first leaf.

Growth Stage and Diagnostics

Planting to Emergence

Corn begins germination when the primary root or radicle first emerges from the swollen seed, which under favorable conditions, will occur within 24 to 36 hours after planting. Emergence can occur in 4 to 5 days after planting in warm, moist soils, but may take two weeks or longer when soils are cool or dry.

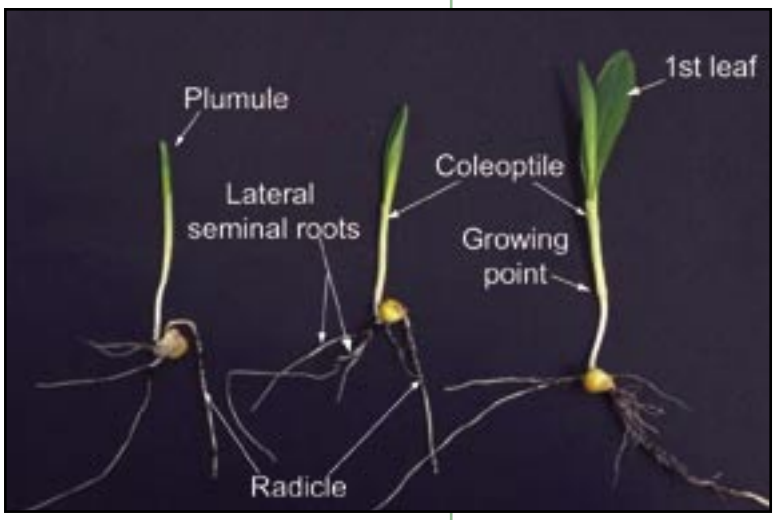


Figure 8. The first plant part emerging though the soil surface is the coleoptile. The plant above ground grows from the embryonic plant (plumule), contained in the coleoptile. Once in sunlight, elongation of the coleoptile stops and new leaves emerge from the tip of coleoptile. The growing point (stem apex) of the plant remains protected 1 to 1.5 inches below ground until the V6 growth stage. The radicle and the seminal system roots develop directly from the seed. The seminal roots will make up only a fraction of the total root system, but are significant until the primary root system (often called nodal or crown) develops. The nodal system begins to develop at V1 approximately 1 to 1.5 inches below ground.

Corn seedling emerging through crust

Management tips

Band nutrients, especially phosphorus, to help early plant vigor when cool soil and a small root system can slow growth.

Soil temperature may be one consideration when deciding whether to irrigate or cultivate corn very early in the growing season. Drier soil warms up faster during the day, but does not retain heat at night as well as moist soil and may impact the severity of an early season frost.

Troubleshooting planting to emergence

Symptom	Possible cause
Seed missing	• planter skips • eaten by birds, rodents or other animals
Seed does not germinate	• poor seed quality • cold soil temperature • planted in dry soil • poor seed bed • poor seed to soil contact • seed rot
Seed germinates, but doesn't emerge	• fertilizer burn • damping-off • seed planted too deep in cold, wet soil • soil crusting due to rain or high sodium • chemical injury • seed corn maggot • seed corn beetle • wire worm • rodents or birds • soil pathogens

Emergence to Knee-high

Corn at the three-leaf (V3) growth stage has three clearly visible leaf collars. Little stem elongation has taken place and the seminal root system stops growing. Ear and leaf shoots are forming and will be complete by V5. The growing point remains protected below the soil surface.

V3 growth stage

Knee-high

Depending on the hybrid, the six-leaf (V6) growth stage occurs when 400 to 650 GDUs have accumulated since planting. Due to differences in hybrid, soil fertility, weather, and other environmental factors, a V6 plant range from 8 to 24 inches. Also at this stage, the crown root system develops rapidly and is the major source of water and nutrients.

Management tips

- It's time to evaluate side-dress nitrogen needs (see page 58 for information on PSNT).
- Scout for 1st generation corn borer larvae and egg masses.

Troubleshooting emergence to knee-high

Symptom	Possible cause
Physical injury	• shoot attacking insects • early hail • lightning • cutworm, army cutworm, pale western cutworm, white grubs, false cinch bugs, thrips, grasshoppers • onion wrapping or buggy whip • wind damage
Poor vigor and slow growth	• weather conditions • soil compaction • nematodes, wireworm, rootworms and other root feeding insects • shallow planted corn, compacted soils that leads to rootless corn syndrome • nutrient deficiencies of N, P or Fe • cool temperatures causing purple corn • drought • excessive moisture • weeds

With six visible leaf collars, the V6 plant has more elongated stalks than previous stages and will begin rapid growth and nutrient uptake. The growing point and tassel are now above ground and can be damaged by hail, frost or other weather damage.

Diagnosing nutrient deficiency symptoms

Are the symptoms on the upper leaves or the lower leaves?

Upper Leaves

What's the color pattern?

Light green

Are the plants spindly?

YES

SULFUR
deficiency

Source: California Fertilizer Association

Yellow stripes

Are the internodes short?

YES

ZINC
deficiency

NO

IRON
deficiency

Lower Leaves

What color are the leaves?

Yellow

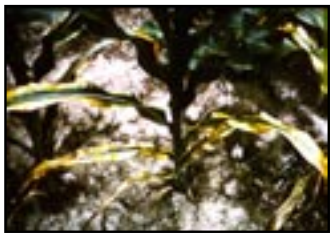
Where is the yellow color?

Leaf Tip and Along Midvein

NITROGEN
deficiency

Leaf Edges

POTASSIUM
deficiency



Source: P.P.I.

Purple

PHOSPHORUS
deficiency

Knee-high to Tassel

At 10 leaf (V10), the corn plant undergoes rapid growth and dry matter accumulation, and gains a new leaf stage every two to four days. (Nutrient and water uptake are increasing to meet growth demand.)

Management tip (V6 - V10)
Although water demand is increasing, the soil can be allowed to deplete to 60% of available water. At V10, plants can undergo some water stress without significantly impacting grain yield.

The final number of leaf stages (V15 to V22) a corn plant develops varies due to hybrid. During later vegetative stages, the upper ear shoot develops rapidly. Brace root development should be obvious by late vegetative growth. Brace roots support the larger plant and help meet increased water and nutrient needs.

The tassel is perhaps the most identifiable part of the corn plant, but this growth stage has some distinct boundaries. The tassel (VT) stage is considered completely initiated when the last branch of the tassel is fully visible, and it ends when the first silks first appear. Although the tassel is a reproductive structure (holding the male flowers), VT is considered a vegetative growth stage because the female flower (silks) emerges shortly after the tassel. The time between VT and R1 is typically short (2-3 days) but varies considerably between hybrids. It is not uncommon to see significant variability in tassel development within a field, representing the variety of environment impacts on corn growth.

V10 corn plant

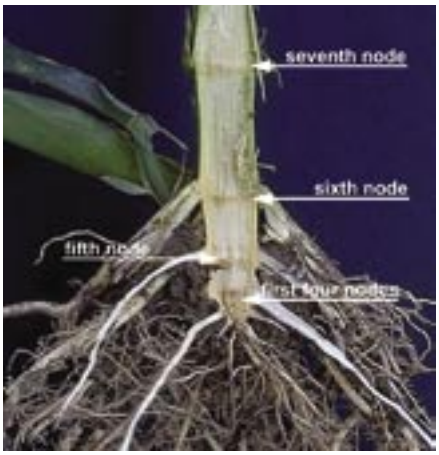


Figure 9. Identifying leaf growth stages starting around V7 becomes more difficult as the lowest leaves may have already deteriorated. For precise identification, it is often necessary to dissect plants lengthwise and count leaf nodes from the bottom of the plant upwards.

VT plant

Management tip (V12 - VT)
The plant now requires 100% of reference ET (see page 70), so water demand is peaking (Table 18) and weather conditions during this time of year (high temperatures, low humidity, wind, and long days) put a high ET demand on fields. Keep a close watch on spider mite control especially during hot, dry weather.


Tassel at VT


Tassel at R1

Growth Stage and Diagnostics

Early hail

Anhydrous ammonia leaf burn

Foliar salinity damage from sprinkler application

Poor stand due to surface compaction

Troubleshooting Knee-high to Tassel

Symptom	Possible cause
Physical injury	• banks and two-spotted spider mites, grasshoppers, thrips, armyworm, corn earworm, western bean cutworm • 1st generation corn borer • wind damage • hail
Lodging	• rootworm • herbicide damage: 2,4-D, dicamba, dinitroanilines • high winds
Poor growth	• N, S deficiency (yellow plants) • P deficiency (purple plants) • water deficiency
Drought appearance	• compaction • drought • salinity • poor irrigation uniformity
Leaf damage or burn	• herbicide drift • leaf disease • late herbicide damage • burn from anhydrous application or liquid fertilizer application

Management tip (VT)
Tassel initiation begins a period where the corn plant is highly sensitive to a variety of environmental stresses, particularly weather. Hail damage at this time can greatly impact grain yield. Corn plants are most vulnerable to hail damage through R1.

Silking

Visible silks outside the husks mark the beginning of the silking (R1) stage. The plant is now in reproductive development, changing its photosynthetic capacity from building a factory (the corn plant) to assembling the product (grain). Each ear can have up to 1,000 potential kernels, although only 400 to 600 kernels actually form. The dust-like yellow pollen that falls from the anthers of the tassel represents millions of pollen grains. Each grain contains the male genetic material necessary for fertilizing one potential kernel.

Management tip

Hail damage between tassel (VT) and R1 can greatly impact grain yield. Water stress also impacts yield during this period calling for irrigation adjustment. Scout for adult corn rootworm beetles feeding on silks, especially in continuous corn. Generally, clipped silks require at least 0.50 inches of exposed, uninjured silk tissue for pollen germination to occur.

Ear shoot at early tassel. In order for potential kernels (ovule) to be pollinated, pollen must travel from the male flower (anthers hanging from the tassel) to the female stigma (silk) leading to each ovule.

Management tip

Although not as sensitive as during pollination, kernel abortion can occur due to severe water stress. Nitrogen and phosphorus uptake is still rapid; however, the plant has started moving these nutrients from the stalks and leaves to the grain. Researchers have measured grain yield responses to nitrogen applied as late as R3 when soil nitrogen was insufficient for maximum yields. Utilize tissue testing (ear leaf) or a chlorophyll meter if nitrogen deficiency is suspected.

R2 blister corn

Blister

Blister (R2) stage is identified by fertilized kernels that no longer have an attached silk and resemble a blister in shape with a pointed nub at the top. Pollinated silks are turning brown and drying out. The success of pollination can be observed by carefully pealing the husks off an early R2 ear and gently shaking the ear upside down. Kernels with detached silks have successfully fertilized and those with attached silks have not.

Management tip

R3 is a good time to inspect kernel set on ears throughout the field and begin assessing yield potential. The appearance of ears can be misleading because husks and cobs continue to lengthen even if kernel set is incomplete. Although row number is determined by V12, kernels per row is sensitive to environmental stresses from V12 through R1. Incomplete kernel set may be caused by both unsuccessful pollination and kernel abortion. Severe water stress can still cause kernel abortion, although not as easily as at the blister stage. Kernel moisture content is approximately 80%.

Milk

Kernels that are mostly yellow and contain milky white fluid identify the milk (R3) stage of development. Starch accumulation creates a milky fluid as the kernels rapidly accumulate dry matter. Depending on the hybrid, R3 occurs 18 to 22 days after silking.

Milk (R3)

R4 corn plant

Dough

When the kernel's milky inner fluid changes to a pasty or doughy consistency due to continued starch accumulation in the endosperm, the plant is considered to be at R4.

R4 kernels have accumulated close to half of their dry matter and are at about 70% moisture.

Management tip

During the grain fill stages (late R2 to maturity) grain yield is much less sensitive to water and heat stress than during pollination. Water use (ET) is decreasing significantly. Severe stress at this stage will reduce yield by decreasing kernel weight.

Ear at dent

Dent

Dent (R5) is one of the most obvious stages to identify. As kernels dry down, a hard white starch layer forms at the top of the kernel. As the kernel matures and approaches maturity, this starch layer (called milk line by some) will move down towards the base of the kernel as it accumulates dry matter and loses moisture. The progress of the starch accumulation can be checked by pressing a kernel with a thumbnail. Full dent arrives when nearly all kernels have dented. Some hybrids have a more pronounced dent than others.

Management tip (R4 - R5)

Water use by the plant is rapidly declining with shorter, cooler days and senescing plant tissue. Depending on soil type and system, the final irrigation should be planned or already complete (see irrigation section). Nutrient uptake has dramatically slowed, but nutrients are moving from the plant to the grain. Subsequently, nitrogen deficiency symptoms often appear on lower leaves as N is moved out of these leaves first to the grain. The degree of these late season symptoms can be hybrid specific but do not always indicate that the plant had an insufficient nitrogen supply for maximum yield. An early frost prior to maturity will lower yield by reducing or halting dry matter accumulation and often cause dry down problems for harvest.

Late R5 kernels. Beginning dent kernels have about 55% moisture content.

Troubleshooting Tassel to Maturity

Symptom	Possible cause
Poor growth or yellowing	• nutrient deficiency • leaf blights
Leaf damage	• corn leaf aphid • wind, hail • salinity • early first frost • leaf miner • air pollution • grasshoppers • spider mites
Poor pollination or ear damage	• corn earworm • smuts • rodents, raccoon, birds • corn rootworm adults clipping silk • western bean cutworm • drought/heat stress
Lodging	• stalk rot • root rot complex • high winds • no brace roots - due to chemical, poor planting depth or insect damage

Drought affected corn

Late hail damage

Heat stress and drought

The potential yield loss from heat stress or drought may result from a combination of possibilities.

- Delayed silk emergence plus a shorter pollen shed duration results in asynchrony (poor timing) of pollen shed and silk availability.
- Silks not receptive to pollen grain germination because of silk desiccation.
- Abortion of fertilized ovules during the first week or two after pollination.
- Pollen viability itself is commonly not an issue during drought stress unless temperatures surpass 100^{O}F for a number of consecutive days.

Other contributing factors besides strong wind may predispose corn plants to lodge.

Reduced root systems may be due to:

- severe corn rootworm injury, especially in later-planted corn fields.
- excessively wet and cold soils during initial nodal root formation for early-planted corn.
- excessively dry or cloddy soils during initial nodal root formation for later-planted corn.
- nematode injury on sandy soils.
- nitrogen deficiency in areas of fields where significant nitrogen loss had occurred earlier.
- compaction from tilling wet soils.
- wet soils at the time of the wind damage that made it easier for the roots to be "pulled" by the force of the wind.

Lodging

The consequences of root lodging depend on the growth stage of the plants at the time damage occurs. The younger the corn, the more plants are able to "straighten up" following severe root lodging without noticeable "goose-necking" of the plant. Older and taller corn plants are less likely to straighten up, but will instead goose-neck as the upper stalk internodes continue to elongate. The goose-necking or curvature of the stalk results from a hormonally driven response to the nearly horizontal position of the lodged plant. Large areas of goose-necked corn are a challenge to harvest and often increase harvest loss of grain if stalks or ears break off before being captured by the combine header.

As corn begins to pollinate, plants are near full height and recovery or straightening up from root lodging is not likely. Severe lodging at or during pollen shed can greatly reduce seed set of the downed plants because silks are often covered by leaves of other fallen plants. The photosynthetic stress imposed on the lodged plants because of shading may limit the survival of fertilized ovules on the ears.

Root systems already limited or damaged by soil compaction, soggy soils or corn rootworm feeding have limited recovery.

R6 kernel. Depending on the hybrid, the moisture content should be 30-35% at black layer R6.

Maturity

Corn reaches physiological maturity (R6) when kernels accumulate maximum dry matter, the hard starch layer has advanced completely to the cob and by the formation of a brown or black layer at the base of the kernel. Kernels on the ear will mature progressively from the tip to the base. Once the black layer forms, kernels no longer accumulate dry matter or water.

Management tip

Scout fields to determine maturity and harvest date depending on planting date, season length, variety, and stalk condition. Early harvest and mechanical drying is rarely profitable in Colorado and research has shown that field drying maintains yield stability.