VirginiaTech Invent the Future
Virginia Cooperative Extension
www.ext.vt.edu
VIRGINIA STATE

Green Stem Syndrome in Soybean

David Holshouser, Extension Agronomist

To maintain yield and quality, soybean should be harvested as seed moisture approaches 13%. Timely harvest minimizes pre-harvest shattering, combine losses, splits, and poor seed quality. Most importantly, delaying harvest after the seed are mature can increase the incidence of Phomopsis seed decay, a common disease associated with poor seed quality. If mature seed are left in the field too long, seed quality can decline and result in an unsellable product within a few weeks.

Normally, soybean leaves drop and stems lose their green color as the crop matures. But a disorder commonly called "green stem syndrome" can prevent the stems from drying down properly and cause the stems to remain green after seed are mature (Fig. 1). Occasionally, green leaves are also present. The green stems are tough, hard to cut, and more likely to plug the combine. It is a natural inclination to wait until the stems lose this green color before harvesting. But harvest should proceed if seed moisture is 13% or lower due to the reasons previously mentioned, even if stems are green and/or tough. This may require making sure that the combine is in good condition and is properly adjusted, sharpening cutting knife sections, and slowing ground speed to allow the green material to pass evenly through the combine.

Green stem syndrome may or may not be associated with yield loss. In some cases, green stems are related to high yield; in others, the green stems can be directly associated with yield loss via the failure to maintain pods or seed. Green stems can be indirectly associated with excessive harvest losses if combine adjustments are not made. Another indirect loss relates to increased shattering from delaying harvest.

FIGURE 1. Green stems on soybean with 12-13% seed moisture, Virginia Soybean Variety Tests, Suffolk 2007.

Green stem syndrome is common throughout the United States and occurs every year in one location or another. For example, its incidence was greater throughout Virginia in 2008. This publication presents a physiological explanation for green stem syndrome, presents factors that may contribute to its occurrence, and preventative strategies

Physiological Basis for Green Stem Syndrome

Specific causes of green stem syndrome vary from year to year and location to location, but are almost always associated with plant stress during pod and seed development. An understanding of the physiological processes involved with soybean yield and how stresses affect those processes is needed to fully understand the occurrence.

Soybean has been called a "self destructive" plant because of the manner it re-distributes soluble sugars, starch, nutrients and other photosynthetic products - hereafter referred to as photosynthates - from the leaves and stems (the source) to the pods and seed (the sink). Before this redistribution begins, a soybean crop will need to store as much of these photosynthates as possible. Dry weight (weight minus moisture) accumulation in leaves and stems is slow at first, but increases at an almost exponential rate until the late vegetative stages with determinate plants or until pods begin to form (R3 stage) with indeterminate plants. After these stages, the rate of dry weight gain attributed to additional leaves and stems slows. Even so, new leaves and stems continue to be added until seed begin to form (R5 stage). After R5, dry weight increases rapidly as seeds grow. Leaves cannot generally supply enough energy and generate adequate photosynthates to keep up with the high demand from the developing seed; therefore, during the full-seed stage (R6), the plants begin to translocate photosynthates from the lower leaves to the developing seed. These leaves begin to yellow and eventually fall from the plant. This process continues until most of the leaves are yellow or fallen. After all leaves have fallen, additional photosynthates are moved from the stems and they too will turn brown or tan. Soybean is considered mature (R8 stage) when 95% of the pods have reached their final brown or tan color.

If growth and development proceeds normally, there should be no green stems when soybean are ready to harvest, about one week after R8. This is because there is usually not enough green plant material available to sustain as many pods as soybean is capable of producing or to completely fill the seed to their genetic capacity. If sufficient photosynthates were available, soybean might average three large seed per pod and 75 pods per plant. In a field containing 150,000 plants per acre, the yield would be 225 bushels per acre if 2500 seed per lb were assumed. Theoretically, such a yield is possible; practically, limited resources restrict soybean from producing that yield. If vegetative growth is limited, soybean will adjust for limited leaf area by aborting flowers, pods, and seed. Even with excessive leaf area, inefficient photosynthesis occurring within shaded lower leaves will regulate the number of pods and/or seed. Soybean has an uncanny ability to adjust pod number, seed number, and seed size to its ability to provide for those yield components.

Of course, leaf area and photosynthetic capacity are not the sole regulators of yield. Anything that limits light, water, nutrients, CO_2, or O_2 during the reproductive stages can cause flower, pod, or seed abortion. If a pod-aborting stress occurs after flowering has ceased, the crop becomes dependent on seed number and/or seed size to compensate for the lack of pods. But there is only so much additional weight that seed can add. In order of importance, soybean yield is dependent on pod number, seed size, and number of seeds per pod. The later is primarily genetically controlled. Seed weight cannot make up for lack of pods or seeds. If the period of stress is extended, soybean can also lose leaves; therefore, the ability to provide photosynthates is also reduced and the balance between the capacity to fill the seed and number of seed to be filled is somewhat maintained. But, if the pod-aborting stress is brief and most leaves remain intact, the need of the crop to use any excess photosynthates is lessened. These "extra" photosynthates maintain water absorption in the roots, results in greater stem moisture, and greener stems at maturity. When green stems are present, one will usually observe fewer pods or seed than expected. If stress is relieved after R6, seed size can be larger than normal.

Therefore, a brief but significant period stress during either R4 or R5 can greatly alter the source:sink ratio in soybean. The stress may abort pods and/or decrease seed number (Fig. 2). There are then more leaves and stems than needed to fill the remaining seed. The stress can be abiotic (water, nutrients, O_2) or it can be biotic (insects, disease, etc.). It will likely be short and can go unnoticed to anyone not visiting the field on a weekly basis. In an extreme case, all pods might be aborted and soybean plants (leaves and stems) remain completely green at harvest.

FIGURE 2. Seed abortion due to severe drought stress that occurred from R5 through R6 to maturity group V soybean with good canopy development, Suffolk, VA 2007.

This relationship between pod removal and green stems was clarified in a Kentucky study conducted from 2002-2004. In these experiments, researchers removed 25% and 50% of the pods of nine varieties at the beginning of R6. Pod removal had little effect on pod and seed maturation, but stem maturation was always delayed. When 25% of the pods were removed, stems remained green less than 10 days longer than the control. But when 50% of the pods were removed, stems in most plots remained green for more than 20 days.

In Virginia, an example of green stem syndrome occurred several years ago in one of our experiments. Indeterminate, maturity group III and IV varieties were planted in April on an excellent soil with high yield potential. The growing season was generally good with only brief periods of drought. Insect pests or disease were not present. Plants had ample vegetative growth and leaves that were transpiring lots of water. The plots had very high yield potential. Rainfall occurred at regular intervals through late July, corresponding to the R4 and R3 development stages for the group III and IV varieties, respectively. Then, a 2-3 week dry period in early-August, culminating during seed development for the group III varieties and late-pod development for the group IV varieties, caused the plants to wilt every day for about a week. Although lots of young pods dropped, yield potential still looked good and we did not expect anything unusual. In late-September, several "windshield" checks were performed to determine maturity. After wondering why it was taking so long for the early-maturing varieties to mature, we inspected the pods and seed. Seed moisture was 12 to 13%! We harvested soon afterwards, slowly pushing the green stems and leaves through our small plot combine. Maturity group III and IV varieties averaged 44 and 48 bushels per acre, respectively; hardly a poor yield. But, there was enough vegetation and pods present before the drought event to have yielded 60 bushels or more.

There is an important message here - green stems are not always bad. Yield potential might be very good. Kip Cullers, a Missouri grower who broke his own 2006 record of 139 bushels per acre with 155 bushel per acre in 2007, indicated to me and other Extension Specialists that one of his goals was to keep as many leaves as possible on the plant and the stems green right up until harvest. In theory, the strategy is reasonable if trying to maximize yields. In practice, that is what Mr. Cullers did.

But, green stems are not always a result of a potentially high-yielding soybean crop that has encountered a brief period of stress. Green stem syndrome can also occur with low yield potential going into pod and seed development stages. It can occur anytime there is more leaf and stem material needed to completely fill the seed that are present. It doesn't always result in large seed or fewer pods or seeds per pod. This scenario can happen regardless of the amount of dry weight or leaf area accumulated.

Finally, varieties may differ in their sensitivity to green stem syndrome. Illinois researchers evaluated over 1000 varieties for incidence of green stems in their official soybean variety tests during 2001 to 2004. Differences among varieties were found in 29 of 31 tests and certain varieties appeared to be less sensitive to the disorder. In general, maturity group II varieties had a greater proporti on of green

FIGURE 3. One of the symptoms of Tobacco Ringspot Viru in soybean is blight or death of the terminal growth leading development of a crook-shaped stem. Photo courtesy of L.

stem incidence than maturity group III varieties. However, incidence of green stems varied more with location and year than with variety, indicating that environment plays a more important role than genetics in the occurrence of green stem syndrome. Still, the consistently low incidence in a few varieties offers hope that varieties can be developed with less sensitivity to green stem syndrome.

Diagnosing the Causes of Green Stem Syndrome

Causes of green stem syndrome include: viral infections, insect feeding, and environmental stresses. With virus infections, an entire field will not show symptoms but plants with green stems will occur in small irregular spots within the field.

If soybean plants within the localized green areas are void of pods and still contain most if not all of their green leaves, bud blight might be suspected. Tobacco ringspot virus, the causal agent of bud blight of soybean, was implicated as causing the disorder a few years ago in Virginia. These infected fields did not only contain green stems, but green leaves as well. A curving of the terminal bud on the main stem, forming a "shepherd's crook", is also an important symptom of this particular virus (Fig 3). Leaflets may also be abnormally small, cupped, and/or have wrinkled edges. If infection is severe during pod development (R3-R4), pods will abort or not develop properly. If the infection occurs after pods are set and during seed development (R5-R6), as was the case in this particular field, infected pods may develop dark blotches and not produce seed, resulting in flat pods. In addition, root growth and nodulation are suppressed; therefore, a poorly-developed root system with few nodules may also indicate that this disease has caused the green stems. Thrips, grasshoppers, and the dagger nematode are capable of transmitting the disease, but all three have proven to be inefficient vectors. Seed transmission is an important means of long-range dissemination across time and space; but because infected plants rarely form seed, this too is a poor mechanism of spread. Although bud blight can definitely cause soybean to remain green at harvest, is not usually the reason behind most fields with green stem syndrome.

Bean pod mottle virus is commonly associated with green stem syndrome in the Midwest due to regular and early-season infestations of bean leaf beetle. Researchers in Illinois and Wisconsin tested this hypothesis by excluding bean leaf beetle from soybean with insect-proof cages and found no relationship between the level of insect feeding and the incidence of green stem syndrome. Some plants infected with the virus did not exhibit green stems. Furthermore, in the 2001 Illinois soybean variety tests, bean pod mottle virus was detected in only 8% of plants with green stems. Therefore, there does not seem to be a strong association of green stem syndrome with bean leaf beetle infestation.

Soybean mosaic virus has also been implicated as causing green stem syndrome, but the claim is unproven by research. In limited studies, no correlation between this virus and green stems was found. This disease can be transmitted from infected weeds or other nearby plants to soybean by aphids. Variety resistance to soybean mosaic virus is available in many varieties and has been an effective way to control this disease.

Keep in mind that viral infection does not mean that stems will remain green. Only if the virus infects the crop early and incidence becomes great enough to prevent pod formation will the disease result in green stems. In most fields infected with virus, effects of virus go unnoticed and cause very little if any yield loss.

Insects such as stinkbugs and corn earworm can also contribute to green stem syndrome. Stinkbugs puncture soybean with piercing and sucking beaks and extract plant fluids. When this feeding occurs during beginning seed formation (R4), seed may be deformed, shriveled, or aborted. Green stems can arise when a stinkbug infestation considerably reduces seed size or number. To diagnose if stinkbugs may have contributed to green stem syndrome, examine the seed in several mature pods. If the seed is flat and discolored and you can observe puncture marks in the pod or seeds, stinkbug might have been the cause. On the other hand, if the seed is not discolored and no

FIGURE 4. Virus symptom on a young soybean plant, 2004. Note the light and dark green, and the raised or blistered areas of the leaf.

puncture marks can be found on the seed or pod, then the flat seed are likely due to another stress. Figure 5 shows pods obtained from a field that was infested with stinkbugs, but also suffered from drought during the late seed fill stage (R6).

Corn earworm is a common pest to Virginia soybeans. Theoretically, severe infestations of the pest could contribute to green stem syndrome by eating seed and pods without simultaneously reducing vegetative plant parts. The problem with corn earworm being the primary cause of green stem syndrome lies in the fact that a full canopy discourages infestations. Usually, higher numbers of corn earworm are found in thin canopies of less productive soybeans. Since a full canopy is usually necessary for the occurrence of green stems, the likelihood of corn earworm being related to green stem syndrome is small.

Management of Green Stem Syndrome

Since there are several explanations for green stem syndrome, it is difficult to diagnose a single cause. Environmental and biotic stress may occur at the same time within the same season. Still if green stems are a recurring phenomenon for a field or farm, then efforts should be made to diagnose the source of the problem.

If late-season drought is suspected as the primary reason for green stems, one may think there is little that can be done. But, this is not always true. Of course if soybean can be irrigated, timely irrigations during pod and seed fill can alleviate water stress that causes pod and seed loss. In addition, continuing irrigation through mid-R6 to completely fill the seed will ensure that all photosynthates are utilized by the developing seed. If irrigation is not available, examine the long-term weather patterns for the area. If a consistent dry spell occurs during certain weeks or months, adjust planting date and variety maturity. As an example, assume that the first two weeks of August are consistently dry and variety with a relative maturity of 4.6 is planted in late April to early May. This crop will usually flower by mid-July, produce pods during late-July to early August, and begin to fill seed by mid-August. If a variety with a relative maturity of 5.6 was substituted and planted two weeks later, flowering would begin approximately 15 days later during the first week of August. Pod fill would take place in mid-August and seed fill would begin in late-August to early-September, a time when rainfall is more probable.

Although there may be variety differences in plant response to green stem syndrome, little is actually know how specific varieties respond. It may be worthwhile to consult the seed company for more information.

FIGURE 5. Soybean seed damaged from stinkbug (left pod) and drought (right pod). Pods were obtained from the same Virginia field.

Viruses do not seem to be directly related to green stem syndrome. Therefore, any action taken to prevent green stems via virus control is most likely futile. Furthermore, preventing viruses by controlling insect vectors has not been consistently effective in soybean. Unfortunately, there is no known variety resistance to bean pod mottle virus and very few soybean varieties contain any resistance to tobacco ringspot virus. However, selecting varieties with soybean mosaic virus resistance continues to be beneficial for reasons other than green stems.

Controlling pod- and seed-feeding insect pests if they exceed economic thresholds is strongly encouraged for maximum economic yields. But doing so solely to lessen the effects of green stems is not justified. If the pest exceeds the economic threshold, then by definition yield is being lost and control measures need to take place. It is not likely however that insect infestation below economic thresholds would contribute to green stem syndrome. Therefore, regularly scouting soybean fields for pod- and stem-feeding pests and implementing control measures only when economic thresholds are exceeded are the best strategies for preventing green stem syndrome from an insect pest perspective.

Finally, delaying harvest is not usually a viable solution in Virginia. Stem drying time will vary depending on root and stem moisture, which cannot be easily measured or predicted. Therefore, one cannot estimate when harvest can begin. Early maturity groups are especially susceptible to seed diseases due to the warm and humid time of the year that they are maturing. Harvest of acreage planted to these varieties should not be delayed. Even with later maturing varieties, seed quality will suffer, shattering losses may increase, and seed moisture will continue to decrease. In the end, keeping harvest equipment adjusted and in top condition may be the best management strategy. Harvesting once the seed reaches 13% moisture, even if stems are green, is usually the most profitable solution.

References

Egli, D.B. and W.P. Bruening. 2006. Depodding causes green-stem syndrome in soybean. Online. Crop Management doi:10.1094/CM-2006-0104-01-RS.

Hill, C.B, G.L. Hartman, R. Esgar and H.A. Hobbs. 2006. Field evaluation of green stem disorder in soybean cultivars. Crop Sci. 46:879-885.

Holshouser, D.L. and J.P. Whittaker. 2002. Plant population and row-spacing effects on early soybean production systems in the Mid-Atlantic USA. Agron. J. 94:603-611.

Hobbs, H.A., C.B. Hill, C.R. Grau, N.C. Koval, Y. Wang, W.L. Pedersen, L.L. Domier, and G.L. Hartman. 2006. Green stem disorder of soybean. Plant Dis. 90:513-518.

Stanton, M. and K. Thelen. 2008. Green stem disorder in Michigan soybeans. Soybean Facts, Jan. 2008, Michigan State Univ.

Acknowledgments

The author would like to thank Drs. Maria Balota and Ames Herbert for their thorough reviews of this publication.