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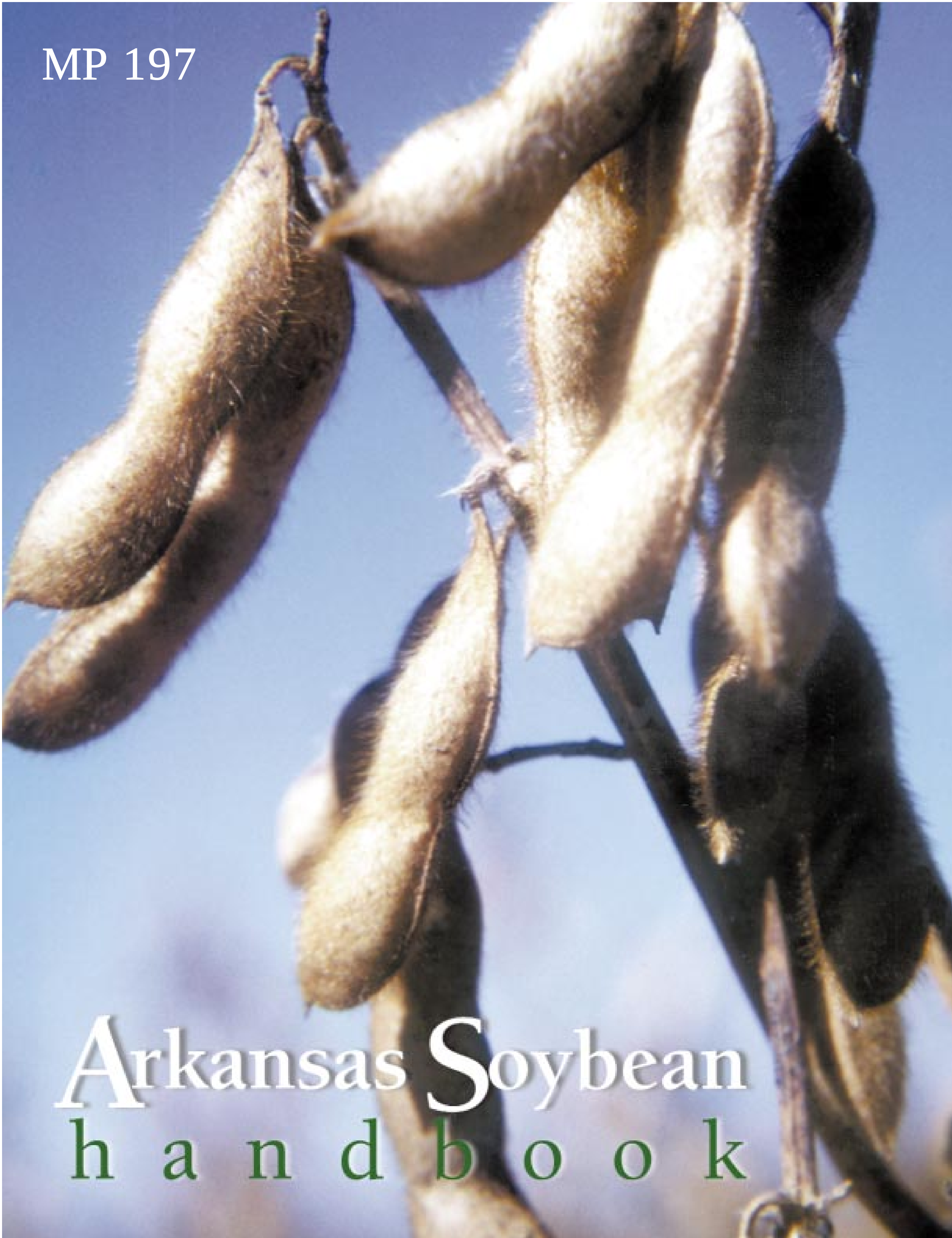

Arkansas Soybean handbook

Arkansas Soybean handbook

Developed by
the Soybean Commodity Committee of the
Cooperative Extension Service, University of Arkansas, and
authored by professional soybean workers of the
University of Arkansas Division of Agriculture

UofA
UNIVERSITY OF ARKANSAS
DIVISION OF AGRICULTURE
Cooperative Extension Service

ARKANSAS SOYBEAN PROMOTION BOARD

Funded by
Arkansas Soybean Producers
through the Arkansas Soybean Promotion Board and
the Cooperative Extension Service,
University of Arkansas Division of Agriculture

COVER PHOTO: Jerry W. Sites, Drew County Extension Agent - Staff Chairman, Cooperative Extension Service, University of Arkansas

TABLE OF CONTENTS PHOTOS: (top) William L. Russell, Jr., Extension Video Specialist, and (middle) C. Richard Maples, Extension Communications Specialist, Cooperative Extension Service, University of Arkansas; (bottom) A.C. Haralson, Arkansas Department of Parks and Tourism

Arkansas Soybean Handbook

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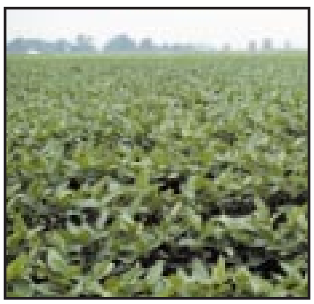

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Chapter 1

The Arkansas Soybean Industry

by R. Coats and L. Ashlock

More than 6,800 Arkansas soybean farmers produce about 110 million bushels and receive cash receipts of $747,098,000. This accounts for 13.4 percent of the total cash receipts from marketing of all commodities in Arkansas (Table 1.1) and 37 percent of the total cash receipts for crops.

The top five Arkansas agricultural exports for 1997, ranked starting with largest value, are soybeans, poultry, rice, wheat and cotton (Table 1.2). In 1997, Arkansas soybean exports totaled $435 million compared to poultry.

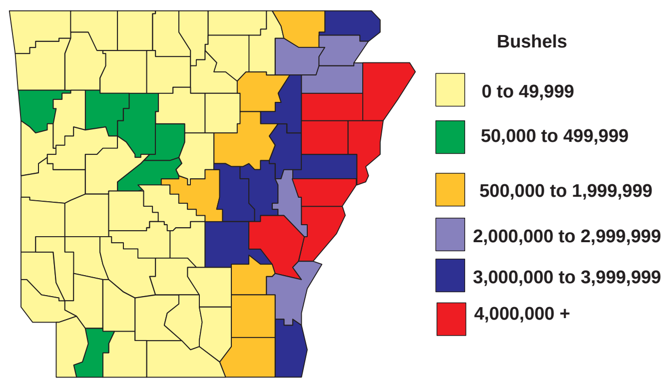
Figure 1.1 shows 1998 Arkansas county soybean production locations. Mississippi, Poinsett, Cross, Crittenden, Lee, Phillips and Arkansas counties each produce 4 million plus bushels. Soybeans comprise the single largest acreage of any Arkansas row crop. Typically, 3.5 million acres of soybeans are planted with approximately 100,000 acres devoted to seed production.

Arkansas ranks 8th nationally in total receipts with $747,098,000 (see Table 1.3 on the next page). Of the three Delta states (Arkansas, Mississippi and Louisiana), Arkansas ranks first, followed by Mississippi and Louisiana. Cash receipts from Mississippi soybeans equal 59 percent of Arkansas' cash receipts, and Louisiana's receipts are 36 percent.

Approximately 33 percent of the annual production is processed in-state into raw components of oil and protein meal and other value-added products, leaving the remaining noncrushed beans to be shipped to port areas. A 60-pound bushel of soybeans yields about 11 pounds of oil and 48 pounds of protein-rich meal or 39 pounds of defatted soy flour or 20 pounds of concentrate or 12 pounds of isolate.

Figure 1.1. 1998 Soybean Production.

85,000,000 bushels



Three companies in Arkansas process soybean grain into oil, meal and other value-added products. A considerable portion of the meal is used as a

Table 1.1. Top Five Arkansas Agricultural Commodities, FY 1997

Rank	Commodity	% of State Total Farm Receipts	% of U.S. Total Value
1	Broilers	35.7	14.8
2	Soybeans	13.4	4.3
3	Rice	12.2	43.2
4	Cotton	9.5	8.6
5	Cattle and Calves	6.6	1.0

Table 1.2. Top Five Arkansas Agricultural Exports, Estimates, FY 1997

Rank	Commodity	Rank Among States	Value Million $
1	Soybeans and Products	8	435
2	Poultry and Products	1	413
3	Rice	1	411
4	Wheat and Products	4	238
5	Cotton and Linters	5	208
	Overall	8	1,918

Table 1.3.
Soybeans: Top 15 State Rankings for Cash Receipts

Rank	State	Value of Commodity Group Receipts ($000)	Percent of Commodity Group Total
1	Iowa	3,095,040	17.5
2	Illinois	2,802,418	15.8
3	Minnesota	1,646,190	9.3
4	Indiana	1,556,280	8.8
5	Ohio	1,274,262	7.2
6	Missouri	1,124,109	6.4
7	Nebraska	905,280	5.1
8	Arkansas	747,098	4.2
9	S. Dakota	730,538	4.1
10	Kansas	572,760	3.2
11	Michigan	476,611	2.7
12	Mississippi	442,773	2.5
13	Kentucky	302,496	1.7
14	Tennessee	302,464	1.7
15	Louisiana	272,093	1.5

Numbers may not add due to rounding.

protein source for the state's livestock industry (cattle, swine, poultry and aquaculture). Several grain companies export grain primarily by barge along major rivers of the state.

More soybeans are grown in the United States than anywhere else in the world. Recent harvests have yielded about 2.5 billion bushels of soybeans each year. More than half the total value of the U.S. soybean crop is exported as whole soybeans, soybean meal and soybean oil. Major export markets include the European Community, Japan, Mexico, Taiwan, China, the Republic of Korea and others.

Since export markets are important to producer profitability, the American Soybean Association, with headquarters in St. Louis, Missouri, has created a worldwide web network of international offices in Austria, Germany, Belgium, Russia, Cyprus, Japan, Korea, Singapore, Taiwan, China, India, Mexico, Venezuela and Turkey. The expansion of international markets for U.S. soybeans and products is made possible by producer checkoff dollars invested by the United Soybean Board and various State Soybean Councils, as well as cost-share funding provided by the U.S. Department of Agriculture.

The domestic and export market for soybeans is derived from the many uses of soybeans as oil products, whole soybean products and soybean protein products. The eight essential amino acids in soybeans are necessary for human nutrition and are not produced naturally in the body. The soybean is a natural source of dietary fiber. Soy hulls are processed into high-fiber breads, cereal and snacks.

Soybean oil finds its way into such products as margarine, salad and cooking oils. The dry portion of the soybean is used to produce soy flour and grits, which are used in the commercial baking industry. These products aid in dough-conditioning and bleaching. Their moisture-holding qualities help keep products from going stale.

In recent years, nonedible products derived from soybeans have been developed and include "soy ink," building materials and soyoil products used as "bio diesel" and in the cosmetic industry.

Acreage

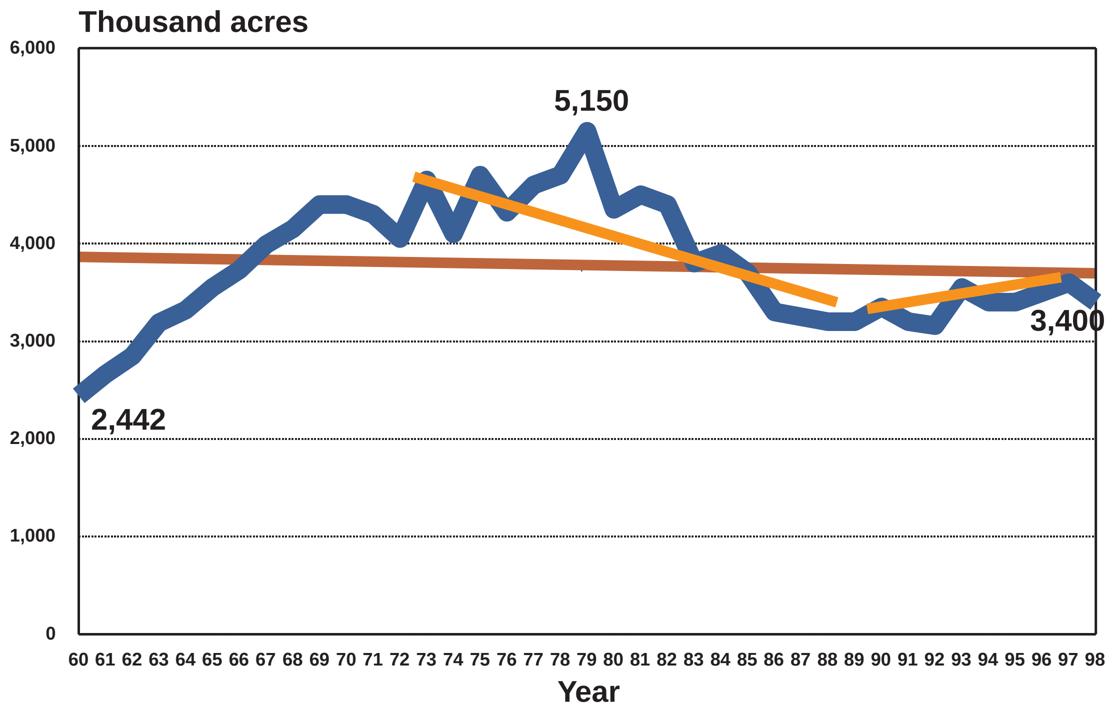
Figure 1.2 shows the historical rise of soybeans as a major row crop for the state. As indicated, Arkansas soybean producers harvested 2,442,000 acres in 1960 and 3,400,000 acres in 1998. The trend line for this period is slightly negative because of South American competition. Arkansas soybean producers harvested a record 5,150,000 acres of soybeans in 1979.

Notice the harvested acreage trend line for years 1973 to 1989 has a negative slope. Soybean acreage in 1973 was 4.65 million acres with a high of 5.15 million in 1979 and a low of 3.2 million acres in 1989.

During the 1980s, demand weakened and soybean acreage returned to a more normal long-run equilibrium level.

During the 1990s, Arkansas soybean harvested acreage stabilized and is showing a positive trend line. Improved varieties and the adoption of technological advances are contributing to the acreage increase.

Figure 1.2. Arkansas Soybean Harvested Acreage – 1960-1998.



The top five soybean-producing counties ranked by total harvested acreage are shown in Figure 1.3. In 1998, Mississippi County ranked No. 1 with 200,000 acres and Phillips County ranked No. 2 with 195,000 acres.

Figure 1.4 shows the top five irrigated soybean-producing counties ranked by total acreage. Arkansas County soybean producers irrigated 163,500 acres of soybeans, followed by Cross, Lonoke, Poinsett and Prairie counties.

Of the top five irrigated soybean-producing counties, when ranked by percent irrigated, Arkansas County had 87 percent of its soybean acreage irrigated, while Lonoke County, the third largest irrigated soybean acreage, had 80 percent of the county acreage irrigated, followed by Cross (76 percent), Prairie (71 percent) and Poinsett (69 percent).

Figure 1.3. Top Five Soybean Counties, Ranked by Harvested Acreage, Arkansas, 1998.

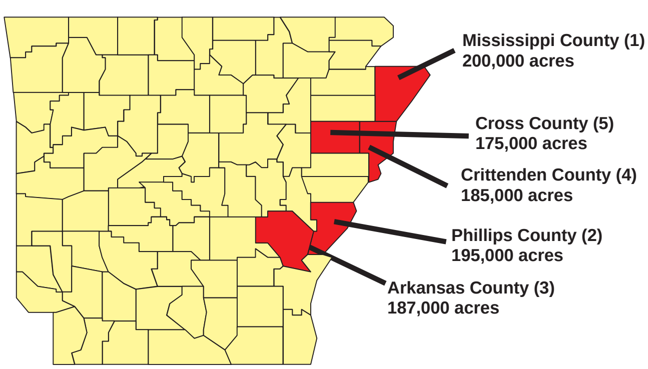


Figure 1.4. Top Five Soybean Counties, Ranked by Irrigated Harvested Acreage, Arkansas, 1998.

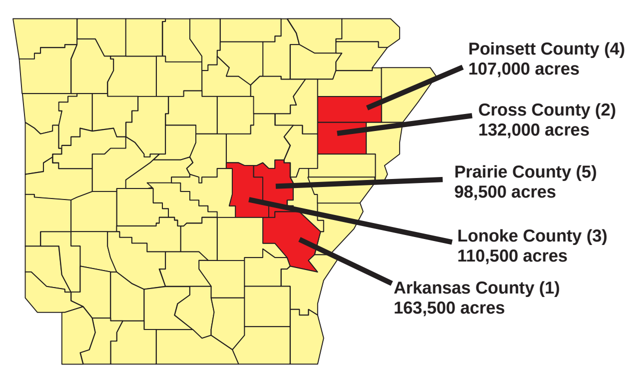
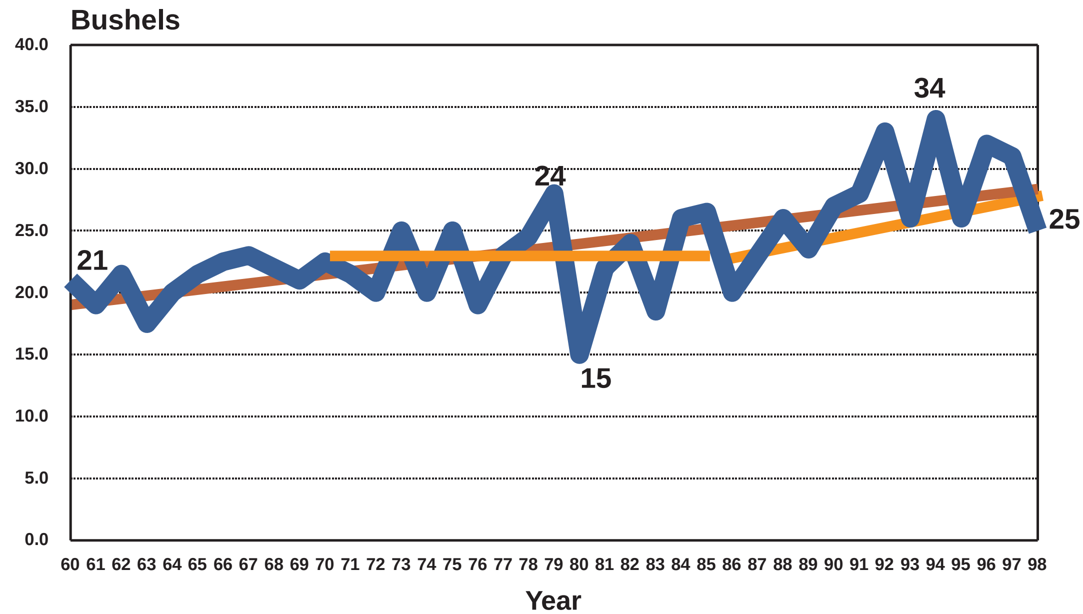


Figure 1.5. Arkansas Soybean Yield, 1960-1998.



Yield

Figure 1.5 shows average state yields for 1960 through 1998. As indicated, Arkansas soybean producers had an average yield of 21 bushels in 1960, a yield low of 15 bushels in 1980 and a yield high of 34 bushels per acre in 1994. The trend line for soybean yields for years 1986-1998 is significantly more positive than the trend line for years 1960-1998. This is a good indicator that Arkansas soybean producers are placing increased emphasis on improving agronomic production practices. Improved yields are highly correlated with checkoff monies provided by the Arkansas farmer for research and Extension educational programs.

The top five soybean-producing counties ranked by yield are shown in Figure 1.6. Arkansas and Cross counties ranked 1st with 30 bushels per acre, followed by Poinsett, Prairie and Lincoln counties with 28 bushels.

Figure 1.7 shows the top five irrigated soybean-producing counties ranked by yield per acre. Randolph County ranked No. 1 with an average yield of 37 bushels. Next were Cross and St. Francis counties with 34 bushels per acre, followed by Arkansas, Prairie, Independence, Poinsett and Chicot, each averaging 33 bushels per acre.

Figure 1.6. Top Five Soybean Counties, Ranked by Yield/Acre, Arkansas, 1998.

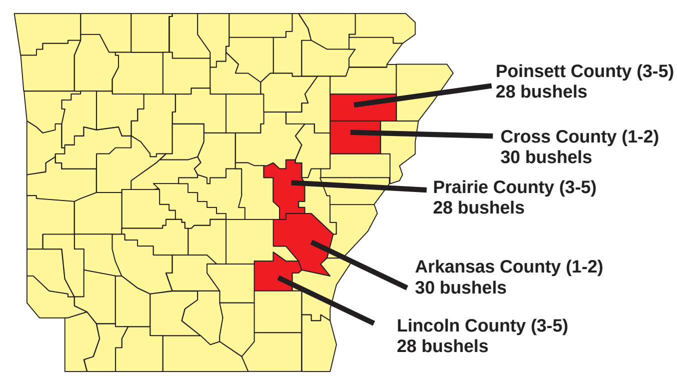


Figure 1.7. Top Irrigated Soybean Counties, Ranked by Yield/Acre, Arkansas, 1998.

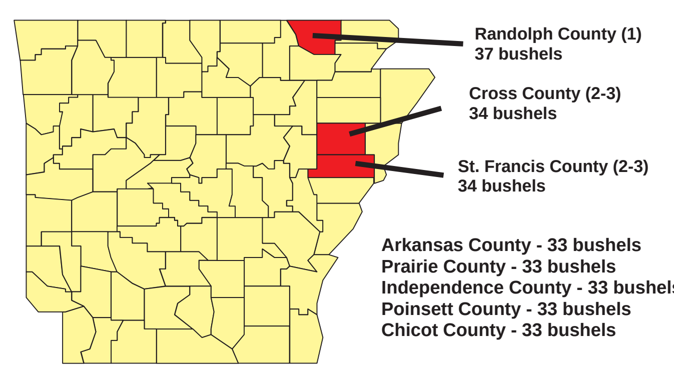
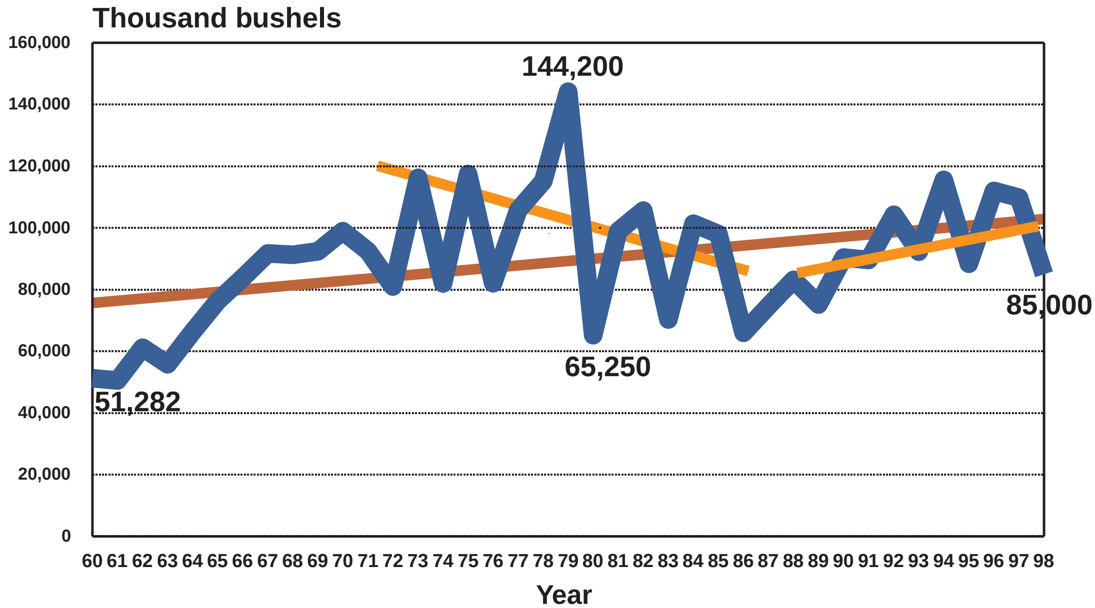


Figure 1.8. Arkansas Soybean Production, 1960-1998.



Production

Arkansas soybean production in 1960 was 51.3 million bushels. Figure 1.8 shows a negative production trend for 1973 to 1986. In 1979 Arkansas soybean producers produced their largest statewide production, 144.2 million bushels. For years 1997 and 1998, total production was 110 and 85 million bushels, respectively. The trend line for the past decade shows significant improvement over preceding years.

The top five soybean-producing counties ranked by production, listed first to last, were Arkansas, Cross, Mississippi, Lee and Poinsett (Figure 1.9). The No. 1 irrigated soybean-producing county was Arkansas with 5,314,000 bushels being produced under irrigation (Figure 1.10).

Figure 1.9. Top Five Soybean Counties, Ranked by Production, Arkansas, 1998.

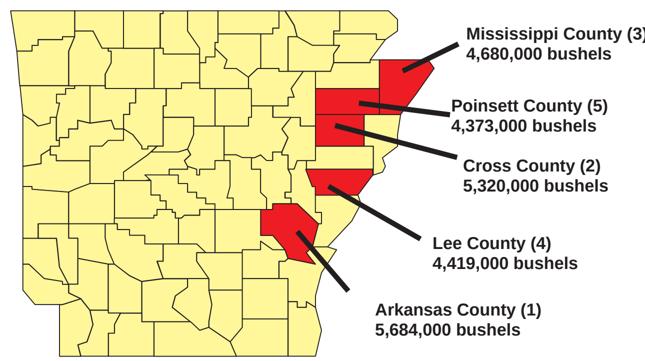
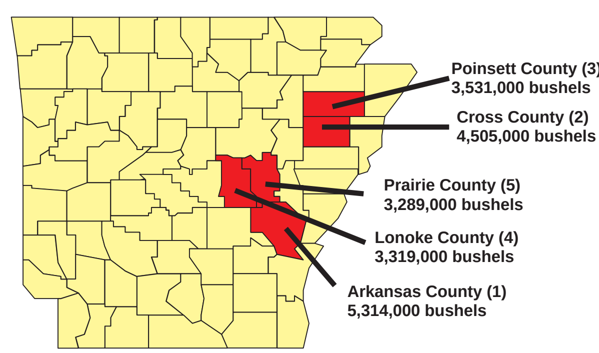


Figure 1.10. Top Five Irrigated Soybean Counties, Ranked by Production, Arkansas, 1998.



Summary

Arkansas farmers provide $2.5 to $3 million annually for research, education and market development in support of this important industry to the overall agricultural economy. One-half, or about $1.25 to $1.5 million, remains in Arkansas and funds in-state research and Extension efforts. This in-state effort is administered by the Arkansas Soybean Promotion Board. The composition of the board is as follows:

- Nine soybean producers representing the Arkansas Agriculture Council (2)
- Arkansas Farm Bureau (3)
- Arkansas Soybean Association (2) and
- Riceland Foods (2)

The Arkansas Soybean Promotion Board funds sound projects in the following three areas – improving soybean profitability, base programs (requiring long-term continuous research) and new innovations.

The remaining $1.25 to $1.5 million is sent to the United Soybean Board. Arkansas has three representatives on the 58-member United Soybean Board in St. Louis. The United Soybean Board provides funding for improvement and development related to both international and domestic marketing, production, new uses and producer communication. These efforts are designed to strengthen the U.S. soybean industry.

The Arkansas Soybean Promotion Board is providing significant funds for the development and printing of this handbook. The Board and the authors of this handbook hope you find this publication both informative and profitable.

DIVISION OF AGRICULTURE
RESEARCH & EXTENSION
University of Arkansas System

Soybean Growth and Development

Larry C. Purcell, Montserrat Salmeron and Lanny Ashlock

The progenitor of soybean grows wild throughout eastern China, Korea, Japan and the far eastern portion of Russia. Domestication of soybean is believed to have occurred in the Yellow or the Yangtze River valleys of central or southern China somewhere between 3,000 and 5,000 years ago. There are numerous references to soybean in some of the earliest Chinese literature.

An important characteristic of soybean is that it is a legume and forms a symbiotic relationship with *Bradyrhizobium japonicum* (commonly referred to as rhizobia) bacteria that results in nodules forming on the roots (Figure 2-1). These nodules reduce atmospheric nitrogen gas to a form that the plant can utilize. A major advantage of soybean is that because of nitrogen fixation, it does not require any nitrogen fertilizer.

Figure 2-1. A well-nodulated root system of a young soybean plant.

A second important characteristic of soybean that has important implications for crop management is that it is a short-day plant. That is, soybean is triggered to flower as the day length decreases below some critical value. These critical values differ among maturity groups (MGs). Both nitrogen fixation and the response of soybean to day length are discussed with regard to their importance on crop management in more detail later in this chapter.

Seed

Soybean seeds are living organisms and should be treated with care. Avoid unnecessary dropping of seed through augers and conveyers as this can damage the seed coat. Also, seed should be kept in a cool, dry environment to preserve seed quality and vigor. Hot and humid conditions can result in rapid deterioration of seed quality, which can decrease seed germination especially under stressful conditions.

Soybean seeds vary in shape but are generally oval. A soybean seed consists of a large embryo enclosed by the seed coat. There are large variations in seed coat color (light yellow, green, brown, black, mottled), but commercial soybean is nearly always yellow. The embryo is comprised of two cotyledons (Figure 2-2), 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

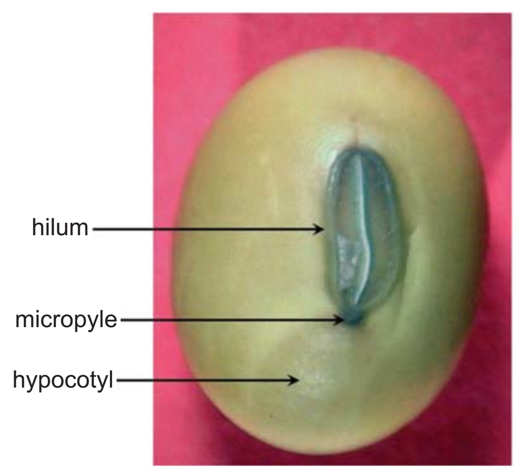


Figure 2-2. A mature soybean seed.

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, brown, buff and clear). The micropyle is a very small hole located near the hilum that is formed during seed development. The micropyle accounts for nearly all of the gaseous exchange between the seed and its environment, whereas water can be absorbed through the entire seed coat surface.

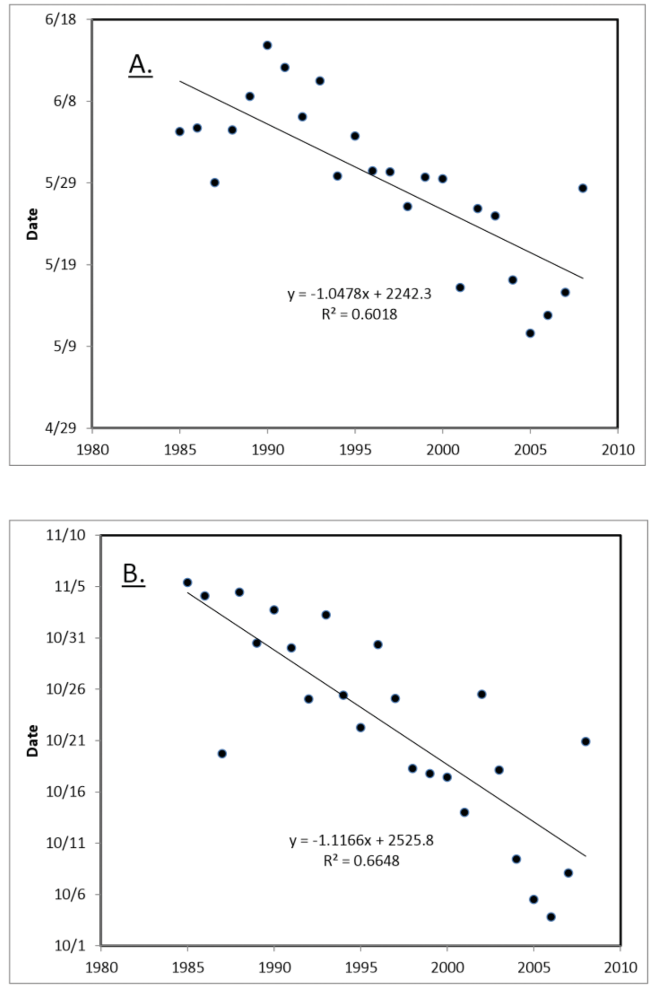
Germination and Seedling Establishment

The soybean crop has a wide planting window, typically from early spring, after the danger of frost has passed, until mid- to late-June. The trends for soybean production in Arkansas in recent years are for planting to occur earlier each year. On average, since 1985, planting has occurred one day earlier each year (Figure 2-3). In conjunction with earlier planting, the average soybean harvest date has also been about one day earlier each year. The combination of early planting and early maturity has advantages for avoiding late-season drought and disease and insect pressure. The predominant MGs grown in Arkansas today are 4 and 5, whereas MGs 5, 6 and 7 were predominant prior to 1985.

Soybean seed is typically planted at a depth of about 1 inch. Many seed companies provide fungicide and insecticide treatments on their seed, which can be especially beneficial to soybeans emerging and growing slowly in early spring due to cool temperatures. In fields where soybeans have not been grown in 3 or more years, a rhizobium inoculant (specific for soybeans, *Bradyrhizobium japonicum*) should be applied as a seed treatment or in furrow at planting. There is little supporting research to show that inoculation improves yield in fields where soybeans have been grown in recent years.

High-quality seed requires three appropriate conditions for germination – soil moisture, temperature and oxygen. Provided that the soil is not saturated, oxygen concentration is not a limitation, but germination will not occur in flooded soil due to lack of oxygen. Within 24 hours of planting, assuming that soil moisture is adequate, seed size doubles and seed moisture content increases up to 50%. During this time period, proteins become active and respiration increases. Respiration is temperature sensitive and requires oxygen, and germination rates range from 2 weeks or more in cold soil (50°F or less) to about 4 days under optimum soil temperatures (82° to 85°F).

Figure 2-3. The date when 50% of Arkansas soybeans were (a) planted and (b) harvested from 1985 to 2008. Data compiled from statewide averages of the Crop Reporting Service.



The radical (root) is the first structure to emerge from the germinating seed, usually within 48 hours of planting under optimum conditions. The radical grows downward rapidly and can provide moisture to the germinating seed if the soil surrounding the seed becomes dry. If a seed begins to germinate and the soil dries around the radical before it reaches soil moisture, the seed will most likely die.

The hypocotyl is the seedling structure that emerges from the soil surface (Figure 2-4a). The hypocotyl is either greenish or purplish in color reflecting differences in white or purple flowers that will be evident later in the season. As the hypocotyl emerges from the soil, it forms a crook as it pulls the cotyledons from the soil (Figure 2-4b). This is a critical stage in seedling emergence. In a crusted soil, the hypocotyl may be unable to push through the soil surface, resulting in a swollen hypocotyl, or the cotyledons may break from the hypocotyls, leaving

Figure 2-4a. **Stages of soybean germination, emergence and seedling establishment.** ***(Drawing by Chris Meux)***

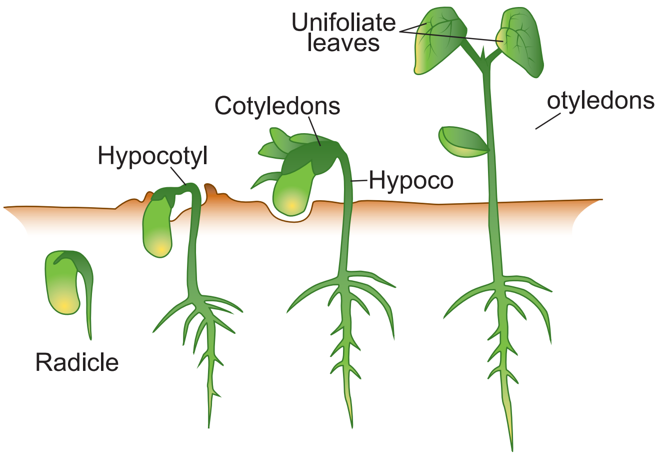


Figure 2-4b. Different stages of seedling emergence in the same field at the same time. The two soybean seedlings on the left have swollen hypocotyls due to a crusted soil surface. The two seedlings in the middle emerged normally in an area without crusting. The hypocotyl of the two seedlings on the far right has straightened and the cotyledons are beginning to unfold. ***(Photo by Ryan J. Van Roekel)***

the cotyledons and terminal beneath the soil. Under these conditions, crust-busting equipment such as a rotary hoe may be able to fracture the soil crust and improve seedling emergence.

Once through the soil surface, the cotyledons unfold, synthesize chlorophyll and begin to photosynthesize. The cotyledons are rich in protein and oil and are the primary source of nutrients for the developing seedling for the first 7 to 10 days. Once the cotyledons are through the soil surface, the plant is said to be at the VE stage of development.

Two unifoliate leaves emerge opposite from one another on the main stem as the cotyledons unfold and expand. Once cotyledons and the edges of the unifoliate leaves are not touching (leaf unrolled), the plant is considered to be in the VC development stage.

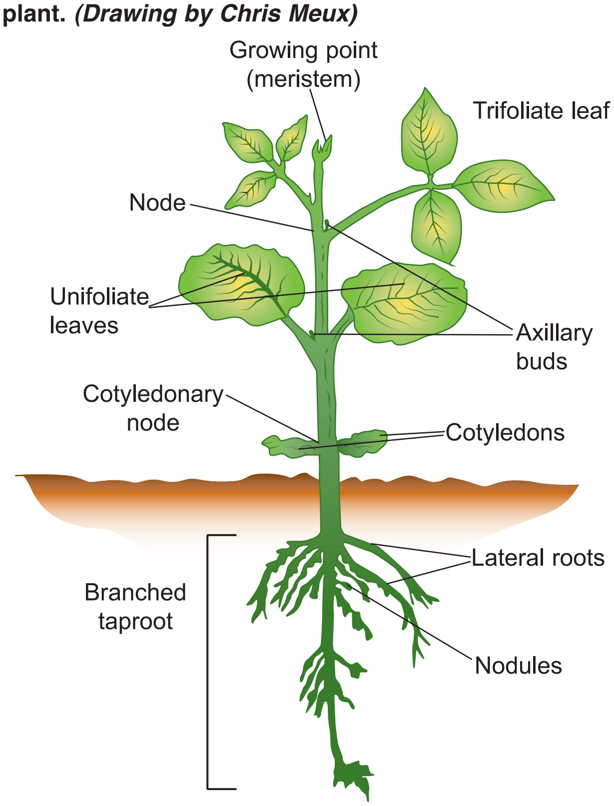
Germination Management Tips

- 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%; the loss of the unifoliate leaves plus cotyledons at V1 is around 7%.
- Consider using fungicide and insecticide seed treatments, especially when planting in cool soils.

Vegetative and Root Development

Once the unifoliate leaves are fully expanded, the plant is described as being at the V1 stage of development. To determine when a leaf is fully expanded, examine the young leaf at a node above. If the edges of the leaf at the node above the leaf in question are not touching, the leaf at the node below can be considered fully expanded and that node is counted. For example, Figure 2-5 illustrates a soybean plant with unifoliate leaves and with two trifoliate leaves. In this figure, the edges of the young developing trifoliate are not touching. Therefore, the unifoliate node is counted and the first trifoliate node is counted, and the plant is at V2.

Figure 2-5. Vegetative structures of a young soybean plant. ***(Drawing by Chris Meux)***



The nodes above the unifoliate leaves have trifoliate leaves, and vegetative development is identified from V2 (the node with the first trifoliate leaf) to the topmost node of the plant (Vn, Table 2-1). Trifoliate leaves are arranged in an alternate pattern up the stem. When temperatures are warm and soil moisture is adequate, new nodes will appear about every 4 days. Cool temperatures and drought can slow and even halt node and leaf development. The time required to reach full canopy closure decreases as rows are narrowed and populations increased, resulting in a crop more competitive against weeds.

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 exceed the root dry weight. By V3, small root nodules are usually visible on the main root, but if there is substantial carryover of N in the soil, nodule development may be delayed. Three to four weeks after emergence, nodules begin providing nitrogen to the plant. A nodule continues to increase in size until it is about 8 weeks old, and after this, it loses activity. As nodules die and lose activity, new nodules are formed, often on branch roots, and provide a continued N supply throughout seed fill. Active nodules have a dark reddish color on the inside, whereas inactive nodules are black, gray or greenish on the inside (Figure 2-6).

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. During vegetative development, roots can grow 0.5 to 0.75 inch per day. Figure 2-5 depicts above- and below-ground vegetative development of a young soybean plant.

Management Tips

- At full growth, more than 80% 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 and increase the need to maintain adequate soil moisture (irrigation).
- Decreasing row spacing to 20 inches or less results in faster canopy coverage and lessens the dependence on post-emergence herbicides.

Growth Habit

The growth habit of soybeans is described as being either determinate or indeterminate. Traditionally, determinate varieties have been from MGs 5 to 10 and indeterminate varieties have been from MGs 000 to 4. In more recent years, however, this division has become less distinct, and there are numerous MG 4 varieties that are determinate and MG 5 varieties that are indeterminate.

Determinate soybean varieties stop vegetative growth and producing nodes on the main stem soon after flowering starts, whereas indeterminate varieties continue producing nodes on the main stem until the beginning of seed fill (growth stage R5). Determinate varieties, however, will continue producing nodes on branches until the beginning of seed fill. While determinate varieties have a relatively short flowering period of nodes on the main stem (~3 weeks), the entire flowering period when including branches is similar to indeterminate varieties of the same maturity. The total length of the flowering period will depend upon planting date and maturity but may range from 3 to 6 weeks.

Figure 2-6. Cross section of soybean nodules (a) actively fixing nitrogen, (b) beginning to senesce and lose nitrogen fixation activity and (c) senescent. Note that the active nodule has a deep red color compared to the gray and dark green color of the senescent nodule.

Determinate varieties are characterized as having a terminal raceme that results in a cluster of pods under good growing conditions at the uppermost main stem node. Under stressful conditions, some or all of the pods may abort and the terminal raceme appears as a notched spine at the top of the plant. Determinate varieties also typically have leaves at the topmost three or four nodes that are similar in size. In contrast, indeterminate varieties lack a terminal raceme, and the nodes at the top of the plant tend to form a zigzag pattern. Leaves of indeterminate varieties progressively decrease in size beginning at about the fifth node from the top to the plant's terminal.

Table 2-1. Description of vegetative stages.

Stage No.	Abbreviated Stage Title	Description
VE	Emergence	Cotyledons above the soil surface
VC	Cotyledon	Unifoliate leaves unrolled sufficiently so that the leaf edges are not touching
V1	First node	Fully developed leaves at unifoliate node
V2	Second node	Fully developed trifoliate leaf at node above the unifoliate node
V3	Third node	Three nodes on the main stem with fully developed leaves beginning with the unifoliate node
Vn	n^{th} node	n number of nodes on the main stem with fully developed leaves beginning with the unifoliate node

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, MG and day length. The main effect of day length on soybean development is that of floral induction. Soybeans are referred to as short-day plants because short days (i.e., long nights or dark periods) initiate flowering (floral induction).

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).

Table 2-2. Description of reproductive stages.

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% 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% moisture

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.

The R1 stage begins when there is one flower at any node on the plant. Usually the first flower is located between the fourth and sixth nodes. The R2 stage occurs when there are open flowers at one of the two uppermost nodes. Between R1 and R2, open flowers appear at nodes from the bottom of the plant toward the top. In a late-planted soybean crop (e.g., double-crop soybeans), R1 and R2 may occur almost simultaneously or be separated by as much as 6 days. For full-season soybeans (e.g., MG 5 variety planted in early May), the time period between R1 and R2 ranges between 3 and 10 days.

After flowering begins, plants continue to grow vegetatively, producing new nodes on both the main stem and branches. The time between R2 and beginning pod stage (R3) depends upon planting date, growth habit (determinate or indeterminate), MG, temperature and other factors that affect plant growth (e.g., drought). Indeterminate varieties may spend 2 or more weeks at R2 because new nodes are produced on the main stem after first reaching R2.

The beginning of the seed fill period is designated as R5. At this time, seed are 1/8-inch long in full-size pods at one of the uppermost four nodes. Flowering ends and plants reach their maximum vegetative weight at the beginning of R5. During the flowering and early pod formation stages (R1 through R4), plants adjust the number of flowers and young pods in response to the environment. Flowers and young pods may abort when conditions are stressful for a few days, but then fewer flowers and young pods may abort later if environmental conditions improve. Soon after plants reach R5, however, there is little pod abortion, and stress (e.g., drought, prolonged flooding, etc.) results in a short seed-filling period, early maturity and small seed.

The R5 development stage ends and the R6 development stage begins when the seed fills the pod cavity from a pod at one of the uppermost four nodes on the main stem. Because much of seed dry weight accumulates during R6, it is critical to ensure that the crop continues to be managed for irrigation and pests. Toward the end of R6, the canopy begins to yellow and leaves begin to senesce.

The R7 development stage begins when there is one mature-color pod at any node on the plant. Mature pod color in soybeans differs among varieties. The pod wall color in commercial varieties is usually tan but may be brown. Additionally, the pubescence (small hair-like structures on the plant) of varieties may be either gray or tawny (brown). The mature pod color of soybeans, therefore, varies from light gray to dark brown. At R7, seed moisture is still high, but the seed has reached its maximum dry weight. Seeds can still be damaged by stinkbugs at this stage. The R7 stage is also referred to as physiological maturity. Once 95% of the pods turn a mature pod color, the plant has reached R8 and can be harvested once seed moisture is less than 15%.

Management Tips

- Having a full canopy by R2 is important in setting a maximum number of pods.
- Begin scouting soybeans regularly for diseases and pod-feeding insects (especially bollworms and stinkbugs) beginning at R3 and continuing through seed fill.
- Irrigation should be continued at least until the crop is in the R6 development stage. If soil moisture is high when leaves first begin to turn yellow, irrigation can be terminated.

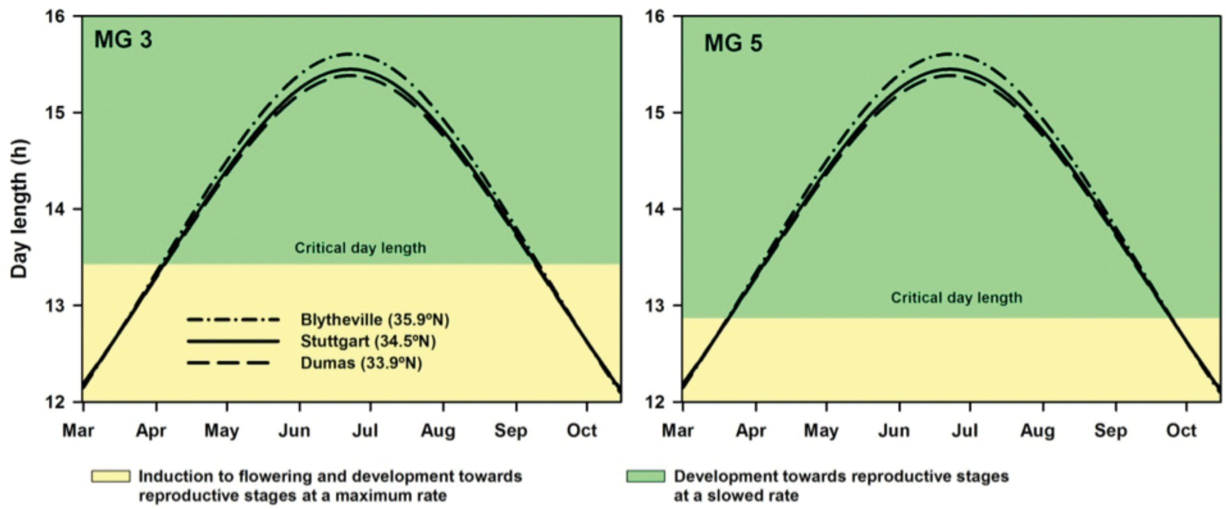
Days Between Growth Stages

Soybean development is influenced by temperature and day length and will also be affected by soil moisture conditions, plant nutrition and other factors. The number of days between stages will also vary greatly depending on the MG and variety used. Therefore, the timing of development stages will be different depending on the variety, climate and planting dates.

Emergence will depend primarily on temperature under correct moisture conditions. Plants will emerge when soil temperatures are higher than 41°F, and higher temperatures will enhance a faster emergence. For instance, emergence can take about 14 days at 46°F but only 4 days at 59°F. During the vegetative period, the plant will produce nodes at an average rate of 1 node every 4 days. The total number of nodes will vary between approximately 16 and 23, depending on the cultivar and length of the vegetative period.

The beginning of flowering and subsequent reproductive development is greatly affected by photoperiod. The soybean is a short-day plant, meaning that days shorter than a critical value will induce the plant to flower. Figure 2-7 shows the day length across the growing season for Dumas (33.8° latitude), Stuttgart (34.5° latitude) and Blytheville (35.9° latitude), Arkansas. The yellow-shaded region near the bottom of the figures show the critical day length at which the development rate toward flowering is at a maximum. For MG 3 varieties, the critical day length that induces soybeans to flower at a maximum

Figure 2-7. Day length versus date for three locations in Arkansas. The yellow-shaded regions indicate the day lengths that result in MG 3 (left panel) and MG 5 (right panel) varieties' rapid progression toward flowering. As the day length becomes longer (green region), the rate of progression toward flowering decreases.



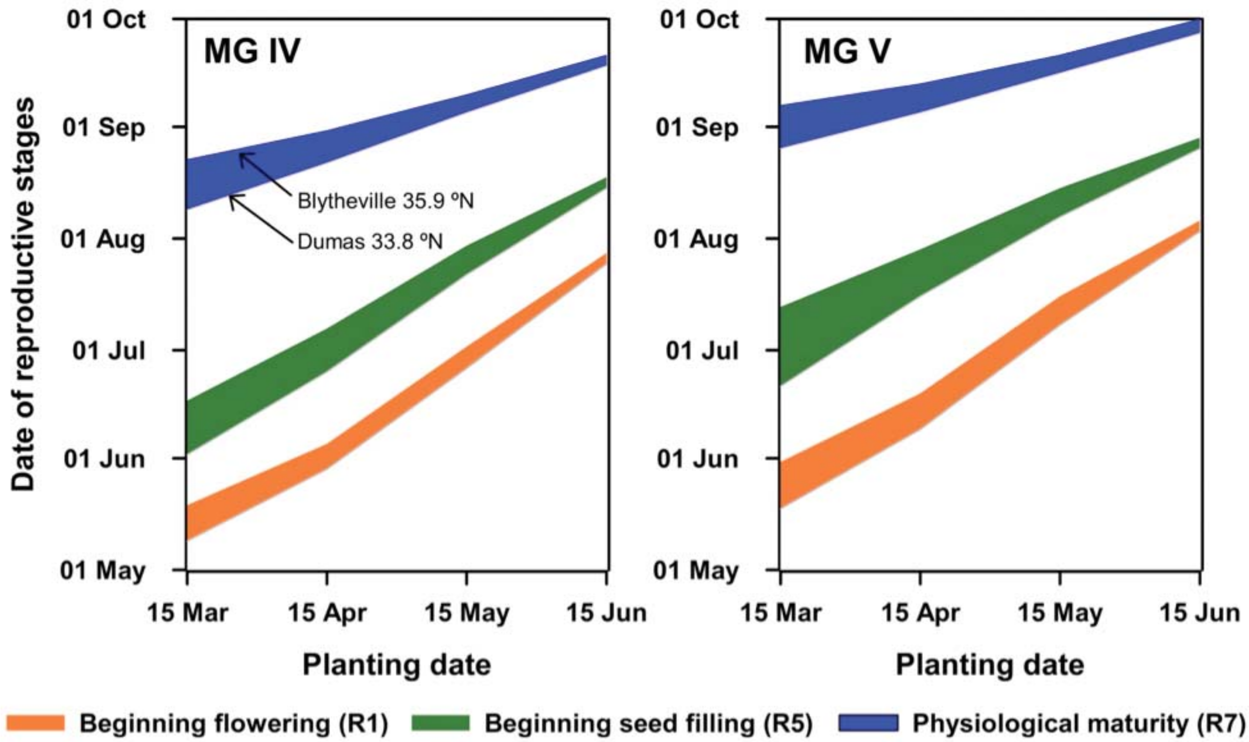
rate is about 13.4 hours, whereas for a MG 5 variety, the critical day length is about 12.8 hours. When day length is longer than these critical values, plants will continue to be induced to flower but at a progressively slower rate (green region in Figure 2-7).

For example, a MG 3 variety will be induced to flower at a maximum rate whenever the day length is less than 13.4 hours, which corresponds to dates earlier than April 1 (Figure 2-7). For a MG 5 variety, plants will be induced to flower at a maximum rate whenever the day length is less than 12.8 hours, which corresponds to dates earlier than March 15 (Figure 2-7). Note that if planting is delayed until mid-May, the photoperiod is longer than the critical day length for both MG 3 and 5 varieties (green region of Figure 2-7), which means that the progress toward flowering will take considerably longer. For double-crop or late-planted soybeans (late June or early July), the day length is shorter each day, which means that the development rate toward flowering is increasing. From a practical standpoint, these scenarios mean that early-planted or late-planted soybeans should be planted in more narrow rows (< 20 inches or twin rows) and at a higher population density than soybeans planted in mid-May. Likewise, MG 3 and early MG 4 soybean varieties will have less time for vegetative growth compared to MG 5 varieties, which may require more narrow rows and a higher population density.

In addition to photoperiod, higher temperatures will accelerate reproductive development. Using long-term weather data for Blytheville and Dumas, Arkansas, we have estimated dates when flowering (R1), beginning seed fill (R5) and physiological maturity (R7) are expected to occur over a range of planting dates using a computer simulation model (CropGro, Figure 2-8). Assuming average temperatures for early plantings on March 15, the time from planting to flowering (averaged across the two locations) will be about 60 (May 14) and 70 (May 24) days for MG 4 and 5 varieties, respectively. As planting date is delayed, the number of days to flowering is shortened. For instance, with late planting on June 15, the number of days from planting to flowering will be about 42 (July 27) and 50 (August 14) days for MG 4 and 5 varieties, respectively. The development rate toward flowering and the subsequent reproductive stages will be faster in years with higher temperatures and/or locations in south Arkansas.

The beginning of seed filling, or the R5 stage, will occur about 27 (June 10) and 39 (July 2) days after beginning of flowering for MG 4 and 5 varieties planted on March 15, but it will shorten to 21 (August 17) and 23 (August 27) days for MG 4 and 5 varieties when planted on June 15.

Figure 2-8. Estimated dates of beginning flowering (R1), beginning seed filling (R5) and physiological maturity (R7) based upon planting date for MG IV and V soybeans. The lower edge of each colored region represents dates for Dumas, AR (latitude 33.8°N), and the upper edge represents estimates for Blytheville, AR (latitude 35.9°N). Estimates were made using a crop simulation model (CropGro) and using long-term weather data for each location.



Finally, the expected number of days from beginning of seed filling to physiological maturity (R7) will be about 67 (August 16) and 61 (September 1) days for MG 4 and 5 varieties with an early planting on March 15, and the R7 date is expected to be about 34 (September 20) and 32 (September 28) days after R5 for MG 4 and 5 varieties with a planting date in mid-June.

The number of days from R7 until all the pods are mature and the crop is ready to harvest (R8) can range from 6 to 13 days depending on the cultivar and weather conditions. Under non-irrigated conditions or dry years, the soybean crop can reach maturity about 7 to 10 days earlier than the reported expected dates. Conditions of prolonged drought during flowering through early seed fill (R5) followed by favorable growing conditions may result in few pods on the plant, a delay in maturity, and green leaves and stems when pods are mature. Likewise, insect infestations resulting in a large loss of pods can also delay maturity and result in green leaves and stems when pods are mature.

Chapter 3

Variety Development, Testing and Selection

by W. Mayhew, C. Sneller, C. Coker, D. Dombek and D. Widick

Selecting soybean varieties for planting is perhaps the most important management decision a grower can make. With more than 100 soybean varieties available, selecting a few varieties to plant is challenging. A grower should consider many factors in making this extremely important decision.

The University of Arkansas provides a soybean variety testing program. The information obtained from this program is available to growers through an annual newsletter called *Soybean Update* and a computerized soybean variety selection program entitled *SOYVA*. Using this information will aid growers in selecting varieties adapted to each field.

Variety Development

The numerous varieties available to Arkansas growers come from publicly funded breeding programs in states throughout the South and from private companies. Arkansas growers are fortunate to have many private breeding programs represented in the state as well as two public breeding programs. These breeders strive for high-yielding lines and disease resistance with particular emphasis on resistance to stem canker, soybean cyst nematode and Phytophthora root rot. In addition, new breeding lines are also screened for tolerance to stress that is typical of Arkansas production environments.

Variety Testing

Each year the University of Arkansas Division of Agriculture conducts replicated variety field performance tests at locations representing the major production regions in the state. From each of these tests the following information is recorded:

- Yield
- Maturity date
- Lodging
- Shattering
- Plant height
- Ratings for naturally occurring diseases

Also, Division of Agriculture scientists conduct laboratory, greenhouse and field experiments to measure variety reaction to nematodes, diseases, excessive levels of soil chloride and tolerance to herbicides.

Variety performance tests, like all field experiments, are subject to uncontrollable variability. Variability may result from differences in soil texture, disease pressure or uneven soil moisture within the test area. For these reasons, variety tests are replicated three times. A test with three replications has each variety planted in three different plots within the test, and the information from the three plots is averaged.

Figure 3.1. Replicated University variety trials provide information on yield potential and enable screening for genetic differences in tolerances to diseases, herbicides and chloride.

Factors Affecting Variety Selection

There are many factors to consider when selecting soybean varieties for planting. These factors are discussed in the following section:

Maturity

Commercial production of soybeans in Arkansas uses maturity groups III through VII. For an efficient harvest, select varieties that mature over a suitable time period. Varieties with different maturity are more likely to spread out harvest than planting one variety at different times.

An earlier variety tends to be a better choice where a fall grain crop such as wheat will be planted or where fall land formation work will be conducted. However, many growers may not want a variety that matures before the completion of rice or corn harvest.

In dryland production, consider long-term weather patterns. Avoiding the brunt of late summer droughts in one of two ways is possible. First, an indeterminate maturity group (MG) III or IV variety can be planted early (April) to allow for pod fill before the drought. Second, a late-maturing variety (MG VI or VII) could use late summer rains to fill pods. The risk of poor growing conditions in any part of the season can be minimized by spreading out crop maturity with variety selection.

Table 3.1 shows the suggested percentage of acreage to plant within each maturity group for dryland and irrigated conditions. There is also benefit to planting varieties of differing maturity within a maturity group. For example, there is more maturity difference between varieties of a relative maturity of 5.1 and 5.9 than varieties with relative maturity ratings of 5.9 and 6.2.

Table 3.1. Recommended Planting Percentage of Specific Maturity Groups for Dryland and Irrigated Plantings in Different Regions of Arkansas

State Location	Suggested % of Acreage: Very Early[1] (III, IV)	Early (V)	Mid-Season (VI)	Late Mid-Season (VII)
Dryland Acres				
Northern 1/3	20	60	20	0
Central 1/3	20	50	30	0
Southern 1/3	20	30	30	20
Irrigated Acres				
Northern 1/3	35	50	15	0
Central 1/3	30	50	20	0
Southern 1/3	25	50	25	0

[1]Some MG III and IV varieties tend to shatter, so timely harvesting is very important. Seed from these varieties planted in Arkansas typically have low germination. The seed should not be kept for planting purposes unless tested for germination.

Lodging

Lodging can reduce yield and increase harvest loss. Excessive lodging before or during early soybean pod fill can reduce yields up to 30 percent. Lodging later in the season can reduce yields by reducing combining efficiency and slowing the speed of harvest. It tends to be more pronounced in rich, productive soils that produce a lot of plant growth. Lodging can be worse in dense populations. Plant varieties that tend to lodge at the lower end of the optimum seeding rate.

If lodging typically occurs in particular fields, select varieties that resist lodging and monitor plant populations closely.

Disease and Pest Resistance

The success or failure of a soybean variety in a field can be determined at times by a single disease organism. The positive identification of each disease is the key to disease management. The most feasible method of control is to select a variety with resistance to that disease. Variety selection must take into account the yield-limiting diseases known to be present in a field and those diseases that have a relatively high probability of occurring. (A more detailed discussion on this topic is covered in Chapter 11.)

Phytophthora Root Rot – This disease is predominantly found in clayey soils. It can cause stand loss and yield reduction. Varieties planted on clay (often referred to as gumbo) soils should contain resistance or field tolerance to Phytophthora root rot.

Root-Knot and Soybean Cyst Nematode – Some of the nematodes in Arkansas soils can reduce soybean yields drastically when left undetected. Yield losses are often mistakenly attributed to “inadequate fertility” or “weak ground.” To determine the level and kinds of nematodes present, take a nematode sample in each field. Send the sample to the Nematode Diagnostic Laboratory by way of the local county Extension office for a general analysis.

Soybean cyst nematode control should represent a planned program of growing a non-host crop such as grain sorghum or corn followed by a resistant soybean variety and then by a susceptible soybean variety. If soybean cyst nematode is at a high level, a race determination test also needs to be conducted.

Root-knot nematode control can be assisted with resistant varieties and rotation with grain sorghum. Most corn varieties are excellent hosts of root-knot and should **not** be considered in a rotational plan as a non-host crop if root-knot is present in the field.

Frogeye Leaf Spot – This foliar disease reduces soybean yield of susceptible varieties in years where there is frequent rainfall and high humidity. This disease can be controlled with resistant varieties or by a properly timed foliar fungicide application.

Stem Canker – Once this disease has been identified in a field, consider it a serious threat to production each time soybeans are planted in that field. When weather conditions are favorable, this disease will be devastating to a susceptible variety. Select a variety resistant to stem canker for any field where stem canker has been identified.

Sudden Death Syndrome – Historically, this disease tends to affect high-producing, well-managed irrigated soybeans more frequently than dryland soybeans. In fields where this disease has been identified, select a resistant variety.

Aerial Web Blight – This disease is caused by the same organism that causes sheath blight in rice. It can reduce yields in soybeans. Data from Louisiana State University show that some soybean varieties have moderate resistance to this disease. Growers planting soybeans after rice with heavy sheath blight pressure should consider aerial web blight as a possible yield-limiting factor in their variety selection.

Herbicide Considerations

Soybean varieties respond differently in their ability to tolerate different herbicides. Some varieties express good tolerance to the herbicide metribuzin (Sencor®, Lexone® and Canopy®). Some varieties are severely injured when planted in soils where metribuzin has been applied. Additionally, some soybean varieties are severely affected by drift levels of propanil. Variety selection should take into account where propanil drift may occur after soybean emergence as well as where metribuzin may be used for weed control.

Some new soybean varieties have resistance to specific herbicides. Examples presently in place include Roundup® Ready and STS (sulfonylurea tolerant soybeans). The STS soybeans can more effectively tolerate Synchrony® and Pinnacle®, as well as Classic®, Lexone® and Sencor®.

Depending on weed spectrum, herbicide cost, etc., the availability of these new soybeans can greatly influence variety selection. Caution should be used that other important variety selection factors such as disease resistance, etc., are not overlooked when using a herbicide-resistant variety.

Chloride Sensitivity

Some soils in Arkansas have high levels of soil chloride. Soybean varieties have different responses to these chlorides. Some varieties are **includers** where roots take up the chlorides and distribute them throughout the plant. Other varieties are **excluders** where roots take up the chlorides but restrict them to the roots. Both includers and excluders are affected by high chloride levels, but damage to includers can be catastrophic. Therefore, where chlorides are a problem, select varieties that are chloride excluders.

Yield

One of the most important factors to consider in variety selection is yield potential. Varieties should be selected first on all other factors that affect production and then on yield. The best indicator of yield is to compare multi-year averages between varieties. Some varieties yield well on one particular soil type, location in the state or production system. Select varieties that perform well at locations similar to a particular farm or that perform well at all locations. Selecting varieties that will be high yielding in a particular field is difficult. University of Arkansas variety trials provide estimates of the relative yield potential of currently available varieties in different soil types and production systems.

It is important to consider the magnitude of yield difference when comparing varieties. Scientists use a least significant difference (LSD) value to determine if two varieties have different yield potential. Small yield differences (less than the LSD value) are probably not meaningful, while large yield differences (greater than the LSD value) reflect difference in yield potential between two varieties.

One approach to take when evaluating new varieties is to plant a few selected new varieties each year on a rather limited basis. You can then evaluate these new varieties within their own unique production environment. Varieties will be produced with the grower's planting dates, row widths, irrigation and level of management. Then, varieties that perform well can be increased in acreage.

Soybean Update and SOYVA

The Cooperative Extension Service prints *Soybean Update* annually. This newsletter details the University of Arkansas' evaluation of soybean varieties in the Variety Testing Program. *Soybean Update* includes data, if known, on all the factors discussed in this section for variety selection. This publication can be used to select soybean varieties for specific field conditions that have high yield potential.

Essentially, all the data in *Soybean Update* is in a computerized program entitled *SOYVA*. This program asks specific questions concerning disease pressure, soil type, location in the state, irrigation or dryland, planting date and herbicide. The program then provides a list of recommended varieties and those not recommended. The two-year average yield of the recommended varieties can be compared for any location conducting variety testing trials.

To receive *Soybean Update* or a computer disk of the *SOYVA* program, contact your county Extension office. *SOYVA* and *Soybean Update* can also be downloaded from the Extension Agronomy Section website at http://www.uaex.uada.edu.

Conclusion

Soybean growers in Arkansas are fortunate to have numerous varieties adapted to their soybean growing conditions. Selecting the proper varieties is an important management decision. This decision-making process should represent a planned program to account for all factors associated with variety selection. Yield potential certainly is a major portion of this decision, but yield-limiting factors that threaten yield potential must be identified and considered during this production management process.

Soybean varieties are continually being improved. Use *Soybean Update* and *SOYVA* to choose varieties that allow for the highest possible chance of positive net returns. Using this information to test new varieties on farm each year is an excellent management tool available to soybean producers.

Chapter 4

Seed Grain Composition, Quality and Testing

by L. Ashlock, D. Longer and M. Smith

Arkansas is a major producer of soybean grain that is relatively high in oil and protein. In addition, much of the planting seed for the determinate southern soybean production region is produced by Arkansas seedsmen. The state's geographic location provides relatively cool conditions during seed maturation for varieties in maturity groups V, VI, VII and IV (with restrictions). The existing irrigation capabilities (due to the state's extensive rice acreage) provides an inherent advantage to Arkansas seedsmen.

Seed Composition – Grain

Soybean seed grown in Arkansas typically contains 18 to 19 percent oil and 42 percent protein. Therefore, a typical bushel (60 pounds) of soybean grain contains approximately 11 pounds of oil and 22 pounds of protein. The extraction of the oil and protein and the use of these compositional products are discussed in Chapter 18 of this publication.

Since Arkansas produces around 90 million bushels of grain annually, the direct processing and/or the export of soybean grain translates into a $500+ million industry annually. At present, approximately 33 percent of the production (30 million bushels) is processed in the state, while 60 million bushels are exported annually.

Seed Quality – Planting Seed

Soybean producer checkoff monies are used to complement an extensive seed variety development program directed by the University of Arkansas Experiment Station. More than 400 Arkansas seed producers produce between 4 and 5 million bushels of public and private label seed beans annually on about 200,000 acres. Certified soybean seed acreage accounts for 22 percent of all seed acres planted in Arkansas.

Six private companies have seed breeding programs and research units in Arkansas, and eight other companies have test plot locations in Eastern Arkansas. The annual income generated by the soybean seed industry approaches $75 million annually.

Figure 4.1. Arkansas ranks 9th nationally in the production of soybeans.

Testing for Seed Quality

Most factors associated with seed quality are effectively determined by approved seed testing laboratories. Listed below are the main factors normally associated with seed quality. In addition to these factors, Extension Fact Sheets 2019 and 2141, available from your county Extension office, present more detailed discussions on seed quality.

Varietal Performance and Purity

An extensive variety evaluation (testing) program is conducted by the University of Arkansas. In addition, private companies and Extension demonstrations further evaluate varietal performance under local conditions. Based on relative yield performance across a wide range of environmental conditions, a group of varieties (over 100 representing maturity groups IV through VII) is considered adapted to Arkansas conditions and is included in Cooperative Extension's computerized variety selection program, *SOYVA*.

Before varieties are recommended for specific field conditions, genetic characteristics such as shattering, lodging, herbicide sensitivity, relative disease resistance and relative yield potential must be determined. Planting seed that is varietally pure is essential to obtain optimum yields while not contributing to present and/or future yield-limiting problems. Many problems, including nematodes, diseases, etc., are perpetuated because the varietal purity of planting seed is not maintained at the on-farm level.

Physical Purity

Many production problems including the spread of weeds, nematodes, etc., could be reduced if seed were subjected to approved testing procedures. These procedures determine the percentage by weight of (1) pure seed, (2) other crop seed, (3) weed seed and (4) inert matter. The physical purity percentages show the effectiveness of seed cleaning processes. When buying seed for planting, expect and demand a label (see Figure 4.2) showing these percentages as well as the germination percent (this is required by state and federal laws).

Figure 4.2

Seed label.

Management Tips

1. If you see significant differences in hilum color, then you probably have a mixture of varieties.
2. Soybean seed produced under severe "stress" may not appear as originally described (seed size may vary considerably).
3. Prior to planting, clean all seed and submit a sample to an approved seed testing laboratory (i.e., Arkansas State Plant Board).

Germination – Vigor Test

The standard germination test is conducted by private or public seed testing laboratories under controlled conditions and determines (by percentage) the number of seeds capable of producing "normal" seedlings during a specific period of time under near optimal conditions. Vigor tests are designed to predict field performance potential and to evaluate the extent of seed deterioration. Seed death is typically gradual and cumulative. As seed cells die, critical parts of the seed are unable to perform the essential functions associated with the complex process of germination. Some seed quality tests performed by the Arkansas State Plant Board are:

Standard Germination Test – Some 400 seed are picked at random, placed on a moistened germination towel, covered and placed in a germination chamber for 6 to 8 days at a constant 77˚F or an alternating temperature of 68˚-86˚F. (The seed is kept at 68˚F for 16 hours per day and 86˚F for 8 hours per day.) Both the constant and alternating temperature regimes are acceptable in the Association of Official Seed Analysts (AOSA) rules and regulations for optimum soybean germination.

The number of normal seedlings is determined based on the following criteria:

(a) Vigorous root system sufficient to anchor the seedling;
(b) A sturdy hypocotyl (stem);
(c) At least one cotyledon attached; and
(d) An epicotyl that consists of at least one primary leaf and an intact terminal.

Accelerated Aging Test (AA) – This test is designed to measure the vigor of the seed and is used to predict field emergence under stress conditions associated with soil temperatures, soil crusting and adverse soil moisture.

The AA test consists of weighing out 1.34 ounces of seed and placing them in a 100 percent humidity environment at 106˚F for 72 hours, after which 200 seed are picked at random and subjected to the same testing criteria used in the standard test. The number of normal seedlings is then expressed as percent.

Other tests are also performed by the seed testing laboratories to help determine seed quality and vigor. For details of those tests refer to Extension Fact Sheet 2019, *Measuring Soybean Seed Quality* (available from your county Extension office).

Suffice it to say that the vigor of seed will further help determine the true quality of seed and enable the grower to better determine the seeding rate to use in order to obtain the proper number of plants per acre.

At present, the Standard Germination Test is the only nationally recognized test for determining the germination of seed for labeling purposes. Soybean seed is relatively short-lived, and environmental conditions in Arkansas (i.e., warm temperature and high humidity) lead to rather rapid seed deterioration during the summer months. Growers are not encouraged to carry seed over from one year to the next but rather are encouraged to have all seedlots tested prior to planting.

Management Tip

All seedlots should be re-tested to determine germination and vigor within 30 days of July plantings.

Table 4.1. Suggested Planting Dates for Quality Seed Production[1]

Varietal Maturity Group	Range in Planting Date	Optimum Planting Date
4	June - July 15	June 15 - July 1
5	May 15 - July 1	June
6	May - June 15	May 15 - June 15
7	May	May

[1]At this time these planting dates should result in acceptable seed quality without undue sacrifice of yield.

Factors Affecting Seed Quality and Germination

Several of the factors that affect seed quality and germination include climate, harvest, storage, genetics, cleaning and seed treatments.

Climate

Climatic conditions, especially temperature and humidity, greatly affect seed quality. Hot, humid conditions during seed maturation (growth stage R 6.0 - 7.0) can greatly reduce seed quality, especially germination. These extreme conditions normally occur between July and early September. For these reasons, April planting of maturity groups IV and V is not recommended for soybean seed production. Listed in Table 4.1 are the suggested planting dates by varietal maturity group for seed production purposes.

Harvesting

Harvesting is probably the most critical phase of soybean seed production. Listed below are guidelines that are useful for producing good-quality seed for planting:

- **Clean the Combine** – Disassemble and clean the combine prior to harvesting planting seed. It is not unusual to clean out 1 to 2 bushels of seed, weed seed, trash and soil from the augers of a combine after it has emptied the grain hopper.

- **Harvest Timeliness** – Seed moisture at around 14 percent reduces cracking, but long-term seed storage at less than 14 percent helps maintain good germination. Delayed harvest accompanied by continued re-wetting of mature seed can result in a 20 percent loss in germination or worse. Fungal seedborne disease organisms can also reduce germination and usually impact seed at moisture content in excess of 13 percent.

> **Management Tip**
>
> Seed produced in warm, humid conditions may result in lower-than-normal germination. The use of a registered seed treatment (fungicide) may improve the germ test (sometimes up to 30 percent) if fungal seedborne organisms are the major contributor to the germination problem.

- **Reduce Mechanical Damage** – Use belt buckets rather than spiral elevators whenever possible. Use “bean ladders” or a spiral “let-down” inside bins. Rubber-coated beltrators and bucket elevators also reduce seed impact damage.

- **Storage** – Storing seed with less than 14 percent moisture is preferred. Warm and humid conditions during winter months require periodic aeration to prevent temperature rises and moisture migration. (See Chapter 15.)

  Exercise care in using heat to reduce seed moisture. Cool, dry air at temperatures less than 60°F forced through the seed at 2 to 3 cfm/bu is usually adequate and safe.

  Hot weather affects seed quality. Storage temperatures in excess of 75°F cause the seed cotyledons to deteriorate. The respiration rate of soybean seed increases with increased temperatures up to 122°F.

- **Clean the Seed Conditioning Plant** – Thoroughly clean the seed plant facilities prior to handling each variety of seed since the storage bins, cleaning equipment and handling machines are sources of contamination.

> **Management Tip**
>
> Seed stored at a moisture level of 15 percent coupled to 86°F temperatures loses all viability in about 4 months while seed stored below 12.5 percent moisture and 68°F with a relative humidity of 60 percent should remain viable for up to 8 or 9 months.

DIVISION OF AGRICULTURE
RESEARCH & EXTENSION
University of Arkansas System

Fertilization and Liming Practices

Nathan Slaton, Trenton Roberts and Jeremy Ross

Soybeans have long been considered the "other crop" grown in crop rotation systems in Arkansas. Proper fertilization programs for soybeans have long been ignored. However, high soybean prices and interest in the production of ultra-high (>100 bu/acre) soybean yields have stimulated interest in maximizing soybean yields via proper fertilization. The soybean crop is very nutrient-intensive with total aboveground uptake of 5.0 lb N, 1.0 lb P_2O_5 and 3.8 lb K_2O required to produce each bushel of soybeans. For perspective, the aboveground phosphorus (P) and potassium (K) uptake needed to produce one bushel of soybeans is 1.5 to 3.0 times greater than the amounts of P_2O_5 and K_2O equivalent needed to produce one bushel of corn or rice. Just like any other crop, sufficient soil fertility coupled with a well-planned fertilization program is only one component of producing high soybean yields. Identifying and correcting other soil-associated yield limitations (e.g., slope, poor drainage, excessive drainage, etc.) that are potentially greater yield-limiting factors than soil fertility is important for fertilization to be an economical practice. This chapter's objectives are to (1) review soil test-based fertilizer recommendations, (2) describe the symptoms of nutrient deficiencies or toxicities and (3) provide research- and/or experience-based insight on nutrient management strategies.

Soil Testing

Fertilizer and lime applications should be made using the most recent soil test results, the field's history of soil test results and an examination of the field's crop yield and fertilization history. The field's most recent soil test results provide a current assessment of the field's nutrient availability status and pH suitability for soybeans and crops that may be grown in the rotation. The history of soil test results will provide an indication of how consistent the soil nutrient availability information has been across time and may provide insight about nutrient depletion or accumulation as a result of the balance between the amounts of nutrients removed by the harvested crop and added via annual fertilization practices. In some years, abnormal soil test results can occur from sampling error or short-term environmental influences (e.g., extremely dry weather conditions). Should the most recent soil test results differ substantially from previous years' results, we would recommend using the old soil test results to make fertilization decisions if resampling fields is not an option.

Monitoring a field's soil test P and K fertility history can be done quite easily in most spreadsheet programs (Fig. 5-1). Making a graph of soil test P and K values across time is an excellent way of monitoring soil test trends. Note that the use of soil test results from different labs or even the same lab can be tricky. Be sure that the soil test information for P and K is compared using the same soil test methods and units. For example, the University of Arkansas Soil Test Laboratory made slight adjustments to the soil test methodology in January 2006 which affected the amount of soil nutrients that were extracted and reported on the soil test. The University of Arkansas uses the Mehlich-3 soil test method and shows soil test information with units of both lb/acre and parts per million (ppm, which is one-half of lb/acre). Units reported as lb/acre assume that the soil sample was collected from an acre furrow slice that weighs 2 million pounds. For most Arkansas silt loam soils, this

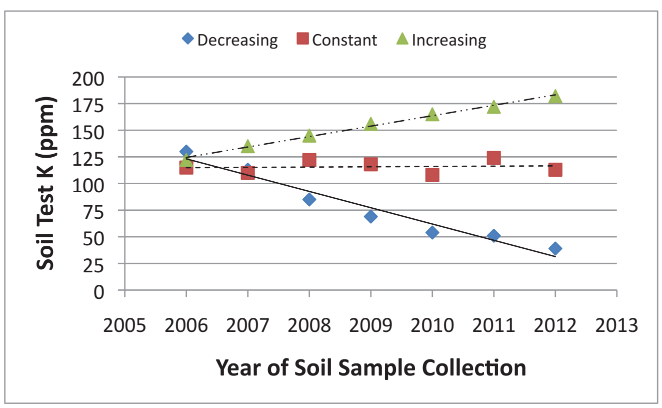


Figure 5-1. Example of graph showing trends for soil test K to increase, decrease or remain constant across time.

would require that soil samples be collected to a 7-inch depth. The University of Arkansas recommends a 4-inch soil sample depth for soybeans because the presence of a hard pan makes sampling deeper than 4 inches impractical. All University of Arkansas soil test-based P and K recommendations are correlated and calibrated for a 4-inch sample depth. Due to nutrient stratification (e.g., soil nutrient concentrations decline with increasing soil depth), collecting samples from a greater depth usually decreases the soil test values and may result in greater fertilizer rates being recommended. Collecting samples from less than a 4-inch depth would cause soil test values to be greater and would potentially reduce the amount of P and K fertilizer that would be recommended and potentially lead to under-fertilization.

As a general rule, soil samples should be collected following the same crop in a crop rotation sequence and at approximately the same time (month) each year. This is especially important in fields rotated with rice because the soils may be flooded for two or three months during the summer and the anaerobic/flooded soil conditions can influence soil nutrient availability. Soil test P values tend to be lower following rice compared with samples taken following soybeans in a 1:1 rice:soybean rotation. Other than this exception, research suggests that soil test P is consistent across the fall, winter and spring months, but pH and soil test K can fluctuate substantially (Table 5-1). Soil samples collected in the fall (October to November), late winter (February to March) and spring (April) showed the soil test K was always slightly higher when samples were collected in the fall.

The University of Arkansas fertilizer recommendations are sufficient to produce high soybean yields as nutrient availability is only one component influencing yield potential. Fertilizer recommendations for soybeans are a combination of research trial data and soil nutrient management logic (e.g., building the fertility levels of depleted soils). Fertilizer recommendations provide an indication of the magnitude of yield response that can be expected and the probability that a significant yield increase will occur. Phosphorus and K fertilizer recommendations should be based on yield goals only when one is trying to replace the nutrients removed by the harvested crop. Soil test results are simply a nutrient availability index and not an absolute amount of total nutrients or plant-available nutrients in the soil. The nutrient removal rate used in University of Arkansas recommendations is calculated based on a 50 bu/acre soybean yield, although yields >50 bu/acre may be produced with these recommendations.

Lime

Economic yield reductions due to soil acidity generally occur on sandy and silt loam soils at pH values less than 5.5. Fields with pH values below 5.3 require close attention. If soil pH values are 5.0 or less, liming should take priority over P and K fertilization. Soybeans may tolerate pH values as low as 5.2 on many alluvial clayey soils without significant yield loss (Table 5-2). However, crops grown in rotation with soybeans, such as wheat and corn, may suffer from aluminum (Al) and manganese (Mn) toxicities.

The University of Arkansas Soil Test Laboratory makes lime recommendations based on the soil pH and soil calcium (Ca) content (an indicator of soil texture, Table 5-3). Other laboratories typically use what is called a buffer pH to determine lime rate. It should be noted that soil pH is not a static soil property. Soil pH can fluctuate by approximately 1.0 unit (±0.5 from the true mean pH) during the calendar

Table 5-1. Effect of soil sample collection time on soil test P, K and soil pH (values are the average of 12 to 24 composite soil samples with each sample representing a 150 ft^2 plot at each sample time) in five silt loam soils.

Site	Soil pH			P			K		
	Fall†	Winter‡	Spring§	Fall	Winter	Spring	Fall	Winter	Spring
	- - - - - - - pH - - - - - - -			- - - - - - - ppm P - - - - - - -			- - - - - - - ppm K - - - - - - -		
Convent	6.1	6.7	6.1	43	39	38	138	123	108
Convent	6.4	6.7	6.4	39	35	41	138	126	115
Calloway	6.8	6.6	6.6	12	11	10	118	108	103
Calloway	6.6	6.7	6.8	6	6	6	105	86	79
Calloway	7.1	7.2	6.9	15	14	14	115	89	90

†Fall, late October to mid-November
‡Winter, mid-February to early March
§Spring, mid-April

Table 5-2. Expected yield reductions due to soil acidity.

Soil pH	Expected Yield Reduction†	
	Sandy and Silt Loams	Clayey or Alluvial Soils Along Streams and Rivers
	%	%
4.6 – 5.0	30 – 50	15 – 20
5.1 – 5.4	20 – 30	10 – 15
5.5 – 5.7	10 – 20	5 – 10
5.8 – 6.0	0	0

†Reduction in yield relative to an optimum pH level of approximately 6.0 to 6.5. Expressed as a percentage of potential yield.

Table 5-3. Arkansas lime recommendations for soybeans.

Soil Texture	Soil Test Ca	Below Optimum			Medium	Optimum
		<5.0	5.0 – 5.3	5.4 – 5.7	5.8 – 6.2	6.2 – 6.9
	- - - ppm Ca - - -	- - - - - - - - - - - - - - - - - - - lb ag lime/acre - - - - - - - - - - - - - - - - - - -				
Sandy loam	≤500	4,000	3,000	2,000	0	0
Silt loam	501 – 1,500	5,000	4,000	2,500	0	0
Clay loam	1,501 – 2,500	6,000	5,000	3,000	0	0
Clay	≥2,501	7,000	6,000	4,000	0	0

year with the highest pH values typically occurring in the winter months and the lowest pHs occurring in the hot, dry summer months. During fall and winter months (the time that most soil samples are collected) with abnormally low amounts of rainfall, soil pH values may be lower (e.g., 0.5 lower) than normally observed. However, these lower pH values may be representative of what the crop will endure during the summer months.

Rice, the crop grown in rotation with soybeans on the greatest number of acres, is quite tolerant of low pH and sensitive to alkaline pH. When fields used for rice and soybean production must be limed, lime should be applied following the rice crop, and uniform application of lime is critical. In the rice-soybean rotation, growers may want to apply lower rates of lime more frequently to avoid the likelihood of over-liming and inducing Zn and P deficiencies in the rice crop.

When lime is needed, it is best applied in the fall following rice harvest, but benefits can still be realized when lime must be applied shortly before planting. Mechanically incorporating the lime (e.g., before soybeans are planted) will help distribute lime particles in the topsoil. When the soil has adequate moisture, the fine lime particles in agricultural lime will begin reacting to neutralize soil acidity immediately, and the maximum pH increase may be attained within one to six months, depending on the lime source. Based on 715 lime samples evaluated by the Arkansas State Plant Board between 2006 and 2009, the typical agricultural lime in Arkansas has a calcium carbonate equivalent (CCE) of 91.5% (4.1% standard deviation), an average fineness factor of 59.5 (9.5% standard deviation) and an overall lime quality score, referred to as Effective Calcium Carbonate Equivalent (ECCE), of 54%.

Pelletized lime is commonly sold in Arkansas because it is easy to handle and spread. Pelletized lime is usually composed of a binding agent and fine lime particles (<100 mesh) that may be calcitic (Ca based) or dolomitic (contains Ca and Mg). Unfortunately, pelletized lime is reportedly and inappropriately marketed as being four or five times more effective than agricultural lime (i.e., requiring only 200 to 500 lb/acre to provide the same soil pH adjustment as one ton of agricultural lime). Research suggests that the time required for pelletized lime to increase soil pH is similar to, but not faster than, agricultural lime when rates with equivalent ECCE are applied. The amount of pelletized lime needed to neutralize the same amount of acidity as agricultural lime can be calculated using the CCE and fineness factors of two lime sources (see Example 5-1). If pelletized lime is used, it should be applied to the soil surface and the pellets allowed to "weather" (or disintegrate following several rainfall events) before it is mechanically incorporated. Droughty conditions following lime application, regardless of the source, can delay lime reaction or the time required to neutralize acidity.

Example 5-1. Lime source comparison example (hypothetical data).

Lime Source	CCE†	Fineness Factor Information‡			ECCE§	Equal Rates¶
		10 mesh	60 mesh	Fineness Factor		
						- - - lb/acre - - -
Ag lime	90%	92%	38%	59.6	53.6	2,000
Pelletized lime	80%	100%	100%	100.0	80.0	1,340

†CCE, calcium carbonate equivalent.
‡The values in each column represent the percentage of material passing through a 10- and 60-mesh sieve. Fineness factor coefficients of 0, 0.4 and 1.0 multiplied by the percentage of lime having a diameter of >10-mesh (8%), <10-mesh and >60-mesh (54%), and <60-mesh (38%) were used to calculate the fineness factor for ag lime.
§ECCE, effective calcium carbonate equivalent, is the product of [fineness factor x (CCE/100)].
¶Equivalent rates, the amount of lime needed from each source to neutralize the same amount of acidity. Calculated by [((Ag lime ECCE/pelletized lime ECCE) × 2,000 lb ag lime/acre) = lb pelletized lime/acre]

Molybdenum

Molybdenum (Mo) is an essential micronutrient that is especially important for legumes and required by the bacteria (rhizobia) that form nodules on soybean roots and fix atmospheric N_2 gas into a form that can be used by the plant (biological N fixation). Unlike most other micronutrients, the availability of Mo increases as soil pH increases. Molybdenum deficiencies are most likely to occur on acidic soils. On low fertility, acidic soils, soybean yield response to recommended P and K fertilizer may be limited if Mo is not applied. With adequate Mo, recommended rates of P and K fertilizer have a greater chance of increasing soybean yields.

When lime cannot be applied to sandy or silt loam soils with pH values below 5.8, treating seed with Mo is recommended. Treating seed with Mo is a low-cost practice that may be beneficial whenever the pH is ≤7.0, if lime has been applied within the last year or in fields with a wide range of soil pH values. On some clayey soils with a pH below 5.8, responses to Mo have been nearly as good as response to lime alone or a lime and Mo combination. The application of Mo to soybean seed should not be used as a substitute for maintaining the soil at an optimal pH using a proper liming program. When needed, the application of 0.2 to 0.4 oz Mo/acre is recommended. These Mo sources can also be sprayed onto the soil if application to the soybean seed is not feasible. Some fungicide seed treatments used on soybean contain Mo.

A Mo deficiency will cause stunted soybeans with leaves that are pale green or yellow, giving the same appearance as nitrogen (N) deficiency (Fig. 5-2 and 5-3). Molybdenum-deficient plants will have few or no nodules on the root system. Determining the soil pH will help differentiate between the possibility of N deficiency caused by insufficient Mo or lack of the N-fixing rhizobia in the soil. Ammonium and sodium molybdate are water-soluble fertilizers that can be foliar applied in the case that a Mo deficiency is diagnosed.

Figure 5-2. Nitrogen deficiency – closeup of N-deficient soybeans.

Figure 5-3. Nitrogen deficiency – non-nodulating soybeans receiving no N surrounded by nodulating soybeans.

Nitrogen and Seed Inoculation With Rhizobia Bacteria

Soybean seed should be inoculated with the proper rhizobia on land where soybeans have not been grown in the previous three to five years or where previous soybean crops have had poor nodulation. Some states recommend that inoculant be added to seed that will be planted in fields that were previously flooded. Limited research in Arkansas reported no benefit from inoculation following two years of flood-irrigated rice production. There is no effective means of delivering inoculum to soybean roots after soybeans have been planted. Failure to apply the proper or viable inoculum to soybeans planted on soils that have not recently been used for soybean production (e.g., fields used for continuous cotton production) may result in N deficiency. If poor nodulation results in N deficiency, application of N may be warranted. If soybeans are determined to be N deficient due to lack of nodulation, application of a minimum of 40 to 60 lb N/acre can stimulate growth and increase yield. Additional N applications may be needed.

Nodules should be present on soybean root systems and fixing N by the V2 to V3 growth stage. In fields where proper nodulation occurs, neither soil- nor foliar-applied fertilizer N has increased soybean yields consistently or economically in hundreds of experiments conducted in Arkansas and other soybean-producing states. Therefore, applying N fertilizer to soybeans is not a recommended practice.

Phosphorus and Potassium

The current University of Arkansas phosphate (P_2O_5) and potash (K_2O) fertilizer recommendations for full-season and double-cropped soybeans are shown in Table 5-4. The recommendations are specific for the Mehlich-3 soil test and soil samples collected from a 4-inch depth. The use of results from different soil test methods or soil samples from different depths may influence the accuracy of the results. Field experiments show that soybean yield responses to K fertilization (Table 5-5) are larger and more frequent than yield responses to P fertilization (Table 5-6).

Table 5-4. University of Arkansas phosphorus and potassium fertilizer recommendations for full-season and double-cropped soybeans based on Mehlich-3 soil test P (as determined by ICAP) and K.

Nutrient	Soil Test Level	Soil Test Value	Production System	
			Full-Season Soybeans	Wheat and Double-Crop Soybeans†
		- - - ppm P - - -	- - - - - - - - lb P_2O_5/acre - - - - - - - -	
Phosphorus	Very Low	≤15	80	120
	Low	16 – 25	60	90
	Medium	26 – 35	40	50
	Optimum	36 – 50	0	0
	Above Optimum	≥51	0	0
		- - - ppm K - - -	- - - - - - - - lb K_2O/acre - - - - - - - -	
Potassium	Very Low	≤60	160	180
	Low	61 – 90	120	120
	Medium	91 – 130	60	80
	Optimum	131 – 175	50	60
	Above Optimum	≥176	0	0

†Double-crop soybean P and K fertilizer recommendations include the recommendations for winter wheat. The cumulative fertilizer rate can be applied in the fall.

Table 5-5. Summary of trials conducted between 2004 and 2008 describing soybean yield response to K fertilization by soil test level.

Potassium Level	Range	Sites Tested		Average Yield (Unresponsive Sites)		Average Yield (Responsive Sites)			
		Total	Responsive	No K	Fertilized	No K	Fertilized	Loss	
	ppm K†	#	% of total	- - - - - - - - - - - - bushels/acre - - - - - - - - - - - -					%
Very Low	≤60	4	100%	--‡	--	29	46	17	37
Low	61 – 90	13	92%	55	64	44	60	16	27
Medium	91 – 130	22	41%	51	55	51	59	8	14
Optimum	131 – 175	6	0%	62	64	--	--	--	--
Above Optimum	≥175	2	0%	48	51	--	--	--	--

†Soil test units are listed as parts per million (ppm or mg/kg) and may be converted to pounds per acre by multiplying the ppm value by 2 (ppm × 2 = lb/acre) assuming an acre furrow slice of soil weighs 2 million pounds.
‡Cells with no values had no observations (responsive or unresponsive sites) in this soil test level.

Table 5-6. Summary of trials conducted between 2004 and 2012 describing soybean yield response to P fertilization by soil test level.

Phosphorus Level	Range	Sites Tested		Average Yield (Unresponsive Sites)		Average Yield (Responsive Sites)			
		Total	Responsive	No P	Fertilized	No P	Fertilized	Loss	
	ppm P†	#	% of total	- - - - - - - - - - - - bushels/acre - - - - - - - - - - - -					%
Very Low	≤15	18	56	60	63	52	59	7	12
Low	16 – 25	14	21	63	65	53	61	8	13
Medium	26 – 35	11	0	54	55	--‡	--	--	--
Optimum	36 – 50	4	25§	60	62	54	62	8	13
Above Optimum	≥51	3	0	49	49	--	--	--	--

†Soil test units are listed as parts per million (ppm or mg/kg) and may be converted to pounds per acre by multiplying the ppm value by 2 (ppm × 2 = lb/acre) assuming an acre furrow slice of soil weighs 2 million pounds.
‡Cells with no values had no observations (responsive sites) in this soil test level.
§The one trial that responded to phosphorus fertilization had a mean soil test P of 39 ppm, but the soil test P within the research area was highly variable. Positive responses to phosphorus fertilization on soils with an Optimum soil test P level are not likely.

Soil test K tends to be a more accurate predictor of soybean response to K fertilization than soil test P is for predicting yield response to P fertilization. The recommendations for K fertilization fit the soil test level definitions and exhibit the concept of soil testing very well. The concept of soil testing is that plant growth or yield increases to fertilization are highly probable when soil nutrient availability is very low or low, improbable when soil nutrient availability is optimum or above optimum and somewhat unpredictable in the middle. By definition, the Medium soil test level, as interpreted in the University of Arkansas recommendations, is the soil test level of uncertainty regarding the potential yield benefit from fertilization. The soil test K recommendations for soybeans fit these soil test level definitions quite well (Table 5-5), whereas soil test P recommendations do not follow these concepts as closely (Table 5-6). Nominal K fertilizer rates are recommended for soils with nutrient availability indices in the Medium level (Table 5-4) for numerous reasons, including yield increases may occur less than 50% of the time, actual soil test values within a field or grid are variable, fertilization aids in maintaining the Medium level and soils with values in the lower range of the Medium level tend to be more responsive than when soil test values are in the upper half of the level, especially values near the lower boundary (e.g., 91 to 100 ppm). Yield potential may also be a factor influencing whether a yield increase results from fertilization on soils having Medium nutrient levels. Growers should note that a nominal rate of K fertilizer is recommended for soils having an Optimum soil test K level. This recommendation should simply be viewed as a grower option as no significant yield benefit is expected (during the year of application), but applying some potash will help maintain adequate soil K fertility for high-yielding soybeans in future years.

Potassium-depleted soils usually test Low or Very Low and receive recommendations for 120 or 160 lb K_2O/acre. The most common and economical K fertilizer is muriate of potash or potassium chloride (KCl). Muriate of potash (60% K_2O) is 52.5% K and 47.5% Cl. Application of 120 to 160 lb K_2O/acre also supplies about 95 to 125 lb Cl/acre. Although Cl toxicity is a concern in many poorly drained soils, the amount of Cl in these high K fertilizer rates alone will not likely cause Cl toxicity. Applying high rates of K fertilizer in the fall or early spring may allow rainfall to flush the Cl laterally (i.e., runoff) or vertically (i.e., leaching) from the field. Potassium sulfate (K_2SO_4, which is 50% K_2O) or potassium-magnesium sulfate (K_2SO_4 and $MgSO_4$, which is 22% K_2O, also sold as Sul-Po-Mag and K-Mag) are alternative K fertilizers that may be used in place of muriate of potash if chlorides are a significant concern. In most areas of Arkansas, K deficiency is more likely to be a greater yield-limiting factor for soybeans than Cl toxicity.

For variable rate fertilizer application, K fertilizer rates can be calculated using Equation 1. An equation for applying variable P fertilizer rates has not been developed, due in large part because soil test P has been a less reliable indicator of yield response than soil test K. For example, an area or grid with a Mehlich-3 soil test K of 75 ppm (150 lb/acre) would have a calculated fertilizer rate of 116 lb K_2O/acre [237 – (75 × 1.61) = 116.25].

Equation 1:

lb K_2O/acre = 237 – 1.61 x (where x = soil test with units in ppm)

Arkansas research shows that significant soybean yield increases to P fertilization may occur in the Low and Very Low soil test levels (Table 5-6). When soybean yields are increased by P fertilization, the yield increase tends to range from 10% to 15%. Results show that soil test P is highly accurate at predicting that soybean yields will not be increased by P fertilization on soils with Medium or greater soil test P levels. Phosphorus recommended for the Medium soil test level (Table 5-4) is not expected to increase soybean yields (Table 5-6) but serves to help maintain soil test P by replacing a portion of the P that will be removed by the harvested grain.

Triple superphosphate (46% P_2O_5) is the most commonly used P fertilizer in Arkansas and is appropriate for soybeans. Diammonium phosphate (18-46-0), monoammonium phosphate (11-52-0) and MicroEssentials® (10-40-0-10S-1Zn) are alternative P fertilizers sold in Arkansas that can be used for soybean fertilization, but their N content has not been shown to increase soybean yields compared to triple superphosphate. Purchase the P fertilizer that provides the recommended amount of P at the most economical price.

Poultry litter can be applied as a P and K source for soybeans. High-quality litter will contain 50 to 70 lb P_2O_5 and K_2O/moist ton, but because litter nutrient and moisture contents vary considerably, subsamples of litter should be analyzed for total nutrient content to determine its P and K fertilizer value. The P and K in poultry litter should be considered equivalent in availability as commercial fertilizer sources. Research on undisturbed soils (i.e., not recently precision graded) in Arkansas has shown no yield benefit from litter applied to soils with Optimum or Above Optimum soil nutrient availability, suggesting that poultry litter alone does not increase crop yield potential. However, on low-fertility soils, soybeans fertilized exclusively with poultry litter have produced equal to slightly higher yields than soybeans receiving equivalent rates of P_2O_5 and K_2O as commercial fertilizer. The most significant concern in using poultry litter or other animal manures as a fertilizer source is uniform distribution of nutrients.

The recommendations for double-cropped soybean should be used in conjunction with the recommendations for small grain (winter wheat or oats). The cumulative (small grain + double-crop soybean rate) fertilizer rate can be applied in the fall or split applied (Table 5-4).

Research has shown that fertilizer application rate rather than application time (e.g., fall vs. spring) is the most important factor influencing full-season and double-crop soybean response to fertilization. Although field research has shown no difference in soybean yields between fall and spring P and K fertilizer application, several factors should be considered in making this decision. As a general rule, a soil's capacity to rapidly fix P and K fertilizer into unavailable forms increases as soil test index value decreases. Therefore, to ensure maximum nutrient availability, spring fertilizer application may be best on soils with Very Low soil test levels. The exception to this rule may be in fields with a history of chloride toxicity problems, in which case K fertilizer might best be applied in the fall or late winter. Fall application of fertilizer on soils with Medium or Optimum soil test levels is appropriate since fertilization is largely intended to maintain soil nutrient levels by replacing nutrients removed in the harvested portion of the crop. Fall application of P and K fertilizer should also be avoided on sandy loam soils with very low cation exchange capacity, fields where erosion is a concern and fields where nutrient deficiencies have been previously observed. In fields that will be flooded for waterfowl habitat (or are located in a flood-prone area), fertilizer should always be applied as close to planting as possible as the alternating flooded (anaerobic)-nonflooded (aerobic) conditions can influence soil and fertilizer nutrient availability and loss.

The potential benefit of foliar feeding soybeans with liquid solutions containing N, P, K and other nutrients has been well researched in the United States. The University of Arkansas recommends that macronutrients like P and K be supplied to the soil preplant. Foliar feeding may be used at the grower's discretion as a supplement to an agronomically and economically sound soil fertilization program. Research has shown no consistent benefit from supplemental foliar feeding, especially on soils with sufficient fertility. Exclusive use of foliar feeding may eventually deplete soil nutrient levels, especially on low CEC soils, and lead to nutrient deficiencies and reduced crop yields. Numerous foliar applications of K fertilizer would be needed to supply enough K to produce maximum yields on K-deficient soils. On silt loam soils with Medium soil test K levels, crop yields may decline significantly within three or four years after a soil fertilization program is abandoned (Fig. 5-4).

Potassium is mobile within the plant, indicating that deficiency symptoms should first appear on the older (bottom) leaves as a chlorosis or yellowing along the leaf margin (Fig. 5-5 and 5-6). The amount of the leaf that is chlorotic increases as the duration and severity of K deficiency increases. Potassium deficiency symptoms are often present on leaves in the middle and top of the plant. Observations made in commercial fields and research trials indicate that K deficiency symptoms in the youngest leaves are common. Symptoms that appear in the early season may indicate very low soil K availability, problems involving uptake of soil K (e.g., drought) or both. Early-season symptoms are common when soils become very dry or in areas with significant soil compaction.

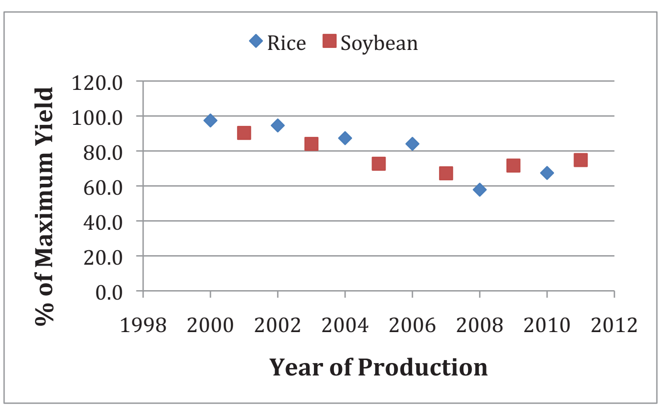


Figure 5-4. The percentage of the maximum yield (relative yield) produced by rice and soybeans that received no potassium fertilizer compared to rice and soybeans that received an annual application of potassium fertilizer. ***(Slaton, unpublished data)***

Figure 5-5. Potassium deficiency – early-season symptoms on double-cropped soybeans (note dry soil condition).

Figure 5-6. Potassium deficiency – advanced symptoms.

If K deficiencies occur prior to early seed development (before R5) or if K fertilizer was not applied, K fertilizer may still be applied and watered in with prompt irrigation or a timely rain. Significant yield increases can be achieved from mid- to late-season K fertilization. The trifoliolate leaf nutrient concentrations shown in Table 5-7 can be used as a guide to interpret soybean leaf analysis. Arkansas research shows that leaf K concentrations >1.80% at the

R1-R2 growth stage are sufficient for optimum yield, 1.50% to 1.80% can be considered low (probable deficiency) and <1.50% indicates K deficiency. These guidelines tend to work best on varieties with a determinate growth habit. The growth stage that soybeans are sampled is important because leaf K concentrations tend to decline as pod and seed development progresses beyond the R2 stage. Limited research suggests that trifoliate leaf K concentrations decline by 0.015% per day (or 0.10% per week) after the R2 growth stage. Additional information on sampling soybeans for leaf tissue analysis is given in a later section.

Phosphorus deficiency of soybeans occurs much less frequently than K deficiency. The deficiency symptoms exhibited by P-deficient soybean plants are usually subtle in that the plants have small leaves and an overall unthrifty appearance. In some instances, P-deficient plants may exhibit an interveinal reddening on the lower leaves (Fig. 5-7).

Figure 5-7. Phosphorus deficiency – stunted plant with reddish interveinal coloration of lower leaves. ***(Photo by Bryan Stobaugh)***

Phosphorus is mobile in the plant, and symptoms should be more severe on the lower leaves, but growth of the whole plant is usually affected. The most recently mature trifoliate leaves are considered P deficient when P concentrations are <0.25% at the R2 growth stage, but concentrations of 0.25% to 0.30% P should be considered low. Similar to K, leaf P concentrations decline quite rapidly following the R2 stage as P is translocated to the developing pods and seeds, making the growth stage at the time of sampling an important consideration for interpreting leaf P concentrations. There has been very little research regarding the management of P-deficient soybeans to indicate whether foliar or soil application of a P-containing fertilizer will produce a significant yield increase.

The average amount of nutrients removed by harvested soybean seed is shown in Table 5-8 on a per-bushel basis and for an average yield of 50 bu/acre. Soybean stalks are sometimes baled following harvest and also contain nutrients. On average, one ton of soybean stalks (following harvest) contains 4 to 5 lb P_2O_5 and 10 to 15 lb K_2O/ton. If pods (without the seed) and/or leaves remain on the stalks following harvest, the nutrient content of the soybean residue will be greater than the listed values. The nutrient content of soybean stover following grain harvest is dependent on a number of factors, including initial soil fertility levels, the amount of fertilizer applied and how soon after harvest the stover is baled. If the unharvested stover will be baled and sold, samples should be collected and submitted to a laboratory for nutrient analysis to determine its average nutrient content. This will allow the fertilizer value of the stover to be calculated.

Table 5-7. Suggested sufficiency ranges of nutrients in the most recently fully expanded trifoliolate leaves (top three or four nodes) of soybeans at the flowering stage (R1-R2). ***(Sabbe et al., 2000)***

Range	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	B
	- - - - - - - - - - - - - - - - - - - % - - - - - - - - - - - - - - - - - - -						- - - - - - - - - - - - - - - ppm - - - - - - - - - - - - - -				
Low†	3.25	0.25	1.50	0.80	0.25	0.25	25	17	21	4	20
High	5.00	0.60	2.30	1.40	0.70	0.60	300	200	80	30	60
†Values below the Low boundary are considered deficient.											

Table 5-8. Nutrient removal (grain content) for 50 bu/acre soybean yield. Values based on analysis of soybean seed from various research studies or grower fields in Arkansas from 2004-2011. ***(Slaton, unpublished data)***

Yield	N	P_2O_5	K_2O	Ca	Mg	S	Fe	Mn	Zn	Cu	B
	- lb nutrient/bushel (or 50 bushels) -										
1 bu/acre	3.6	0.79	1.19	0.18	0.13	0.20	--	--	--	--	--
50 bu/acre	178	39	60	9	7	10	0.23	0.12	0.13	0.03	0.07

Boron

Soybeans are generally not considered to be highly susceptible to boron (B) deficiency, but B deficiency of soybeans is widespread in northeast Arkansas, making it the most common micronutrient deficiency of soybeans in Arkansas. Boron deficiency was diagnosed in northeast Arkansas in the early 2000s on silt loam soils. Fields that are likely to show B deficiency have been irrigated long-term with groundwater high in calcium (Ca) and magnesium (Mg) bicarbonate, soil pH >7.0, silt and sandy loam texture and are located north of Interstate 40 to the Missouri line and west of Crowley's Ridge. Boron deficiency has also been observed after liming acidic silt loam soils in Prairie and Arkansas counties.

Symptoms of B deficiency may be evident shortly after emergence or in the late reproductive growth stages, but symptoms are most commonly observed during mid- to late-vegetative growth (e.g., V6 to early bloom) after the first irrigation (Figure 5-8 through 5-15). The symptoms of B deficiency may include leaf cupping, stunting (i.e., short internodes), swollen nodes, leaf malformation that may resemble phenoxy herbicide injury, leaf chlorosis and, when severe, death of the terminal growing point. In its later stages, B-deficient soybean plants are short, the leaves become thick and dark green, retain their leaves longer than soybeans with sufficient B nutrition, have few pods and maturity is delayed.

Figure 5-9. Boron deficiency – stunted plant with regrowth (branching) from lower node.

Figure 5-10. Boron deficiency – plant recovering from deficiency (note multiple branches from lower node).

Figure 5-8. Boron deficiency – leaf appearance after prolonged boron deficiency.

Figure 5-11. Boron deficiency – delayed maturity (leaf retention) as a result of boron deficiency.

Figure 5-12. Boron deficiency – normal growth from previous year's rice levees with deficient plants between.

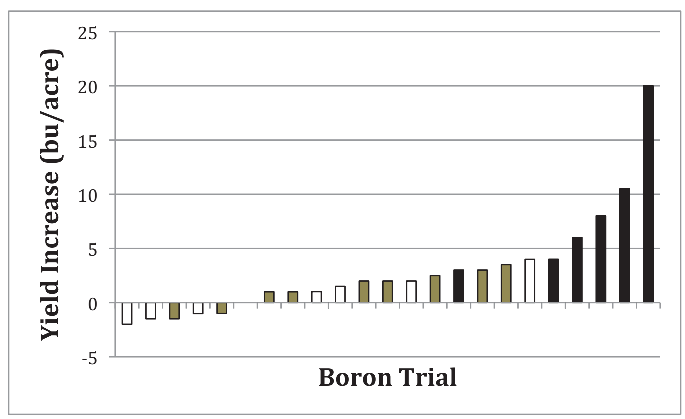
Figure 5-13. Boron deficiency – small soybean plant with dead growing point.

Figure 5-14. Boron deficiency – dead growing points after falling off plant.

Figure 5-15. Boron deficiency – healthy leaf (left) compared to leaf from boron-deficient plant (right).

Boron deficiency tends to be more widespread in years with below-normal rainfall (Fig. 5-16) and on shallow or compacted soils that restrict rooting depth.

Figure 5-16. Summary of soybean yield increase attributed to boron fertilization in 23 trials conducted on silt loam soils in Arkansas. [Sites with white bars had soil pH <7.0, and soybean yield was not expected to increase from boron fertilization. Sites with black bars had soil pH >7.0, and boron-fertilized soybeans produced greater yields than the no-boron control. All other sites (tan-colored bars) had pH >7.0, and soybean yield was not significantly (i.e., statistically) affected by boron fertilization.] *(DeLong et al., 2007)*



Toxicity is also a concern with boron. Boron toxicity symptoms initially appear as chlorotic leaf margins that develop into necrotic areas that make the leaf margins ragged (Figure 5-17). Very limited field experience with this problem in Arkansas suggests that only subtle symptoms are expressed on plants with B concentrations of 100 to 150 ppm B and the severity of symptoms increase when plants have greater leaf B concentrations. Boron toxicity is most likely to occur on soils with below optimal pH (<6.0) and moderate to high soil test B (Mehlich 3 > 2.5 ppm).

Figure 5-17. Boron toxicity – symptoms of boron toxicity on lower soybean leaves.

Identifying B-deficient soils from routine soil analysis has not been highly successful in Arkansas. Soil test (Mehlich 3) results commonly show soil test B values of <0.5 ppm (<1.0 lb/acre) and are not sensitive enough to differentiate between B-sufficient and B-deficient soils in eastern Arkansas. However, soil test results with high amounts of B may accurately indicate high availability from an accumulation of B.

Boron deficiency can usually be diagnosed using tissue analysis. During the growing season, the B nutritional status of soybeans can be evaluated by collecting 10 to 20 fully expanded (e.g., mature) trifoliolate leaves (no petiole) from the top three or four nodes. If a deficiency is suspected, samples from plants with and without visual symptoms should be collected and submitted to an analytical lab for analysis. Trifoliolate leaf B concentrations <20 ppm indicate probable B deficiency, and concentrations <10 ppm indicate definite B deficiency. Experience and research suggest that these leaf analysis guidelines are accurate for soybeans at the R1 to R2 growth stage but may not accurately reflect the B status of small soybean plants with a poorly developed root system. Soybean seed can also be used as an indicator of B deficiency. Soybean seed B concentrations <5 ppm indicate severe B deficiency, and B concentrations of 6 to 10 ppm suggest B deficiency is probable.

Prevention of B deficiency is the recommended fertilization strategy in the geographic area (NE Arkansas) where it is commonly observed, because severe B deficiency can cause near complete yield loss and B application following the expression of symptoms does not always result in a positive growth response. Granular B fertilizer (1 lb B/acre) may be blended with P and K granular fertilizers and applied preplant. Most granular B fertilizers marketed in Arkansas contain 15% B, and 6.7 lb of fertilizer is needed to supply 1 lb of elemental B per acre. While this method of application is typically effective, B deficiency may occur when dry conditions persist following fertilizer application. Application of granular B weeks in advance of planting and mechanically incorporating the fertilizer are recommended practices. The alternative to granular fertilizer is to apply 0.2 to 0.5 lb B/acre as a solution usually tank-mixed with pre- or post-emergence herbicides. The higher rate (0.5 lb B) should be used pre-emergence and the lower rate used post-emergence. Post-emergence or foliar-applied B may cause some leaf burn, which is cosmetic. The amount of leaf injury is affected by the product applied (in addition to tank mix components), environmental or climatic factors and B rate – minimal leaf injury usually occurs when B rates are <0.25 lb B/acre. Ten years of field observations suggest that B should be applied each year that soybeans are grown in the rotation. Growers are cautioned that B toxicity is also a potential problem. Application of B fertilizer on acidic soils may result in elevated plant uptake of B.

Sulfur

Research in Arkansas has not shown a significant soybean yield response to sulfur (S) addition. On deep sandy soils, 10 to 20 lb of sulfate (sulfur) per acre may be beneficial. Deficiencies may show up initially as pale green to yellow leaves in the top of the plant. As deficiency progresses, the entire plant may turn green to yellow. Prolonged S deficiency results in plant symptoms similar to prolonged N deficiency.

Magnesium

Most of the soils used for soybean production in eastern Arkansas contain adequate magnesium (Mg) because Mg is present in groundwater used for crop irrigation. Fields irrigated from surface water sources that are sandy and/or highly weathered soils located in northwest Arkansas may contain low Mg concentrations that require attention. If soil tests indicate exchangeable Mg levels below 35 to 40 ppm (70 to 80 lb/acre), providing Mg from resources such as sulfate of potash magnesia (Sul-Po-Mag or K-Mag), magnesium sulfate (epsom salts) or dolomitic limestone, when lime is recommended to correct low soil pH, may be beneficial. Poultry litter usually contains about 0.50% to 0.70% Mg (10-14 lb Mg/ton).

Manganese, Copper, Iron and Zinc

Copper (Cu), iron (Fe) and zinc (Zn) deficiency have not been diagnosed or recognized as nutrients limiting soybean yields in Arkansas. Ensuring that the soil Zn level is optimal for corn and rice that may be grown in the rotation sequence will ensure adequate Zn is available for soybeans.

Limited soybean growth/yield response to Mn fertilization has been reported on some eastern Arkansas silty clay soils where soil-test Mn levels were below 10 ppm (20 lb/acre). Trifoliolate leaf Mn concentrations less than 20 ppm are considered deficient and have reliably confirmed foliar symptoms. The most common Mn deficiency symptom is an interveinal chlorosis of the uppermost leaves while the leaf veins remain green (Figure 5-18). Localized Mn-deficient areas in soybean fields will often have a yellow cast that is visible from a distance (e.g., edge of field, Figure 5-19). In states where Mn deficiency of soybean is a consistent problem, the standard recommendation is to apply 0.25 to 0.5 lb Mn/acre to soybean foliage. Manganese fertilizer should not be tank-mixed with glyphosate as the efficacy of the glyphosate may be substantially reduced. The amount of antagonism that occurs in a tank-mixture of Mn fertilizer and glyphosate varies among Mn fertilizers, but as a general rule, fertilizers containing Mn-EDTA are least antagonistic. When Mn is actually deficient, 0.2 to 0.5 lb Mn/acre should be applied 7 to 10 days after the glyphosate.

Figure 5-18. Manganese deficiency – interveinal chlorosis.

Figure 5-19. Manganese deficiency – hot spot (chlorotic area) in middle of field.

Glyphosate-resistant soybean varieties (following treatment with glyphosate) may be more sensitive to Mn and possibly other micronutrient deficiencies than conventional soybean varieties. Glyphosate is capable of forming complexes (e.g., chelating) with Mn and other metal cations in the plant and soil, which can temporarily reduce nutrient availability. The Mn deficiency problems with glyphosate-resistant soybeans are most pronounced in areas where Mn deficiency was also a problem with conventional soybean varieties. While this topic is actively being researched, there are no glyphosate-resistant variety-specific nutrient management recommendations. In Arkansas, symptoms similar to Mn deficiency are sometimes observed in young soybeans following a glyphosate application (a.k.a., glyphosate flash). The glyphosate flash symptoms look very similar to Mn deficiency with symptoms including interveinal chlorosis (veins remain green) of the young or upper leaves. The "yellow flash" has been attributed to either Mn deficiency or the accumulation of a degradation product of glyphosate. In Arkansas, a limited number of tissue analyses of young plants exhibiting the "yellow flash" show tissue Mn concentrations are usually more than adequate. The yellow-flash symptoms tend to be most pronounced and prolonged when less-than-optimal growing conditions exist (e.g., hot, dry weather). Although these soybean fields can look very unthrifty, observations in grower fields and limited research suggest that foliar application of Mn and/or Fe fertilizers have little or no effect on improving the physical appearance, growth or yield of soybeans. The symptoms are usually alleviated when soil moisture availability improves from a timely rain or irrigation. Unless plant tissue analyses indicate deficiencies of these nutrients (Table 5-7), foliar application of nutrients is likely an unnecessary expense and is not recommended.

Poultry Litter on Leveled and Salt-Affected Soils

Response of soybeans to poultry litter on soils that have been recently cut or leveled to facilitate irrigation has been similar to responses by rice. The use of poultry litter to supply recommended rates of P and K on recently leveled soils is recommended. Rates of fresh or pelleted litter, ranging from 1,000 to 2,000 lb/per acre, may help restore soil productivity and increase crop yields. Repeated applications of litter for several years may be necessary to fully restore soil productivity. Research on the interaction between phosphate and potash fertilizer and poultry litter rate indicates that the response from litter is not entirely from the litter's fertilizer value as some other factors are also involved (e.g., microbial). Many growers continue to apply recommended rates of commercial fertilizer on leveled fields that are treated with poultry litter to help rebuild soil fertility. Subsoils with low soil pH or that are high in sodium (Na) may be exposed in fields with deep cuts (>6-8 inches) and may benefit from lime. When time allows, collecting soil samples by zones based on cut and fill areas or crop growth may be helpful in making decisions involving the need for lime, commercial fertilizer and/or poultry litter. The cause for poor crop growth, especially soybean, in many deep cuts is due to a combination of factors that may include soil physical properties (e.g., compaction/restricted rooting depth) and fertility-related maladies (salt injury or P and micronutrient deficiencies). Following land leveling, rice rather than soybeans is most often grown because the continuous flood irrigation eliminates the added effect of periodic water-stress (for soybeans) and its interaction with nutrient stress. Rice is much less sensitive to soil acidity than soybeans and produces more biomass than soybeans to help build soil organic matter.

Chloride Toxicity

Significant amounts of chloride (Cl) can be delivered in the irrigation water and/or exist in the rooting zone of poorly drained soils. Soybean plants may show leaf scorching symptoms, and yields may be reduced by chloride toxicity. At present, the most practical way to reduce problems from Cl toxicity is to select a "chloride-excluding" variety. Chloride-excluding varieties do not readily translocate Cl from plant roots to the shoots. Information regarding soybean variety classification as either a Cl "includer" or "excluder" is available in University of Arkansas variety performance summaries and from literature provided by many seed companies.

Chloride toxicity may occur in localized field areas or be present across most of a field's acreage. Hot spots may occur in plants located in (1) "potholes or low spots" where water pools and salts become more concentrated as the water evaporates, (2) points where subsurface, lateral water flow emerges at the soil surface and deposits salt and/or (3) plants located in the center of beds. Use of poor-quality irrigation water that contains excessive chloride (>70 to 100 ppm Cl or 2 to 3 mmol or meq/L) coupled with poor soil drainage may cause field-wide problems. Application of 10 acre-inches of irrigation water (per acre) that contains 3 mmol or meq Cl/L during a growing season results in the deposition of 240 lb Cl/acre/season.

Plants affected by Cl toxicity will have leaves that appear scorched along the edges, and the scorching will generally be worse on the lower leaves of large plants or relatively uniform on small soybeans (Figures 20-25). The petioles will eventually detach from the stem of chloride-affected plants, but once this occurs the plants are usually dead. To our knowledge there are no published leaf concentrations for diagnosing Cl toxicity of soybeans. Analysis of tissue from soybean plants (usually includer varieties) suffering from Cl toxicity indicate Cl concentrations range from 20,000 to 40,000 ppm Cl (2.0% to 4.0% Cl) in the lower leaves and >10,000 ppm (>1.0% Cl) in the most recently matured trifoliolate leaves. Chloride concentrations in recently matured trifoliate soybean leaves at the R2 stage ranging from 2,000 to 4,000 ppm have been measured in plants showing no symptoms of Cl injury and are therefore considered normal until more specific information becomes available. If soil tests show the need for K, muriate of potash (which is potassium chloride) or another suitable K source may still need to be applied to provide adequate K nutrition.

Diagnostic Sampling

Plant tissue analysis is a valuable tool for diagnosing plant nutritional problems. For best results, collect the most recently matured trifoliolate leaves (no petiole) from one of the top three or four nodes of 15 to 20 plants. For plants in early vegetative growth, collecting the whole aboveground plant may be warranted. Samples should be placed in labeled paper bags and shipped to an appropriate laboratory. Plant and soil samples taken for diagnostic purposes should include separate samples from the "normal or healthy" and "abnormal or problem" areas of the field. Plants that are severely stunted and have been nutrient deficient for a long period are not always the most informative samples. The plants that

Figure 5-20. Chloride Injury – damage in low area.

Figure 5-21. Chloride injury – scorching on margin of older leaves.

Figure 5-22. Chloride injury – dead soybean plant with detached petiole.

Figure 5-23. Chloride injury – Poor stand caused by chloride injury.

Figure 5-24. Chloride injury – mottled and scorched leaves.

Figure 5-25. Chloride injury – middle rows of soybeans planted on beds suffering from Cl toxicity.

look healthy sometimes provide a better assessment of plant nutrition problems as they may be suffering from hidden hunger. When possible, a third sample of plants showing slight or intermediate symptoms should be sampled too. This sampling procedure allows for an in-field comparison plus comparison to published nutrient levels. If the leaves or whole plants are dirty/dusty, they should be rinsed briefly, albeit thoroughly, in clean water while the leaves are still fresh.

The sufficient ranges of nutrient levels at bloom (R1-R2) for soybeans are shown in Table 5-7. Even though a nutrient level drops below the desirable range, this does not necessarily imply a need for that plant nutrient. Other factors such as drought, nematodes, herbicide damage, diseases and insect damage may be the problem or contribute to the problem. Follow a thorough diagnostic procedure that includes soil, plant and irrigation water analyses, along with detailed observations of field conditions and history, crop management practices, crops in adjacent fields, and plant root and shoot observations (nodules, plant growth stage, leaf color, etc.) for accurate diagnosis of plant nutrition problems.

Tissue analyses during the early vegetative growth or late reproductive stages, while helpful, do not have good predictive values for assessing nutrient limitations. As much as 60% or more of a soybean's total nutrient uptake occurs after bloom (R2). The desired nutrient levels (Table 5-7) may be used before bloom but only as a general reference to detect gross nutrient imbalances. It should also be recognized that not all of the sufficiency levels listed in Table 5-7 were developed from research and may represent the outer limits of leaf concentrations from a survey. Consulting someone with extensive experience in interpreting soybean leaf analysis is encouraged. More specific information for interpreting leaf nutrient concentrations is often included in the chapter sections covering specific nutrients.

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Chapter 6

Drainage and Tillage

by G. Huitink and P. Tacker

Drainage and tillage take aim on a target to provide a season-long root zone that will produce outstanding soybean yields. Weather, good and bad, has a major influence on how near one gets to the bull's-eye – **maximum yield**. There are a number of fields that have unique drainage and tillage needs which require creative solutions beyond the limited comments below.

Proper tillage choices (including no-till planting) can enhance rapid, extensive root growth and improve water infiltration. This reduces oxygen depletion in flat Delta soils after rains and can expand the moisture reservoir in droughty upland soils. In a productive soil, soybean roots expand and the taproot extends deep enough to access nutrients for maximum yield. Effective tillage practices complement seeding to obtain vigorous, properly spaced seedlings. Effective tillage also provides the soybean roots the best environment to reach moisture and plant nutrients at critical stages in plant development.

Adequate drainage is essential to soybean production whether dryland or irrigated. Poor drainage hampers field operations from field preparation through harvest and limits the effectiveness of irrigation. Eliminating poorly drained areas preserves natural soil productivity by reducing field rutting that requires additional tillage operations to correct. Poorly drained areas reduce yields and often require the most tillage. Water infiltration is also reduced if a soil is tilled when it is too wet. Good field drainage complements all crop production practices.

Management Tip

Direct drainage improvement efforts toward having minimal standing water on a field 24 hours after a rainfall or an irrigation.

Improving Surface Drainage

Soybeans need good surface drainage. Field surface smoothing and forming can improve the surface drainage of a field and should be done whenever possible. Use land planes to smooth out the high spots and fill in the low areas so that the field has a more uniform slope toward a drainage outlet. Low areas that are larger than 100 feet across or that need more than 6 inches of fill require more soil moving and compaction than a plane provides. These areas should be overfilled and compacted with equipment tires before being planed.

Another option for improved drainage is to plant on raised rows or beds if this fits the production plans for a field. Raised rows are not common in soybean production but may be necessary on some fields that are not adequately drained using other efforts.

Drain furrows are commonly used to improve a field's surface drainage. Furrows are shallow and narrow and can be constructed with several different types of equipment. Concentrate the furrows on the low areas in a field rather than putting them in randomly. Drain furrows should generally run with or at a slight angle to the natural slope of the field but not across the direction of the slope.

Make an effort to accurately determine a field's drainage flow pattern. Some limited surveying of field elevations can be very helpful in determining where to place a furrow to drain a low spot. Deciding where water will drain by simply looking at the field is not easy. The furrow should have continuous positive grade to assure that the water will be directed off the field. When surveying isn't possible, someone who knows the drainage flow pattern of the field should oversee the drain furrow installation. A drain furrow will not be successful unless the water can drain into it freely. If a berm remains on the

Figure 6.1. A PTO power ditcher is one tool that is used to construct drain furrows for improved surface drainage.

upgrade side of the furrow drain after it is constructed, water movement into the furrow will be restricted. If the berm is unavoidable, then it should always remain on the downgrade side of the furrow. Furrow or ditching equipment that spreads the soil evenly on both sides of the furrow helps avoid this problem. A drain furrow is not complete until it is connected to a ditch or pipe that carries excess water away from a field.

Precision grading of a field provides a positive method of improving surface drainage. It is limited to fields with relatively flat (less than 1 percent) slopes, or the cost can be prohibitive. If a field is being considered for precision grading, the soil should be evaluated to determine what problems might occur if deep cuts are made in some areas. These cut areas may expose soil with reduced production capability. County soil survey reports, published by the Natural Resources Conservation Service (formerly SCS), can help identify soils with unproductive subsoils. Poultry litter application may improve the productivity of cut soils. An Extension publication, Soil and Fertilizer Information Article 2-90, *Poultry Litter as an Amendment for Precision Graded Soils*, reports on results of litter applications.

The finished slopes of graded fields should range from 0.1 to 0.5 percent (0.1 to 0.5 ft. per 100 ft.) if possible. This range provides good surface drainage without increasing erosion potential. Grading for slopes of less than 0.1 percent should be limited and restricted to smaller fields with slope lengths of a quarter mile or less. These flatter slopes are more difficult to construct with precision, and they tend to develop more low areas and reverse grades. An elevation survey of the field is required before any design work can be done. Survey information can be entered into a computer program that evaluates possible drainage options for a field and determines the required dirt work. Most dirt-moving contractors offer the computer program design, and it is also available through Natural Resources Conservation Service offices. Precision grading is usually expensive and is a long-term investment for increasing the production potential and market value of the land.

An important component of field drainage is the ditch system that receives the excess water and carries it away from the field. Flow restrictions in these ditches can cause excess water to remain on a field. Maintain drainage ditches and routinely clean them out to effectively handle the drainage water from a field. Ditch outlets and drainage structures should also be routinely checked to assure that they are functioning properly and are not becoming restricted. Beavers often cause problems by damming ditches, culverts and drainage pipes. A Beaver Pond Leveler pipe has potential to reduce these problems in certain situations. This device is described in Extension publication FSA 9068, *Flood Water Management With a Beaver Pond Leveler.*

Drainage problems related to ditches may involve other property owners. It may be necessary to work with neighboring farms to correct common drainage problems. Planned drainage improvements could impact areas that may be classified as wetlands. If this is a possibility, contact the local Natural Resources Conservation Service. Their staff can visit the site and determine if there are drainage restrictions related to wetlands preservation laws.

Management Tip

Include both short- and long-term goals for improving drainage in every farm improvement plan.

Improving Internal Drainage

Most Arkansas soils have limited or restricted internal drainage. Internal drainage may be improved on a short-term basis when soybeans are rotated with crops such as corn or grain sorghum. The rooting pattern and root residue of these grass crops improve the soil's internal structure and the movement of water through the soil. Soybeans grown behind rice often produce higher yields, partially due to crop residue that improves infiltration and water-holding capacity of the soil. Some clean-tilled silty soils tend to seal over or crust after rainfall or irrigation. This restricts the infiltration and the internal drainage of the soil. Maintaining some crop residue on the soil surface reduces surface sealing so that the water can move into the soil profile more freely.

Naturally occurring restrictive soil layers and those formed by tillage equipment restrict internal drainage. This is desirable when growing rice, but restrictive layers reduce the root and water reservoir available for soybeans. The shattering of these layers prior to planting a soybean crop can improve both internal drainage and plant root extension.

Compaction

Subsoiling increases non-irrigated soybean yields in some droughty, shallow soils. Dig up several complete root systems to evaluate taproot length and branching. Use a soil probe, shovel or backhoe to determine whether tight soils are limiting moisture infiltration or root penetration and to check the depth and thickness of any compacted zone. Limited research available indicates that only loamy sands have consistently produced greater yields from subsoiling. Subsoil other soils only when they have a compacted zone and are dry enough to shatter. Wetter, silty and clayey soils are not consistently responsive to subsoiling. Fall subsoiling assures time to store winter rains and allows some natural crumbling of the large soil aggregates. Subsoiled fields may remain soft longer in the spring, delaying early field operations, because the soil strength is inadequate to support traffic.

The most effective subsoiling depth is just below the bottom of the restrictive layer. If the restrictive layer begins at 8 inches and is only 2 to 3 inches thick, then the tillage shank must penetrate to 10 to 12 inches deep. The key is that the deep tillage implement extends just below the restrictive layer so that the layer is effectively lifted and shattered. Surface tillage, especially disking, reforms restrictive layers very quickly and should be avoided, if possible, or at least limited.

Use practical techniques to reduce soil recompaction before seeding. Maintain the shattered soil zone as an additional moisture reservoir to promote rooting into a greater soil volume. Recompaction from tractor tires in the immediate vicinity of the taproot is typically less likely after soybeans emerge. Larger diameter tires, minimum tire inflations and reduced axle loads are several of the best options to limit tire forces that may affect soil to depths of 20 to 24 inches.

Disks and highly inflated tires compress soil in the upper 10 inches. Heavy cutting disks may apply more than 200 pounds of force downward onto the soil below each blade. This, together with fine clay particles that sift down to the tilled depth in sandy soil, tends to form a hard layer that retards moisture infiltration. Axle loads greater than 7 tons exert forces with long-term soil effects below a foot that typically reduce the soil voids available for air, water and root growth. Subsoil no deeper than the compacted zone to avoid extra power and fuel consumption that increases the cost of subsoiling. "In-row" subsoilers that penetrate through the "hardpan" are more effective than random subsoiling paths due to recompaction from subsequent trips. High-residue subsoilers or ripper-hippers are suggested for maintaining the same row location year after year.

Management Tip

To profit, subsoiling must provide a yield increase ranging from 2 to 3 bushels per acre.

Figure 6.2. Less surface soil disturbance occurs when a high-residue subsoiler is used. This type of subsoiler can be used in no-tillage fields and requires less subsequent tillage in other production systems to adequately prepare the field for seeding.

Tillage Principles

Appropriate tillage to aid infiltration and to reduce the effect of too little or too much rain often contributes to increased soybean yield. Emphasis should focus on tilling the soil properly to promote adequate root expansion as much or more than on weed control. Regardless of the tillage system used, the goal is to obtain the most profitable production and best root environment. Tillage generally accelerates organic residue deterioration, destroys soil structure and leaves it vulnerable to soil erosion. The forces of tractor tires and disks downward into the soil may cause compaction that is worse at higher soil moisture contents. Greater tractor axle loads transfer force deeper into the soil and cause compaction below 6 inches in the soil that persists longer. If less tillage is profitable compared to clean-tilled (conventional) systems, long-term soil improvements are beneficial to both the farm manager and the landowner.

Some reasons for tillage are to:

- Provide loose soil for soybean seeding and root growth.
- Aid drainage, infiltration or retard evaporation from the soil.
- Shape the soil surface and/or reduce the soil aggregate size to provide better soil aeration, soil-seed contact and moisture for germination and root growth. Soybean seeds need water equal to 50 percent of their weight to activate enzymes for germination.
- Mix herbicide uniformly and/or destroy weeds to limit competition for nutrients.
- Warm and dry soil faster to help early-seeded soybeans.
- Suppress some diseases or insects by mixing plant residues into the soil.

Concern for a proper rootbed and soybean production cost are “juggled” by a grower to produce soybeans profitably.

Management Tip

If the field is not rutted, stale seedbed or no-till approaches may be profitable options.

No-Tillage

Good surface drainage and the proper use of herbicides and heavy-duty no-till seeding equipment are keys for consistent no-till success. Exercise care to get a uniform stand, and time herbicide applications to avoid no-tillage “messes.” Growers who accurately diagnose field weed species early and spray effectively make this option look simpler than it is. No-tillage fits situations where good weed control is possible for equal or less herbicide and application costs than the projected tillage cost. Some strengths of this option are:

- Heavy clays can be seeded without tillage that makes hard chunks of soil and without exposing soil surfaces that contribute to losing moisture needed for germination/emergence.
- Silt loams can be planted with greater assurance of obtaining a stand because the potential for soil crusting is substantially less with residue remaining on the surface.
- Rapid soybean emergence reduces the risk of partial germination and “skippy” soybean stands due to moisture leaving the topsoil from mixed or sandy soil.

- Soybeans double-cropped with wheat can be seeded in the same field during harvest completion, providing more timely planting and potentially greater yield than other options.

- Less soil is lost from the field due to erosion during intense rainfall.

Plant only when the soil is dry enough to close the furrow well and soil moisture is available for rapid seedling growth. Cut completely through surface residue to assure adequate soil contact with seed. Adjust seeding depth and covering devices to assure that seed is placed into moist soil. Refer to Extension publication FSA 1015, *Planting Reduced-Tillage Soybeans*. Although furrow irrigation is generally not feasible in no-till production, other irrigation methods are possible.

Figure 6.3. Aggressive closing wheels on a planter or soybean drill prevent soil cracking in the furrow before the soybeans sprout.

Soybeans Following Wheat

Timely planting is vital to minimize yield reductions that typically occur when soybeans are seeded after June 15. Research indicates that yield potential decreases at least one-half bushel each day for seeding after June 15. Row or drill spacings narrower than 30 inches are preferred.

The John Deere 750 is an excellent no-till drill for seeding soybeans in late June or July when a 15-inch or narrower row spacing is recommended. Since late-planted soybeans are especially vulnerable to drought stress in July and August, use tillage practices that conserve soil moisture to obtain a quicker stand.

Before seeding wheat in the fall, plan to provide excellent drainage for both crops – the wheat and the no-till soybeans following the wheat. Phosphorous and potash, and in some cases lime, (meeting both wheat and soybean requirements) are best applied in the fall. If the chaff discharged behind a combine is over an inch deep (typical with combine headers over 20 feet wide and wheat yields above 50 bushels per acre), use a chaff spreader attachment on the combine to eliminate most wheat residue problems. Plant directly into wheat stubble. Avoid burning wheat fields because even temporary additions of organic matter improve soil tilth and water-infiltration rates.

Untilled soils with sufficient moisture for emergence typically provide a seed environment that is equal to, or better than, one made with the best selection of tillage tools. Typically, herbicide incorporation leaves the top few inches of soil too loose for rapid seed development, especially on lighter-textured soils. The soil below the top 4 inches may suffer excessive compaction from tractor tires, disks, land planes and other implements.

Tillage is the best alternative for rutted fields or dry soil. If the field is too dry for reliable soybean germination, either wait for rain before seeding or irrigate (flush) the field. Growers with sprinkler irrigation have the option to seed or “dust in” soybeans 1/2 to 1 inch deep and water to promote emergence.

Reduced Tillage

Covering previous soybean, wheat or rice residue before seeding soybeans is not essential. Pulling a small land plane over the places where last season’s levees were may possibly help eliminate ridges or furrows. Good field drainage permits timely planting and aids seedling growth. Today’s modern no-till planters and certain drills cut through residue from a previous bumper crop. One seedbed criteria is a surface smooth enough for accurate seed placement. If an incorporated herbicide is needed, schedule planting soon after tillage for good soil-seed contact before soil moisture escapes. Planting quickly after soil preparation allows seeds to absorb soil moisture before it evaporates and avoids possible rain delays. Rains foster surface crusting and weed germination in newly tilled soils. Including some early-season soybeans (Group IVs) that can be planted in either April or early May could enable planting more fields immediately after seedbed preparation.

Limit seedbed preparation to a minimum number of tillage passes. Usually this is two or three passes (possibly a chisel or disk and a field cultivator or a combination finishing tool that may incorporate a herbicide). Few growers exceed four preplant tillage passes if rains don't interrupt seeding.

Management Tip

Produce optimum yields with as few tillage operations as necessary for profit and soil preservation.

Herbicide Incorporation

Two passes, the second at an angle to the first, provide excellent incorporation with a field cultivator operated 2 to 3 inches deep. The best soil mixing occurs when sweeps are used and the field cultivator is pulled at least 5 to 7 mph. Always operate the front row of shanks at least as deep or slightly deeper than the rear row. In lighter-textured soil, a drag harrow or board mounted behind the field cultivator improves herbicide distribution within 1 inch of the surface.

Figure 6.4. Herbicide effectiveness is enhanced by a thorough mixing to the depth recommended for the target weed species.

Combination incorporation implements provide the best herbicide uniformity with one pass. Implements such as a Triple K, with a spiral "basket," incorporate herbicides well into light- and medium-textured soils. Those implements with field cultivator teeth, a ground-driven reel and a drag harrow similar to a DoAll provide adequate one-pass incorporation. Newer conservation incorporation tools are equally effective at mixing herbicides.

Precautions for red rice and johnsongrass control:

- **For red rice control, use two passes of a conservation incorporator, DoAll, Triple K or similar implement.**
- **For rhizome johnsongrass control, the proper herbicide needs to be placed 4 inches deep. Consult the herbicide label to avoid excess soybean injury.**

Tandem disks invert the soil and mix herbicides deeper than the implements designed for incorporation. A single disk pass leaves soil areas with low herbicide concentrations where weeds can often survive. The second pass of a disk improves the uniformity of herbicide concentration. As far as herbicide uniformity is concerned, the direction or angle of the second pass relative to the first makes little difference. A disk is better for rhizome johnsongrass control than for other herbicide-mixing tasks.

Disks with 7-inch blade spacings provide the best herbicide uniformity; 9-inch spacings must operate deeper and, even so, incorporate poorly. Disks with 11-inch spacings tend to cause the greatest soil compaction below the operating depth and are unacceptable for incorporating herbicides.

Stale Seedbed

"Stale seedbed" refers to fields where the soil has consolidated since the last tillage (rainfall, freezing, thawing, etc.). This term describes fields where the last preplant tillage occurred at least a month prior to planting. The stale seedbed approach shifts preplant tillage from the spring rush immediately before planting to an "off-peak" time for labor. Completing tillage when soil tilth is excellent eliminates any further need for "freshening." Green vegetation must be eliminated by an early spring "burndown" herbicide (possibly two sprays).

On clay soil, soybean yields from stale seedbeds may exceed yields from fields that receive a full complement of spring tillage operations. Stale seedbed soybean production is successful on clay soil that often remains wet and forms clods when tilled. Several rains are necessary to mellow clods in the stale seedbed before planting. This approach works if all green vegetation is killed. When soil is mellow and plant residue is minimal, planting difficulties are rare. In other words, with ideal moisture and little residue, almost any well-maintained planter or drill can provide an excellent stand.

Stale seedbed has been successful on most soil types. Early soybean growth is vigorous because the soil moisture is frequently excellent just below the surface. Burndown herbicides may add $9 to $15 per acre cost, but the approach enables timely seeding. Thus, tillage during dry fall and early winter periods permits farming more soybean acres.

Growing Soybeans on Beds

Bedded soybeans may increase yields if surface water movement from the field is slow, especially for fields that are nearly flat. After intense rains, these soybeans don't stand in water as long, and the beds may also provide faster emergence because they are warmer.

The extra cost of planting systems using beds can be offset with an extra 2 to 3 bushels of soybeans per acre. Above-average yields often are essential, partly because many of these fields are so flat that they require annual land planing before bedding. Furrow irrigation complements this tillage option. Where an impervious pan is near the surface of prairie silt loams, irrigation is essential for obtaining yields necessary for long-term economic enterprise survival. Bedded rows can also be useful on shallow soils. Limiting tire compaction to specific middles is helpful; thus, properly spacing tracks and selecting equipment widths enhance the root environment below most of the "outboard" rows.

Beds can be formed on centers as narrow as 30 inches, but this row spacing may be too wide for maximum yields on certain soils if foliage doesn't lap the middles by the reproductive stage (R2). Middlebusters are an excellent way to form rows with less preliminary tillage. Corn stalks do not tend to snag on middlebusters, whereas preliminary tillage is almost always necessary after a corn crop before operating disk hippers. Clay soils may tend to "slab" more with middlebusters than with disk hippers.

Management Tip

Bedded rows may salvage soybeans, especially during intense, early-season rainfalls, if water stays on a field more than one day.

Managing Tillage

Developing an adequate seedbed is partly science and partly experience on many soils. Observing the seedbed condition is easy compared to judging what is appropriate tillage for the unseen soil. To achieve maximum yield, especially without irrigation, later-season root access to nutrition and moisture is critical. The effects of tillage on soil below the top 4 inches may persist a number of years. Mastering seedbed preparation is simple compared to improving the rooting zone.

The cost of conventional tillage practices for soybean production ranges from $20 to $35 per acre. Tillage operations on fields with high yield potential may provide profits that marginally productive fields won't. Poor soils in fields where the best yield potential ranges between 22 to 28 bushels per acre do not justify extra operations if nutritional or other limitations prevent significant yield boosts. For fields with projected yields below 28 bushels per acre, set goals of keeping preplant tillage costs below $15 per acre. A selection of estimated tillage costs is listed in Table 6.1 and additional estimates are available in Extension publication FSA 21, *Estimating Farm Machinery Costs*, available from your county Extension office.

Proper tillage supports long-term soil productivity while reducing tillage costs related to the current crop. An effective, inexpensive weed control program is another aspect that must be coordinated with the production system. Enhance soybean profits by producing more soybeans with less tillage. Select tillage and complementary operations that have the potential to increase soybean yields and offset the cost of extra inputs.

Table 6.1. Typical Costs of Tillage Operations When Implement Is Operated at Proper Depths, Speeds, Etc.

Operation	Estimated Cost Per Acre for One Pass
Bed conditioner	$2.00 - $3.25
Chisel plow	$4.00 - $6.00
Combination incorporator	$2.50 - $3.25
Cutting disk	$4.50 - $6.00
Disk bedder	$2.25 - $3.25
Field cultivator	$1.75 - $2.75
Land plane	$4.50 - $6.00
Light disking	$3.50 - $5.00
Rotary hoe	$1.50 - $2.00
Row cultivator	$3.50 - $5.00
Subsoiler	$7.00 - $14.00

Chapter 7

Planting Practices

by L. Ashlock, R. Klerk, G. Huitink, T. Keisling and E. Vories

Many different planting practices are used by Arkansas soybean producers to get acceptable stands of soybean plants depending on grower preference, available equipment, soil texture, cropping system and, to some extent, planting date. Acceptable and consistent stands can be obtained with both conventional and no-till row planters and drills. In recent years many farmers have gotten rather consistent, and fairly uniform, stands with broadcast seeders. Current University of Arkansas research is being directed toward improving stand establishment in clay soils using broadcast and drill plantings on beds. Additional work has begun to evaluate the potential of aerial seeding. This chapter deals with some of the more important grower considerations when planting the Arkansas soybean crop.

Figure 7.1. Stand of Arkansas soybeans.

Planting Depth

Planting depth has an important influence on the number of seedling plants that emerge to a stand. The optimum depth in most soils is 1 to 1.5 inches. In clay soils it is important to place the seed about 0.5 inch into the wet soil or muck. The soybean seed needs to absorb up to 50 percent moisture by weight to germinate, so it should be planted in moisture. If adequate moisture is not available, the seed may only absorb enough moisture to swell and begin, but not complete, germination. Deep planting increases the risk of the soil crusting from heavy rains before the seedlings emerge. Shallow planting is particularly desirable when planting in early April while the soil is very cool and/or the potential for significant rainfall is great.

To obtain a satisfactory stand, most planters and properly designed drills can accomplish the task of placing the seed into moisture while firming the soil around the seed. However, some planter modification may be necessary to accommodate large amounts of residue and/or hard, dry soil conditions (including no-till). Coulters are often used to slice through the residue. Weights may be added to exert enough downward pressure to force the seed opener through the hard soil to place seed into moisture.

Seed Quality

Obtaining soybean seed of acceptable quality for planting is highly recommended. This will help ensure establishing an optimum stand of vigorously growing seedlings. Seed with a standard germination test of 80 percent or better generally result in adequate stands during the April and May plantings. As plantings are delayed into June and especially into July, the vigor of the seed becomes more important if marginal soil moisture and elevated soil temperatures occur. Seed that has less than 80 percent germination late in the planting season may produce poor stands especially if there are significant adverse conditions at planting due to low seed vigor. Seed vigor, as measured by the Accelerated Aging (AA) test, may be below 50 percent in late June and July. Growers who plant bin-run seed should obtain both the Standard Germination and the Accelerated Aging tests of all potential seedlots to determine if the seed is even suitable for planting (**see Chapter 4**).

Management Tips

1. Generally, seed placement should be **at least** 0.5 inch into the moist soil zone but should not greatly exceed 2 inches below the soil surface.
2. Downward pressure (sometimes up to 500 pounds per seed opener) may be required to place seed into moisture in hard, dry soil conditions.
3. Soil temperature should be at least 55˚F. **(See Chapter 2.)**

Soil Temperature

Although optimum soil temperature for soybean germination is around 95˚F, soybean seed will germinate between 37˚F and 109˚F (**see Chapter 2**). Growers can expect rather uniform stand establishment after soil temperatures reach or exceed 50˚F. In Arkansas, this typically occurs during the month of April.

Variety Selection

As indicated in **Chapters 3** and **16**, proper variety selection is crucial for profitable soybean production, and many tools such as Extension's *Soybean Update* and the computerized variety selection program *SOYVA* are available to assist growers.

Management Tips

1. Seed Quality – As discussed in **Chapter 4**, seed should have 80 percent or better germination and preferably with vigor (Accelerated Aging test) within 15 percent of the Standard Germination test. Seedlots with less than 80 percent germination in April will likely have very poor vigor in July.
2. Growers who plan to use bin-run seed should obtain a Standard Germination and Accelerated Aging (AA) test to determine if the seed is suitable for planting.

Seed Treatments

There are instances when the use of a fungicidal seed treatment is essential to obtain acceptable and vigorous stands. These instances include April plantings (cool, wet soils), late plantings (especially no-till doublecrop) and in fields that have a history of seedling disease problems. Where there is increased concern for serious seedling disease problems, growers are urged to treat seed with a systemic fungicide such as Apron, Allegiance or Apron XL to minimize Pythium and seeding Phytophthora root rot problems. Growers are encouraged to use products such as Vitavax 200, Vitavax M or Maxim, etc., to enhance the control of Rhizoctonia organisms. A more thorough discussion of seedling diseases and related control measures is available in **Chapter 11**.

Figure 7.2. Soybean germination and emergence.

Seed Inoculation

Specific nitrogen (N)-fixing bacteria (Brady-rhizobia) form the round nodules commonly seen on soybean roots. These bacteria are not native to Arkansas soils and are introduced by inoculating the seed. The bacteria take gaseous N from the atmosphere and fix it into compounds required by the soybean plant. The amount of N fixed by the bacteria can exceed 300 pounds per acre during the growing season. These nodules exist in a symbiotic (mutually beneficial) relationship within the soybean root system, obtaining food sources from the root and, in turn, fixing the considerable amount of nitrogen for the plant. Active nodules will have a

Management Tips

1. Inoculate soybean seed when soybeans will be grown on land that has not been planted to soybeans within the past five years or where previously grown soybean plants did not have adequate nodulation.

2. A seed treatment of the micronutrient Molybdenum (Mo) at the rate of 0.2-0.4 oz/A should be applied in acid soil to enable the N-fixing bacteria to function properly.

pinkish color when sliced open. After the bacteria are well-established in the soil, adequate populations will generally survive (even in the absence of soybean plants) for three or more years. Additional information related to this topic is presented in **Chapter 5**.

Planting Date

Soybean plants from most commercial varieties are sensitive to the photoperiod, or length of daylight (more specifically the number of hours of darkness). Thus, soybean plants can be especially affected by the planting date since it impacts the number of days to flowering, the amount of time available for vegetative plant growth and plant development, which all are necessary for good yields. Planting beyond the optimum date will cause yields to be reduced. Planting too early or too late can reduce yields because of poor stands due to excessively cold or hot soil temperatures or because day lengths are too short. Short day length may result in plants flowering early and having reduced vegetative growth.

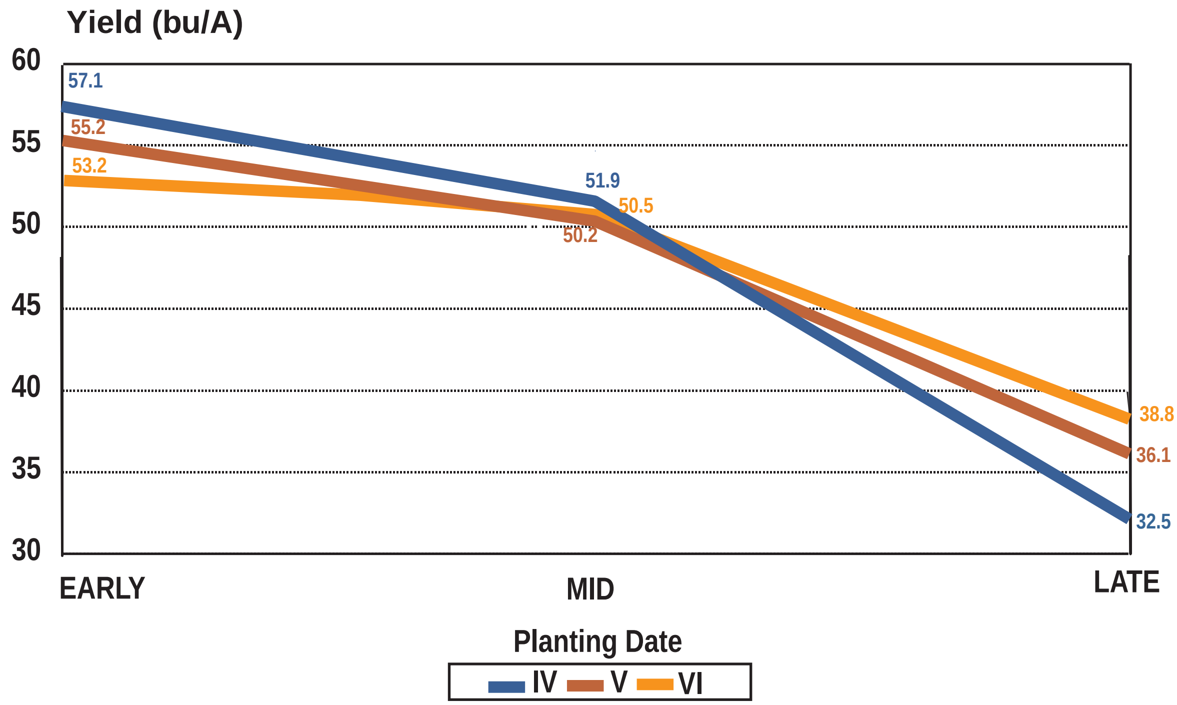
As described in **Chapter 2**, the response to day length determines whether a variety is early or late in maturity. The minimum number of hours of darkness required to induce flowering is the factor that separates the early from the late-maturing varieties. In the southern United States, most MG V and VI adapted varieties require at least 10 hours of darkness before flowering is initiated.

The standard recommendation for planting determinate varieties in Arkansas is between April 25 to June 30. Planting before this date as early as April 1 in southern and April 15 in northern Arkansas can be accomplished when planting the early maturing indeterminate MG IV varieties. Slow emergence and growth often occur with this early planting date, but the potential for an early harvest (August or early September) and the possible avoidance of summer drought during seed filling often result in improved grain yields (both irrigated and non-irrigated). This early planting of MG III and IV varieties is commonly referred to as the Early Soybean Production System (ESPS) and is further discussed in **Chapter 16**. For a more thorough discussion pertaining to determinate and indeterminate growth types, see **Chapter 2**.

Planting during the conventional time period (mid-May to early June) usually provides for rapid seed germination and emergence. Although plants will grow taller and are more apt to shade the middles sooner, maximum yields appear to occur at a slightly earlier planting date (Figure 7.3). These recent research findings indicate that varieties of different MGs react somewhat differently to planting date, with MG IV and V performing well in earlier plantings while MG VI varieties tend to perform better in the later planting dates. This apparent maturity group by planting date interaction has significant implications to the economic viability associated with the soybean production systems in Arkansas (**see Chapter 16**).

Earlier research findings suggest that planting after June 15 results in a 1 to 2 percent yield loss per day, with the yield loss potential increasing to 2 to 3 percent per day after July 1 under moisture-limiting conditions. Some of the yield loss associated with late planting can be minimized by changes in variety, variety growth habits, herbicide selection, increasing the plant population and decreasing the row spacing to 20 inches or less. Plantings after July 15 are not recommended due to a greatly shortened growing season although some late MG IV and MG V varieties usually have enough time to produce mature seed before a fall frost if emerged by August 1. Plant height and grain yields will be greatly reduced in the July plantings.

Figure 7.3. Effect of Planting Date on Irrigated Soybean Yield by Maturity Group, Pine Tree Experiment Station – 1995-98



Early – Comprises planting dates between April 25 and May 6.
Mid – Comprises planting dates between May 25 and June 5.
Late – Comprises planting dates between July 1 and July 10.

Seeding Rate and Plant Population

Soybean plant populations (number of plants per acre) can vary often without seriously impacting grain yield. Thick plant populations in ideal growing conditions may result in plants that are more subject to lodging, while thin plant stands may result in plants that set pods close to the ground making harvest more difficult.

Generally, it is not wise nor cost effective to greatly vary from the Extension-recommended seeding rates. The data in Table 7.1 were obtained from studies on Starks Farm in Miller County by Ashlock, et al., on a deep alluvial silt loam soil. This data indicated that under non-irrigated conditions there were relatively small differences in the soybean grain yield at seeding rates varying from 60,000 (approximately 30 lbs of seed/A) up to 240,000 plants/A (120 lbs of seed/A). However, more recent research on sharkey clay soil in Northeast Arkansas by Vories, et al., suggested that an increased seeding rate may be advisable in field environments that typically result in reduced plant development (canopy width and height). Although further work is needed in this area for other soils and environments, it appears the seeding rates listed in Tables 7.2 and 7.3 are sufficient for most fields. Optimum seeding rates should result in growers obtaining stands of recommended

Table 7.1. Effect of Plant Population on Soybean Yield (Bu/A), Averaged Over Four Varieties and Three Row Spacings, Starks Farm, 1994-96

Seeding Rate (#/A)	1994	1995	1996	Average
60,000 (30)	51.1	20.8	47.2	39.7
120,000 (60)	51.7	20.7	51.2	41.2
180,000 (90)	53.9	19.9	51.9	41.9
240,000 (120)	53.4	18.8	50.3	40.8
LSD (.05) =	2.6	1.2	3.3	

Table 7.2. Soybean Seeding Rate Recommendations for Indeterminate MG III and IV Varieties Anticipating a Final Plant Population of 130,000 Plants Per Acre[1]

Row Spacing	Recommended Seeding Rate (Seed Per Row Foot)	Desired Plants Per Row Foot	Row Width Factor[2]
36-38	12.8	9.2	14.13
28-30	10.0	7.2	18.02
25-27	9.0	6.5	20.10
22-24	7.9	5.7	22.73
19-21	6.9	5.0	26.14
16-18	5.8	4.2	30.75
13-15	4.8	3.5	37.34
10-12	3.8	2.7	47.52
7-9	2.8	2.0	65.34
Suggestions for Broadcast Plantings	**Planted Seed Per Square Foot**	**Desired Plants Per Square Foot**	**Square Foot Factor**
Broadcast[3]	5.0	3.0	43.56

[1]The assumption is made that the seedlot has germination of 80 percent and that 90 percent of the viable seed will survive.
[2]The "row width factor" is the length of row at the various row spacings or planting patterns required to represent 1,000th of an acre.
[3]An assumption is made that 60 percent of planted seed will emerge to a plant stand with broadcast seedings.

Table 7.3. Suggested Soybean Seeding Rates for Determinate Varieties of Maturity Groups V, VI and VII for Both Irrigated and Dryland (Non-Irrigated) Production Resulting in an Approximate Final Stand of 100,000 and 80,000 Plants Per Acre, Respectively[1]

Row Spacing	Recommended Seed Rate (Seed/Row Foot)		Desired Plants Per Row Foot		Row Width Factor[2]
	Irrigated 100,000	Dryland 80,000	Irrigated 100,000	Dryland 80,000	
37-39	10.1	8.1	7.3	5.8	13.75
34-36	9.3	7.4	6.7	5.4	14.93
31-33	8.5	6.8	6.1	4.9	16.34
28-30	7.7	6.2	5.5	4.4	18.02
25-27	6.9	5.5	5.0	4.0	20.10
22-24	6.1	4.9	4.4	3.5	22.73
19-21	5.3	4.3	3.8	3.1	26.14
16-18	4.5	3.6	3.3	2.6	30.75
13-15	3.7	3.0	2.7	2.1	37.31
10-12	2.9	2.3	2.1	1.7	47.52
7-9	2.1	1.7	1.5	1.2	65.34
Suggestions for Broadcast Plantings	**Planted Seed Per Square Foot**		**Desired Plants Per Square Foot**		**Square Foot Factor**
Broadcast[3]	3.8	3.1	2.3	1.8	43.56

[1]The assumption is made that the seedlot has germination of 80 percent and that 90 percent of the viable seed will survive.
[2]The "row width factor" is the length of row at the various row spacings or planting patterns required to represent 1,000th of an acre.
[3]For broadcast seeding only 60 percent of the planted seed are expected to germinate.

plant populations which do not significantly jeopardize yield, do not contribute to excessive lodging and result in the setting of the lower pods high enough on the plant to facilitate an efficient harvest.

Determining Actual Seeding Rate

Seed vary in size according to varieties and the year grown; therefore, the number of seed per row foot is a better guide for calibrating the planter than using pounds of seed per acre. Although there are numerous ways to calibrate a planter, one method is to determine the actual seeding rate by counting the number of seed in 10 feet of row and dividing by 10 to obtain an estimate of the average number of seed per row foot. (This should be done at least three or four times to obtain an average number of seed per row foot.) Planter units should also be checked for consistency when changing varieties or when the seedlot changes within a variety. Planting too many or too few seed per acre can be costly in terms of yield, lodging, seed cost and harvest efficiency. Travel speed and field roughness may also affect planting rate.

Determining Planting Seed Requirements

To find out the approximate amount of seed required to plant a specified acreage, a grower needs to determine:

1. The seeding rate in number of seed per row foot,
2. The row spacing,
3. The germination and seed size (the number of seed per pound), and
4. The acreage to be planted. Shown below in Equations 1 and 2 is a method that can be used to determine seed requirements using Tables 7.2 and 7.3.

Planter Row Spacing

Earlier Arkansas research conducted by Caviness, et al., with a determinate MG VI variety suggested a grain yield increase when row widths are reduced from wide rows (38 to 40 inches) to narrow rows (20 inches or less). Additional research

Equation 1

$$\frac{\text{Seeds Per Foot x Row Width Factor x 1,000}}{\text{Variety Seed Size}} = \text{Lbs of Seed/Acre by Variety}$$

Equation 2

$$\frac{\text{Lbs of Seed/Acre x No. of Acres Planted/Variety}}{\text{Lbs of Seed/Bag}} = \text{No. of Bags/Variety}$$

Example

A grower plans to plant and irrigate 100 acres of Hutcheson (with 3,400 seed per pound) on a 20-inch row spacing. The seed had 80 percent germination, so the recommended seeding rate is 5.3 seeds per row foot. Using Equations 1 and 2 and Tables 7.1 or 7.2, we calculate that approximately 82 bags are required to plant the 100-acre field:

Equation 1

$$\frac{5.3 \times 26.14 \times 1{,}000}{3{,}400} = \text{40.75 lbs/A of the variety with 80 percent germination and a seed size of 3,400 seed per pound}$$

Equation 2

$$\frac{\text{40.75 lbs/A x 100 A}}{\text{50 Lbs. of Seed/Bag}} = \text{81.5 (no. of 50-lb bags required for 100 acres)}^{1}$$

[1]If for some reason seed with seed germination is less than 80 percent, the seeding rate would need to be increased accordingly.

Row Spacing (Inches)	1994	1995	1996	Average
10	54.8	19.4	50.2	41.5
20	55.2	19.5	48.3	41.0
30	47.9	21.4	52.0	40.4
LSD .05 =	2.6	2.1	2.9	

Table 7.4. Effect of Row Spacings on Soybean Grain Yield (Bu/A), Averaged Over Four Varieties and Seeding Rates, Starks Farm, Miller County, 1994-96

(Table 7.4) suggests that row spacings of less than 30 inches may result in a significant yield increase, but this yield increase is not always consistent over years and/or environments. A yield increase due to planting MG V and VI (determinate) varieties in narrow row spacing is more likely to occur when one or more of these conditions exists: (1) planting before May 15; (2) planting after June 15; or (3) the field environment is such that soybean plants do not obtain canopy closure with current row spacing by flowering (R2). This reduced plant growth is often associated with flat clayey and/or droughty soils. Additional research findings suggest increases in grain yield often result from row spacings of less than 30 inches in the Early Soybean Production System (ESPS) (**see Chapter 16**).

Planting Systems

Fields are becoming larger as a result of fewer producers farming larger tracts of ground. The need exists to develop faster planting systems while retaining the basics of good seed placement into moist soil at recommended seeding rates. Some of the newer planting systems include airflow and other broadcast seeding systems (spreader trucks, etc.). Many growers are using no-till and/or conventional drills in lieu of the more conventional row planters in an attempt to reduce labor and their equipment inventory as well as take advantage of potential yield increases often associated with the more narrow row spacing.

Current University of Arkansas soybean research includes efforts toward improving stand establishment in environments with poor surface drainage, including using beds with both conventional planters and drills. As the data in Table 7.5 indicate, many different planting systems can result in acceptable grain yields if adequate, uniform plant stands are obtained. This previously unpublished research conducted by Huitink, et al., suggests that getting a good stand is more important than how it is obtained. The magnitude of the grain yield confirms that timely management after stand establishment is essential for good yields.

Table 7.5. Effect of Different Planting Systems on Conventional Planted Hutcheson Grain Yields (Bu/A) in Stuttgart Silt Loam at the Pine Tree Experiment Station, 1994-96

Planting System	1994 (May 27)	1995 (June 2)	1996 (June 6)	Average
Drill (7.5 inch)	59.2	57.0	59.4	59.5
30-inch w/o cultivation	52.7	52.7	67.0	57.5
30-inch with cultivation	53.0	53.3	68.1	58.1
Simulated airflow	57.0	55.7	64.1	58.9
Simulated broadcast	55.9	50.1	72.5	59.5
LSD .05 =	4.6	3.6	10.5	

Chapter 8

Irrigation

by P. Tacker and E. Vories

Adequate drainage is essential for maximum soybean production and becomes even more important with irrigation. The benefits of irrigation are usually reduced if a field is poorly drained. Little can be done to improve internal soil drainage, so efforts should be directed to improving surface drainage. Drainage recommendations are covered in more detail in Chapter 6, "Drainage and Tillage."

> **Management Tip**
>
> An irrigated crop will not achieve its full potential if adequate surface drainage is not provided.

Why Irrigate?

When growth and yield factors are rated according to importance, the availability of moisture always ranks near the top. Yields, up to a point, are determined by the availability and use of moisture. Irrigation is a means by which an adequate moisture supply to the crop can be better assured. This provides a potential for increased yields over dryland production and the opportunity to stabilize year-to-year fluctuations in yield and seed quality. This yield stabilization can allow a more aggressive marketing program. In addition, loaning agencies in some areas are evaluating the percentage of a grower's soybean acreage that can be irrigated before they issue a crop production loan. By the reproductive growth period, when irrigation is often first needed, approximately 50 to 60 percent of the production costs are already invested in the crop. Irrigation serves as insurance against a drought that can result in yields that do not even cover production costs, especially for double-crop soybean production.

Yield

Irrigated yields are well documented in many research and Extension studies. The Arkansas Soybean Performance Tests include several varieties that consistently produce in the 50 bu/ac range when irrigated. These same varieties average 10 to 20 bu/ac less without irrigation. The SRVP (Soybean Research Verification Program) 16-year (1983-98) average irrigated yield for 140 full-season production fields is 47 bu/ac. During this same period, there were also 57 irrigated double-crop fields that averaged 44 bu/ac. Many soybean producers are consistently harvesting 50 to 60 bu/ac on well-managed, irrigated fields. This indicates that irrigated yields can vary due to various production factors, but a realistic irrigated yield for most acreage is in the 45 to 50 bu/ac range. However, the 16-year (1983-98) state average irrigated yield is only 33 bu/ac according to data from the Arkansas Agricultural Statistics Service. Even though this is 10 bu/ac greater than the 23 bu/ac state dryland average over the same period, it indicates that many producers are not achieving the full yield potential from irrigation. The information presented in the remainder of this chapter is intended to help producers increase and stabilize irrigated yields.

> **Management Tip**
>
> A realistic irrigated yield goal for most acreage is 45 to 50 bu/ac.

Water Needs

A soybean crop will produce approximately 2 bu/ac for every inch of water it uses through the season. Yields in the 40 to 50 bu/ac range require 20 to 25 inches of available soil moisture during the growing season. The irrigation water needed will vary depending on the beginning soil moisture and the rainfall received during the growing season. An irrigation system needs to be capable of providing 10 to 15 inches of water during the season to assure an acceptable yield.

Daily water use varies as the crop develops. Table 8.1 shows the general growth and daily water use relationship for soybeans.

Table 8.1. General Soybean Growth and Water Use	
Crop Development	**Water Use (in/day)**
Germination and seedling	0.05 - 0.10
Rapid vegetative growth	0.10 - 0.20
Flowering to pod fill (full canopy)	0.20 - 0.30
Maturity to harvest	0.05 - 0.20

Moisture stress anytime after planting can reduce growth and yield. The goal of early irrigation (prior to bloom) is to promote adequate vegetative growth and node development. Prebloom irrigation is almost always needed on late-planted and double-crop soybeans. The crop should be irrigated as needed to avoid moisture stress and to provide good soil moisture at seed fill (R5-R6 growth stage), ensuring that the seeds achieve their maximum size. Most growers realize the need to irrigate when the crop is blooming and setting pods. Experience indicates, however, that many growers tend to be late with the first irrigation and then quit before the crop can reach its full potential. The lack of early and late season irrigation is often responsible for a soybean crop not reaching its irrigated yield potential.

Management Tip

Adequate moisture is essential throughout the growing season for maximum yields.

Irrigation Scheduling

The timing of irrigation is commonly referred to as irrigation scheduling. Correct timing is critical to maximizing yield. Having the ability to irrigate is important, but it is also essential that a grower have a commitment to apply irrigation in a timely manner. Too often growers irrigate by the appearance of the crop. Visual stress, especially during bloom and pod set, results in yield loss. Also, once irrigation is started, the time required to finish a field will result in part of the crop suffering even greater stress. If the soil moisture can be determined, then irrigation timing decisions can be improved.

Determining the soil moisture by visual observation or by kicking the soil surface is difficult and can be misleading. The "feel" method can be used to more accurately determine the soil moisture condition. This method involves using a shovel or soil probe to pull a soil sample from the root area. In general, if the soil forms a hand-rolled ball, the soil moisture is adequate. A key to this method is to take samples across the field at different depths to better determine the soil moisture for the field. The challenge is to determine when to begin irrigation so the entire field can be irrigated before any part becomes too dry, but satisfactory results can be achieved with experience.

A more precise method employs tensiometers, a sealed, water-filled tube with a vacuum gauge on the upper end and a porous ceramic tip on the lower end. The tensiometer is installed in the seedbed at a depth where the majority of the roots are located. A 12-inch depth is commonly used for surface irrigation, except where a hardpan exists, and there it is placed just above this layer. Shallower settings at about 8 inches deep are recommended for center pivots. Two or three tensiometers per field are recommended to avoid a problem if one of the tensiometers quits working. Starting irrigation at a vacuum gauge reading of 50-60 centibars on silt loam and clay soils, and 40-50 centibars on sandier soils, is recommended. *Tensiometers are fairly reliable and effective when checked and maintained properly. However, the time and effort required usually results in most producers not being able to use them very effectively.*

Soil moisture accounting is used to calculate the soil-water balance in the root zone throughout the growing season. This method is sometimes called checkbook irrigation scheduling because a record is kept on the water that enters and leaves the soil like an account balance is maintained in a checkbook. Two forms of the checkbook procedure are available through county Extension offices in Arkansas – the Checkbook User's Guide and the Irrigation Scheduling Computer Program.

The Checkbook User's Guide is used to keep a written record of the soil moisture balance when a computer is not available. It is a three-page handout that shows how to use a water use chart and a water balance table to monitor the soil moisture. The water use chart shows an estimate of how much water the crop uses each day based on the maximum temperature and the age of the crop. Daily water use and rainfall amounts are entered into a water balance table. Maximum temperature data can be taken from the weather, newspaper, etc., but the rainfall should be measured with a gauge at each field. Adding and subtracting these numbers in the table determines the soil moisture deficit. Table 8.2 shows the recommended allowable deficits that are included in the User's Guide to help determine when to irrigate. The allowable deficits vary depending on the soil type, crop and irrigation method.

The Checkbook User's Guide, water use charts and water balance tables are available through your county Extension office at no cost. This method does require some record keeping, but it can be helpful in deciding when to irrigate.

Table 8.2. Recommended Allowable Deficits – Soybeans

Predominant Soil	Flood, Furrow or Border Irrigation (Inches)	Pivot Irrigation (Inches)
Clay	2.00	1.50
Silt Loam w/pan	1.75	1.25
Silt Loam wo/pan	2.50	2.00
Sandy Loam	2.25	1.75
Sandy	2.00	1.50

w/pan – with shallow (<10") restrictive layer
wo/pan – without shallow restrictive layer

If a computer is available, then the Irrigation Scheduling Computer Program can be used for the record keeping. This program operates much like the Checkbook method just described except that the computer does the calculations. It also uses local daily maximum temperatures and rainfall measured at the field to determine a soil moisture deficit for the field. The program is being successfully used by growers in Arkansas, Mississippi, Louisiana, Tennessee and Missouri. It is also being used in numerous irrigation studies and demonstrations conducted in Arkansas. A three-year (1994-96) demonstration of the program at the Southeast Branch Experiment Station (SEBES) in Rohwer indicated that it successfully scheduled irrigations in a field situation very comparable to growers' fields (Table 8.3).

In field studies using both tensiometers and the scheduler program it was found that they are usually within one or two days of each other on indicating when to irrigate. However, the program is much easier to use and maintain than tensiometers. The program also has the option to predict when irrigation will be needed in the next 14 days if no rainfall occurs. This offers a real benefit to managing irrigation labor and sharing irrigation water with other crops. The program is available through the county Extension office.

Table 8.3. Irrigation Scheduler Demonstration SEBES – Rohwer, Arkansas

Treatment	Avg. 1994 Yield (bu/ac)	Avg. 1995 Yield (bu/ac)	Avg. 1996 Yield (bu/ac)	Avg. 3-Yr. Yield (bu/ac)
Irrigate at:				
2 inch deficit	62	63	61	62
3 inch deficit	58	57	57	57
4 inch deficit	51	52	50	51
Nonirrigated	25	16	22	21

Variety NK S59-60, emergence mid-May, furrow irrigated, 19 inch x 1,000 ft. rows, silty clay, 0.1-0.15% slope

Management Tip

Commitment to irrigation scheduling helps a producer better achieve the benefits of irrigation.

Irrigation Termination

Growers are also faced with making the decision on when to stop irrigating soybeans. The goal is to have adequate soil moisture to ensure that the seed will obtain its maximum weight. Field experience indicates that inadequate moisture for full seed development can result in as much as 10 bu/ac yield loss. A practical rule of thumb for terminating irrigation is to determine if 50 percent or more of the pods have seeds that are touching within the pod. (The upper two pods in Figure 8.1.)

Figure 8.1. Seeds touching in the pod and ready for irrigation termination (upper two pods) along with pods needing at least one more irrigation (lower two pods).

If there is good soil moisture at this point, then irrigation can be ended. If the soil is becoming dry, an additional irrigation is needed to assure maximum seed weight. A final irrigation at this stage should be as quick a flush as possible if flood (levee) or border irrigating, or every other middle with furrow irrigation. About 1 inch should be applied with a pivot at this time, and in five to seven days the soil moisture and crop development should be checked again to determine if an additional irrigation is needed.

Irrigation Methods

Surface and sprinkler irrigation methods are used on soybeans. Each method has different characteristics that could make it the best for a particular situation. No one method can be labeled as the best – each has its place. The SRVP has included the four primary soybean irrigation methods. Table 8.4 shows that the four methods averaged essentially the same yield over a 16-year period.

Table 8.4. SRVP Yields by Irrigation Method (1983-98)

Irrigation Method	Avg. Yield (bu/ac)	Number of Fields
Center Pivot	47	41
Flood	46	68
Furrow	49	86
Border	51	8

Levee Irrigation

Flood irrigation with levees should really be thought of as flush irrigation. The challenge is to get the water across the field as quickly as possible. It is also important that irrigation is started before the crop experiences drought. If plants are drought stressed and then subjected to an extended wet soil condition, plant development can be delayed and some plants may die.

Levees should be marked early to strengthen the commitment to pull levees and irrigate when needed. The levee spacing depends on the slope, but spacing on a vertical difference of 0.3 to 0.4 feet is common. A narrower spacing on a 0.2- to 0.3-foot vertical difference may be necessary on very flat fields or when trying to irrigate small beans (less than 8 inches tall). Levees are often broken in several places or completely knocked down to get the water into the next bay. Rebuilding the levee in time for the next irrigation is often difficult because the levee area tends to stay wet. Some growers install

Figure 8.2. Levee irrigation with flume ditch for multiple inlets into field.

gates or spills in the levees to avoid irrigation delays due to rebuilding the levees between irrigations. When possible, it is recommended that gates or spills are also installed in the outside levee. This provides better drainage of a field in a situation where a rain occurs during or soon after the irrigation.

It is recommended that water not be allowed to stand on any area for longer than two days. This can be difficult on big, flat fields. Some growers are able to divide these type fields into two smaller fields when they start irrigating so they can better manage the water. If this isn't practical, then providing multiple water inlets to the field can be helpful. Multiple inlets help avoid running water too long at the top of the field in order to get water to the bottom of the field. One multiple inlet method is to water the upper half of the field from the pump discharge or riser and then run irrigation pipe or tubing from the discharge down the field to water the lower half. A canal or flume ditch alongside the field can also be used for multiple inlets. The water can be directed from the ditch through cuts or spills into individual bays down the length of the field.

Another possibility is to run tubing the full length of the field and install several of the 2 1/2-inch plastic gates in each bay. These slide gates are adjustable from completely closed to fully open, where they deliver 65 to 75 gpm and they are reusable from year to year. This method is well suited to fields that have a permanent outside levee or road that the tubing can be laid on. However, the heavier tubing (9 to 10 mil) has been run up and over levees successfully as long as it is going down slope. The 9- to 10-mil tubing is better suited for these multiple inlet-type applications than the 6- to 7-mil tubing.

> **Management Tip**
>
> It is recommended that water not be allowed to stand on any area for longer than two days.

If the soil cracks readily, then levee irrigation becomes even more of a challenge. Multiple inlets can help, but it is still important to irrigate on time. Planting on a raised bed can also provide extra drainage and help avoid some of the water management challenges of levee irrigation.

A minimum irrigation capacity of 15 gpm per irrigated acre is recommended for levee irrigation. At that rate, about four days would be required to complete an irrigation. Starting late would increase the time required, resulting in severe drought stresses in the last portion to get water. The more pumping capacity available for levee irrigation, the better. Opportunities for getting more pumping capacity to a field should be explored and developed whenever possible so the pumping time required to irrigate a field can be reduced. Although levee irrigation presents a challenge, it can be done successfully. There are many producers who consistently produce high yields by paying close attention to the precautions and recommendations that have been presented.

Furrow Irrigation

Furrow irrigation can be a very effective irrigation method. *One of the biggest requirements for furrow irrigation is that the field must have a positive and continuous row grade.* This usually requires precision land grading which can be rather expensive. However, the grading results in positive field drainage that greatly enhances production. The row grade should be a minimum of 0.1 percent and no more than 0.5 percent; row grades between 0.15 and 0.3 percent are especially desirable.

The row length to be furrow irrigated is another key consideration. Row lengths of 1/4 mile or less generally water more effectively than longer rows. Row lengths less than 1/4 mile are usually required if sandy soils are to be irrigated effectively.

When row lengths cannot be altered, it may be necessary to control the furrow stream flow by adjusting the number of rows that are irrigated at one time. Experience shows that in most situations it is desirable to get the water to the end of the row in 10 hours or less. Watering much longer than this can cause overwatering at the top of the row and cause problems, especially if it rains and stays cloudy soon after the irrigation. This has become more of a concern with the expanded use of irrigation tubing with punched holes for furrow irrigation. The tendency with the tubing is to punch holes as long as water still comes out of them without much concern for how long it will take to water out the row. This is desirable from the standpoint of not having to plug and open holes and operate the tubing in sets. However, the caution is to water according to what is more effective for the field and crop rather than what is easiest.

Figure 8.3. Furrow irrigation with gated pipe.

Furrow irrigation requires a water supply of at least 10 gpm per irrigated acre, and more capacity is desirable if available. At 10 gpm/acre, about five to six days should be expected to complete an irrigation. Practices like waiting until morning to change sets when rows water out at night can add significantly to the time, making it difficult to finish the field much before it is time to begin the next irrigation. A well-defined furrow is needed to carry the irrigation water. Planting on a good bed is the most desirable option for having a good water furrow. If a bed is not used, then it is necessary to cultivate with a furrow plow that moves enough soil from the middle of the rows so that a good furrow is created. Plowing out a furrow is probably not an option on rows less than 19 inches wide, so the border method may be a better option on those fields.

> **Management Tip**
>
> Furrow irrigation requires a water supply of at least 10 gpm per irrigated acre.

Some producers prefer to water alternate middles under certain conditions. This is especially true on row spacing of 20 to 30 inches. Watering alternate middles can result in getting across the field quicker and not leaving the soil as saturated as it might be if every middle were irrigated. Then, if rain comes soon after the irrigation, it is possible for it to soak into the soil rather than run off or collect and stand in low spots. However, with alternate middles on narrow rows and/or cracking soils, the skipped middle is sometimes saturated.

Producer preference and experience, along with the crop and field condition, will determine whether it is best to water every middle or alternate middles. Alternate middle irrigation will result in having to come back with the next irrigation somewhat sooner than when every middle is watered if the water doesn't soak across the dry rows.

Furrow irrigation by necessity requires that there be some amount of tail water runoff from the end of the rows. All the middles will not water out at the same rate, especially those that are wheel middles. Also, cracking soils can make furrow irrigation management more challenging. However, irrigating on the appropriate schedule will reduce the problems associated with too much cracking.

Border Irrigation

This is an old irrigation method that is relatively new in Arkansas. The concept is to flush a large volume of water over a relatively flat field surface in a short period of time. Borders are raised beds or levees constructed in the direction of the field's slope. The idea is to release water into the area between the borders at the high end of the field. The borders guide the water down the slope as a shallow sheet that spreads out uniformly between the borders.

Border irrigation is best suited for precision graded fields that have slope in only one direction. The soybeans need to be flat planted in the direction of the field slope or possibly at a slight angle to the slope. Planting across the slope tends to restrict the water flow, especially on fields with less than 0.1 ft. fall per 100 feet. Fields with slope in two directions are not as well suited to border irrigation, but it may still be possible if the borders spacing is relatively narrow.

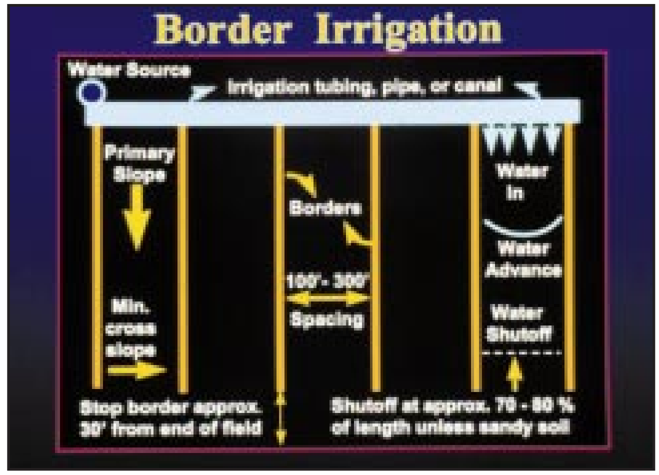


Figure 8.4. Border irrigation system general layout.

The spacing between borders is dependent on soil type, field slope, pumping capacity, field length and field width. A clay soil that cracks is sometimes difficult to irrigate, but with borders the cracking actually helps as a distribution system between the borders. This factor also makes it possible to use borders on clay fields that have a slight side or cross slope. The tendency on fields with side slope is for the water to flow to the lower side and not spread out uniformly between the borders. The soil cracks lessen this effect because the water will spread laterally as it follows the cracking pattern. The border spacing on clay soil will generally be between 200 and 300 feet with the narrower spacing on fields with side slope.

The border spacing on sandy and silt loam soils that tend to seal or crust over is more of a challenge than with the cracking clays. Side slope on these soils results in the border spacing having to be narrower in order for the water to spread uniformly between the borders. The border spacing on these soils will generally range between 100 and 200 feet with the narrower spacing on fields that have side slopes.

The pumping capacity and field dimensions (length and width) are used to determine the number of borders needed and how many can be irrigated in a reasonable time. Calculations can be made to estimate the time required to irrigate a border, and it is usually possible to work toward approximately 12-hour set times. The 12-hour time set is very desirable because it fits very well for managing water and labor. The border can be constructed in a variety of ways and with different types of equipment. The method used is partially determined by whether or not soybeans are to be grown on the border. A settled border height of 2 to 4 inches is all that is needed on ideal fields with no side slope, but a 4- to 6-inch settled height is required if the field has side slope or if the field has potholes. *If the border is constructed with a disk-type implement, an effort must be made to fill the ditch left at the base of the border so it will not act as a drain furrow.* The borders need to stop at least 30 feet from the low end of the field so they will not restrict drainage.

The water can be delivered into the area between the borders from a canal, gated pipe or gated irrigation tubing. If irrigation tubing is used, it is recommended that it be the heavier 9- to 10-mil tubing. The 2 1/2-inch plastic gates that deliver 65 to 75 gpm each can be installed in the tubing, reducing the number of holes needed and simplifying closing gates at the end of a set.

If border irrigation can be used on a field that is usually flood irrigated, then it can provide certain advantages:

1. Less production area lost with border than with levees.

2. Improved ability to irrigate small beans.

3. Don't have to repair or rebuild border between irrigations, thus a potential for time and labor savings.

4. Field drainage is not restricted by borders.

5. There is better possibility of growing soybeans on the border.

Border irrigation will not work on all fields and is not necessarily a better method where soybeans are already grown on good beds and furrow irrigated. However, if a grower wants to move toward flat planting and reduced tillage on these fields, then border irrigation may be more appealing than flood. There is not adequate space in this publication to cover all of the details associated with border irrigation. However, more information is available through your local county Extension office.

Center Pivot Irrigation

Center pivots offer the ability to irrigate fields that have surface slopes that make it impossible or impractical to irrigate with surface methods. They also offer more water management options than surface irrigation. *The need for good surface drainage still exists with pivot irrigation and should not be overlooked.*

Pivots are best suited for large square-, rectangular- or circular-shaped fields free of obstacles such as trees, fences, roads, power poles, etc. Field ditches are also a concern if the pivot towers must be able to cross them. Pivots can cover a range of acreage depending on the allowable length, but the common 1/4-mile system will cover approximately 130 acres of a 160-acre square field. It is also possible to tow a pivot from one field to another. *It is usually best for a system not to be towed between more than two points during the season.*

Figure 8.5. Center pivot sprinkler system.

Pivots provide the ability to control the irrigation amount applied by adjusting the system's speed. This gives the operator advantages for activating chemicals, watering up a crop and watering small plants. These advantages are especially important for double-crop soybeans, since they are more likely to encounter a drought soon after planting. It is also possible to apply liquid fertilizer and certain pesticides through the system if the necessary precautions are taken. One of the biggest advantages of pivot irrigation is the limited labor required for operating the system.

It is recommended that a pivot have a water supply of at least 5 gpm per acre that is irrigated. At that rate, nearly four days are required to apply a 1-inch irrigation. A water supply less than this leaves little room for breakdown time without the risk of getting behind in meeting the crop water needs. The capacity for a towable system should be greater to account for the added time needed to move the system. Most new pivots are being equipped with low-pressure sprinkler packages. Many of these are mounted on drops so that the water is released closer to the soil surface. This is desirable as long as the system application rate is matched to the soil and field characteristics so that excessive runoff is avoided. If a field has a rolling surface and a soil that tends to crust or seal over, this should be taken into account in the sprinkler package selection. The application amount can be adjusted to reduce runoff to some degree, and most producers find that applying approximately 1 inch works best.

The biggest challenge with center pivots is the initial cost. However, it does offer some advantages that can justify the initial cost, especially when surface irrigation is not possible and the cost is spread over an expected service life of at least 15 years.

When considering the different irrigation methods, it is important to remember that any method that is well planned and is properly installed, operated and maintained can give the results desired. *Every method requires time to irrigate the whole field, so it is very important that irrigation be started early enough that no part of the field suffers moisture stress.*

Arkansas Situation

Consistent and profitable soybean production is difficult without irrigation. Fortunately, once irrigation is in place, the energy cost for pumping water is relatively cheap at $2 to $5 per acre for each irrigation. This cost is easily justified by the yield increase that can result from the irrigation. The maximum profit usually results when the maximum yield is obtained, so the irrigation goal is to obtain the maximum yield by preventing crop moisture stress. *Irrigation is not a cure-all. Maximum yield and profit will be achieved only when irrigation is coupled with other production practices that establish profitable yield potentials.*

Chapter 9

Weed Control

by F. Baldwin, L. Oliver and K. Smith

The following information guides are available from the Cooperative Extension Service, University of Arkansas to aid growers in making weed control decisions:

1. *Soybean Weed Control Computer Program*
2. *Recommended Chemicals for Weed and Brush Control in Arkansas* (MP-44)
3. *Your County Extension Agent*

Soybean Weed Control is a computer program that will determine the potential yield losses due to any given combination of weeds and infestation levels. In addition, it will select the most effective soil-applied and postemergence herbicides for any combination of soybean weeds entered. The cost of the computer program is $15, and it is available from the Cooperative Extension Service, Attention: Steve Hall, P. O. Box 391, Little Rock, AR 72203; or by contacting your county Extension agent.

Recommended Chemicals for Weed and Brush Control in Arkansas (MP-44), available from any county Extension office, contains a complete listing of all herbicides available for weed control in soybeans. It also contains other information, such as:

- Herbicide Rates
- Reduced Rate Recommendations
- Weed Response Ratings
- Crop Rotation Restrictions
- Tank Mix Compatibility
- Proper Nozzle Selection
- Herbicide Application
- Guideline for Preventing Herbicide Resistance

Your County Extension Agent receives extensive training and updates on soybean weed control technology. The agent also has immediate access to research scientists and Extension specialists within the University of Arkansas system.

Keys to Weed Management

Proper Weed Identification – Don't Guess!

Weeds must be properly identified in the seedling stage in order to select the most effective herbicides. Weeds such as hemp sesbania versus northern jointvetch and prickly sida versus hophornbeam copperleaf can be difficult for the untrained eye. While the weeds may look similar, they can have an opposite response to any given herbicide.

> **Management Tip**
>
> Get immediate identification of any new or "strange" weed that may appear in a field for the first time and stop reproduction.

Sources of help on weed identification are:

- The *color photos (Figure 9.4, Seedling and Immature Weeds)* at the end of this chapter (also refer to Figure 9.3).
- *SWSS Weed Identification Guide* available as a reference in the county Extension agent's office or order forms are available for purchase from the county Extension office.
- The *County Extension Agent* – Take the weed in to the agent or ask the agent to come look.

Scouting – You Have to Look!

Fields should be scouted at harvest and maps constructed identifying all weed species present. This information is important for selecting soil-applied herbicide for the following crop. Fields should then be scouted beginning about seven days after crop emergence to determine both weed species present and plant density. This information is necessary to decide if treatment is needed and which postemergence herbicides will be most effective.

Give the Advantage to the Soybeans

Any practice that promotes rapid soybean stand establishment, proper plant density and rapid canopy closure will increase the ability of soybeans to compete with weeds, thereby increasing the effectiveness of a given herbicide program.

How Weeds Affect the Crop

Weeds reduce income by lowering yields, reducing harvesting efficiency, causing foreign matter dockage and contaminating the soil for future crops.

Management Tip

Have fields weed free by 14 days after soybean emergence for the greatest returns on herbicide investment.

Proper Use of Soil-Applied Herbicides

Growers are becoming increasingly dependent on postemergence herbicides. However, in situations where weed densities are severe or proper application timings for postemergence herbicides are

Table 9.1. Example Interference Losses Caused by Selected Weeds at Various Plant Densities (Percent Soybean Yield Reduction Due to Weed Interference)

Weed Species	Weeds/20 Ft of Row (Full-Season)			
	5	10	20	40
	(% Yield Loss)			
Palmer amaranth	26	40	64	66
common cocklebur	30	44	58	73
entireleaf morningglory	26	36	46	56
smooth pigweed	11	22	45	49
sickplepod	7	16	31	47
velvetleaf	9	14	25	38
common ragweed	6	12	24	48
johnsongrass	12	15	21	32
spurred anoda	0	---	5	16
jimsonweed	4	7	12	13
barnyardgrass	0	0	1	2
hemp sesbania	7	17	37	59
pitted morningglory	1	16	31	46

Table 9.2. Percent Savings in Potential Gross Returns by Controlling Common Cocklebur at Specified Times

Plants/20 Ft of Row	Weed Controlled by (Weeks After Emergence)			
	0-3	4	6	8
	(% Savings in Returns)			
2	13	11	8	5
4	26	22	16	11
10	43	36	27	18
20	56	47	35	24
40	68	57	43	28

frequently missed, soil-applied herbicides greatly improve weed control even in Roundup Ready programs.

Match the herbicides to the weeds.

- Refer to MP-44.
- Refer to *Soybean Weed Control* computer program.
- Refer to weed response ratings in Table 9.3 (later in this chapter).

Management Tip

Take advantage of reduced rate recommendations and use soil-applied treatments consisting of a grass herbicide, plus a reduced rate of a broadleaf herbicide such as Scepter, Canopy or Canopy XL.

Note

Certain soybean cultivars are more sensitive to propanil, metribuzin in Sencor, Lexone and Canopy; and sulfentrazone in Canopy XL. This information is available from your county Extension agent.

Proper Choice of Postemergence Herbicides

Choose a herbicide that fits the weed spectrum in the field. If the herbicide does not match the weeds, failure is assured.

- Refer to MP-44.
- Refer to *Soybean Weed Control* computer program.
- Refer to weed response ratings in Table 9.3 (later in this chapter).

Proper Herbicide Timing

- Applying postemergence herbicides too late is the number one cause for failure in soybean weed control programs.
- Proper timing for postemergence herbicides is from 5 to 14 days after weed emergence. Since soybeans and the first flush of weeds usually emerge together, the application can be best timed to soybean emergence. An alternative would be to add the normal number of days from planting to emergence on your farm. If one assumes 5 days from planting until emergence, the proper timing would be 10 to 20 days after planting.
- The photographs below illustrate the beginning and ending window for proper postemergence herbicide timing.

Figure 9.1. The proper timing of most postemergence applications is between the V1 and V2 growth stages.

Figure 9.2. V3 growth stage.

Waiting to apply postemergence herbicide applications between V3 and V5 often results in disappointing weed control.

Note

After proper choice of herbicides, the three most important factors influencing post-emergence herbicide activity are Timing, Timing and Timing.

Management Tip

Apply the first postemergence application 10 days after soybean emergence.

Environmental Conditions

Next to proper timing, environmental conditions are the most important factors in determining herbicide activity. Soil moisture, temperature and relative humidity (in that order) are the critical factors.

- Soil moisture and application timing often go hand-in-hand. One reason the 7 to 10 days-after-emergence (DAE) application timing is so effective is weeds will seldom be drought-stressed. In contrast, by 14 DAE, drought stress is common if rainfall has not occurred since planting. Beyond 14 DAE, weeds will almost always be drought-stressed if rainfall has not occurred since planting.

> **Management Tip**
>
> If adequate rainfall does not occur after planting and soil moisture is being lost, consider making the postemergence application two or three days earlier than intended.

- Even a herbicide like Roundup Ultra that is capable of killing large weeds will fail unless soil moisture is adequate.
- Temperature and relative humidity cannot be changed. However, higher temperatures and higher relative humidity can mean lower herbicide rates can be used.
- Optimum soil moisture is needed for proper activation of preplant incorporated herbicides.
- Rainfall or overhead irrigation is needed within five days to activate preemergence herbicides.

> **Management Tip**
>
> If soil moisture is getting marginal, consider application just before dark to take advantage of higher nighttime relative humidity and dew formation.

> **Save $$**
>
> **Early timing and good growing conditions will allow the use of reduced rates in MP-44 to save $$.**

Put Together a Program

Today there are two primary types of weed control programs:

- Those for conventional soybeans and
- Those for Roundup Ready soybeans

Programs for most fields planted to conventional soybeans will include both soil-applied and post-emergence herbicides. Fortunately, there are a number of herbicides that are effective on weeds commonly found in Arkansas soybeans. There is usually no "one best" herbicide or herbicide program for all situations. Specific herbicide programs for individual fields must be based on weed species present.

The following are examples of conventional weed control:

- **Example 1:** For control of common cocklebur, smooth pigweed, morningglory species, hemp sesbania and annual grasses:

  Prowl or Treflan plus reduced rate of Scepter or Canopy XL preplant incorporated, followed by reduced rate of Reflex or Storm applied at 10 DAE.

- **Example 2:** For control of annual grasses, red rice, prickly sida, morningglory and hemp sesbania:

  Dual ppi followed by Assure II at 14 DAE followed by Storm one day later.

Example program for control of most weeds, including sicklepod, Palmer amaranth and red rice in Roundup Ready soybeans:

- **Example 1:** Roundup at 1 pt/A applied at 10 to 14 DAE and repeated 10 to 14 days later. If the proper timing cannot be assured, see next example.
- **Example 2:** Prowl, or Treflan plus one-half rate of Scepter or Canopy XL, followed by 1 qt/A Roundup at 14 to 21 DAE.
- **Example 3:** If red rice is a predominant weed:

  Dual ppi followed by 1 pt/A Roundup 10 to 14 DAE and repeated 10 to 14 days later

> **Note**
>
> **Touchdown and generic glyphosate may be used interchangeably with Roundup Ultra if the formulation has a Roundup Ready label.**

Weed Resistance to Herbicides

In Arkansas and surrounding states, the following examples of weed resistance to herbicides in soybeans have been documented:

- common cocklebur resistance to Scepter
- Palmer amaranth resistance to Scepter, Classic and DNA (Prowl, Treflan, etc.)
- goosegrass resistance to DNA (Prowl, Treflan, etc.)
- johnsongrass resistance to Fusilade and Assure

The following concepts promote resistance:

1. Assuming weed resistance will not happen to you – even within a herbicide like Roundup Ultra.
2. Over-dependence on herbicides.
3. Relying on a single herbicide or mode of action.
4. Sequential applications of the same herbicide or mode of action.

In order to manage herbicide-resistant weeds and prevent the widespread development of resistance or weed shifts, the University of Arkansas recommends the following strategies:

General Resistance Management Strategies – including those for Roundup Ready crops:

1. Rotate crops where possible.
2. Use preplant tillage, cultivation and other cultural practices for weed control where possible.
3. Rotate herbicides having different modes of action.
4. Use tank mixtures of herbicides having different modes of action.
5. Avoid sequential applications of the same herbicide or herbicides having the same mode of action.
6. Control weeds on fallow or set-aside land.
7. **If you suspect resistance after herbicide application**, attempt to eradicate escapes with alternative herbicides or cultural methods, i.e., **do not let them go to seed**. Collect seed samples from suspect plants and take them to your county Extension agent who will have them tested at the University of Arkansas.

Management Tip

Refer to the Weed Resistance section in MP-44 for examples of herbicides having the same mode of action.

Remember – Herbicides Are Not the Only Answer!

A combination of cultural practices and timely herbicide applications, however, is the key to successful weed management.

Some cultural practices most favorable for soybean weed control are:

- Proper crop rotation
- Good seedbed preparation
- Delayed planting
- Row spacing
- Good stands
- Rotary hoeing
- Timely cultivation

Figure 9.3. Identification Terminology (Seedling 1-5 Leaf Stage)

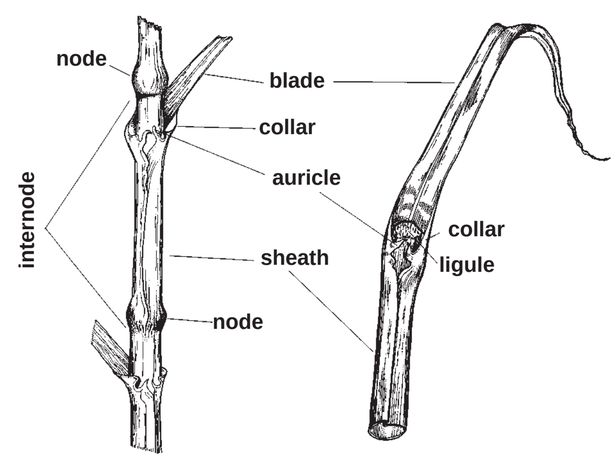


Table 9.3. Weed Response Ratings for Soybean Herbicides (January, 2000)

NOTE: The University of Arkansas offers a computerized soybean weed control program that aids greatly in selecting the best herbicide. This program is available through your local county Extension agent.

HERBICIDES / WEEDS	Barnyardgrass	Broadleaf Signalgrass	Crabgrass	Goosegrass	Seedling Johnsongrass	Rhizome Johnsongrass	Giant Foxtail and Fall Panicum	Cocklebur	Entire and Ivyleaf Morningglories	Pitted Morningglory	Palmleaf Morningglory	Smallflower Morningglory	Purple Moon Flower	Woolly Croton	Smartweed sp.	Hemp Sesbania (Coffeebean)	Northern Jointvetch (Curly Indigo)	Prickly Sida (Teaweed)	Spurred Anoda	Palmer Pigweed and Tall Waterhemp	Smooth Pigweed	Balloonvine	Texas Gourd	Sicklepod	Cutleaf Groundcherry	Common Ragweed	Nutsedge, Yellow	Flatsedge (Annual)	Velvetleaf (Wild Cotton)	Jimsonweed	Red Rice	Spurge	Hophornbeam Copperleaf	Crop Tolerance G = Good F = Fair
Preplant																																		
Frontier	9	8	9	9	6	0	9	0	2	2	2	2	2	-	6	5	3	7	-	6	10	-	-	6	9	8	8	10	5	-	7	7	7	G
Treflan, Prowl	9	9	9	9	9	3***	9	0	2	2	2	2	1	0	2	0	-	0	0	7	9.5	0	0	2	0	3	0	3	2	3	4	2	0	G
Treflan or Prowl + Sencor/Lexone	9	9	9	9	9	3	9	5	2	6	7	8	5	5	9	9	-	9	9	8	10	7	6	6	9	9	2	-	8	7	6	9	9	F
Dual	8	8	9	9	6	0	9	0	2	2	2	2	2	4	4	2	-	5	3	8	9	1	5	5	9	7	9	10	4	5	7	3	5	G
Lasso/lFreedom/Micro-Tech	8	8	9	9	6	0	9	0	2	2	2	2	2	4	5	2	-	8	3	8	10	1	5	7	10	8	7	10	4	5	7	4	6	G
Dual or Freedom + Sencor/Lexone	9	9	9	9	6	0	9	5	3	6	7	8	5	6	9	9	-	9	9	8	10	7	6	7	10	9	7	10	8	8	7	9	9	F
Prowl or Treflan + Scepter	10	10	10	10	10	7	10	9	8	9	9	9	8	5	9	5	-	9	8	10	10	5	9	8*	9	9	8	9	8	9	6	9	6	F
Dual or Freedom + Scepter	9	9	9	9	8	0	9	9	7	9	9	9	7	5	9	5	-	9	8	10	10	5	9	8	9	9	9	9	8	9	7	9	6	G
Prowl or Treflan + Canopy	10	10	10	10	10	5	10	9	8	9	9	9	5	5	9	9	7	9	9	9	9	8	7	8*	9	9	7	8	7	9	-	9	9	F
Broadstrike + Treflan	9	9	9	6	9	3	9	9	8	8	-	7	4	-	-	0	0	10	9	9	10	-	-	8	-	8	5	5	8	8	-	8	7	G
Preemergence																																		
Broadstrike + Dual	9	8	9	9	7	0	8	8.5	7	7	-	7	4	-	-	0	0	10	9	9	10	-	-	8	-	8	7	9	9	8	7	8	7	G
Frontier	9	8	9	9	6	0	9	0	0	0	0	0	0	-	6	5	-	6	-	5	9	-	-	6	8	6	6	9	4	-	5	6	6	G
Command	9	9	9	9	9	3	9	5	0	7	6	6	0	5	9	0	-	9	9	0	6	5	0	0	0	5	0	0	10	8	2	0	0	G
Canopy XL	8	6	8	7	-	0	-	9	8	8	-	-	-	-	-	3	-	9	-	9	10	-	-	3	-	-	5	-	-	-	-	-	-	F
Dual or Lasso	8	7	9	9	5	0	9	0	0	0	0	0	0	3	4	0	-	3	0	9	9	1	3	5	8	5	6	9	3	4	5	3	5	G
Sencor/Lexone	6	6	6	6	5	0	6	6	2	7	7	8	2	5	9	9	-	9	9	9	9.5	7	7	8*	9	9	2	8	7	7	4	9	9	F
Lasso or Dual + Sencor/Lexone	9	9	9	9	7	0	9	7	2	7	7	8	2	6	9	9	-	9	9	10	9.5	7	7	8*	10	9	5	9	8	8	7	9	9	F
Scepter	6	6	6	6	6	3	6	9	6	9	9	9	5	3	9	4	-	7	7	9	10	5	9	8*	9	9	5	9	6	8	5	9	6	F
Dual or Lasso + Scepter	9	9	9	9	8	3	9	9	6	9	9	9	5	3	9	4	-	9	7	10	10	5	9	8*	9	9	5	9	6	8	5	9	9	F
Canopy	6	6	6	6	5	0	6	9	8	9	9	9	5	5	9	9	7	9	9	9	9	7	7	8*	9	9	5	8	7	9	-	9	9	F
Dual or Lasso + Canopy	9	9	9	9	8	0	9	9	8	8	9	9	5	5	9	9	7	9	9	9	9	7	7	8*	9	9	7	9	7	9	7	9	9	F
Postemergence-OT																																		
Flexstar	0	0	0	0	0	0	0	9	8	9	9	9	9	9	9	9.5	7	6	6	8	10	8	-	2	9	9	6	-	7	9	0	-	9	G
Basagran	0	0	0	0	0	0	0	9.5	3	7	8	9	3	0	9	4	-	9	8	4	4	8	0	0	0	8	6	8	8	8	0	0	0	G
Blazer	2	2	2	0	4	0	6	7	8	9	9	9	9	9.5	9	9.5	-	2	2	8	10	8	9	0	9	9	3	7	4	9	2	5	9	G
Blazer + Basagran or Storm	2	2	2	4	4	0	6	9	8	9	9	9	9	9.5	9	9.5	-	8	8	8	10	8	9	0	9	9	4	8	7	9	0	5	9	G
Scepter	0	0	0	0	6	3	0	9.5	0	7	10	5	0	0	7	0	-	3	0	6	9	0	7	4	0	8	0	0	0	0	6	0	0	G
Scepter + Blazer	2	2	2	2	6	3	2	9.5	8	9	9	9	9	9	9	9	-	4	0	8	10	8	9	4	9	9	0	0	4	9	0	5	9	G
FirstRate	0	0	0	0	0	0	0	9	8	9	9	10	6	-	-	5	-	4	9	2	3	-	-	6	-	-	-	-	8	-	0	-	-	G
Front Row	0	0	0	0	0	0	0	9	8	9	9	10	6	-	-	5	-	7	9	2	3	-	-	6	-	-	-	-	8	-	0	-	-	G
Liberty 1.75 pt/A 1 app	8	9	8	-	9	6	9	9	5	8	-	-	-	-	9	9	9	8	-	4	5	-	-	9	-	9	5	-	6	-	9	-	-	G
Classic	0	0	0	0	0	0	0	9	8	9	8	9	5	-	9	10	6	0	0	5	9	5	6	7	-	9	6	-	7	10	0	0	-	
Cobra	0	0	0	0	0	0	0	8	6	8	8	9	7	9	7	9.5	-	8	7	8	10	9.5	9	5	9	9	2	2	8	9	0	8	9	G
Reflex	0	0	0	0	0	0	0	9	8	8	9	8	9	9	8	9.5	6	2	2	8	10	8	-	2	9	9	6	-	-	9	0	5	9	G
Pursuit	7	7	7	5	8	5	8	7	7	9	8	9	3	-	7	0	-	6	6	6	10	4	4	0	-	5	7	7	7	9	8	9	5	G
Poast	8	9	9	9	9.5	8	9	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	7**	0	0	G
Fusilade DX/Fusion	7	8	7	9	9.5	9	8	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	6**	0	0	G
Assure II	8	9	9	9	9.5	9	9	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	8**	0	0	G
Select	8	9	9	9	9.5	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	G
Roundup, Glyphosate, Touchdown, Split	9	10	10	10	10	10	10	10	8	8	9	9	8	-	7	7	9	8	7	10	10	8	-	9	9	9	5	8	8	9	9	8	8	G
Roundup, Glyphosate, Touchdown, Single	8	9	9	9	10	9	9	9	6	6	7	7	6	-	5	4	7	6	5	10	9	6	-	8	7	9	4	7	6	8	8	8	6	G
Post Direct (2 applications)																																		
2,4-DB	0	0	0	0	0	0	0	9	9	9	9	9	9	3	0	3	-	3	2	2	2	1	2	0	0	1	0	-	3	4	0	0	2	G
Lorox + 2,4-DB	7	7	8	7	7	0	7	9	10	9	9	10	9	9	7	8	-	8	8	9	9	9	5	7	10	9	2	-	7	8	6	7	9	G
Sencor/Lexone + 2,4-B	7	7	8	7	7	0	7	9	10	9	9	10	9	9.5	7	8	-	8	8	9	9	9	8	9	10	9	2	-	7	8	6	7	9	G

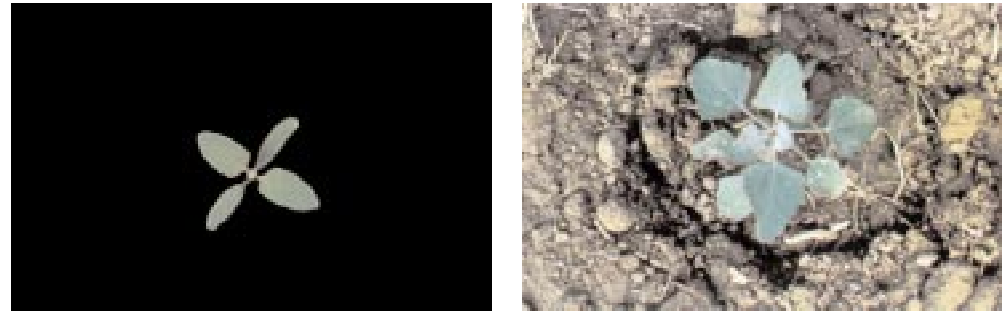
*Follow-up postemergence spray will be necessary to achieve these ratings.
**Red rice ratings with Poast, Fusilade and Assure can be increased if repeat applications used.
***Rhizome johnsongrass ratings with Treflan and Prowl increased to 7 if 2x rate used.

Rating Scale - 0 = No Control 10 = 100% Control
Dash = insufficient data

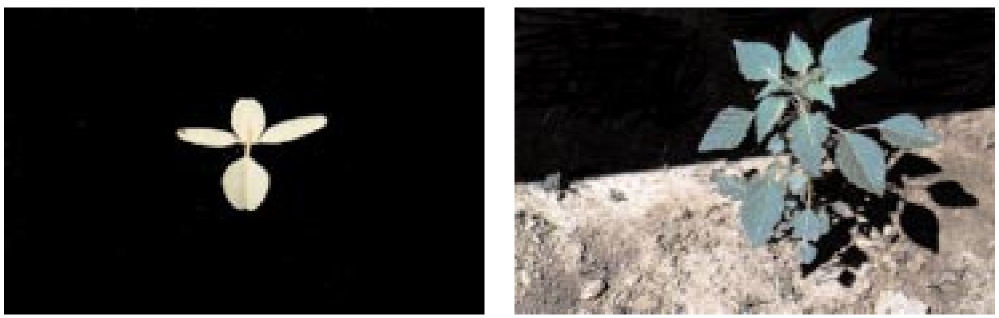
Figure 9.4. Seedling and Immature Weeds

smooth pigweed
redroot pigweed

Note pubescent stems.



common lambsquarters



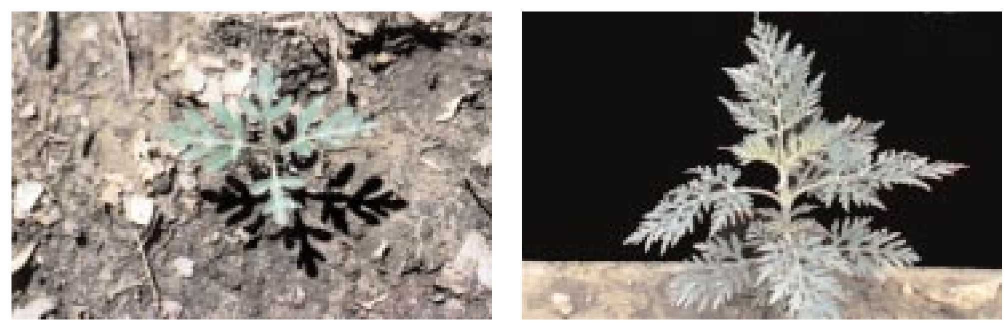
Palmer amaranth

Note elongated petioles and rosette shape.

common cocklebur

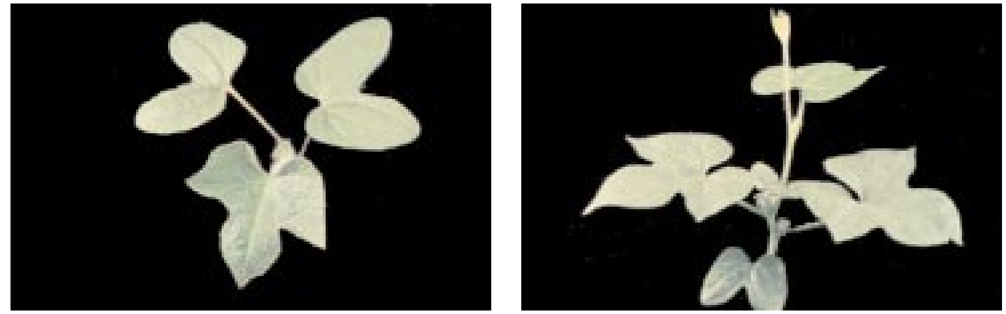
tall waterhemp

Note elongated leaves and “wet” look.



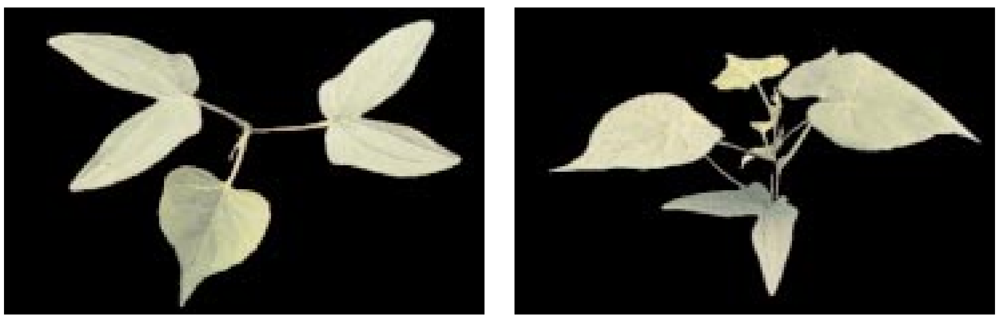
common ragweed

eclipta



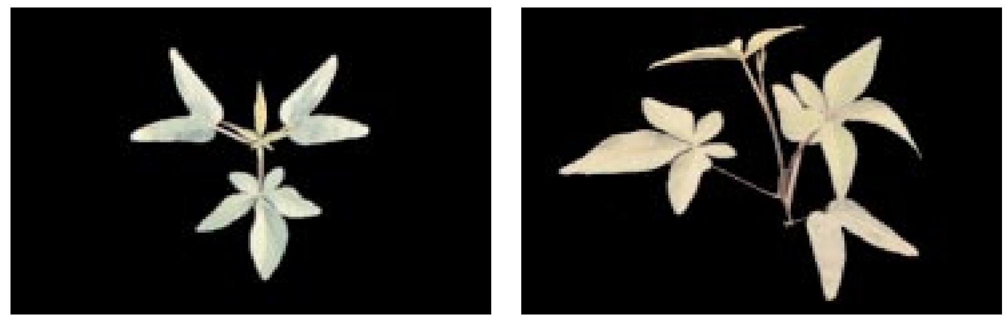
ivyleaf morningglory

Note leaf shape and densely hairy leaf and stem surfaces.



pitted morningglory

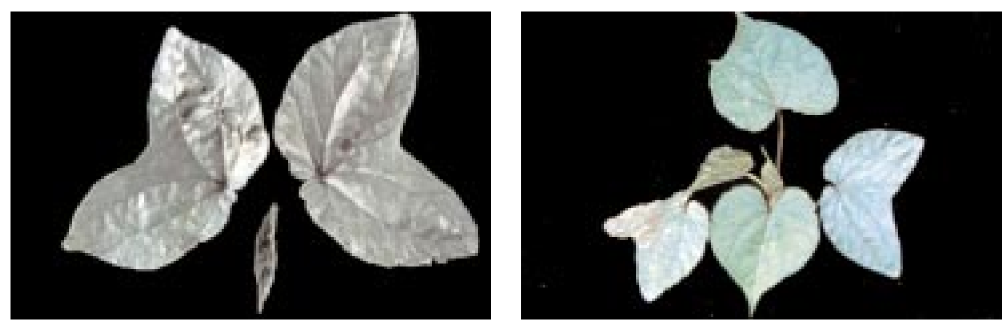
Note deeply lobed cotyledons; purple stems and leaf margins, and lack of hair. Leaf shape may vary from deeply lobed to heart-shaped as some are shown here.



palmleaf morningglory

entireleaf morningglory

Note heart-shaped leaf and densely hairy leaf and stem surfaces.

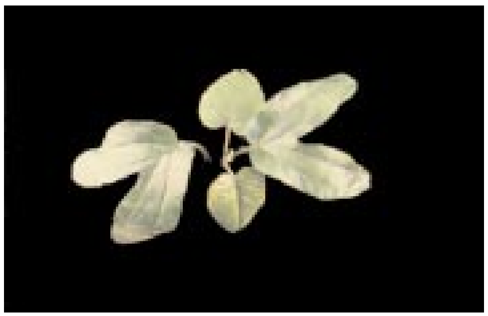


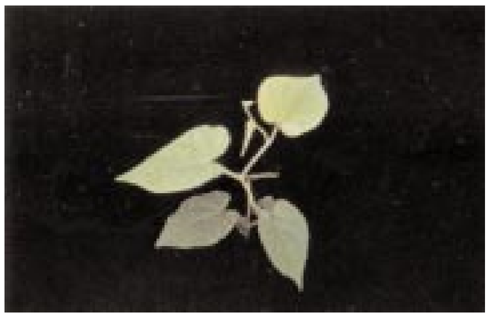
purple moonflower

smallflower morningglory

hophornbeam copperleaf

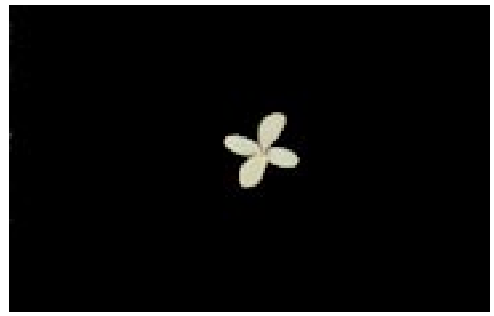
Compare the opposite true leaves in seedling stage to the alternate (single) true leaf of prickly sida.

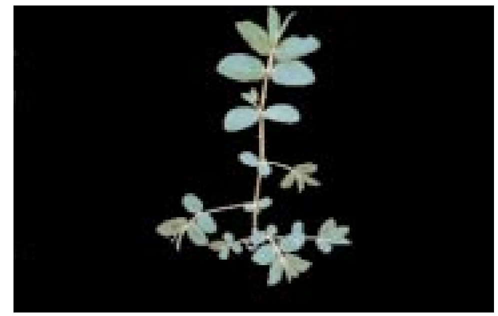




bigroot morningglory

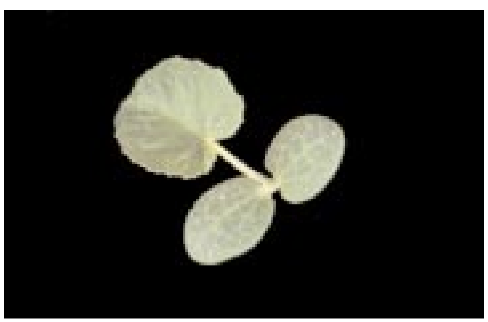
Note apical meristem (growing point) is below the soil surface.

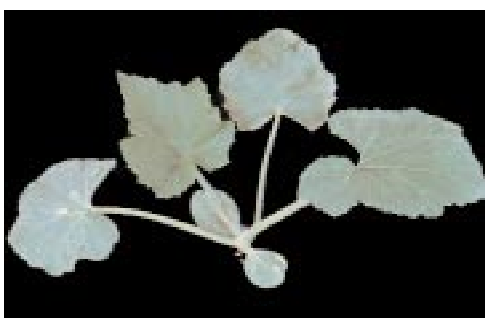




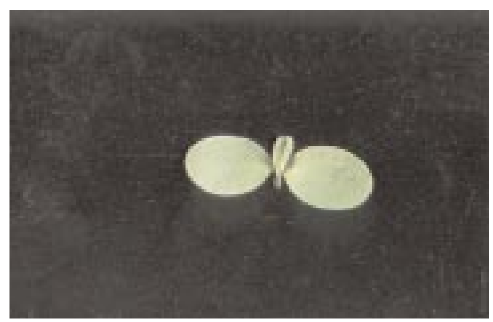
spotted spurge

Note milky sap. Prostrate spurge similar but forms mat on soil surface.



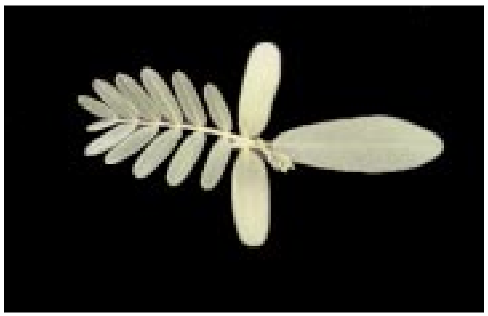


Texas gourd



woolly croton

tropic croton

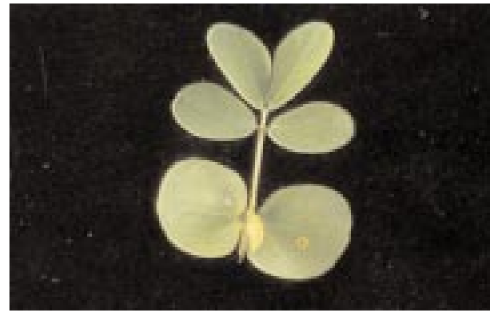


hemp sesbania (coffeebean)

Note 1st true leaf is simple leaf.

northern jointvetch (curly indigo)

Note 1st true leaf is a compound leaf. Large stipules present at leaf axils of larger plants.

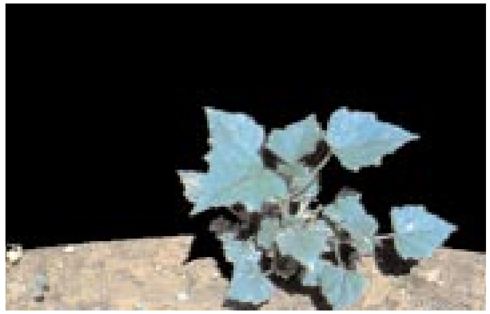


sicklepod

showy crotalaria

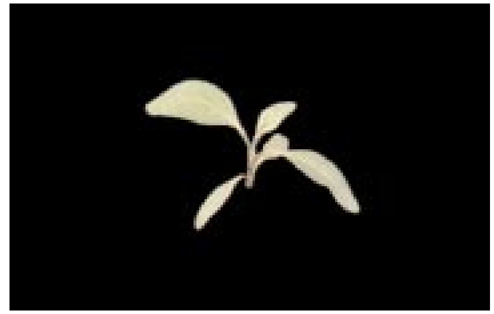
prickly sida

Note lack of hairs and small cleft in tip of cotyledons. Compare to spurred anoda, velvetleaf and hophornbeam copperleaf.

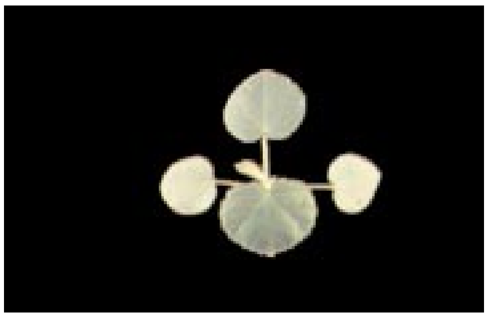



spurred anoda

Note larger cotyledons and distinct presence of hairs.

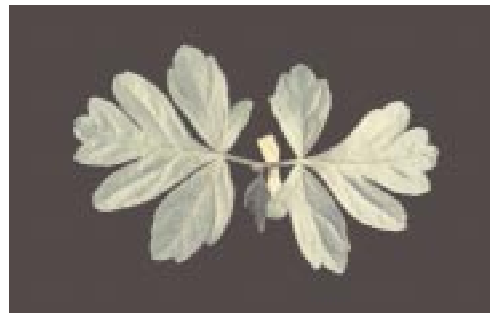



Pennsylvania smartweed

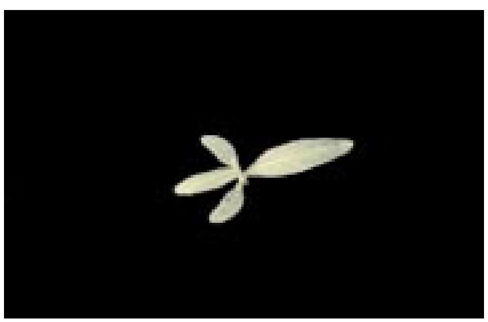



velvetleaf

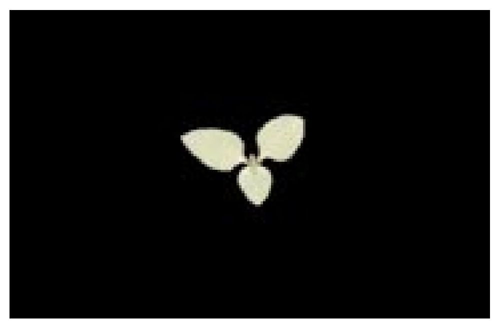
Note hairs present but plant must be closely examined to see.




balloonvine

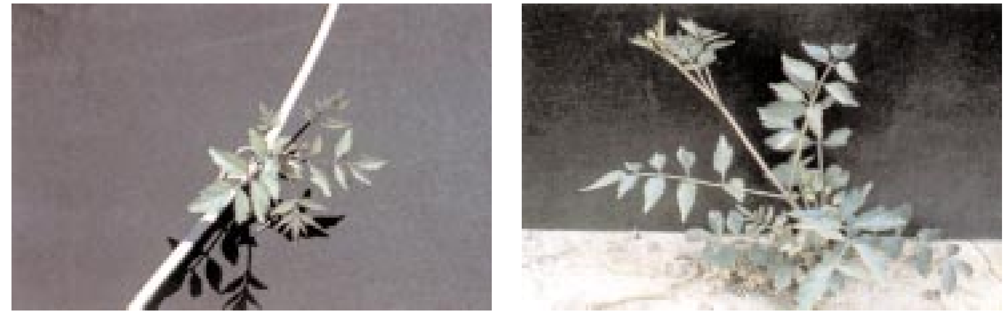



pale smartweed



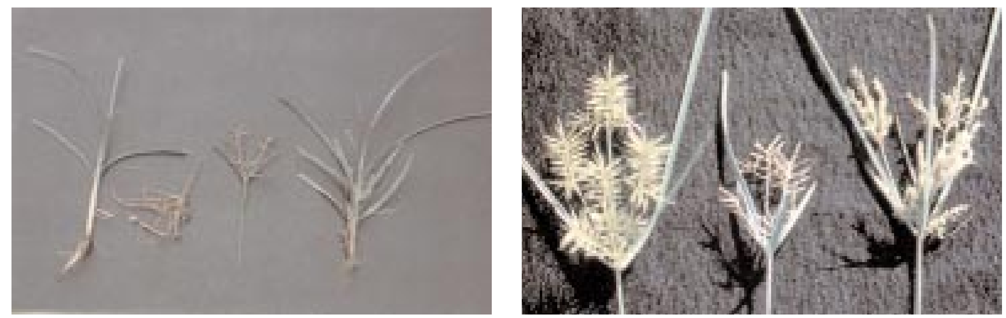

cutleaf groundcherry

jimsonweed



trumpetcreeper

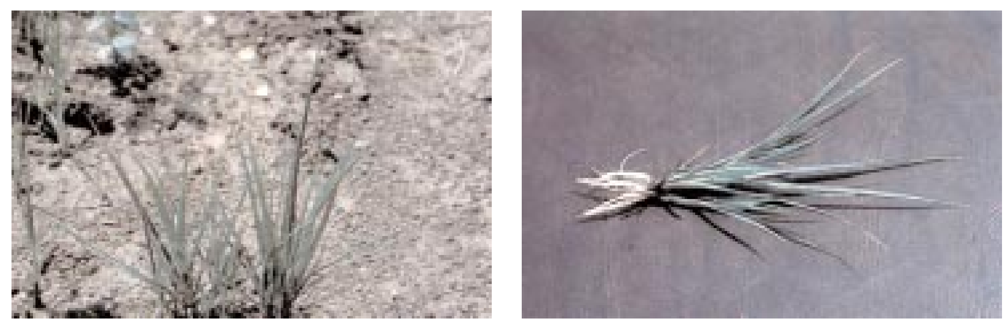
puncturevine



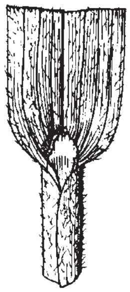
nutsedge

purple nutsedge – left picture. Yellow vs. purple nutsedge vs. annual sedge (L to R) – right picture. Both plants have underground tubers. Purple nutsedge tubers are rough and have distinct camphor taste. Yellow nutsedge tubers are smooth and sweet.

redvine

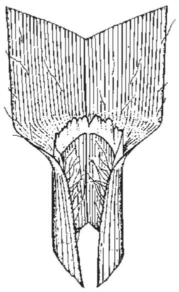


annual sedge



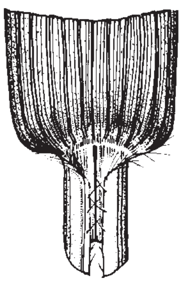
large or southern crabgrass

First leaf very short – only about two times as long as wide.
Leaf sheath and blades hairy.
Ligule – membranous.
Auricles – absent.



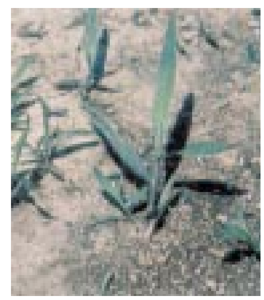
goosegrass

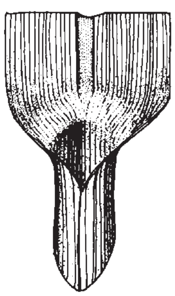
First leaf obviously ribbed with veins, and dark green lines.
Basal stem silver in color.
Leaf sheath – light green or white.
Ligule – very short, ciliated membrane.
Long hairs on leaf base.
Auricles – absent.



broadleaf signalgrass

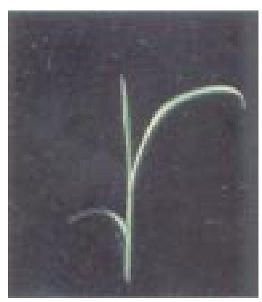
First leaf four to five times as long as wide – often reddish.
Basal stem often purple to red.
Hairs short (velvety texture).
Sheath – densely hairy.
Blades – often tinged maroon, velvety hairy. Collar region red on edges.
Ligule – a fringe of hairs.
Auricles – absent.

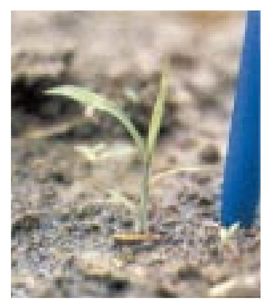




barnyardgrass

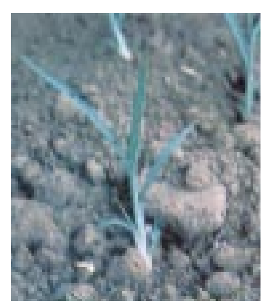
Stems flattened.
Sheath – smooth and flattened with solid, overlapping, smooth margins. Sometimes tinged maroon.
Blade – smooth on both sides.
Ligule – completely absent.
Auricles – completely absent.





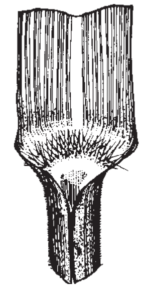
junglerice

Very similar to barnyardgrass except leaf blade has red watermarks.
Ligule – completely absent.
Auricles – completely absent.



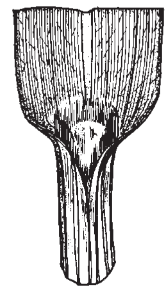

fall panicum

Seedling leaf blades densely hairy on both surfaces.
Less hairy in older seedlings.
Leaf sheath – hairy with overlapping membranous margin.
Ligule – row of dense hairs approximately 1 mm long.
Auricles – absent.



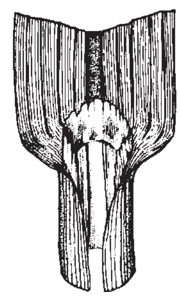

giant foxtail

Leaf blade – hairy upper surface (must be closely examined on seedling) and smooth to rough lower surface.
Leaf sheath – smooth and split with overlapping sparsely hairy margins.
Ligule – a hairy ring.
Auricles – absent.



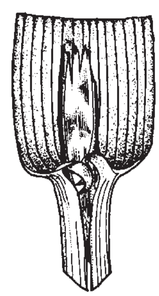

johnsongrass

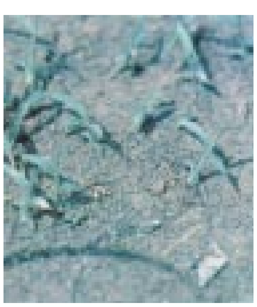
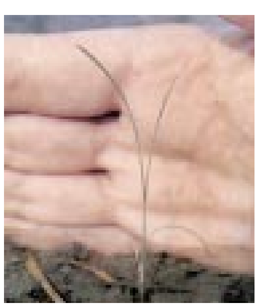
Leaf blade – smooth on both surfaces, midvein distinct at base as broad white line. Often has reddish spots caused by leaf rust. First leaf short.
Stem – reddish in lower portion.
Ligule – long rounded membrane.
Auricles – absent.
No evidence of rhizomes in seedlings up to 5th leaf stage.




red rice

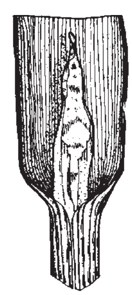
Leaf blade – rough textured when rubbed from tip to base.
Ligule – long membrane.
Auricles – present, clasping, hairy.



loosehead (bearded) sprangletop

Leaf blade – flat to slightly inrolled. Youngest leaf rolled. Distinct white midrib but often not obvious on seedling plants. Leaf blades obviously ribbed on seedling plant. Leaf on older plants very long and slender.
Leaf sheath – smooth and open.
Ligule – very long, thin, pointed membrane.
Auricles – absent.
A similar species, tighthead sprangletop, has shorter ligule and lacks the white midrib on older leaves.



DIVISION OF AGRICULTURE
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Nematode Management

Terry Kirkpatrick, Travis Faske and Bob Robbins

Although many different nematodes can be associated with soybeans in Arkansas, only a few are sufficiently damaging to the crop to be of economic concern. Unfortunately these economic species are widespread throughout the soybean production regions of the state. Yield suppression as high as 50% may occur with these nematodes at high population densities under the right conditions.

Three nematode species – the southern root-knot nematode (RKN), *Meloidogyne incognita*, the soybean cyst nematode (SCN), *Heterodera glycines*, and the reniform nematode (RN), *Rotylenchulus reniformis* – are responsible for the majority of soybean yield losses due to nematodes. In addition, the lesion nematode (LN), *Pratylenchus* spp., occasionally may suppress soybean yield. Historically in Arkansas, SCN was the most widespread, but in recent years RKN has surpassed it as our most common nematode. RKN is also the most damaging species and can actually kill infected plants in sandy soil types if populations are high enough (Figure 10-1).

Figure 10-1. Severe root-knot nematode damage in soybeans.

Root-Knot Nematodes

As the name implies, RKN damages plants by inducing knot-like swellings (called galls) to form on roots of infected plants (Figure 10-2). These galls can lower the ability of the root system to absorb and translocate water and nutrients, and they also provide entry points for secondary fungal pathogens that may further damage the roots.

Figure 10-2. Root galling caused by the root-knot nematode.

Life Cycle – RKN overwinters in the soil as eggs in egg masses attached to roots of the previous crop, although in mild winters, particularly in southern Arkansas, immature nematodes (juveniles) may be present in the soil throughout the winter. When soil temperature is favorable (77°-86°F), eggs hatch and juveniles migrate to soybean roots. RKN enter roots and migrate to the vascular tissue where they establish a permanent feeding site, become stationary and develop through three molts to adults. The feeding activity of the adult female induces gall formation. Within 20-30 days, depending on soil temperature, several hundred eggs are deposited into an egg mass on the surface of the root.

Symptoms – Root galls are diagnostic for RKN. It is the only nematode that causes root galling. RKN is not uniformly distributed in fields, and the presence of "hot spots" with stunted, yellow plants is an indication that RKN may be involved (Figure 10-3). Because infection interferes with normal root function, nutritional deficiency symptoms are commonly associated with nematode-infected plants. During late season, severe root-knot damage may actually include plant death, due in part to the activity of secondary fungal pathogens. The severity of yield suppression caused by RKN is dependent on several factors that include the population density of the nematode and the severity of other stress factors in the field.

Figure 10-3. Symptoms of RKN in a field. Note the presence of hot spots.

Soybean Cyst Nematodes

In contrast to RKN, SCN does not cause gall formation on soybean roots. SCN can, however, be relatively easily diagnosed with a hand lens because they are visible on the exterior of the root as small white or yellow lemon-shaped females (Figure 10-4). As the females age, they turn darker in color and die – becoming the cysts for which the nematode is named (Figure 10-5).

Figure 10-4. White soybean cyst females attached to soybean roots.

Life Cycle – The nematode overwinters primarily as eggs that are encased in the cysts. Both the cysts and the eggs themselves are very resistant to damage from the environment, and some eggs within cysts may remain viable for at least eight years in the absence of a host. In the spring, eggs hatch and the immature (juvenile) nematodes emerge from cysts to infect soybean roots. The juveniles infect the roots and establish a feeding site where they remain through the remaining three molts. In contrast to RKN that reproduces by parthenogenesis so mating of males and females is not necessary, adult SCN males leave the root and mate with adult females who are attached to the roots by their head and neck. Within a few days after mating, females begin to lay eggs that are either retained inside the body or deposited into an egg mass attached to the posterior of the female. The generation time for SCN is around 25 days at favorable soil temperatures (75º- 82ºF).

Figure 10-5. Ruptured soybean cyst containing eggs and second-stage juveniles.

Symptoms – Plant symptoms of SCN infection can range from essentially undetectable to readily apparent depending on the severity of the problem. SCN can occur in the field as a number of biotypes, called "races" or "HG types," that differ in their ability to parasitize different soybean cultivars and breeding lines. Some of these biotypes cause more dramatic symptoms than others on certain cultivars. In general, however, symptoms of severe SCN infection are similar to those with RKN, although it is rare for SCN to result in plant death. Stunted, chlorotic plants, particularly when they occur in patches or localized areas in fields, are an indication that SCN may be involved.

Reniform Nematodes

Detection of RN in the field is more difficult than with either RKN or SCN because they do not produce cysts or cause root galling.

Life Cycle – RN overwinter as eggs in egg masses attached to root pieces or as juveniles or immature adults free in the soil. In the spring, males and infective females partially enter roots and establish a feeding site. As the females mature, they become reniform- or kidney-shaped and can sometimes be seen with a hand lens protruding from the root surface (Figure 10-6). The life cycle of RN is slightly shorter than for RKN or SCN and is completed in 17-23 days at favorable temperatures (81°-86°F).

Figure 10-6. Mature female reniform nematodes protruding from the surface of a soybean root.

Symptoms – As with SCN, symptoms of RN damage are general stunting and chlorosis of infected plants. RN are less widely distributed in Arkansas than RKN or SCN and are much more common in southeastern Arkansas than in production areas in the northeastern part of the state. RN have not been detected in Southwest Arkansas or in the Arkansas River Valley. RN is generally more uniformly distributed within fields than either RKN or SCN, so patches or "hot spots" of stunted plants are not usually obvious. Root systems of infected plants may be smaller than normal with fewer feeder roots, and foliage may exhibit nutrient deficiency symptoms or a general chlorosis. However, the only accurate method for determining RN presence is through a soil assay for nematodes conducted by a nematology laboratory.

Lesion Nematodes

On occasion, lesion nematodes may be found at high levels in soybeans. This nematode has only infrequently been associated with yield loss in soybeans, but severe root infection can suppress plant growth and yield. LN are migratory endoparasites that penetrate into the roots and feed in the cortex, without any external signs other than the formation of discolored lesions that occasionally form on feeder roots. A soil assay by a nematology laboratory is required for detection of LN.

Nematode Management

The foundation of any nematode control program is the identification of the types of nematodes that are present and an estimation of their relative population density. The most effective means of determining these things is with a soil sample that is assayed by a nematology laboratory. Careful and thorough sampling of each field and proper handling of the sample after collection are vital to developing an effective nematode control program.

The Arkansas Nematode Diagnostic Laboratory

The Arkansas Nematode Diagnostic Laboratory located at the Southwest Research and Extension

Center near Hope, Arkansas, offers soil nematode assay for a small fee to any Arkansas producer. Details of this service and a list of fees may be obtained by emailing rbateman@uada.edu or by contacting your local county Extension agent.

There are two types of nematode samples: predictive samples, which are collected in the late summer or early fall to help determine a strategy for the next year, and diagnostic samples that are collected during the growing season to help diagnose a nematode problem in the current crop.

Predictive Samples

Collecting soil for a predictive nematode assay is done in much the same way as for a soil test for fertilizer recommendations. Sample each field thoroughly. Large fields should be divided into smaller blocks so that no more than 50 acres is represented by a single sample. Where obviously different soil types exist in a field, sample each soil type separately. A sample is defined as a composite of several subsamples (soil cores) collected across the field with a soil sampling tube. Cores should be taken in the bed or in the root zone for flat-planted crops to a depth of 6 to 8 inches using a soil core sampler (sampling tube). Include at least 20 individual cores to represent each field that is sampled. The total volume of soil per sample should be approximately one pint.

A second type of predictive assay that is available is a SCN race determination. This test is a biological assay that actually evaluates the ability of the SCN detected in the soil to reproduce on an array of soybean cultivars (called differentials) – which is how races are determined. With this test, SCN are isolated from the soil sample and increased in a greenhouse by growing them for 45-60 days on a susceptible soybean cultivar. The SCN is then inoculated onto the soybean differentials and allowed to grow for about 30 days to ensure that a single generation of the nematode has been completed. The race is then determined based on the ability of the nematodes to reproduce on the differentials.

Diagnostic Samples

Diagnostic samples are used to determine if nematodes are present in a particular field or are causing a specific problem. These samples are mainly used to identify possible causal agents and quantify the types of nematodes that are associated with the issue. Diagnostic samples can be taken at any time during the growing season, but are most useful if they are taken soon after a problem is seen. In addition to soil samples, plants in the affected area should also be dug up (carefully, as if preparing to transplant) with a shovel and root systems inspected for the presence of galls, cysts or lesions. It is generally a good practice to collect soil and plants from the affected area and also soil and plants from adjacent areas that are not showing symptoms for comparison. Either a core sampler or a cone sampler (Figure 10-7) can be used to collect soil for diagnostic samples, and soil should be collected within the root zone. If neither a core or cone sampler is available, a shovel can be used to collect a composite sample. Soil that is shaken from the root system can be used for the soil assay, and the roots can be inspected for signs or symptoms of nematodes. The total volume of soil per sample should be approximately one pint, and root samples should be placed in a separate bag.

Figure 10-7. Cone-sampler (left) and core sampler (right) for collection of soil samples.

Proper Handling of Samples

Nematodes are living organisms and must remain alive until the assay is performed. This means that special care is needed in handling, storing and shipping soil samples for an accurate nematode assay. Immediately upon collection, place each composite sample into a plastic bag and seal the bag to retain moisture. Label the outside of the bag with the field number or name and the farm name. Protect soil in the bag from direct sunlight and from excessive heat or cold as this could contribute to an inaccurate count of nematodes in the soil sample. Placing the samples into insulated coolers (without ice) is the best way to protect nematodes samples until they can be shipped to the nematology laboratory. Samples in sealed plastic bags may be stored for several days in insulated coolers at cool (60°F) room temperature, but should be shipped soon after sampling. If samples are diagnostic, plant samples should, however, be either stored in an ice chest with ice or in a refrigerator until they are shipped. DO NOT STORE SOIL FOR NEMATODE ASSAY ON ICE.

Thresholds

Although many factors influence the severity of the damage that can be caused by nematodes, thresholds have been established for RKN, SCN and RN that can be useful guidelines for determining the risk associated with nematodes in a particular field or site. Thresholds are the population densities at which there is a high probability of yield loss due to the nematode. Although thresholds provide a general guide to identifying problem fields, keep in mind that the presence of these nematodes at any level in a field indicates a potential problem. As indicated earlier, samples collected during late summer or early fall are the most useful in predicting nematode risk for the following year. Samples collected in the winter or early spring may not accurately detect RKN or SCN because at that time the population is surviving mainly as eggs that are not recovered efficiently with most laboratory soil assay procedures. It appears that because RN survives well as juveniles or immature adults, samples during the winter or spring are useful in predicting crop risk. Thresholds that are used in Arkansas in reporting results from soil assays are given in Table 10.1.

Table 10-1. Soil population density thresholds for soybeans.

Nematode	No. Nematodes/100 cm^3 of Soil	
	June - November	December - May
RKN	60	NA*
SCN	500	NA
RN	1,000	500

*Not appropriate – soil samples collected during this time period may not be accurate.

Resistant Cultivars

Planting nematode-resistant cultivars is an effective and economical method for managing nematode problems. Resistance in the cultivar must match the nematode that is present in the site, and there are RKN-, SCN- and RN-resistant cultivars available. Very few cultivars, however, are resistant to all three species. In addition, as indicated earlier, SCN can occur as numerous races, so resistance to one biotype may not provide resistance against others. Information on the nematode-resistant cultivars that are available and adapted to Arkansas is available through all county Extension offices, in the current *Soybean Update* and in SOYVA. As a service to growers, many new cultivars are screened for nematode resistance each year through the annual Soybean Cultivar Disease Screening Program that is supported through the Arkansas Soybean Promotion Board. This information is used to develop the annual *Soybean Update*, which is available at http://www.arkansasvarietytesting.com/. Although few RKN-resistant MG IV cultivars are available, there are numerous MG V cultivars with good resistance to RKN. Planting a resistant cultivar generally results in yield improvement of 10%-25% depending on the severity of the problem, although where RKN is extremely severe, yield improvement can be much greater (Figure 10-8). An additional advantage of growing a resistant cultivar is that generally nematode population densities decline in the site. Some cultivars are advertised as moderately resistant or moderately susceptible to RKN, and these may result

Figure 10-8. RKN-resistant cultivar (foreground) and susceptible cultivar.

in a significant yield improvement if the nematode pressure is not excessive. However, most of these cultivars also allow the nematode to reproduce at nearly normal rates, so nematode populations remain high and may pose a risk for the next crop that is grown in the field. Numerous SCN-resistant cultivars are available across all soybean maturity groups, but these cultivars are not resistant to all SCN. Unfortunately, a majority of the available SCN-resistant cultivars are effective against races of historical importance in Arkansas (races 3, 9 and 14), none of which are common in the state today. A few RN-resistant cultivars exist, but the majority of soybean cultivars are susceptible to this nematode. No cultivars with LN resistance are known to exist.

Crop Rotation

Crop rotation has become a much more attractive tactic in an overall nematode management strategy in recent years due to the increasing diversity of Arkansas crop production systems. Growing crops that are not hosts for a particular nematode can be a very effective way to lower nematode population densities, and the inclusion of a non-host in the cropping sequence at the appropriate times can maintain nematode populations below economic levels for sustained periods of time. As with selection of the right resistant cultivar, it is vital that the cropping sequence be matched to the nematode species that are to be managed. For example, if SCN is the issue, then any of our more popular crops including rice, corn, cotton, grain sorghum or peanuts can be effective in lowering nematode density because none are hosts for SCN. However, if RKN is severe, then growing rice, peanuts or grain sorghum can effectively lower the nematode population, but growing cotton, corn or soybeans in the field will likely enhance the severity of the problem. Always obtain an accurate identification of the nematode(s) that are of economic concern in each field before planning a rotation sequence. Suggested crops for management of RKN, SCN and RN are listed in Table 10.2. Rice and cotton are effective in lowering LN populations.

Table 10-2. Suggested rotation crops for nematode management.

Nematode	Suggested Crops	Crops Not Recommended
RKN	grain sorghum peanut rice	corn cotton vegetable crops (watermelon, tomato, sweet potato, etc.)
SCN	grain sorghum corn cotton peanut rice	green beans
RN	grain sorghum corn peanut rice	cotton vegetables
LN	rice cotton	corn grain sorghum peanut

Nematicides

Few nematicides are available for use in soybeans, and generally nematodes can be managed much more economically through the use of resistant cultivars and crop rotation.

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Soybean Diseases

Travis Faske, Terry Kirkpatrick, Jing Zhou and Ioannis Tzanetakis

Soybean diseases can be a significant economic factor in Arkansas. On average, diseases reduce yields in the state by an estimated 10%, although in individual fields and with certain diseases, losses may be much higher. Because soybean pathogens are common statewide, accurate disease identification and an awareness of the potential for disease losses are essential for the continued success of Arkansas soybean production. The following symptom descriptions and color photographs of common diseases in Arkansas should help you identify and manage soybean diseases before they become a yield-limiting problem.

Bacterial Diseases

Bacterial Blight

Bacterial blight is the most common bacterial disease of soybeans and occurs in all soybean-producing regions of the world. Although this disease is of limited importance in most Arkansas production areas, it is one of the first leaf spot diseases to appear on young plants. Bacterial blight has been reported to cause significant yield reductions on susceptible cultivars under heavy disease pressure.

Bacterial blight is primarily a leaf disease, but symptoms can occur on stems, petioles and pods. Leaf symptoms begin as small, angular, translucent, water-soaked yellow to light-brown spots. As the spots age, their centers darken to a reddish-brown, become sunken and are surrounded by a water-soaked margin bordered by a yellowish-green halo (Figure 11-1). The halo is more noticeable on the upper leaf surface. When environmental conditions favor disease development, spots may enlarge and merge to form large, irregular, necrotic areas. These large dead areas of the leaf often fall out or tear away after strong winds and beating rains, giving leaves a ragged appearance. When disease is severe, premature defoliation may occur.

Figure 11-1. Small necrotic lesions with yellow halos caused by bacterial blight. ***(Photo by T. R. Faske)***

Leaf symptoms of bacterial blight may resemble those of the fungal disease brown spot. However, bacterial blight moves upward within the canopy rapidly whereas upward movement is slow for brown spot. A simple test for bacterial blight is to hold infected leaves to the light; bacterial blight spots will be translucent.

Bacterial blight is caused by the bacterium *Pseudomonas savastanoi* pv. *glycinea* which overwinters in seed and infected soybean debris. Lesions develop on cotyledons from infected seed and can spread to cause secondary infection on leaves. The pathogen enters the plant through stomata or wounds. The bacterium is spread from infected tissue by wind-blown rain and during cultivation or spraying when the foliage is wet. Seeds can be infected through the pods during the growing season. Windy, cool, rainy weather at temperatures of 75° to 79°F favor the development of bacterial blight whereas hot, dry weather suppresses its development.

Management of this disease is primarily dependent on cultivars that are resistant to bacterial blight. Cultural management practices consist of planting high-quality, disease-free seed and using tillage practices that lead to rapid decomposition of crop residue. Narrow row widths and high plant populations should be avoided in fields with a history of bacterial blight.

Bacterial Pustule

Bacterial pustule has been reported worldwide. In Arkansas, bacterial pustule is not as common as another bacterial disease, bacterial blight, and is of minor importance because of the availability of highly resistant cultivars.

In susceptible cultivars, early symptoms are characterized by small yellow-green spots with elevated reddish-brown centers that are most conspicuous on upper leaf surfaces (Figure 11-2). As these leaf spots mature, a small, slightly raised, pale-colored pustule develops at the center of each lesion that is most noticeable on lower leaf surfaces. Leaf lesions vary from very small specks to large, irregular, mottled necrotic areas depending on the susceptibility of the cultivar and environmental conditions. Diseased leaves develop a ragged appearance when the necrotic areas are torn away by stormy or windy weather. Severe infection often results in premature defoliation that may decrease yield by reducing seed numbers and size.

Figure 11-2. Small, reddish brown lesions caused by bacterial pustule. ***(Photo by C. Coker)***

Symptoms of bacterial pustule may resemble those of bacterial blight, and it is common for both diseases to occur together. Pustule formation and the absence of a water-soaked appearance during the early stages of lesion development (before the leaf spots turn yellow) distinguish bacterial pustule from bacterial blight.

Bacterial pustule is caused by *Xanthomonas axonopodis* pv. *glycines* that overwinters in infested seed and soil on crop residue. The bacteria spread from crop residue or nearby diseased plants by splashing water, windblown rain and during cultivation when the foliage is wet. The bacterium enters the plant through stomata and wounds. Disease development occurs during warm (86° to 91°F), wet weather conditions.

Management of this disease is primarily dependent on the use of cultivars that are resistant to bacterial pustule. Cultural practices include planting high-quality, disease-free seed and using tillage practices that hasten rapid decomposition of crop residue. Cultivation when foliage is wet should be avoided to reduce disease spread.

Fungal Diseases

Anthracnose

Anthracnose occurs worldwide and reduces plant stand, seed quality and yield by 16% to 26% in the U.S. Anthracnose is also an important disease in Arkansas with pod infections contributing to a greater impact on yield loss than stem or petiole infections.

Soybeans are susceptible at all stages of development. Pre- and post-emergence damping-off occurs when infected seeds are planted. On emerging seedlings, dark brown, sunken lesions develop on the cotyledons. These lesions can extend along the stem when conditions favor disease development, causing one or both cotyledons to become water soaked, wither and abscise from the stem. Under severe disease development, numerous small lesions may kill young plants.

Foliar symptoms often occur at early reproductive growth stages with irregular-shaped brown lesions that develop on stems, petioles and pods. Premature defoliation may occur throughout the canopy on maturing plants when anthracnose lesions girdle the leaf petiole, resulting in a shepherd's crook symptom (Figure 11-3). Early-season infection of pods or pedicels can result in fewer and smaller seed or no seed development.

At advanced stages of disease development, near soybean maturity (R7-R8), black fungal fruiting bodies called acervuli that produce minute black spines (setae) are abundant and randomly distributed on infected tissue. Setae are diagnostic of anthracnose and may be seen with a good hand lens or a dissecting microscope (Figure 11-4). In contrast, the fungal

Figure 11-3. Shepherd's crook caused by anthracnose canker on a petiole. ***(Photo by T. R. Faske)***

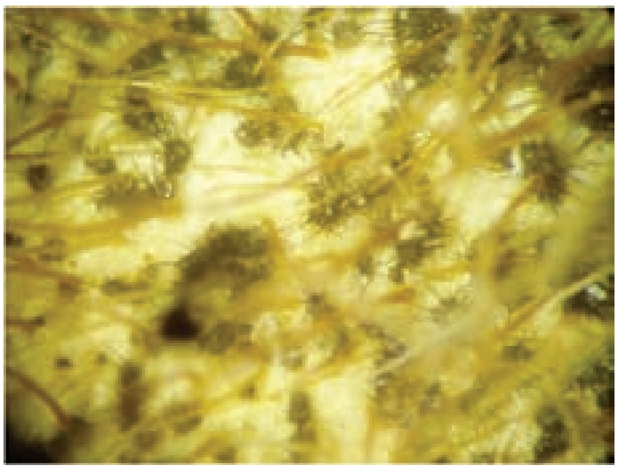


Figure 11-4. Acervuli of *Colletotrichum truncatum* on soybean pod. ***(Photo by A. Greer)***

fruiting bodies of another common pathogen on pods and stems, *Diaporthe phaseolorum*, which causes pod and stem blight, do not contain setae and are often arranged in rows.

Anthracnose is caused by *Colletotrichum truncatum* and several related species, which overseason as mycelium on crop residue or in infected seed. Infected seed may result in damping-off, or seedlings may become infected and colonized by the fungus without symptom development until early reproductive stages. Warm, wet weather favors stem and pod infection whereas dry weather suppresses disease severity.

Management of anthracnose includes the use of high-quality, disease-free seed and tillage or rotation practices that reduce soybean residue. Applying a fungicide between beginning pod development (R3) and initial seed formation (R5) can be effective at suppressing anthracnose. Fungicide seed treatments are also effective at minimizing the effects of anthracnose on seedlings.

Brown Spot

Brown spot or Septoria leaf spot has been reported throughout the southern U.S. soybean-growing region. This disease can cause premature defoliation that contributes to yield losses when susceptible cultivars are planted and conditions favor disease development. This disease is of minor importance in Arkansas because it rarely causes significant yield losses.

Irregular, small brown leaf spots vary in size from a small speck to 1/5 inch in diameter and develop on the upper and lower leaf surfaces. Adjacent leaf spots may coalesce resulting in irregular-shaped blotches. The lesions gradually darken to blackish brown and often develop a yellow halo around the leaf spot (Figure 11-5). Additionally, irregular-shaped brown lesions with undefined margins may form on the stem, petioles and pods. Though leaf spots are generally confined to the lower canopy, the disease may progress to the upper canopy under favorable environmental conditions. As the plant nears maturity, severely infected leaves appear rusty brown and may drop prematurely.

Figure 11-5. Brown lesions with yellow halo caused by brown spot. ***(Photo by T. R. Faske)***

A visual examination of infected leaves by holding them to light reveals that brown spot leaf lesions are dark and opaque. In contrast, bacterial blight lesions, which may appear similar to the casual observer, are translucent.

Brown spot is caused by the fungus *Septoria glycines*, which overwinters on crop residue and in infected seed. Initial infections develop on cotyledons and leaves from conidia (spores) discharged from pycnidia, which are flask-shaped fruiting structures that form on crop debris. Conidia germinate on leaf surfaces and enter the plants through stomata. Secondary infection occurs as conidia are dispersed upward in the canopy by wind or splashing rain on leaves, petioles, stems and pods.

Infection and disease development may occur at any time during the season. Optimum conditions for disease development are warm (79° to 83°F), wet weather. Hot, dry weather conditions, on the other hand, suppress disease development. Consequently, brown spot is most severe when soybeans are planted early, particularly after extended periods of rainfall, where soybeans are grown continuously in the same field, or when the crop is planted in poorly drained fields.

Soybean cultivars vary in susceptibility to brown spot, so planting a less susceptible, adapted cultivar will suppress this disease. Cultural practices that may help minimize brown spot include planting high-quality seed, rotating with non-host crops (corn, cotton, rice or grain sorghum) for 2 years and implementing tillage practices that reduce crop residue on the surface of the field. In rare situations where brown spot is severe enough to pose a threat to yield, and where yield potential is high and conditions favor continued disease severity, a fungicide application timed between beginning pod fill (R3) and initial seed formation (R5) can be effective in minimizing yield loss.

Cercospora Leaf Blight and Purple Seed Stain

Cercospora leaf blight and purple seed stain are caused by the same fungal pathogen. Disease development typically occurs late in the growing season from beginning of seed development through pod fill. Though both diseases have been reported in all soybean-growing regions of the U.S., yield losses are higher in southern states.

The first visible symptom of Cercospora leaf blight is a light purple discoloration on the upper leaf surface. This discoloration can deepen and expand to cover part or the entire upper leaf surface, giving a leather appearance, sometimes mistaken for sunburn. Numerous infections cause rapid necrosis of leaf tissue resulting in defoliation, starting in the upper canopy. Lesions on petioles or stems are reddish purple and several millimeters in length (Figure 11-6). Infected petioles remain attached to the plant that has been defoliated by Cercospora leaf blight (Figure 11-7).

Figure 11-6. Purple discoloration of a soybean leaf caused by Cercospora leaf blight. *(Photo by C. Coker)*

Figure 11-7. Cercospora leaf blight on stems and petioles with accompanying defoliation. *(Photo by C. Coker)*

Purple seed stain is characterized by irregular light to dark purple blotches on the seed that may cover much or even all of the seed coat. Infection can lower seed quality, germination and seedling vigor. Prolonged delay of harvest may contribute to a higher frequency of seed infection and discoloration.

The fungus *Cercospora kikuchii* is the causal agent of both diseases that overwinter in crop debris and infected seed. The pathogen produces a light-activated plant toxin called cersposporin, which is suspected of contributing to the reddish-purple discoloration of diseased tissue. Spores produced on infected debris are dispersed by wind or rain onto nearby soybean plants. Infection and disease development are favored by extended periods of high humidity and warm weather (82° to 86°F).

Disease management strategies include planting high-quality, disease-free seed, using tillage practices that hasten decomposition of crop residue, growing the least susceptible cultivars that are adapted for the area, crop rotation with non-host crops such as corn, cotton, rice or sorghum, and timely harvest. Fungicides applied when weather conditions favor disease may suppress disease severity.

Downy Mildew

Downy mildew is distributed worldwide and is frequently observed in Arkansas, but rarely causes yield losses. Under extremely favorable environmental conditions, the disease may become severe enough to cause premature defoliation contributing to lower seed quality and reduced seed size.

Early symptoms of downy mildew may occur on young plants, but the disease does not become widespread in a field until late vegetative or early reproductive growth stages. Downy mildew appears on the upper leaf surface of young leaves as pale green or light yellow lesions (Figure 11-8). Lesion size and shape depend on leaf age. Older lesions may turn grayish brown to dark brown with yellow-green margins. On lower leaf surfaces, when conditions favor disease development, lesions are covered with grayish tufts of fungal hyphae and spores. Severely infected leaves turn from yellow to brown and prematurely drop. In some regions, although rarely in Arkansas, infected seeds may produce systemically infected seedlings. Systemically infected plants remain stunted, and grayish tufts are commonly observed on the underside of leaves. With systemic infection, light green areas appear at the base of young leaves and spread along the vascular system infecting the entire plant.

Figure 11-8. Upper (light green spots) and lower (grayish-beige downy tufts) leaf surface of soybean leaves with downy mildew. ***(Photo by T. R. Faske)***

Downy mildew is caused by *Pernospora manshurica* which overwinters in leaf debris and less often on seeds. The fungus survives as oospores (thick-walled resting spores) that germinate and infect seedlings the following spring. Once infection has occurred, sporangia (infectious spores) are produced on newly infected leaves from sporangiophores (spore stalks). These fungal structures make up the tufts of down-like growth that can be seen on the lower leaf surface, hence the name downy mildew. Sporangia are dispersed by wind to infect other plants. Disease development is favored by cool (68° to 72°F) temperatures and high humidity. Temperatures above 86°F halt fungal sporulation. Soybean leaves become more resistant as they age, and although lesions may increase in number, they decrease in size on older leaves.

Management practices for downy mildew include use of resistant cultivars, fungicide seed treatment, crop rotation with something other than soybeans for a year and crop residue destruction.

Frogeye Leaf Spot

Frogeye leaf spot is a common fungal disease in Arkansas. If not managed properly, severe yield losses can occur on a susceptible cultivar when conditions favor disease development.

Leaf spots are circular to angular in shape and range from 1/32 to 6/32 inch in diameter (Figure 11-9). Leaf symptoms begin as dark brown, water-soaked spots and mature into lesions with tan or brown centers and a narrow reddish-brown to purple margin. Older lesions are translucent and have whitish centers containing black dots (stromata). In severely infected plants, several lesions may coalesce into larger irregular-shaped spots. When

Figure 11-9. Frogeye leaf spot lesions on a soybean leaf. ***(Photo by T. R. Faske)***

leaves are heavily infected (> 30% severity), they may wither quickly and prematurely shed, a condition called blighting.

Stem and pod symptoms are less common, but may appear late in the growing season with prolonged conditions that favor disease development. Stem lesions are elongated whereas pod lesions are circular. Mature lesions are slightly sunken with light gray centers and brown borders. The fungus can grow through the pod into the seed. Infected seeds may be gray to brown in color.

The causal agent is a fungal pathogen, *Cercospora sojina*, which overwinters on soybean residue and seed. Conidia (spores) produced on crop residue are dispersed by splashing rain or wind onto soybean plants. Warm (81° to 85°F), wet weather (e.g., heavy dew) conditions favor infection and disease development. Symptoms become visible 7 to 14 days after infection. Infection can occur at any stage of development, but young leaves are more susceptible than older leaves. Five known races of this pathogen have been reported in the U.S., and in the South, races at any location may change dramatically from year to year. Reaction of cultivars varies from highly resistant to susceptible.

Host resistance is the most effective and economical management practice for frogeye leaf spot. Single dominant genes *Rcs1*, *Rcs2* and *Rcs3* confer resistance to races, 1, 2 and 2 + 5, respectively. Rcs3 is the only gene with multi race resistance, and it confers resistance to all races that are known to occur in the U.S. Fungicides can be effective in managing the disease and are most effective when applied preventatively to protect new growth when conditions favor disease development. The most favorable environmental conditions often occur from full bloom to beginning seed (R2 to R5) in Arkansas. Strobilurin-resistant populations of *C. sojina* were confirmed in 2012 in several Arkansas counties, thus all strobilurin fungicides (FRAC 11) are not effective on these resistant populations of frogeye leaf spot. Triazole fungicides (FRAC 3) are effective on the strobilurin-resistant strains of *C. sojina*. Cultural management practices consist of planting high-quality, disease-free seed and implementing tillage practices that improve crop residue decomposition.

Aerial Blight

Aerial blight, also called aerial web blight or Rhizoctonia foliar blight, is a common disease on soybeans in the rice-growing regions of the U.S. and along the Gulf Coast. When the disease occurs in rice, it is referred to as sheath blight. This disease can cause significant yield loss in both soybeans and rice. Extensive yield losses (40% to 50%) have been reported in soybeans when conditions favor disease development.

Foliar symptoms often occur during late vegetative growth stages on the lower portion of the plant following canopy closure. Initially leaf symptoms appear as water-soaked, grayish-green lesions that turn tan to brown at maturity (Figure 11-10). The pathogen may infect leaves, pods and stems in the lower canopy. Reddish-brown lesions can form on infected petioles, stems, pods and petiole scars. Long strands of web-like hyphae can spread along affected tissue (Figure 11-11), and small (1/16 to 3/16 inch in diameter) dark brown sclerotia form on diseased tissue (Figure 11-12).

Figure 11-10. Water-soaked, greenish lesions caused by aerial blight on soybean leaves. *(Photo by M. Emerson)*

Figure 11-11. Web-like hyphae of *Rhizoctonia solani* spreading along the stem of soybean. *(Photo by M. Emerson)*

Figure 11-12. Mature sclerotia of *Rhizoctonia solani* on soybean petiole. *(Photo by M. Emerson)*

Aerial blight is caused by a fungus, *Rhizoctonia solani* AG1-IA, which overwinters as sclerotia in soil or plant debris from the preceding crop. During warm, wet weather, mycelium spread extensively on the surface of plants forming localized mats of "webbed" foliage. Spread from these localized areas can be rapid when conditions favor disease (high RH and 77° to 90°F). Because this pathogen also causes sheath blight of rice, soybean fields that follow rice with a history of sheath blight are likely to have high incidence of aerial blight.

There is little resistance to *R. solani* in soybeans, but some cultivars are less susceptible than others. Plant the least susceptible and best-adapted cultivar. Rotating with poor or non-host crops such as corn or grain sorghum for 2 years and avoiding narrow row widths and high plant populations are good management practices. When aerial blight is present in highly susceptible cultivars and environmental conditions are favorable for disease, fungicides should be applied.

Soybean Rust

Soybean rust (SBR) was first reported in 1902 in Japan and has been an important disease in Asia and South America for many years. SBR recently became an important disease in the continental U.S. It was first reported in 2004 in Louisiana and was confirmed in eight other states including Arkansas the same year. Since 2004, SBR has been observed on average three of every five years in Arkansas. Yield losses (30% to 80%) have been reported in other countries; however, yield losses in the U.S. have remained low due to early detection and timely application of fungicides.

SBR (also called Asian soybean rust or Australasian soybean rust) is caused by the fungus *Phakopsora pachyrhizi*, which requires a living host to survive. Typically, symptoms are observed first on the leaves in the lower canopy at or after flowering (R1 to R3). Lesions appear as small (2-5 mm), tan or reddish-brown, angular spots on leaves. Lesions are often observed first at the base of the leaflet near the petiole. Volcano-shaped pustules (uredinia, Figures 11-13 and 11-14) can be observed within the lesion on the underside of the leaf. When pustules are mature, they rupture and exude spores (urediniospores) that cause new infections. Pustules can be observed in the field with a 20x hand lens (Figures 11-13 and 11-14), but may be misdiagnosed as bacterial pustule by untrained observers. As the disease progresses and secondary infections occur,

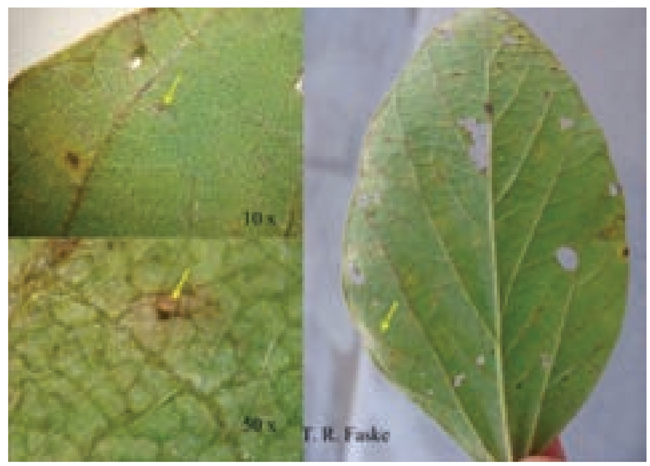


Figure 11-13. Soybean rust pustule (yellow arrows) development at no magnification (right) and 10x and 50x magnification (left). *(Photo by T. R. Faske)*

Figure 11-14. Numerous soybean rust pustules on the lower leaf surface of a soybean leaf. *(Photo by T. R. Faske)*

Figure 11-15. Defoliation of soybean leaves caused by soybean rust. ***(Photo by M. Emerson)***

leaves begin to turn yellow and defoliate (Figure 11-15). Severely diseased plants may completely defoliate resulting in fewer and smaller seeds.

Soybean is the most important agronomic host of *P. pachyrhizi*, but the fungus can parasitize several other members of the Fabaceae (legume) family, including kudzu and common bean. Soybean rust does not overwinter in Arkansas, so each year new infectious spores must be disseminated from Gulf Coast states where it overwinters mainly on kudzu. Soybeans are susceptible to rust at any stage of development, but are most susceptible during the early reproductive stages. Conditions that favor disease are extended periods of leaf wetness over a wide range of temperatures (61° to 82°F). Temperatures above 86°F retard disease development. Infection can occur within 6 to 12 hours under optimum conditions, and new spores can be produced within 7 to 10 days after infection. A single uredinium can continue to produce spores for a 3-week period. Thus, when conditions favor disease, there is a high potential for spore production and secondary infection.

Management of SBR relies mainly on fungicides. Although fungicides are effective at managing SBR, both the type of fungicide applied and timing of application are critical in disease management. Strobilurin fungicides are effective as protectants and should be applied prior to disease presence whereas triazole fungicides, which are systemic, can be effective after disease has been observed in the field. Triazoles, however, are also most effective when applied prior to disease development. Although data is limited in Arkansas, a fungicide applied after 10% disease incidence in the lower canopy under favorable environmental conditions in a South American field trial did not completely control rust. Since rust must be reintroduced each year into the state, early detection is crucial to management. An ongoing service provided to soybean growers in Arkansas is a network of sentinel plots and regular inspection of kudzu, and early-planted commercial fields to detect initial infections and provide early warning of disease presence in the state. Details of rust movement through the U.S. can be found on the IPM PIPE website or Arkansas Row Crops Blog. This early warning system allows timing of fungicides in high-risk fields for maximum effectiveness. In general, this will include a fungicide application during the early stages of reproduction (R1 to R3) and a second application made 14 to 21 days after first application. Applying a fungicide after the R6 growth stage may not provide a significant economical return; however, untreated fields may supply spores to later-planted soybeans in the area. A management tactic that appears to be effective in minimizing losses from SBR is simply planting early to avoid infection by late-season dissemination of spores from surrounding states or areas. Conversely, producers planting late-season soybeans or double-crop soybeans should budget for a fungicide application.

Target Spot

Target spot is a foliar disease that has been reported in all soybean-growing regions of the U.S. Yield losses of 18% to 32% have been reported on susceptible cultivars in some areas of the country when conditions favored disease for a prolonged period of time, but this disease rarely causes significant yield losses in Arkansas.

Leaf lesions are reddish-brown, round to irregular-shaped spots that range in size from 3/8 to 5/8 inch in diameter. Lesions are frequently surrounded by a yellowish-green halo. Larger spots on leaves often develop diagnostic zonate patterns, hence the common name target spot (Figure 11-16). Infected areas on stems and petioles are dark brown and range from specks to elongated lesions. Lesions on pods are typically small (1/32 inch), circular purple or black spots with brown margins.

Target spot is caused by the fungus *Corynespora cassiicola* that overwinters on crop debris. Initial infections require high humidity (> 80%) or free moisture. Dry weather conditions suppress disease development.

Figure 11-16. Single target-patterned leaf spot surrounded by a yellowish-green halo caused by target spot. Other smaller lesions are caused by frogeye leaf spot. ***(Photo by T. R. Faske)***

Typically, this disease is managed by using high-yielding soybean cultivars, managing surface crop residue and avoiding soybean monoculture. Fungicides are rarely justified economically.

Charcoal Rot

Charcoal rot is a root and stem disease that commonly occurs in hot, dry weather conditions. This disease is most severe when plants are stressed from lack of moisture or nutrients, at excessive plant populations, or where soil compaction, other diseases or nematodes or improperly applied pesticides impair root development.

Charcoal rot symptoms typically appear as soybeans approach maturity. The earliest symptoms are smaller than normal sized leaves, which become chlorotic, then turn brown, but remain attached to the petiole giving the entire plant a dull greenish-yellow appearance. In many cases, these plants wilt and die. At early reproductive stages, a light gray to silver discoloration of the sub-epidermal tissue develops on taproot and lower part of the stem (Figure 11-17).

At advanced stages of disease development, near soybean maturity (R6-R7), the lower stem epidermal tissue is often shredded in appearance and exhibits an ashy-gray discoloration. Removal of epidermal tissue reveals numerous small, charcoal-black fruiting bodies (microsclerotia) embedded in the lower stem and taproot (Figure 11-18). Microsclerotia are often so numerous they resemble charcoal dust, hence the name of the disease.

The disease is caused by the soilborne fungus *Macrophomina phaseolina* which can infect more than 500 plant species. The pathogen overwinters as sclerotia in soil or in crop debris, and these sclerotia can remain viable for at least 2 years. Infection can occur at seedling stage of development (2 to 3 weeks after planting), but symptoms remain latent unless the plants undergoes environmental stress during reproductive stages of growth. The optimal growth of the fungus is 82° to 93°F. Planting late-season or double-crop soybeans may encourage greater charcoal rot severity.

Figure 11-17. Discoloration of a lower soybean stem by charcoal rot. ***(Photo by T. R. Faske)***

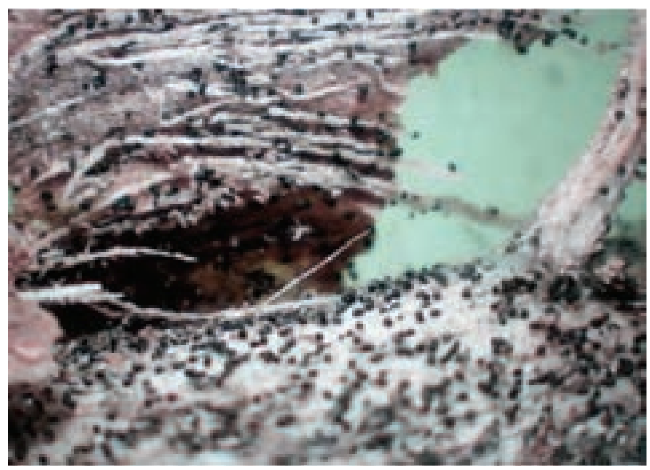


Figure 11-18. Numerous black microsclerotia of *Macrophomina phaseolina* on soybean. (Photo by A. Greer)

Currently, there are no commercially available resistant cultivars or fungal practices that effectively suppress charcoal rot. Fields with a history of severe charcoal rot should be rotated for 1 to 2 years with non-host crops (cereals). Avoiding excessive seed rates and maintaining adequate soil fertility to maintain healthy, vigorous plants reduces losses by this disease. The best way to avoid issues with charcoal rot is to limit drought stress during the reproductive stages of growth. Production systems like no-till that conserve soil moisture may also reduce losses by charcoal rot.

Pod and Stem Blight

Pod and stem blight is a common disease in all soybean-growing regions in the U.S. This disease can cause reduced seed quality and yield losses on susceptible cultivars when conditions favor disease development.

Infection may occur early in the season without any definite visible lesion development on leaf, stem, petiole or pod (Figure 11-19). Late in the season (R7), small, black, flask-shaped fungal fruiting bodies called pycnidia occur in linear rows on lower stems, petioles and pods, confirming early-season infection (Figure 11-20). Seeds within pods containing pycnidia are usually infected, thus reducing seed quality. Occasionally, bright red to brown lesions develop on cotyledons or hypocotyl (at or near soil line) of seedlings from infected seed.

Pod and stem blight is caused by a fungal pathogen, *Diaporthe phaseolorum* var. *sojina*, which overwinters in infected seed or on crop residue.

Figure 11-19. Pod and stem blight on soybean stem and pods. ***(Photo by A. Greer)***

Figure 11-20. Pod and stem blight fruiting structures on soybean pod. ***(Photo by A. Greer)***

Infection occurs when spores are splashed onto plants from crop residue or nearby diseased plants. Systemic, asymptomatic infection occurs throughout the growing season during prolonged warm (> 69°F), wet weather conditions. Such conditions favor seed infection and pycnidia development on maturing plants. Delayed harvest contributes to a higher incidence of infected seeds.

Management of pod and stem blight includes the use of high-quality, disease-free seed. Crop rotation to crops other than soybeans and tillage practices that hasten crop residue decomposition are helpful. Genetic resistance is available, and the least susceptible cultivars should be used in fields with a history of pod and stem blight. Timely fungicide applications during pod development (R3) and seed formation (R5) can be effective in suppressing disease development. Fungicide seed treatments can be effective at suppressing infection by pod and stem blight.

Stem Canker

Stem canker has been divided into two groups (northern and southern stem canker). Southern stem canker was first reported in 1973 in the South and by 1984 had been detected in all southern states. Stem canker can be one of the most destructive soybean diseases. Yield losses in susceptible cultivars can approach 90% under the right environmental conditions. The frequency and severity of stem canker outbreaks in Arkansas have been erratic and unpredictable from year to year, but stem canker is found somewhere in the state just about every year.

Leaf symptoms are characterized by yellowing and browning of the tissue between the main veins (Figure 11-21) that occur during the reproductive stages of development. Although leaf symptoms are somewhat diagnostic, they may resemble symptoms of sudden death syndrome or stem-boring insects, so diagnosis is based on both leaf symptoms and the presence of the characteristic stem cankers. Stem cankers are tan-brown lesions (cankers) with dark red-purple margins on the lower stem. Cankers first appear as small reddish-brown lesions on the main stem at a lower node. As the disease develops, the cankers enlarge and may extend for several inches along the main stem or up lateral branches (Figure 11-22). The lesions rapidly become definite, but the slightly sunken cankers rarely girdle the stem complexly. The cankers generally run along one side of the stem with adjacent stem tissue remaining green. Lengthwise sections cut through stems of symptomatic plants will show internal brown discoloration of the pith in the canker area.

Figure 11-21. Leaf symptom of southern stem canker showing yellowing and browning between the main leaf veins. ***(Photo by Kim Rowe)***

Figure 11-22. Stem canker on main stem and lateral branches. ***(Photo by Kim Rowe)***

The fungus *Diaporthe phaseolorum* var. *meridionalis* overwinters mainly in infested stem debris and may survive up to 14 months in soil. Susceptible plants can be infected at any stage of development, although infection generally occurs during the vegetative stages. Severe disease strongly correlates with prolonged rainy periods and temperatures from 70° to 85°F during early vegetative stages. Infection occurs when spores are splashed onto wet foliage during rainy weather. Stem canker can be extremely severe in susceptible cultivars, and yield loss can be extensive. High levels of resistance to this disease are available, and resistant cultivars are the primary means of control.

Stem canker is more severe with continuous soybean production and in no-till planting regimes. Soybean fields should be scouted each year during the reproductive stage to determine if stem canker is present. Small areas of stem canker in a field in one year may result in widespread disease the following year unless a resistant cultivar is selected.

Sudden Death Syndrome

Sudden death syndrome (SDS) was first reported in Arkansas in 1971 and since then has been found in most major soybean production regions of the U.S. This disease is often observed in well-managed, high-yield potential, irrigated fields growing under optimal conditions. Yield losses range from slight to 100% depending on the time of infection, cultivar susceptibility and disease severity.

Symptoms are most pronounced at mid-reproductive stages of development. Initial foliar leaf symptoms are scattered, chlorotic blotches between the main leaf veins that become necrotic, leaving mid-vein and major lateral veins green (Figure 11-23). Severely infected leaves detach from the petiole while the petioles remain green and attached to the stem long after leaf defoliation (Figure 11-24). Leaf symptoms of SDS may be confused with those seen with stem canker because they look so similar. However, with stem canker, leaflets remain attached to the petiole on plants after they die. In addition to leaf symptoms, flower and pod abortion, which is associated with the greatest yield losses, are symptoms of SDS.

Although there are no external symptoms of SDS on stems in contrast to visible stem lesions with stem canker, the vascular tissue of SDS-infected plants is

Figure 11-23. Chlorotic and necrotic blotches between central leaf veins on plants infected with sudden death syndrome. ***(Photo by T. R. Faske)***

Figure 11-24. Green petioles without leaves remain attached on plants severely infected with sudden death syndrome. *(Photo by T. R. Faske)*

gray to brown on plants expressing foliar symptoms. The pith (central portion of the stem) in infected plants, however, remains white or slightly cream colored. Vascular discoloration often extends up the stem progressing farther on plants expressing higher disease severity.

Sudden death syndrome is caused by a soilborne fungus, *Fusarium virguliforme*, which overwinters as thick-walled spores (chlamydospores) in soil or on crop residue. Infection may occur early as seedlings development, but symptoms are not visible until plants have reached mid-reproductive stages of development. Symptoms are most severe at 68° to 77°F. Hot, dry weather appears to slow SDS although severe disease has been reported under these conditions. Disease development can be especially severe in fields that are also infested with soybean cyst nematodes, and disease is most problematic in cultivars that are susceptible to both the fungus and the nematode. Sudden death syndrome is usually most severe in saturated soils and is often most severe near the header pipe in furrow-irrigated fields or in low-lying areas in fields that are prone to standing water. Other factors that increase disease severity are high fertility and soil compaction.

Management options are limited for SDS, and foliar fungicides are not effective at suppressing this disease. Currently, there are no highly resistant cultivars available to producers, but some soybean cultivars are less susceptible to SDS. Delayed planting of fields with a history of SDS may be beneficial if saturating rains do not occur during early reproductive stages. Cultural practices that improve field drainage and crop rotation (2 years) with a non-host crop for soybean cyst nematodes may reduce severity of SDS.

Phytophthora Root Rot

Phytophthora root rot has been reported in all major soybean-producing areas of the U.S. and is common in Arkansas. This disease is most severe in poorly drained soils that remain wet for several days. Plant stand losses and 100% yield reductions can occur on highly susceptible soybean cultivars.

Symptoms may be found at any stage of soybean development, and severity is dependent on soybean susceptibility. Pre- and post-emergence damping-off occurs when soils remain saturated for several days after planting. On susceptible, intolerant cultivars, stems of older seedlings may appear water soaked and leaves may become chlorotic (Figure 11-25). Generally, these plants wilt and die rapidly. Where Phytophthora rot is present, soybean plants may die throughout the season (Figure 11-26). Symptoms include yellowing between leaf veins and margins and chlorosis of upper leaves followed by wilting. Leaves often remain attached to the dead plant. Because this is a soilborne pathogen, foliar symptoms are the result of a compromised root system. Root symptoms include roots that are discolored, with rotted lateral roots. Severe infection results in a girdling stem lesion (Figure 11-27) that may progress up the stem as high as 10 nodes before the plant wilts and dies on highly susceptible cultivars. On less susceptible cultivars, stem lesions may not girdle the stem, thus the plant does not wilt. Some cultivars may be susceptible, but highly tolerant, and although root systems are discolored and rotted, plants may remain alive. These plants can be stunted and slightly chlorotic, with stem lesions that develop along only one side of the stem.

Figure 11-25. Soybean seedlings infected with Phytophthora root rot. *(Photo by J. Rupe)*

Figure 11-26. Phytophthora root rot in soybean field. ***(Photo by J. Rupe)***

Figure 11-27. Lesion caused by Phytophthora root rot on soybean stem. ***(Photo by J. Rupe)***

The causal agent, *Phytophthora sojae*, overwinters in the soil or on crop residue as oospores (thick-walled resting spores). Oospores can remain viable for several years in the soil in the absence of soybeans. Oospores germinate at cool temperatures (< 60°F) and infect soybeans directly, or they can produce zoospores that are motile. Zoospores cause the primary infection in the spring. Flooding rains shortly after planting result in the most severe disease development. Increased disease severity has been observed with reduced tillage practices (especially no-till) and monocropping of soybeans.

Resistance is the most economical management tactic, but resistant genes in soybeans are only effective on specific races of the pathogen. Few soybean cultivars are resistant to all known races. An alternative to race-specific resistance is tolerant cultivars, which are effective against all races. Tolerant cultivars tend to sustain growth and yield even after infection, although the level of tolerance that is expressed in a cultivar is highly dependent on both the amount of inoculum (pathogen) that is present and the favorability of the environment for disease development. Tolerant cultivars also contribute to a higher level of inoculum (oospores) for the following season, thus soybean monoculture should be avoided where Phytophthora rot is known to occur. Seed treated with the fungicide metalaxyl is effective in suppressing seedling infection. No foliar fungicide provides good suppression of Phytophthora root rot after the plants have emerged.

Southern Blight

Southern blight is considered a minor disease of soybeans in Arkansas. Typically, this disease occurs on isolated plants scattered through a field. Rarely does yield loss exceed 1% in fields affected by southern blight in Arkansas.

Symptoms can occur at any time during the season from seedlings to mature plants. The disease generally is most visible in plants during mid-reproductive stages. Seedling infection results in pre- or post-emergence damping-off. Later in the season, entire plants may become yellow and wilt, with leaves turning brown and often remaining attached to the plant (Figure 11-28). A dark brown lesion that girdles the stem occurs at the soil surface. This lesion is generally accompanied by the development of conspicuous white, fanlike mats of fungal mycelium that form on the base of the stem, on leaf debris and on the soil surface around infected plants (Figure 11-29). Numerous small, round fungal bodies that are about the size of mustard seeds (called sclerotia)

Figure 11-28. Yellow and wilted soybean plants infected with southern blight. ***(Photo by T. R. Faske)***

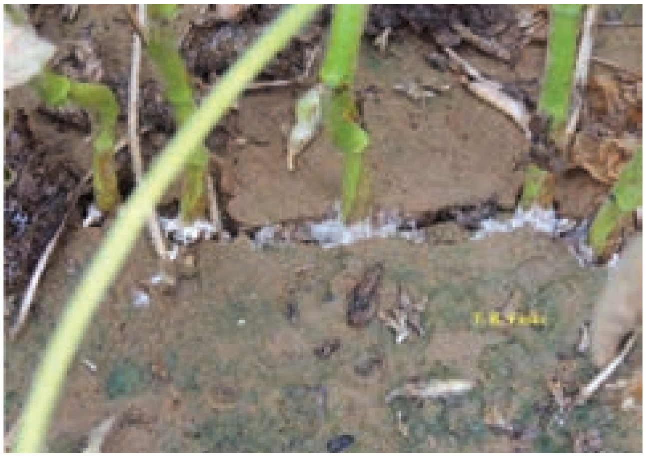


Figure 11-29. White fungal mats of southern blight beginning to develop around soybean stems. ***(Photo by T. R. Faske)***

Figure 11-30. Fungal hyphae of *Sclerotium rolfsii* on soybean plant with immature sclerotia developing above the soil line. ***(Photo by M. Emerson)***

form on these fungal mats and on the lower stem (Figure 11-30). Initially, sclerotia are yellow-tan then progress to a reddish-brown color and finally dark brown at maturity.

The causal agent is the soilborne fungus *Sclerotium rolfsii* which has a host range of more than 200 plant species. This pathogen overwinters as sclerotia that can remain viable 3 to 4 years near the soil surface. Disease development is favored by hot (77° to 95°F), humid weather conditions, hence the name southern blight.

All soybean cultivars are susceptible to southern blight. Crop rotation with corn, grain sorghum or wheat for 2 years can be beneficial at reducing survival and buildup of sclerotia in the soil. Deep cultivation to bury sclerotia in the soil reduces sclerotia longevity and may be an option in certain farming systems.

Viral Diseases

Soybean Mosaic Virus

Soybean mosaic virus (SMV) occurs in all soybean production areas of the world. Yield loss ranges from 8% to 35% with a high of 94% in some production systems. Though symptoms can vary among soybean varieties, a green-yellow mosaic pattern is the most common (Figure 11-31). At advanced stages a yellow-brown mosaic pattern is often observed, often followed by premature defoliation (Figure 11-32). Infected seeds are mottled brown or black; however, other diseases may cause seed discoloration, thus a laboratory assay is necessary to verify SMV infection. Yield and quality losses are related to smaller seed size with lower germination rate than healthy seeds. The yield losses caused by SMV infection in Arkansas have not been thoroughly documented.

Figure 11-31. Mosaic pattern on infected soybean. ***(Photo by J. Zhou)***

Figure 11-32. Leaf yellowing at late infection stage. ***(Photo by J. Zhou)***

SMV may be introduced into a virus-free region by planting infected seed. The pathogen is spread from plant to plant by aphids. The soybean aphid, *Aphis gylcines*, the most common SMV vector, is the only aphid species that can establish colonies on soybeans. Once an aphid feeds on an infected soybean plant, it only takes a short time (seconds to a few minutes) for the insect to acquire the virus. As the virus-carrying aphids move and feed on healthy plants, the virus will be spread around. In the absence of soybeans the virus can overwinter on a wide range of hosts from five plant families (Bean, Amaranth, Passionflower, Figwort and Nightshade). The ability of the soybean aphid to overwinter in Arkansas and alternative host species of importance for SMV in Arkansas are not known. Chemical control of the soybean aphid is not recommended because some insecticides may increase the movement of the vector in the field, which facilitates further dissemination of the virus.

It is important to use virus-tested seeds to minimize incidence of this disease. Resistant cultivars have been widely used, and planting SMV-resistant soybean cultivars is the most economical practice to manage the disease. Several resistance genes have been identified and are effective against some, but not all, virus strains. Based on the differential reactions on a set of soybean cultivars, SMV has been classified into numerous strains. In the U.S, nine strains, G1-G7, G7a and C14, are currently recognized. Additional strains have been identified in other countries (Canada, China, Japan and South Korea), including isolates that overcome all known resistance to the virus. In Arkansas, only high-yielding cultivars with resistance to most (or all) SMV strains, such as Ozark, USG 5002T and USG 5601T, are widely used in controlling SMV. An additional management tactic is avoiding late planting to minimize aphid transmission at an early-crop growth stage.

Bean Pod Mottle Virus

Bean pod mottle virus (BPMV) is another important virus of soybeans. It was first reported in Arkansas in 1951 and is now prevalent in all production areas in the U.S. Yield reduction ranges from 10% to 60% depending on variety and geographic area, with highest yield reduction occurring when the virus infects plants early in the season. The yield loss in Arkansas is not known at this time.

Symptoms on infected soybeans may vary depending on the variety. Foliage symptoms range from mild chlorotic mottling in the upper canopy (Figure 11-33) to puckering and severe mosaic (Figure 11-34) in lower leaves. Acute symptoms develop on young leaves. "Green stem" caused by delayed maturity due to BPMV infection is often observed in the field close to harvest season (Figure 11-35). Mottling of the seed coat is another prominent symptom, but this symptom is not a reliable predictor of BPMV infection because soybeans infected with soybean mosaic virus (SMV) also exhibit similar symptoms.

Seed contamination is not important in BPMV epidemiology. The virus is primarily transmitted by the bean leaf beetle (*Cerotoma trifurcata*). The virus has been found in overwintered bean leaf beetle adults which may survive in grass, leaf litter or even rocks and colonize soybeans as seedlings emerge in the spring. Because most flight events of beetles are limited to about 30 meters, it is likely that BPMV spread is restricted within and between fields. Other

Figure 11-33. Mottling on BPMV-infected soybean leaves. *(Photo by J. Zhou)*

Figure 11-34. Puckering and rugosity of soybean leaves. *(Photo by J. Zhou)*

Figure 11-35. "Green stem" caused by BPMV infection on soybean plant. ***(Photo by R. Valverde)***

than overwintering beetles and infected seeds, alternate hosts in the field can also serve as an inoculum source for disease development. Leguminous hosts including cowpea and some bean species sustain virus replication, as well as *Demodium* species which are natural hosts for BPMV.

Soybean cultivars with BPMV resistance are not available. Consequently, elimination of alternative hosts and vector control are important for disease management. Insecticides targeted at emerging overwintered beetles (F_0) and the first seasonal generation (F_1) population of *C. trifurcata* can reduce vector populations throughout the growing season, provide limited reduction in virus incidence and improve both yield and seed coat color. In addition, it is also advisable to delay soybean planting so that the early-season mortality of beetles increases and thereby reduces vector populations.

Synergistic Interaction of SMV and BPMV – A synergistic interaction between SMV and BPMV may lead to severe symptoms and yield losses. Co-infection with both viruses may result in yield reduction ranging from 66% to 86% compared with 8% to 35% when plants are infected with SMV alone or 10% to 60% with BPMV alone. Symptoms in plants infected with both viruses include severe dwarfing, foliar distortion, leaf necrosis and mottling. Seed coat mottling may also occur, but this symptom is not diagnostic. The effect of co-infection on yield and the degree of seed transmission depends on virus strain, cultivar and time of infection by either virus.

Tobacco Ringspot Virus

Tobacco ringspot virus (TRSV) on soybeans can have a severe impact on seed yield and quality. Yield reduction ranges from 25% to 100% due to reduced pod set and seed formation with lower protein and oil content in infected seeds.

The most distinct symptom of TRSV infection on soybeans is bud necrosis (Figure 11-36) and excessive growth of leaves and buds (Figure 11-37). Virus

Figure 11-36. Bud necrosis caused by TRSV infection on soybean. ***(Photo by J. Zhou)***

Figure 11-37. Excessive growth of buds on soybean. ***(Photo by I. E. Tzanetakis)***

infection causes leaves to be thicker and darker in color. Stems of infected soybeans remain green for 1 to 2 weeks longer than healthy ones, and the pith of stems and branches of infected plants may exhibit brown discoloration. Infected plants are generally stunted and have a low seed formation rate. Pods are usually undeveloped or aborted because insufficient pollen is produced for fertilization. This in turn may cause production of a proliferation of new buds and pods leading to "green bean syndrome."

Seed transmission is the most important mode for long-distance dissemination of the virus, and the infection rate is much higher when soybeans are infected before flowering. The virus can invade the embryo where it remains viable for at least 5 years. TRSV is also mechanically transmissible and can be transmitted by the dagger nematode (*Xiphinema americanum*).

TRSV triggers symptomatic and asymptomatic infection on a wide host range including vegetables, ornamentals and common weed species. The elimination of indigenous weeds in soybean fields, such as Palmer amaranth (*Amaranthus palmeri*) and lambsquarter (*Chenopodium album*), is important for disease control. Given that no resistance for TRSV has been reported in soybeans, it is critical to use virus-free seeds when planting. Minimize dagger nematodes, which are efficient vectors of the virus, through tillage practices.

Soybean Vein Necrosis Virus

Since the first report in 2008, soybean vein necrosis virus (SVNV) has been reported in all soybean-producing areas in the U.S. Yield loss estimates for this virus are still under investigation.

Typically, symptoms of SVNV start as vein clearing along the main veins (Figure 11-38), with veins yellowing and finally becoming necrotic as the season progresses (Figure 11-39). Clearing or lesions may occur on one or multiple areas of the affected leaves, and severely affected leaves die off. Early infection is usually detected by mid-June in the southcentral and eastern states, but timing of the first symptoms may vary depending on cultivar and local weather pattern. The distinction between infected and non-infected plants may be difficult due to the absence of well-defined lesion edges in early infections. Unlike other diseases that cause foliar lesions such as frogeye leaf spot or bacterial blight, lesions caused by SVNV expand from main veins to the surrounding areas of the blade. Symptom intensities vary among cultivars. Mild infections cause thread-shaped vein clearing whereas severe infections result in purple or dark brown lesions expanding to the majority of the leaf blade. Disease symptoms are more evident higher in the canopy because newly emerged leaves are preferential feed sites of the virus vector, the soybean thrips.

Figure 11-38. Early symptom of SVNV on soybean leaf. ***(Photo by J. Zhou)***

Figure 11-39. Typical lesion of SVNV on soybean leaf. ***(Photo by J. Zhou)***

SVNV is transmitted by the soybean thrips (Figure 11-40), probably the most abundant thrips species in soybean fields. An indigenous weed species commonly found in soybean fields, Ivyleaf morning glory (*Ipomoea hederacea* Jacq), may function as a virus reservoir. Two other legume species, cowpea and mungbean, can also be infected by SVNV. Because the soybean thrips is a common pest in different legume species, it is highly possible this virus is a new threat not only to soybeans but also other legumes. Virus infection can occur at any time during the growing season, but symptoms usually become most visible after flowering. Cool temperature favors symptom development, and a mild winter followed by a warm spring may promote vector proliferation.

Control of soybean thrips is critical in lowering SVNV incidence, and control of Ivyleaf morning glory in fields. At this point, other cultural practices that are effective in lowering SVNV incidence are unknown, and the identification of resistance and development of resistant cultivars are still underway.

Figure 11-40. Soybean thrips.
(Photo by M. E. Rice)

Chapter 12

Insect Pest Management in Soybeans

by G. Lorenz, D. Johnson, G. Studebaker, C. Allen and S. Young, III

The importance of insect pests in Arkansas soybeans is extremely variable from year to year due in large part to environmental conditions. For example, hot, dry years favor many lepidopterous pests such as the soybean podworm and the beet armyworm; and when drought conditions occur, these pests usually are abundant. Many other lepidopterous pests, such as the velvetbean caterpillar and the soybean looper, may cause problems following migrations from southern areas, particularly in concurrence with winds out of the Gulf region where they are a common problem. Generally, insect pressure is greater in the southern part of the state compared to northern Arkansas due to warmer temperatures and closeness to the aforementioned migration sources.

Production practices also have an impact on the occurrence of pest insects in soybeans. For example, insects such as the Dectes stem borer and grape colaspis usually occur at damaging levels only in soybean monocultures. Row width can also affect insect pest pressure. Soybean fields which fail to achieve canopy closure by bloom are the ones most susceptible to damage by the soybean podworm. Planting date, tillage and adjacent crops can also have an impact on pest species occurrence. The Early Soybean Production System (ESPS), which is the planting of indeterminate varieties (MG III and IV) in April, has gained increasing popularity in the state. Fields planted to the ESPS are susceptible to pests such as the foliage-feeding bean leaf beetle and the pod-feeding stink bug complex. Because of the limited acreage in this system, such fields are a virtual “oasis” as a preferred host for these insects which normally would be found primarily on wild hosts.

A soybean field in Arkansas will contain millions of insects comprising a multitude of different species, both pests and beneficials, in a growing season. Proper insect identification and knowledge of the injury associated with pest species are the keys to any soybean insect pest management (IPM) program. Secondly, we must be able to determine the level of pest insects in the field by sampling and assessing the threat of the pest(s) to the crop using such strategies as percent defoliation, stand loss, etc. Finally, it is important to determine what management tactics are available and whether or not they are economically feasible.

Insect Identification

The three types of insect pests found in soybeans in Arkansas are:

1. **Foliage feeders**, which comprise the biggest group of insect pests,
2. **Pod feeders**, which are probably the most detrimental to yield, and
3. **Stem, root and seedling feeders**, which are often the hardest to sample and are not detected until after they have caused damage.

Some insects, such as the bean leaf beetle, may feed on both foliage and pods but are primarily considered foliage feeders. The following information on individual insects is meant to provide the reader with basic information on some of the more common pests found in soybeans including the injury they cause, important descriptive information, relevant life history details and management considerations.

Foliage Feeders

Management Tip

Treatment levels for all foliage feeders (except thrips) are at 40 percent defoliation prior to bloom and 25 percent defoliation after bloom, with foliage feeders present.

Green Cloverworm

The green cloverworm larva is light green in color with white stripes running down each side of the body. A full-size larva is approximately one inch in length. Green cloverworms can be distinguished from all other lepidopterous larvae because they are the only ones that have three pairs of abdominal prolegs. When disturbed, larvae wiggle violently and fall to the ground, similar to the velvetbean caterpillar. The green cloverworm is usually the

Figure 12.1. Green Cloverworm.

first foliage-feeding lepidopteran found in soybeans. Although it is considered an important pest in northern states, it rarely reaches damaging levels in Arkansas. Many entomologists feel the green cloverworm may be more beneficial than harmful because it provides a feeding source for beneficial insects, allowing them to build up for the time when more damaging larvae may occur. When the green cloverworm does reach damaging levels, it can be controlled with the lowest labeled rates of insecticides. Commercial formulations of *Bacillus thuringiensis* (*B.t.*) are very effective for control, even at the lowest labeled rates.

Loopers

The soybean looper and the cabbage looper are both commonly found in Arkansas. Although the two species are almost indistinguishable, particularly in the larval stage, control methods are extremely different. The cabbage looper is not hard to control while the soybean looper is resistant to pyrethroids and requires the use of more expensive insecticides to control.

The main characteristic for separation of loopers from other lepidopterous larvae is that they have only two pairs of abdominal prolegs. The body is thickest at the posterior end of the larva and tapers toward the head. The larva is light to dark green with longitudinal stripes on each side of the body and two stripes along the back. Soybean loopers often have black legs and markings on the head and body; however, this is not a reliable technique for identification because some soybean loopers do not have these markings.

The most reliable technique to identify larvae of the two species is examination of mandibles. Soybean looper larvae have mandibles with ribs terminating in an enlargement near the outer margins while cabbage loopers have ribs which extend to the outer margins of the mandible.

Larvae of both species can become quite large, reaching almost 1.5 inches in length. Larvae generally feed in the lower one-half to one-third of the canopy. As the larvae develop, they eat irregular areas of leaves, leaving the larger leaf veins. Loopers are voracious feeders, particularly the large larvae (fourth-sixth instar) which consume 90 percent of the total food required by the developing larvae. Soybean loopers have been observed to occasionally feed on pods.

Generally, loopers do not reach damaging levels in Arkansas due to the natural enemy complex of beneficial insects and pathogens. However, when they do occur, it is usually late in the season and typically in areas where cotton is also grown. Cotton nectar provides a carbohydrate source which can greatly increase the egg production of the female moth.

Figure 12.2. Soybean Looper.

Management decisions should be based on estimates of defoliation and the number of larvae present. Also, when scouting, attention should be given to the appearance of larvae. As previously mentioned, there are many natural enemies of loopers. The ability to spot dead or diseased larvae can often mean the saving of an expensive insecticide application. If treatment is warranted, consider the use of a registered, effective formulation of *B.t.* in areas where resistance to insecticides has been a problem. Finally, remember that loopers often occur with other lepidopterous foliage feeders such as the green cloverworm and velvetbean caterpillar. If the combination of these larvae produces 25 percent defoliation after bloom, then control measures are warranted.

Figure 12.3. Bean pod mottle virus transmitted by bean leaf beetle.

Figure 12.4. Bean Leaf Beetle Adult.
(Photo by L.G. Higley, University of Nebraska-Lincoln)

Bean Leaf Beetles

The bean leaf beetle is a small beetle which primarily feeds on leaves but will occasionally feed on pods. Adults are about one-fourth inch long with color ranging from light yellow to red with four black spots on their back and a black margin around the edge of the wing covers. Also, a black triangle will be present just behind the prothorax or "neck." This triangle is always present, but the four black spots may or may not be seen. The grub or immature stage is found in the soil where it feeds on roots and nodules. It is white with a black head and anal shield. Damage by bean leaf beetle adult is characterized by small circular holes between leaf veins as opposed to jagged leaf damage from caterpillars and grasshoppers.

The time of greatest concern with the bean leaf beetle is early in the season when plants are small (growth stages V1-V3). Defoliation levels exceeding 50 percent on these small plants can occur in a very short time span. In Arkansas, early planted (especially ESPS) soybean fields are particularly vulnerable to attack. Late in the season, defoliation by bean leaf beetles in conjunction with other leaf-feeding pests can result in reaching the economic threshold of 25 percent defoliation.

Current research indicates that the pod feeding of bean leaf beetles may be even more important than the defoliation it causes. Beetles feeding on the pod result in increased susceptibility to secondary pathogens, such as *Alternaria*, damage to the seed and seed loss. Adults have also been observed to feed on the pod peduncle causing loss of soybean pods. Also, the bean leaf beetle is known to transmit bean pod mottle virus (BPMV). The earlier this disease is transmitted to soybean plants, the more devastating the effects of the disease can be. Yield losses can range from 10 to 17 percent. However, when plants are infected with both BPMV and soybean mosaic virus (SMV), yields can be reduced by 60 percent. SMV is often a seed-transmitted disease.

Velvetbean Caterpillars

The velvetbean caterpillar is usually not a problem in Arkansas. However, every five to ten years this pest is found in damaging levels, usually only in the southern region of the state. The velvetbean caterpillar is a voracious feeder and can strip a soybean field of leaves in a short time.

When larvae are very small, first to third instar, they can be misidentified as green cloverworms. However, when the larvae reach the third instar (medium-size larvae), dark longitudinal lines with alternating lighter colored stripes are visible. Larvae typically range in color from pale green to dark green or even brown or black. Larger larvae are easily distinguished from green cloverworms

Figure 12.5. Velvetbean Caterpillars.

and loopers because they have four pairs of prolegs. When disturbed, they exhibit violent wiggling behavior much like the green cloverworm which helps separate them from other species with four pairs of prolegs (such as the corn earworm or any of the armyworm complex). The adult is characterized by being dark brown with a darker line running laterally across the middle of both wings.

This pest is susceptible to many natural enemies, particularly the fungus *Nomuraea rileyi*, which can decimate a population of velvetbean caterpillar in short order. Numerous insecticides are effective for control, including several commercially available *B.t.* formulations.

Armyworms

Several species of armyworms may be found in soybeans during the growing season including the yellowstriped armyworm, the fall armyworm and the beet armyworm.

Figure 12.6. Beet Armyworms.

The yellowstriped armyworm occasionally occurs on seedling soybeans in large enough numbers to cause damage, but usually the plants can recover with no loss to yield potential, and control is seldom necessary. The yellowstriped armyworm larva is dark to black with a yellow stripe running down each side of the body. Also, there is usually a black spot on each side of the first abdominal segment. As with the fall armyworm and beet armyworm, the yellowstriped armyworm has four pairs of prolegs.

Usually fall armyworm populations occur late in the season and do not build up to damaging levels. However, the fall armyworm has occasionally been observed to be present in the early spring on seedling soybeans at levels high enough to cause damage. Control is usually not required. The fall armyworm larvae can vary from tan to green in color and have black bumps with dark black hairs on the body. On the eighth abdominal segment there are four distinct black spots on the upper half of the body. Also, the fall armyworm has an inverted "Y" on front of the head.

In recent years the beet armyworm has been observed to develop large populations in soybeans late in the season. Larvae feed on blooms, pods and foliage and have caused significant yield loss in isolated incidents. Mature larvae are green in color with prominent lateral stripes. Unlike the fall armyworm, the beet armyworm has no stout black hairs on the body, and there is usually a black spot on each side of the body on the second thoracic segment, just above the middle pair of true legs. The beet armyworm and fall armyworm have shown resistance to pyrethroids and can be difficult to control.

Blister Beetles

The margined blister beetle and the striped blister beetle are both common in Arkansas. The adults are elongate with a broad head, narrow neck and long, slender legs. The margined blister beetle

Figure 12.7. Striped Blister Beetle.

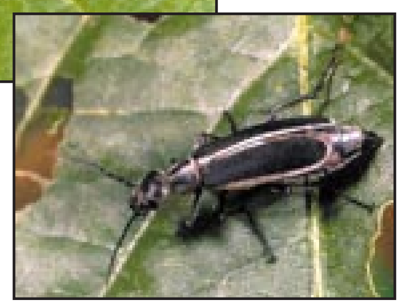


Figure 12.8. Margined Blister Beetle.

is dark gray to black, while the striped blister beetle is yellowish orange with brown stripes on the wing covers. Adults usually feed in groups in the field and can virtually strip all the leaves in spots in a soybean field. If enough areas in a field are infested, spot treatment may be required.

Grasshoppers

The redlegged grasshopper and the differential grasshopper are two grasshopper species that are common in soybeans in Arkansas. Grasshoppers are rarely a problem. However, when grasshopper populations build to damaging levels, it usually occurs in fields with undisturbed pastures or hay fields close by. Typically they are found first along the edge of the field in large numbers early in the season and then disperse throughout the field as the season develops. Often treatments can be made along the field edge to control grasshoppers before they disperse if necessary. Grasshoppers will feed on leaves and pods, if they are available. Grasshoppers are favored by drought conditions and are often associated with two or more consecutive years of drought conditions.

Garden Webworms

Larvae of the garden webworm usually appear early in the season. They are green with black spots on every body segment. Webworms are easily distinguished from other larvae by the silken webbing they produce. Also, when disturbed the garden webworm will back away from the disturbance. Control is normally not required. However, in situations of high populations or in conjunction with other foliage feeders, severe defoliation can occur. Garden webworms are generally found first on pigweed, and localized field infestations are generally associated with this weed.

Figure 12.9. Garden Webworm.
(Photo by M.E. Rice, Iowa State University)

Thrips

Thrips are one of the most abundant arthropods found in soybeans. They are very small, less than one-tenth of an inch in length. The most common species found in soybeans is the soybean thrips. Adults of this species have characteristic transverse bands of brown and white on the abdomen. Larval stages are yellow to orange in color. Thrips injury is characterized by a silvery appearance to the leaves, blackening of the terminal and a general reduction of plant vigor. Plants are most susceptible to thrips injury during drought conditions or other stress situations that result in stunted growth. Usually thrips are not a problem. However, when they occur in large numbers (especially under stressful conditions), seedling mortality can occur. In these situations, control measures may be necessary. Under normal conditions, plants outgrow any injury and can withstand very high thrips populations (even up to 100 per plant).

Pod Feeders

> **Management Tip**
>
> Scout fields closely at least once a week starting at bloom and examine the plants for visual signs of damage.

The pod feeders represent the insects that have the greatest potential for causing economic losses to soybeans. The soybean plant does not have the ability to compensate for damage at this stage of growth, and injury to pods and/or seed is directly reflected in lower yields.

Corn Earworms

The number one insect pest of soybeans in Arkansas is considered by many to be the corn earworm. In cotton, this pest is referred to as the cotton bollworm. While in soybeans, it is often called the soybean podworm. It has an extremely wide host range and is a major pest of not only corn, cotton and soybeans but also grain sorghum and tomato (in tomato it is called the tomato fruitworm).

Figure 12.10. Corn Earworm.

While small larvae feed on new, tender leaves and blooms, larger larvae can be found on any part of the plant and will feed on leaves, stems or pods but prefer blooms. Small larvae are off-white in color, but larger larvae can vary in color from yellowish-green to green, pink, brown or even black, each having longitudinal light-colored lines along the body. Compared to armyworms, they generally have much more hair over the body. The head is most often orange in color. When disturbed, these larvae usually curl up into a “C” shape. Larvae, particularly small ones, are subject to high mortality from natural enemies. For this reason, pesticide treatment recommendations are generally aimed at medium and large larvae.

The most vulnerable time for soybean fields to infestation by the corn earworm is during bloom (R2 growth stage), which usually coincides with the second field generation. Fields should be closely monitored at this time, particularly fields that are blooming and have not achieved canopy closure. Also, the treatment level for corn earworm is reduced for drought-stressed beans because the ability of plants to compensate is reduced in this situation. Studies have shown that, under normal conditions, when larvae eat one bean out of a pod, the other beans in the pod will increase in size to overcome the loss.

The rates of insecticide needed for control are typically lower for soybeans than cotton because the larvae are much more exposed to the insecticide. The treatment level for corn earworm in soybeans prior to bloom is 40 percent defoliation. After bloom, treat when populations approach four larvae that are one-half inch or longer per row foot (38-inch rows). For dryland soybeans under stress, treat at three larvae per row foot. For thresholds at different row widths, consult the table provided later in this chapter.

Stink Bugs

Three species of stink bugs are found in Arkansas. They are the green stink bug, the southern green stink bug and the brown stink bug. Both the adult and nymphal stages of the stink bug complex can cause injury to soybeans. Damage is caused when they insert their piercing-sucking mouthparts into the plant and extract plant juices. The stink bug will feed on the stems, foliage, pods and blooms. Damage is greatest when they feed on the seed in the developing pod. Stink bug feeding can cause abortion of blooms and pods resulting in yield reduction. Stink bug feeding early in the development of pods can result in shriveling of seed or seed size reduction. Feeding on large-sized seed results in seed discoloration and lowering of seed quality. When stink bugs feed on the developing seed, digestive juices are injected into the seed causing deterioration of tissue.

Figure 12.11. Stink Bug.

Stink bug eggs are distinctively laid on the leaves of soybeans in clusters in tight rows. Individual eggs are barrel-shaped. As nymphs, they are gregarious in habit and remain close to the egg mass from which they hatched. As they develop, they begin to feed and disperse. Southern green stink bug nymphs are, at first, reddish black or black. Later they develop a white spot on the back. As they reach mid-size, they turn black in color or green with pink markings on the back and white spots on the abdomen. Late instar nymphs are lighter green than the adult stink bugs with pink and black markings and white spots on the margin of the abdomen. Southern green stink bug adults can be differentiated from green stink bug adults by the red bands on the antennae. Green stink bug nymphs are, at first, reddish brown, then light green with black and white stripes on the abdomen. Late-stage nymphs are green and have stripes on the abdomen colored yellow and black or green with a black spot in the center of the abdomen. Adult green stink bugs have black bands on the antennae. Brown stink bug nymphs are light brown with brown spots down the middle of the abdomen. The brown stink bug adult is brown and has rounded shoulders. They are often confused with the spined soldier bug, a predaceous stink bug which has sharp points on each shoulder.

Stink bugs are often found along field borders, particularly along tree lines where they overwinter as adults. **Threshold levels in Arkansas are one per row foot (38-inch rows) after blooming and pod formation begins. For thresholds at various row widths, consult the table later in this chapter.**

Root and Stem Feeders

Threecornered Alfalfa Hoppers

The threecornered alfalfa hopper adult has a distinct triangular shape, from which it derives its name, and is bright green in color. Adults are about one-fourth inch in length. Nymphs have 12 pairs of spines along the top of the body. First instar nymphs are extremely small and translucent. As the nymphs grow, they become green like the adult although the later instar nymphs can also be brown in color.

Threecornered alfalfa hoppers overwinter as adults in a reproductive diapause state. That is, they are active on warm days but do not reproduce. They are often found in the winter beneath pine trees where they reside under plant debris in unfavorable weather and move up into pine trees

Figure 12.12. Threecornered Alfalfa Hopper Adult.

and feed on warm days. In the early spring they leave pine and move into alternate hosts such as clovers, vetch, dock, wild geraniums and other hosts for the first generation. As the first generation of nymphs becomes adults, they move into soybeans in May and June. Usually two to three generations occur in soybeans.

Damage to soybeans caused by threecornered alfalfa hoppers is caused by their unique feeding behavior. Nymphs and adults are phloem feeders and will often feed in a circular pattern around a stem or petiole resulting in girdling. This girdling disrupts the vascular flow. Plants girdled on the mainstem near the soil surface may die or may survive the damage only to break over later in the season due to high winds and/or rain. When the latter occurs, growers are often prone to treat the

Figure 12.13. Girdling Caused by Threecornered Alfalfa Hopper.

field although the damage occurred several weeks before. Plants are susceptible to the hopper feeding that causes this type of damage until they are about 10 inches tall. Scouting for this damage should be done from emergence until plants are 10 inches tall. During this period, treatment should be considered if 50 percent of the plants are girdled or if less than four to six ungirdled plants per row foot remain in conventional rows (30- to 38-inch rows) and hoppers are present. Later as the plant develops, the hoppers will move up into the canopy and cause girdling on vegetative branches and petioles. However, this damage does not appear to cause economic damage in Arkansas. Studies in Louisiana have shown economic yield losses when these pests girdle stems attaching blooms and pods.

Grape Colaspis

The grape colaspis is considered to be a minor pest of soybeans. Larvae and adults are common in soybean fields throughout the state but rarely at economic levels. In recent years, however, growers in Lee, Monroe, St. Francis and Woodruff counties have had a serious problem with this pest.

Figure 12.14. Grape Colaspis Adult.
(Photo by M. Kogan, Oregon State University)

The adult is a small light brown-colored beetle about one-fourth inch long. The adult is a foliage feeder but has not been known to cause economic injury. In contrast, the soil-dwelling larval stage can cause problems. The larvae or grubs are white to tan in color with a brown head capsule and cervical shield.

Figure 12.15. Grape Colaspis Grub.

Figure 12.16. Grape Colaspis Grub Feeding Symptoms on Root.

Grubs can be up to about one-third inch in length. These grubs feed on the roots and underground stem portions of the plant. This feeding can cause stunting or even loss of stand when populations are high. The damage remains unnoticed in many cases until after larvae have finished development. Also, the damage is often mistaken for soybean cyst nematode damage. In severe cases, reports of growers losing three stands of soybean plants in one field in a season have been observed. At the present time there are no effective insecticides for control.

Cutworms

Several species of cutworms are found in Arkansas. Occasionally, cutworms can destroy a stand of soybeans. Damage is generally spotty in the field. Infestations most often occur during early wet seasons in conjunction with heavy vegetative cover. With the increase in reduced- and no-till throughout the state, this pest has the potential to become more of a problem. In reduced- and no-till situations, it is important to rid the field of grass and weeds three to five weeks prior to planting to help reduce the chances of a problem.

Cutworm feeding is easily detected by walking the field and looking for seedling plants which have been damaged or cut off just above or below the soil surface. Usually a small hole will be seen around the damaged plant. This is where the larva resides during daylight hours. Often the larva will cut the plant and drag the top part of the plant back to its lair.

Figure 12.17. Cutworm.

(Photo by M.E. Rice, Iowa State University)

If you suspect cutworms, dig up the soil around the plants to find if cutworms are still present. Spot treatments should be made when 30 percent or more of the plants are damaged or if plant stand counts indicate less than four to six plants per row foot (30- to 38-inch rows) and larvae are present.

Insect Scouting

Insect scouting is essential in determining pest levels in soybeans. All of the thresholds used to make insecticide application decisions are based on the number of insects found and/or the extent of damage caused by insects. Soybean fields should be scouted weekly. The time period from the onset of bloom (R1-R2) through physiological cutout (R7) is especially critical. When sampling, at least four areas in the field should be chosen at random that will provide adequate coverage of the field. Samples should be taken from each side of the field to adequately detect early insect infestations from one side of the field. Samples should be taken no less than 50 to 100 feet from the edges of the field. Remember, many insects such as grasshoppers, stink bugs and others often feed on wild hosts before entering a field and can often be detected on one side of the field which has suitable habitat before dispersing throughout the field.

In Arkansas two tools are used to sample soybean insect pests: (1) the drop cloth or shake sheet and (2) the sweepnet. Each of these methods has advantages and disadvantages.

Drop Cloth

The drop cloth is also referred to as the shake cloth or shake sheet. The drop cloth is made of heavy cloth or plastic, 36 inches in length, with a one-half inch or larger doweling about 42 inches long at both ends. Samples are taken by extending the cloth with the dowels parallel to the soybean rows and shaking the 3 feet of plants on each row over the cloth. Insects that fall onto the cloth are then counted and the total divided by six to obtain the number of insects per row foot. Some keys to taking good drop cloth counts are:

- **Bend the plants gently over the cloth, then shake vigorously** to dislodge insects onto the cloth.
- **Minimize disturbance of the plants prior to sampling** – that is, do not walk through the plants to be sampled then turn around and sample the plants.

- **Be aware of your shadow**. Many insects are triggered to fly by a shadow.
- Check the soil at the base of the plants and the areas just below and above the shake sheet. Count any insects found.
- **Count flying insects first** such as stink bugs and threecornered alfalfa hoppers before they can get away.
- Later in the season, as plants get larger, shake only one row per site. Remember to divide by three (not six) to obtain the number of larvae per row foot.

The drop cloth is very effective for sampling soybeans. It is easy to use and make. Sample uniformity is easily maintained. Late in the season, particularly when insect populations are high, the drop cloth is faster to use than the sweepnet and samples more of the plant. However, the drop cloth cannot be used effectively on narrow rows (less than 19-inch rows), drilled or broadcast soybeans.

Sweepnet

Sweepnet sampling is conducted with a heavy-duty 15-inch diameter sweepnet. Swing the net briskly through the top 15 inches of the canopy. Some of the keys to taking good samples with the sweepnet are as follows:

- The bottom of the net should be angled up so dislodged insects will fall into the net. Each pass of the net through the canopy counts as one sweep.
- Sample only one row per sweep in soybeans planted on 36-inch or greater row widths. In narrow rows, let the normal arc of the sweep continue through the adjacent row(s).
- Sweeps should be made 2 1/2 to 3 feet apart down the row, and be aware of your shadow.

The sweepnet has several advantages for sampling soybean insects. It can be used on any row width. It is more efficient to use than the drop cloth in short- to moderate-height soybeans, once the correct technique is learned. Also, the sweepnet is quicker than the drop cloth early in the season when insect populations are low. Disadvantages of the sweepnet are that sample uniformity is hard to maintain, less of the plant is sampled compared to the drop cloth, it is less efficient than the drop cloth late in the season, and sweepnets are not readily available.

Insect Management

Integrated Pest Management (IPM) is the use of all available control tactics to effectively keep pests from reaching population levels which will cause economic crop injury. These control tactics may include cultural control, biological control, host plant resistance and chemical control.

Table 12.1. Treatment Levels for Various Larval Insect Pests of Soybeans for Different Row Spacings Using a Drop Cloth

Row Spacing (inches	Larvae/Row Ft.		Comments
	CEW	SL/CL/BAW/VBC	
38	4	6-8	Treat when worms are 1/2 inch or larger. For loopers and other defoliaters, the number of larvae is in addition to 25 percent defoliation after bloom. For drought-stressed fields, reduce CEW threshold levels by one for 30-38 inch rows and by 1/2 for 9-19 inch rows.
30	3	4.5-6	
19	2	3-4	

CEW=corn earworm; SL=soybean looper; CL=cabbage looper; BAW=beet armyworm; VBC=velvetbean caterpillar

Table 12.2. Equivalent Economic Threshold Conversion Between Drop Cloth and Sweepnet

	Drop Cloth	Sweepnet		
Insect	Number/ Ft. of Row	Number/ 25 Sweeps	Number/ 50 Sweeps	Number/ 100 Sweeps
Stink bugs	1	9	18	36
SL, CL, VBC, GCW[1]	6	29	58	116
CEW[2]	4	15	30	60

[1] SL=soybean looper; CL=cabbage looper; VBC=velvetbean caterpillar; GCW=green cloverworm. Threshold numbers in association with 40 percent defoliation before bloom and 25 percent after bloom. Number represents medium and large larvae.

[2] CEW=corn earworm. Since CEW are difficult to sample with a sweepnet, sweep deeper into the canopy using extra force. Supplement with visual checks for bloom and pod feeding.

Management Tip

Assessing pest population and damage levels is an essential component in developing a sound insect management program. Remember, it is important to check fields at least once per week, especially once bloom (R2) begins, and this should be continued through physiological maturity (R7).

Cultural Control

Cultural control of insects involves agricultural practices such as crop rotation, planting dates, tillage practices, row patterns, etc., which may help in the control of a pest. It is important to remember that such practices must be in harmony with agronomic practices that promote maximum economic yield.

Tillage such as disking, chisel plowing or other practices can expose many soil insects to an unsuitable environment. Insects such as wire-worms, grape colaspis larvae, bean leaf beetle larvae, Dectes stem borer and others may be affected by stirring the soil. The effect of no-till or minimum tillage on insect pests is not well understood. However, it is theorized that no-till cultural practices may aggravate problems of soil-dwelling insect pests.

Crop rotation is one method of cultural control that has been proven effective for control of diseases, nematodes and weeds. However, little is known in regard to insect pests. Experience in Arkansas seems to indicate that problems with Dectes stem borer and grape colaspis are worse in fields with no crop rotation.

Planting date can also impact the outbreak of an insect pest. However, planting dates are generally determined by climatic conditions, varietal and economic considerations. Insect management normally should not play a major role in determining when to plant. As mentioned earlier, the early planting of MG III and IV varieties often provides insect pests such as the bean leaf beetle and stink bug with a food source which is not usually available and may result in pest populations of damaging levels. Late planting may help in avoiding problems with pests such as the bean leaf beetle and grape colaspis. However, late planting can extend the growing cycle of soybeans, resulting in greater potential to pod and seed damage by corn earworm and stink bugs. By avoiding the extremes of planting too early or too late, it may be possible to avoid some insect problems.

Row width can have a definite impact on insect problems. For agronomic as well as pest management concerns, it is critical that canopy closure be achieved by bloom (R2). It has long been realized that soybean fields which do not reach canopy closure by bloom are more susceptible to damage by the corn earworm.

Biological Control

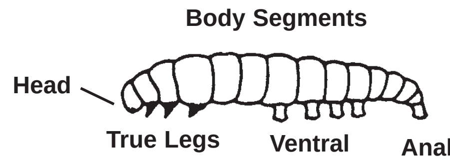
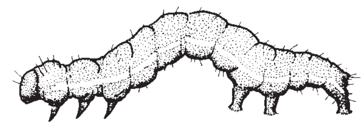
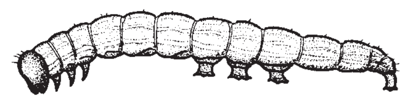
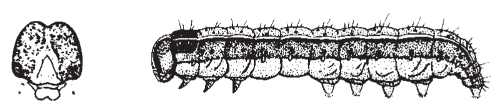
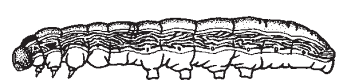
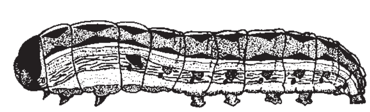
Biological control in soybeans is, for the most part, the conservation and utilization of natural enemies of insect pests to keep them from reaching damaging levels. In the soybean IPM system, the major objective is to allow natural enemies to do their work without disruption from insecticides. Growers who make insecticide applications only when they are absolutely necessary take full economic advantage of the natural enemies. Also, when insecticides are needed, consideration should be given to products that are less disruptive to beneficial insects. *Bacillus thuringiensis* may be used for lepidopterous pests such as velvetbean caterpillar, green cloverworm and the looper complex and can provide good control.

Chemical Control

Insecticides should be thought of as a “last resort” to prevent insect damage when cultural and biological controls have failed to keep insect pests below economically damaging levels. When insect pest levels reach economic thresholds and action must be taken to avoid economic losses, conventional insecticides have been proven to provide effective and economical control. The only way to determine if an insecticide application is necessary is by scouting the field to determine pest population levels. Never assume that if one field is at treatment level, all fields should be treated. Differences in planting date, growing conditions, stage of maturity and other factors often influence pest population levels. Scout every field.

Correct insect identification is critical to ensure the use of a labeled and effective insecticide. Always read the label of any pesticide before use. Insecticides are an important component of any soybean IPM program. The careful and judicious use of the proper insecticide in accordance with instructions on the pesticide label is crucial for maintaining an effective insect management program.

Figure 12.18. Identification Guide
To Caterpillars on Soybeans Using Number of Ventral Prolegs and Description

GENERAL INSECT	
Number of Ventral Prolegs and Description	**Physical Appearance**
ONE PROLEG **Geometrid Larvae** Various colors.	
TWO PROLEGS **Soybean Looper** Green colored, often black true legs, white stripes.	
THREE PROLEGS **Green Cloverworm** Green colored, wiggles violently when touched.	
FOUR PROLEGS **Corn Earworm** Various colors, often balls up when touched.	
Velvetbean Caterpillar Green to black colored, white stripe, wiggles violently when touched.	
Fall Armyworm Usually brown, smooth appearance, prominent white to creme colored inverted "Y" on front of head.	
Beet Armyworm Green to black, prominent black spot above second true leg.	
Yellow Striped Armyworm Double row of triangular shaped markings on back, with bright yellow stripe on side.	

Chapter 13

Chemical Application and Calibration

by D. Gardisser and J. Walker

Chemical applications play an important role in Arkansas soybean production. The proper application of chemical products, both plant nutrients and pesticides, will provide the best economic return. Proper application of chemicals also includes care to ensure that materials do not drift away from the target site. In some cases, chemicals may be placed in a band to conserve input costs. It is imperative that all chemical applications be done with precision!

There are several ways to calibrate a sprayer. You should use the one that you feel most comfortable with. The method that will be described here is universal. It may be used to calibrate for almost any type of known row crop situation which may arise.

Management Tip

Nozzle manufacturer catalogs should always be consulted for sprayer component and tip selection, setup and operation guidelines. These catalogs are also an excellent source of other technical information that will help applicators make more efficient applications.

Nozzle Selection

Selecting the correct nozzle is very important to obtain the desired droplet size and coverage. No one nozzle will do every job. Almost all of the major nozzle manufacturers provide guidance in their nozzle catalogs to assist with the selection of the correct tip. In many cases there may be more than one tip that will work, but some may be more desirable than others.

Chemical labels should be carefully read to see if they require a specific droplet size or size classification. A new U.S. standard has set up six standard categories: very fine, fine, medium, coarse, very coarse and extremely coarse. The categories denote the average size as well as the number of fines one might expect. Tables are being provided in almost all the manufacturer catalogs to illustrate what droplet category can be expected for each size and pressure configuration.

Broadcast Tips – Broadcast tips are generally of a flat fan or simple fan or cone-shaped design. The application rate from broadcast tips tapers down from the center of the tip output to the outer edges. This tapering effect allows overlapping to occur for uniform coverage across the boom.

Drift Reduction Tips – Nozzle manufacturers have made major strides in the development of spray tips that will cut down on the number of fines developed during spray operations. Small droplets, or fines, are generally considered one of the major causes of high drift potential. Nozzles that produce very few droplets less than 200µm will help keep materials on target.

Droplet sizes are generally referred to as VMD (volumetric median diameter). VMDs from 250-500 are desirable for almost all spray applications. Droplets smaller than this may drift or evaporate, and larger droplets will generally result in poor coverage.

Drift-reducing tips of many styles are now available. These have some design characteristics that will help avoid making small droplets. Operators should study the information in their operator's manual carefully when spraying drift-sensitive products. Almost all of these use a chamber design where the metering function is separated from the pattern development phase of the nozzle outlet. A popular design concept that uses a venturi built between these two functions also helps reduce fines. These are typically referred to as air induction nozzles.

Banding – Banding applications require different tips also. Band applications that are sprayed on the soil surface should use flat fan, even style tips. The deposition rate does not taper off near the end of the spray pattern, thus allowing an even application all the way across the band with only one tip. Over-the-top band applications may be done with flat fan even tips or a combination of cone-type tips if the spray is being directed onto the plant surfaces of an individual row (example: three nozzles over the top, sometimes referred to as a *Basagran rig*).

Calibration

Calibrations should be done often enough to ensure that the dosage is correct.

Step 1

Determine that the correct tip has been selected and that all tips are the same size and flow rate. Flow rate test each tip across the boom to make sure the flow rates do not fluctuate more than 10 percent. This is easily done by catching the flow from each nozzle for approximately 30 seconds and comparing the values. If they vary by more than 10 percent, clean, replace or adjust as appropriate.

Step 2

Determine the sprayer operating speed. This needs to be done precisely – do not rely on the tractor/sprayer speedometer unless it is GPS driven. Speed should also be measured on a soil surface similar to what is going to be sprayed. If a tillage tool or planter is going to be pulled by the spray unit, the speed check should be done with that unit attached and operating normally.

Speed Equation

$$\text{Speed (MPH)} = \frac{\text{Distance (ft)} \times 60}{\text{Time (Seconds)} \times 88}$$

Any distance may be used, but longer distances will be more accurate. A minimum of 100 feet for each 5 MPH of travel speed is recommended.

General Calibration Equation

$$\text{GPA} = \frac{5{,}940 \times \text{GPM (per nozzle)}}{\text{MPH} \times \text{W (inches)}}$$

where:
MPH = miles per hour
W = width that the nozzle(s) are responsible for
GPM = flow rate

These values are all rather straightforward, except the W term:

- For broadcast spraying, this is the nozzle spacing.
- For single nozzle band spraying, this is the band width.
- For multiple nozzle band spraying, this is the band width divided by the number of nozzles.
- For directed spraying, when no band is being used, this is the row width divided by the number of nozzles per row.
- This works well if all the nozzles spraying a band or row are all the same size. If there are different sizes being used on a band or row, the sum may be treated as a single nozzle, and the total GPM would be entered in along with the total width of the nozzle group application.

The General Calibration Equation may be manipulated to solve for other variables as well.

Nozzle Size Equation

$$\text{GPM (per nozzle)} = \frac{\text{GPA} \times \text{MPH} \times \text{W}}{5{,}940}$$

The Nozzle Size Equation is used to determine the nozzle size needed if the application rate desired (GPA), travel speed (MPH) and nozzle spacing (W) are known. One will generally be able to find one to three nozzles of the style desired that may produce the desired flow rate. Spray pressure has a direct influence on droplet size. If smaller droplets are desirable, select a high pressure. If larger droplets are needed to control drift, select a nozzle with lower pressure. If droplet size is not a factor that plays into the selection, choosing a nozzle size that will allow lower operating pressure will result in longer wearing tips.

Useful Conversion

One gallon = 128 fluid ounces

Step 3.

Nozzle Flow Rate Check – Set the sprayer at a pressure that you think will provide the desired application rate. Catch the flow rate from one nozzle and determine the GPM flow rate. Use the following equation to convert ounces collected to GPM.

$$GPM = .469 \times \frac{\text{number of ounces collected}}{\text{number of seconds during collection}}$$

Example: 28 ounces were collected in 30 seconds

GPM = .469 x 28/30 = 0.44 GPM

Another method would be to catch the discharge from one nozzle for 60 seconds and divide by 128 to obtain GPM.

Step 4.

Determine GPA – Once the speed, nozzle flow rate and nozzle spacing are known, the GPA is easily determined by plugging these values into the general calibration equation.

Example: 5.2 MPH, 0.44 GPM, 20-inch spacing

$$GPA = \frac{5{,}940 \times .44}{5.2 \times 20} = 25.1\ GPA$$

Adjustments – Adjustments to the application rate may be accomplished by changing the following variables: travel speed, nozzle spacing and size, and spray pressure.

Changing spray pressure is the hardest to manipulate. The spray pressure must be changed by four times to get twice the flow rate. If the pressure is changed, the droplet size will follow inversely. Small droplets result from higher pressures.

Nozzle spacing is also hard to manipulate. If the nozzles have not been purchased, this is probably the best way to change the desired application rate. If large changes are needed, this may be the only way.

Travel speed may be changed sometimes. There is a direct and linear relationship between travel speed and application rate. If the speed is cut in half, the rate doubles, simply because you would be in one location twice as long. If the speed is doubled, one-half the original rate will be applied for the same reasons.

All nozzles have a preset recommended operating pressure range. The maximum and minimum allowable travel speeds needed to stay within these parameters may be determined by manipulating the general application equation and solving for speed at the lowest and highest flow rates that correspond to the lowest and highest pressures.

$$MPH = \frac{5{,}940 \times GPM\ \text{(per nozzle)}}{GPA \times W\ \text{(inches)}}$$

Spray patterns are almost always deformed if sprayers are operated below the recommended minimum pressure range. Operating above the recommended range increases wear and creates excessive fine droplets.

This technique may be used to help one determine the minimum and maximum operating speeds that must be observed when a spray controller is being used. The spray controller will automatically lower the flow and/or pressure as the unit slows down and increase as the speed increases to apply the correct rate. The controller will do this even though the pattern may be distorted at the low and high positions.

Look for additional sprayer setup and calibration information in other Cooperative Extension Service publications such as the MP-44 and MP-144, which are available from your county Extension office.

Chapter 14

Harvesting Soybeans

by G. Huitink

Combine operation requires an expert. A skilled operator may add more than $50 profit per hour of harvest. However, surveys indicate that only 10 percent of all combine operators check their combine adjustments regularly and match forward speed to soybean conditions. Constantly changing weather conditions affect soybeans and require that certain combine adjustments be fine-tuned to get the best operation. Large combines are costly to own and maintain. Harvesting is the single most costly operation of soybean production. Table 14.1 highlights one aspect of the worth of a skillful operator.

Make a commitment to be an expert combine operator. Every extra bushel saved at harvest is profit. In fact, the value of expert combine operation compared to average operation is impressive. Evaluate where you can improve as follows:

1. Know how to operate and adjust your combine properly in order to keep your harvest loss low.
2. Know how to quickly measure soybean field loss.
3. Know what losses are reasonable from each combine component.
4. Identify how much soybean damage and foreign matter content are allowed without getting market dockages.
5. Know how to reduce foreign matter dockage, field loss and soybean damage using proper cultural practices and helpful combine options.

Harvest Management

An expert operator adjusts for varying crop conditions, including weedy or droughty areas. In spite of costly attempts in the past 20 years to automate controls for forward speed, threshing and separation adjustments, an expert operator is still more reliable. Experiments indicate that adjustments are needed every two or three hours during most days to maintain combine efficiency. Frequent fine-tuning of combine forward speed, reel speed and reel height can increase soybean income by several hundred dollars per day. In addition, weedy areas, daily moisture fluctuations and changing fields are reasons to recheck your thresher speed, concave spacing and fan speed.

Characteristics of Expert Combine Operation

- No skipped (uncut), standing soybean strips between combine passes.
- Gathering loss is roughly 90 percent of all field loss when operating during favorable harvesting conditions.
- Very little foreign matter (f.m.) reaches the grain tank in a weed-free field. Soil is often the most common f.m. dockage. An expert combine operator slows forward speed to reduce foreign matter in soybeans harvested from weedy spots in the field.
- Few, if any, split soybeans in the grain tank (fewer than 1 split per 50 soybeans).

Table 14.1. The Value of Improving Combine Operation and Reducing Soybean Field Loss Using a 40 Bushel Per Acre Example of Soybeans Selling for Either $5 or $6 Per Bushel

Operator Skill Level	Combine Operation Loss, Bu/A	Acres Per Hour	Soybean Loss, $ Per Hour	Gain (Over New Operator), $ Per Hour, at Soybean Price of *$5/Bu*	Soybean Loss, $ Per Hour	Gain (Over New Operator), $ Per Hour, at Soybean Price of *$6/Bu*
New	2.6	10	$130	---	$156	---
Average	1.6	10	$80	$50	$96	$60
Expert	.9	10	$45	$85	$54	$102

- Soybean stalks that discharge from the combine fairly intact, not “chewed up,” suggest that threshing adjustments are good. (If you operate a straw chopper on your combine, this check isn’t useful.)
- Of the soybeans that are gathered, fewer than 1 percent leave the rear of the combine. Only immature “green” beans are left in pods behind the combine.
- Soybeans are no more than half of the recycled material in the tailings system. The tailings system should be only moderately loaded.
- If the combine separator is suddenly stalled or “killed,” chaff should be spread evenly on the chaffer, the straw walkers and across the width of rotary components or the cylinder/concave.
- Skilled control of the combine loading rate, fan speed and sieve settings may eliminate light, low-quality seed or other foreign material, thus improving soybean market value.

Timely Harvest

To avoid moisture discounts from the quoted market price per bushel, soybeans must contain 13.5 percent, wet basis, or less moisture. However, a small loss of water affects soybean value above and below 13.5 percent moisture content (m.c.). The entries in the second column of Table 14.2 show the weight loss per bushel at moisture contents below 20 percent m.c.

Management Tip

If the content of the tailings is mostly soybeans, careful combine readjustment is needed. If the tailings system is fully loaded, check thresher adjustments first, then sieve openings and, finally, fan speeds to reduce the amount of recycled soybeans.

Obviously, every grower receives less income than the quoted price because he cannot afford enough combines, grain carts, trucks and grain-handling facilities to cut every bushel at 13.5 percent m.c. One option is to utilize farm grain drying and handling facilities to aerate or remove some soybean moisture. Another approach is to examine moisture discounts at local grain terminals to determine the range of harvest moisture that provides greater income for the entire crop.

For example, two discount rates for soybeans below 20 percent m.c. are shown in Table 14.2. Entries in the center and right columns are the net soybean values after taking the discounts above 13.5 percent m.c. and adjusting the weights to the 13.5 percent m.c. market standard. The net effect on deliveries for a $6.00 per bushel soybean price is shown in this table. Moisture discounts and the soybean weight loss above 13.5 percent m.c. have opposite effects on the payment received for “high”

Table 14.2. Two Discount Schedules for $6.00 Per Bushel Soybeans and the Weight/Value Lost From Soybeans at Moistures Other Than 13.5 Percent M.C. Standard

Soybean Harvest Moisture, %, Wet Basis	Weight of Water Loss (+) or Gain (-), Lbs/Bu to Convert Soybeans to 13.5% Moisture	Discount of $.12 Per Bushel Per Point of Moisture (2% Per Point of Moisture)			Discount of $.20 Per Bushel Per Point of Moisture (3.3% Per Point of Moisture)		
		$.12 Discount Per Bushel, $	Price Per Bushel, $	Value Per Bushel, $, Adjusted for Moisture	$.20 Discount Per Bushel, $	Price Per Bushel, $	Value Per Bushel, $, Adjusted for Moisture
19	4.33	-$.66	$5.34	$5.77	-$1.10	$4.90	$5.33
18	3.66	-$.54	$5.46	$5.83	-$.90	$5.10	$5.47
17	2.89	-$.42	$5.58	$5.87	-$.70	$5.30	$5.59
16	2.14	-$.30	$5.70	$5.91	-$.50	$5.50	$5.71
15	1.41	-$.18	$5.82	$5.96	-$.30	$5.70	$5.84
14	.70	-$.06	$5.94	$6.01	-$.10	$5.90	$5.97
13		0	$6.00	$6.00	0	$6.00	$6.00
12	-.68		$6.00	$5.93		$6.00	$5.93
11	-1.35		$6.00	$5.86		$6.00	$5.86
10	-2.00		$6.00	$5.80		$6.00	$5.80
9	-2.64		$6.00	$5.74		$6.00	$5.74
8	-3.26		$6.00	$5.67		$6.00	$5.67

moisture soybeans. The “penalties” for soybeans delivered at less than 13.5 percent m.c. are shown for both $.12 and $.20 discounts for each 1 percent m.c.

The discount schedule used by your grain terminal is the key factor in planning what is the best moisture to begin soybean harvest. One approach or goal is to balance the high moisture discounts of early harvest with late season value reductions from low moisture sales. Often moisture discounts are quoted as a percent of the “points” or moisture level of the soybeans. This ties the moisture discount to the soybean market price. In other words, as the price increases, the cash discount per bushel for “wet” soybeans increases proportionately. When soybean prices rise, a slightly greater return is realized from selling soybeans nearer to 13.5 percent m.c. Essentially, each grower should examine his local terminal’s discount schedules carefully, evaluate his ability to “condition” soybeans on the farm and then plan his harvest timing. Planning may reduce the impact of market terminal moisture discounts if it is possible to begin soybean harvest at higher moistures or to obtain an extra combine, if discounts justify this, for more rapid harvest.

If harvesting begins at 16 percent soybean moisture, the income penalty (depending on discounts, on-farm drying, weather, etc.) may be less than marketing extremely dry soybeans later. During a wet harvesting season the penalty for late harvest is much costlier. Every grower knows how wear and repair expenses increase in muddy fields. In addition, a delayed harvest may result in high field shatter loss. Gathering loss increases from field deterioration, and possibly storms, sometimes as much as 5 bushels per acre. This cost may easily exceed the loss from early season moisture discount reductions. If soybeans deteriorate and become moldy and sprout in the field, further damage occurs during threshing and handling. Buyers and soybean crushers are apt to discount these soybeans for field deterioration or excessive splits.

Management Tip

Plan to maximize net crop income by balancing the high moisture discount early season with the soybean weight loss penalty later when soybeans dry. High moisture discounts at terminals may justify aerating or drying soybeans to avoid severe moisture penalties.

Gathering Soybeans Is Challenging

Getting all of the soybeans into the header is challenging. Bean pods may set low on the stalk – close to the ground. Dry soybeans, especially those that are dry and then get a rain, tend to shatter. Research shows that beans lost at the header account for more than 90 percent of the total loss. Gathering loss is the sum of shatter, stubble, lodged and stalk loss.

Cutting across flat-planted rows at an angle helps feed soybeans into the header more smoothly, thus reducing gathering loss. Drilled soybeans usually feed more uniformly into the header than 30- or 38-inch rows. This tends to keep gathering loss lower in drilled soybeans.

Header Options

A flexing cutterbar with automatic height control provides excellent gathering for fields with drain furrows, levees or low pods. Use care not to damage the header height sensor; for some models, this can occur if the header is down when backing. Follow the manufacturer’s procedure to set the response time and position control.

A lateral-tilt header gathers more low-podded soybeans if the combine chassis doesn’t remain parallel to the terrain. For example, this header gathers more soybeans in areas where wheels on one side of the combine are on a row and wheels on the other side follow a low middle. Lateral-tilt may gather more soybeans near irrigation levees, in muddy fields or on terrain with varying side slopes. One end of a wide header may be a foot high. If your soybeans pod low, as Group IVs often do, and your fields have levees, ditches or ridges, the lateral-tilt option may recover enough soybeans to offset this option’s cost.

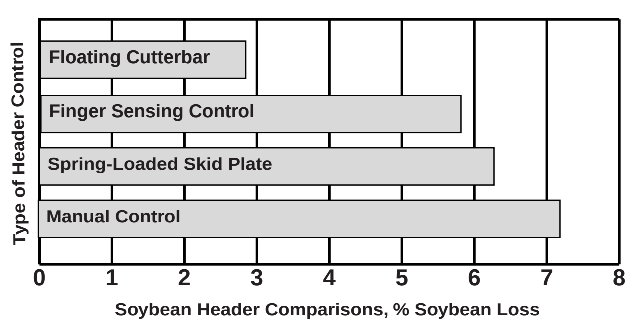


Figure 14.1. Harvest losses with various combine headers for soybeans.
W.R. Nave, University of Illinois, Champaign, Illinois

Draper headers do not follow the terrain like flexible headers. The big advantage of draper headers is the capability to cut all Delta crops well – soybeans, rice, wheat, grain sorghum, etc. In addition, Case, Ford-New Holland, Honey Bee, John Deere and MacDon drapers feed soybeans very uniformly into the thresher. This increases the effective capacity of any combine. However, a full, uniform rate is most critical with Axial Flow™ threshers. Uniform feeding reduces combine field loss and utilizes a combine's capacity. Obtaining more return on combine investment is essential with new combine prices approaching $200,000.

Suggestions for Improved Gathering

Gradually increase forward speed while checking both soybean stubble loss and separation loss (soybeans leaving the rear of the combine). Keep the combine speed below the point where gathering loss or separating loss increase rapidly. Speed should be slower in short, droughty soybeans to limit gathering loss well below 2 bushels per acre. An expert operator needs to be especially alert in well-watered, high-yielding soybeans to avoid high soybean loss out the rear of the combine. Every combine, no matter how large or how new, has a harvest capacity that varies with field conditions. Increasing feed rates (often a travel speed increase) increases field loss suddenly when a combine's capacity is exceeded.

Cutterbar

As forward speed increases, soybean cutting height increases (rapidly, at times), causing more gathering loss. Excessive forward speed may also cause excessive shatter and stubble loss. Combines have a fixed sickle speed. When the combine exceeds its practical speed limit, the sickle begins stripping stalks as it cuts. Soybean pods, stripped from the stalk, shatter and fall to the ground. Uneven stubble height is one hint that forward speed may be too fast for the sickle speed. Headers with 1 1/2-inch sickle section spacing may reduce gathering loss at high forward speeds compared to the common 3-inch spacing.

A sharp, well-adjusted cutterbar is vital to speeding harvest and minimizing gathering loss. Four items need to be checked: (1) all sickle sections are sharp, (2) all sickle hold-downs are gapped properly, (3) all guards are in alignment (if a guard is bent up, align it by tapping with a hammer). Misalignment causes rapid wear and ragged cutting on adjacent guards. And (4) inspect the sickle to assure it is in correct guard register. Refer to your operator's manual for specifications.

A proper cutterbar angle with the soil surface reduces gathering loss. Frequent sinkage (ruts) under muddy conditions, small diameter drive tires or an improper feed elevator/header combination may position the cutterbar too flat with respect to the soil. High row beds or an accumulation of residue worsen this problem. The bottom of the header may push soil when trying to cut low.

Large tires or a short, mismatched feed elevator add more tilt to the cutterbar. A steep cutting angle is easily noted. Residue is quick to hang in the cutterbar and soil is readily pushed onto the cutter-bar, sometimes contributing to soil reaching the grain tank and causing f.m. discounts.

Most manufacturers offer a long divider option for both ends of the header. If soybeans are drilled, lodged or weedy, this option is especially helpful. Cleaner cutting and gathering at both ends of the header reduce both field stoppages and gathering loss.

Reel

Improper reel speed and reel position cause more shattered soybeans than any other mal-adjustment. Maintain reel tip speed 10 to 25 percent faster than travel speed. If the reel fingers are angled back slightly, it is even more important that the reel is operated at the slowest speed that tilts stalks slightly toward the cutterbar. From an operator's viewpoint, it appears as if the reel is slowly pulling the combine into standing soybeans. Probably the most useful option on a combine is an automatic reel control that maintains a constant forward/reel speed ratio as forward speed is adjusted for the incoming crop.

Figure 14.2. Reel adjustment for gentle soybean handling is more critical after soybeans have dried down once (or with certain Maturity Group IV varieties).

The reel should be lowered in areas where soybeans did not grow tall. If reel speed matches forward speed and the reel contacts the top one-third of the plant, soybeans are seldom flailed out of their pods.

Usually, positioning (fore and aft) the reel as close to the auger as possible provides the most uniform feed rate to the combine. This may seem trivial, and with some soybeans, fore and aft positioning isn't important. However, improper reel position may clump or cause uneven feeding that usually increases separator loss and reduces harvesting capacity. Check the fore/aft reel position when entering fields with substantial soybean height changes or when the pickup fingers must be angled back for lodged soybeans. It takes an expert operator to remedy uneven or "slug" feeding, but it pays off handsomely with better combine performance.

In short, droughty soybeans, lower the reel to reduce soybean "stacking" on the cutterbar. If a dense crop is not feeding across the header uniformly, check the reel position first. Then check if the sickle is sharp and cutting cleanly. Sometimes a header slip clutch or drive belt causes momentary hesitation, thus an uneven feed rate. LEXION™ has retractable fingers across the full header width to improve crop flow into the feed elevator.

Header Auger

Finally, observe if the auger fingers are aggressive. The gap between the auger fingers and the header floor should be 5/8 inch. For best performance, adjust the auger finger timing for soybean height, size of lower branches, etc. Check that the auger is properly positioned, especially notice the clearance above the bottom of the header.

Threshing

With proper adjustment, up to 90 percent of the soybeans pass through the concave or rotor grate, greatly simplifying separation. Threshing and separation losses are usually nil if the thresher is adjusted properly. Threshing loss is unthreshed beans remaining in pods that pass through the combine. When pods are green or damp, check that mature, unthreshed pods do not leave the rear of the combine, especially in weedy areas. Thresher speed and concave spacing or rotor/grate spacing should be re-evaluated when soybean moisture content changes and when starting into a different soybean variety. Cutting across a field that has both irrigated and non-irrigated crop is one reason for accepting a little threshing loss.

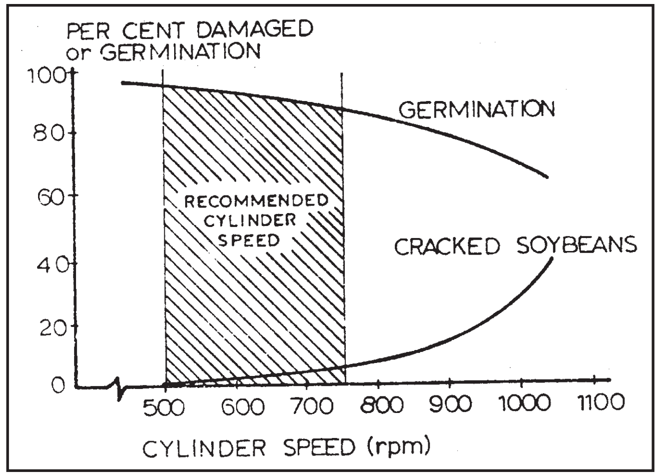


Figure 14.3. Effects of thresher speed on damage and germination.

However, over-threshing is a common oversight in Arkansas, especially with spike tooth cylinders. Since increasing thresher speed increases threshing severity, choose the slowest thresher speed that beats soybeans out of the pods. Pods and stalks should not be pulverized. Another indication of over-threshing is excessive chaff and stalk returning in the tailings. Over-threshing simply increases the chaff and fine stalk material on the chaffer sieve and may complicate cleaning soybeans. Always look for a few immature green soybeans and leave these in the pods.

To avoid over-threshing, start by narrowing the thresher to concave or rotor grate spacing to the position recommended in the operator's manual and then reduce it further if some unthreshed pods are leaving the rear of the combine. For seed beans, a thresher rpm slower than the recommendation in the manual may be practical. Research indicates that soybean germination declines at roughly the same rate as damage (splits, etc.) increases when threshing is too aggressive (Figure 14.3). Dry soybeans (8.5-13 percent moisture) need very gentle threshing.

Don't take poor threshing of soybeans as an acceptable diagnosis until you've checked whether the header dropped the unthreshed pods, examined carefully all threshing components for excess wear and narrowed the concave/grate to thresher gap. During rice harvest or during soybean harvest when soil is pushed into the combine, rapid wear occurs. Thresher components, the impeller feeding the Axial-Flow™ rotor and accelerator cylinders ahead of the thresher must be maintained to obtain full combine capacity. Worn spike teeth can cut combine capacity roughly by one-half, resulting in poor threshing, poor separation and damaged soybeans, all at once. Growers remark that their combine threshes like a new one after replacing worn threshing components.

Always make only one adjustment at a time. Then check combine performance under normal load. Count losses in the field, evaluate the bin sample and monitor the tailings throughout the harvest day.

Damage from worn auger flighting is another source of soybean splits and damage. Augers handling the grain behind the sieves are prone to wear rapidly when harvesting rice, so they may need replacement.

Cleaning

Fan Adjustment

Fan speed is the key adjustment for cleaning. Fine-tune the fan speed frequently, as stalk moisture varies and the amount of material other than soybeans changes. Be alert to possibly needing additional fan speed when harvesting larger areas with weed infestations. Check the grain tank and the losses behind the combine to evaluate your fan speed setting. If the sample in the grain tank contains too many soybean stalk or weed portions, this suggests that the fan speed should be increased, if the sieves are set properly.

The first indication that fan speed is too high is an excessive amount of threshed soybeans in the tailings return. Too much air velocity pushes soybeans off the chaffer and cleaning sieves, into the tailings return. Soybeans may also begin leaving the combine with the chaff, causing high separation loss. Separation loss consists of soybeans discharged from the combine separator, already hulled out of the pods.

Reduce the fan speed as stalks dry. If you expect to cut at less than full capacity for some time, determine whether the fan speed should be reduced. Separation of soybeans from chaff is done primarily with air by using sufficient velocity to tumble the mixture. Soybeans, which are heavier, fall through the sieve. High air velocity keeps the chaff tumbling and moving off the rear of the combine. The denser, heavier soybeans should fall through this airflow, onto the cleaning sieve.

If anything disrupts the air passing through the sieves, soybean cleaning will suffer. Cleaning fan inlets covered with chaff starves the fan, preventing uniform tumbling on the sieves. Large weeds hanging in the air path disrupt the air velocity; thus, it's important to keep the path from the fan clear of any kind of blockage that hinders separation.

Separation Through the Sieves

Start with the chaffer and cleaning sieve openings suggested in your operator's manual for soybeans. Later you may wish to **reduce the chaffer (upper) sieve opening first**, if too many stalk portions are reaching the grain tank. Remember, the fan speed should be in the proper range and then fine-tune sieve openings to get the best cleaning. Sieve settings close to the manual's suggestions normally perform very well. Damaged chaffer or cleaning sieves need repair or replacement to avoid excessive foreign matter and dockage.

The cleaning (lowest) sieve openings should be somewhat smaller than the chaffer setting. This sieve's task is to keep small stalk sections, unthreshed pods and cocklebEurs from getting into the grain tank. Never make two adjustments at once in order to identify the effect of your fine-tuning.

Soybeans are not hard to separate from chaff. However, maintaining expert cleaning really requires tweaking the fan speed throughout the day, whenever situations require it. Never be concerned about using fan speeds higher or lower than suggestions in the operator's manual, as long as separation loss remains low and the grain tank sample is clean.

Figure 14.4. Uneven wheat emergence and growth are evidence of poor combine distribution of soybean residue.

Soybean Residue

Stalks and chaff should be discharged uniformly behind the combine to minimize seedbed preparation for the next crop. Adding a chaff spreader is simple on certain combines. Observe the soybean residue behind your combine if you plan to begin seeding no-tillage wheat. Soybeans provide little residue, even from well-irrigated plants. However, when soybeans are never rotated with another warm-season crop, there are situations where certain diseases overwinter in the dense “windrow” of soybean thatch behind a combine. Spreading soybean residue uniformly provides some soil protection from erosion without hindering a good no-tillage drill.

Wheat, rice or soybeans can be seeded with a no-tillage drill if the combine discharge isn’t concentrated. Maintain the straw spreader properly, so it pitches stalks across roughly two-thirds of the header width. Chaff spreaders distribute the sieve discharge. An inexpensive chaff spreader is available for Case combines. Growers with recent models of Ford-New Holland, John Deere and LEXION™ combines have a chaff spreader option. With a good chaff spreader, residue from high-yielding soybeans does not hamper a good no-till drill (even for drilling wheat immediately after a soybean crop), unless the combine stops while threshing. Straw choppers pulverize soybean stalks without affecting the chaff while increasing combine engine load and operation cost.

Performance Evaluation

Loss monitors and yield monitors have become valuable management tools; calibrating them properly maximizes their benefit. Loss monitors require re-indexing (validating) for changes in seed moisture. Sensitivity settings are relative, but a loss monitor is an excellent diagnostic tool to confirm that your combine is at its capacity. One indicator of excess forward speed is separation loss; the signal from a loss monitor helps harvest more acres without blowing too many soybeans off the rear of the sieve.

Combine Loss Monitors

Grain loss monitors may help optimize operating adjustments and forward speed. Grain loss sensors must be installed properly in the straw and chaff discharge to intercept soybeans leaving the combine. The sensitivity must be set to assure that only grain and not straw segments trigger the indicator. To check whether a sensor is functional, tap it lightly while someone watches the monitor needle in the cab. For precision, reset the indicator for swings in soybean moisture content. Calibrate the monitor for soybeans by occasionally checking behind the combine to prove that actual separation loss is proportional to the signal in the cab.

Brief monitor fluctuations should be overlooked. However, observing a monitor and the field conditions will quickly highlight conditions that increase soybean separation loss. An alert operator fine-tunes thresher speed and forward speed to use his combine capacity while avoiding excess soybean loss.

Figure 14.5. Yield monitors can be especially helpful in documenting the differences between well-watered soybeans and those receiving inadequate rainfall or those growing in soils that remain too wet at times.

Yield Monitors

A yield monitor basically provides dry weight yields, based on data gathered from the moisture sensor and the grain flow sensor. The processor estimates yield at every point in the field. It is vital to calibrate for soybeans to get useful management data. Take several soybean samples to a moisture meter like those used at grain terminals. Calibrate the yield monitor, compare the readings and confirm the moisture content of each. Yield monitor information helps to identify the benefits of good drainage, irrigation, variety selection, subsoiling, and a variety of fertility or herbicide applications. New uses continue to develop.

Where levees and point rows are few, yield monitors can be very accurate. Both the differential global positioning system (DGPS) with the mapping capability and the non-recording, instantaneous non-DGPS models provide valuable management data. However, harvesting a constant width (near full header width) is essential to get accurate acreage data, thus correct yield per acre data.

Soybean moisture is displayed on the monitor throughout the harvest day. The processor typically adjusts soybean weight to 13.5 percent m.c. if it is calibrated properly. If moisture is not properly calibrated or it is biased by residue, the processor converts the data to incorrect yields. If soil enters the header, be alert that soil can accumulate on the moisture sensor in the clean grain delivery. Residue typically has high moisture and converts its data to unrealistically high soybean moistures. The processor then adjusts the dry weight (13.5 percent soybeans) down and, consequently, records lowered yields (without real reason). If the display moisture content rises more rapidly than justified, it is wise to check the metal sensor for residue. Plant residue may stick on the metal sensor without an apparent cause. When sampling in the grain tank, always check that the metal sensor is smooth and shiny (no residue). Until the sensor is thoroughly clean, erroneous readings persist, *even for years*! Moisture errors are one of the most common errors that exceed 2 percent.

Safe Operation and Overall Combine Management

Always make only one adjustment at a time. Then check the combine performance under normal operation. Count losses in the field, evaluating the bin sample and monitoring the tailings throughout the harvest day.

If the cutterbar or feed elevator entry plugs, stop the combine engine before reaching into the header to remove the obstruction. Never attempt to remove obstructions or perform maintenance with the thresher turning. Replace all shields and covers after repairing or adjusting combine components. Do not engage power before all guards and shields are in place. Don't fail to give ladders and overhead work your full attention. Falls from combines are the most common combine accident. They may cause lifetime paralysis and have caused death to a number of farmers.

Never work under a combine header without securely blocking the lift cylinder. Men have been crushed under a header making adjustments when the hydraulic system failed. Others have been pinned when someone else bumped the header lift control.

Management Tip

Six combine performance evaluation points:

1. Soybean field loss.
2. Soybeans in tailings.
3. Material other than soybeans in tailings.
4. Foreign material in grain tank sample.
5. Soybean splits, damaged seed or reduced germination.
6. Degree of stalk destruction behind combine (if not flailed through a straw chopper).

Use auxiliary flashing lights when operating a combine on a public road. Combines are large and motorists are not alert to equipment moving less than 25 mph. Make every effort to move on roads during well-lit daylight hours.

Reducing Soybean Field Loss

Soybeans are fairly easy to harvest when the soil is dry. A skillful operator can maintain loss at reasonable levels. Indeterminant soybean varieties have traditionally set higher on the plant than determinant varieties commonly grown in the Midwest. Table 14.3 (on the next page) illustrates several comparisons that relate to the type of soybean production. Pre-harvest loss samples averaged slightly higher at Illinois locations due to their climate and a tendency of determinant varieties to shatter readily. Also, flood-irrigated soybeans in Arkansas tend to pod higher and have less gathering loss than similar varieties in Mississippi that haven't been irrigated. Another important observation is that field losses do not necessarily correlate with yields or moisture content at harvest. Probably, an expert operator is the key influence on the level of field loss in higher yielding, irrigated soybeans. However, harvesting muddy fields tends to increase gathering loss; consequently, total field loss rises significantly.

Combine manufacturers consider the maximum combine capacity to be the feed rate (weight) at 3 percent field loss. However, maintaining field loss between 1/2 and 2 bu/A is a realistic goal for every grower. For 20 bu/A soybean yields, the desired loss range varies from 1/2 bu/A under normal field conditions to 1 1/2 bu/A with either extremely droughty, low-podded soybeans or muddy fields. For 60 bu/A yields, a desirable loss range is from 1/2 to

Table 14.3. Summary of Harvest Comparisons Based on 35 Field Samples Gathered From Grower-Operated Combines
W. R. Nave, University of Illinois, Champaign, Illinois

Location	Champaign County, ILLINOIS	Shelby County, ILLINOIS	Arkansas County, ARKANSAS	Sunflower County, MISSISSIPPI
Number of Combines	11	9	8	7
Loss				
Pre-Harvest Loss, %	.32	.24	.01	.15
Gathering Loss, %	6.26	3.86	2.24	11.05
Threshing and Separating Loss, %	3.17	1.11	1.31	1.69
Total Field Loss, %	9.44	4.97	3.54	12.74
Total Yield, Bu/A	49.38	36.07	36.87	21.13
Stubble Height, Inches	3.67	3.67	4.20	4.33
Soybean Moisture Content at Harvest, %	13.30	12.90	13.80	12.20

Header width varied from 10 to 20 feet wide.

Table 14.4. Annual Samples of Soybean Field Loss in Arkansas.
Arkansas Agricultural Statistics Service*

Year	Field Loss (Bu/A)
1990	1.8
1991	1.1
1992	1.3
1993	1.5
1994	1.3
1995	2.5
1996	2.1
1997	1.5
1998	1.6
1999	1.1
10-Year Average	1.6

* Data collected from 74 small field plot samples across Arkansas. These unofficial averages are from randomly selected locations using a consistent sampling procedure.

1 1/2 bu/A with good harvesting conditions. When harvest is delayed and soybeans remain in the field, excessive shattering or severely lodged soybeans may cause unavoidable field loss levels up to 2 bu/A.

Table 14.4 shows total field losses in Arkansas that have been sampled and summarized annually. The dominant factor influencing total field loss over the decade appears to be **weather**. When rains occur during harvest, the losses rise, especially if combines "rut" the fields to finish. When the growing season is dry, the soybeans on non-irrigated fields set so low that they become a significant portion of the soybean yield. If efforts to recover low pods are successful, the harvested yield is raised and field losses don't "spike" as high.

A quick count of soybeans lying on the ground is a reliable estimate of field loss. Four to five soybeans per square foot spread uniformly across a field equal a bushel per acre loss. **To obtain a good sample, soybeans in 10 square feet should be counted**, and the number of soybeans found in that area should be divided by 40 or 50 (see Procedure section later in this chapter). Divide the number of large-seeded soybeans that you've counted by 40.

Table 14.5. Preliminary Guide That Includes a Few Soybean Sizes to Help Develop a Perspective of Whether 4 or 5 Seed Is the Appropriate Soybean Count to Use in Estimates of Field Losses

Four soybeans per square foot equal one bushel per acre loss.		Five soybeans per square foot equal one bushel per acre loss.	
Selected LARGE-seeded varieties that normally require LESS than 3,300 seed to weigh 1 pound.	**Seed Weight (Seeds/Lb)***	**Selected SMALL-seeded varieties that normally require MORE than 3,300 seed to weigh 1 pound.**	**Seed Weight (Seeds/Lb)***
Delta King 5961RR	2,500	Hutcheson	3,400
NK S46-44	2,500	Asgrow A5547	3,500
Pioneer 9594	2,500	Deltapine DP 3478	3,500
Terral TV4975	2,500	Hartz Variety H6191	3,500
HBK 5990	2,600	Asgrow A6297	3,600
UARK-5798	2,800	Delta King 5850	3,600
Accomac	3,000	Crowley	3,700
Manokin	3,000	Novartis NK59-V6	3,700
Asgrow 5959	3,100	Riverside Robin - 5	4,100
Caviness	3,200	Dyna-Gro 3576	4,600

*There are genetic differences among varieties, but seed size will vary considerably from lot to lot, depending upon environmental conditions.

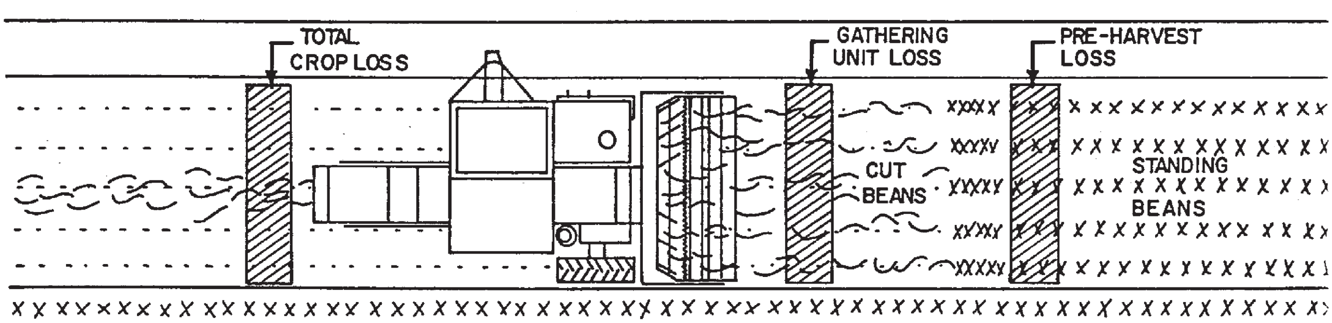
Small-seeded soybeans cannot amount to as great a loss. Divide the number of small-seeded soybeans in a 10 square foot area by 50.

Table 14.5 provides a general guide to soybean size. Soybeans vary in size, according to their growing conditions. When purchasing seed, the number of soybeans in a bushel may differ in different lots. The table is an example that is provided to help select whether 40 or 50 is the best choice to use as the divisor.

Management Tip

Four soybeans per square foot distributed uniformly equal 1 bushel per acre loss if there are **2,904 seed per pound**. If **3,630** seed weigh a pound, then **5 seeds per square foot** spread uniformly across a field equal 1 bushel per acre loss. When estimating, use 5 seeds for small soybeans requiring at least 3,300 seed to weigh 1 pound.

Figure 14.6. Locations for Checking Various Components of Harvest Loss.



Procedure

Observe your grain loss indicator where you plan to sample loss in order to relate the position of the monitor needle to threshing and separating loss. (However, pre-harvest and gathering losses cannot be measured with a loss monitor.)

1. Stop combine at least 300 feet from field borders where **soybeans** and **combine operation** are **typical** of most of the field. Back combine about 15 feet from standing soybeans. Place rectangular frame enclosing 10 square feet across swath harvested behind the combine. Count all beans in frame and enter this count in cell 1-A of the soybean field loss data table (Table 14.6). Divide this number by 40 or 50 to enter ***total field loss*** in bushels per acre in cell 1-B. If total field loss is below 3 percent of yield, continue harvesting. If loss is greater, then pinpoint the cause of the loss and remedy it.

2. Sample ***pre-harvest loss*** by laying rectangular frame in standing soybeans. Count the beans on the ground, both loose and in pods. Enter this number in cell 2-A and then divide by 40 or 50 to get pre-harvest loss in bushels per acre. Enter this pre-harvest loss in cell 2-B.

3. Estimate ***combine loss*** by subtracting pre-harvest loss from total field loss. Subtract cell 2-B from 1-B. If loss is high, check further by counting gathering losses.

4. Sample ***gathering losses*** by placing rectangular frame between your parked combine and standing soybeans. Then make soybean loss counts as follows:

   a. ***Shatter loss*** – Count all loose beans and beans in pods on the ground and enter this number in cell 4a-A. Refer to your count in cell 2-A to subtract pre-harvest loss from the number in 4a-A before dividing by 40 or 50 to enter the bu/A shatter loss in column 4a-B.

   b. ***Loose stalk loss*** – Count all beans in pods attached to stalks that were cut but weren't gathered. Enter this number in cell 4b-A and divide by 40 or 50 to enter the bu/A loss in cell 4b-B.

   c. ***Lodged loss*** – Count all beans in pods on lodged stalks (lodged soybean stalks, still rooted). Enter this count in cell 4c-A and divide by 40 or 50 to enter the bu/A loss in column 4c-B.

   d. ***Stubble loss*** – Count all beans in pods still on the stubble. Enter this number in cell 4d-A, divide by 40 or 50 and enter bu/A stubble loss in cell 4d-B.

5. Total **gathering losses** by adding shatter, loose stalk, lodged and stubble losses in column B. Enter this total in cell 4-B.

6. **Threshing and separation losses** are obtained by subtracting gathering loss from combine loss. Enter this difference (3B - 4B) in cell 5-B.

7. Compare your loss sample levels to those in column C. As you harvest, put emphasis on operating practices and combine adjustments that reduce the total field loss. Repeat loss counts in other field areas to improve the reliability of your loss estimate.

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LEXION™ is a trademark of Caterpillar Inc.

Table 14.6. Soybean Field Loss Data				
	COLUMN A		COLUMN B	COLUMN C
Source of Loss	**Number of Beans Found in a 10 Sq. Ft. Area**	**Number of Soybeans Equal to 1 Bu/A**	**Your Soybean Loss Bu/A**	**Acceptable Loss for a 40 Bu/A Yield (Bu/A)**
1. Total Field Loss		40 or 50		1.3
2. Pre-Harvest Loss		40 or 50		0.1
3. Combine Loss				1.2
4. Gathering Loss Total of:				1.1
a. Shatter		40 or 50		0.4
b. Loose Stalk		40 or 50		0.2
c. Lodged		40 or 50		0.2
d. Stubble		40 or 50		0.3
5. Threshing and Separation Loss				0.1

DIVISION OF AGRICULTURE
RESEARCH & EXTENSION
University of Arkansas System

On-Farm Drying and Storage of Soybeans

Sammy Sadaka

Arkansas farmers harvested more than 3.1 million acres of soybeans in 2013. With a state average of 43 bushels/acre, Arkansas soybean production reached 133 million bushels. Soybean producers are increasingly interested in on-farm drying and storage due to the various advantages they offer. For example, producers can afford to harvest soybeans early at higher moisture contents than normal to reduce the possibility of harvest losses. Additionally, they may harvest soybeans at faster rates if daily harvesting hours can be extended. Moreover, on-farm storage may provide marketing flexibility and advantage during the soybean selling process.

Figure 15-1. Newly harvested soybeans.

Since soybean quality is highest at harvest, soybean producers should promptly dry newly harvested beans (Figure 15-1) to safe moisture levels in order to maintain their quality. In most cases, producers are able to adapt dryers that were designed for rice or corn for use with soybeans. However, dryers that recirculate or stir grain constantly should be avoided. Drying fans sized for rice or corn will produce greater airflow through soybeans, resulting in a higher drying rate. This chapter will discuss the principles and methods of on-farm drying for soybeans, fans, storage, grain handling safety and soybean drying costs.

Fundamentals of Soybean Drying

Drying Process

The ultimate goal of soybean drying is to get rid of the excess moisture in the kernel in order to make it less accessible to living microorganisms, such as fungi and bacteria. In this process, moisture is evaporated from the kernel to the surrounding air. Therefore, soybeans are dried in most cases by passing relatively large volumes of air, either ambient or heated, through the grain. Figure 15-2 shows an example of an on-farm grain drying and storage site. The quality of the drying air determines the final moisture content of the bean kernels. In addition, the

Figure 15-2. Grain drying and storage bins.

speed of soybean drying (known as the drying rate) depends on the moisture content and temperature of kernels as well as on the temperature, relative humidity and velocity of the drying air. Soybeans are typically dried down to 13.0% or 12.0%, depending on whether they are going to be marketed directly or stored for several months.

Air Properties

Air is the means by which grain is dried, serving as the medium that transports moisture away from the grain. Air contains some energy and humidity. Air quantity and quality are important factors that determine the final moisture content of kernels. Its quantity is the volume of air that the drying fan can deliver. More specifically, it should be divided by the number of bushels the drying air passes through, presented as cubic feet per minute per bushel (cfm/bu). On the other hand, air quality is related to its temperature and relative humidity. Air properties are determined graphically using a psychrometric chart (Figure 15-3).

It should be noted that a specific volume of air (say, 1 cubic foot) at a certain temperature has the capability to hold a specific amount of moisture. Increasing the temperature of that volume of air increases its capacity to carry more moisture, as shown in Figure 15-3. It is noticeable that air temperature at Tdb2 is greater than at Tdb1. As a result, air relative humidity (RH) at the higher temperature, RH2, is greater than that at the lower temperature,

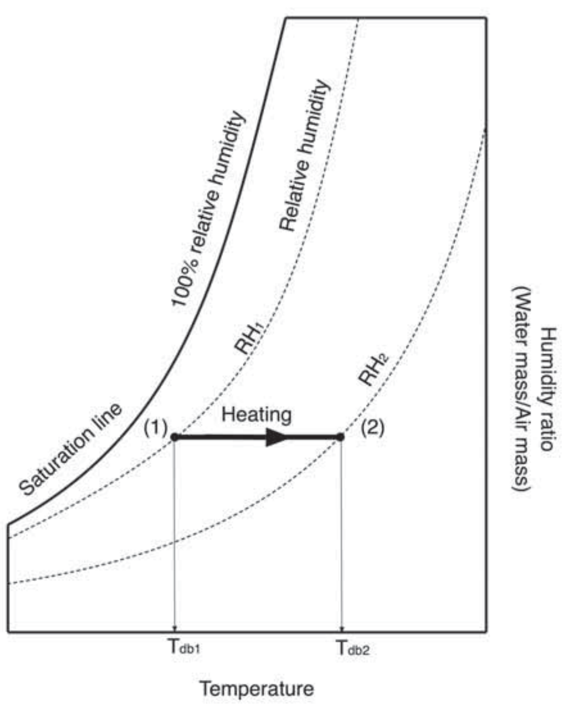

Figure 15-3. Psychrometric chart.

RH1. This means that the air-drying capabilities could be increased by adding energy to the drying air. As a rule, the drying time is reduced by passing larger volumes of air over soybeans or by increasing the air temperature, or both. However, it should be mentioned that soybeans are sensitive to temperature fluctuations and can be easily damaged by air that is too hot or too dry. Accordingly, the recommended minimum airflow rates for drying soybeans are shown in Table 15-1.

Table 15-1. Minimum airflow rates for drying soybeans.

Measured Moisture Content	Minimum Airflow Rate
(%)	(cfm/bu)
18% to 20%	3.0
15% to 18%	2.0
13% to 15%	1.0
11% to 13%	0.5

Equilibrium Moisture Content

As mentioned earlier, in order to dry soybeans, a large quantity of high-quality drying air is passed through the bean pile deposited in a drying bin. At a given air temperature and relative humidity, there is a corresponding grain moisture content that the seed will achieve and will not gain or lose water beyond. This moisture level is known as the equilibrium moisture content (EMC). Table 15-2 shows the EMC of soybeans at different values of air temperature and relative humidity. For example, if the air temperatures and relative humidity are 60ºF and 70%, respectively, the beans will be dried to 13.7% moisture content, assuming the air is allowed to pass through the soybean pile under the same conditions for a sufficient time. Increasing air temperature to 80ºF at the same RH level will decrease EMC to 13.2%.

Table 15-2. Soybean equilibrium moisture content.

Temperature (ºF)	Relative Humidity (%)						
	30	40	50	60	70	80	90
40	6.4	7.7	9.3	11.3	14.2	18.9	28.7
50	6.3	7.6	9.1	11.1	14.0	18.6	28.2
60	6.2	7.4	8.9	10.9	13.7	18.3	27.8
70	6.1	7.3	8.8	10.7	13.5	17.9	27.3
80	5.9	7.1	8.6	10.5	13.2	17.6	26.9
90	5.8	7.0	8.4	10.3	13.0	17.3	26.5
100	5.7	6.9	8.3	10.1	12.7	17.0	26.1

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Soybean Shrink Factor

Each soybean kernel contains dry matter and oil, which represent the grain's primary value, in addition to water. Most buyers use the moisture content (MC) of 13.0% as the base moisture for soybeans. When grain is delivered to the elevator above its base MC, buyers use a factor called "the shrink factor" in order to adjust the quantity for the excess moisture. This is because grain buyers will not pay for the cost of removing the excess water. Applying the shrink factor approximates the equivalent number of bushels that would be in the load if the grain was dried to the base MC. Conversely, some farmers often deliver grain to the elevator at moisture levels below the base MC. This case is also less profitable to the producer since the buyer will not apply an expansion factor. These factors clearly demonstrate how sensitive the soybean production economics are to the moisture content of the soybean kernels sold. A good example to demonstrate the potential loss due to soybean shrinkage using 200 tons of dry matter as basis for calculations is shown in Table 15-3. It is clear from column 6 that the penalty due to shrinkage increases with the increase in the soybean moisture. The buyer determines the penalty due to shrinkage as follows:

$$\text{Shrinkage penalty (bu)} = \text{total weight (bu)} \times 0.013 \times (\text{mc decimal} - 0.13)$$

It is clear that marketing soybeans at any moisture level greater than 13.0% will decrease the total profit.

The total removable water could be determined as follows:

$$\text{Total removable water (lb/bu)} = (52.2 / (1.0 - \text{mc decimal})) - 60.0$$

Soybean Drying and Handling Guidelines

Soybean Harvesting

The preferable moisture content for soybeans at harvest is about 14%. With an adequate drying setup on the farm, producers could potentially harvest their grain at higher moisture contents, i.e., up to 18%. Drying soybeans to safe levels of moisture content requires removing significant amounts of water, which in turn increases the cost of drying. On the other hand, if soybeans were left to dry a little more in the field, a smaller range of moisture removal would be required for storage (usually less than 5%), making soybean drying relatively easier when compared to other grains. Therefore, producers can maximize their return by allowing the beans to dry in the field, down to approximately 14%-16% moisture content, before harvest if the weather conditions allow.

Air Relative Humidity

Prior to exploring available on-farm drying methods, it should be mentioned that the most unusual drying characteristic of soybeans is the susceptibility of the seedcoat to cracking and splitting. The key factor in avoiding seedcoat cracks is to keep the relative humidity of the drying air above 40%. When exposed to air below 40% relative humidity for extended periods, the seedcoat becomes very susceptible to cracking. As an example, assume that a producer uses air at 70ºF and relative humidity of 70% for drying. If the air temperature increased to 90ºF, the air relative humidity will drop to about 35% since air relative humidity is roughly cut in half with each 20ºF increase in its temperature. As a result, this case will compromise the grain quality due to the decreased level of relative humidity. In other words,

Table 15-3. Effects of shrinkage factor on total loss.

Dry Matter Content	Moisture Content	Excess Moisture	Soybean Gross Weight	Total Soybean Weight	Penalty Due to Shrinkage
lb	%	%	lb	bu	bu
200,000	13.0	0	229,885	3,831	0
200,000	14.0	1	232,558	3,876	50
200,000	15.0	2	235,294	3,922	102
200,000	16.0	3	238,095	3,968	155
200,000	17.0	4	240,964	4,016	209

although the temperature is not exceedingly high, the drop in relative humidity below 40% will cause some seedcoat cracking.

Air Temperature

The maximum safe temperature for the heated air used in drying soybeans is determined by the final use for those beans. As mentioned earlier, high drying temperatures can easily cause widespread seedcoat cracks and splits. If soybeans are intended for both oil production and food production, the temperatures in heated-air batch driers should be limited to 130ºF. On the other hand, the soybeans that are used for seed should not be exposed to air above 100ºF. However, even at this relatively mild temperature, seedcoat cracks are likely to occur. Therefore, temperatures below 85ºF might be the safest recommendation.

Soybean Handling

Soybean seeds, like corn or rough rice, are susceptible to mechanical damage. The mechanical damage to the soybean seed results from the impact with a hard surface or the impact with other seeds. The extent and severity of mechanical damage depends on the seed moisture content, velocity at impact and the hardness of the impacted surface. Unfortunately, a certain amount of splitting will occur each time they are dropped. For example, a single 10-foot drop of soybean seeds, at less than 12% moisture, against a metal surface can reduce germination by 10% to 15%. Therefore, handling of soybeans should be minimized and if necessary performed as gently as possible.

On-Farm Drying Methods

As mentioned earlier, there are different factors that should be taken into account while drying soybeans. Therefore, drying systems that were designed for other grain can be used to dry soybeans but only after careful selection of the appropriate air temperature and relative humidity levels. Drying systems that facilitate extreme high temperatures for air-drying (130ºF-150ºF) should be avoided when drying soybeans to minimize seedcoat cracks. Batch and continuous-flow drying systems are less desirable in drying soybeans because the heat input is difficult to reduce, not to mention they require more handling than is required for in-bin drying systems. Consequently, bin-drying systems, i.e., natural-air drying and low-temperature drying, are usually the best options for drying soybeans.

Natural-Air Drying

Natural-air drying is a technique used to dry soybeans by passing unheated (natural) air through the soybean mass until its moisture content reaches the EMC level. Since soybeans are hygroscopic (susceptible to moisture absorption), their moisture content will adjust according to the quality of air used. Therefore, drying soybeans with natural air can be accomplished only if the air temperature and relative humidity conditions allow a net moisture transfer from the soybeans to the air. The drying speed under natural-air drying depends on the moisture content of the soybeans as well as the temperature and relative humidity of the drying air. Natural-air bin drying systems are very efficient for drying soybeans but can only be used under favorable weather conditions. As a rule, air temperature should be above 60ºF and the humidity below 75% to achieve natural-air drying.

A natural-air drying system (Figure 15-4) typically consists of a bin with a perforated floor equipped with a drying fan, a grain spreader, a sweep auger and an unloading auger. Stirring devices may also be added. An external energy source, typically from fossil fuels, is required to supply the electricity for the drying fan and the various augers. On the other hand, the energy required for evaporating the moisture from the soybeans comes from the energy already present in the ambient air. Successful soybean drying with natural air is usually the most energy-efficient method of drying. However, it is also the slowest drying method and has the greatest potential for grain spoilage. Furthermore, natural-air drying is extremely sensitive to weather conditions. Consequently, it requires the highest level of management if spoilage problems are to be prevented. Special attention should be paid to soybean management

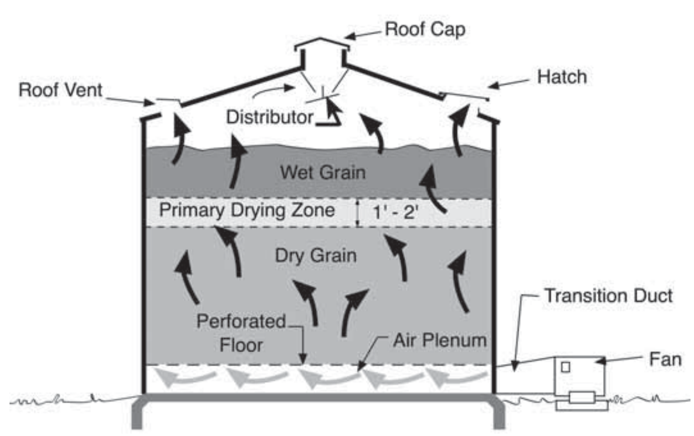

Figure 15-4. Natural-air drying bin.

practices in natural air when excessive moisture or adverse weather is encountered. Unheated air-drying will not be feasible in extended periods of damp weather.

Low-Temperature Drying

In low-temperature drying of soybeans, the drying air is heated 10°F above ambient conditions. Similar to natural-air drying, low-temperature drying also requires a perforated-floor bin, a grain spreader, under-floor unloading auger and a sweep auger. A stirring device may also be added. The low-temperature drying technique has a higher potential to dry soybeans to the accepted long-term storage moisture contents when compared to natural-air drying. Soybeans could be dried using the low-temperature drying technique then stored in the same bin, thus minimizing handling and labor costs. Generally, the comparative total cost for drying decreases as less energy is used to heat the drying air. Thus, successful low-temperature drying is relatively economical in terms of energy cost when compared to higher-temperature techniques. Attention should be paid also to the fact that more energy is required to operate the drying fans than is needed to heat the air.

Soybean producers could use their corn dryers under specific environments. They should set the drying air temperature lower than they use for corn and they also should avoid dryers that recirculate the crop during drying. This is because the soybeans are susceptible to fracture if they are dried too fast or handled roughly. Some researchers reported that it might be possible to use the corn dryer for soybean drying. Producers should limit drying air temperature to 130°F-140°F for commercial beans and 100°F for seed beans. Retention time in the heated section of dryers should be less than 30 minutes. They also recommended that the relative humidity of the drying air should be greater than 40% to help prevent skin cracks. Studies have shown that it is possible to develop 50%-100% splits in less than 5 minutes of exposure time if incorrect drying procedures are followed. Cracked soybeans will not keep well in storage and will break easily during handling. Therefore, in some cases, it is recommended to use a simple shield to recirculate some of the moist drying air back to increase the humidity of the drying air. This approach facilitates a safe and gradual increase in drying temperatures. Alternatively, filling the bin halfway will double the drying air volume per bushel of grain, thus decreasing the time needed to accomplish the desired drying levels.

Grain-Drying Fans

Grain bin fans are responsible for circulating air through the grain for holding, drying and cooling processes. Fans also determine the rate of air circulation. Once again, air is the most essential element to successful grain operations since it controls grain moisture and temperature, reduces biological and insect activity and prevents moisture migration. It is desirable during grain drying to move as much air through the grain as possible. Technically, doubling the airflow reduces the drying time by about 50%. Practically, however, all fans are susceptible to a drop in the capacity of air that can be circulated as the static pressure increases. Therefore, careful selection of grain fans is a necessity to ensure fast and efficient drying.

Types of Grain-Drying Fans

There are two basic types of fans, i.e., the axial flow fan and the centrifugal fan. The axial flow fan (Figure 15-5) closely resembles a ceiling fan. Centrifugal fans (Figure 15-6) are encased in a round housing that rotates and forces air to move in a direction perpendicular to that of air entry.

Axial fans supply more cubic feet per minute (cfm) per unit of horsepower at low grain depths (static pressures below 4.5 inches of water) when compared to centrifugal fans. That is why axial fans

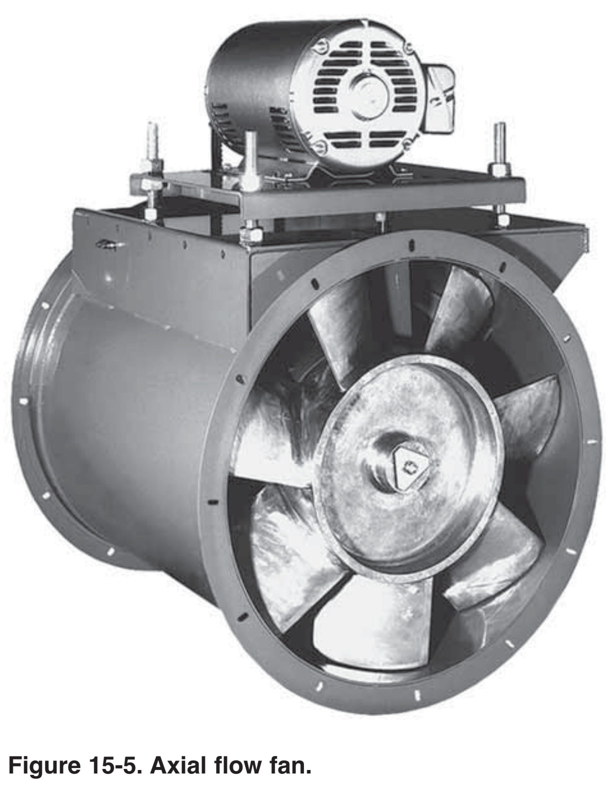

Figure 15-5. Axial flow fan.

Figure 15-6. Centrifugal fan.

are preferable in shallow-depth bin-drying systems such as batch-in-bin and continuous-in-bin systems. Axial fans are also suitable for deep-bin drying (up to 20-foot depth) when a flow of 1 cfm/bushel or less is required. They are generally lower in initial cost but operate at a higher noise level than centrifugal fans. These fans are typically unsuited for use in bins that will also handle rice due to the high static pressures expected – typically, air is more difficult to move up through a column of rice. Axial flow fans are less costly than centrifugal fans. In cases where a high static pressure is expected, centrifugal fans are usually selected.

Centrifugal fans supply more cfm per horsepower at static pressures above 4.5 inches of water when compared to axial fans (Figure 15-4). These are especially suited for deep grain beds (12 to 20 feet) where high volumes of air circulation are required. In addition, centrifugal fans are selected when low operation noise is a factor. Larger diameter centrifugal fans typically move more air per horsepower.

Fan Performance

Fan performance is normally illustrated in a graph (performance curve) or a performance table showing the correlations between airflow rate (cfm), static pressure (inches of water) and the horsepower. Each fan type has its unique performance characteristics, similar to the curves presented in the graph below (Figure 15-7). The static pressure of a drying bin is a measure of the resistance of the grain bed to airflow. In a properly designed system, grain is the main restrictor to airflow within the bin. The selected fan must operate at the static pressure needed to overcome this airflow resistance. From the graph below it is clear that using a centrifugal fan is recommend in most cases, particularly with medium to high static pressure. This is because as the depth of the grain increases, the value of static pressure required for moving air through the grain increases. Additionally, centrifugal fans are less noisy than axial fans if both were pushing the same volumes of air. It should be noted that the curves shown here are presented as examples and should not be used in system planning.

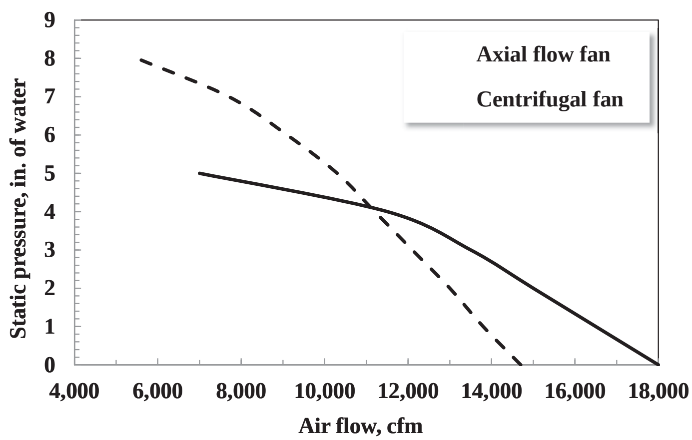

Figure 15-7. Axial and centrifugal fan curves.

As mentioned earlier, the static pressure increases with the increase in grain depth. Therefore, the critical question is what is the acceptable number of soybean bushels that a producer can place in a bin during the drying process? The following steps are useful to answering this question:

1. Determine the soybeans' moisture level.
2. Look at Table 15-1 to determine the minimum cfm per bushel that is needed at that moisture level.
3. Go to the fan chart or table and determine the cfm corresponding to each static pressure level.
4. Measure static pressure with a manometer.
5. Determine the amount of air being moved, cfm, by the fan.
6. Determine the number of soybean bushels in the bin.
7. Limit the fill level to keep the cfm per bushel within acceptable limits.

Drying Fan Selection

Airflow rates for drying vary from 0.5 cfm/bu to more than 50 cfm/bu for commercial or batch dryers. For on-farm drying, airflow rates vary from 0.5 to 6 cfm/bu, depending on the initial moisture content of the grain and on the amount of heat added to the drying air. Several rules of thumb have been developed for sizing fans in drying systems: (1) doubling the grain depth at the same airflow rate (cfm/bu) requires 10 times the horsepower, and (2) doubling the airflow rate (cfm/bu) on the same depth of grain requires 5 times the horsepower. These rules can be seen clearly from Figure 15-8. The available power can be quickly overwhelmed as the grain depth and/or air requirements (cfm) increase.

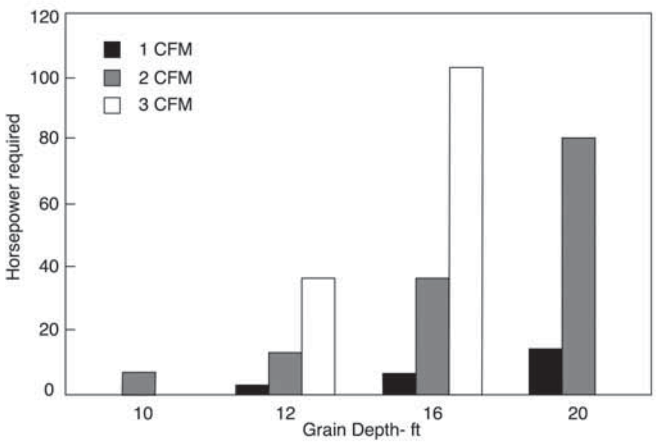

Figure 15-8. Fan power requirements versus depth.

Fundamentals of On-Farm Soybean Storage

Newly harvested soybeans are at their highest quality when they come from the field to the drying and storage facilities. Producers are looking to follow all the required instructions that help preserve that quality. Dried soybeans may be easily stored in facilities that were designed for rice or wheat. Air moves through relatively clean soybeans, more than many other grain types. As mentioned earlier, beans should be dried as quickly as possible to moisture levels of 13% or less without inducing thermal cracks in the seedcoat. A moisture level of 11% is desirable if beans are to be kept longer than six months. Beans should also be cooled to avoid moisture collection throughout the winter season. Dry and cool beans are relatively safe from fungi and insects – the two primary potential sources for grain damage.

Table 15-4. Safe Soybean Storage Periods (Number of Days).

Moisture Content (%)	Soybean Temperature (°F)					
	30	40	50	60	70	80
11	>300	>300	>300	>300	200	140
12	>300	>300	>300	240	125	70
13	>300	>300	230	120	70	40
14	>300	280	130	75	45	20
15	>300	200	90	50	30	15
16	>300	140	70	35	20	10
17	>300	90	50	25	14	7

The length of the storage period influences the amount of spoilage in grain. In general, the longer the storage period, the lower the moisture content should be to ensure safe storage. Microbial growth and reproduction can occur even under conditions considered safe for storage, although the growth would be difficult to detect. This effect could eventually become detectable after very long storage time.

- Allowable storage time is the storage period before quality loss is expected to affect the grain.
- Airflow through the grain maintains the grain temperature but does not extend the allowable storage time beyond that listed in Table 15-4.
- Allowable storage time is cumulative. If 16% moisture soybeans were stored for 35 days at 50°F, one-half of the storage life has been used. If these soybeans were cooled to 40°F, the allowable storage time at 40°F is only 70 days.

Storing soybean seed at moisture contents that are too high often results in rotting or decreased germination within just a few days. When compared to corn, soybeans are more susceptible to spoilage due to their higher moisture content. Consequently, soybeans need to be about two points drier than corn for the same storage period. Researchers at Iowa State University established the following moisture levels, which correspond to different storage periods:

1. 13% or less for commercial storage during winter storage.
2. 12% or less for up to one year.
3. 11% or less for more than one year.

4. 12% or less for soybean seed stored for one planting season.

5. 10% or less for carryover seed.

Soybean moisture level is critical for maintaining storage quality. Beans should be kept at moisture levels of about 12% or less. Access to an accurate moisture meter is highly recommended for bean storage. Moisture levels may also affect germination quality. Moisture-related problems will usually change the appearance of the kernel. However, the viability or germination of soybeans will often decline before there is any visual change in the appearance – and almost certainly if there are obvious appearance changes. Storage temperature plays an important role with moisture interaction. Warmer temperatures require drier beans in order to maintain the same quality. Seed beans should be kept at lower moisture levels. Moisture levels of 10% are recommended for long-term storage in the southern regions of Arkansas, with a maximum of 12% in the northern parts.

Aeration

Even after drying soybeans down to an acceptable moisture level, care must be taken to maintain the beans at this level. Soybeans have the ability to lose and regain moisture more readily than many other grains. This explains why moisture migration and condensation seem to occur faster in soybeans. Moisture will be drawn in from outside the bin, and natural convection currents will set up – resulting in an accumulation of moisture in the center and top area of the grain. If the center area is allowed to stay moist for any length of time, it is an excellent area for fungi growth if temperatures become favorable.

Aerate with natural air once the grain is below 13%. The grain should be cooled as much as possible with early fall conditions. Cooling air should be checked for humidity, being careful to aerate when humidity is below about 60%, or better yet when the EMC content is at or below the grain target moisture level. Aeration with high-humidity air will add moisture back to the grain. Accumulated moisture can typically be managed very easily if the grain is aerated every couple of weeks. As the grain temperature in the bin stabilizes, all the beans get about the same temperature; the moisture migration problem will lessen.

Probe the bin periodically to check for insect infestation and grain temperature increase. Grain temperature increase usually means moisture migration. Aerate whenever this is detected. If the problem is in the center of the bin and aeration is not effective, moving the grain to another bin to solve the problem may be necessary. Problems in the center of the bin usually indicate a lot of fines and/or trash accumulated in this area during filling.

Temperature

Fall Aerate continuously at any time when the equilibrium moisture content is acceptable and air temperature is 10ºF to 15ºF cooler than grain temperature until grain is cooled to 40ºF.

Winter Aerate about every two weeks when air temperature is within 10ºF of grain temperature. Try to get at least 24 hours of drying time per two-week period.

Spring When mean daily temperatures show steady increase, aerate continuously whenever air temperature is 10ºF to 15ºF warmer than grain temperature until grain temperature reaches 60ºF to 65ºF.

The key to excellent on-farm soybean storage is controlling the moisture level in soybeans. This requires excellent management coupled with an adequate aeration system.

Fungi and Insects

Fungi and insects are both fueled by high moisture levels and are more apt to occur in trashy grain or in grain with many damaged kernels. High temperatures and high humidity set up an excellent scenario for fungi to grow. Once grain is cooled down to 40ºF, the likelihood of fungi growth is much less. Fungi are the most important cause of soybean damage in storage. Soybeans have an excellent seedcoat, which helps protect them from insect assault. Insects are more likely to attack damaged beans – either from handling damage or being damaged by some other source, such as fungi.

Soybean Storage Tips

- Cool the grain off as soon as possible in the fall. Target temperatures should be initially around 60°F.
- Continue to aerate and uniformly cool grain to between 30°F to 40°F if possible. This will help avoid internal moisture migration and insect activity.
- Monitor grain and aerate monthly to maintain uniform temperature and moisture levels throughout. Aerate more often if moisture or temperatures increase.
- Keep the grain cool as long as possible into the early spring.
- Do not aerate in early summer unless problems develop.
- Cover fans and openings when not in use to help avoid air, moisture and potential insect movement.
- Monitor carefully and fumigate if needed.
- Inspect soybean surface at least every week throughout the storage period.

Soybean Handling Safety

Soybean producers should always think safety first around drying and storage bins because grain suffocation accidents happen all too often. Wear an effective dust mask when exposed to grain dust when working in dusty conditions, particularly those resulting from moldy or spoiled grain. Exposure and inhalation of mold can cause severe allergic reactions.

Good safety practices are necessary for producers and workers who operate in soybean drying, storage and handling. Grain drying and handling can be dangerous. A deadly hazard exists for anyone in a grain bin as deaths occur every year from suffocation and injuries caused by unloading augers. Power to the unloading auger should be disconnected before entering bins. A knotted safety rope hanging near the center of the bin offers greater protection, and a second person should be standing by who can offer assistance. Air pockets sometimes form when grain bridges over unloading augers due to spoiled grain and moisture. This crusted surface should not be walked over because the pocket can collapse. Transport augers can hit power lines, unguarded augers can catch hands or feet, and fans and shafts can catch unsuspecting victims.

Soybean Drying Costs

Maintaining the drying cost in the minimum level is important in order to maximize profits (returns on investment). As mentioned earlier, in order to dry soybeans, producers need to determine the total pounds of water they will remove from 1 bushel of grain. The number of BTUs to extract 1 pound of water will vary from 1,100 to 1,400, depending on how easily moisture is given up by the kernel. As the kernel begins to dry, more energy is needed to extract the last bit of moisture. A good estimate is to use an average of 1,200 BTU/pound of water to calculate the energy needed to get rid of 1 pound of moisture. Table 15-5 summarizes the BTU/unit of fuel as well as the burning efficiency.

Table 15-5. Heating value of fuels as well as their corresponding efficiencies

Fuel	BTU	Unit	Burning Efficiency
LP gas	92000	gallon	80%
Natural gas	1000	ft^3	80%
Electricity	3413	kWh	100%

Drying costs may be estimated using the following equations:

Fan motor cost:

$$\text{Fan motor cost (\$/h)} = \text{fan HP} \times 0.7475\ (\text{kW/HP}) \times \text{electricity cost (\$/(kW.h))}$$

Fuel cost:

$$\text{Fuel cost (\$/bu)} = [(\text{BTU/lb}_{water}) \times (\text{lb}_{water\ removed}/\text{bu}) \times \text{fuel cost (\$/unit of fuel)} \times 100] / [(\text{BTU/unit of fuel}) \times \text{burning efficiency \%})]$$

Example 1

Assume that you have a 20 HP fan with an electricity cost at $0.10 kWh, no demand charges are applied; determine the cost to run this fan per hour of operation:

$$\text{Fan motor cost (\$/h)} = 20 \text{ HP} \times 0.7475 \text{ (kW/HP)} \times 0.10 \text{ (\$/(kW.h))} = \$1.50$$

Example 2

Determine the drying cost per bushel of soybeans harvested at 20% to 13% moisture using LP at a cost of $2.40/gallon.

There are 5.25 pounds of water per bushel above the value for 13% soybeans to be removed. Following, the fuel cost could be determined using the equation below:

$$\text{Fuel cost (\$/bu)} = [1200 \text{ (BTU/lb)}_{water} \times 5.25 \text{ (lb}_{water\ removed}\text{/bu)} \times 2.40 \text{ (\$/unit of fuel)} \times 100] / [92{,}000 \text{ (BTU/unit of fuel)} \times 80\%] = \$0.205$$

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Chapter 16

Production Systems and Economics

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Arkansas soybean producers use several different irrigated and non-irrigated production systems including full-season (FSSPS), doublecrop (DCSPS) and early soybean production (ESPS). In addition, these production systems are implemented in differing tillage regimes ranging from conventional to no-till.

Yield potential, production cost, time of harvest, available equipment, etc., should be considered when determining which soybean production system to use. Some of the pertinent advantages and disadvantages of each of the major production systems are covered in this chapter.

Regardless of the production systems, there are several factors that warrant discussion when attempting to maximize yield and/or net returns. Certainly the implementation of many of the factors discussed will require an economic investment with the expectation that the returns will exceed the investment.

Factors Associated With All Soybean Production Systems

Soil Fertility – Production of high-yielding soybeans requires soil fertility levels that do not limit yield. Proper soil sampling, soil testing and fertilization according to soil test recommendations assure adequate plant nutrition. Both the soil sampling and testing represent relatively low-cost investments that can result in tremendous returns (**see Chapter 5**).

Soil pH – Optimum soybean production is achieved in soil pH ranges of 6.5 to 7.0. Although liming is only recommended when soil pH values fall below 5.8, the lack of available molybdenum results in reduced yields in the soil pH range of 5.8 to 6.9. If soil pH is less than 7.0, treat seed with molybdenum to minimize potential yield loss (**see Chapter 5**).

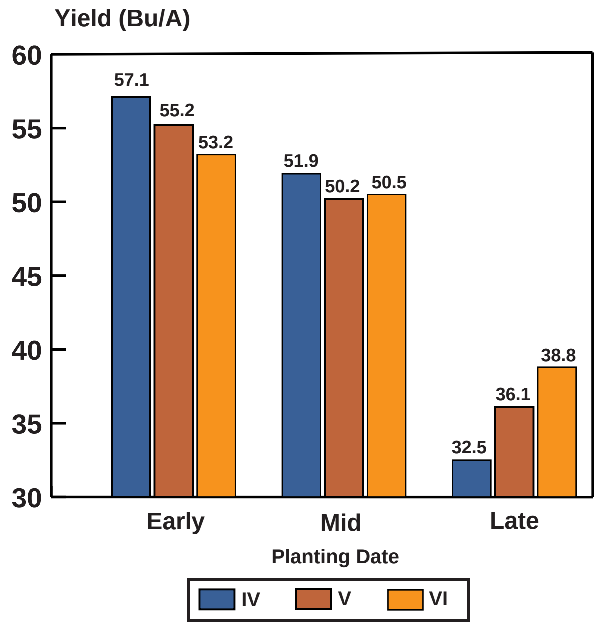
Drainage – Adequate drainage is essential for consistent production. Standing water in the field can reduce plant stand, promote seedling diseases, stunt plant growth and may even result in crop failure. The lack of adequate surface drainage is often the most serious detriment to profitable soybean production, and it should be improved at every opportunity (**see Chapter 6**).

Rotation – Research consistently shows that rotating soybeans with rice, grain sorghum, corn or cotton increases soybean yield potential (5 bu/A is common). Gains in yield potential probably arise from breaking cycles of diseases, weeds and insects, and by a general increase in soil productivity.

Figure 16.1. Crop rotation generally increases soybean yields.

Variety Selection and Planting Date – High yields cannot be obtained unless the variety being grown has a high yield potential within the cropping environment. Variety selection should represent a planned program giving consideration to diseases, soil texture, planting date, maturity, yield, etc. The data in Figure 16.2 (Ashlock, et al.) illustrate the importance of planting date on varietal grain yield by maturity group in Arkansas. From an overall farm perspective, the use of high-yielding varieties from differing maturity groups offers many advantages to Arkansas growers, including a more stabilized grain yield from year to year, especially with dryland or non-irrigated systems (**see Chapters 3 and 9**).

Figure 16.2. Effect of Planting Date on Irrigated Soybean Yield by Maturity Group (Pine Tree Experiment Station – 1995-1998)



Early – comprises planting dates between April 25 and May 6.
Mid – comprises planting dates between May 25 and June 5.
Late – comprises planting dates between July 1 and July 10.

Tillage – In all production systems, growers should look for ways to minimize tillage trips. The use of "stale seedbed" or "no-till" can be advantageous to growers for both time and labor savings, increasing the potential for higher net returns. In addition, sub-soiling has resulted in increased yields in certain situations, which will be addressed toward the end of this chapter (**see Chapter 6**).

Row Spacings – Research has demonstrated that row spacings of 30 inches or less may (but not always) result in increased yields. These yield increases occur more consistently in April and July plantings where row spacings of 20 inches or less are preferred (**see Chapter 7**).

Pest Control – Different production systems may be prone to different pest problems. For example, stink bug can be a serious problem in the ESPS but is not as likely to be of economic significance in doublecrop plantings. Regardless of the pest and/or production system, when economic thresholds are reached, control measures are warranted and should be implemented **(see Chapters 9, 10, 11 and 12**).

Early Soybean Production System (ESPS)

This production system is often profitable for many soybean producers in Arkansas. The system generally consists of planting indeterminate MG III and IV varieties in April. This system can be very effective in years when moisture is adequate until mid- to late July. Research findings indicate many MG V and VI varieties also perform well when planted during the last week in April, although plant height of most determinate varieties, regardless of MG, is reduced. Several details will now be examined that are unique to this production system.

Planting Date – The recommended planting dates for ESPS are listed in Table 16.1 for southern and northern Arkansas. **Specific varieties planted in the ESPS environment are available at the county Extension office and at Extension's website *http://www.uaex.uada.edu* in the form of a newsletter entitled *Soybean Update* and Extension's computerized soybean variety selection program, *SOYVA*.**

Table 16.1. Suggested Planting Dates for the Early Soybean Planting System (ESPS) in Arkansas

Maturity Group	South Arkansas		North Arkansas	
	Dryland	Irrigated	Dryland	Irrigated
MG IV*	4/1-4/25	4/1-4/30	4/7-4/30	4/7-5/7

* Planting indeterminate MG III and IV varieties early (April) especially in narrow row spacings (20 inches or less) allows for adequate plant growth before flowering.

Row Spacings – Research findings suggest that row spacings of 20 inches and less are often superior to 30-inch rows in the ESPS. In addition to increased grain yield, narrow row spacings help assure early canopy closure, reduce weed problems at maturity and generally result in increased profits.

Diseases – The ESPS encompasses a different seedling environment than experienced during the conventional planting dates of FSSPS (May-June). When planting in cool, wet soils, there is increased concern for serious seeding disease problems. Growers are urged to treat seed with a systemic fungicide (such as Apron, Allegiance or Apron XL) to minimize Pythium and seedling stage of Phytophthora root rot. Growers are also encouraged to include products such as Vitavax 200, Vitavax M, Maxim, etc., which will minimize damage due to Rhizoctonia organisms. Since the potential for stem canker also exists with the ESPS, growers should exercise caution when planting varieties susceptible to this disease.

Insects – Certain insect pests, especially stink bugs, may increase in the ESPS system while others decrease. Due to the limited ESPS acreage, these fields often serve to attract foliage-feeding bean leaf beetles early in the growing season, while later in the growing season stink bugs can greatly impact grain quality as they feed on developing seed. Generally, the foliage-feeding worm complex (corn earworm and loopers) are not serious problems in the ESPS. Insects should be monitored closely and economic thresholds used to determine when treatment is warranted (**see Chapter 12**).

Weed Control – Early season weed control strategies associated with the ESPS are not unlike those encountered in FSSPS. Varieties used in the ESPS typically mature in late August or early September, resulting in the opening of the plant canopy. This scenario coupled with row spacings greater than 20 inches can easily contribute to late weed emergence, which can be a problem at harvest. Fortunately, fields in narrow row spacings (20 inches or less) coupled with good early season weed control generally do not require desiccation (**see Chapter 9**).

Seed Quality – In most years, ESPS plantings mature seed in an environment of high temperature and high humidity. These environmental conditions typically result in seed that are unacceptable for planting purposes. Generally, only slight (if any) deductions for grain quality are experienced at the elevator except in seasons of extreme drought and/or stink bug damage.

MG IV seed production plantings should not be attempted without irrigation and should be confined to June plantings (**see Chapter 4**). Furthermore, seed yield (and perhaps quality) may be further enhanced if the MG IV plantings are confined to the northern portion of the state. Following these guidelines should enable Arkansas seed growers to produce MG IV seed of acceptable germination and vigor while obtaining acceptable seed yield.

Full-Season Soybean Production System (FSSPS)

Most soybeans produced in Arkansas are produced in a FSSPS and consist of both dryland (non-irrigated) and irrigated production systems. FSSPS irrigated fields planted to MG V and VI varieties in late April and May have very good yield potential (50+ bu/A) statewide but may not always be the most profitable due to increased irrigation and pest problems (weed and foliar diseases). Also, FSSPS dryland fields can be profitable, but success with this system is dependent upon receiving timely rainfall and the inherent productivity of the soil; therefore, yearly fluctuations in grain yield and profitability are often quite variable for this production system.

Planting Date – The most effective time to plant the FSSPS is between April 25 and June 15, depending on the variety (maturity group) and geographic region of the state as depicted in Table 16.2. Later plantings up to July 15 can be accomplished if soil moisture is adequate, but research has shown that yield potential is reduced as much as 2 percent per day after June 15 (**see Chapter 7**).

Table 16.2. Suggested Planting Dates for the Full-Season Soybean Production System (FSSPS) in Arkansas[1]

Maturity Group	South Arkansas		North Arkansas	
	Dryland	Irrigated	Dryland	Irrigated
MG IV	NR*	5/1-5/15	5/1-5/15	5/1-6/15
MG V	4/25-6/15	4/25-6/15	4/25-6/15	4/25-6/15
MG VI	4/25-6/15	4/25-6/15	4/25-6/15	4/25-6/15
MG VII	4/25-6/15	4/25-6/15	NR	NR

*NR – Not recommended [1]See Management Tips on next page.

Maturity – Varieties of differing MGs produce grain yields that vary considerably due to planting date, geographic location within the state and when adequate soil moisture becomes available (due to irrigation and/or timely rainfall), especially during the reproductive stages of plant development [i.e., from pod set (R3) through seed fill (R6)]. Since yields vary so much from year to year between varieties of

Management Tips

Suggestions for Improving Planting Seed Quality (Germination and Vigor) in Arkansas Plantings

- MG IV varieties may be planted for seed production with irrigation after June 15 especially in northern Arkansas.
- MG V varieties may be planted for seed production after June 1 in southern Arkansas and May 25 in northern Arkansas.
- MG VI varieties may be planted for seed production after May 25 in southern Arkansas and after May 15 in northern Arkansas.

Specific varieties planted in FSSPS environment are available at the county Extension office and at Extension's website *http://www.uaex.uada.edu* in the form of a newsletter entitled *Soybean Update* and Extension's computerized soybean variety selection program,*SOYVA*.

differing maturity groups (especially true for dryland production systems), growers are encouraged to plant three or four high-yielding varieties from more than a single MG.

Pest Management – Weeds, insects and diseases (including stem canker and frogeye leaf spot) can reach or exceed threshold levels with the FSSPS. Proper variety selection can be a great aid in minimizing the impact of many of the disease problems.

Row Spacings – Row spacing should be a width that works well in the overall farm operation (i.e., other crops in rotation), but again, preference should be given to row widths of 30 inches or less for the FSSPS. The key is for the determinate varieties to lap (obtain canopy closure) by the time the plants start to flower (R2). For indeterminate varieties, plants should be at least close to lapping or canopy closure when they are at the R2 growth stage. If lapping is occurring consistently by R2 growth stage, row spacing or width should not significantly impact yield.

Doublecrop Production System (DCSPS)

Generally, one-third of the state's soybean acreage is planted doublecrop behind wheat. This production system allows growers to harvest two crops in a single season. With **irrigation**, DCSPS yields of **50+ bu/A** are possible with proper management if planted by June 15. Research has shown that this system often results in the greatest net returns when both crops (wheat and soybean) are considered.

The dryland DCSPS is often at higher risk for stand establishment due to inadequate soil moisture in mid- to late June. If moisture is not available for germination and emergence, stand establishment is delayed and yield potential is greatly reduced. Also, the shortened season associated with a late planting date intensifies the effect of any stress on the crop. These stresses often result in reduced plant development and increased insect feeding.

Planting Date – Doublecrop soybeans should be planted as soon after wheat harvest as practical. Keep in mind that grain yield potential decreases every day after June 15 that soybeans are not planted or where dry conditions exist that prevent seed from germinating. A 40 bu/A yield potential does exist for soybean plantings that have emerged by July 1. The planting date guidelines depicted in Table 16.3 include the latest research findings regarding the performance of leading commercial varieties of differing maturity groups to late planting dates that are common with the DCPS.

Variety Selection – Recent research findings continue to support Extension recommendations for selecting varieties that are of late MG V (> 5.6) through MG VI for the doublecrop system. **Specific varieties planted in DCSPS environment (i.e., late planting dates) are available at the county Extension office and on Extension's website at http://www.uaex.uada.edu in the form of newsletter entitled *Soybean Update* and Extension's computerized soybean variety selection program, *SOYVA*.**

Row Spacing – DCSPS planting should be in rows less than 20 inches wide. For dryland production, this is an especially good practice for clay soils and when planting after July 1. With proper management, irrigated doublecrop production will often lap on 20-inch rows unless planted after July 1.

Pest Management – Soybean production within the DCSPS is generally characterized with somewhat reduced weed presence, reduced incidence of plant diseases, but often experiences accelerated insect problems (both foliage and pod feeders).

Table 16.3. Suggested Planting Dates for the Doublecrop Soybean Production System (DCSPS) in Arkansas

Maturity Group	South Arkansas		North Arkansas	
	Dryland	Irrigated	Dryland	Irrigated
MG IV[1]	NR*	6/1-7/15	NR	6/1-7/15
MG V[2]	6/1-7/15	6/1-7/15	6/1-7/15	6/1-7/15
MG VI[3]	6/1-7/15	6/1-7/15	6/1-7/15	6/1-7/15
MG VII	6/1-7/1	6/1-7/1	NR	NR

*NR-not recommended

[1] MG IV varieties normally mature prior to an early frost, but reduced yield potential suggests that these and the early MG V varieties can only be warranted if planted for seed production.

[2] Limit MG V dryland plantings to varieties that are of a 5.7 or later maturity.

[3] MG VI varieties perform best in DCSPS, but refrain from planting late MG VI (> 6.5) varieties in northern Arkansas after July 7 due to potential frost damage.

Conservation Tillage – The practice of reduced tillage and/or no-till soybean production in a doublecrop system is growing in popularity. This management tool may result in an earlier planting, in cooler soils, with less labor, and the conservation of moisture for the doublecrop planting. Recent research by Keisling, et al., suggests that improved soybean yields have resulted, indicating that some shallow or slight tillage of the crusting soils prior to planting resulted in improved yields. This yield increase probably relates to improved water infiltration and/or conservation. Caution should also be taken in variety selection. Select varieties that have moderate to high levels of resistance to lodging, because plants that emerge through the wheat straw often become spindly or etiolated. The use of a seed treatment is recommended for all no-till planting, and treatment products discussed earlier with the ESPS also perform well in no-till doublecrop systems.

Additional Considerations

Non-Irrigated or Dryland Soybean Production

Dryland soybean production can have positive net returns, but there is no way to guarantee this outcome. Therefore, growers should weigh the risk of crop failure against input costs. There are several aspects of dryland production that should be considered to maximize yield while holding input costs down.

Weather Considerations – In dryland production, long-term weather patterns must be considered. Growers should look at ways to avoid late summer drought. One possibility is to divert at least 20 percent of the acreage to the ESPS system. In many years, the ESPS system allows seed to fill before major drought conditions occur. Another alternative is to plant a late-maturing group V or early VI variety in late May or early June to use late summer rains. The risk of poor growing conditions in any part of the season can be minimized by coupling well-adapted varieties of differing maturity groups to the different production systems.

Controlling Input Costs – Growers must continue to control input costs in all production systems, but it is imperative to control cost in all dryland or non-irrigated production systems. Reducing tillage trips by using “stale seedbed,” “minimum tillage” and/or “no-till” as well as properly timed reduced-rate herbicide technology offers the most obvious way to minimize input costs.

Conserving and Improving Moisture Utilization – Attempts should be made to optimize plant extractable soil moisture. Reduce tillage trips and consider using no-till when possible and/or appropriate. Avoid using tillage implements that promote drying the soil such as a chisel plow or disk. If these implements are used, follow immediately with a finishing tool. Additionally, recent research and Extension demonstration work document that some soil types respond significantly with improved soybean yields if **sub-soiled** in the fall when the soil is very dry. Generally, the most consistent response has been with alluvial soils that have severe root-restricting layers or plow pans within the top 6 to 8 inches and are characterized with fine sandy loam or are silty clay topsoils. Since sub-soiling is a relative expensive project and results have not been consistently positive, growers may wish to consult with their county Extension agent or the Natural Resources Conservation Service (NRCS) prior to implementing this practice.

Seeding Rates – Refer to **Chapter 7** for the current seeding rate recommendations for the production system and row spacing. Considerable research is ongoing to further refine these recommendations. Recent research findings (Vories, Keisling, et al.) suggest that increased seeding rates which contribute to higher plant populations than those listed in **Chapter 7** resulted in increased yields under certain field conditions. Fields in which increased seeding rates may be warranted are characterized with reduced development (reduced

Management Keys for Dryland Systems

1. Restrict dryland wheat-soybean doublecropped system to alluvial or highly productive soils.
2. Use recommended varieties of IV, V and VI with appropriate pest control genetics (at least moderate resistance to Frogeye Leaf Spot).
3. Utilize the ESPS system on at least 20 percent of acreage. This system would be especially useful on deep alluvial soils that have deep rooting and lots of stored water (i.e., Red River Valley, Arkansas River Valley, Mississippi, White and St. Francis). This system is not as effective in shallow soils.
4. Use molybdenum seed treatment on acid soils (soil pH less than 7.0).
5. Apply fertilizer according to soil test recommendations, especially ensure adequate soil pH (>5.7) and potassium (K).
6. Consider narrow row spacings and increased plant population on the more marginal soils.
7. When cost effective, utilize crop rotation with at least a one-year rotation between two year successive soybean crops for all but clay soils to reduce nematodes and soil insect problems.

height and canopy width). Further work is ongoing in this area, but suffice it to say that the seeding rates listed in **Chapter 7** are sufficient for many situations.

Irrigated Soybean Production

In irrigated production systems the major cause of crop failure (drought) is removed and therefore risk is diminished. However, there is the added expense associated with irrigation. With lower risk and increased expense, irrigated production systems should, with proper management, result in improved yields and greater net returns.

Level of Management

A higher level of management is necessary to recover cost of irrigation and to produce increased net returns. All factors associated with production that limit yield potential must be determined and minimized. Yield-limiting factors must be addressed and continually reevaluated.

Irrigation

Eliminating water stress from the crop is critical to producing high yields. Irrigation should be conducted prior to water stress for the entire growing season. Growers lose yield potential when they are reluctant to start irrigation. With a 30 percent chance of rain, some growers will not irrigate; however, there is greater than a 70 percent chance it will not rain a significant amount. Even if it does rain, generally only a small portion of the soybean acreage is being irrigated at any one time.

Producing High Yields

Irrigated soybean production offers the greatest chance of producing high yields. A few growers in the state averaged 50+ bu/A over their entire soybean acreage the last few years with good management including proper irrigation. Growers who have irrigation available for soybean production should strive to consistently produce 50+ bu/A yields.

Management Keys for Irrigated Systems

1. Make sure the field has adequate surface drainage prior to investing in irrigation. Extended wet periods, especially following irrigation, can have devastating effects on the poorly drained areas.
2. Use high-yielding, recommended varieties of differing maturity groups.
3. Follow fertilizer and lime recommendations based on annual soil test.
4. Control pests including foliar diseases with systemic fungicides if warranted.
5. To minimize pest problems, especially on silt loam soils, it is generally wise to utilize crop rotation with at least a one-year rotation of corn, sorghum, rice or cotton between two-year successive soybean crops.
6. Irrigate timely to prevent stress, even prior to bloom (R2) and through seed development (R6) by utilizing the University of Arkansas Computerized Irrigation Scheduling Program.

Production System	No. Bu/A	Yield Bu/A	Expenses[1]	Returns Above Total Expenses[2]	Returns Above Total and 25% Rent[3]
Irrigated Full Season	138	46.9	$184.20	$108.20	$35.10
Irrigated Doublecrop	57	43.6	164.96	106.88	38.92
Dryland Full Season	36	28.0	114.54	60.02	16.38
Dryland Doublecrop	10	26.1	98.36	64.18	23.55
Irrigated Early Season	4	48.4	205.71	95.51	20.21
Dryland Early Season	13	31.7	117.34	80.25	30.85

Table 16.4. Costs and Returns by Production System, SRVP, 1984-98

[1]Total expenses include direct and fixed expenses.
[2]Based on 10-year season average price of $6.23 per bushel.
[3]A 25 percent crop share rent was assumed with no cost sharing.

Production System Economics

The Soybean Research Verification Program (SRVP) uses the different production systems discussed in this chapter. The SRVP fields are commercial fields across the state that have received a high level of timely management. The overall goal of the program is to produce the highest net returns possible in each field.

Agronomic and economic results from 1984 through 1998 SRVP are presented in Table 16.4. Yield averages presented for the different production systems represent the high level of management and demonstrate the long-term yield potential present with available technology. Across all three irrigated production systems, the 199 SRVP fields averaged 46 bu/A compared to the state irrigated average of 33.3 bu/A. The 59 SRVP dryland fields across the three production systems averaged 29 bu/A compared to the state dryland average of 23.5 bu/A.

Production expenses are a major factor in determining net returns. SRVP production costs have been maintained at a reasonable level for the production systems. The three dryland production systems have total (specified and fixed) expenses that averaged $112/A. To ensure positive net returns in dryland systems, production expenses must be controlled. In the SRVP, this has been accomplished by reducing tillage, utilizing reduced-rate weed control recommendations, proper seeding rates and variety selection and timeliness of all inputs to ensure cost effectiveness.

Total expenses across all three irrigated production systems have averaged $180/A. The total expense figure in the ESPS reflects a high weed control cost associated with one of the four fields, but the lowest expense was associated with the irrigated DCSPS. This lower expense is due to an average savings of $8/A for operating costs and $10/A less ownership (equipment) costs.

SRVP returns above total expenses, including a 25 percent crop rent, are also presented in Table 16.4. These long-term average returns across all production systems suggest that irrigated FSSPS and DCSPS production systems have average returns above total expenses of $40/A greater than these same production systems made in dryland conditions. The irrigated production systems had an average net return of $35/A after assigning a 25 percent land rent, while the dryland fields averaged $21/A.

The SRVP has produced soybeans with profitable net returns in six different production systems. The highest net returns have been associated with the three irrigated systems, and lowest but positive net returns have been obtained in the three dryland systems. Increasing yield while minimizing production expenses has been one of the major objectives of the SRVP.

Conclusion

Several production systems are available to growers. One of the major challenges is to determine which factor(s) is either limiting yield or contributing to higher production cost in the farming operation or in a specific field. Addressing the factor(s) will increase production efficiency in a step-by-step process. The recent advances in “site specific” or “precision agriculture” technology should further result in improved identification of yield-limiting factors, enabling the Arkansas producer to increase soybean production efficiency with both higher yields and, hopefully, lower production cost. With the soybean production and marketing technology today, there are many situations whereby the Arkansas soybean producer can accomplish both objectives simultaneously.

Chapter 17

Soybean Marketing

by D. Neff and N. Smith

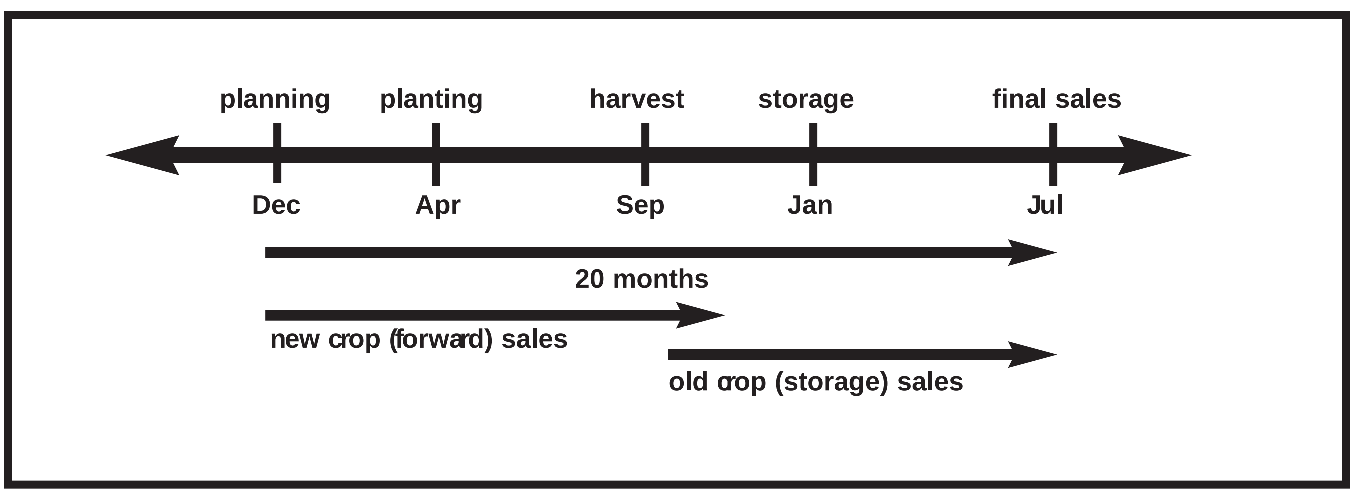
The Arkansas soybean marketing system provides producers with many attractive alternatives for marketing soybean production. Arkansas is fortunate to be located on the Mississippi, Arkansas and White River waterways which facilitate the movement of soybeans by barge for export at the Port of New Orleans. When this export demand for soybeans is combined with the needs of Arkansas soybean processors, grain terminals and elevators, the result is that state producers can generally expect to receive close to or, in some instances, above soybean futures prices for their product.

In the United States, the soybean marketing year begins on September 1 and ends on August 31. Soybeans produced for the 1998-1999 marketing year were harvested in fall, 1998. By utilizing cash, futures or options markets, soybeans may be sold for at least ten to twelve months prior to harvest and then eight to ten months after harvest. This results in nearly a two-year window which is available to sell soybeans produced in each marketing year (Figure 17.1).

The **planning** period occurs during the winter months prior to planting. During this time, it is important to focus on projected costs of production and price forecasts for the new crop. Costs of production will be affected by individual farm and field agronomic and financial characteristics. After the first of the year, private forecasts of average cash price for the new crop marketing year (beginning September 1) become available. The USDA price forecasts for the new crop year are available in the May Crop Production Report. These price forecasts can be compared with new crop forward contract prices and new crop (November) futures. If these price levels are high relative to season average price projections and projected costs of production, pricing or sales using cash, futures or options may be appropriate for a portion of the soybean crop to be grown.

At **planting time and during the growing season**, it is important to focus on costs of production, season average cash price forecasts, forward and futures prices and local basis levels. There are a number of different ways to price or sell

Figure 17.1 . Example of a 20-Month Soybean Marketing Period.



new crop production prior to harvest using cash, futures or options markets. These methods include:

1. **Cash Forward Contracts** – Private contracts with cash buyers (elevators, processors, etc.) which specify the quantity, quality, location and time of delivery of new crop soybean production. The price which is received is the buyer's current forward price for soybeans.

2. **Hedge-to-Arrive or Short Futures Hedge** – A hedge-to-arrive contract fixes a price level for the new crop production. The price which is agreed upon is associated with a particular futures contract (e.g., November soybean futures). The producer must set the basis later. This type of cash contract is similar to a short futures hedge. With a short futures hedge, producers sell futures using a commodity broker. Later, the production is priced and the basis is set.

3. **Basis Contract** – A basis contract fixes the basis (but not price) at the time the contract is made. After harvest, basis contracts usually provide for a cash advance after the soybeans are delivered. The price level must be set prior to a specified date in the contract.

4. **Floor-Price-to-Arrive or Long Put Hedge** – A floor-price-to-arrive contract sets a price floor for the new crop production. The contract involves purchasing a soybean futures put option and the price floor will be below the current forward price by approximately the cost of the put. If prices decrease, the price which is received will be equal to the price floor. If prices increase, however, the producer is still able to sell at a higher price. A floor-price-to-arrive contract is similar to a producer purchasing a near-the-money put option from a commodity broker.

5. **Minimum Price or Long Call Hedge** – A minimum price contract sets a minimum price for the soybeans somewhere below the forward contract price. The difference is approximately the price of a near-the-money soybean futures call option. The minimum price is received upon delivery and then, if prices increase, additional money is received for the production when the price is set. If prices decrease, the producer receives the minimum price only. This type of cash contract is the same as a producer selling the production, then "buying it back" by purchasing a soybean futures call option from a commodity broker. If prices increase, the option becomes more valuable and is sold for an additional profit on the production. If prices decrease, the premium, or price paid, for the option is the maximum loss.

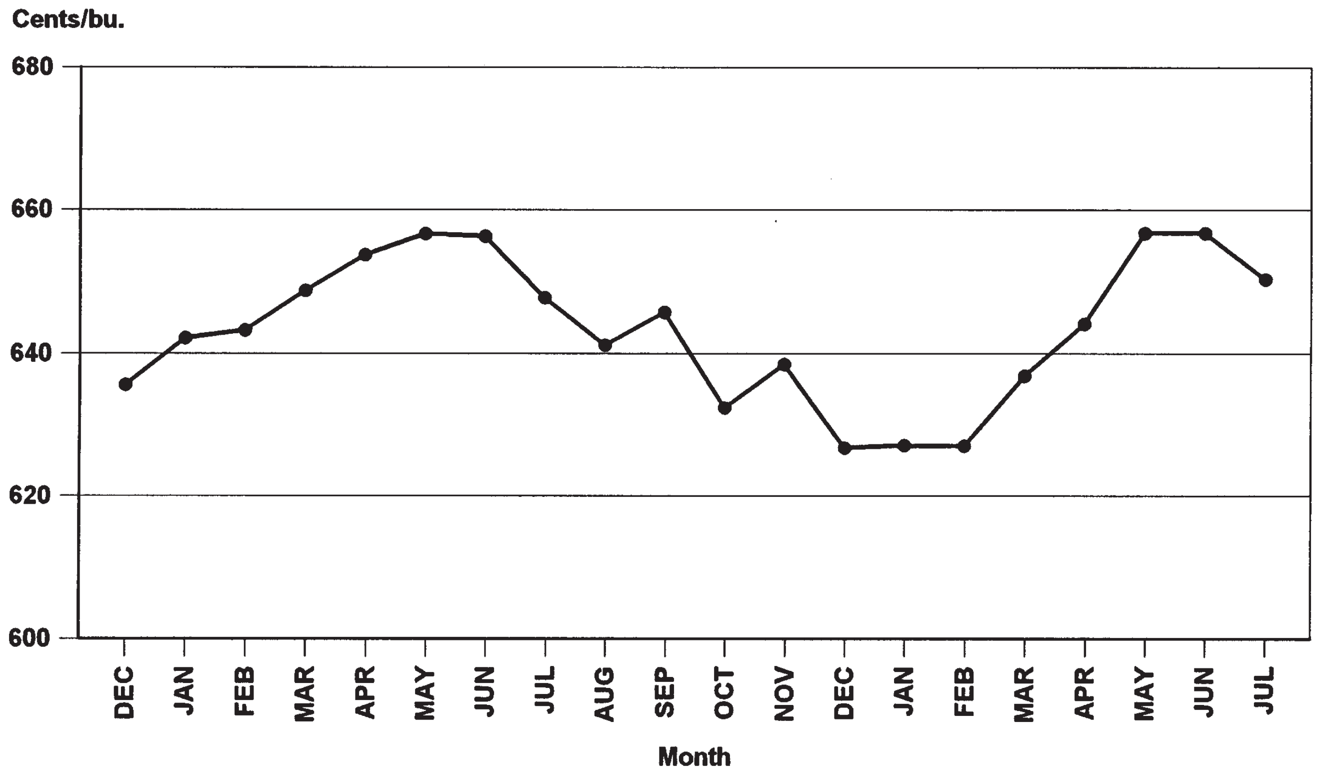
6. **Mini-Max or Bull Call Spread** – A mini-max contract sets both a minimum and a maximum price that will be received for the new crop production. The minimum price is higher than that which would be received from a minimum price contract. However, this increase comes at a cost – the maximum price which could be received is lower than that of a minimum price contract. An equivalent strategy which a producer could do using a commodities broker is to first sell or price the crop locally and then purchase an at-the-money or near-the-money soybean futures call and sell a higher strike call option. This also establishes a minimum and maximum price for the production.

When production is priced or sold forward prior to harvest, care should be taken to ensure that the production will actually be produced. A general guideline is that no more than 30 percent of expected production should be priced forward to allow for the possibility of low yields. Producers with soybeans in higher-risk areas (e.g., flood plains) should price less than this. Producers producing soybeans under irrigation could perhaps price more than this.

Each month, USDA and private firms update soybean supply and demand estimates. This involves new projections of supply (production and stocks) and usage (crush, exports and seed). This also implies new projections of ending stocks and the season average price. Producers should follow updates as they occur in order to be knowledgeable about realistic price goals for soybean production.

At **harvest**, decisions must be made about storing all or a portion of the crop. Again, current USDA or private predictions of average price should be considered and compared with current cash forward and futures prices.

Figure 17.2 . Average Monthly New Crop (November) Futures Prices (from December to November), Then Old Crop Cash Prices (December to July), 1978 to 1997 Marketing Seasons.



Historically, the average price of soybeans is at its lowest yearly level during and immediately after harvest. Figure 17.2 shows average monthly prices of new crop futures (prior to harvest), then old crop cash prices (after harvest). Although there is considerable variability from year to year, forward prices for soybeans have dropped an average of about $0.30/bu. from planting to the end of the year. After that, cash prices for stored soybeans have risen on average by about $0.30/bu., an indication of the returns to storage.

After harvest during the **storage** period, it is again important to monitor USDA or private predictions of average price. Comparisons with current cash forward and futures prices should be made and the costs of storage should be considered.

Over the past 20 years, the period average price of soybeans for a particular marketing year was in the top third of its price range 42 percent of the time during the **planning** season (Table 17.1). It also was in the bottom third 42 percent of the time. So, forward sales prior to planting had about an equal chance of receiving the high or low price for that year's crop.

During **planting and the growing season**, the period average price traded in the middle third of the season average price range more than 50 percent of the time. Forward sales during this time period had a better-than-average chance of receiving an average soybean price and about an equal (but lower) chance of selling at the high or low price.

At **harvest and during the winter months**, the average price for this period was never in the top third of the season average price range. In fact, the average price during this period was in the bottom third of the season average price range 63 percent of the time. Harvest sales and sales during the four to five months following harvest had a very high chance of receiving low prices for soybeans.

Soybeans stored and then sold in the **spring and summer period** when the new crop is being planted and grown had about a 42 percent chance of

Table 17.1. Percent of Time the Average Soybean Price for the Period Was in the Top, Middle and Bottom Third of the Season Average Price Range, 1978 to 1996 Crops

Period	Months	Season Average Price Range		
		Top Third	Middle Third	Bottom Third
		- - - - - - - - Percent - - - - - - - -		
Planning	December to March	42	16	42
Planting and Growing	April to September	21	53	26
Harvest and Winter	October to March	0	37	63
Spring and Summer	April to July	26	42	32

being sold in the middle third of the season average price range. Twenty-six percent of the time prices averaged in the top third, and 32 percent of the time they were in the bottom third.

Domestic and world supply and demand factors for each soybean crop changed each year and during each year. Very few years are "alike," and it is difficult to predict when prices will be high relative to their season average price from past price data. However, it is apparent from Table 17.1 that in the past 20 years harvest and post-harvest sales resulted in lower-than-average prices being received. Storage is one way to offset this problem. However, it is not a viable option for all producers because, in many cases, soybean sales are necessary due to lack of storage or to pay expenses. Producers could consider basis, minimum price or mini-max contracts as alternatives. These contracts allow the grain to be delivered at harvest. A cash advance or minimum price is received which can be used to meet expenses.

Another way to circumvent harvest sales is to use forward sales, hedge-to-arrive or floor-price-to-arrive contracts. Forward contracts and hedge-to-arrive contracts allow price or both price and basis to be set for an agreed-upon amount of production. A floor-price-to-arrive contract establishes a minimum price for the production and also allows possible price increases to be received.

During the four different periods discussed above, there are many alternatives and opportunities for marketing soybeans. Producers should reserve some time each week (or more often) to devote to analyzing current and potential marketing opportunities. Important information for producers can come from at least four sources:

1. **Marketing meetings** hosted by private firms or the Cooperative Extension Service. Educational meetings offer the latest information and provide important reference materials.

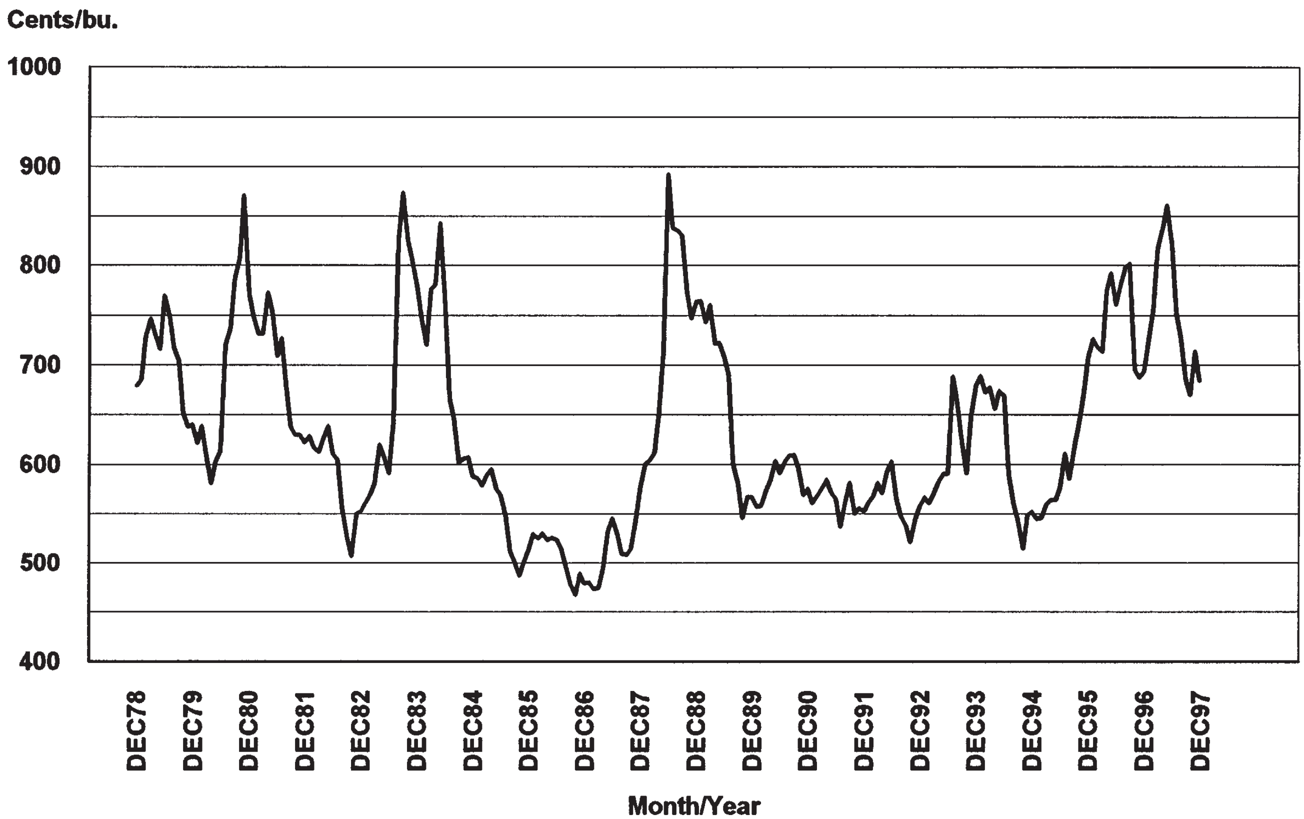
2. **Price and other marketing information** from farm magazines, marketing services or other media sources. Concentrate on three to five sources and check them regularly for current information.

3. **Local cash contract alternatives** available at elevators, processors or other cash commodity buyers. It is important to know where and what cash contracts are available and how they may be used when needed.

4. **Opinions from other soybean producers** on current and future price and marketing alternatives/opportunities. Consider forming or joining a soybean marketing club to regularly discuss soybean marketing with other producers.

We are in a highly volatile period of agricultural production. Demand was strong and supply was low in the 1995 and 1996 crops. However, the 1997 and 1998 soybean crops were large, and ending stocks are projected to be higher than the previous two

Figure 17.3. Monthly Average Cash Soybean Price, December, 1978 to December, 1997.



years. Historically, cash prices have been above $7.00/bu. for soybeans at only six different periods over the last 20 years (Figure 17.3). Two of these periods have been in the last three years.

The price of soybeans grown in the United States is heavily dependent upon supply and demand factors in the rest of the world. Nearly a third of the U.S. soybean crop is exported each year. Soybean production in the rest of the world (particularly in South America) greatly affects the demand for U.S. soybean exports. These changes in world supply, combined with changes in world demand (particularly in Asia, Europe and Mexico), are important influences on U.S. soybean prices.

As each soybean crop is marketed, it is important to keep abreast of current price information and projections. This information, when compared with the costs of production and storage, forms the foundation of producer marketing decisions. Keep in mind four things when making marketing and sales plans:

1. **Know your costs of production and storage** in order to compare to current and projected market prices.

2. **Have a price objective** and sell (pull the trigger) when it is met.

3. **Revise and review at least weekly** all cost and price information in order to update the soybean marketing plan.

4. **Avoid emotional marketing decisions** which cause decisions to be delayed or changed.

Remember, the market does not care what your costs are. Only you, as a farm producer, can make the appropriate decisions to sell your soybean production according to your costs and your expectations about future price opportunities.

Chapter 18

Processing and Utilization

by L. Ashlock, R. Rodibaugh, N. Hettiarachchy and A. Proctor

Arkansas ranks eighth nationally in soybean production with approximately 3.5 million acres devoted to soybeans and an annual production of between 80 to 100 million bushels. Three processing plants (ADM in Little Rock and Helena, and Riceland Foods in Stuttgart) process about 33 percent, or 30 million bushels, annually. The initial raw products of the processing operation are:

1. Oil products
2. Whole soybean products
3. Protein products

Figure 18.1. Products made from soybeans include tofu, soy milk and soy chips.

A typical bushel of soybean grain (60 pounds) will yield about 11 pounds (18.3 percent) of oil and 48 pounds (80 percent) of protein-rich meal. Hulls make up the remaining 1.7 percent. The relatively high oil and protein content and the almost infinite uses and transformations of soybean grain have resulted in the crop being referred to as the "Cinderella Crop." This chapter will briefly address the extraction processes used to obtain the raw products and will concentrate on some of the new and very beneficial uses of the soybean.

Processing Soybeans

Although there are continued advancements and/or refinements in the technology associated with processing soybeans, the primary method used at the present is referred to as the "Extraction or Solvent" process. This process uses organic solvents such as hexane to recover 95 to 98 percent of the oil and about 95 percent of the protein. Other, but less common, methods include Hydraulic and Expeller or Screw-Press. Typically, these older and less common methods recover less oil but slightly higher protein. Regardless of the soybean processing method, the soybeans need to be cleaned, heated (dried), crushed and then flaked before either of the previously identified processes are implemented.

Oil Products

Oil products can be manufactured into many products as shown in Figure 18.2. Crude oil is the major raw oil product, but it must be further processed to obtain a bland-tasting, light-colored oil acceptable to consumers. This additional processing removes substances which would compromise the quality of the refined oil, but these substances can be developed into other commercial products. One of these commercial products includes soy lecithin, which is comprised mainly of phospholipids and serves as an important emulsifying agent for food, pharmaceutical and other industries. Lecithin is also removed from the oil to avoid cloudiness and discoloration of the refined oil. Free fatty acids and glycerol are formed as a result of oil breakdown. Free fatty acids are removed to avoid the smoking when oil is used for frying. The extracted free fatty acids are used as emulsifying agents. Glycerol is distilled from the oil during a deodorization process. Sterols, sterol esters and tocopherols (vitamin E) are important nutritional substances also extracted from the oil during deodorization processing.

Many of the major soyoil products are developed from further modification(s) of *refined soyoil* for either *edible* or *technical* uses. Refined vegetable oils are hydrogenated to produce hydrogenated oils for margarines and shortenings. Salad oils are made by cooling the refined oil to precipitate waxes out of solution by a process referred to as “winterization.” This ensures the oil is refrigerator stable. Some of the more recent nonfood products developed from soybean oil include bio-diesel, soy ink and soy-based crayons.

Whole Soybean Products

Whole soybean products can also be manufactured into a host of products as shown in Figure 18.3. Most major whole soybean products are used for edible purposes with the final product dependent upon the consumer. Recent research findings support the health benefits of soyfoods and have been at least partially responsible for an increase in human consumption of nearly all edible products, including the whole soybean products.

Figure 18.2.

Soybean Oil Products

Glycerol

Fatty Acids

Sterols

Refined Soyoil

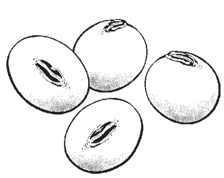
EDIBLE USES
Coffee Creamers
Cooking Oils
Filled Milks
Margarine
Mayonnaise
Medicinals
Pharmaceuticals
Salad Dressings
Salad Oils
Sandwich Spreads
Shortening

TECHNICAL USES
Anti-Corrosion Agents
Anti-Static Agents
Caulking Compounds
Core Oils
Disinfectants
Dust Control Agent
Electrical Insulation
Epoxys
Fungicides
Inks – Printing
Linoleum Backing
Metal Casting/Working
Oiled Fabrics
Paints
Pesticides
Plasticizers
Protective Coatings
Putty
Soap/Shampoos/Detergents
Vinyl Plastics
Wallboard
Waterproof Cement

Soybean Lecithin

EDIBLE USES
Emulsifying Agents
Bakery Products
Candy/Chocolate Coatings
Pharmaceuticals
Nutritional Uses
Dietary
Medical

TECHNICAL USES
Anti-Foam Agents
Alcohol
Yeast
Anti-Separating Agent
Margarine
Dispersing Agents
Paint
Ink
Insecticides
Rubber
Stabilizing Agents
Shortening
Wetting Agents
Calf Milk Replacers
Cosmetics
Paint Pigments



The soybean plant provides a high-quality protein and phytochemicals that may be protective against heart disease, certain types of cancer and osteoporosis.

Soybean Protein Products

Soybean protein products can also be manufactured into many products as shown in Figure 18.3. Protein and protein products are the other major raw products derived from processing the grain and are broadly classified into two categories – *soy flour concentrates and isolates* and *soybean meal*, which has long been recognized as one of, if not the major, protein source available for livestock and humans. Soy flour concentrates and isolates undergo further modification into a host of products that are included in a *technical use* group or an *edible use* group. Many new environmentally friendly products, such as biodegradable plastics, are being developed or researched at the present time.

Figure 18.3.

Whole Soybean Products

EDIBLE USES

Seed

Stock Feeds

Soy Sprouts

Baked Soybeans

Full Fat Soy Flour
- Bread, Cakes and Cake Mixes
- Candy
- Doughnut Mix
- Frozen Desserts
- Instant Milk Drinks
- Low-Cost Gruels
- Pancake Flour
- Pan Grease Extender
- Pie Crust
- Sweet Goods

Roasted Soybeans
- Candies/Confections
- Cookie Ingredient/Topping
- Crackers
- Dietary Items
- Fountain Topping
- Soynut Butter
- Soy Coffee

Traditional Soyfoods
- Bean Curd
- Miso
- Natto
- Tempeh
- Soymilk and related products (i.e., soycheese)
- Tofu

Soybean Protein Products

Soy Flour Concentrates & Isolates

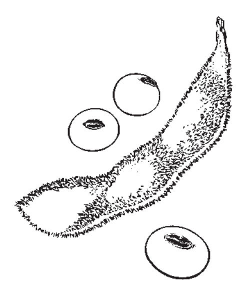
TECHNICAL USES
- Adhesives
- Analytical Reagents
- Antibiotics
- Asphalt Emulsions
- Binders – Wood/Resin
- Cleansing Materials
- Cosmetics
- Fermentation Aids/Nutrients
- Films for Packaging
- Inks
- Leather Substitutes
- Paints – Water Based
- Particle Boards
- Plastics
- Polyesters
- Pharmaceuticals
- Pesticides/Fungicides
- Textiles

EDIBLE USES
- Baby Food
- Bakery Ingredients
- Beer and Ale
- Candy Products
- Cereals
- Diet Food Products
- Hypo-Allergenic Milk
- Infant Formulas
- Meal Replacement Beverages
- Meat Substitutes
- Noodles
- Prepared Mixes
- Sausage Casings
- Seafood Products
- Special Nutritional Products
- Yeast

Soybean Meal

FEED USES
- Aquaculture
- Bee Foods
- Calf Milk Replacers
- Fish Food
- Fox and Mink Feeds
- Livestock Feeds
- Poultry Feeds
- Protein Concentrates
- Pet Foods

HULLS
- Dairy Feed
- Premia



Additional Arkansas Research and Educational Efforts

Research is being done in Arkansas to create new value-added products from low-value soy hulls. Pectin has been extracted as a food grade competitor to citrus pectin.

Soy hulls have been used to produce novel carbon adsorbents for water purification and vegetable oil processing hulls. The structure and effectiveness of activated charred soy hull carbon has been demonstrated to and recognized by the U.S. soybean industry.

Soy lecithin is also being used as nutraceuticals and emulsifiers in medical nutritional foods for specific patients who cannot digest conventional oils. A series of dairy analogue foods has been made in which soy lecithin stabilizes medium chain triglyceride (MCT) emulsions used in medical nutritional products. This application of soy lecithin enables the creation of a wider range of MCT foods than has been previously available. Discussions are underway with industry to commercialize these products.

Figure 18.4. Navam Hettiarachchy, a University of Arkansas food scientist, shows experimental products she has made from soybean proteins in her laboratory.

Summary

The soybean plant, which has often been referred to as the “Miracle” or “Cinderella” crop, seemingly has not lost any of its luster in the 21st century. Recent advances have resulted in the development of plastics, cosmetics and nutraceuticals. Continuing research findings are confirming the health benefits of soy-based products and seem to indicate that additional environmental and health-related products are on the horizon.

Chapter 19

Soybean Facts

*by W. Morrison**

Scientific Name: *Glycine max*
Family: *Leguminosae* (Legume)

Soybean Seed Size:
Small = 3,500-3,900 per pound
Medium = 3,100-3,500 per pound
Large = 2,600-3,100 per pound

Flower Colors: Purple, White

Seed Colors: Yellow, Brown, Black Green, Bicolored, Variegated

Hilum Colors: Buff (colorless), Black, Imperfect Black, Brown

Pubescence Colors: Tawny (golden brown), Gray

Plant Height: 20"-50" (varies by variety and environmental conditions)

Pod Number: 0-400 per plant

Seed/Pod: 1-5; 2-3 more common

Hypocotyl Color: Green, Purple

1 bushel = 60 lbs.
1 cwt. = 1.66 bu.
1 short ton = 33.33 bu.
1 metric ton = 2,204.6 lb.
1 metric ton = 36.7 bu. soybeans
1 short ton = 0.907 metric ton
1 hectare = 2.471 acres
1 acre = 0.405 hectares
34 bu/A soybeans = 2.29 metric tons/hectare
Protein content of seed – 40%
Oil content of seed – 20%
1 bushel = 11 pounds of oil
1 bushel = 48 pounds of protein-rich meal

Grade Specifications (#1 yellow):
Test Weight – 56 pounds or higher
Heat Damage – 0.2% or less
Total Damage – 2% or less
Foreign Material – 1% or less
Splits – 10% or less
Soybeans of Other Colors – 1% or less

Major Export Customers:
(1) Economic Community Countries (EU)
(2) Japan
(3) Taiwan
(4) Mexico
(5) South Korea

Major U.S. Crops:
(1) Corn – 23%
(2) Wheat – 23%
(3) Soybeans – 19%

Major World Oilseed Crops:
(1) Soybeans – 51%
(2) Cottonseed – 13%
(3) Rapeseed – 12%
(4) Peanut – 10%
(5) Sunflower – 9%

Major Soybean Producers:
(1) U.S. – 43%
(2) Brazil – 21%
(3) Argentina – 11%
(4) China – 11%

U.S. Edible Oil Consumption:
(1) Soybeans – 77%
(2) Corn – 6%
(3) Tallow/Lard – 5%
(4) Cottonseed – 4%

Major Uses:

Oil – Margarine, coffee creamer, vegetable oil, salad dressing, mayonnaise, carriers in inks and paints, environmental friendly fuel for diesel engines, lecithin.

Protein and/or Whole Soybean – Feed for poultry, swine and other animals, tofu, soy sauce, soy flour, soy sprouts, roasted nuts, soy milk, meat extenders, plastics, wood adhesives and textile fibers, pharmaceuticals.

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* Taken from *Louisiana Soybean Handbook*. Used with permission from Dr. Walter C. Morrison, Specialist (Agronomy), Louisiana Cooperative Extension Service, Baton Rouge.

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http://www.uaex.uada.edu

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