

## Chapter 6

### Soybean Growth and Development

*Palle Pedersen, Department of Agronomy, Iowa State University*

*Saratha Kumudini, Department of Agronomy, University of Kentucky*

*James Board, Department of Agronomy, Louisiana State University Agricultural Center*

*Shawn Conley, Department of Agronomy, University of Wisconsin*

### Soybean Morphology

Two stem types — indeterminate and determinate — of soybean are grown in the United States. Growth of both types is similar during the vegetative growth phase, and at the time of flowering (R1), plants have less than 50 percent of the total leaf area they will eventually amass. Once flower initiation occurs, indeterminate and determinate plants differ dramatically in stem growth habit. Indeterminate plants continue to develop leaves on the main stem and branches throughout the flowering period, which can last as long as 40 days. In contrast, determinate plants cease growth on the main stem at R1, but leaves continue to develop on branches (which will hold most of the yield) until the beginning seed (R5) growth stage.

The importance of new leaf development and expansion comes into play following a fungicide application. For example, once an indeterminate plant reaches R1 (or just prior to that) a new trifoliolate leaf is initiated every three to five days, depending on temperature and the soil moisture. This means

that 3.5 to 7 new untreated trifoliolates will develop over the 14- to 28-day efficacy period of many fungicides. These untreated leaves would be completely unprotected against new soybean rust infections. Thus, the need to re-treat rust-infected crops with a second fungicide application must consider an assessment of plant growth since the last application, as well as post-application development of soybean rust in the crop.

### Soybean Development

The impact of soybean rust on soybean is dependent on the developmental stage when infections occur. Soybean development can be separated into two major developmental phases — vegetative and reproductive. The duration of these phases is controlled by genetics, temperature, and day length. Soybean producers influence the duration of these phases through variety selection (genetics), the location of the farm (day length and temperature), and planting date (day length and temperature). Despite these variables, the duration of developmental stages falls within a rather predictable range (Table 6.1).

**Table 6.1. Soybean Reproductive Stages as Defined by Fehr and Caviness (1977).**

Stage ID	Description of Developmental Stage (abbreviated stage title in bold)	Duration of Growth Stage (days) †
R1	<b>Beginning bloom</b> — One open flower at any node on the main stem.	R1 through R4 20 – 45
R2	<b>Full bloom</b> — An open flower at one of the two uppermost nodes on the main stem with a fully developed leaf.	
R3	<b>Beginning pod</b> — Pods are 3/16 inch (5 mm) at one of the four uppermost nodes on the main stem with a fully developed leaf.	
R4	<b>Full pod</b> — Pods are 3/4 inch (2 cm) at one of the four uppermost nodes on the main stem with a fully developed leaf.	
R5	<b>Beginning seed</b> — Pod at one of the four uppermost nodes on the main stem contains seeds that are 1/8 inch (3 mm) long.	R5 through R6 25 – 45
R6	<b>Full seed</b> — Pod at one of the four uppermost nodes on the main stem contains green seeds that fill the pod cavity.	
R7	<b>Beginning maturity</b> — One normal pod on the main stem has reached its mature pod color.	R7 to R8 7-18
R8	<b>Full maturity</b> — 95 percent of the pods have reached their full mature color.	

† Data are compiled from Board and Setimmi, 1986; Egli, 1994; Egli and Bruening, 2000; Kumudini, 1999 on MGs 00-VII. The duration of a growth stage is dependent on variety/maturity group (MG), latitude, planting date, and temperature. The durations are shorter for early MGs, later planting, and higher temperatures.

Both the vegetative and the reproductive phases of development are subdivided into a number of growth stages. A specific vegetative or reproductive growth stage for a field of soybean is first reached when 50 percent of the plants in the field have reached that specific growth stage.

### Vegetative Phase

Vegetative stages are described from the time the plant emerges from the soil. Apart from the earliest two stages, each vegetative stage is designated with a V followed by a number. This number represents the number of nodes on the main stem with a fully developed leaf, beginning with the unifoliolate

node. A fully developed leaf is defined as a leaf that has a leaf above whose leaflets have unrolled sufficiently such that the two edges of each leaflet are not touching. As an example, V1 refers to the stage at which the unifoliolate node has a fully developed leaf, meaning that the leaf above is unrolled.

### Reproductive Phase

Crop physiologists generally agree that the reproductive phase is the most important for yield determination. Stages R1 to R5 are important in determining seed number, and stages R5 to R7 are critical for determining seed number and seed size (Table 6.1).

The reproductive phase begins when a single flower opens anywhere on the main stem of 50 percent of the plants in a field. The time and the location of the first flower depend on genetics, temperature, and day length. Generally, the first flower for an indeterminate soybean cultivar appears in the lower to mid-canopy position. For determinate soybeans, the first flower usually appears at the fourth or fifth main stem node down from the apex. Flowering then proceeds both up and down the main stem and spreads along the branches.

The earliest formed flowers will be fertilized first and will form the first pods. Once formed, pods go through a rapid expansion process. Once pods have expanded to their maximum size, seed growth accelerates, and seeds begin to fill the pod cavity. Seed growth continues until the plant reaches physiological maturity. Therefore, depending on when the first flowers formed, a single soybean plant may have some nodes that have flowers and other nodes that have pods. Thus, pods may vary in size and maturity based on when their flowers were formed and fertilized.

Physiological maturity (R7) signals the end of pod and seed development throughout the entire plant. Physiological maturity corresponds to a point when one normal pod on the main stem has reached its

mature pod color (usually tan or brown) (Table 6.1).

## Development and Yield

Final crop yield is a function of the number and size of seeds. The period from R1 (flower initiation) to R6 (full seed) is critical for yield determination, because this is when both pod and seed number are determined. Seed size can also be influenced during this period because R3 to R6 is when the cotyledonary cell number (very important for final seed size) is determined. Stresses occurring during the R1 to R6 period have a greater impact on number of pods and seeds than on seed size. The period between R5 (beginning seed) and onset of R7 (physiological maturity) is critical for seed growth and is also important in setting seed size.

Because pod development begins at R3 and seed growth ends at R7, conditions that limit growth during this period can impact yield by limiting seed number, seed size, or both. As explained earlier, a single plant that is not yet at R7 may have a number of different organs (flowers, pods, and seeds) at various developmental stages at the same time. Table 6.1 outlines general development and timing of the reproductive periods, but does not specify exactly when, and by how much, the different growth stages overlap.

## Stresses and How They Impact Yield

From an agronomic perspective, stress is usually defined as an external factor that adversely affects crop yield. Stresses may be biotic or abiotic. Biotic stresses are those associated with a living organism such as weeds, insects, and diseases. Abiotic stresses are caused by environmental factors, such as light, water, soil minerals, soil pH, and wind. Soybean rust is a biotic stress. Yield losses caused by soybean rust result either from impaired photosynthetic function of infected leaves or actual defoliation of the leaves. The relative contribution of each to yield loss is not known.

Limited research has indicated that yield loss associated with soybean rust is strongly correlated with green leaf area. This is the total leaf area remaining in a healthy, green state. However, researchers familiar with the disease report that yield loss appears to be more related to defoliation than to the unhealthy effects associated with lesions prior to defoliation. Because of its ability to cause leaf drop within three weeks after infection, defoliation potentially is the greater factor affecting final yield. For this reason, understanding how defoliation affects yield will ultimately help us understand how rust affects yield. This information, in turn, is vital for fine tuning good farming practices to prevent yield loss in

soybean due to soybean rust.

Leaf area must be maintained at critical levels during the seed-filling period to avoid yield loss. Leaf area during the early and mid seed-filling periods should be great enough to intercept about 95 percent of sunlight. The main effect of defoliation on yield is caused by decreased canopy light interception, which decreases the crop's cumulative photosynthetic activity. This impairs crop growth rate (ability of the crop to produce dry matter) and results in a yield loss.

The effect of defoliation on yield differs markedly with developmental stage and the level of defoliation. Investigators have determined that defoliation at the start of the seed-filling period (R5) has the greatest effect on yield. Leaf growth ends at this time and regrowth potential is very limited compared with earlier developmental periods. Furthermore, pod and seed number per area are still being determined. Thus, a significant reduction in leaf area and light interception at the start of seed fill can result in serious yield reduction by reducing pod number, as well as decreasing seed number and seed size. This is why soybean producers are warned to protect their fields with fungicides when soybeans are in the early reproductive stages and the risk of soybean rust is high.

By the time the R5 (beginning seed) growth stage is reached, vegetative dry weight has approached a maximum and final pod and seed number are nearly determined. Leaf area index also reaches its maximum level at R5. This level is maintained, even with minor defoliation, unless stresses occur during the R5 to R7 period. Soybeans become increasingly more tolerant to defoliation as the seed-filling period progresses. However, complete defoliation must be avoided during most of the R5 to R7 period to maintain optimal yield potential. Eventually, normal plant senescence results in rapid defoliation in the last week or so of the seed-filling period.

## References

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## Summary

- **The need to re-treat rust-infected crops with a second fungicide application must consider an assessment of plant growth since the last application.**
- **Growth of indeterminate and determinate soybean is similar during the vegetative growth phase, and at the time of flowering (R1), plants have less than 50 percent of the total leaf area they will amass.**
- **A fully developed leaf is defined as a leaf that has a leaf above that has unrolled sufficiently such that the two edges of each leaflet are not touching.**
- **The reproductive phase begins when a single flower opens anywhere on the main stem of 50 percent of the plants in a field.**
- **Yield losses caused by soybean rust result from both impaired photosynthetic function of infected leaves and from defoliation.**
- **Rust infections that cause leaf defoliation and/or lesions on the mid to top canopy between R1 and R7 have the greatest effect on yield.**



**Growth Stage R3**

Pod is 5 mm (3/16 inch) long at one of four uppermost nodes on the main stem with a fully developed trifoliate leaf node.

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**Growth Stage R4**

Pod is 2 cm (3/4 inch) long at one of the four uppermost nodes on the main stem with a fully developed trifoliate leaf node.

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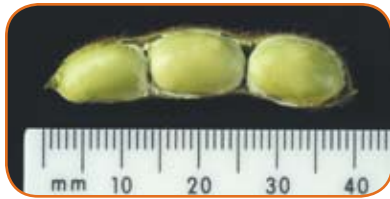




**Growth Stage R5**

*Seed is 3 mm (1/8 inch) long in the pod at one of the four uppermost nodes on the main stem with a fully developed trifoliate leaf node.*

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**Growth Stage R6**

*Pod containing a green seed that fills the pod cavity at one of the four uppermost nodes on the main stem with a fully developed trifoliate leaf node.*

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