

Impact of Drought on Corn Physiology and Yield

1.0 Introduction

The corn crop requires adequate water in all stages of its physiological development to attain optimum productivity. But like other cereal crops, there are critical points in its growth stages where lack of soil moisture greatly impacts grain production and yield. Growers—especially those in rainfed farms—should know this by heart. Precautions must be taken to prevent loss of crop productivity due to avoidable circumstances.

Being prepared means making informed on-farm decisions. A pro-active stance would include listening to climate advisories, planting at the proper time, watching out for signs of moisture stress in the corn crop, and knowing the correct timing for input application or supplementation. With majority of local corn crops planted in rainfed farms, farmers must be in sync with seasonal climate projections to ensure that there would be sufficient rainfall during critical growth periods.

2.0 The growth stages of corn

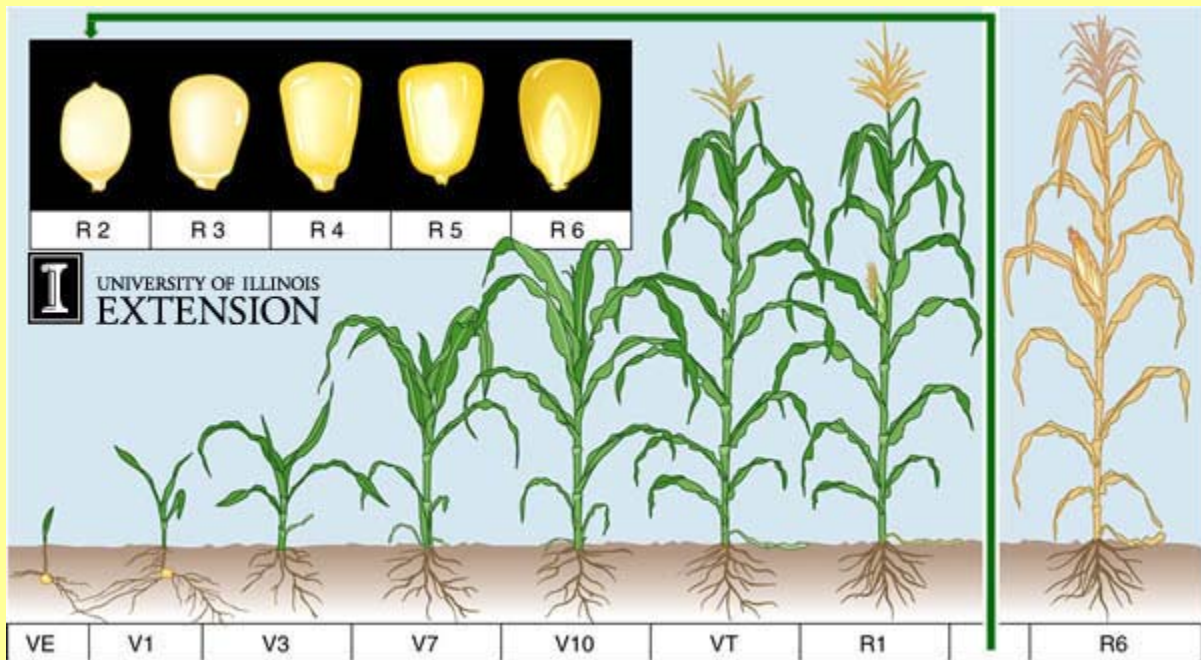
Typical corn plants develop 20 to 21 total leaves, silk about 65 days after emergence, and mature around 120 days after emergence. The specific time interval, however, can vary among hybrids, environments, planting date, and location. The length of time between each growth stage, therefore, is dependent upon these circumstances. For example, an early maturing hybrid may produce fewer leaves or progress through the different growth stages at a faster rate. In contrast, a late-maturity hybrid may develop more leaves and progress through each growth stage at a slower pace. ^[3]

The development of a corn plant is divided into two major phases: (a) the vegetative stage and (b) the reproductive stage. The vegetative stage starts from seedling emergence up to tasseling. The reproductive stage commences at silking and pollination, up to grain-filling and maturity. Agronomists had further divided the vegetative phase by using the number of matured leaves (with exposed leaf collar) present on the corn plant. The reproductive phase starts with the fertilization of the kernels and ends with grain maturity.

Almost all pest management decisions for corn are based on the vegetative stage ^[3]. This means that the application of herbicides and other pesticides must be completed within the first two months of corn development. Fertilizer application, usually done in two batches, must be completed within the first month to aid the crop's physiological progress.

By the time the plant reaches the 5th leaf stage or 14 days after emergence, all leaves, ear shoots and the tassel are already formed in miniature. Although the plant may be only 8 inches in height, the numbers of kernel rows on the ear have already been determined. At this time, the growing point is still at or below the soil surface protecting the young plant from yield reductions due to outside stresses^[9].

The final vegetative stage is full emergence of the tassel. At this point, the corn plant has nearly attained its full height. The 14-day periods before and after silking are crucial to final yield. Growing conditions that place the plant under stress will reduce yield, since final plant elongation, and ear development will be affected. When the corn plant reaches silking with good fertility, good water reserves and no physical damage, growers will be well on their way to an excellent crop. ^[9]



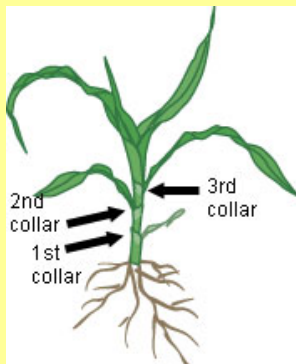
Vegetative and reproductive stages of a corn plant

Vegetative Stages

- VE** emergence (0 day)
- V1** first leaf
- V2** second leaf (7 days)
- V3** third leaf
- V4** fourth leaf
- V5** fifth leaf (14 days)
- V8** eighth leaf (28 days)
- V12** twelfth leaf (42 days)
- V16** sixteenth leaf (55 days)
- VT** tasseling (55-65 days)

Reproductive Stages

- R1** silking (55-65 days)
- R2** blister (77 days)
- R3** milk (85 days)
- R4** dough (91 days)
- R5** dent (101 days)
- R6** physiological maturity (115-120 days)



The number of collars present on the corn plant identifies the different vegetative stages. The leaf collar is the light-colored “band” located at the base of an exposed leaf blade, near the spot where the leaf blade comes in contact with the stem of the plant. Leaves within the whorl, not fully expanded and with no visible leaf collar are not included. A plant with 3 collars would be called a V3 plant, however, there may be 6 leaves showing on the plant.^[3]

Figure 1. Vegetative and reproductive stages of corn.^[1,2,3,4,6,7]

3.0 The Impact of Drought at Different Stages of Development

Corn is very susceptible to drought damage due to the plant's requirement for water for cell elongation and its inability to delay vegetative growth. Therefore, there is always the danger of yield loss regardless of the timing of dry weather. The golden rule of corn production is that highest yields will be obtained only where environmental conditions are favorable at all stages of growth. The amount of yield loss that occurs during dry weather depends on what growth stage the corn is in and how severe the dry conditions become.^[5]

Daily soil moisture use by a growing corn plant will vary depending on the growth stage (Fig. 2). Corn commonly uses about 0.1 inch per day through lay-by to a maximum of 0.35 inch per day during pollination and then drops back to about 0.05 inch per day at the black layer stage (physiological maturity). The effects of water deficiency depend on growth stage, deficiency level and environmental changes during drought. Even minor drought during specific physiological stages can reduce corn yields substantially. Four days of visible wilting just before tasseling can reduce corn yields by 10 to 25 percent. More specifically, four days of visible wilting between the boot stage (only a week prior to tasseling) and the milk stage may reduce yield by 50 percent or more. During later, reproductive stages, yield losses from drought decrease as corn nears physiological maturity. Research indicates that from tasseling (VT) through the soft dough (R4) stage, corn will require about 7 inches of water for normal growth and development. This demand for moisture at key periods of growth shows corn's vulnerability to drought. To produce optimum grain sorghum yields, 23 to 25 inches of water are required during the growing season.^[10]

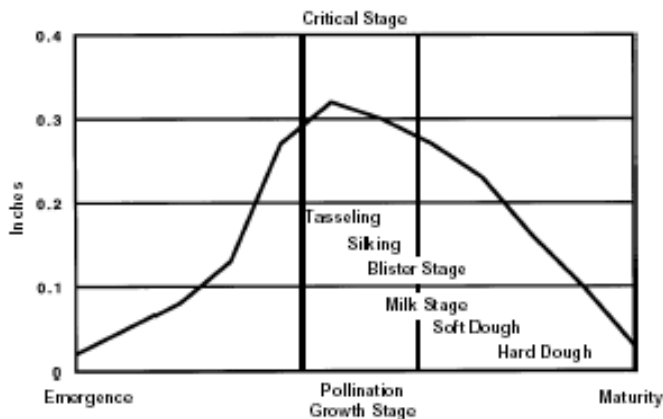


Figure 2. Daily water use by corn

3.1 Yield loss through evapotranspiration

Yield is reduced when evapotranspiration demand exceeds water supply from the soil at any time during the corn life cycle. **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.^[1]

Nutrient availability, uptake and transport are impaired without sufficient water. Plants weakened by stress are 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 1 and Fig. 3). Corn yield is most sensitive to water stress during flowering and pollination, followed by grainfilling, and finally vegetative growth stages.^[1,8]

Table 1. 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)
	mm. per day	inches per day	%
Seedling to 4 leaf	1.52	0.06	---
4 leaf to 8 leaf	2.54	0.10	---
8 leaf to 12 leaf	4.57	0.18	---
12 leaf to 16 leaf	5.33	0.21	2.1 - 3.0 - 3.7
16 leaf to tasseling	8.38	0.33	2.5 - 3.2 - 4.0
Pollination (R1)	8.38	0.33	3.0 - 6.8 - 8.0
Blister (R2)	8.38	0.33	3.0 - 4.2 - 6.0
Milk (R3)	6.60	0.26	3.0 - 4.2 - 5.8
Dough (R4)	6.60	0.26	3.0 - 4.0 - 5.0
Dent (R5)	6.60	0.26	2.5 - 3.0 - 4.0
Maturity (R6)	5.84	0.23	0.0

Source: Rhoads and Bennett (1990) and Shaw (1988)

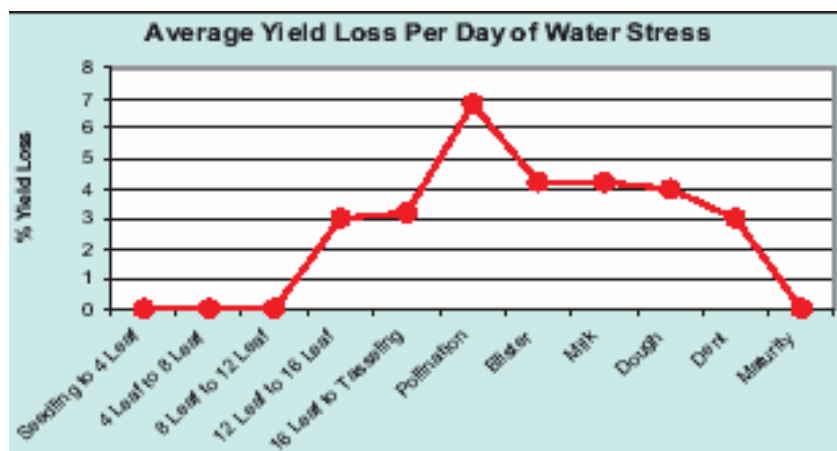


Figure 3. Average yield loss per day of moisture stress^[8]

3.2 Yield reduction through loss of leaf surface area during early vegetative stage

Plant growth from emergence to V8 (eighth leaf full emerged or about 4 weeks after planting) determines the size that the plant achieves and the size of the individual leaves. Dry weather during this period will reduce plant and leaf size. Impact on yield will be based on the reduction in leaf area available for photosynthesis. Minor reductions in leaf size will have little impact on yield while major reductions (all leaves removed from the plant) could reduce potential yields as much as 20 percent. Extended dry weather that results in leaf burning and loss will have the greatest impact on yield. Figure 4 shows the relationship between leaf area and yield loss during this growth period. Corn growers should keep in mind that even though there is little or no leaf burn, leaf size can be affected by drought and result in reduction in leaf area.^[5]

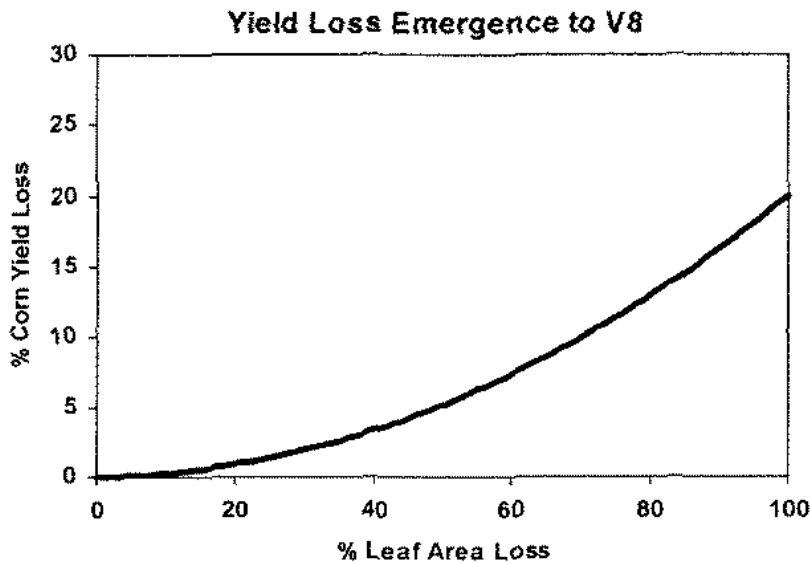


Figure 4. Effects of leaf area loss on corn yield

3.3 Yield reduction due to continuous drought just before tasseling/silking stage

Plant growth from V8 to V16 (All leaves emerged, start of tasseling; from 4 weeks to 66 days after plant emergence) determines ear size and the number of kernels set. From V8 to V14, ear size is set. Drought during this period will reduce ear size and potential yield. Potential yield losses could range from 10 percent to 30 percent. From V14 to tasseling, the number of kernels that can be fertilized are determined. Drought during this period can reduce corn yields 10 to 50 percent. Throughout the V8 to V16 period the key question is how long the drought stress is present. Figure 5 shows the relationship between the length of drought during the V8 to V16 period and the loss of potential corn yield.^[5]

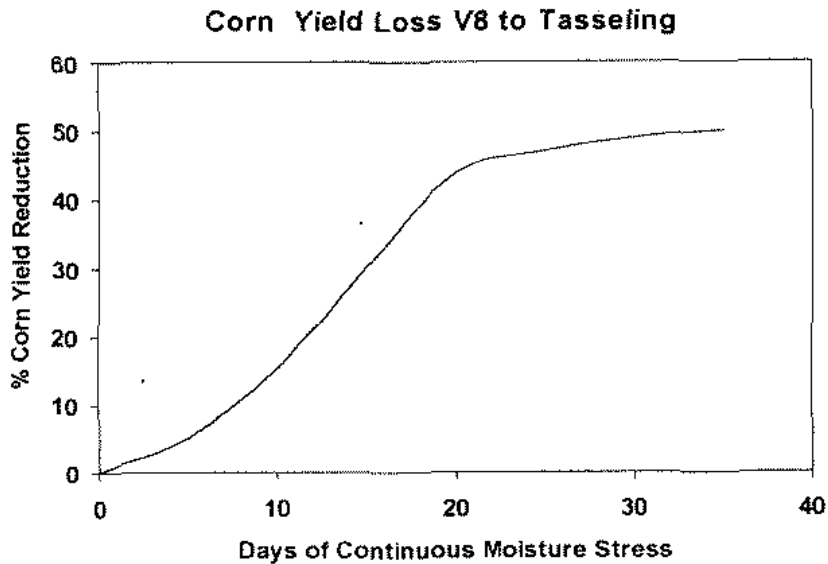


Figure 5. Corn yield loss due to moisture stress from V8 to tasseling

3.4 Yield loss through disruption of reproductive stage

Water stress around flowering and pollination delays silking, reduces silk length, and inhibits embryo development after pollination. Moisture stress during this time reduces corn grain yield 3 to 8 percent for each day of stress (Table 1). Moisture or heat stress interferes with synchronization of 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, exposed silks may desiccate and become non-receptive to pollen germination. ^[1]

Silking or the onset of the reproductive stage is the most sensitive stage for drought stress. Drought during silking coupled with high temperatures can result in 100 percent yield loss. High daytime temperatures can kill pollen before it can reach the silks. High humidity often results in heavy dew which can help pollen reach the corn silk. However, severe yield reductions can occur due to incomplete pollination and the loss of kernel number. ^[1]

There are no good measures of yield loss. Scouting of the corn crop can determine the number of kernels set following pollination and can help determine yield potential. To determine if pollination has occurred, remove the shucks from the ear and take your hand and run it over the surface of the ear. If the silks brush off easily, then the kernel has been pollinated. If the silks stay attached then pollination has not occurred. Another good measure of pollination is to examine the length of the silks. The silk will continue to grow until pollination occurs or until it becomes damaged. The longer the silks, the less efficient the pollination process was. ^[1]

3.5 Yield loss through disruption of grain filling

Drought after silking stage up to maturity affects kernel weight. Severe drought can reduce corn yields during this period by 20 to 30 percent. Again, the key factor is how long the drought occurs and how late in this period it occurs. Drought immediately following silking has the largest

impact, and can reduce yield substantially. Drought later in this period is less damaging, but can hasten maturity. While each stage is important, drought during some stages can be especially devastating. The key stage is silking followed by the V8 to V16 period and then the grain fill period from silking to maturity. Dry weather that starts early and covers several growth periods will have a compounding effect with severe reductions in corn yields.^[5]

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 percent with each day of stress (Table 1). Kernels are most susceptible to abortion during the first two weeks following pollination. Kernels near the tip of the ear generally are last to be fertilized and are less vigorous than the rest, so they 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.^[1]

If soil moisture becomes depleted during the “milk” and “dough” stages of grain-fill, then grain abortion may occur, resulting in shrunken and light bushel-weight grain. Maximum grain yields are obtained when soil moisture is available through “physiological maturity”, or black layer formation^[7]

4.0 Managing drought stress in corn

While there is little that corn growers can do to avoid drought, they can improve their chances of success by knowing the critical periods of plant growth in relation to drought stress, by using management practices that improve the amount of plant available water stored in the soil, and by proper hybrid selection and plant population management.^[5]

The following may be done to alleviate the ill-effects of drought on corn production:

- Time the cropping season with the coming of rains—making sure that identified critical periods fall on historically wet days/months
- Plant corn no-till into a residue mulch to conserve soil moisture.
- Minimize soil cultivation/tillage/movement to lessen moisture loss through evaporation. Cultivated soil has more exposed surface area where water could evaporate from
- Judiciously apply herbicides (instead of cultivation) relative to crop growth stages and at times when the crop is not under stress conditions
- Apply side-dressing fertilizer well enough in advance (V3-V8) of crop needs to strengthen the crop and avoid nutrient deficiencies
- Facilitate deeper root penetration through: use in-row subsoiling on soils prone to claypans or hardpans; and application of lime to neutralize acidic subsoils.
- Plant drought tolerant, stretch type corn hybrids.
- Plant at lesser density (i.e. populations of 18,000 to 20,000 plants per acre)
- When possible, establish low-cost small-scale supplemental irrigation systems like on-farm reservoir, tube wells, etc.

5.0 Literature Cited

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