

Chapter 2

Growth and Development

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The soybean plant, a legume, is thought to have originated in the Orient and has a long history as a crop plant for human food and livestock feed. Soybean represents the class of short-day plants in which the onset of flowering is regulated by exposure to a critical length of darkness (i.e., photoperiodic response).

Seed

Viable soybean seeds are living organisms that carry on metabolic processes (even in storage). They vary in shape but are generally oval. A soybean seed consists of an **embryo** enclosed by the **seed coat**.

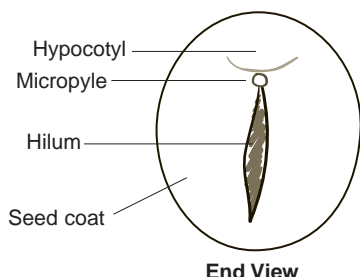


Figure 2.1. Mature soybean seed.

The embryo is comprised of two cotyledons (Figure 2.1), which upon germination produce a plumule with two simple leaves (unifoliate leaves) and a **hypocotyl** (which is green or purple depending upon whether the variety produces white or purple flowers). The embryo also consists of the radicle (root). The **hilum** (seed scar) is easily visible on the surface of the seed coat and is classified by color (i.e., black, imperfect black, buff and clear). The

micropyle, a very small hole located near the hilum which is formed during seed development, accounts for nearly all of the gaseous exchange between the seed and its environment, while water can be absorbed through the entire seed coat surface.

Germination

Germination as depicted in Figure 2.2 is a complex process that begins with **viable** seed exposed to moisture and proper temperature (>50°F) and results in a plant capable of completing a normal life cycle. During the onset of germination the following occur under favorable conditions:

- Water is absorbed by the seed, which in turn doubles in size.
- Normally within two days the root (radicle) becomes apparent, and the first branch of the developing root occurs when the radicle is about 1-inch long.
- The hypocotyl (green or purplish in color) is the seedling structure which breaks through the soil surface exposing the cotyledon to sunlight (from 3 to 7 days). Emergence of seed planted in cool soil (temperatures of less than 55°F) may require 10 to 17 days.

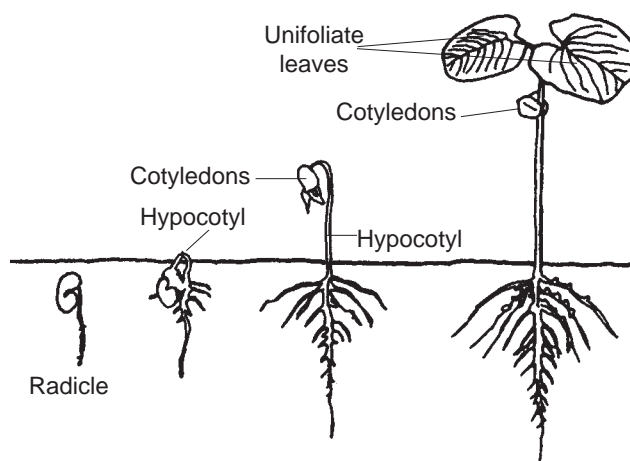


Figure 2.2. Stages of soybean germination, emergence and seedling establishment.



Management Tip

Since soybean seeds are living organisms, be careful in handling the seed. Minimize the dropping of seed and the use of augers. Keep the temperature cool and seed moisture around 10 percent for long-term storage.

- Cotyledons provide the immediate food reserves for the developing seedlings. They develop chlorophyll and begin to carry on photosynthesis (transforming sunlight energy and carbon dioxide into plant carbohydrates) upon exposure to sunlight.
- Unifoliate leaves (one leaf blade per leaf stalk or petiole) usually appear between 5 and 10 days and are located opposite each other on the main stem (the unifoliate node).
- Root development is rapid, with root nodules (Figure 2.3) appearing within 7 to 14 days after emergence. These nodules fix nitrogen for the plant. The root system consists of both a taproot and lateral roots (i.e., a branched taproot).
- Bud development (Figure 2.3) occurs at the axil or the junction of the main stem and the leaf. Flowering buds (axillary buds) develop normally at the fourth node.



Germination Management Tips

- An example of the effect upon yield due to the loss of various plant parts during seedling development is as follows: the loss of cotyledons at VC is around 8 to 9 percent; the loss of the unifoliate leaf plus cotyledon at V1 is around 7 percent.
- The temperature range for soybean germination is 37°F to 109°F, but the optimum temperature is 95°F. More importantly, the relative elongation of the hypocotyl, which is necessary for stand establishment, is optimized between 77°F and 90°F. Hypocotyl elongation, although slowed, occurs rather normally down to soil temperatures of 50°F.

Vegetative and Root Development

Under good environmental conditions, the root depth increases faster than shoot height during the vegetative development phase, but the dry weight of the aboveground parts does exceed the root dry weight. Both root and vegetative development depend on a good environment such as adequate soil moisture and nutrition (including adequate nodulation for nitrogen fixation) and the absence of high levels of disease and nematode infection. Figure 2.3 depicts above- and below-ground vegetative development of a young soybean plant.

Vegetative development is characterized by the continued increase in the number of nodes along the

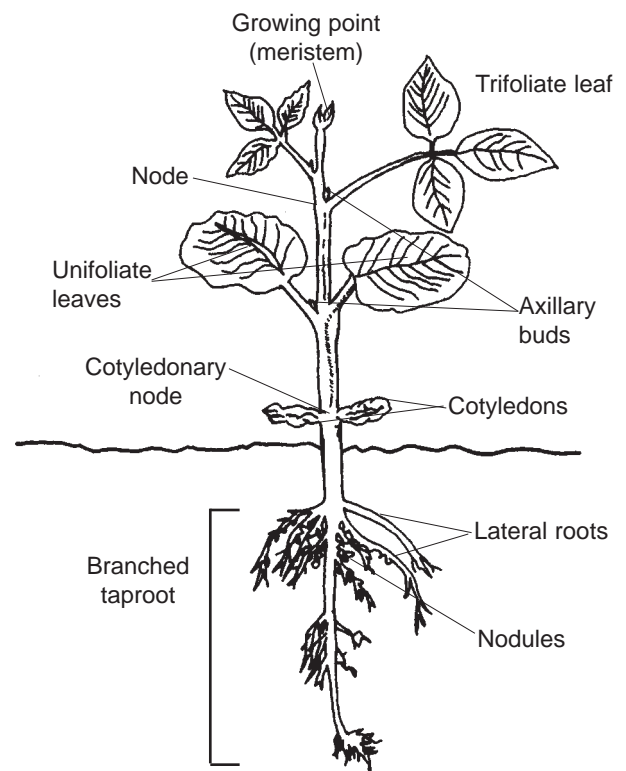


Figure 2.3. Vegetative structures of a young soybean plant.

main stem which are accompanied by the trifoliate leaves and are alternately arranged along the main stem. **The unfurling of each new trifoliate along the main stem is used to describe the vegetative (V) development of the plant as is shown in Table 2.1.** The lowermost node is the point of cotyledon attachment, the next node gives rise to the opposite unifoliate leaves, and all subsequent nodes produce single trifoliate leaves and are alternately arranged up the stem (see Figure 2.5).



Management Tip

At full growth, more than 80 percent of the roots are in the upper 4 inches of soil with a restrictive pan. This creates a situation in which deep cultivation (root pruning) or drought may reduce yields.

Growth Habit

Depending on the variety, maturity group, etc., a mature determinate soybean plant often has between 15 and 20 nodes while some indeterminate plants have up to 22 to 24 nodes. The terms “determinate” and “indeterminate” refer to two distinct growth habits. Determinate varieties are

Stage No.	Abbreviated Stage Title	Description
VE	Emergence	Cotyledons above the soil surface
VC	Cotyledon	Unifoliolate leaves unrolled sufficiently so the leaf edges are not touching
V1	First-node (See Figure 2.4.)	Fully developed leaves at unifoliolate nodes
V2	Second-node	Fully developed trifoliolate leaf at node above the unifoliolate nodes
V3	Third-node	Three nodes on the main stem with fully developed leaves beginning with the unifoliolate nodes
V _n	n th -node	n number of nodes on the main stem with fully developed leaves beginning with the unifoliolate nodes

generally associated with maturity groups (MG) 5-10 while indeterminate varieties are typically associated with MG 000-4, but there are exceptions within nearly all maturity groups. Additionally, many varieties have been developed that exhibit characteristics of both indeterminate and determinate and are referred to as “semi-determinate” varieties.



Figure 2.4. V1 growth stage.

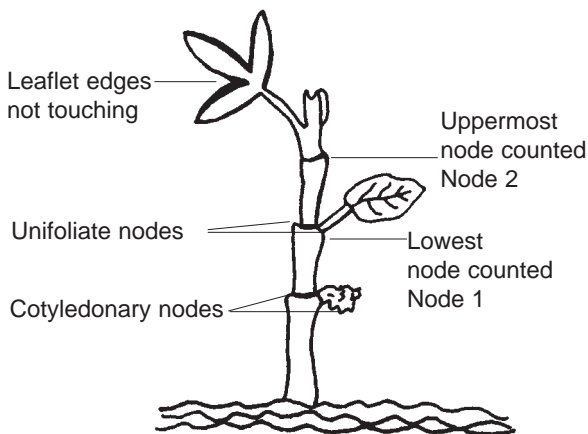


Figure 2.5. Identification of nodes on a soybean plant at the second-node (V2) stage with a cotyledon, unifoliolate leaf and first trifoliolate leaf removed.

The determinate growth type is typified by completing over 80 percent of vegetative growth prior to bloom and is further characterized by a terminal raceme and normally blooms over a two- to three-week period. Indeterminate varieties exhibit continued vegetative development while they bloom and set pods; they have an obvious terminal raceme and may bloom for up to six weeks.

Reproductive Development

When a soybean plant begins to flower, it is classified as being in a reproductive (R) growth stage. Each reproductive stage from flowering until maturity is designated in the reproductive growth stage scheme as indicated in Table 2.2. The length of time for plant development (both vegetative and reproductive) varies depending on several factors including temperature, maturity group and day length (number of hours of darkness). The average and range for both the vegetative and reproductive growth stages are shown in Table 2.3. The main effect of day length on soybean development is that of flowering induction. Soybeans are referred to as short-day plants because short days (i.e., long nights or dark periods) initiate flowering (floral induction).

Reproductive Characteristics of Soybeans

- Generally, the soybean plant will flower when the length of darkness exceeds a critical length of time.
- When a variety is planted south of its zone of adaptation or proper latitude, as shown in Table 2.4, the plant will flower and mature earlier than it would when planted in its zone of adaptation. The reverse situation occurs when southern varieties are moved northward (i.e., the plant matures later than its normal calendar date).
- Soybean varieties are adapted to a rather narrow range of latitude because of this response to the photoperiod or day length (Figure 2.6). Some varieties, such as Vernal, have been developed that are less sensitive to the photoperiod.
- Full-season determinate varieties planted prior to April 25 (especially in North Arkansas) may result in early blooming and reduced plant height which could cause reduced yields.
- Severe stress, either moisture and/or temperature, can modify the photoperiod effect on the blooming which makes it difficult to predict the date of blooming with certainty. Stress blooms normally do not result in significant pod set.

Stage No.	Abbreviated Stage Title	Description
R1	Beginning bloom	One open flower at any node on the main stem
R2	Full bloom	Open flower at one of the two uppermost nodes on the main stem with a fully developed leaf
R3	Beginning pod	Pod 3/16 inch long at one of the four uppermost nodes on the main stem with a fully developed leaf
R4	Full pod	Pod 3/4 inch long at one of the four uppermost nodes on the main stem with a fully developed leaf
R5	Beginning seed	Seed 1/8 inch long in a pod at one of the four uppermost nodes in the main stem with a fully developed leaf
R6	Full seed	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 leaf
R7	Beginning maturity	One normal pod on the main stem that has reached its mature pod color
R8	Full maturity	95 percent of the pods have reached their mature pod color; 5-10 days of drying weather are required after R8 before the soybeans have less than 15 percent moisture

Stages	Average Number of Days	Range in Number of Days
Vegetative Stages		
Plant to VE	10	5-15
VE to VC	5	3-10
VC to V1	5	3-10
V1 to V2	5	3-10
V2 to V3	5	3-8
V3 to V4	5	3-8
V4 to V5	5	3-8
V5 to V6	3	2-5
V6 and later	3	2-5
Reproductive Stages		
R1 to R2	0*, 3	0-7
R2 to R3	10	5-15
R3 to R4	9	5-15
R4 to R5	9	4-26
R5 to R6	15	11-20
R6 to R7	18	9-30
R7 to R8	9	7-18

* Stages R1 to R2 generally occur simultaneously in determinate varieties. The time interval between R1 and R2 in indeterminate varieties is about 3 days.

	New Orleans, Louisiana	Memphis, Tennessee	Champaign, Illinois	Minneapolis, Minnesota	Winnipeg, Canada
May					
4	13:24	13:42	14:01	14:24	14:49
9	13:31	13:51	14:12	14:37	15:08
14	13:39	13:59	14:21	14:49	15:22
19	13:45	14:06	14:31	15:00	15:36
24	13:50	14:12	14:38	15:10	15:48
29	13:55	14:19	14:45	15:19	15:59
June					
3	13:59	14:23	14:52	16:26	16:08
8	14:02	14:27	14:56	15:31	16:15
13	14:04	14:30	15:00	15:35	16:20
18	14:04	14:30	15:00	15:36	16:22
23	14:04	14:30	15:01	15:37	16:22
28	14:04	14:30	15:00	15:36	16:20
July					
3	14:02	14:28	14:56	15:32	16:16
8	<u>13:59</u>	14:24	14:52	15:25	16:09
13	13:58	14:19	14:45	15:19	16:01
18	13:50	14:14	14:40	15:12	15:50
23	13:46	14:07	14:32	15:02	15:38
28	13:40	<u>14:00</u>	14:28	14:51	15:24
August					
2	13:34	13:52	14:14	14:39	15:11
7	13:26	13:43	<u>14:03</u>	14:29	14:55
12	13:19	13:34	13:53	14:19	14:39
17	13:11	13:25	13:41	<u>13:59</u>	14:23
22	13:03	13:15	13:29	13:45	<u>14:05</u>
27	12:54	13:04	13:16	13:30	13:47

The soybean starts to flower soon after the day length begins to shorten. This table, set up on five-day increments, shows that there are more daylight hours on a given date in the northern region than in the southern region. The flowering of northern varieties is initiated by a longer day than that of southern varieties. A southern variety that starts flowering when there are less than 14 hours of daylight will flower at New Orleans about July 8. Flowering occurs progressively later (underlined figures in chart) the further north the variety is used, until the variety flowers in mid- to late August at Winnipeg. This, of course, is unacceptable in the north, because the variety will fail to mature before it is killed by cold weather.

(Source: *Modern Soybean Production*, Walter O. Scott and Samuel R. Aldrich. Second Edition, 1983. S&A Publication, Champaign, Illinois 61820.)

Reproductive Stages

Reproductive stages are based on flowering, pod development, seed development and plant maturation. Each stage description is given a reproductive stage (R) number and an abbreviated title (Table 2.2).

The main stem is used for determining reproductive stages. When the main stem of a plant is broken or cut off, reproductive development on the new branches may be retarded. Plants that have intact main stems are used to determine stage development.

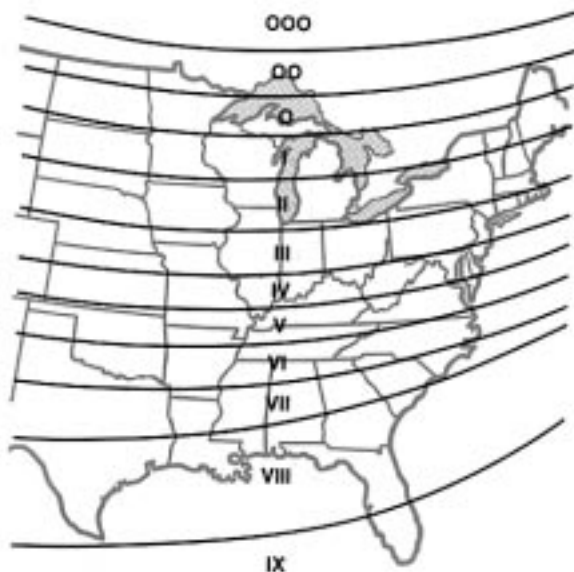


Figure 2.6.

There are 13 maturity classes of soybean varieties. Those varieties adapted for use in southern Canada are designated 000 and are the earliest maturing. The higher the number, the later the maturity and the farther south the variety is adapted for full-season use. The lines across the map are hypothetical. There are no clearly cut areas where a variety is or is not adapted. Maturity group X is not grown commercially in the United States.

(Source: *Modern Soybean Production*, Walter O. Scott and Samuel R. Aldrich. Second Edition, 1983. S&A Publication, Champaign, Illinois 61820.)

Stages R1 and R2 may occur almost simultaneously in determinate varieties because flowering begins at the upper nodes of the main stem. The two stages are approximately three days apart for indeterminate varieties, in which flowering begins in the lower portion of the main stem and progresses upward.

Pods reach nearly full size before the seed begins to develop rapidly. Pod length measurements for R3 and R4 are made from the base of the calyx (leaf-like tissue at the bottom of the pod) to the tip of the pod (Figures 2.7 and 2.8). When pods are 3/4 inch (2 cm) long or R4, the pod cavity in which each seed will develop is outlined by a white membrane. At R6 the seed has enlarged enough to cover the entire membrane (Figure 2.9). The seed continues to get larger after R6 until its full size is achieved.

As the soybean plant matures, leaf and pod yellowing generally occur simultaneously. In some circumstances, however, leaves may remain green after the pods have attained their mature pod color. Leaves and stems remaining green after seed and pod maturity can interfere with harvest.

Soybean varieties differ in their mature pod color. The most common colors are brown and tan, but soybean lines with black pods exist.

Days Between Growth Stages

Soybean development can be influenced by temperature, water availability, day length, variety and other factors. Consequently, there can be considerable variation in the number of days between stages.

Temperature is the major factor influencing vegetative development. Low temperatures retard and high temperatures enhance seedling emergence and leaf development. Therefore, the number of days from planting to the emergence stage (VE) can vary from about 5 to 15 days, depending on temperature (Table 2.3). The effect of temperature becomes less important after the fifth-node (V5) stage. A new node is produced on the main stem about every three days after V5.

Temperature, day length and variety can be important in determining the beginning of flowering and subsequent reproductive development. Low temperatures retard and high temperatures enhance reproductive development. Long days (short nights) retard and short days speed the beginning of reproductive development.

Knowing the number of days between stages is useful. The time intervals listed in Table 2.3 include the average number of days and the range in number of days between stages that scientists have reported. These are average values and must be considered as estimates of what may occur in any particular growing season.



Management Tips

Utilize Different Growth Stages

- The failure to control weeds within 30 days or V4 can greatly affect yield.
- Prior to reproductive development (R1-R2), plants can tolerate up to 40 percent defoliation (hail, insects, etc.) without significant yield loss, but 20 percent defoliation between R2 and R6 can significantly affect yield.
- Foliar diseases developing prior to R6 can significantly reduce yield.
- At growth stage R7 plants have reached physiological maturity and yield potential is determined.
- Stink bugs should be controlled up to R8.
- Plants require good soil moisture through the R6 growth stage.

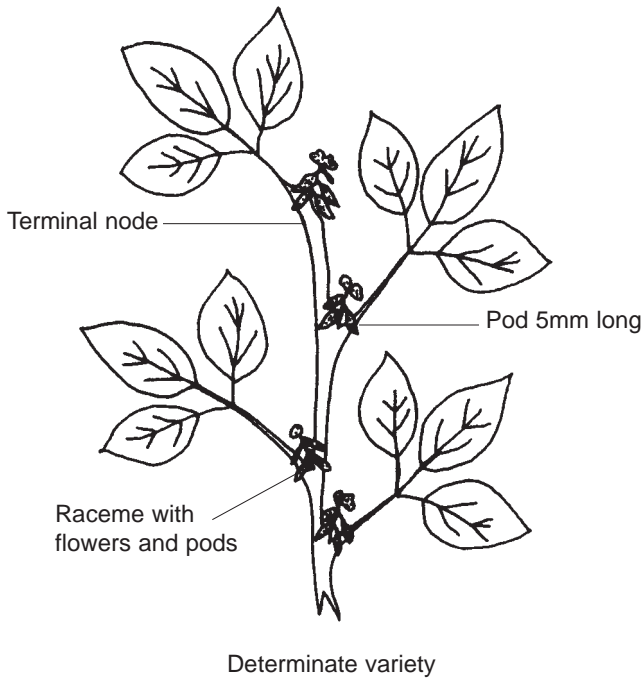


Figure 2.7. Beginning pod (R3) stage – Pod 5 mm (3/16 inch) long at one of the four uppermost nodes on the main stem with a fully developed leaf.

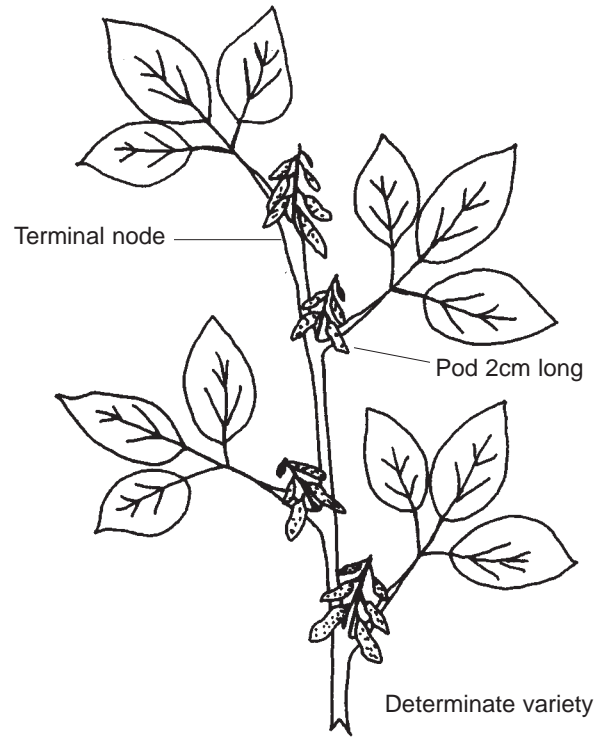


Figure 2.8. Full pod (R4) stage – Pod 2 cm (3/4 inch) long at one of the four uppermost nodes on the main stem with a fully developed leaf.



Figure 2.9.

Vivid changes occur within a soybean pod in the final weeks of maturity. These pods, collected on a single day from varieties of three different maturities, show how the bean changes in shape, size and color as it matures. The mature bean is at the top; the most immature bean is at the bottom.