HOW DO YOU MANAGE A CORN CROP AFTER STRESS?

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To understand how to manage a corn crop after stress, you must first understand how the corn plant develops and how genetics and environment influence yield. Corn growth and development occurs during a growing season with predictable stages. The plant is the ultimate integrator of the environment in which it grows. The environment has much more impact than we have with management, but we need to provide basic inputs at the right time in order to increase our chances for successful yields.

Grain yield in corn is comprised of the components: ears per unit area, kernel number per ear consisting of kernel rows and kernels per row, and kernel weight. Each of these yield components is determined at different stages in the lifecycle of the plant. Yield components develop by initial cell division near the growing point and formation of numerous primordial tissues that eventually become ears or kernels. Often the number of these early structures is greater than what the plant is later capable of supporting. The plant "adjusts" yield components according to environmental and management stresses that take place during the growing season.

The plant has the "potential" to produce more ears and kernels than what is "actually" harvested. For example, the corn plant typically produces 6 to 10 ear shoots, but only one ear (at most two) actually develops. In some years, hybrids may produce 20 rows of kernels on an ear, but most of the time only 12 to 16 rows of kernels develop on the hybrids used in Wisconsin. If you were to examine the ear shoot at the V18 stage (just prior to tasseling) using a microscope, you could count 50 to 60 kernel ovules in a row. Multiplying the number of kernel ovules by the number of kernel rows indicates that 600 to 1200 kernels could potentially grow on an ear. Usually only 300 to 600 kernels develop on the ears of Wisconsin hybrids. Likewise, test weight (an indirect measure of kernel weight) is affected by environmental stresses.

The tasseling, silking, and pollination stages of corn development are extremely critical because the yield components of ear and kernel number can no longer be increased by the plant and the potential size of the kernel is being determined. Table 1 describes when yield components are at their greatest "potential" and when under normal conditions are "actually" determined and are not further affected under typical conditions. For example, the potential number of ears per unit area is largely determined by number of seeds planted, how many germinate, and eventually emerge. Attrition of plants through disease, unfurling underground, insects, mammal and bird damage, chemical damage, mechanical damage, and lodging all will decrease the actual number of ears that can be produced. The plant often can compensate for early losses by producing a second or third ear, but the capacity to compensate ear number is largely lost by R1 and from then on no new ears can be formed.

Likewise, kernel number is at its greatest potential slightly before R1, the actual number of kernels formed is determined by pollination of the kernel ovule. The yield component of kernel number is actually set by pollination and fertilization of the kernel ovule. If the ovule is not pollinated, the kernel cannot continue development and eventually dies. No new kernels form after the pollination phase is past.

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The only yield component remaining with some flexibility is kernel weight. For the first 7 to 10 days after pollination of an individual kernel, cell division occurs in the endosperm. The potential number of cells that can accumulate starch is determined. At black layer formation (R6) no more material can be transported into the kernel and yield is determined.

Table 1. Corn growth and development stages when yield components are at maximum potential and actually determined (105 day hybrid).

Stage	GDU required to reach growth stage	Yield components	
		Potential	Actual
VE (Emergence)	125	Ears/area	-----
V6 (six leaf collars)	470	Kernel rows/ear	"Factory"
V12	815	-----	Kernel rows/ear
V18	1160	Kernels/row	-----
R1 (Silking)	1250	Kernel weight	Kernel number Ears/area
R6 (Black layer)	2350	-----	Kernel weight

Identifying corn growth stages is necessary for post-emergence application of pesticides or growth regulators, to monitor the progress of seasonal development, and to determine the effect on yield of a hail storm, insect feeding, disease, drought or early frost. The objective of this paper is to describe management options for corn from cool wet soils, flooding, hail, lodging, drought, and frost stresses. The last section describes management options when pollination is poor.

Stress from cool, wet soils

Saturated soils, cool temperatures, wet weather are all prescriptions for delaying corn emergence and seedling development. Seeds and germinated seedlings will not sustain any measurable growth or development until soils have warmed above 50°F.

Of particular concern is the development of seedling blight diseases, as the cool conditions predispose the plant to root infection. Slower growth and development of the root system does not allow the plant to produce more root mass quickly enough to overcome bacterial damage, as a normal growing plant would.

The disease that will quickly take advantage of the stressed corn seedling is Pythium. Pythium is the most common cause for seed rots and seedling damping off in corn and thrives in saturated soils, and in soils between 45° and 53°F the corn plant's ability to defend itself and outgrow the infection is severely limited. A corn crop, during a period of cool, wet soil conditions, can suffer stand loss. This stand loss can be made worse when the crop is under some other stress, like frost injury.

Once the soils become saturated, corn seedlings suffer from lack of oxygen. Oxygen is a necessary element that all plants need in order to grow and develop. If roots are deprived of oxygen, the transport of nutrients and water ceases, and root formation comes to a standstill. This condition can only be solved by drier weather, or adequate drainage.

Flooding Stress

The extent to which flooding injures corn is determined by several factors including: plant stage of development when flooding occurs, duration of flooding, and air-soil temperatures.

Prior to V6 (6 visible leaf collars) the growing point is near or below the soil surface. Corn can survive only 2 to 4 days under flooded conditions. The oxygen supply in the soil is depleted after about 48 hours in a flooded soil. Without oxygen, the plant cannot perform critical life sustaining functions; e.g. nutrient and water uptake is impaired, root growth is inhibited, etc. If temperatures are warm during flooding (greater than 77 degrees F) plants may not survive 24-hours. Cooler temperatures prolong survival.

Once the growing point is above the water level, the chances of survival improve greatly. Even if flooding doesn't kill plants outright, it may have a long-term negative impact on crop performance. Excess moisture during the early vegetative stages retards root development. As a result, plants may be subject to greater injury during a dry summer because root systems are not sufficiently developed to access available subsoil water. Flooding and ponding can also result in losses of nitrogen through denitrification and leaching.

If flooding in corn is less than 48 hours, crop injury should be limited. To confirm plant survival, check the color of the growing point. It should be white to cream colored, while a darkening and/or softening usually precedes plant death. Also look for new leaf growth 3 to 5 days after water drains from the field.

Disease problems that may become greater risks due to flooding and cool temperatures are corn smut and crazy top. There is limited hybrid resistance to these diseases and predicting damage is difficult until later in the growing season.

Hail Stress

Those who advise growers faced with the likelihood of hail damage should prepare by consulting the National Corn Handbook NCH-1 "Assessing Hail Damage to Corn". This publication does a good job of describing factors to consider, and has charts used by the National Crop Insurance Association for assessing yield loss due to 1) stand reduction through tenth-leaf stage only, and 2) defoliation.

Hail affects yield primarily by reducing stands and defoliating the plant. Defoliation causes most yield loses. **Knowing how to recognize hail damage and assess probable loss is important for decision making.** The effect of hail damage on corn yield is well documented in agronomic literature. Hail adjusters use standard tables to calculate compensation for yield loss associated with hail. Four assessments are made on corn when hail occurs after silking (Vorst, 1990) including:

1. Determining yield loss due to stand reduction,
2. Determining yield loss due to defoliation,
3. Determining direct ear damage, and
4. Bruising and stalk damage.

Because it is difficult to distinguish living from dead tissue immediately after a storm, the assessment should be delayed 7 to 10 days. By that time regrowth of living plants will have begun and discolored dead tissue will be apparent.

Determining yield loss due to **stand reduction** is made by comparing yield potential of the field at its original population with yield potential at its now-reduced population. Yield loss after silking is adjusted directly by determining the percentage of killed plants. Likewise **ear damage losses** are adjusted directly by determining the percentage of damaged kernels on ears.

In corn, most yield reduction due to hail damage is a result of **leaf loss**. To determine yield loss due to defoliation, both the growth stage of the field and the percent leaf area removed from the plant must be determined. Significant yield damage due to defoliation occurs immediately after silking and decreases as the plant matures (Table 2).

Table 2. Estimated percent corn yield loss due to defoliation occurring at various stages of growth.

	Percent leaf area destroyed				
	20	**40**	**60**	**80**	**100**
Tassel	**7**	**21**	**42**	**68**	**100**
Silked	**7**	**20**	**39**	**65**	**97**
Blister	**5**	**16**	**30**	**50**	**73**
Milk	**3**	**12**	**24**	**41**	**59**
Dough	**2**	**8**	**17**	**29**	**41**
Dent	**0**	**4**	**10**	**17**	**23**
Black layer	**0**	**0**	**0**	**0**	**0**

derived from National Crop Insurance Service Bulletin

Damage due to **bruising** is determined at harvest by counting the number of lodged plants. Bruising may allow an avenue of infection for stalk rots and molds that cause mycotoxin problems. Weather conditions during the remainder of the season affect disease severity.

As the season progresses past the V-10 stage of development, hail injury and losses could become more significant. Some comments on concerns not covered by NCH-1:

1. **After** the tenth leaf stage, yield and stand reductions are on about a one-to-one ratio (eg. 80% stand = 80% potential) and are in addition to losses shown in the defoliation chart.
2. Plants with bruised, but not severed stalks or ears will usually produce a near normal, harvestable ear.
3. Growers should monitor stalk rot of severely defoliated plants which have a good-sized ear. Photosynthate will be mobilized towards the ear rather than the stalk. This could weaken the stalk and encourage stalk rot development. These fields may need to be harvested early to avoid standability problems.
4. Nitrate levels in corn may become elevated. Animal performance could be reduced. Growers with complete defoliation and high soil nitrogen levels (due to fertilizer, manure, or legume plowdown) should test nitrate levels and probably ensile the corn before feeding.
5. Late season leaf loss will allow more light to penetrate to the soil and late-season weed growth may flourish.

Secondly, an economic estimate should be made of the options (ie. corn grain, high-moisture corn, silage, snaplage, etc.) available in the grower's situation. Estimates of changes in yield and quality due to plant part loss should be taken into account. For corn grain yield, information from crop insurance hail adjusters tables would be a good source for making estimates. Little economic information on hail damage is available on other harvesting options such as silage, high-moisture corn, or snaplage. One approach would be to use yield and quality changes observed under normal development and conditions and adjust downward.

Hail during kernel grain-fill can be very detrimental to grain yield. Depending on the stage of development and the amount of leaf loss, grain yield can be reduced from 0 to 41 percent after the soft-dough stage of development. Any losses due to ear dropping would increase this yield loss estimate .

The types of options available to farmers varies from farm-to-farm and field-to-field. On a farm basis, the decision hinges on availability of other corn handling systems involving drying capacity, silage storage facilities, high moisture corn handling equipment, snaplage equipment, etc. Using these later systems means that the harvested corn product will probably have to be fed on-farm to livestock.

On a field basis, things to consider are mold development, moisture levels for ensiling, and effects on maturation rate, yield and quality. If ears are damaged, easier entry of mold causing organisms into the ear can take place. If it is wet for the duration of the season, mold problems will probably increase. Drier weather may not promote growth of mold producing organisms. Safer storage of corn predisposed to mold causing organisms can be achieved by drying grain to 15.5% moisture, ensiling at the proper moisture for the silo type, or treating high moisture corn with propionic or acetic acid.

Hailed corn will usually achieve physiological maturity earlier, but take longer to dry-down than non-hailed corn. Yield and test weight will likely decrease when stressed by hail.

If ensiling, hail damaged corn should be stored separately from other silage already put up. Hail damaged corn may have lower quality, and by storing separately, the farmer will have the option of mixing poor and good silages to obtain a satisfactory ration, or feeding the damaged silage to animals that do not have high quality forage requirements. An estimate of silage yield and quality should be obtained to compare with the grain yield estimate.

Lodging Stress

The time from silking to maturity is the time kernels are filled. Sugars are needed to simultaneously support the developing kernels and maintain stalk strength. Anything that restricts production or movement of sugars or competes with the stalk or kernels will decrease yield and increase death of root and stalk cells. Rotting organisms more easily enter the stalk reducing stalk strength. Numerous factors restrict or compete for sugars during grain fill including high grain yield, cloudy weather, drought stress, high temperatures, hail, early frost, leaf diseases, and European corn borer. The effect of lodging on various plant physiological processes such as energy required for altering stalk growth, nutrient uptake, water uptake, and light penetration and how these processes influence subsequent yield is not well studied.

The most sensitive stage for lodging to occur is during late vegetative growth stages when the stalk is at full height and brace roots have not yet formed. In a Wisconsin study, lodging occurring at V10 caused little damage, while lodging events that occurred near silking caused 15 to 30 percent yield loss in hand harvested plots (Carter and Hudelson, 1988). The upper regions of the plants straightened to vertical within 2 days following lodging. Lodging during vegetative growth stages did not affect plant development, as silk dates were identical for all treatments and lodging did not influence harvest grain moisture. Later lodging events lowered ear height more than 24 inches due to pronounced lower-stalk curvature.

No research has documented yield loss damage from specific lodging events after silking. Defoliation (Afuakwa and Crookston, 1984) effects on yield may provide some insight (Tables 3 and 3). Much will depend upon the ability of the plant to recover to an upright stature.

Table 3. Grain yield loss after plants killed or defoliated.

Corn Development Stage	Plants Killed	Plants Defoliated
	percent yield loss	
R4 (Soft dough)	55	35
R5 (Dent)	40	25
R5.5 (50% kernel milk)	12	5
R6 (Black layer)	0	0

derived from Afuakwa and Crookston, 1984

Guidelines for Managing Fields after Late-Season Hail and Lodging Events

The types of options available to farmers vary from farm-to-farm and field-to-field. On a farm basis, the decision hinges on availability of other corn handling systems involving drying capacity, silage storage facilities, high moisture corn handling equipment, snaplage equipment, etc. On a field basis, things to consider are plant recovery, mold development, moisture levels for ensiling, effects on maturation rate, and yield and quality. Safer storage of corn predisposed to mold causing organisms can be achieved by drying grain to 15.5% moisture, ensiling at the proper moisture for the storage structure, or treating high moisture corn with propionic or acetic acid.

Silage: Consider chopping a hailed or lodged field for silage, especially if grain prices are low. If ensiling, damaged corn should be stored separately from other silage already put up. Damaged corn may have lower quality, and by storing separately, there is an option of mixing poor and good silages to obtain a satisfactory ration, or feeding the damaged silage to animals that do not have high quality forage requirements. Rotary cutter heads for silage chopping may not be useable in lodged corn.

Grain: The amount of stalk straightening decreases when lodging occurs at VT or later. Harvest speed will likely need to be reduced, especially for lodging occurring later. Test weight will likely be reduced.

Weather has a strong influence on harvesting. It not only influences harvest timing, but also rate of stalk degradation and whether plants will be able to stand until you get to them. Temperature, rain, snow and wind all play key roles in the amount of lodging. Assessing the severity of lodging in fields will help in scheduling grain harvest later. Watch closely fields that were severely lodged and adjust timing of harvest if required.

Drought Stress

To begin talking about water influences on corn growth and development and yield we must begin with the concept of evapotranspiration. **Evapotranspiration** is both the water lost from the soil surface through **evaporation** and the water used by a plant during **transpiration**. Soil evaporation is the major loss of water from the soil during early stages of growth. As corn leaf area increases, transpiration gradually becomes the major pathway through which water moves from the soil through the plant to the atmosphere.

Yield is reduced when evapotranspiration demand exceeds water supply from the soil at any time during the corn life cycle. Nutrient availability, uptake, and transport are impaired without sufficient water. Plants weakened by stress are also more susceptible to disease and insect damage. Corn responds to water stress by leaf rolling. Highly stressed plants will begin leaf rolling early in the day.

Evapotranspiration demand of corn varies during its life cycle (Table 4). Evapotranspiration peaks around canopy closure. Estimates of peak evapotranspiration in corn range between 0.20 and 0.39 inches per day. Corn yield is most sensitive to water stress during flowering and pollination, followed by grainfilling, and finally vegetative growth stages.

Vegetative development

Water stress during vegetative development reduces stem and leaf cell expansion resulting in reduced plant height and less leaf area. Leaf number is generally not affected by water stress. Corn roots can grow between 5 and 8 feet deep, and soil can hold 1.5 to 2.5 inches of available soil water per foot of soil, depending upon soil texture. Ear size may be smaller. Kernel number (rows) is reduced. Early drought stress does not usually affect yield in Wisconsin through the V10-V12 stages. Beyond these stages water stress begins to have an increasing effect on corn yield.

Pollination

Water stress around flowering and pollination delays silking, reduces silk elongation, and inhibits embryo development after pollination. Moisture stress during this time reduces corn grain yield 3-8% for each day of stress (Table 4). Moisture or heat stress interferes with synchronization between pollen shed and silk emergence. Drought stress may delay silk emergence until pollen shed is nearly or completely finished. During periods of high temperatures, low relative humidity, and inadequate soil moisture level, exposed silks may desiccate and become non-receptive to pollen germination.

Table 4. Estimated corn evapotranspiration and yield loss per stress day during various stages of growth.

Growth stage	Evapotranspiration	Percent yield loss per day of stress (min-ave-max)
	inches per day	%
Seedling to 4 leaf	0.06	---
4 leaf to 8 leaf	0.10	---
8 leaf to 12 leaf	0.18	---
12 leaf to 16 leaf	0.21	2.1 - 3.0 - 3.7
16 leaf to tasseling	0.33	2.5 - 3.2 - 4.0
Pollination (R1)	0.33	3.0 - 6.8 - 8.0
Blister (R2)	0.33	3.0 - 4.2 - 6.0
Milk (R3)	0.26	3.0 - 4.2 - 5.8
Dough (R4)	0.26	3.0 - 4.0 - 5.0
Dent (R5)	0.26	2.5 - 3.0 - 4.0
Maturity (R6)	0.23	0.0

derived from Rhoads and Bennett (1990) and Shaw (1988)

To assess the success or failure of pollination, two methods are commonly used: counting attached silks and counting developing ovules. Each potential kernel on the ear has a silk attached to it. Once a pollen grain "lands" on an individual silk, it quickly germinates and produces a pollen tube that grows the length of the silk to fertilize the ovule in 12 to 28 hours. Within 1 to 3 days after a silk is pollinated and if fertilization of the ovule is successful, the silk will detach from the developing kernel. Unfertilized ovules will still have attached silks. By carefully unwrapping the husk leaves from an ear and then gently shaking the ear, the silks from the fertilized ovules will readily drop off. Developing ovules (kernels) appear as watery blisters (the "blister" stage of kernel development) about 10 to 14 days after fertilization of the ovules. The proportion of fertilized ovules (future kernels) on an ear indicates the progress and success of pollination.

Silk elongation begins near the butt of the ear and progresses up toward the tip. The tip silks are typically the last to emerge from the husk leaves. If ears are unusually long (many kernels per row), the final silks from the tip of the ear may emerge after all the pollen has been shed. Another cause of incomplete kernel set is abortion of fertilized ovules. Aborted kernels are distinguished from unfertilized ovules in that aborted kernels had actually begun development. Aborted kernels will be shrunken and mostly white.

Kernel development (grain-filling)

Water stress during grain-filling increases leaf dying, shortens the grain-filling period, increases lodging and lowers kernel weight. Water stress during grain-filling reduces yield 2.5 to 5.8% with each day of stress (Table 4). Kernels are most susceptible to abortion during the first 2 weeks following pollination, particularly kernels near the tip of the ear. Tip kernels are generally last to be fertilized, less vigorous than the rest, and are most susceptible to abortion. Once kernels have reached the dough stage of development, further yield losses will occur mainly from reductions in kernel dry weight accumulation.

Severe drought stress that continues into the early stages of kernel development (blister and milk stages) can easily abort developing kernels. Severe stress during dough and dent stages of grain fill decreases grain yield primarily due to decreased kernel weights and is often caused by premature black layer formation in the kernels. Once grain has reached physiological maturity, stress will have no further physiological effect on final yield (Table 1). Stalk and ear rots, however, can continue to develop after corn has reached physiological maturity and indirectly reduce grain yield through plant lodging. Stalk rots are seen more often when ears have high kernel numbers and have been predisposed to stress, especially drought stress.

Premature Plant Death

Premature death of leaves results in yield losses because the photosynthetic 'factory' output is greatly reduced. The plant may remobilize stored carbohydrates from the leaves or stalk tissue to the developing ears, but yield potential will still be lost. Death of all plant tissue prevents any further remobilization of stored carbohydrates to the developing ear. Whole plant death that occurs before normal black layer formation will cause premature black layer development, resulting in incomplete grain fill and lightweight, chaffy grain. Grain moisture will be greater than 35%, requiring substantial field drydown before harvest.

Management Decisions Will Depend Upon Success of Corn Pollination

After July, the key plant indicator to observe and base future management decisions upon is the success of pollination. Each ovule (potential kernel) has a silk attached to it. When a pollen grain falls on a silk, it germinates, produces a pollen tube that grows the length of the silk which fertilizes the ovule in 12 to 28 hours. If fertilization of the ovule is successful, within 1 to 3 days the silk will detach from the developing kernel. Silks will remain attached to unfertilized ovules and be receptive to pollen up to 7 days after emergence. Silks eventually turn brown and dry up after pollination is over.

Two techniques are commonly used to assess pollination success or failure. The most rapid technique to determine pollination success is the “shake test.” Carefully unwrap the ear husk leaves and then gently shake the ear. The silks from fertilized ovules will drop off. The proportion (%) of silks dropping off the ear indicates the proportion of future kernels on an ear. Randomly sample several ears in a field to estimate the success of pollination.

The second technique is to wait until 10 days after fertilization of the ovules. The developing ovules (kernels) will appear as watery blisters (the "blister" R2 stage of kernel development).

Growers questioning when to chop their corn for silage should wait until:
1. You are sure pollination and fertilization of kernels will not or did not occur and that whole-plant moisture is between 55-70%, so that fermentation can occur without seepage or spoilage losses.
2. If pollination and fertilization of kernels did occur, do not chop until you are sure that there is no further potential to increase grain dry matter and whole plant moisture is in the 55-70% range.

A few cautions and suggestions:
- Be sure to test whole-plant moisture of chopped corn to assure yourself that acceptable fermentation will occur. Use a microwave, an electronic forage tester, or the "grab-test" method for your determination.
- Follow precautions regarding dangers of nitrate toxicity to livestock (especially with green-chopping) and silo-gasses to humans when dealing with drought-stressed corn.
- Keep in mind that "normal" guidelines for determining when to harvest corn for silage will be useful for many, if not most, corn fields. These include using the kernel milkline, and beginning to harvest after the dent stage, when the milkline has moved towards the kernel tip.
- Growers need to carefully monitor, inspect and dissect plants in their own fields as to plant survival potential, kernel stages, and plant moisture contents in determining when to begin silage harvest. Fields and corn hybrids within fields vary greatly in stress condition and maturity.
- In order to estimate pre-harvest silage yields, the National Corn Handbook publication "Utilizing Drought-Damaged Corn" describes methods based on either corn grain yields or plant height (if little or no grain yield is expected).

Grain yield method for estimating silage yield: For moisture-stressed corn, about 1 ton of silage per acre can be obtained for each 5 bushels of grain per acre. For example, if you expect a grain yield of 50 bushels per acre, you will get about 10 tons/acre of 30% dry matter silage (3 tons/acre dry matter yield). For corn yielding more than 100 bushels per acre, about 1 ton of silage per acre can be expected for each 6 to 7 bushels of grain per acre. For example, corn yielding 125 bushels of grain per acre, corn silage yields will be 18 to 20 tons per acre at 30% dry matter (5 to 6 tons per acre dry matter yield). See also Table 2 in A1178 "Corn silage for the dairy ration."

Plant height method for estimating silage yield: If little or no grain is expected, a rough estimate of yield can be made assuming that 1 ton of 30% dry matter silage can be obtained for each foot of plant height (excluding the tassel). For example, corn at 3 to 4 feet will produce about 3 to 4 tons per acre of silage at 30% dry matter (about 1 ton per acre of dry matter).

Frost Stress

Farmers selecting corn hybrids for silage should first consider planting the latest relative maturity of corn that will reach harvest maturity by frost. Higher yields are produced with hybrids that mature slightly later than those adapted for grain production – perhaps 5 to 10 relative maturity units later. These hybrids will result in the highest yield of high quality forage.

When planting is delayed beyond May 20, earlier maturity hybrids should be planted to reach harvest maturity by frost. However there comes a point (about June 1 in northern Wisconsin and June 20 in southern Wisconsin) where planting is delayed to the extent that even shorter maturity hybrids will not reach harvest maturity by frost. At this point it is preferable to plant later maturity hybrids so they reach pollination at frost, and then allow drying after frost to get the hybrid to low enough moisture content for ensiling.

The recommendation to switch back to later maturity hybrids for late planted corn silage is made because corn has two peaks in forage quality: one at pollination and one at harvest maturity. The early peak in forage quality at pollination is high in quality but too wet for ensiling unless frost can dry the corn down. For late planted corn, aiming for a hybrid that will be at pollination at frost becomes a better choice than planting a short season hybrid that will not reach harvest maturity.

Typically in a normal year, corn should be "silking at the end of July and denting on Labor Day." After corn silks, it normally takes about 55 to 60 days for it to mature. Right now heading into Labor Day, we are seeing many fields which are between the silking and milk stages of development. These fields will require 700-1200 growing degree units in order to mature and another 150 units to be at a harvestable moisture (Table 5).

Table 5. Required growing degree units between corn development stages and maturity (black layer).

Corn development stage	Relative maturity zone *(days)* 85-90	95-105	110-120
	Growing degree units		
R1 (silking)	1000	1100	1200
R2 (blister)	800	880	960
R3.5 (late milk / early dough)	600	660	720
R4.5 (late dough / early dent)	400	440	480
R5 (dent)	200	220	240
R6 Maturity (black layer)	0	0	0
Harvest (kernel moisture at 25%)	150	150	150

derived from Carter, 1991

Normally during September, growing degree units in Wisconsin accumulate at the rate of 12 to 19 units per day for a total accumulation of 400 to 450 units (Table 6). Likelihood of a 32 ° F freeze by September 20 is 3 years out of 5 in northern, and 1 year out of 5 in southern Wisconsin.

Table 6. Corn growing degree unit accumulation in Wisconsin.

	North			South		
Month	Daily	Monthly	Total	Daily	Monthly	Total
	Growing degree units					
May	8-11	300	300	10-13	350	350
June	11-17	400	700	13-20	500	850
July	17-20	575	1275	20-23	650	1500
August	20-17	575	1850	23-19	650	2150
September	17-12	400	2250	19-13	450	2600
October	12-8	300	2550	13-10	350	2950

derived from Mitchell and Larsen, 1981

Use tables 5 and 6 to determine the likelihood that a field will mature. For example, if on September 1, your field is at R3.5 (late milk / early dough) and you are in a 95-105 relative maturity zone, it will take about 660 growing degree units to mature the crop before it is killed by a frost. Since corn is usually killed in 3 out of 5 years by September 20 the field in all likelihood will accumulate about 300 to 380 growing degree units and be at the early dent to dent stage of development when it is killed by a frost.

For fields that only had light frost damage, it is too early to harvest. Growing conditions may improve during September allowing the crop to mature and produce reasonable grain and silage yields.

Corn is killed when temperatures are near 32 F for a few hours, and when temperatures are near 28 F for a few minutes. A damaging frost can occur when temperatures are slightly above 32 F and conditions are optimum for rapid heat loss from the leaves to the atmosphere, i.e. clear skies, low humidity, no wind. At temperatures between 32 to 40 F, damage may be quite variable and strongly influenced by small variations in slope or terrain that affect air drainage and thermal radiation, creating small frost pockets. Field edges, low lying areas, and the top leaves on the plant are at greatest risk. Greener corn has more frost resistance than yellowing corn.

Symptoms of frost damage will start to show up about 1 to 2 days after a frost. Frost symptoms are water soaked leaves that eventually turn brown. Because it is difficult to distinguish living from dead tissue immediately after a frost event, the assessment should be delayed 5 to 7 days.

Yield Impact

Yield losses are negligible if frost occurs when grain moisture is below 35 percent. Yield loss is directly proportional to the stage of maturity and the amount of leaf tissue killed. Those who will be advising growers about the likelihood of frost damage and its impact on yield should get ready by consulting the National Corn Handbook NCH-1 "Assessing Hail Damage to Corn" (Vorst, 1990). This publication has charts used by the National Crop Insurance Association for assessing yield loss due to defoliation. **Knowing how to recognize frost damage and assess probable loss is important for decision making.** An abbreviated version of the loss chart is shown in Table 7. For example, corn that was defoliated 20% at the milk stage would have 3% yield loss.

Table 7. Estimated percent corn yield loss due to defoliation occurring at various stages of growth.

	Percent leaf area destroyed				
Stage of growth	**20**	**40**	**60**	**80**	**100**
	Yield loss (%)				
Tassel	**7**	**21**	**42**	**68**	**100**
Silked	**7**	**20**	**39**	**65**	**97**
Blister	**5**	**16**	**30**	**50**	**73**
Milk	**3**	**12**	**24**	**41**	**59**
Dough	**2**	**8**	**17**	**29**	**41**
Dent	**0**	**4**	**10**	**17**	**23**
Black layer	**0**	**0**	**0**	**0**	**0**

derived from Vorst (1990)

The stem on a corn plant is a temporary storage organ for material that eventually moves into the kernels (Afuakwa and Crookston, 1984). Grain yield will continue to increase about 7 to 20% after a light frost that only kills the leaves as long as the stem is not killed (Table 3).

Moisture drydown

Corn silage should be harvested at the appropriate moisture content for the type of silo in which it will be stored. If corn is frosted prior to 50% kernel milk, the moisture content of corn may be too high to be properly ensiled. However, during the drydown period, dry matter yield will decrease due to leaf loss, plant lodging and ear droppage. Thus, a trade-off exists between moisture and yield.

For corn silage frosted prior to the dent stage, the moisture content will be too high for successful ensiling. The silage crop should be allowed to dry in the field for several days and moisture content should be monitored. For corn frosted during the dent stage, harvest should begin quickly to prevent yield loss as damaged leaves are shed or break off the plant.

Since mold can occur on the ears before the desired moisture level is reached, harvest may have to begin immediately. To help control problems with excess moisture, wet silage can be mixed either with ground grain, straw, or chopped hay to reduce the overall moisture of the stored silage, The rule of thumb is about 30 pounds of dry material per ton of silage will be needed to reduce silage moisture one percentage unit.

Grain quality impact

Late season frost damage can affect grain quality and is directly proportional to the stage of maturity and leaf tissue killed. Severe impacts on grain quality can occur at mid-dough, while moderate impacts are seen at the dent stage. By the time the kernel has reached half milk line only minor impacts will occur to grain quality. Differences among hybrids, overall plant vigor at the time of frost and subsequent temperatures will all affect final grain quality.

Other considerations

Growers should monitor stalk rot of severely defoliated plants which have a good-sized ear. Photosynthate will be mobilized towards the ear rather than the stalk. This could weaken the stalk and encourage stalk rot development. These fields may need to be harvested early to avoid standability problems.

If frosted corn is ensiled at the proper moisture content and other steps are followed to provide good quality silage, nitrate testing should not be necessary. However, it is prudent to follow precautions regarding dangers of nitrate toxicity to livestock (especially with grazing and green-chopping) and silo-gasses to humans when dealing with drought-stressed corn.

Management Guidelines for Handling Cornfields With Poor Pollination

Typical management options and uses are available for corn that has successfully pollinated. If pollination is unsuccessful, we are usually trying to make the best of a bad situation. If **pollination is good**, harvest in a normal fashion for either grain or forage use. If **pollination is poor** yet some kernels are developing, the plant can gain dry matter and farmers should wait with harvest. In Wisconsin, many farmers have the option of harvesting poorly pollinated fields for silage use. If there is **no pollination**, then the best quality forage will be as found as close to flowering as possible. Quality decreases after flowering. The challenge is to make sure that no potential pollination occurs and that the forage moisture is correct for the storage structure.

Drought-stressed corn can be grazed or used for forage, either as green chop or silage. Because of the potential for nitrate toxicity, grazing or green chopping should be done only when emergency feed is needed. The decision to chop corn for silage should be made when:

1. You are sure pollination and fertilization of kernels will not or did not occur and that whole-plant moisture is in the proper range for the storage structure so that fermentation can occur without seepage or spoilage losses. If there is no grain now, florets on the ear were either not pollinated or have not started to grow due to moisture stress, and the plant will continue to be barren. If the plant is dead, harvest should occur when whole plant moisture is appropriate for preservation and storage.
2. If pollination and fertilization of kernels did occur but it was poor, do not chop until you are sure that there is no further potential to increase grain dry matter and whole plant moisture is in the proper range for the storage structure. These kernels may grow some now, if the plant is not dead and in those fields receiving rain. If kernels are growing dry matter is accumulating and yield and quality of the forage is improving.

Green, barren stalks will contain 75-90% water. If weather remains hot and dry, moisture content drops, but if rain occurs before plants lose green color, plants can remain green until frost. Drought stressed corn has increased sugar content, higher crude protein, higher crude fiber and more digestible fiber than normal corn silage. Drought generally reduces yield and grain content resulting in increased fiber content, but this is often accompanied by lower lignin production that increases fiber digestibility.

Forage quality of normally pollinated corn

Corn has two peaks in forage quality: one at pollination and one at harvest maturity (Figure 1). The early peak in forage quality at pollination is high in quality but too wet for ensiling. The later peak is more familiar, and is the one we typically manage for when producing corn silage.

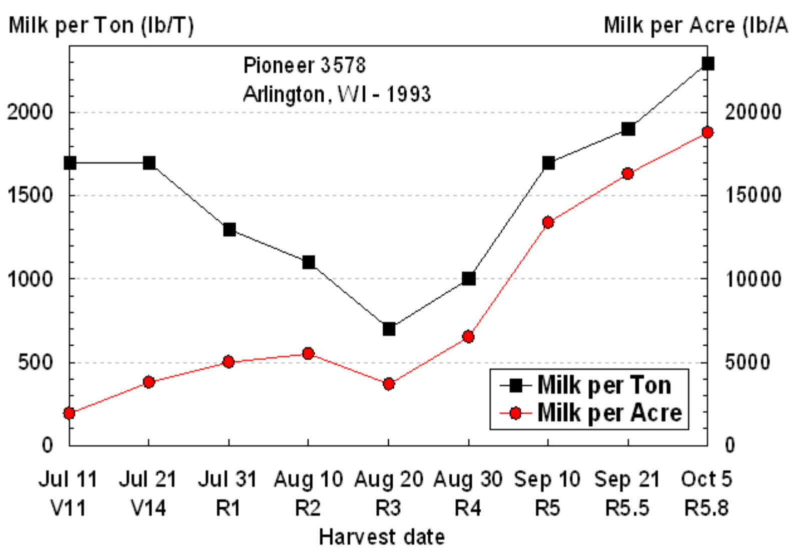

Figure 1. Corn Silage Yield and Quality Changes During Development

Forage quality of poorly pollinated corn

Coors et al. (1997) evaluated the forage quality of corn with 0, 50 and 100% pollination of the kernels on an ear during 1992 and 1993. These years were not considered "drought" stress years, but they can give us an idea as to quality changes occurring due to poor pollination. These plots were harvested in September.

A typical response of corn to stress is to reduce grain yield. Bareness reduced whole-plant yield by 19% (Table 8). Kernels on ears of 50% ear fill treatments were larger and tended to more than make up for reduced numbers (Albrecht, personal communication). With the exception of protein, as ear fill increased, whole-plant forage quality increased.

Table 8. Forage yield and quality of corn with differing amounts of pollination grown at Madison in 1992 and 1993 (n= 24).

Ear fill	Forage yield	Crude protein	NDF	ADF	IVTD	NDFD
%	% of control	%	%	%	%	%
0	81	8.5	57	30	74	52
54	93	8.0	54	28	76	52
100 (control)	100	7.5	49	26	77	54
LSD (0.05)	6	0.3	1	1	1	1

derived from Coors et al., 1997

Forage moisture

If the decision is made to harvest the crop for ensiling, the main consideration will be proper moisture for storage and fermentation. The crop will look drier than it really is, so moisture testing will be critical. Be sure to test whole-plant moisture of chopped corn to assure yourself that acceptable fermentation will occur. Use a forced air dryer (i.e. Koster), oven, microwave, electronic forage tester, NIR, or the rapid "Grab-Test" method for your determination. With the "Grab-Test" method (as described by Hicks, Minnesota), a handful of finely cut plant material is squeezed as tightly as possible for 90 seconds. Release the grip and note the condition of the ball of plant material in the hand.

- If juice runs freely or shows between the fingers, the crop contains 75 to 85% moisture.
- If the ball holds its shape and the hand is moist, the material contains 70 to 75% moisture.
- If the ball expands slowly and no dampness appears on the hand, the material contains 60 to 70% moisture.
- If the ball springs out in the opening hand, the crop contains less than 60% moisture.

The proper harvest moisture content depends upon the storage structure, but is the same for drought stressed and normal corn. Harvesting should be done at the moisture content that ensures good preservation and storage: 65-70% in horizontal silos (trenches, bunkers, bags), 60-65% in upright stave silos, and 55-65% in upright oxygen limiting silos.

Raising the bar

Depending upon farm forage needs, raising the cutter-bar on the silage chopper reduces yield but increases quality. For example, raising cutting height reduced yield by 15%, but improved quality so that Milk per acre of corn silage was only reduced 3-4% (Lauer, Wisconsin). In addition the plant parts with highest nitrate concentrations remain in the field (Table 9).

Nitrate problems

If drought-stressed corn is ensiled at the proper moisture content and other steps are followed to provide good quality silage, nitrate testing should not be necessary. The risk of nitrate poisoning increases as pollination becomes poorer. Nitrate problems are often related to concentration (i.e. the greater the yield the less chance of high nitrate concentration in the forage).

If pollination is poor only about 50 to 75% of the dry matter will be produced compared to normal corn forage.

Table 9. NO_3N of corn plant parts.

Plant part	NO_3N
	ppm
Leaves	64
Ears	17
Upper 1/3 of stalk	153
Middle 1/3 of stalk	803
Lower 1/3 of stalk	5524
Whole plant	978

derived from Hicks, Minnesota

It is prudent to follow precautions regarding dangers of nitrate toxicity to livestock (especially with grazing and green-chopping) and silo-gasses to humans when dealing with drought-stressed corn. Nitrates absorbed from the soil by plant roots are normally incorporated into plant tissue as amino acids, proteins, and other nitrogenous compounds. Thus, the concentration of nitrate in the plant is usually low. The primary site for converting nitrates to these products is in growing green leaves. Under unfavorable growing conditions, especially drought, this conversion process is slowed, causing nitrate to accumulate in the stalks, stems, and other conductive tissue. The highest concentration of nitrates is in the lower part of the stalk or stem. If moisture conditions improve, the conversion process accelerates and within a few days nitrate levels in the plant returns to normal. Nitrate concentration usually decreases during silage fermentation by one-third to one-half, therefore sampling one or two weeks after filling will be more accurate than sampling during filling. If the plants contain nitrates, a brown cloud may develop around your silo. This cloud contains highly toxic gases and people and livestock should stay out of the area. The resulting energy value of drought-stressed corn silage is usually lower than good silage but not as low as it appears based on grain content. The only way to know the actual composition of drought-stressed corn silage is to have it tested by a good analysis lab.

Marshfield Plant and Soil Analysis Laboratory
8396 Yellowstone Dr.
Marshfield, WI 54449-8401
Phone: (715) 387-2523

Estimating Yield

Growers need to carefully monitor, inspect, and dissect plants in their own fields as to plant survival potential, kernel stages, and plant moisture contents in determining when to begin silage harvest. Fields and corn hybrids within fields vary greatly in stress condition and maturity. Often questions arise as to the value of drought-stressed corn. In order to estimate pre-harvest silage yields, the National Corn Handbook publication "Utilizing Drought-Damaged Corn" describes methods based on either corn grain yields or plant height (if little or no grain yield is expected). Below is a summary of this publication.

Grain yield method for estimating silage yield

For moisture-stressed corn, about 1 ton of silage per acre can be obtained for each 5 bushels of grain per acre. For example, if you expect a grain yield of 50 bushels per acre, you will get about 10 tons/acre of 30% dry matter silage (3 tons/acre dry matter yield). For corn yielding more than 100 bushels per acre, about 1 ton of silage per acre can be expected for each 6 to 7 bushels of grain per acre. For example, corn yielding 125 bushels of grain per acre, corn silage yields will be 18 to 20 tons per acre at 30% dry matter (5 to 6 tons per acre dry matter yield). See also Table 2 in A1178 "Corn silage for the dairy ration."

Plant height method for estimating silage yield

If little or no grain is expected, a rough estimate of yield can be made assuming that 1 ton of 30% dry matter silage can be obtained for each foot of plant height (excluding the tassel). For example, corn at 3 to 4 feet will produce about 3 to 4 tons per acre of silage at 30% dry matter (about 1 ton per acre of dry matter).

References and Further Reading

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Utilizing Drought-Damaged Corn (NCH-58) www.agcom.purdue.edu/AgCom/Pubs/NCH/NCH-58.html

Weather Stress in the Corn Crop (NCH-18) www.agcom.purdue.edu/AgCom/Pubs/NCH/NCH-18.html