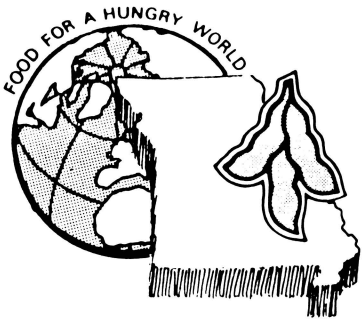
Missouri Soybean Handbook

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University of Missouri-Columbia College of Agriculture & Extension Division
Missouri Soybean Merchandising Council
Manual 123



Missouri Soybean Merchandising Council

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Fellow Soybean Producer:

This is the second edition of the Missouri Soybean Handbook which incorporates the changes in technology that have occurred since the handbook was first printed in 1982. It is provided to you by the Missouri Soybean Merchandising Council in cooperation with research and extension faculty of the University of Missouri-Columbia College of Agriculture.

This handbook is but one benefit you receive from your checkoff dollars. Some information presented here is the direct result of research supported by the checkoff program.

More than 22,000 copies of the first edition were distributed at no charge to Missouri soybean producers. The quality of the handbook was evident by the requests from universities and agribusinesses to purchase the publication. An additional 2,000 handbooks were sold to universities and commercial interests, most of which have their orders in for this updated issue.

The Council's intent is to invest checkoff funds in areas that will help all Missouri producers improve the profitability of soybean production. We hope you will find this handbook a useful reference in your production management system.

Thank you for your continued support of the soybean checkoff self-help program.

Sincerely,
JACK TIPTON
Chairman

Contents

Chapter	Title	Page
1	Growth & Development	1
2	Varieties	5
3	Seed Quality	9
4	Tillage	15
5	Fertility	19
6	Planting Practices	23
7	Narrow Row Soybeans	29
8	Nematode Control	33
9	Insect Control	37

Color Photos

Soybean Nematodes	36
Common Insects	40
Beneficial Insects	42
Nutrient Deficiencies	43
Diseases	44
Herbicide Injury	46
Grass and Broadleaved Weed Seedlings (including nutsedge)	48
Annual Broadleaved Weeds	49
Annual Grasses and Perennial Weeds (including nutsedge)	50

10	Weed Control	51
11	Disease Control	55
12	Moisture Management	61
13	Harvest, Drying, Storage	65
14	Economics	69
15	Marketing	73
16	Processing	77
17	Human Nutrition	79
18	Livestock Nutrition	81
Subject and Problem Solving Index		85
Publications, Organizations, Credits		Inside back cover

About This Handbook

This second edition of the *Missouri Soybean Handbook* serves as a production, problem solving, and reference guide for Missouri soybean growers. It was written by College of Agriculture and University Extension Division staff of the University of Missouri. Three special sections are included — subject and problem solving index on page 85, color photos in the center section on various pests and problems, and soybean publications and organizations on the inside back cover. Individualized help is available by contacting your county University of Missouri Extension Center or by writing to the authors of chapters in care of the College of Agriculture, University of Missouri-Columbia, Columbia, MO 65211.

The Editorial Committee and the authors acknowledge various contributions by individuals and organizations listed on the inside back cover. We would also like to acknowledge the contribution of many extension field staff and those that authored and reviewed chapters in the first edition.

The Editorial Committee and the authors regret any technical or literary errors that may appear in this handbook.

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Chapter 1

Growth & Development

Diana G. Helsel

Understanding the growth and development of a soybean plant can be useful in making many management decisions on soybean production. This presentation draws heavily on Iowa State University Cooperative Extension publications SR 53, "How a Soybean Plant Develops," and SR 80, "Stages of Soybean Development."

Seed Parts

The soybean seed is generally oval in shape and has two main parts — the embryo and the seed coat (figure 1-1). The seed is made up of:

—Cotyledons: young leaves and food store of seed
—Young leaves, stem and root: found between the cotyledons
—Seed coat: surrounds the cotyledons
—Hilum: seedscar where seed breaks from pod wall
—Micropyle: small hole that allows for air exchange between the embryo and the outside world.

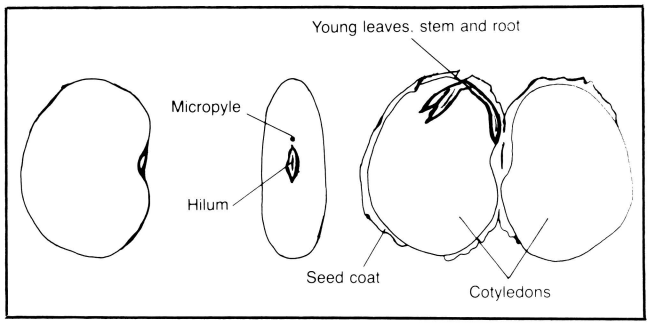


Figure 1-1. Soybean seed anatomy.

Seedling Development

Water uptake:
- seed swells to more than double original size
- 50% seed moisture needed to germinate
- too much water is bad: limits oxygen for root growth and encourages root rotting diseases

Root emerges:
- root (radicle) emerges in 1-2 days
- first branch roots appear when radicle is 1" long

Cotyledons emerge:
- cotyledons pulled above soil in 4-7 days
- cotyledons provide food reserves to begin growth, but also carry on photosynthesis
- loss of one cotyledon not damaging: Loss of both after emergence will reduce yield 8-9%

Leaves emerge:
- first leaves to appear are unifoliate: only one leaf blade per leaf stalk (petiole)
- unifoliate leaf loss is less damaging to yield than cotyledon loss: If both unifoliates are lost, cotyledons compensate for 60% of this loss
- loss of both cotyledons and unifoliates decreases yield 7%.
- can identify unifoliate node when leaves are lost by two opposite leaf scars above the opposite leaf scars left by the cotyledons
- trifoliate leaves formed hereafter (figure 1-3)

Roots develop:
- 14 days after emergence, first root nodules appear that fix nitrogen from air
- root system has a taproot and lateral roots
- at full growth, more than 80% of the roots are in the upper 4 inches of soil. If destroyed by cultivation, yield loss would result

Buds develop:
- an axil is the junction of the main stem and the leaf. This contains an axillary bud which can develop into a flower cluster or a branch
- axillary buds that develop into flowers start at the fourth or fifth node, usually
- immature flowers are present in 3 weeks; flowers not seen until 6-8 weeks after emergence

Vegetative Stages of Development

Soybean development can be divided into stages: The vegetative (V) and reproductive (R) stages. Vegetative development is shown in Figures 1-2 and 1-3, but can also be described by stages which begin at emergence (VE) (table 1-1).

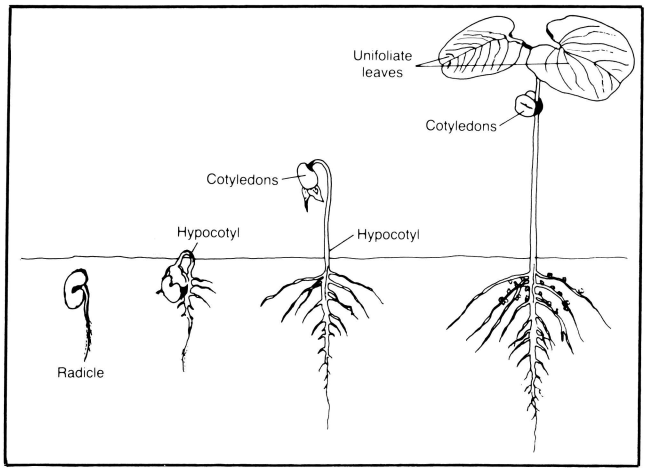


Figure 1-2. Stages of soybean germination, emergence and seedling establishment.

Coping with damage. Soybeans can tolerate complete leaf loss due to low temperatures until about the third trifoliate leaf unfolds. Soybean leaves are less susceptible to frost than are corn leaves: temperatures down to 28°F are tolerable. Soybeans can recuperate from damage, such as frost or hail, as long as buds are not destroyed.

Plants will recover their lost leaves by new development from buds at the unifoliate or cotyledonary nodes. (Corn recovers from frost damage because the growing point is below the soil surface and is insulated by the warmer soil.) If the stem is cut off, the buds form new branches and leaves. Cutting the plant below the cotyledonary node will kill it because there are no buds below the cotyledon for regrowth

Growth habit. There are two main types of stem growth habit and flower initiation in soybeans: Indeterminate and determinate. Determinate type varieties essentially complete their vegetative growth around flowering. The main stem ends in a large, terminal pod cluster. Indeterminate varieties continue to increase in height for several weeks after they begin to flower. Height frequently doubles after the first flowers appear.

Determinate semi-dwarf varieties and semi-determinate varieties combine some characteristics of indeterminate and determinate varieties. They are shorter than the varieties normally grown in Missouri. Determinate semi-dwarfs are true determinate varieties.

Semi-determinate varieties are 6-10 inches shorter than common varieties and add only a small amount of vegetative growth after flowering and podding begin. Flowering period of both types is slightly shorter than commonly grown varieties. Determinate semi-dwarfs and semi-determinates are more lodging resistant than taller types and may yield 5-10% more in high yielding environments (50 bu/A +). UMC Guide 4419 gives a more complete description of these varieties and recommended production practices.

Introduction of flowering. Soybeans are induced to flower by both photoperiod and temperature. In general, photoperiod is more important and causes a soybean variety to be adapted to a relatively narrow range of latitudes. Soybeans are short day plants; they require successive days of shorter duration after a specific number of hours of sunlight has been reached.

Cooler temperatures and longer day lengths cause delays in flowering, while warm and/or short days hasten flowering and maturity. In the early part of the season (before June 1), day length is more influential. Among varieties, later maturing types are more sensitive to daylength than are early maturing types.

When a variety has been planted south of its zone of adaptation it may flower at an earlier stage of development and mature earlier because the shorter days induce flowering at an earlier calendar date.

When a variety is planted north of its zone of adaptation, floral initiation and maturation will be delayed because the critical daylength occurs at a later calendar date. As a result maturity may be delayed until after the average date of the first killing frost.

Reproductive Stages of Development

Reproductive (R) stages cover the period from flowering through plant maturation. The stages are described in Table 1-2.

Flowering and pollination. The first flowers usually appear at nodes five or six on indeterminate soybean plants. Determinate soybeans begin flowering near

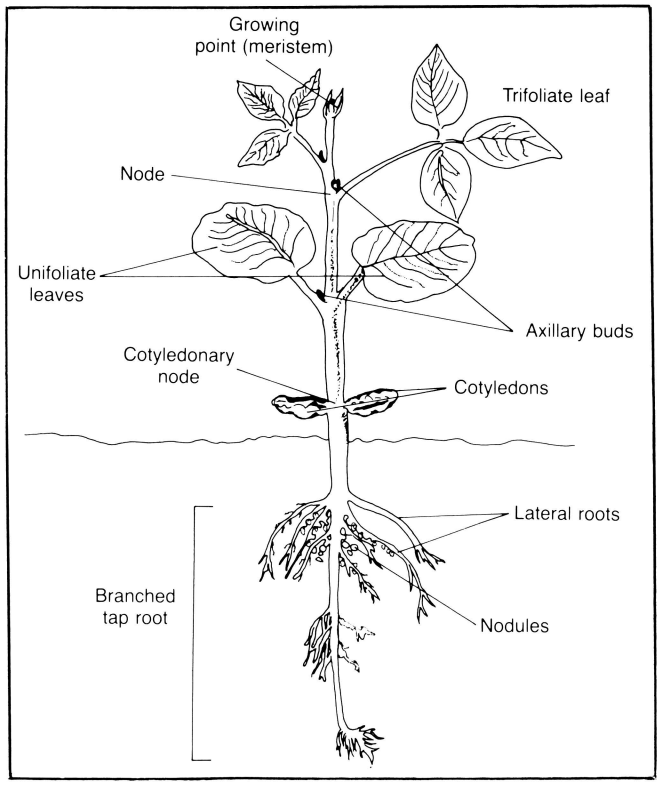


Figure 1-3. Vegetative structures of a young soybean plant.

Table 1-1. Description of vegetative stages.

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

the top of the plant. The flowering period is influenced by the time of planting and may extend for two to four weeks, or more.

Because of the structure of the flower parts, soybeans are almost completely self-fertilized. Pollination may occur in the bud stage, or before the flower has opened. Many more flowers are produced than can develop into pods: Abortion rates are high (20-80%).

Podding. The number of pods produced per plant can have a major effect on increasing or decreasing harvestable yield. Stress during podding may be partially compensated for if flowering is still in progress, but once flowering is complete the plant cannot compensate for losses.

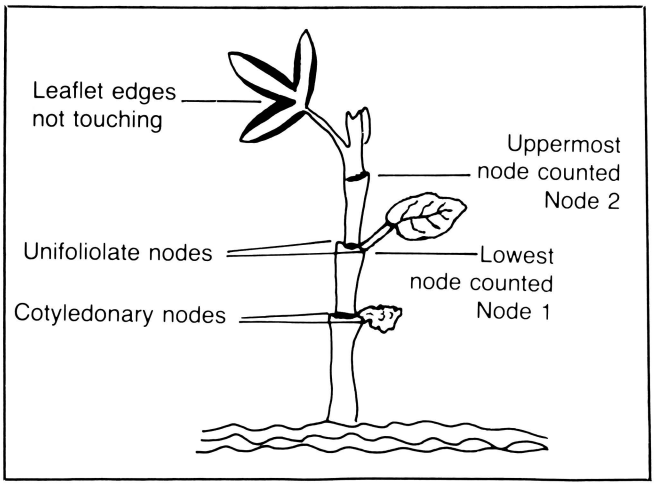


Figure 1-4. Identification of nodes on a soybean plant at the second-node (V2) stage with a cotyledon, unifoliolate leaf and first trifoliolate leaf removed.

Effects of stress. Moisture stress, leaf loss, or other stresses cause maximum reduction in yield if it occurs during pod filling. Total leaf loss between R4.5 and R5.5 can reduce soybean yields by more than 80%. Water stress or high temperatures during flowering or early pod development will cause flower and pod abortion or reduced number of seeds per pod.

Seed filling. At the seed filling stage, the plant attains maximum height, node number and leaf area. Nitrogen fixation rates reach their highest point and begin to decline. Seeds steadily and rapidly accumulate dry matter.

Physiological maturity. At the end of the bean filling period, the maximum amount of dry matter, or yield, has been accumulated in the seeds; the seeds have reached physiological maturity. Cool autumn

Table 1-2. 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 on 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 that have reached their mature pod color. 5-10 days of drying weather are required after R8 before the soybeans have less than 15% moisture

temperatures do not necessarily delay or hasten physiological maturity. Decreasing daylength will hasten physiological maturity more than will warm temperatures. Once physiological maturity has been reached, yield cannot be increased. The seeds contain about 55% moisture. From this point on, water is lost, which results in seed shrinkage. Defoliants may be applied at this stage.

Determining maturity. Three stages of maturity are recognized in soybeans; physiological maturity (PM), visible maturity (VM) and harvest maturity (HM). Physiological maturity of an individual bean occurs at a different time than the physiological maturity of the whole field. Physiological maturity of a bean in a pod is indicated by loss of green color from the pod, with pulling away of the bean from the inside pod wall.

The usual question, however, is the maturity of an entire field. The physiological maturity of a field occurs about 2-5 days after 95% of the plants in the field have reached stage R7, or at least 1-3 days before all the pods on 95% of the plants in the field have lost their green color. Yellowing or dropping of leaves is not a reliable indicator of maturity. Moisture of all the beans from the field at physiological maturity will be about 45%. Effects of frost after late R6 to the beginning of R7 is minimal.

Visual maturity (stage R8) occurs when 95% of the soybean pods on plants have reached their mature color. This stage is used for rating varietal maturity. At this stage, seed moisture is about 32%.

Harvest maturity is defined as 13% moisture average of the harvested beans.

Table 1-3. Days for a plant to develop from one stage to next.

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

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

Table 1-4. Yield loss (%) at various stages of soybean development.

Stage	Percent leaf loss						
	10	15	20	25	30	40	50
Vegetative							
V1				1	1	3	5
V3				1	1	3	5
V5				1	1	3	6
V7			1	2	2	4	6
Reproductive							
R1	1	2	3	4	5	7	9
R3	2	3	4	6	7	10	13
R5	4	5	7	8	10	13	18
R7	0	0	0	0	0	0	0

Growth Stages

The stages of soybean development have been standardized to aid communication among persons working with soybeans. For a review of the vegetative and reproductive stages see Tables 1-1 and 1-2.

To determine the soybean growth stage one must be able to identify the nodes on the plant. Nodes that have had a fully developed leaf are used in counting (see figure 1-4). A leaf is fully developed (the node is counted) when the leaf at the node above has unrolled enough so that the two edges of each leaflet are not touching. In very young leaves, the leaflets are rolled up, resembling cylinders but will unroll as the leaf develops.

Staging a field. The growth stages described were based on the development of individual plants. To stage an entire soybean field examine a sample of individual plants. The average stage of a field is when 50% of the plants are at or beyond a particular stage of development. At least 10 plants per 10 acres should be sampled to determine the field stage.

Average stage length. Soybean development is influenced by many factors. As a result, there can be considerable variation in the number of days between stages. Table 1-3 has been included to provide rough estimates of the number of days required for a plant to develop from one stage to the next.

Yield loss due to defoliation. Growth stage affects the ability of soybeans to tolerate damage. Leaf loss is common, and may be caused by insect damage, postemergence herbicides, hail, or leaf diseases, or all of these. Whatever the cause, leaf loss at various stages of plant development will result in varying degrees of yield loss. See Table 1-4.

Chapter 2

Varieties

Sam C. Anand and Harry C. Minor

Variety Development

The soybean is native to eastern Asia. Varieties introduced from northeastern China adapted well to the Midwest but needed improvement to enhance productivity.

The first soybean variety developed in the Corn Belt was **Lincoln,** released in 1944. In the second cycle of improvement, four important varieties — **Clark** in Maturity Group IV, **Ford** and **Shelby** in Group III and **Chippewa** in Group I — were developed. In the third cycle of improvement, emphasis was placed on disease resistance. New versions of **Clark** and **Chippewa — Clark 63** and **Chippewa 64,** the number indicating the year of release — were evolved, which were resistant to *Phytophthora* root rot. These varieties provided a sound foundation for soybean improvement programs in the northern states.

Ogden, in Maturity Group V, was the first variety developed in the south. **S-100** in Group V was released in 1951 for southeast Missouri, but its low oil content shortened its useful life. **Dorman,** with higher oil content and superior seed qualities, was released in 1952. **S-100** was crossed with **CNS,** a variety resistant to bacterial pustule. This cross resulted in development of **Lee,** a major breakthrough in the southern variety development program. **Lee** provided an erect plant type, shattering resistance, superior yield, and resistance to major foliar diseases.

Varieties such as **Scott, Dare, York** and **Hill,** released after **Lee,** provided other productive varieties with maturity ranges useful to southeast Missouri. Cyst nematode became a serious problem with extensive cultivation of soybeans. **Forrest** and **Bedford** varieties were developed to combat this problem.

Methods of Variety Development. Variety development involves crossing of two soybean varieties, combining desirable characters from both parents. In some cases, one parent may be a wild soybean line with a desirable trait such as resistance to a disease or a pest. Most wild soybean lines have other undesirable characters such as weak stem, shattering, poor seed qualities and black seed coat. Breeders must select against the bad characters and retain only one or two desirable characters. For developing cyst nematode resistant cultivars, each plant is first screened in the greenhouse in the seedling stage (Fig. 2-1) against the known races of the nematode. The selected plants are then progeny tested in the field in a 'cyst nursery.' For testing against phytophthora rot, the seedlings are inoculated with the disease and the surviving (resistant) progenies are saved.



Figure 2-1. Screening for soybean cyst nematode in the greenhouse.

Several breeding methods such as (1) pedigree method, (2) backcross method and (3) single seed descent are used by soybean breeders. The pedigree method and single seed descent are the most common for developing high yielding varieties. The backcross method is generally used to transfer disease resistance from an unadapted variety to an adapted variety. A variety developed by this procedure resembles the adapted variety but has an additional desirable trait.

There is great variability between families and between the plants in the same family after a cross is made. Normally, it takes five to seven generations of selfing to obtain uniform progenies. After that, at least three years of yield testing are required to determine

Table 2-1. Characteristics of major public varieties available in Missouri.

Variety[1]	Maturity Group	Flower Color[2]	Pubescence Color[3]	Hilum Color[4]	Resistance to Races of Phytophthora Root Rot[5]	Resistance to Races of Cyst Nematode[5]	Other Characteristics[5, 6]
Fayette	III	W	Tw	Bl	S	1,3,4	R to BP
Pella[P]	III	P	Tw	Bl	1,2	S	MR to BP, PSB
Pella 86	III	P	Tw	Bl	MR	S	
Williams	III	W	Tw	Bl	S	S	R to BP, PM
Williams 82	III	W	Tw	Bl	1-10,13-15	S	R to BP, PM
Chamberlain	III	P	Br	Bl	MR	S	R to BP, BSR
Sherman	III	W	G	Bu	S	S	
Zane	III	P	G	Im Bl	MR	S	
Winchester	III	W	Tw	Bl	1-9,11, 13-18,21,22	S	
Harper	III	P	Tw	Bl	MR	S	R to BP
Hobbit	III	W	Br	Bl	T	S	Determinate, semi-dwarf
Crawford[P]	IV	P	Tw	Bl	MR	S	MR to PSS
Union	IV	W	Tw	Bl	1,2	S	R to DM
Pershing[P]	IV	W	G	Bu	MR	S	R to BP
Ripley	IV	P	G	Bu	T	S	Determinate, semi-dwarf
Essex	V	P	G	Bu	MR	S	R to BP, DM, PM, FES, LS
Forrest[P]	V	W	Br	Bl	MR	1,3	R to RKN, RN, BP, WF, TS
Bedford[P]	V	W	Br	Bl	MR	1,3,4	MR to FES, RKN
Avery	V	W	Tw	Bl	T	1,3,4	R to BP, RKN
Centennial[P]	VI	P	Tw	Bl	1,2	1,3	R to RKN, RN
Tracy-M	VI	W	Tw	Bl	1-9	S	Similar to Tracy
Davis	VI	W	G	Bu	R	S	R to BP, TS, WF
Lee 74	VI	P	Tw	Bl	R	S	R to RKN
Jeff	VI	P	Tw	Br	T	1,3,4	R to BP, RKN
Leflore	VI	P	Tw	Bl	T	3,4	R to BP, RKN
Braxton	VI	P	Tw	Bl	T	S	R to BP, TS, FES, PM, RKN

1 [P] = protected variety
2 P = purple; W = white
3 G = grey, Br = brown; TW = tawny (light brown)
4 Im Bl = imperfect black; Bl = black; Bu = buff
5 S = susceptible; MS = moderately susceptible; R = resistant; MR = moderately resistant; T = tolerant
6 PSB = pod and stem blight; DM = downy mildew BP = bacterial pustule; FES = frog eye spot LS = leaf spot, RKN = root knot nematode RN = reinform nematode WF = wildfire; TS = target spot PSS = purple seed stain; PM = powdery mildew BSR = brown stem rot

if the new strain is superior and suitable for release. An additional two to three generations are needed for seed increase. Thus it takes 10 to 12 generations from the time a cross is made until a variety is developed and released to growers.

Current Varieties

The University of Missouri has soybean variety development programs at its Delta Center, Portageville, to breed varieties for southeast Missouri and at Columbia to isolate superior varieties for central and northern Missouri. Figure 2-3 shows the yield testing conditions at the Delta Center. Soybean strains developed from these programs and other public institutions are compared in uniform tests in several states and also at a number of locations in Missouri. Varieties that show good overall performance are released. Currently major varieties released by public institutions are listed in Table 2-1.

Varieties described in this chapter are not the only ones suitable for cultivation in Missouri. Varieties developed by private companies are also available. The University of Missouri conducts trials at various locations around the state using varieties from both private companies and public institutions. The results of the crop performance tests are published in a special report every year and are available at local County Extension Centers.

Variety Selection

Selecting a variety is but one of the many decisions a soybean grower must make each spring. Yet, it is among the most important. Soybean varieties may differ markedly in yield potential under any specific set of conditions. Selection of a variety from among those that have the highest yielding ability is ob-

viously important. The ability of a grower to do this will depend to a considerable extent on an understanding of production conditions and the soybean varietal characteristics best adapted to them.

Major characteristics that deserve consideration are maturity, standability, and resistance to pests. Specific circumstances may require the consideration of other factors.

Proper Maturity. An individual variety will be adapted for full-season growth in a narrow band from north to south. Flowering and maturity of these varieties is synchronized to the season because of their reaction to photoperiod, or length of day. Because of this sensitivity to daylength, when a variety is moved to the north, it will flower later; when it is moved to the south, it will flower earlier.

The maturity group classification of a variety is a good guide to where it will be adapted as a full-season variety. Figure 2-2 shows areas where the different maturity groups are grown in Missouri.

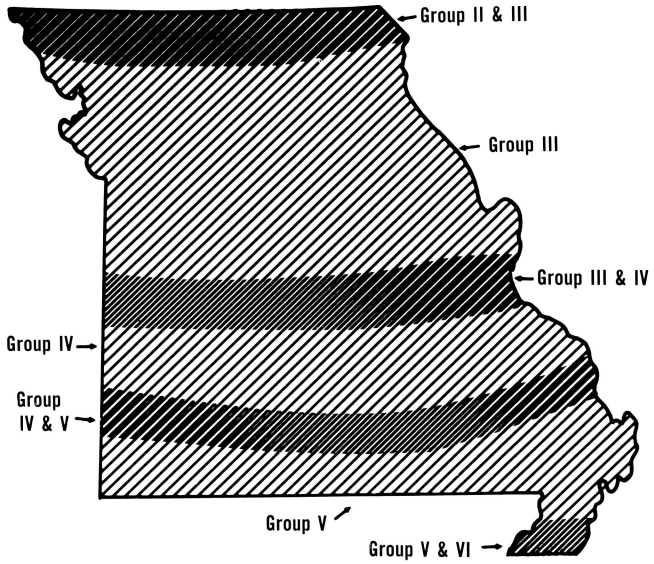


Figure 2-2. Adaptation of different soybean maturity groups.

Most varieties grown in northern Missouri are Group III, although some late Group II varieties are also grown. In the central part Group III varieties predominate but Group IV varieties are also well adapted. In the south most varieties grown are of maturity Groups IV and V. In the extreme southeast Group V varieties predominate, but some Group VI varieties are also planted.

Full-season varieties are generally more productive than early varieties. However, during years when early varieties escape a late drought or other stress, they may produce higher yields. Also, somewhat less than full season varieties may be desirable when wheat is to follow soybeans. In most of southern and central Missouri, mid- to full-season varieties can be expected to mature and be harvested in time to sow small grains. But, if soybean harvest is frequently delayed by wet weather, an earlier variety should be selected.

Late maturing varieties remain vegetative longer and therefore grow taller. As a consequence, they are more competitive with weeds than an earlier variety and tend to produce better on poorer soils. However, under conditions of high fertility and moisture they may make excessive growth and lodge. Clearly, maturity must be closely fitted to the production environment and cropping system.

Planting varieties with varying maturities can spread harvest and increase profits. Staggered maturity dates reduce the risks associated with weather and permit timely harvest with less equipment than would otherwise be necessary.

Standability. To produce maximum grain yields, a variety must be able to remain erect throughout the growing season. When lodging occurs before maturity, yields are decreased. In highly productive environments that produce 50+ bu/A, reductions in yield of 20 to 30% are thought to be common when lodging occurs during the pod-filling period. Further, lodging reduces harvest efficiency, and harvest losses are greater.

Plant breeders and production agronomists to often record lodging scores in research. While scoring systems may vary among research workers, they all strive to express a range of lodging percentages by a single number. Low scores indicate good standability. The scoring system used at the University of Missouri is: 1 = all plants erect, 2 = all plants leaning slightly or a few down, 3 = all plants leaning moderately or 20-50% down, 4 = all plants leaning considerably or 50-80% down, 5 = all plants down.

While lodging is a genetically controlled characteristic, it is greatly modified by the environment. Management practices that accentuate lodging are irrigation, high fertility, high plant population and narrow row spacing especially with high plant population. Irrigation and high fertility stimulate vegetative growth which increase lodging. Likewise, as plant population increases, soybean stems become more slender with longer internodes; as a result, the ability to stand decreases. Therefore, if a variety is somewhat weak in standing ability, planting rates should be at the low end of the optimum range, particularly if other production factors favor rapid vegetative growth.

Results on lodging in narrow rows are somewhat mixed. Plant survival, however, is rather consistently improved in narrow rows because of reduced plant-to-plant competition. Many plants which would be ''weeded out'' in conventional rows would live throughout the season in more equidistance planting pattern (approximated by narrow rows), but lodging pressure increases, usually during the critical reproductive period. For this reason, lodging resistance is a particularly important criteria when selecting a variety for narrow rows. Unless the variety will stand



Figure 2-3. Variety testing at the Delta Center.

well, much of the potential of narrow row spacings may be lost.

Plant strength is usually reduced in late plantings, however because of the shorter plant height, the effect of lodging is reduced. The usual practice of decreasing spacing between rows and increasing planting rate, however, could act to accentuate lodging in late planted beans.

Lodging differences among varieties are most evident in environments favorable for lodging. If little or no lodging occurs in a variety test, it doesn't mean that all varieties have good standability, rather it indicates insufficient stress to differentiate among varieties.

Breeding efforts have improved lodging resistance in soybeans. One method used during the last decade has been introduction of the semi-determinate and determinate growth characteristic into adapted, indeterminate varieties. The result is the determinate (semi-dwarf) varieties like **Ripley, Sprite, Pixie** and **Hobbit** and semi-determinate varieties that are suitable specifically for high yield environments. These varieties may require special management like narrow rows, high seeding rates, early planting, good fertility and moisture to produce maximum yield. However, unless lodging is in fact a problem with the best indeterminate varieties available, higher yields probably will not result from use of the new short varieties.

Resistance to Pests. Pests of soybeans are many, however, not all are well recognized. Diseases, for example go largely unnoticed but are thought to reduce soybean yields about 15%. Essentially all varieties now carry resistance to the bacterial pustule. *Phytophthora* root rot is a variable organism having many races. Some varieties have resistance or field tolerance to prevalent races. A variety with resistance or tolerance to this disease should be selected where this pest is known to be serious. Also, whenever a resistant and susceptible variety of equal yield potential are available, the resistant variety should be given preference, other factors being similar. Reactions to various pests by public varieties are presented in Table 2-1.

Soybean cyst nematodes are an increasingly serious problem. On infested light soils, economic cultivation of susceptible varieties will not be possible unless soil is treated with a nematicide, soybeans are grown in a rotation, or a resistant variety is used. The list of the resistant varieties is given in Table 2-1.

Additional Characteristics. Desirable varieties will hold their seeds until all pods are fully matured. Some varieties have a tendency to shatter, particularly under dry conditions. Such varieties should be avoided unless they are exceptional in other respects and there is a high probability that harvest can be done in a timely fashion.

Height of the lowest pod should be sufficient to prevent harvest losses. In improved soybean varieties with an indeterminant growth type, first pod height is generally only a problem when plant population is inadequate. Semi-dwarf varieties may produce many pods below harvest height when growing conditions do not stimulate rapid vegetative growth.

Small seeded varieties are gaining favor. Small seeds are thought to emerge better under conditions of soil moisture stress. Fewer pounds of small seed are required to establish a given plant population than large seed. Additionally, small seeds generally are less subject than large seed to mechanical damage during harvest. Thus, it is easier to produce a high quality planting seed of a small seeded than large seeded variety.

Not all commercially available seed are pure breeding varieties. Also available as blends, these mixtures of varieties are sold without identification of the varieties or their proportions in the mixture. Blends offer the possibility of yield stability. Should one component of the mixture be adversely affected by production conditions, then another component may be able to compensate so as to stabilize yield. Available data tend to support this hypothesis, but the yield of a blend rarely exceeds that of the highest yield variety used to make it.

Also, the seed harvested from a blend will not be like that which was planted. Components in the blend will change during each production season. Therefore, the grower wishing to grow a specific blend must buy seed each year.

Chapter 3

Seed Quality

Lloyd E. Cavanah, Wynard E. Aslin and Einar W. Palm

Soybean improvement programs have two major objectives: to increase yields and increase quality. One important aspect of yield is quality planting seed. This aspect of soybean production has been recognized by farmers and seedsmen alike. Large-scale, widespread and professional soybean seed programs have evolved, which have no parallel among other nonhybrid grain crops.

Factors of Quality

Varietal purity. Varietal purity is important for performance and uniformity. Inherited characteristics contribute to seed quality and overall performance. Varieties that emerge quickly may carry resistance to diseases that cause deterioration within the seed prior to emergence. The variety may also carry resistance to diseases that affect the seedlings and growing plants that otherwise may cause a reduction in yield to a complete crop failure.

Very often it is possible to determine mixtures of varieties by visual observation. Various seed characteristics, the most obvious is the hilum (seed scar), are helpful in determining trueness to variety. When soybean seeds are produced under "stress," caused by environmental conditions, seed characteristics may not appear as originally described.

Physical purity. Seed should not be contaminated with seed of objectionable weeds or other crops. There should also be a minimum of inert material to aid in obtaining a more uniform rate of planting. The physical purity is assessed in seed testing laboratories. A respresentative sample is analyzed and separated into the percentage by weight of (1) pure seed, (2) other crop seed, (3) weed seed, and (4) inert matter.

Germination — Vigor. The germination test is performed in seed testing laboratories under controlled conditions. It represents the percentage by number of seeds capable of producing "normal" seedlings during a specific period of time, generally under near-optimal conditions. Vigor tests, on the other hand, assay the extent of deterioration of seeds within a population and determines performance potential.

Seed death is gradual and cumulative. As more and more cells die, certain critical parts of the seed become unable to perform their essential functions. There are many so-called vigor tests reportedly being made at present. But there has yet to be a vigor test developed that will give repeatable results in all laboratories. Some tests being conducted are:

(1) *Seedling Growth Rate.* Seeds are placed in a suitable moist media (sand, sand and loam, paper toweling), then into a humid chamber with alternating temperatures of 68°F (16 hrs) and 86°F (8 hrs). On the third day, those seedlings that have reached 1½ inches are counted; on the fourth day, those seedlings that have reached 2 inches are counted. The counts are thought to represent vigor.

(2) *Accelerated Aging.* The seeds are placed in a suitable moist media, then into a chamber with temperature at 107°F and 100% relative humidity. After 48 hours, the seeds are moved to a humid chamber with the normal temperature for germination, 68°F to 86°F for eight days. The normal seedlings are counted, which indicates the vigor.

(3) *Cold Test.* The seeds are placed in a suitable moist media, then into a humid chamber at 55°F for 5 days, then into a humid chamber with normal temperature for 8 days. The normal seedlings represent the degree of vigor in the seed lot. *Until uniform standards are developed, vigor test should not be used in labeling planting seed.*

Soybean seeds are inherently short lived as compared to other major crops. Warm temperatures with high humidity hastens deterioration. To assure the highest available vigor, planting seed should be selected from the crop that was produced the preceding year. Seed carried over into the second year may have relatively high germination but it will have reduced vigor. If carryover seed is planted, the soil should have warmed above 70°F and should be planted only about one inch deep.

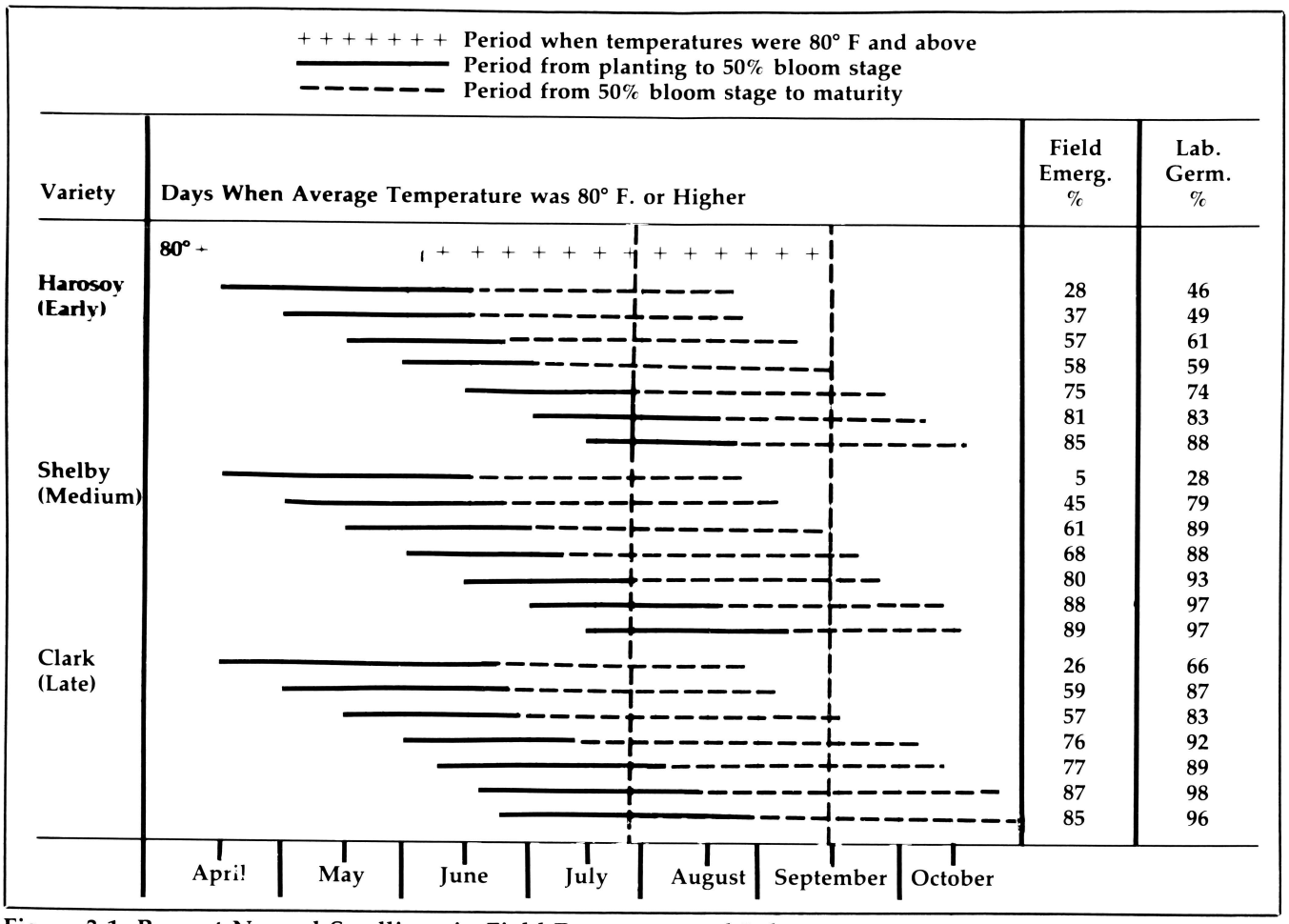


Figure 3-1. Percent Normal Seedlings in Field Emergence and Laboratory Germination Trials of Three Varieties of Soybeans as Affected by Environmental Conditions During Seed Maturation.

Factors Affecting Seed Quality and Germination

Climatic conditions. Quality is very much affected by climatic conditions during early seed development, pre- and post-maturation, and until the seed has been harvested. Stress periods — excessive dry weather and/or high temperature — frequently cause seeds to have low germination and poor field emergence. When soybeans mature during a usual hot dry period, from mid-August to mid-September, germination in laboratory tests are low as well as the percentage of field emergence. Planting soybeans that are being grown for seed production should be delayed to avoid maturing during this stress period. See Figure 3-1.

Harvesting. Harvesting is probably the most critical phase of soybean seed production in relation to seed quality. Expert harvesting is not easy. Attention to details and measuring for proper adjustments are important to reduce the damage that causes lowering of seed quality.

First, improper cleaning of the combine is the major source of varietal contamination. The combine can not be easily cleaned. When disassembled, cleaning with compressed air, or water, or both can produce one to two bushels of material — soybean seed (or seed from preceding crop), weed seeds, trash, soil — from many machines. Discarding one or two hoppers of seed before saving the planting seed aids in removing this material but does not completely eliminate it.

Second, timeliness of harvest is most important in minimizing field deterioration. Ideally, soybeans should be harvested when the seed reaches about 14% moisture. Tests indicate that good germination results could be expected from seed harvested at 13.5% to 10% moisture content. Less soybean seed breakage will occur when combining soybeans at moisture contents above 14%. However, harvesting at the higher moisture level may cause injury that will lower the germination percentage of the seed.

When rains delay harvest, seed moisture usually increases. With adequate drying facilities it is not necessary for the seed to dry to 13.5% before harvesting. However, prolonged delays in harvesting with constant wetting, from heavy dews or rainfall, causes as much as 20% drop in germination within thirty days. Early maturing varieties are affected much more than full season varieties. Soybeans remaining in the field long after normal harvest may be further damaged by fungal diseases.

Hot, dry weather during harvest adversely affects both the physical and physiological quality of soybean seed. Many seeds are shattered or bruised in such a way that germination is lowered, if not lost. If seed moisture is low, harvesting during early morning or late afternoon or evening may reduce damage.

Finally, mechanical abuse during harvesting is probably the most important cause of injury to soybean seed. This may be as a result of improper combine operation, cylinder speed to high, improper concave clearance, improper forward speed, improper moisture content, or a combination of these. Rotary combines have been shown to reduce splits. More detail on the rotary combines and proper adjustments for combining is discussed in Chapter 13.

Handling, Storage and Aeration

Mechanical damage may occur during the handling of the seed after being taken from the combine. Seed can be heavily damaged when elevated into storage bins. Auger elevators are very damaging to the seed, increasing as the quantity of seed is reduced in the elevator and/or when the auger is run at excessive speeds. Soybean seed are best conveyed by "beltvators," belt buckets, continuous bucket elevators, horizontal drag flight or belt conveyor, and gravity spouting systems. The use of "dead boxes" in longer gravity spout runs decreases velocity of seed flow and absorbs impact at points of directional change. Also, "bean ladders" or a spiral "let-down" inside the bin, helps in maintaining quality of soybean seed. Many beltvators and bucket elevators offered today are lined with a rubber coating to reduce seed impact damage.

Soybeans are usually stored in metal bins for a period of time prior to cleaning. Many bins are equipped for aeration and/or drying, with and without stir-aerators. The time in storage may range from a few weeks up to 4 or 5 months. During this storage period, reduction in germination and vigor can occur if the seed is improperly cared for.

Aeration is usually adequate and helpful for maintaining seed viability at 14% or less moisture. If warm humid conditions continue into the winter months, periodic aeration of the seed will prevent temperature stratification and moisture migration throughout the storage bin. Cooling also takes place with the loss in moisture content of 1 to 2%. Seed storage molds are curtailed and further damage to the seed is mostly eliminated.

Drying soybean seed, when moisture is in excess of 14%, may be necessary some years. Very little information is available on using supplemental heat for drying soybean seed. Since high temperature is a causal factor in seed deterioration, caution should be exercised when supplying supplemental heat in the aeration process. Air at ambient temperature forced through the seed at 2 to 3 cfm/bu is usually adequate and safe.

Cleaning

All storage bins, cleaning, and handling machinery are potential sources of contamination. Therefore, facilities in a seed cleaning plant should be thoroughly cleaned prior to handling each variety of seed.

Seed cleaning is necessary to remove impurities such as pods, soil, other crop seeds and immature or otherwise inferior seeds. Cleaning helps to 1) avoid spreading weed seeds, 2) improve germination, 3) ease planting, and 4) establish more uniform stands.

Soybean seed are not difficult to clean. The basic machine is the air-screen cleaner; and when properly operated, it will be adequate. An increasing number of seedsmen pass the seed over spiral separators after the basic cleaning. The spiral separator separates out broken seed, splits, misshapen seed (immature or severely shrunken), soil "peds" and weed seed (moon flower), thus, greatly improving appearance and slightly increasing germination. The spiral separator has been used most to remove soil "peds," the potential carrier of the soybean cyst nematode. Many seedsmen use the specific gravity cleaner after the air-screen with equal results.

Most cleaning problems are associated with overloading the seed screens, preventing the material from coming in contact with the screens, and making it impossible to remove the undesirable material.

Seed Treatment

Treating seed with a fungicide before planting helps to improve germination and seedling vigor by reducing seed decay, damping off and seedling blights. Seed often carries fungus spores of *Aspergillus, Penicillium, Rhizopus* and other molds that injure germinating seeds. In addition, several fungi that cause disease — such as pod and stem blight, anthracnose, purple seed strain, downy mildew and others — can severely affect performance of seed. Cracks in seed coats make it vulnerable to rots and seedling infections from seedborne and soil-borne organisms.

Seed treatment may not be as effective if low germination is due to mechanical injury to the embryo or other physiological disorders. But significant benefits may be achieved on both low and high germinating seed. Seed treatment has insurance value.

The following fungicides have Environmental Protection Agency labels for use on soybeans: Captan (several trade names), Carboxin-captan (Vitavax 20-20), Carboxin-PCNB, Carboxin-Thiram (Vitavax 200), Maneb (several trade names), Metalaxyl (Apron), PCNB (Terraclor Super X), Thiram (several trade names), Thiram + TBZ (Agrosol T). The University of Missouri does not endorse any one material over another.

Only a small portion of soybean seed marketed,

however, is treated because the risk of financial loss to the seedsman is too great. Once seeds are treated with a fungicide they can be used only for planting. For this reason, when soybean seed are treated with a fungicide, the chemical is most frequently applied at the time of planting.

Seed treatment fungicides formulated as liquid, slurry or flowable material may be used in commercial seed treaters. The treatment is metered on at recommended rates and agitated in the machine so all seeds are covered. A dry formulation (dust) fungicide can be applied by a commercial dust treater, by home-made rotary drums or by mixing in the planter box.

When using a dust fungicide in a rotary drum, fill it half full of seed, add correct amount of fungicide over the surface and rotate slowly until the seed is uniformly colored. If the fungicide is added into the planter box, fill to about half full with seed, sprinkle half the correct amount of fungicide. Stir gently with a wooden paddle until uniform coloring is on all seeds. Then add remaining amount of seed and the other half of the fungicide. Stir again. For air planters, the conventional "planter box" treatments are somewhat ineffective and may interfere with planter operation. The better adhering and dust free formulations such as "Evershield" are satisfactory.

All seed treatment fungicides must contain a contrasting colored dye to indicate the seed has been treated. Treated seed must not be used for food, feed, or oil purposes.

Maintaining Varietal Purity: Seed Certification

Seed certification is a system for maintaining varietal purity by keeping pedigree records obtained from a series of field and seed inspections. It may be likened to the pedigreeing of animals — each lot of seed can be traced to the breeding materials and methods used in developing the variety. Seedsmen and farmers thus have assurance of getting genetically pure seeds when they distribute or use certified seed.

The responsibility for certifying seed in Missouri is designated in section 266.092 of the Missouri Seed Law. It states that "Certification of seed in the State of Missouri shall be carried out by an agency or association designated annually by the Director of the Missouri Agricultural Experiment Station at Columbia, Missouri." Historically, the Missouri Seed Improvement Association, Inc., Columbia, Missouri has been designated to perform this service.

The basic function of a seed certification program is to serve agriculture in maintaining high quality genetic purity seed. The certification label can be thought of as a stamp of acceptability from an impartial agency. The label does not mean that the seed is perfect. But, it is a safety feature for sellers and buyers of seeds.

Four classes and sources of certified seed are:

Breeder Seed — Seed or vegetative propagating material directly controlled by the originating or sponsoring plant breeder, institution or firm that supplies the source for additional increases of Foundation Seed. Labels are not issued for Breeder Seed.

Foundation Seed — seed stocks handled so as to maintain genetic identity and purity. Foundation Seed is owned or under the supervision of an Agricultural Experiment Station or the originator, or the sponsoring plant breeder or firm and shall be the source of Registered and/or Certified Seed classes. Foundation Seed shall be tagged with a white label.

Registered Seed — progeny of Breeder or Foundation Seed handled so as to maintain genetic purity and identity and approved and certified by an official certifying agency. Registered Seed shall be of the quality suitable for the production of the Certified Seed class. Registered Seed shall be tagged with a purple label.

Certified Seed — progeny of Breeder, Foundation, or Registered Seed handled so as to maintain genetic identity and purity and certified by an official certifying agency. Certified Seed shall have a blue label.

The certification process begins for the grower when an application is filed with the certifying agency. The application includes information on the identity of the seeds and the cropping history of the field. The variety is eligible if released by the Missouri Agriculture Experiment Station, recommended by the National Crop Variety Review Board or has been accepted for certification by another state agency. The land must not have grown the same crop the preceding year unless the seed crop was the same variety and was also certified.

When the proper seeds have been planted and the land is free of plants or seeds that would dilute varietal purity, field inspection becomes the next important feature of certification. On it hinges heavily the varietal purity of succeeding generations for any observable mixtures of other crops and varieties, and the presence of seed-borne diseases and weeds are determined at this time. Each field is walked by an official inspector of the seed certifying agency to see that every part of the field meets certification requirements. Field inspectors report the presence of other crops and varieties, diseases and weeds. These are compared with the standards to determine if the crop of seeds meets the field requirements for certification.

A further safeguard in maintaining varietal purity is a limitation of the number of generations the seeds may be increased. The number of generations shall be limited to that specified by the breeder or owner. This shall not exceed two generations beyond the foundation seed class unless it is an old variety where foundation seed is not being maintained or an emergency is declared. This limitation minimizes the effect of possible genetic shifts or contamination in varietal purity and performance.

Seed inspections are made to determine whether

Table 3-1. Quality Field and Seed Standards for Certification.

Field Standards

Factor	Maximum Permitted in Each Class		
	Foundation	Registered	Certified
Other varieties[1]	.02% (1-5000)	.04% (1-2500)	.2% (1-500)
Corn, sorghum or sunflower plants bearing seed	None	None	None
Prohibited weed seeds[2]	None	None	None

[1] Other varieties shall be considered to include off-type plants that can be differentiated from the variety that is being inspected.
[2] Field bindweed, Johnsongrass and Sorghum almum.

Seed Quality Standards[3]

Factor	Foundation	Registered	Certified
Pure Seed	98%	98%	98%
Inert not to exceed	2%	2%	2%
Total germination	80.0%	80.0%	80.0%
Other crop seeds (all classes)	Not to exceed three per pound (must be free of corn, sorghum and sunflower)		
Other distinguishable varieties[4]	0.02%	0.04%	0.2%
Prohibited weed seeds[5]	None	None	None
Total weed seeds (all classes)	Not to exceed three per pound (must be free of cockleburs and may contain not in excess of two morning glory in one pound)		

[3]To be accepted for final certification the seed must be cleaned and bagged in new bags.
[4] Off-colored beans due to environmental factors shall not be considered other varieties. Other distinguishable varieties shall be considered to include off-type seeds that can be differentiated from the variety that is being analyzed.
[5] Prohibited weeds are field bindweed, Johnsongrass and Sorghum almum.

the certified seed is of reasonably good planting quality. It is made on a representative sample of the cleaned seed submitted, or drawn by the certifying agency. From these samples, seed analysts determine the percentage of mechanical purity, including varietal purity, weed seeds, other crop seeds, inert matter and germination. This is compared with the standards to see if the crop of seeds meets the seed requirements for certification. Then and only then is a certified seed label issued, for each bag. The field and seed standards are listed in Table 3-1.

Seed Control

The basic purpose of the seed laws in the United States is to insure that seed is labeled truthfully. It is possible for seed dealers legally to sell low quality but correctly labeled seeds. The purchaser therefore should read and understand the information on the label, which must be attached to the container to determine whether he wants to buy the seed.

It is not within the scope of this publication to set out the complete details of Federal and State laws and regulations relating to the sale, transportation, and distribution of seed. The laws protect the farmer, marketer and consumer from mislabeling.

Federal Seed Act — The Federal Seed Act was enacted to regulate seeds in interstate and foreign commerce. Seeds imported into the United States must contain a minimum of 75% pure-live seed, must not contain more than 2%, by weight, of weed seeds and must be free of designated noxious weed seeds as specified in the Act. A basic requirement of the Act is that seeds must be labeled to meet the requirements of the state into which they are being shipped. And, the test to determine the percentage of germination shall have been completed within a five month period, exclusive of the calendar month in which the test was completed. The name and address of the person who transports or delivers for transportation said seed in interstate commerce must be on the label.

Missouri Seed Law — The Missouri Seed Law and Regulations revised in September, 1979, are administered by the Missouri Department of Agriculture, Bureau of Feed and Seed, P.O. Box 630, Jefferson City, Missouri 65102. The Department maintains a laboratory with the necessary seed testing equipment to test seed in the administration of the law. Complimentary,

cost-free analysis will also be performed by the laboratory of a limited number of seed samples for those who wish analysis on seed to be planted on Missouri farms operated by them.

All agricultural and vegetable seeds offered or exposed for sale shall have an analysis tag or label attached in a conspicuous place. Farmers, however, may sell seed of their own production without an analysis tag so long as they sell on their own premise, do not refer to the purity or germination, and do not advertise beyond their local news media. The basic purpose of the law is "truth in labeling," which enables intelligent selection based on fact, not fiction.

The Missouri Seed Law requires that the following information be on the label:

1. Commonly accepted name of kind or kind and variety, of each agriculture seed component in excess of five percent of the whole weight. When more than one component is required to be named, the word "mixture" or "mixed" shall be shown conspiciously on the label.
2. Lot Number or other lot identification.
3. Origin, if unknown, that fact shall be stated.
4. Percentage by weight of pure seed.
5. Percentage by weight of all weed seeds.
6. Percentage by weight of agricultural seed (which may be designated as "crop seeds") other than those required to be named on the label.
7. Percentage by weight of inert matter.
8. Noxious weed seed must be expressed in number per pound for soybeans. The name and number of each kind of noxious week seed must be stated when present singularly or collectively in excess of five seeds per pound. The restrictive weed seeds most commonly found in soybean seed are Johnsongrass and sorghum almum, both prohibited from sale in Missouri; hedge bindweed, purple moon flower and balloon vine are noxious weeds. When there are five seeds or less, a statement stating "None in excess of five noxious weed seeds per pound," is permitted.
9. Germination percent of each agricultural seed in excess of 5 percent and percent of hard seeds if present and total germination and hard seeds, and the calendar month and year the test was completed to determine such percentage.
10. Name, address and zip code of the person who labeled said seed, or the name and address of the person who sells, offers or exposes said seed for sale within the state.
11. If the treatment of the seed is an inoculant, a date of expiration must be stated.
12. Any treatment of seed regulated by this law must be labeled to show the treatment.
    (a) The labeling of a treatment for seed must be done either on a separate tag, or on the bag.
    (b) If the amount of treatment on the seed is harmful to man or animal, the label shall name the additive and state precautions on use. In addition, a contrasting colored dye showing evidence of treatment must be used.
    (c) If a treatment adds more than one percent (1%) to the weight of the seed, that weight must also be included in the inert matter weight of the seed.
13. Agricultural seed labeled to show less than 50% germination must be additionally distinguished by the words "Low Germination." Seed containing less than 25% germination can not be sold.

Seed Testing Laboratories — Seed testing is the science of evaluating seed quality for agricultural purposes. No seed analysis, regardless of how carefully or accurately accomplished, is any better than the sample on which it is performed.

When the sample is received in the laboratory, a portion of the seeds are placed in replicated suitable moist media (paper, toweling, or sand) and placed in seed testing chambers with alternating temperatures of 68°F (16 hrs) and 86°F (8 hrs) for eight days. (This is the Standard Test approved by the Association of Official Seed Analysts and is used in all regulatory control laboratories.) Only seedlings having essential structures indicative of the ability to produce a normal plant under favorable conditions are counted.

The remainder of the sample is separated into percentage by weight for: 1) pure seed, 2) other crop seed, 3) weed seed, and 4) inert matter. Another portion is used to determine the kind and number of common and noxious weeds, and other crop seeds.

The Plant Variety Protection Act — The Plant Variety Protection Act (PVPA) was developed to encourage the development of novel varieties of sexually reproduced plants — by seed — and to make them available to the public, thus promoting progress in agriculture in the public interest. The PVPA, in force since December 1970, thus, provides legal protection to developers of new varieties of plants.

The PVPA is administered by the Plant Variety Protection Commission of the United States Department of Agriculture. Applications are evaluated for each crop variety on the basis of the following criteria: 1) Novelty, 2) Uniformity, and 3) Stability. Novelty is described as distinctiveness on the basis of morphological, physiological, or cytological characteristics. Uniformity requires that all variations within the population must be describable, predictable, and within commercially acceptable limits. Stability requires that its characteristics remain unchanged throughout successive generations of seed increase.

The owner of a variety with a Certificate of Protection from the PVPA has exclusive rights to that variety. The variety cannot be sold without owner permission.

Chapter 4

Tillage

Don Pfost, Jim Gregory, Zane R. Helsel and Joe H. Scott

Tillage is the act of moving soil particles. Movement may result in either an increase or a decrease in bulk density (degree of compactness) and a mixing or turning over of soil. Clod size is usually reduced. The amount of residue on the surface is also usually reduced, and with certain tillage tools surface residue is nearly eliminated.

Water intake is usually increased by primary or initial tillage operations, but rapidly decreases to a value as low or lower than pretilled conditions as further tillage is performed and surface sealing develops from rainfall.

Tillage stimulates microbial activity with the result that organic matter content of the soil is reduced. With the combination of reduced soil cover, reduced infiltration and reduced organic matter content, tillage almost always accelerates soil erosion.

Selecting a Tillage System

Many tillage tools can be used independently or together with other tools. Instead of discussing individual systems, we will attempt to discuss the needs of the seed and plant. Terminology and definitions for tillage operations can be found in American Society of Agricultural Engineers (ASAE) Engineering Practice: ASAE EP 291.1 and ASAE standard: ASAE S414.

Tillage costs money in terms of fuel and time (Table 4-1) thus tillage should be performed for a specific reason. It has been said that proper tillage is the least tillage necessary to produce the desired crop as efficiently as possible.

Planting cannot be done without some tillage (movement of soil particles). It is possible to do a good job of planting with a minimum of tillage. It is a false concept to think that we need to till the entire field to obtain a good seedbed. A few reasons for tilling the entire field are:

- Removal of surface residue to increase soil temperature (Increases up to 10°F to 15°F in the spring during mid-afternoon at a one inch depth can be achieved on some soil types in Missouri with fall or spring tillage depending on the fraction of initial cover.),
- weed control,
- leveling or smoothing land where ditches or ruts exist or drainage is needed, and
- insect and disease control.

Reasons for not tilling the whole field include:

- The potential for soil erosion by water and wind is greatly increased with tillage,
- evaporation from the soil surface is increased as residue is removed with tillage (A silt loam soil will be affected more than a sandy soil due to a higher potential for capillary rise with silt loam soil.),
- the potential for soil crusting and loss of stand is increased with tillage,
- time and cost of production are usually increased with tillage, and,
- fuel consumption is increased as greater volumes of soil are moved. (Table 4-1 indicates fuel usage for various tillage tools and depths of operation.)

Tillage can be reduced by reducing the number of tillage operations, reducing the width of seedbed tilled and reducing the depth of tillage. The first two are affected by the number and type of tillage tools

Table 4-1. Diesel Fuel Consumption of Various Tillage Equipment

Implement	Fuel Consumption (gal/A)
Moldboard Plow (8" depth)	1.80
Moldboard Plow (10" depth)	2.10
Chisel Plow (8" depth)	1.35
Chisel Plow (12" depth)	1.75
Disk (corn stalks)	.45
Disk (plowed)	.65
Field Cultivator	.60
Harrow, Springtooth	.40
Harrow, Spiketooth	.30
Cultivator	.45
Rotary Hoe	.25

used. The depth of tillage is controlled by the operator.

Primary tillage if used should be only deep enough to perform required functions. Moldboard plowing, for example, to 5-7 inches instead of 10-12 inches is often sufficient. Secondary tillage operations, as a rule of thumb, should be only about half the depth of primary tillage. Shallow tillage reduces fuel consumption, cost, time and it prevents dragging of residue, weed seed, and any wet soil back to the soil surface. With no-till planters, depth of operation should be only that necessary to plant the soybeans in moist soil and protect the seed from chemicals, birds, and other pests.

Deep Tillage

Deep tillage can be performed by subsoiling or by deep plowing. Deep tillage is *not necessary* for either of the two main reasons for tillage — seed bed preparation and weed control. Current research at the University of Missouri and other universities indicates that deep plowing or profile modification on some soils can result in improved crop production. Soils with high densities in the subsoil and having poor internal drainage can be improved by deep tillage and the mixing of lime to cause the soil to develop stable aggregates. Claypan soils of northern Missouri are of this type. Deep subsoiling of these soils, however, does not achieve the desired profile modification of mixing the soil and of incorporating lime. If subsoiling is performed on these soils, it should be done when the subsoil is dry. Even then the only benefit may be a temporary break-up of the subsoil which will rapidly reseal after wetting.

Table 4.2. Tillage mulch reduction factors for selected crop residues.[1]

Tillage implement	Wheat	Soybean	Sorghum and corn
Anhydrous applicator	0.60	0.45	0.75
Chisel plow (points)	0.75	0.20	0.40
Disk	0.55	0.50	0.60
Drill (Disc openers)	0.90	0.90	0.90
Field cultivator	0.80	1.30*	1.20*
Moldboard plow	<0.10	<0.10	<0.10
Planter	0.90	0.90	0.90
Till plant	—	0.50	0.50

[1] From Crops and Soils Magazine, page 8, April-May, 1987.

* The field cultivator values listed here are for situations where this operation follows a primary tillage tool, such as a plow or chisel, where the residue cover would be generally less than 50% before the passage of the field cultivator. When the field cultivator would be used in undisturbed soybean residue, as an example, the value would probably be closer to that listed for wheat.

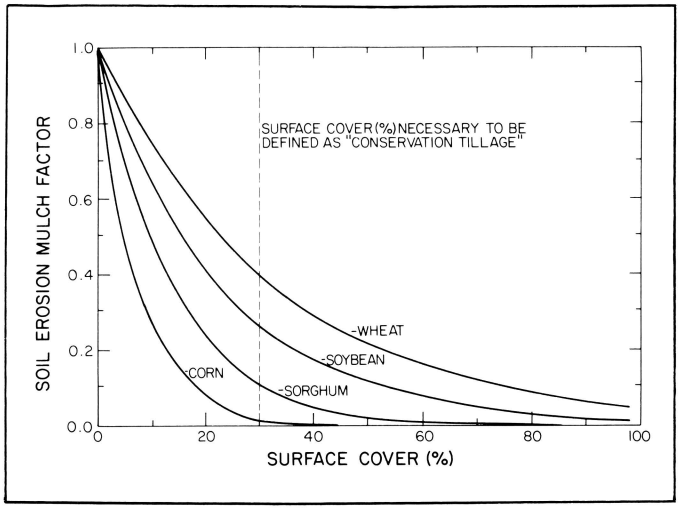


Figure 4.1. The relationship between soil erosion mulch factor and surface cover for wheat, soybean, sorghum, and corn residues. At 30% surface cover, the level defined as conservation tillage, the soil erosion mulch factor varies from 0.40 for wheat to less than 0.10 for corn.[1]

[1] From Crops and Soils Magazine, page 7, April-May, 1987.

Production Constraints from Tillage

Soil Crusting. Many farmers are tempted to plant soybeans deep when conventional tillage is used and the surface soil has become dry. If a hard rain occurs followed by rapid drying, a soil crust often forms on many soils before the soybeans have time to emerge. Obviously the interaction of soil moisture, depth of planting and rate of drying is important. Reducing the number of tillage operations to leave larger soil aggregates on the surface can reduce the severity of soil crusting.

A tillage system that leaves a mulch (residue) on the surface may reduce crusting. Soil moisture content under mulch is nearly uniform to the soil surface. This is not true for bare soil that is drier closer to the surface than at greater depths. The advantage of not tilling for double cropped soybeans after wheat is well illustrated with the following data collected at the University of Missouri Greenley Memorial Research Farm at Novelty, Missouri in 1980:

Planting method	Yield (Bu/A)
no till (irrigated)	30
no till (dryland)	28
plow + disk + disk (irrigated)	22
plow + disk + disk (dryland)	13

Energy required by the seedling to penetrate the soil surface increases greatly with drying time. Large amounts of moisture after planting will result in a more severe problem as drying proceeds. The obvious response is to plant shallow under a mulch-covered surface, which tends to maintain uniform moisture near the soil surface.



Figure 4-2. Excellent residue cover in a wheat-soybean double crop rotation.

Soil Compaction. Repeated tillage operations with heavy machinery leads to increased soil compaction. Compacted soils are often poorly drained and have reduced aeration. Compaction along with poor aeration can cause restricted root growth, decreased nitrogen fixation and increased root rot organisms.

Soil compaction results from any operation that tends to break soil bonding (structure breakdown) followed by a drying condition. Soil bonding can be reduced by tillage operations especially when the soil is wet. Soil bonding can also be reduced by prolonged wetting of the soil. For example, over irrigation of claypan soils can result in poor soil structure the next year. Raindrops falling on the soil surface can also cause soil structure to break down.

Soil compaction can result from prolonged no-till conditions as well as with traditional tillage operations. Generally tillage operations loosen the soil surface temporarily but create a compacted zone immediately below the depth of tillage. Thus, depth of tillage should be varied from year to year when possible. No-till usually has the highest density (soil compaction) at a depth of 1 to 2 inches below the soil surface. It is not known whether the higher density near the soil surface or the problems of weed control with no-till is the cause of reduced yields associated with some no-till soybean production.

Reducing the number of tillage passes following primary tillage will reduce compaction. Tillage passes after primary tillage compacts the soil two ways: (1) from the secondary tillage machine and (2) from the wheel traffic of the tractor. It is a misconception that using dual wheels will reduce compaction. Using duals will reduce the rolling resistance and slippage in loose soil but the area of compaction increases. The best way to reduce compaction is to reduce the amount of traffic or control the traffic so that compaction is limited to the same area.

Soil Erosion. Another problem that affects many farmers is soil erosion. Conceptually, soil erosion is a two-step process: first, detachment of soil particles; then transport. Interference with either of these two processes will reduce soil erosion. Residue management and tillage operations affect water erosion and wind erosion similarly. Since water erosion however is more severe in Missouri than wind erosion, this discussion will be primarily limited to water erosion.

First, a land owner should determine if soil erosion is a problem. There is no point in selecting a tillage system to correct a problem that does not exist. The rule of thumb is that if any evidence of soil movement can be detected on the field, then probably soil erosion rates exceed 10 tons per acre per year. It is not certain how much soil erosion costs in terms of crop produc-

tion; however, with the limited data available, long-term soil loss is thought to be a serious problem. Erosion rates should be below 5 tons/A/year on deep soils and 2-3 tons/A/year on shallow soils.

Soil detachment is primarily caused by raindrops directly striking the soil surface or soil particles moving by wind striking the soil surface. Tillage operations tend to bury or mix surface residue in the tilled zone leaving the soil more exposed to abrasive action. Tillage can also directly cause detachment by loosening the soil surface and reducing the aggregated size on the surface. Obviously the more tillage operations, the finer the soil particles become and the easier it is to transport the soil. Also the finer the soil, the more rapid the development of surface sealing, which in turn causes more runoff and more transport capacity for water erosion. The most important effect of tillage on either water or wind erosion is removal of soil cover.

The moldboard plow, a primary tillage tool, removes 90 to 100% of the existing soil cover. The chisel plow, also a primary tillage tool, removes 25 to 60% of residues such as wheat and corn residues but up to 80% of soybean residue (table 4-2). Soybeans present a somewhat unique problem in that 30 to 50% of the total soybean residue is leaf material and very fragile. By early to mid summer most of the leaf material is gone, even if tillage has not been performed. Wheat residue decays only about one-half as fast as soybean residue with corn decay between wheat and soybeans.

The tillage mulch reduction factors in table 4-2 can be combined using chain multiplication. For example, assume that a soybean field has 90% residue cover at harvest and is immediately tilled and drilled to wheat after chiseling and disking. For chiseling, disking, and drilling, mulch factors of 0.2, 0.5, and 0.9, respectively, would apply. The percent of the surface covered with residue after planting wheat would be calculated as follows:

$$90\% \times 0.2 \times 0.5 \times 0.9 = 8\%$$

From figure 4.1, an erosion reduction of approximately 70% (compared to bare soil) is shown for 8% cover with soybean residue (before any residue decay). The same treatment for corn residue, starting with 90% cover (though corn typically leaves more cover than soybeans) would reduce erosion by about 90%. Note: The above reductions are compared to bare, fallow soil and are for sheet and rill erosion only. Additional erosion will result where water concentrates to form gullies; in such cases, terraces may be required, or, at least, grassed waterways where concentrated water flows.

Using only a no-till planter will reduce soil erosion by about 50 to 60% with soybeans compared to moldboard plowing, while no-till in corn residue will reduce soil erosion by about 90%. No-till and reduced tillage are very effective tillage practices for reducing soil erosion when corn or grain sorghum residue is on the surface. Either of these practices, and particularly the reduced tillage practice, is very limited in benefit when soybean residue is on the surface.

The most promising tillage system for soil erosion control with soybeans appears to be a dual crop no-till system. The key is residue management. First, a crop such as wheat, barley or oats is fall planted and harvested in early summer. Typically 80% of the soil will remain covered after no-till planting in the stubble. Generally the wheat stubble should not be mowed since it has been found that the stubble will cause the soybeans to pod higher and will make harvesting easier. During a normal year with a high yielding wheat crop, green weeds will not be serious in wheat and contact herbicide may not be required at soybean planting. After soybean harvest, wheat can then be no-tilled with a no-till drill in the soybean residue.

Recently technology has made it possible to control weeds with chemicals in no-till soybeans. This technology is discussed in Chapter 10. Another acceptable alternative for residue management for erosion control is a corn-soybean-wheat sequence using no-till or reduced tillage. The key is to follow soybeans with wheat or some other winter cover crop.

Tillage Considerations for Two Different Soils

Finally as an example consider two soils — a claypan where depth of topsoil is limited and the surface is highly erodable and a high clay soil commonly known as gumbo. Much of Missouri is covered with a claypan soil and while the land slope is typically less than 5%, there is a severe erosion problem. Due to the erosion problem a reduced tillage of spring chisel plow and one or two disking operations is recommended as a maximum amount of tillage. If weeds can be controlled so that yields can be maintained, a no-till system should be considered. With no-till, lack of weed control will probably be the greatest cause of failure.

Gumbo soils are a different case, they occur in flat river bottoms and obtaining an acceptable seedbed is difficult. The least risk tillage system is probably fall moldboard or chisel plowing. After winter weathering secondary tillage can then be used to both air the soil for drying and to prepare a seedbed. Tillage practices that work with a surface drainage system should also be used. While no-till may work some years, problems of wet soil at planting and poor seed soil contact may result in lower plant emergence and lower yields. A winter cover crop to dry the soil in the spring may be a solution to this problem.

The more difficult a soil is to work, the more cautious farmers should be in switching from established tillage practices known to produce high yields.

Chapter 5

Fertility

Daryl D. Buchholz and Luther B. Hughes

Soybeans have long been considered poor responders to direct fertilization. Fertilizer used for a previous crop, such as corn or wheat, was usually adequate for soybean production. As Missouri agriculture has moved towards more acres of high yielding and/or continuous soybeans, fertilizer management has become an important issue.

Soil Testing and Interpretation

One way of determining need for a fertilizer nutrient is through soil testing. A soil testing service is available at a nominal charge through your University of Missouri County Extension Center.

Soil acidity and liming. The soybean plant is a legume, requiring the proper soil reaction (acidity) for nodulation, nitrogen fixation and plant growth. In Missouri, soil reaction is determined using 0.01 M calcium chloride solution mixed with the soil and is referred to as salt pH or pH_s. This test for soil acidity is different than the water pH, and will generally result in a pH reading about 0.5 unit lower than a water pH.

Soybeans respond to liming of acid soils. Generally, soils having a pH_s of 5.5 or greater (water pH of 6.0 or greater) are sufficient for obtaining maximum growth of soybeans. As the soil pH_s drops below 5.5, soybean yields will likely decrease. This decrease may be the result of reduced nodulation and nitrogen fixation or toxicity of aluminum or manganese. For a more complete discussion of soil acidity, consult UMC Guide 9102 on liming Missouri soils.

Apply limestone only according to soil tests. Soils used for soybean production are suggested to be limed to a pH_s of 6.0 to 6.5. This allows for some safety and assurance that maximum production can be achieved. Liming is probably not necessary until the soil pH_s decreases to about 5.5. Raising the pH_s above the suggested range has not been proven to be beneficial. Above the recommended range, soybeans may show manganese deficiency due to high soil pH_s.

Nitrogen. Research in Missouri and other soybean growing states shows there is a big advantage in using soybeans to add nitrogen to the soil. Research indicates that soybeans, in some cases, can add the equivalent of about 70 pounds of fertilizer nitrogen per acre.

We recommend a nitrogen credit of 30 to 40 pounds per acre for grain sorghum or corn following beans. For wheat following beans we recommend a 20 to 30 pound nitrogen credit.

Response to fertilizer nitrogen additions on soybeans that are properly inoculated with rhizobium bacteria is unlikely. Rates of 25 lbs. N/A are not detrimental, but also are not likely to give added yield.

Phosphorus. Consistent response to phosphorus fertilization on soybeans is generally limited to soils testing very low and low in available phosphorus even though each bushel removes about 0.9 lb P_2O_5. Soils testing medium in available phosphorus generally give small but infrequent yield responses to direct phosphorus fertilization. Phosphorus soil test ratings and recommendations for 40 bushel soybeans are given in Table 5-1. Recommendations are based on building soil phosphorus levels over eight years.

Phosphorus fertilizer can generally be applied as a direct application, broadcast preplant. Using higher rates on a previous crop such as corn works equally well.

Potassium. Soil tests, much like phosphorus, are the best indicators of potential response of soybeans to potassium. Soybeans remove much higher amounts of potassium (about 1.4 lbs K_2O/bu) in the grain as compared to most other grain crops. Therefore, maintenance applications of potassium on soybeans

Table 5-1. Phosphorus recommended for 40 bushel soybeans.

Rating	Very Low	Low	Medium	High
Bray I (Lbs. P/A)	0-14	14-22	22-45	45 +
Recommended P_2O_5 rate	75-105	60-75	35-60	0-35

Table 5-2. Potassium recommended for 40 bushel soybeans on a silt loam soil.

Rating	Very Low	Low	Medium	High
Soil test level (lbs K/A)	0-90	90-150	150-300	300+
Recommended K_2O rate	130-170	100-130	55-100	0-55

are higher than on corn. Soybeans are likely to respond to potassium fertilization on soils testing very low or low in available (exchangeable) potassium. Medium testing soils give infrequent response to potassium fertilization with soybeans. Soybeans are not likely to respond to direct application of potassium fertilizer on high testing soils. Table 5-2 outlines potassium soil test interpretations and recommendations for buildup and maintenance fertilization for 40 bushel soybeans on a silt loam soil with a cation exchange capacity of 16 milliequivalents.

Secondary and Micronutrients. Generally, secondary and micronutrients are not a problem in soybean production.

Sulfur may become deficient on soybeans grown on very sandy textured soils, low in organic matter. Medium or fine textured soils contain adequate sulfur for high yielding soybeans. On sandy, low organic matter soils, a rate of 15 to 20 pounds of sulfur per acre broadcast should be adequate.

Zinc has been found to be deficient in Missouri soils that have been graded, severely eroded, or are low in organic matter. Soybeans may respond to zinc on soils testing very low in available zinc. Medium or high testing soils likely do not require zinc for high yielding soybeans. Rates of 5 pounds of zinc or less per acre broadcast preplant should be adequate for several years. Available zinc levels can then be monitored with soil testing.

Table 5-3. Nutrient content, in pounds, of a 50-bushel soybean yield.

	Grain	Plant	Total
Nitrogen (N)	185	100	285
Phosphorus (P_2O_5)	42	28	70
Potassium (K_2O)	72	65	137
Calcium (Ca)	—	—	75
Magnesium (Mg)	—	—	32
Sulfur (S)	—	—	25
Zinc (Zn)	—	—	0.2
Iron (Fe)	—	—	1.7
Manganese (Mn)	—	—	0.6
Copper (Cu)	—	—	0.1
Boron (B)	—	—	0.1
Molybdenum (Mo)	—	—	0.01

Adapted from Purdue University Cooperative Extension Service, Agronomy Guide AY-170.

Research with iron, manganese, boron, copper, and molybdenum has not shown response to these nutrients in Missouri. Soils maintained at the proper acidity (pH_s) level will contain adequate amounts of these micronutrients for maximum soybean production potential.

Soybean Nutrient Deficiency Symptoms. A typical soybean plant at harvest in a 50-bushel crop will contain nutrients as given in Table 5-3.

Nitrogen. Nitrogen deficiencies may occur on soybeans as a result of poor microbial nodulation. This is more likely to occur in harsh soil environments such as wet conditions, very hot, dry conditions, or very acid soils. Nitrogen deficiency is characterized by slow, small growth; small, pale green leaves; yellow old leaves; and early defoliation. Nitrogen deficiencies due to poor nodulation can normally be overcome with nitrogen application prior to early pod set. Some yield reduction will likely have occurred.

Phosphorus. Phosphorus deficiencies generally appear as thin and dwarfed stems; lack-lustre leaves; and generally early defoliation will occur. Leaves tend to be more erect and form an acute angle with the stem. A limited supply of phosphorus reduces the number, as well as the efficiency, of nodule bacteria. Correcting a phosphorus deficiency in that crop year is difficult. Heavier phosphorus fertilizer applications with good incorporation into the soil is the best preventative measure. Phosphorus is easily diagnosed through soil testing.

Potassium. Potassium deficiencies appear as stunted growth with shortened internodes. Leaf edges are generally curled downward and appear scorched or yellowed. This is especially true in lower leaves. Under severe deficiency, the leaves may become brownish to blackish along the edges. Correction through preventive measures is again the best policy. Soil tests work extremely well.

Magnesium. Magnesium deficiency in soybeans in Missouri is seldom found. A deficiency would appear as a pale green color occurring between the main veins of soybean leaves. Lower leaves are affected first.

Sulfur. With sulfur deficiency, the younger leaves in soybeans will begin to turn pale green, including the veins. The symptom is very similar to nitrogen deficiency in soybeans, but the deficiency will first appear on the upper leaves with sulfur and on lower leaves with nitrogen. At present, there is not widespread sulfur deficiencies in Missouri. Documented cases have occurred almost exclusively on sandy textured, low organic matter soils. Medium and fine textured soils will seldom display sulfur deficiencies or fertilizer response to sulfur.

Iron. Iron deficiency in soybeans can be character-

ized by yellowing of leaf areas between veins. As the deficiency becomes more severe, the leaf can turn almost white. Iron deficiency will not occur generally in Missouri. Only soils having a very high pH (7.5+) appear susceptible to iron deficiency. This would be limited to a few isolated river bottom soils in extreme Northwest Missouri.

Manganese. Manganese deficiency in soybeans in Missouri is highly unlikely. Deficiency symptoms occur on sandy soils high in organic matter or heavy textured soils high in pH. Manganese deficiency in soybeans is characterized by interveinal chlorosis, while the veins remain green. The deficiency will occur on newer leaves. Manganese toxicity is more likely to be a problem on extremely acid soil. Evidence of toxicity includes stunting and crinkling leaves.

Molybdenum. Molybdenum deficiency may occur on very acid, sandy soils. Liming normally corrects this deficiency. Responses to molybdenum have occurred without deficiency symptoms. Small amounts of molybdenum can be added with a seed inoculant where response is likely.

Zinc. Zinc deficient soybean plants are normally stunted with interveinal areas of the leaves becoming yellow or chlorotic. The chlorosis is most severe on lower leaves. A zinc deficient area in a field will normally appear yellowish-brown in color from a distance. Normally, zinc deficiency will delay maturity.

Several nutrient deficiency symptoms are shown in the picture pages of this publication.

Plant analysis of soybeans can be used to diagnose nutrient deficiencies. When sampling, the last fully developed trifoliate should be taken. The petioles must be discarded so that only leaves make up the sample. Fifteen to twenty trifoliates are usually adequate. For improved interpretations, a sample should be taken from both the affected area and an area where growth is normal. Comparison of results will prove helpful in diagnosing potential deficiency. Critical levels of plant nutrients are given in Table 5-4.

Table 5-4. Common sufficiency range for plant nutrients in soybean leaves.

Nutrient	Sufficiency Range
Nitrogen (%)	4.25-5.50
Phosphorus (%)	0.26-0.50
Potassium (%)	1.71-2.50
Calcium (%)	0.36-2.00
Magnesium (%)	0.26-1.00
Sulfur (%)	0.16-0.36
Boron (ppm)	21-55
Copper (ppm)	10-30
Iron (ppm)	51-350
Manganese (ppm)	21-100
Molybdenum (ppm)	1-5
Zinc (ppm)	21-50

Nitrogen Fixation in Soybeans

The soybean plant is a legume and, therefore, is capable of supplying nitrogen for its growth. This ability to supply its nitrogen using nitrogen from the air (containing about 80% nitrogen) is through a symbiotic nitrogen fixation process, which requires the bacterium, *Rhizobium japonicum.*

When efficient strains of *Rhizobium japonicum* are actively fixing nitrogen, the addition of nitrogen as a fertilizer has no effect on soybean yield. Studies have shown that nitrogen added to an actively growing soybean crop reduces the nitrogen fixed by an amount approximately equal to the amount of nitrogen fertilizer added. Active fixation may not begin until a few weeks after planting. Examination of the interior of the nodules on the root is a simple method of determining if active fixation is occurring. A light pink or greenish nodule interior indicates little, if any, fixation. Soils with poor aeration, including wet soils, may have reduced amounts of fixed nitrogen.

Many soils contain indigenous or native rhizobia that may infect the soybean root. This is especially true in fields where soybeans recently have been grown. However, in fields where soybeans have not been recently grown, inoculation of the seeds with *Rhizobium japonicum* is a highly recommended practice. Inoculation each year may be a good practice, helping to insure that efficient bacteria are present. Inoculation at seeding time is a very inexpensive practice. The inoculant must have been kept cool and prevented from drying. Thorough mixing of the rhizobia inoculant with the seeds in the manner recommended by the supplier is important. This may include slightly wetting the seeds or evenly applying the inoculant in a dry form on the seeds. A sticking agent may be especially necessary when using air planters. Where seed has been previously treated with fungicide, inoculant should be applied within six hours of planting.

Rhizobia fix nitrogen in association with legumes such as alfalfa, sweet clover, red clover, peas, garden beans, etc. Individual strains of rhizobia are very selective in the legumes they infect and fix nitrogen. Only *Rhizobium japonicum* has been shown to effectively nodulate and fix nitrogen with soybeans. Adding the correct strain of rhizobia is important.

Buying "preinoculated" soybean seeds is not generally recommended. Many studies have shown the viability of the rhizobia on unplanted seeds to be only a few hours. Several states have laws that prevent the sale of preinoculated seeds when sold at a higher price. Missouri has no such legislation.

Fertilizer Management for Soybeans

Fertilizer Sources. Fertilizer testing methods used today indicate the amount of available nutrient in a fertilizer material. For nearly all fertilizer application

methods, a pound of available nutrient is a pound of available nutrient, regardless of source. Numerous sources of phosphorus are available — clear liquids, fluid suspensions, or dry material. Performance of the materials is essentially equal, the differences primarily relate to ease of handling.

Clear liquid fertilizers have been touted as being 100% available. All high analysis phosphorus fertilizers must guarantee an amount of available phosphorus. This guaranteed phosphorus is also 100% available for plant use, regardless of its being a clear liquid, suspension, or dry. As phosphorus is applied to soils, it reacts and ties up chemically, thus reducing its availability. This occurs regardless of the source.

Potassium sources have also proven to give similar soybean yield responses per pound of potassium applied, regardless of source.

Foliar Fertilization. Foliar fertilization of soybeans is not recommended as a means of supplying the major nutrients for crop production. Weather conditions seem to have great affects on the crop response after foliar fertilizer is applied. Yield reductions due to foliar burning has been observed in some studies.

Timing of Fertilizer Applications. Soybeans do well on residual fertility from previous crops. If this practice is used, fertilizer applications must be adequate for both soybeans and the previous crop (table 5-5). With no provisions for soil buildup of phosphorus and potassium, 120 bushel corn and 40 bushel soybeans would remove fertilizer equivalents of 88 lbs of P_2O_5 and 94 lbs of K_2O per acre. A 60 bushel wheat crop with 30 bushels of soybeans as a double crop would remove about 61 lbs of P_2O_5 and 61 lbs of K_2O per acre.

Timing fertilizer applications has not proven to be critical for soybean production. It is critical to incorporate fertilizer into the soil to get good utilization by soybeans. Therefore, either fall or spring application of P and K prior to tillage would be recommended.

Fertilizer Placement. Fertilizer placement using any method other than broadcast and incorporated has not shown consistent response over broadcast. Banding of fertilizer close to the seed or in direct seed contact is generally not recommended due to sensitivity of soybeans to potential salt injury from the nitrogen and potassium forms in the fertilizer.

Deeper banding of fertilizer with tillage implements is being studied. Currently a band application of potash fertilizer at a depth of 6 inches on 30 inch spacings or less has shown increased potassium uptake by the soybean crop over broadcast. Yield responses have not been as consistent, however.

Fertilizing for Double Crop. Methods of fertilizing for double crop soybeans following wheat includes indirect fertilizing of soybeans by using heavier rates on the wheat, or direct preplant fertilization of soybeans. Phosphorus and potassium are most efficiently applied preplant on wheat for double crop soybeans.

The rate of phosphorus or potassium to be used is directly related to the soil test level. The University of Missouri's soil testing program includes an option for fertilizer recommendations in a wheat/soybean double crop system. Adequate phosphorus and potassium can be supplied using a recommended rate of fertilizer on wheat plus maintenance rates on the soybeans. Fertilizer recommendations for a double crop system are based upon buildup requirements for one year plus nutrient requirements for maintenance of wheat. Double crop recommendations assume a yield goal of 30 bu/A per acre of soybeans.

Conservation Tillage Fertilizer Management. Phosphorus and potassium do not move readily in soils. Surface application of P and K in conservation tillage management does not allow much incorporation of those nutrients. Placement of P and K deeper in soils low in P and K by application techniques may prove beneficial for soybeans. Injection of P at 6 to 8 inches deep with an anhydrous ammonia applicator adapted for fluid fertilizer application provided a 2 to 4 bu/A increase in Southeast Kansas when compared to surface application and incorporation. In this system, broadcast phosphorus was incorporated, which may suggest more dramatic yield differences under conservation tillage where broadcast phosphorus would not be incorporated.

Generally, when considering conservation tillage, soil phosphorus and potassium levels should be built up prior to conservation management. If not, deep placement of phosphorus and potassium or band placement of phosphorus should be considered as alternatives to conventional broadcasting of fertilizer.

Soil acidity may pose a special problem in conservation tillage due to potential acidity at the soil surface. After two or three years of conservation management, soil sampling the top 2 inches of soil for acidity problems is recommended. Some herbicides are very sensitive to acidity and lose effectiveness rapidly as acidity increases. Lower lime rates with more frequent applications can avoid loss in herbicide effectiveness.

The surface 2-inch sample should *not* be used for determining fertilizer needs. Continued sampling to 6 to 8 inches for fertilizer needs is recommended.

Table 5-5. Nutrient removal of selected crops (grain only) grown in rotation with soybeans.

Crop	P_2O_5	K_2O
	(Lbs/Bu)	
Soybeans	0.84	1.44
Corn	0.45	0.30
Wheat	0.60	0.30
Grain Sorghum	0.52	0.34

Chapter 6

Planting Practices

Zane R. Helsel and Joe H. Scott

No one planting scheme is best suited for all growers. Each location, year and set of growing conditions affect planting recommendations. Rotation, planting date, row width, population, and depth of planting must all be adjusted and integrated with specific conditions and other practices to obtain high, profitable yields.

Rotation

The sequence of crops before and after soybeans affects the productivity of each crop. Several Corn Belt states have shown that corn following soybeans yields 5-15% more than corn following corn. Soybeans following corn have yielded more than soybeans following soybeans. Recent studies suggest soybeans can replace up to 60 pounds of nitrogen for grain sorghum in central and northern Missouri. Soybeans in rotation with other crops will provide approximately 30 pounds nitrogen an acre for the following crop and may reduce the need for pesticides by limiting certain disease or insect problems. Some herbicides used with soybeans and other crops may carry over to the next crop. Reading the herbicide label can provide information on crop rotation restrictions.

Economics often dictate crop sequence, but where choices are available, soybeans should follow crops other than soybeans or other legume crops like alfalfa or red clover. Corn or other grain crops can better make use of the nitrogen provided by legume crops. Weed control and viral diseases can be a problem if legumes volunteer in soybeans.

Planting Date

Variation in yield due to planting date is related to the length of the growing season, weather patterns, varietal maturity, photoperiod response (daylength), and location. Full-season varieties decrease slightly in yield from planting in mid-May to early June (less than 1 bu/week) then decrease at a rate of slightly more than 1 bu/week until late June. Thereafter, yields decrease at about 3/bu/week. Short-season varieties, particularly in northern Missouri, actually yield less when planted earlier than mid-May. Determinate semidwarfs and semi-determinate varieties planted after mid-June produce significantly shorter plants, resulting in lower yields.

The above represents averages of several years of research in Missouri. Each year in each location produced different results. Particularly variable were yields from April planting and late June to July plantings. This variation was a result of poor germination in cool, wet seedbeds in April and some summer dry periods during seed fill. Late June to July planting dates produced variable yields as a result of erratic germination in dry seedbeds, early summer dry periods during vegetative growth and from cool growing conditions during seed fill in late fall.

In addition to yield, planting date affects other agronomic characteristics. Plants are shorter when planted very early or late, compared to May plantings. In southern Missouri, however, the hours of daylight change less and, thus, these differences in height are less pronounced and sometimes absent as good growing conditions may override the daylength effects. Lodging, being related to plant height, follows a similar trend. Soybeans planted early or late are more lodging-resistant than those planted on normal dates. Podding is higher when soybeans are planted in May, but closer to the soil at other dates. The quality of seed produced for planting purposes is best when soybeans are planted between May 15 and June 15.

Maturity dates are also affected by date of planting. In general, a three-day delay in planting results in about a one-day delay in maturity. As planting dates become later, it takes about five days delay in planting to equal one day delay in maturity. The shorter daylength in early fall aids maturity of late planted soybeans. Short season soybeans are less affected by shorter daylength than full season varieties. Temperature differences also affect maturity, as warm temper-

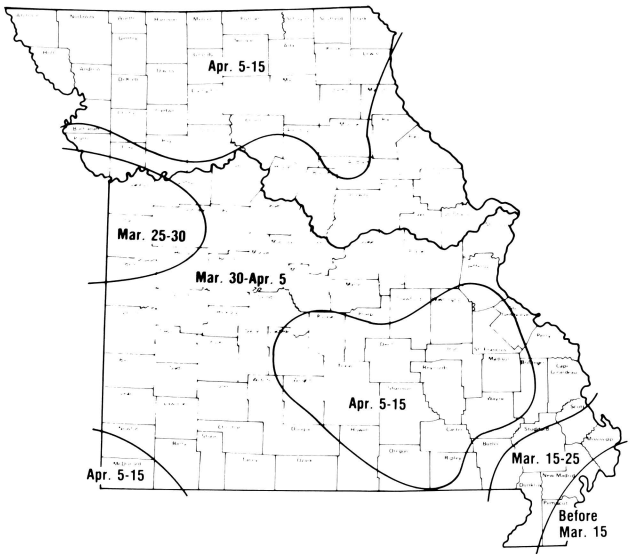


Figure 6-1a. Average last occurrence of 28°F in spring.

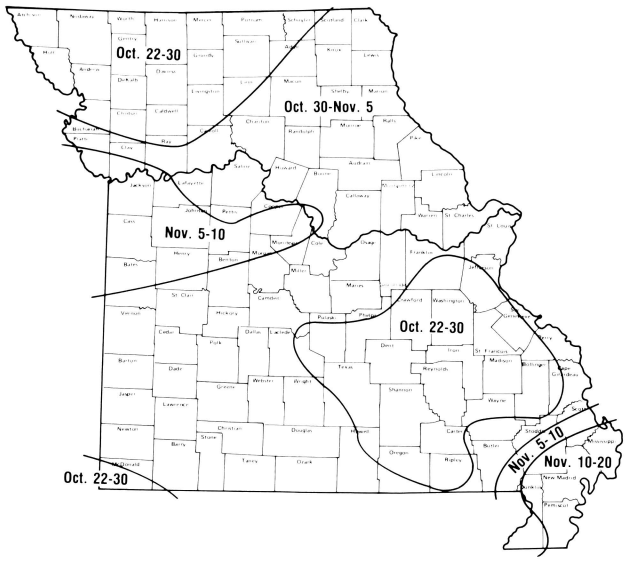


Figure 6-1b. Average first occurrence of 28°F in fall.

atures hasten maturity and cool temperatures slow it. UMC Guide 4411, "Predicting Flowering and Maturity of Soybeans," provides greater detail on the effect of planting date, variety and location on maturity.

Relative to planting date, the length of the growing season in Missouri, while variable, can be looked at in terms of long-term averages. Figure 6-1a presents the frost-free dates for Missouri over the past 30 years. Soybean plants normally do not freeze until temperatures reach 28 to 29°F. Thus, as indicated by Figure 6-1, there is no great frost danger from planting soybeans in early-to-mid April, except in the very northern part of Missouri. Additionally, because soybeans do not emerge for 10 to 14 days when planted early, they can be planted on the date of 50% or less chance of a 28°F temperature and be relatively safe from frost by the time they emerge. If frost injures the beans, adequate time for replanting is still available during May. In many situations, however, wet, cold soils and the time needed to plant other crops cause the delay rather than air temperature. Soybeans normally require a minimum soil temperature (at 3 inch depth) of about 55°F. Untilled, heavy soils also remain cooler for longer periods than drier, lighter, tilled soils, thereby delaying planting.

Soybeans can be frozen at about the same temperature in the fall as in the spring. At freezing temperatures, a full-leaf canopy may, however, result in only the top of the plants being frozen with the middle and bottom parts remaining undamaged. This is caused by the canopy holding warm air near the soil surface. The fall frost chart (figure 6-1b) can be used in combination with UMC Guide 4411 to determine how late certain varieties can be planted and still mature.

Based on the above responses to planting date, some of the following recommendations for planting practices can be made.

April to very early May:

—Use full season varieties
—Fall till if erosion is not a problem, to allow soils to warm up faster
—Plant after soil reaches 55°F at 3 inches depth
—Use high quality seed; increase seeding rates 10-15%
—Narrow rows usually provide good yield response
—Plant 1 inch deep
—A starter fertilizer may improve early growth

May to early June:

—Use full season varieties
—If used, short and midseason varieties perform satisfactorily when planted at this time
—Seeding rates, row widths, fertility, weed control, and planting depth all should be used as recommended in the following sections and chapters

Late June to early July:

—Use full season varieties
—Midseason varieties may be needed for July planting to reach maturity before frost
—Narrow rows provide for significant yield increase
—Increase planting rates 10-15%
—Plant no deeper than 2 inches in sandy soils, 1½ inches in heavier soils
—If dry seed bed conditions exist, don't plant deep, wait until adequate moisture is available for germination
—Use cultipacker or press wheels to conserve moisture

Plant Population

Within a wide range of populations, soybean yields do not vary significantly. At populations below about 70,000 plants/A (about 4 plants/ft of 30-inch rows and 1 plant/ft in drilled rows) decreases in yield may result

Table 6-1. Recommended Seeding Rates

Row Width (inches)	Approximate Lbs/Acre*	Seeds to Plant per ft. of row	Seeds/Acre	Expected Plants Per Ft. of Row†	Expected Plants Per Acre†
40	40	9	118,000	5.4-6.3	71- 83,000
30	50	8.5	148,000	5.1-6.0	89-104,000
20	60	7	183,000	4.2-4.9	110-128,000
10	70	4	209,000	2.4-2.8	125-147,000
7	80	3	224,000	1.8-2.1	134-157,000

*** Assuming 3,000 seeds per pound. See Chapter 7, Table 7-1 for rates at different numbers of seeds/lb.**
† Assuming from 60 to 70 percent emergence of planted seed, based on 80 percent germination seed and average to good conditions for establishment. If higher germination seed is used, planting rate may be reduced accordingly.

from insufficient plant numbers and from harvest losses due to low podding and broken branches. Above about 150,000 plants/A in 30-inch rows (9 plants/ft of row) and 200,000 in drilled rows (3 plants/ft of 7-inch rows), yields may decrease as result of lodging particularly in above average rainfall years. Because of the longer growing season and greater canopy development, soybeans grown in the Bootheel area produce proportionately better at lower plant populations than those in central and northern Missouri.

Varying plant populations affect characteristics other than yields. Low populations result in low podding and excessive branching, but good lodging-resistance. High populations result in increased lodging, higher podding, and less branching.

Seeding rate recommendations should be designed for optimum yield and favorable plant characteristics for most of the environments that will be encountered. Seed costs can be reduced by planting the lowest population needed for optimum yields; however, such a practice often results in final stands that are inadequate because of seed or plant losses resulting from such factors as poor seed vigor and germination, seedling diseases, herbicide injury, insect and hail damage, rotary hoeing, cultivation, and summer pest problems. Low populations also usually do not provide adequate competition against weeds. Table 6-1 presents the recommended seeding rates for soybeans under average conditions and allows tolerance for some of the anticipated problems just mentioned.

Seeding rates should be based on seeds per foot of row, as given in Table 6-1, and not pounds per acre. Many new varieties currently available vary widely in the number of seeds per pound (size can vary from approximately 2200-3800 seeds/lb).

Seeding rates in Table 6-1 are based on average conditions, so the following adjustments should be considered in specific situations:

Increase Seeding Rate per Acre by:

5% for each rotary hoeing planned
10-15% for very early or very late planting
10-15% for short season varieties
20% + for short season varieties planted very early or very late
35% for semi-dwarf determinate and semideterminate varieties
10% for cold soils
50% for broadcasting
10% for no-till
10% for rough seedbeds
10% for thin line varieties
10% if a flexible or floating cutter bar or combine is not used or rough combining conditions are expected

Decrease the Seeding Rate per Acre by:

5-10% if in the Bootheel
5% if lodging has been a problem
5% if planting under ideal conditions in rows
5% if using high quality seed (higher than 85% germination

Seeding rate adjustments are not necessarily additive and, in reality, they are designed only to provide a starting point. Seeding rates should be based on experience. For example, if soybeans grown on riverbottom land lodge almost every year, decrease the seeding rate by about 5% per year until lodging is not a problem (alternatively, choose a more lodging-resistant variety). Seeding rates can be decreased, as long as yields do not decrease. As another example, if pods remain on the uncombined portion of the stalk, increase the seeding rate (as long as lodging does not occur) until podding height increases sufficiently to reduce harvest losses.

Surveys indicate that many planters actually seed at different rates than indicated by the charts that are provided by the manufacturers. Most charts, too, provide seeding rates in pounds per acre and not seeds per foot of row or per acre. It is, therefore, advantageous to actually uncover some planted seeds at the beginning to determine the actual seeds per foot of

row. The seeding rate should be checked again if different varieties or speeds will be used.

Row Width

The most productive row width varies for location, weed control practices, variety, soil productivity, and weather. Soybean yields generally increase as row widths narrow, if light is the limiting factor. A substantial increase in yield is normally expected in going from 38-inch or 30-inch rows down to row widths less than 20 inches. A smaller increase has been noted in going from 20-inch or 15-inch rows down to solid seeded soybeans (6-10-inch rows). Recommendations and greater detail on narrow row soybean production is presented in the following chapter.

Methods of Planting

A method of seed establishment should meet three objectives: 1) adequate and uniform depth of placement; 2) adequate seed numbers and uniformity of distribution; and 3) sufficient seed-soil contact for germination under most environmental conditions. The seedbed preparation and mechanical distribution of the seed must be coordinated to obtain the above objectives. Four basic methods of planting soybeans are: 1) row or unit; 2) drill; 3) broadcast; and 4) aerial. The first two methods predominate because of their consistency in producing good stands. The broadcast and aerial methods have been utilized by some growers to reduce time and expense in planting.

A study in Ohio compared row planter units to drill units. Row planter units produced a more consistent stand and a yield 1-2 bu/A more than the drill unit. For narrow row planting, the cost and practicality of a large number of row units may be prohibitive compared to a grain drill of equal size.

Either the drill or planter can be used in conventional or minimally tilled seedbeds. Disk or shoe openers, press wheels and a depth control mechanism are typically used on planters for conventionally tilled seedbeds to meet the objectives of seed establishment. On minimum and no-till planters, a coulter (fluted, ripple, or smooth), seed opener, depth control mechanism, press wheel, and in some instances a residue moving mechanism and/or covering mechanism, are used. Particularly with no-till planters, various adjustments or modifications to the planter may be necessary to achieve seed establishment objectives. For example, different types of coulters may be needed in wheat stubble vs. sod vs. corn stubble; more weight may need to be added for adequate depth of placement; planter speed may need to be reduced on rough soil surfaces (or in wet or sod conditions) to achieve uniform depth, distribution and coverage; or different press wheels may be helpful in closing the slot and achieving good seed-soil contact.

Broadcast or aerial distribution of seed followed by light tillage can be effective in establishing a stand; however, the odds of success are significantly less than with a row planter or drill. Using tillage to incorporate seed results in seed being placed at random depths. To improve the chances of success with this method, a uniform distribution method should be used to spread seed on a level and somewhat firm seedbed. A light and shallow tillage operation should be used followed by a cultipacker to improve depth, distribution and seed-to-soil contact. Seeding rates in excess of 200,000 seeds/A are needed to assure adequate population.

Depth of Planting

Planting depth is directly related to the ability of soybeans to emerge and establish a uniform stand. Data show that the best emergence occurs at a 1 to 1½ inch planting depth. Several other factors affect emergence rate and percentage from various depths.

Varieties differ physiologically in their ability to emerge from certain depths at specific soil temperatures. Figure 6-2 conceptualizes the emergence of three different types of varieties at different planting depths at a soil temperature of 77°F. The graph indicates that varieties, particularly like Williams, are not adapted to deeper planting depths when soil temperatures are approximately 77°F. These severe effects are not noted, however, at cooler or warmer soil temperatures. Until all varieties are evaluated for this physiological characteristic, it is wise not to plant deeper than 2 inches.

Various conditions dictate slightly different planting depth recommendations. Sandy soils are often droughty, not susceptible to crusting, and impart less soil resistance; and, therefore, soybeans can be planted 2 inches deep for good emergence. Heavier soils which impart more resistance and often crust, but hold moisture better than lighter soils, should have soybeans planted at 1 to 1½ inches deep. Soybeans can be planted shallow, about 1 inch, when planting into cool, moist soils early in the growing season. When planting late as in double cropping, planting should be no greater than 2 inches. If soils are very dry, don't plant deep to moisture. Wait for rain and plant shallow. Emergence will be as fast or faster and more uniform by waiting than planting deep.

With certain herbicides, like metribuzin (Sencor/Lexone) and linuron (Lorox), planting depth is recommended at 1¾ inches by the manufacturer to reduce the potential of crop injury.

Planting equipment should be set for each field planted, as soil textural and seedbed conditions can affect planting depth from one field to another at the same equipment setting. Speed of travel can affect depth, thus actual planting depth should be checked when travel speed is changed.

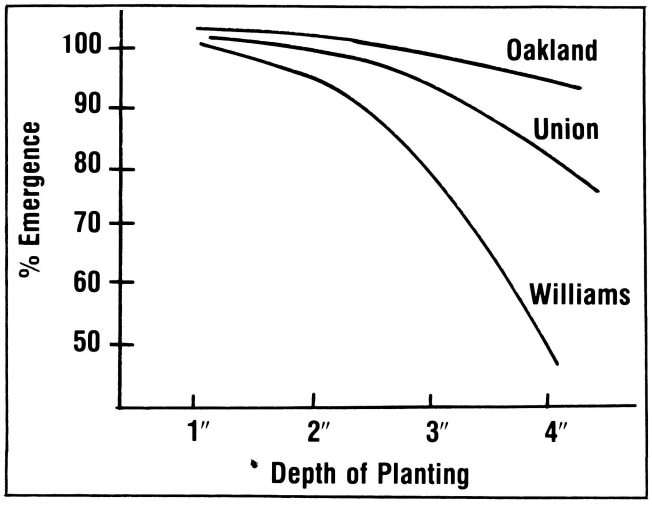


Figure 6-2. Emergence of three types of soybean varieties from various depths at 77°F soil temperature. Adapted from Iowa St. Univ. data.

Replanting

Every year, on numerous farms in Missouri, stands can be damaged by such factors as herbicide injury, hail, insects and flooding. If crop insurance covers the damage, consult your agent before taking action. When all of a stand in a field is lost, it is realistic to replant if adequate growing season remains for beans to mature. When only parts of a stand are lost in a field, the decision to replant or not to replant is more difficult. Large areas may be replanted while leaving the remainder of the field as is. If the stand loss is random or erratic throughout the field, a stand count should be taken to determine the number of viable plants remaining.

Where 40% (about 30% in southern Missouri) or less of the recommended stand (table 6-1) remains, and it has been three weeks or less since the first planting date (or replanting can be done before June 15), it is probably economical to replant. (Note: about 3 plants/ft of row in 30-inch rows equal a 40% stand). If more than 40% (30% in southern Missouri) of the uniform stand remains, replanting is probably not economical. When replanting cannot take place before mid-June and there are at least 25,000 plants (1.5 plants/ft of 30-inch rows) remaining, do not replant; if less, replanting may be profitable. These are only general guidelines and replanted stands may not be better. A computer program (AG0031) at Extension Centers is available for more assistance on replant decisions.

When replanting, shallow tillage may be beneficial to kill any germinating weeds. Do not apply more soil herbicide. If linuron (Lorox) caused the stand problem, till deeply, thoroughly mixing the soil. If metribuzin (Sencor/Lexone) damaged the stand, DO NOT TILL the soil. Where weeds are a problem following replanting, consider using a post emergence herbicide. If soybeans will be planted after another crop has failed, check the label on the herbicides used on the previous crop to determine if and how the soybeans should be planted. When replanting late, increase the seeding rate by 10 to 15%, use a full season variety, and consider narrow rows to improve yield.

Double Cropping

Double cropping has gained popularity in recent years (particularly in the Bootheel and where irrigation is available). Double cropping can be practiced anywhere, but risk of failure increases as this practice is used on the more droughty soils or further north in Missouri. A specific discussion of double cropping profitability can be found in Chapter 14.

The two basic objectives that need to be met to obtain reasonable double cropping yields are: 1) to plant as early as possible; and 2) to conserve or have adequate moisture available.

Time for planting double crop soybeans is limited by the time of first crop harvest and the last date at which soybeans will still reach maturity. In the Bootheel, 3-4 weeks are available between average date of wheat harvest and the latest date for planting soybeans. Southwest and Central Missouri may have up to 2 weeks and, in northern Missouri, as little as a week or less may be available for planting soybeans. Nevertheless, the objective is to plant as soon as possible to realize the approximate 3 bushel yield increase from each week's early planting.

Several methods are useful in attempting to plant as early as possible:

1) On farms where forage is used, the first crop could be harvested in May or early June for green chop, silage or hay, allowing for an almost normal planting date for soybeans.
2) Winter rye or barley could be grown with a resulting grain harvest being several days to two weeks earlier than normal wheat harvest.
3) Wheat or other first crops can be harvested 3-7 days earlier at high moisture levels (20 to 22%) and artificially dried. Drying during late June and early July can often be done inexpensively, because air tempteratures are normally high enough that only fans are needed for drying. Because wheat compacts more than corn, thinner layers of wheat should be dried in batch dryers. Alternatively small grains can be cut and windrowed 1-2 weeks before normal harvest and beans no-tilled at that time.
4) Fertilizing for both crops prior to planting the first crop will reduce preparation time prior to soybean planting.
5) Using minimum till, particularly no-till planting, will reduce field operation time and effort.

All methods for early planting listed above will normally provide more moisture at planting. Rainfall is normally greater in June than in July and a longer

growing season provides for more opportunity for rainfall. Residue management and tillage can greatly affect moisture conservation. No-till has proven successful for conserving soil moisture for double cropped soybeans. Where one or more tillage operations are used, planting should follow immediately. A planter with press wheels or a cultipacker can help conserve soil moisture and speed germination.

Surface residue from the first crop conserves moisture. Leaving a 6-12 inch stubble with the remaining straw chopped and distributed evenly will provide the best conditions for a no-till planter operation and moisture conservation. Burning the first crop straw can improve stand establishment and yield if the seedbed is prepared by plowing or disking. Burning, however, reduces organic matter over time. Unless planter operation is impeded by excessive straw there is no benefit to stand establishment by burning straw prior to no-till.

Beyond the recommendations just given, other practices are important to obtain respectable soybean double cropping yields. Weed control is of paramount importance, but is dealt with in Chapter 10. Using row widths of 20 inches or less greatly improves the yield potential. Particularly with no-till, seeding rates should be increased by 10 to 15%. Choosing the fullest season variety that will safely mature before frost is needed so that sufficient height is obtained to set adequate number of pods and to allow for easy harvest. Tall varieties or varieties such as Avery, Bradley and Centennial in the bootheel are often good choices.

More detail on double cropping can be obtained by reading MU Guide #4953, Wheat-Soybean Double Crop Management in Missouri.

Intercropping

Intercropping is the practice of planting soybeans into a standard first crop before it is harvested. Several variations of intercropping methods have been used and evaluated. Aerial seeding of soybeans into standing wheat or other crops have been tried. Broadcasting seed by bulk spreader, no-till drilling, and no-till row planting into skipped rows of wheat have also been evaluated. Trials in Tennessee, Illinois and Ohio suggest that all these methods are highly variable in their results. Aerial and broadcast seedings were considered to be particularly risky. A survey in Ohio revealed that 60% of the plantings were failures. No-till drilling or skipped row planting into the standing wheat, however, produced yields on the average equal to or better than the no-tilled beans planted after wheat harvest.

Through the soybean growers check-off program a wheat-soybean intercropping study was conducted from 1982-85 near Columbia. Based on the results from this and other work the following suggestions can be used for evaluating intercropping on your farm.

Heavy vigorous stands of wheat compete strongly with intercrop soybeans. Poor or winter damaged stands of wheat and lodging resistant varieties of wheat with less than 100 lbs. N applied are the best prospects for intercropping.

Mid-April to early May planting of soybeans resulted in little damage to the wheat, but caused lower soybean yields due to poor emergence. Planting later in May favored soybean yields, but wheel track damage to wheat depressed yields. Wheel tracking effects could be minimized by using narrower tires and wider planters and/or the skip row systems. If wheat or soybean prices can be locked in by forward pricing or other means, then a high price of soybeans relative to wheat may dictate mid-May plantings, whereas high wheat to soybean prices would dictate early planting which favors wheat yields. When price or moisture factors do not influence the decision on when to plant, soybeans should be planted before the boot stage of wheat (before stems of wheat can actually break), that is about mid-April in southern Missouri and late-April to early-May in northern Missouri. If equipment is available that will result in very minimal damage to wheat, wait until early heading to plant. In any case, if soils are very dry with no rain expected, intercropping should not be attempted.

Recommended planting rates from Table 6-1 should be increased by 25% for no-tilling into standing wheat, particularly if planting early into rough seedbeds. For aerial seeding or broadcasting, a minimum of two bushels of good quality seed should be used on moist soils. Seed moisture content should be 14% or slightly higher to reduce damage upon impact from aerial seeding.

Full season, lodging-resistant varieties should be used for intercropping. If no-tilling early, planting depth should be about 1 inch. Under warmer soil conditions, 1½ inches is appropriate. Weed control may be difficult with intercropping, in that very few preemergent herbicides are suited for this practice. Post emergent herbicides are now available to control most weeds; however, following wheat harvest, weeds may be too large for these herbicides to be extremely effective. No herbicides may be necessary if weeds are not a problem at soybean planting. If small broadleaves are present, 2,4-D or bromoxynil may be used.

In some years (especially when planted early), soybeans will be similar in height to the wheat when the wheat is ready for harvest. If anticipated early enough, the wheat can be harvested several days early as high moisture grain to avoid the problem. Otherwise, the cutterbar should be just low enough to efficiently harvest the wheat while clipping as few of the soybean tops as feasible. If soybeans are flowering, clipping the tops will reduce further top growth. Harvesting wheat, when soils are particularly wet, may result in combine tires muddying soybean plants into the soil prohibiting them from growing back.

Chapter 7

Narrow Rows

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Narrow row soybeans refers to soybeans planted in rows that are 20 or fewer inches apart. During early years of soybean production in Missouri, the crop was used primarily for hay and drilling in narrow rows (usually 10 in. or less) was the predominate planting method. Some weed growth was tolerated. As emphasis shifted to production for beans, an almost complete shift to wide rows occurred.

Although weed control is a major constraint to narrow row soybeans, chemicals are now available to control most weeds. Growers have the option of using solid seeding without undue risks of excessive weed competition. Solid seeding is gaining popularity. From 1984 to 1986, an estimated 23% of Missouri's soybean acreage was seeded in narrow rows, making the state a leading user of the practice in the Midwest.

Even though weed control and stand establishment are constraints to narrow row soybean production, several major advantages of narrow row soybeans over wide rows make them attractive to growers. With optimum plant population, soybeans grown in narrow rows have higher pods and are often slightly more resistant to lodging than those grown in wide rows. Harvesting is normally easier with narrow row soybeans. Without cultivator ridges and with higher podding height, the combine header can collect almost all pods. The more uniform distribution of plants in narrow rows allows them to feed evenly into the combine as does wheat and other small grains.

Earlier closing of the plant canopy shades the soil surface, which suppresses growth of late germinating weeds and conserves surface moisture. Erosion is substantially decreased in narrow row soybean production once plants are established. More uniform distribution of roots holds more soil and earlier plant cover reduces raindrop impact. Figure 7-1 shows the obvious benefits of narrow rows in controlling erosion on sloping soils.

Potential for higher yield is another reason for considering solid seeding. Missouri research shows about 10% yield increase when compared to yield in 30-inch rows (Figure 7-2). Check-off supported on-farm trials in mid Missouri showed a 2.7 bushel yield increase. The yield advantage tends to decrease from north to south because of differences in growing conditions and soybean growth types. In Missouri's southern areas, determinate soybean varieties are grown. These

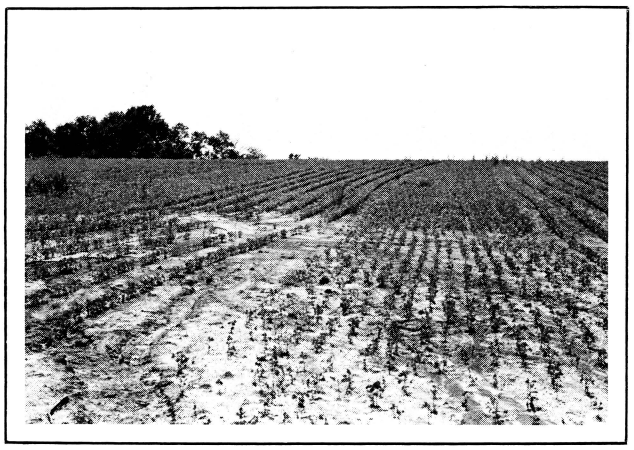


Figure 7-1. Difference in soil erosion in field of drilled rows and conventional row spacing of soybeans.

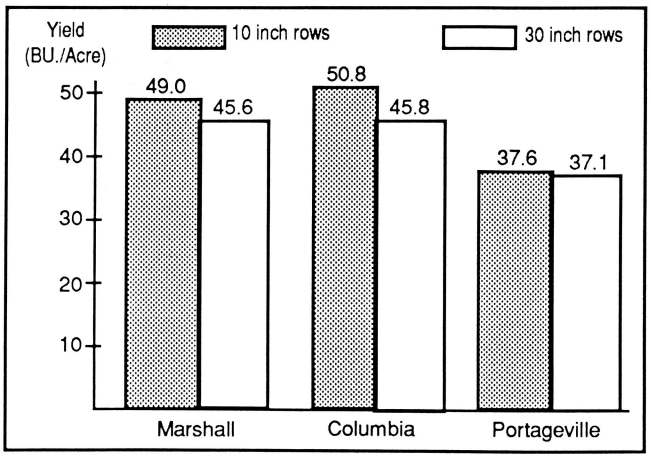


Figure 7-2. Average 1981-82 yields in 10-inch and 30-inch row spacings, seeded in June at 157,000 seeds/A. The number of varieties in each test varied from 47 to 72. Supported by check-off dollars.

complete essentially all their vegetative growth by the time flowering begins. Early season temperatures are warmer than farther north and the varieties used make sufficient growth to close the canopy in 30-inch rows by the time of flowering. Under these conditions, yield is relatively stable over a range of row spacings.

In contrast, most varieties grown in the central and northern parts of the state are indeterminate in growth habit. Flowering of these varieties begins when they have completed about half of their vegetative development. Therefore, pod production begins well before the plant achieves its full-size and, in 30-inch rows, before interception of solar radiation is complete. Since the critical time for high light interception begins with the onset of flowering, yields in wide rows may suffer. Thus, the old recommendation applies that rows should be close enough together to provide a closed canopy by time of flowering.

The closed canopy principle helps to identify other situations where solid seeding may increase yields over 30-inch rows. These include late planting, use of an early variety, and less productive soils. Each would tend to reduce plant growth and lessen the chance for development of a full canopy in wide rows. Solid seeding is a possible method of increasing yield within the limitations of these situations, but other practices may produce equal or even larger responses. If a grower is producing average or below average yields, other management inputs such as increased fertility, better weed control, or selection of an improved variety are probably limiting production and need to be corrected before solid seeding is tried.

Requirements for Success

A Uniform Stand. A stand without gaps is a first goal. An even stand helps achieve the objective of early, complete interception of sunlight. It will also suppress late season weed development. To achieve a uniform stand, the following are important:

Smooth Seedbed: Proper soil preparation is more critical when soybeans are to be planted with a drill than when they are to be planted with conventional rowed units. Most drills do not offer as accurate control of planting depth as conventional planters nor do they operate as well on "trashy" seedbeds. While grain drill type planters for soybeans are being constantly improved (Fig. 7-3), most function best when crop residue has been incorporated and the soil surface well prepared. A smooth, friable, clod-free surface contributes to good seed-soil contract and is essential for effective use of preemergence herbicides.

Fall plowing facilitates preparation of a good seedbed in the spring but is desirable only where erosion can be controlled. Following plowing, preplant tillage should be limited to those operations needed to prepare an adequate seedbed. This procedure saves energy and reduces compaction. One or two disc harrowings just before planting appears adequate both from the standpoint of seedbed preparation and weed control. Thoroughly killing annual weeds at or just before the time of planting is as effective a weed control measure as killing several crops of weeds by harrowing three to four times at weekly intervals before planting.

Depth Control: Soybean seed should be planted 1 to 2 inches deep. The new soybean drills with packer wheels provide for better depth control than the older type drills. However, many farmers continue to use the older type drills successfully. With all drills, avoid excessive speeds that produce "drill bounce." Four to five miles per hour should be the top speed. Use some device, such as a small sweep or tines behind tractor wheels, to prevent a compacted seedbed in wheel tracks and a different depth of seeding. An alternative to get adequate seed depth and soil coverage may be to adjust the pressure on the drill's disk openers that run in the tractor tracks.

An Adequate Seeding Rate: Most research shows that plant populations of indeterminate soybean varieties should be similar for both planted and drilled soybeans. However, higher seeding rates are generally recommended in solid seedings to compensate for potentially lower emergence rates and to provide insurance against irregular stands. Reduced emergence can result because of less precise seed placement; also, in the event of crusting, the more widely spaced individual seeds in solid seedings do not have close neighbors to help break the crust. Regular stands help insure a full, uniform canopy that aids weed control.

A good target population for solid seeded soybeans is 150,000 to 200,000 plants per acre. The lower figure would be appropriate for 11- to 20-inch rows for varieties susceptible to lodging, on fields of high fertility, or on droughty soils. The higher population should be used for drilled soybeans or with early maturing varieties, with double crop or other plantings made late in the season, and with varieties that stand well.

Semi-dwarf, determinate soybeans are less susceptible to lodging than are the indeterminate varieties and can be grown at the higher plant population level. While it is frequently recommended that the semi-dwarf varieties be grown at populations as high as 300,000 plants per acre, above "normal" populations are not beneficial in Missouri. Guidelines for adjustments in seeding rates to achieve a desired plant population are given in Chapter 6. Additionally, the seeding rate should be adjusted for seed quality and size. Table 7-1 shows that seeding rate should vary according to the desired plant population and the seed size. Seed size of a single variety can vary between lots because of differences in production environments; however, the major reason for variation in seed size

Table 7-1. Seeds (lbs/A) required to achieve a desired plant population when seed size varies.

Desired Plant Pop.	Seeds per pound					
	2200	2400	2600	2800	3000	3200
	pounds of viable seed[1]					
150,000	68	63	58	54	50	47
175,000	80	73	67	63	59	57
200,000	91	83	77	71	67	63

[1] To compensate for a germination percentage of less than 100, use the formula:

$$\frac{\text{Desired lbs/A of live seed}}{\text{Germination percentage}} = \text{Actual seeding rate in lbs/A}$$

among varieties is due to genetic differences. **Essex,** for example, has smaller seed than **Pella** and will require fewer pounds of viable seed to establish a desired population.

When purchasing seed and calibrating a planter, allow for seeds that are not viable. Divide the seeding rate by percentage germination to determine the quantity of seed required. Don't use seeds with less than 80% germination.

Sufficient Fertility. Soybeans require adequate nutrition to produce high yields. While specific requirements for solid seeded soybeans have not been defined, the higher yield potential of the system may require more fertilizer. Get a fertilizer recommendation based on a reliable soil test. The concept of applying fertilizer in line with expected crop yields is built into the University of Missouri soil test recommendation. Therefore, if this service is used, allow for the increase in yield potential. A reasonable estimate of increased yield potential is 5 to 10%. Depending on soil test level, more fertilizer may, or may not, be needed. See Table 7-2. Once the amounts are determined, they should be uniformly broadcast and incorporated before planting.

Productive Varieties. Most varieties can be expected to yield more in solid seeding than in conventional 30-inch rows. It has been observed that the shorter, less branched, and slightly earlier varieties respond best (percentage-wise) to solid seeding. *Maximum yields* in solid seeding are usually produced by varieties that yield well in wide rows. A variety that produces low yields in 30-inch rows and top yields in solid seeding has not been identified.

Lodging resistance also appears to be an important trait. Percentage yield response is useful only as a criterion of comparison among varieties having similar levels of performance in wide rows.

A plot of individual variety yields in 30-inch and 10-inch drilled rows is shown in Figure 7-4. Each point is the average performance of a variety at three central and northern Missouri locations. The relationship shows the association between yield level in the two row widths. The highest yields in solid seeding were produced by varieties that also produced the highest yields in 30-inch rows. On the basis of these findings, high yield potential in conventional rows should be a primary selection criteria when choosing a variety for solid seeding. To withstand a high level of management with respect to other practices, the variety selected for solid seeding should also have good standability.

Effective Weed Control. Early season weed control is essential until the canopy develops. Solid seeded soybeans are not recommended where weeds cannot be satisfactorily controlled. Particularly important is freedom from tall growing perennial weeds. Perennial weeds are difficult to control without some cultivation. Solid stands eliminate shovel cultivation and reduce opportunities for "over-the-top" applications with recirculating sprayers or rope-wick applicators. By the time the perennials overtop the soybeans sufficiently to be treated, tractor wheels can be expected to damage soybean plants. So fields with many perennial weeds may not be suitable for solid seeding until effective herbicides are available.

Table 7-2. Fertilizer application rates as a function of soybean yield and soil test values

Soybean Yield (Bushels/Acre)	Nutrient Removal (Pounds/Acre)		Fertilizer Recommended (Pounds/Acre)					
			P_2O_5 Soil Test Level[1]			K_2O Soil Test Level[2]		
	P_2O_5	K_2O	low	med	high	low	med	high
40	34	58	75	45	20	100	65	20
50	42	72	85	55	20	115	80	25
60	50	86	95	60	20	130	95	30
70	59	101	100	70	20	145	110	35
80	67	115	110	80	20	155	125	40
90	76	130	120	90	25	170	140	45
100	84	144	125	95	30	185	155	50

[1] Low, medium, and high P_2O_5 soil test levels are 15, 30, and 50 pounds per acre, respectively.

[2] Low, medium, and high K soil test levels are 150, 250, and 325 pounds per acre, respectively, for a soil with a cation exchange capacity (C.E.C.) of 12.



Figure 7-3. One of several new grain drills designed especially for soybean planting. Courtesy International Harvester Co.

Early season weed control must be primarily with chemicals, although rotary hoeing is feasible to control emerging weeds and to break soil crusts. A good job of selecting and properly applying chemicals is vital. Decisions on which chemicals fit particular situations are even more critical than where cultivation is possible. Refer to the "Weed Control Guide for Missouri Field Crops" for current herbicide options. This guide is updated annually and is available in University of Missouri Extension Centers.

Good preemergence grass control materials are available and are widely used. Postemergence grass control chemicals that effectively control some grass species have recently become available.

Postemergence materials that control many broadleaf weeds give an extra safety factor. Some growers use these products as their only broadleaf control material. For best results apply them 18 to 23 days after planting (first to third trifoliate stage). Weeds will be small and may appear insignificant at this time, but early control is more effective and usually suffices until the canopy develops.

The rotary hoe is often useful with solid seeded stands. When dry conditions follow application of preemergence chemicals, a rotary hoeing may help move some of the chemical down to sufficient moisture to start activation and may destroy many of the weed seedlings that are just germinating. It is also a useful tool to break soil crusts that form after a heavy rain. A rotary hoe will reduce plant population by 5 to 10%, so allow for this when selecting a seeding rate.

Experience indicates that soybeans no more than 8 to 10 inches high (Stage V4) can be run over by tractor wheels one time with no lasting damage. Two times over in the same wheel tracks will cause some harm, and three or more times over can be expected to badly injure both stand and productivity. Thus, when fields are not wet, judicious use of the tractor is feasible either for rotary hoeing or applying "over-the-top" herbicides.

Early Planting Date. As with row planted soybeans, highest yields generally can be expected from drilled plantings made early in the season. But extremely early planting will sometimes result in reduced emergence, slow early growth, delayed canopy development and reduced weed control. As planting is delayed, soybeans have less time to develop before flowering and, therefore, make less total growth. Greater percentage yield increases with narrower row spacing (drilling) are realized when planting is delayed, although total yield may be less than from plantings made earlier in the season.

Adequate Moisture. Moisture availability during the growing season can markedly influence the response to narrower row spacing. During summers of severe drought, drilled soybeans can yield less than those in 30-inch rows, apparently because they use moisture more rapidly early in the season. For this reason, drilled soybeans should be preferentially planted in soils with good moisture holding capacity or which can be irrigated.

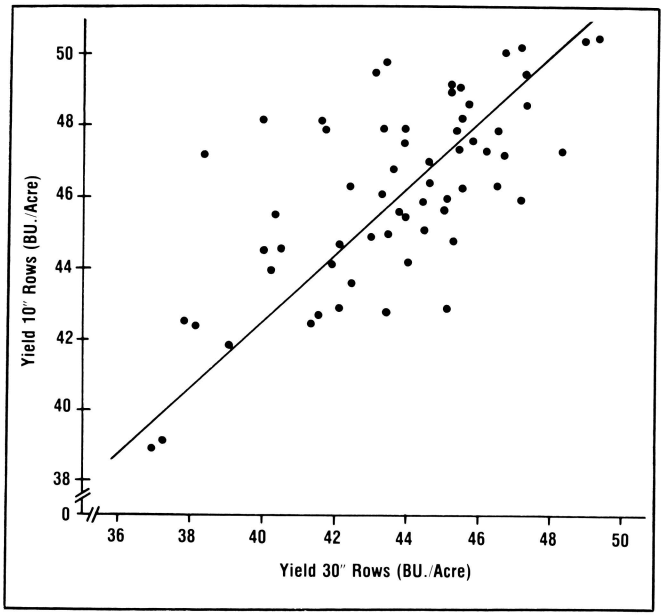


Figure 7-4. Yields of 62 soybean varieties in 10-inch rows as a function of yield in 30-inch rows. Tendency is strong for highest yields in 10-inch rows to be produced by varieties that produce high yields in 30-inch rows.

Chapter 8

Nematode Control

Al Wrather, Sam C. Anand and Rao Arelli

Nematodes are small worm shaped animals that move like snakes. Most are very small, ranging from 1/1000 inch to 1/4 inch long. So, these pests cannot be seen without using a magnifying glass.

Nematodes are found in water and soil anywhere in the world. They feed on microorganisms, other nematodes, animals, and plants. Generally those that attack plants will not feed on anything else.

Most nematodes that infect field crops such as soybeans, corn, cotton, or milo attack the root system, and feed on fluids in the roots. This damages the root and reduces its ability to absorb and supply water and nutrients to the rest of the plant. The reduced water and nutrient uptake results in a stunted plant which may show signs of drought stress and nutrient deficiency.

The damage to the plant may range from unnoticeable to severe depending on the susceptibility of the plant, the weather, soil type and the number of nematodes attacking the plant.

Several different nematodes live in the soil and feed on soybeans. Soybean Cyst Nematode is the only one that has been a severe problem in Missouri. However, Root Knot Nematode is also present in some southeast Missouri fields.

Soybean Cyst Nematode (SCN)

SCN was first reported in Japan in 1915, in North Carolina in 1954, and the upper Mississippi Delta (Southeast Missouri and West Tennessee) in 1956. It has been found in 25 states and new infested areas are being discovered every year. The cyst nematode has spread into 42 Missouri counties.

SCN is one of the most damaging pests of soybeans in Missouri. The Southern Soybean Disease Workers estimate that Southeast Missouri producers lose 5 to 15% of their crop to SCN each year. A 10% loss of our crop equals approximately 3 million bushels of soybeans.

Spread. SCN can move through the soil only a few inches a year by its own efforts. However, it is easily spread by means of farm and construction equipment, birds, root crops, drainage water or flood waters, wind and contaminated soil particles in bagged soybean seed.

Biology. The SCN *Heterodera glycines,* gets its name because the protective covering the females body forms around her eggs resembles a cyst. Eggs within the cyst begin to hatch as the soil warms in the spring. Young nematodes then leave the cyst and seek roots to feed on. They penetrate roots by means of a very fine needle-like tooth, and then feed on the central part of the root.

Nematodes imbeded in the root grow into a sac-shaped adult female or an elongate male. The male leaves the root and the body of the adult female continues to swell and eventually breaks through the root surface. Most of the female's body can then be seen as a tiny, 1/25 inch in diameter, white, spherical object attached to the root. The adult female mates with the male, which is in the soil, and about 200 to 500 eggs then develop within the female. Some eggs are excreted by the female and some are retained. Under optimum conditions, most eggs will hatch and the larvae infest roots. As the female matures, her color changes from white to yellow and finally brown.

The length of the life cycle (from egg to adult) will vary with soil temperatures. At 80°F one generation lasts three to four weeks, and several generations can develop in one growing season. The eggs within the cyst became dormant as the soil temperature drops in late fall. These eggs in the brown protective cyst can survive winter and other adverse conditions such as drought and floods very well.

Symptoms. The symptoms of SCN infection can be mistaken for symptoms of other soil problems like nutrient deficiency, drought, and root rot. Consequently, it is very important to know what to look for to diagnose the problem.

The above ground parts of affected plants may be stunted and have yellow-green leaves (fig. 8-1). The leaves may wilt in the midday summer sun more

Table 8-1. Soybean Cyst Nematode Resistant Varieties for Missouri

Name	Maturity Group	Resistant to SCN Races	Other Features
Fayette	III	3 & 4	Similar to Williams in other characteristics
Avery	V	3 & 4	Resistant to Root Knot Nematode
Forrest	V	3	Resistant to Root Knot Nematode
Bedford	V	3 & 4	Resistant to Root Knot Nematode
Jeff	VI	3 & 4	Resistant to Root Knot Nematode
Centennial	VI	3	Resistant to Root Knot Nematode
Leflore	VI	3 & 4	Resistant to Root Knot Nematode

readily than those on healthy plants. These symptoms develop in small to large circular or oval areas in a field (Fig. 8-2).

Check the root system when the above symptoms are noticed. Cyst-infected roots will be stunted, darker in color, and have less nitrogen fixing nodules than healthy roots. Attached SCN females may be visible as shiny white or yellow, spherical bodies on the roots (Fig. 8-3). For examination, dig up the root system and gently shake the soil off to see the cysts. The only sure way to confirm an infestation of SCN is to take soil samples and submit them to a laboratory for nematode analysis.

Host Plants. Soybean cyst nematode can also attack many different plants, however, the soybean is the favorite host. Other legumes may be attacked such as lespedeza (common and annual), certain varieties of hairy vetch, garden bean (common and snap) and some clovers. Weeds such as hempsesbania are also hosts. The previously mentioned hosts should not be allowed to grow as weeds in the area infested with SCN.

Control. There is no easy solution to combating SCN. Growers with cyst problems have three control practices to use: crop rotation, resistant varieties, and nematicides.

Resistant Varieties

In 1957, about 2,800 lines in the Soybean World Collection were tested for their resistance to SCN. Five were found to have a high level of resistance; subsequently, five more were added to this list. Recently, we screened over 9,000 plant introductions of soybeans in the greenhouse at the Delta Center, Portageville, MO and isolated 45 lines resistant to race 3, 12 resistant to race 4 and 10 resistant to race 5. One of these (PI437654) was found to be highly resistant to all the five known races of SCN.

The line Peking provided resistance to races 1 and 3 in Custer, Dyer, Pickett, Mack, Forrest, and Centennial, resistance to race 4 in Bedford, Nathan, Avery, Bradley, and Fayette came from PI88788. The list of SCN resistant soybean cultivars (public varieties) available in Missouri is given in Table 8-1.

The initial tests of soybean lines for cyst nematode resistance was done with cysts collected in North Carolina. Later, additional testing was done with cysts collected in Tennessee. Some soybean lines resistant to the Tennessee culture were reported to be susceptible to the North Carolina culture. This indicated the presence of physiological races of SCN that would attack one soybean line but not the other. In 1970, the researchers working with soybean cyst nematode identified four races of SCN, depending on their ability to attack various soybean lines. Recently, a new biotype of SCN has been found which attacks cultivars with resistance from PI88788. This has been identified as race 5. It is not very widespread at present, however it may become a problem in the future.

Control of cyst nematode with resistant varieties is very effective. However, continuous cropping of soybeans in any field is not recommended. Soybeans should be rotated with other crops to prevent the build up of other soybean diseases, insect pests and weed problems.

Rotation

Soybean cyst nematode larvae cannot survive without the presence of a host plant. Rotating a field out of soybeans and into a non-host crop such as milo, cotton, rice, wheat milo double crop, or an SCN resistant soybean variety for a year takes away the food supply from the cyst nematodes in that field. In the absence of a host plant the SCN larvae that hatch during that year will starve, as a result the number of nematodes in the soil will decline.

Data collected at the University of Missouri Delta Center indicate that the cyst numbers in sandy loam soil will decline 60 to 80% during the first year, 30 to 50% during the second year, and 10 to 20% during the third year the field is planted to a non-host crop. Rotating a field out of susceptible soybeans and into a non-host crop for one year before growing more susceptible soybeans is a useful control practice in areas that have few cysts. A three year rotation program with soybeans every third year may be needed for control in areas heavily infested with cysts.

A crop rotation program is useful for cyst control,

but the population of cysts in the soil will increase dramatically on susceptible soybeans the first year they are planted after a non-host crop. Monitoring of SCN infestation is necessary for crop rotation.

Nematicides

The use of a nematicide is another cyst control technique along with crop rotation and resistant varieties. Nematicides are used for cyst control primarily when planting a susceptible variety in a cyst infested field.

These products provide some short term protection to soybean roots from infection by nematodes. This gives the plant time to establish a sound root system. Nematicides decompose in four to eight weeks, and the nematodes can begin to infect and live on the roots normally after that time. The established root systems protected by the nematicide are more able to support the plant for the remainder of the summer than a root system that was not protected.

Nematicides work by killing nematodes or upsetting their ability to find the root. In either case, the infection of the roots is reduced for a short time. Temik, Nemacur and Furadan are effective nematicides that can be used to control soybean nematodes, and are readily available. Temik 15G, Nemacur 15G and Furadan 10G can be applied as granules, and Nemacur 3EC and Furadan 4F can be sprayed into the soil at planting time. The efficacy of nematicides varies, depending on the chemical, method of application, soil type, rainfall, temperature and other environmental factors.

Very little is known about how nematicides in combination with other pesticides affect nematodes. Results from experiments conducted in North Carolina indicate that the application of the nematicide Dasanit with the herbicide Lorox to cyst infested soil may result in an increase of cyst nematode numbers at harvest. However, these results are not clear, and there is no indication that this will occur in Missouri soils. Nematicides are expensive and require extra work for application. However, they are useful in a cyst management program.

Soil Fertility and SCN

Whenever soil fertility is low, especially potash, SCN injury and yield losses are more severe. Soil should be brought up to fertility test recommendations as production will be poor on these soils even when the nematode is not present. There is no proof that adding fertilizer to soil will control the nematode population, but it may reduce the severity of loss in low fertility fields.

Root Knot Nematode

The disease caused by Root Knot Nematode has been reported from most soybean growing areas of the world and is a problem in localized areas in Southeast Missouri. Maximum damage occurs in warm climates and more on sandy, light textured soils than in heavy soils. Yield losses can range from none to very high depending on the susceptibility of the plant, environment, and type of root-knot nematode in the soil.

Symptoms. Infected plants may be stunted, have a yellow-green color, a decreased formation of nitrogen fixing nodules, reduced yield, increased susceptibility to other diseases, and a tendency to wilt under moisture stress during hot, dry weather. The disease can be identified by the presence of knots or galls of varying size and shape on the roots of infected plants (fig. 8-4).

Biology. Root Knot is caused by a nematode called Meloidogyne. The young nematodes that hatch from eggs in the spring and summer are attracted to growing soybean roots. The worms move through the soil and penetrate the roots. They cause tumors to develop in the plant roots on which they feed. The tumors cause the roots to swell and gives them the lumpy appearance typical of root-knot infection. The roots are disrupted by the tumor formation, which reduces the water and nutrient uptake by the roots.

The adult nematodes mate and the female lays approximately 1,500 eggs. Some eggs are excreted into the soil and some remain in the root. Those in the soil may hatch and young worms infect other roots. Several generations may develop in one season. The eggs remaining unhatched in the soil or root can survive the winter.

Control. Controls for Root-Knot are similar to those for SCN. Growers can use crop rotation, resistant varieties, and nematicides. Root-Knot will attack many different plants, which makes rotation ineffective in many cases. The crops that can be used in a rotation plan depend on the type of root-knot nematode present in the field. Cultivars resistant to Root-Knot are available and serve as the primary control (Table 8-1). Nematicides can also be used as effective short term controls.

Other Nematodes

In addition to the Cyst and Root-Knot nematodes, Reniform, Lesion, and Sting nematodes can also damage soybeans. How much damage these nematodes do to soybeans in Missouri has not been established. Fortunately, none of these has been found in high numbers in any Missouri soybean field.

Reniform nematode is generally distributed in the southeastern and Gulf Coast area of the U.S. and occurs throughout most tropical regions of the world. This nematode is a serious soybean pest in the tropics.

Lesion nematodes are distributed in soils throughout the world and attack a wide range of crops and weeds. Lesion nematode can attack and feed on the outer part of the root. This feeding causes the formation of dark lesions and overall browning of the roots.

The affected plants will become yellow, stunted and yields will be reduced.

Sting nematodes are presently found in the southeastern and Gulf Coast areas of the United States. They are most common in light sandy soils. Initial symptoms are small dark lesions on root tips. These lesions often destroy the growing point on a root so the roots have a stubby appearance. The plant will be yellow and stunted.

There are other nematodes found on soybeans in various parts of the world but their importance is uncertain. They are: Lance, Stem, Ring, Spiral, Dagger, Stunt and Stubby Root.

Sampling Soil for Nematodes

What You Can Do

As indicated previously, the only sure way to diagnose a nematode problem is to have a nematode analysis performed on your soil. The soil sample should be taken from as small an area as possible, preferably no larger than 20 acres. One soil sample from the top 8 inches should be taken from every acre within the field. These samples should be mixed and ½ gallon of this mix sealed inside a plastic bag and sent to the nematode laboratory closest to you. The senders address and the sample identification should accompany the sample. The lab in Southeast Missouri is the Delta Plant Health Clinic, Delta Center, Portageville, Missouri 63873, and the lab in Central Missouri is the Diagnostic Clinic, 3-22 Agriculture, Columbia, Missouri 65211. Precautions should be taken to prevent samples from drying out. The sample should be kept cool, out of the sun, and shipped soon after collection.

The results of the nematode analysis are used to determine a nematode control program. A suggested nematode control program will be sent to you along with the results of your soils analysis. The suggested control program is based on results from research conducted by the University of Missouri scientists on crop rotation, nematicides, soil fertility, soil type effects on SCN and breeding programs for developing SCN resistant varieties. Support for this work has been and is continuing to come from the Missouri soybean check-off program and the USDA.

Soybean Nematodes



Figure 8-1 Stunted, yellow-green plants are symptoms of cyst nematode infection.



Figure 8-2 Cyst nematode infected area in field.



Figure 8-3 Females of cyst nematode visible as white, spherical objects on roots.

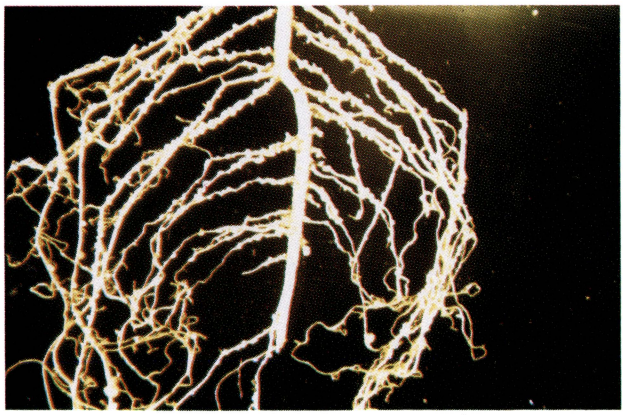


Figure 8-4 Galls on roots caused by root-knot nematode.

Chapter 9

Insect Control

Wayne Bailey, George W. Thomas and Walton Mullins

Currently, there are no consistent, major insect problems affecting Missouri soybean production, although new insect problems may develop with increased use of no-till production methods.

The soybean plant can withstand a good deal of insect damage without materially affecting yield or quality. Insects may cause injury to soybeans during all stages of development. Beginning with the planted seed, insects may feed on or within the seed, seedlings, roots and nodules, stems, foliage, fruiting structure including both pods and developing beans within the pods, and on the harvested crop while in storage. They may also damage soybeans by transmitting certain disease organisms.

Detection and Survey for Insect Pests

The initial step in the management (control) of a pest problem is detection. Detection and diagnosis (identification) as early as possible after initial infestation usually makes management easier. No single scouting or survey technique can be recommended for all insect pests or for every situation.

Three methods to survey for soybean insects or damage are: (1) visual inspection; (2) sweep net method; and (3) drop cloth method.

Plants less than 12 inches tall should be visually inspected. Use either sweep net or drop cloth when height exceeds 12 inches. *Fields should be checked at least once each week from plant emergence to maturity.*

Due to unequal distribution of insects, make five to ten counts in four or more randomly selected areas in each field. Samples should not be taken near field borders.

Visual searches are generally conducted as the surveyor (scout) walks along a premeasured length of row counting and/or collecting all stages of all insects observed on all portions of the plants.

The sweepnet is similar to a butterfly net but of stronger materials. Plants are sampled by swinging the open net through the foliage or plants in a 180° arc during each step of the surveyor. Each stroke of the net is counted as one sweep and represents approximately one square yard. Sweep net sampling is the most convenient and fastest sampling procedure but may not always be an accurate assessment of insect populations.

The crop cloth or ground cloth method is the most accurate method of sampling most soybean insects. It is a heavy white cloth stretched between two wooden sticks. Place the drop cloth between two adjacent rows of soybeans, kneel down, bend the plants of one row over the cloth and shake or beat the plants vigorously. Insects are counted and identified as they drop onto the cloth. The drop cloth method is not effective in narrow row beans and cannot be used in drilled or broadcast soybeans.

Surveying Insect Damage

Soybean growers are most concerned about how much yield or seed quality loss will result from the presence of pest insects. Loss of yield or seed quality will result only when the amount of injury exceeds the tolerance of the plant. This is known as the "injury threshold" of the plant.

Defoliation is the most common and visible form of chewing insect damage to soybeans. Defoliation is a reduction in the amount of leaf surface, which in turn reduces the photosynthesizing ability of the plant. When the amount of defoliation reaches a certain point, yield loss result. Growers tend to grossly overestimate defoliation. However, you can estimate defoliation damage by removing 10 to 20 leaflets from the middle and upper portion of plants from several areas of the field. Compare and score these leaflets to the series of illustrations in Figure 9-1, average the percentage defoliation, and the mean will reflect the level of defoliation for the field.

The defoliation level needed before a control measure is applied will vary depending on insect numbers and stage of development, growing conditions, variety grown, expected yield, economic factors, and plant population. Table 9-1 presents the amount of defolia-

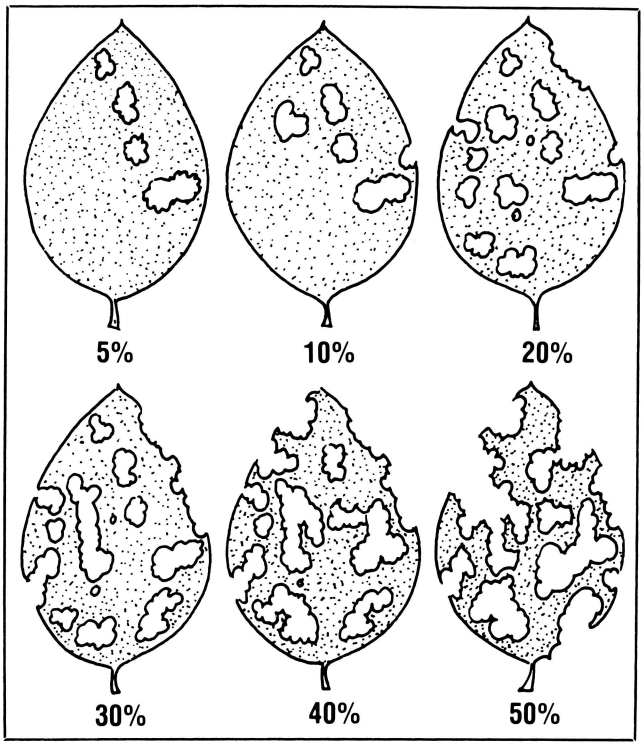


Figure 9-1. Levels of soybean leaf defoliation.

tion by stage of growth to reach injury threshold.

Estimating the amount of injury to pods and seeds is difficult. The estimate must be based on both the number of pods and/or seeds damaged, and the loss in quality or weight of seed damaged by insects. Treatment decisions for the control of pod and seed feeders are normally based on the number of pest insects present as detected by survey.

Soybean Insect Pest Problems

Insect injury may begin at the time the seed is planted and continue throughout all stages of plant development until harvest. Even soybeans in storage may be infested by one of the stored grain insect pests.

Soybean insect pests are discussed by the parts of plants attacked, as well as by their preferred habitat, such as those occurring in the soil. Surveying may need to be done only at various stages of growth. Refer to the picture pages for identification and comments on some of the more common insect pests.

Soil Insect Pests. Insects attacking the planted seed before, during and briefly following germination include seed corn maggot, wireworms and larvae of the redheaded flea beetle. Of these, seed corn maggot has been the most widespread and damaging, and may develop into a major pest problem under conditions of reduced tillage and no-till plantings.

Other below ground feeding insects include black, dingy and sand hill cutworms, white grubs, and the larval stages of bean leaf beetle and grape colaspis. Cutworms chew into and/or through the underground stem. The remainder of the above mentioned species feed on primary and secondary roots.

Seedling Insect Pests. (Growth stages VE through V3). Insects attacking soybean seedlings include several of the soil insects mentioned above plus at least three other species attracted to this tender host. Growth stages VC and VE continue to be damaged by seed corn maggot and larvae of redheaded flea beetle feeding and tunneling within the underground stem. Also, double cropped soybeans may be similarly damaged over the southern fourth of the state by larvae of the lesser corn stalk borer. Various cutworm species cut plants underground during any and all growth stages.

As soon as the cotyledons emerge above ground, seedlings may be attacked by certain above ground feeders — overwintering adults of the bean leaf beetle and the spotted cucumber beetle. The feeding injury of these beetles is usually confined to the unifoliate and first trifoliate leaves, and occasionally to the tender stem below the cotyledons. Double cropped beans may also be damaged in the seedling stage by larvae of the garden webworm, grasshoppers, and by nymphs and adults of the soybean thrips.

Foliage Feeding Insects. This large group receives the most attention and concern by producers. More insecticidal applications are used to control these foliage feeding pests than for control of all of the other pests. In reality, instances of defoliation exceeding the thresholds by growth stages are uncommon except during drought years.

During most seasons, double cropped beans are more subject to foliage feeding pests than are early plantings. Also, during drought years, soybeans are more heavily attacked by foliage feeding pests, largely because of the lack of other acceptable, green vegetation.

Stem Feeding Pests. These include the lesser corn stalk borer, Dectes stem borer and three-cornered

Table 9-1. Injury Threshold of Defoliation by Stages of Growth

Stage of Growth		Percent Defoliation
VE, VC, V1, V2, V3	(cotyledon to 6 nodes — 10-12")	50-65
V4-V(n)	(8-14 nodes)	40-50
R1	(1 open flower)	35-40
R2	(flower below top node)	30-35
R3	(pod visible at top node)	30
R4	(full podding)	25-30
R5	(beginning seed)	20
R6	(full seed, green)	25
R7	(physiological maturity)	45-50
R8	(maturity)	*

* No economic importance

alfalfa looper over the southern fourth of the state, and the European corn borer statewide.

Losses caused by these stem feeding pests have to date been minor and generally non-economic. Prompt harvesting of fields infested by Dectes stem borer avoids yield losses caused by lodging or broken stems.

Pod Feeding Insects. Pod feeding species cause the greatest loss in yield and bean quality. Corn earworms and bean leaf beetles cause a direct loss of yield by eating on the pods or developing beans within the pods. Grasshoppers and fall armyworms may also cause similar types of losses. Green stink bugs lower quality by feeding through the pods and within the maturing beans.

Storage Insects. Insect damage continues following maturity and harvest. A stored grain pest, Indian meal moth, feeds on soybeans while in storage. Problems with this pest usually develop with an overabundance of weed seed and cracked or broken beans. Indian meal moth larvae feed on the germ and on the edges of cracked beans. These larvae are silk spinners, and occasionally may web 1 to 4 inches of the top bin surface into a thick, tough mat. Such situation makes control efforts difficult.

Soybean Insect Pest Management

Most producers realize that an insect free environment is neither desirable nor possible. Nor is it desirable to rely solely on one method of insect pest control such as the use of insecticides.

A new strategy, "insect pest management" or "integrated pest management," has developed. It refers to the use of all possible means (biological, chemical, cultural, etc.) of maintaining pest levels below the economic threshold. An *economic threshold* is simply that number of pests or level of pest damage capable of reducing yields and/or quality exceeding the cost of control measures. Following are insect pest management strategies to consider before and during the growing season.

Planting Date. Early planted soybeans have had relatively few insect pest problems. Late plantings, no-till plantings and double cropped plantings are more likely to develop insect problems. However, the potential for insect damage is relatively minor in choosing the planting date.

Row Width. Certain insect pests, such as corn earworm (soybean podworm) prefer to infest fields with open canopies. Narrowing of rows allows early development of plant canopies, that are less attractive to corn earworm moths. However, other factors involved in choosing row width are more important than consideration of insect damage.

Resistant Varieties. No soybean varieties commercially available in Missouri offer a significant degree of insect resistance. Sources of resistance to some insects have been identified and insect resistant varieties may be commercially available in the future.

Irrigation. Irrigation can significantly favor or hinder the development of insects. How and why irrigation effects insect population in soybeans is not known, but be attentive to the insect conditions in fields following irrigation.

Insect Scouting and Population Monitoring. Scout fields regularly to stay abreast of insect situations. The University of Missouri Cooperative Extension Service has traditionally published a weekly newsletter containing information about the current status and likelihood of certain pests in soybeans and other crops throughout the season.

Biological Control. Beneficial insects (those that feed on the pest insects) are vitally important. Apply insecticides only when pest levels reach economic thresholds. Untimely application may eliminate beneficial species. In the absence of these natural enemies, pest populations may rebound more rapidly and again exceed threshold levels.

Insecticide Selection and Use. Some insecticides are more effective in controlling beetle-like insects, while others are more effective in controlling worm-like insects, and some will control both types with equal effectiveness. Be sure that the insecticide is appropriate for the particular pest situation. Your University of Missouri Extension Center, chemical dealer and/or commercial applicator should be able to help you in making the correct choice.

Because insecticides vary in their labeled crop uses, recommended rates, method of application, selectivity and toxicity, it is imperative that you read and carefully follow the directions on the pesticide label.

Economic Thresholds. Apply insecticides only when pest numbers reach or exceed threshold levels. Economic thresholds are always changing to include

- stage of development of crop
- stage of development of pest(s)
- weather
- yield potential
- market price of commodity
- cost of pesticide and its application

Thresholds have been established for most major insect pests and for several minor pests. Become familiar with the threshold values for the major soybean pests in your area. These can be found in the annual Missouri Insect Control Recommendations handbook (MX3) available from local UM Extension Center.

Common Insects



White grub



Bean leaf beetle and foliage injury



Twospotted spider mite damage



Seed maggots



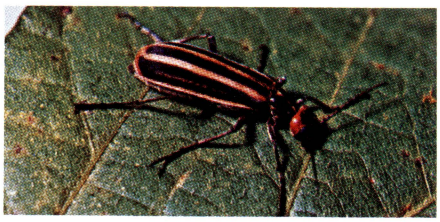
Pod scars caused by bean leaf beetle



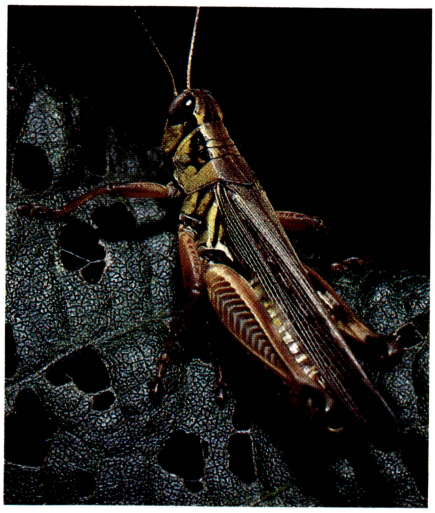
Corn earworm



Green cloverworm



Striped blister beetle



Grasshopper



Looper



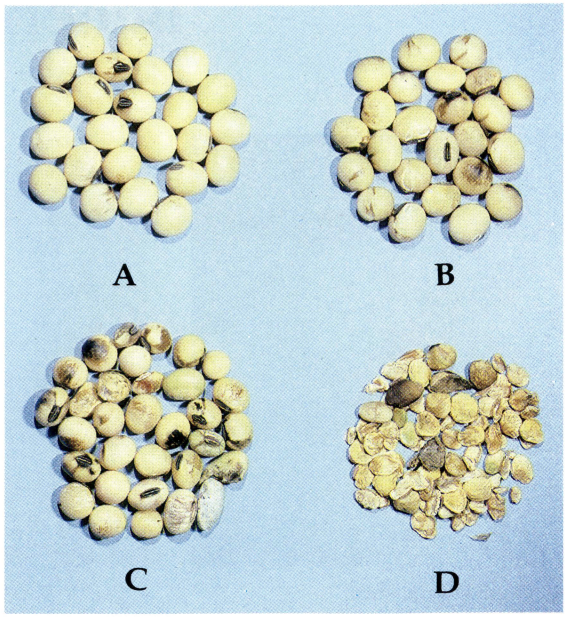
Thrips



Green stink bug nymph



Newly hatched stink bug nymphs



Classes of seed injury by stink bugs: A, none; B, light; C, medium; and D, heavy.

Common Soybean Insects

Bean leaf Beetle adults overwinter under debris. They attack germinating soybeans by chewing on cotyledons, underground stems and first sets of true leaves. Adults are about 1/5-inch in length, either reddish or tannish in color, and with or without four black spots on the back. Eggs are deposited in soil around bean stems. Larvae are small, slender, white with brownish heads and brownish spot at the end of the abdomen. They feed on smaller roots and eventually on nodules. There are two generations annually over most of Missouri. Adults feed primarily on foliage; however, the last generation adults may occasionally feed on blossoms, newly set pods, or developing beans within pods.

Cabbage looper and other closely related species of looper larvae may occasionally cause some defoliation of late planted soybeans from July to September, especially in southern counties. Looper larvae are light green in color, slightly more than 1 inch in length when fully grown, gradually taper toward the head, and crawl with a distinct looping or measuring worm motion. There are several generations on other preferred host plants before moving to soybeans.

Corn earworm larvae may attack soybean foliage and pods, especially in southern counties. Newly hatched larvae feed on terminal foliage for a few days before moving down to small pods and eventually to larger pods. Pod injury is most severe on mid-season and late planted beans during late August and early September. There are three generations annually, but the last generation is the one most likely to damage soybeans.

Grasshoppers, nymphs and adults of several species, may feed on soybean leaves and pods, especially during a dry summer. Damage is usually confined to rows adjacent to fences, ditch banks, and grassland. Grasshoppers overwinter as eggs in the soil, hatch during May and June, and the partially grown to mature hoppers begin to move into crops during July and August when surrounding vegetation becomes scarce or matures.

Green cloverworm larvae are light green in color with five faint white lines running the length of their bodies, just over 1 inch in length when fully grown. They are primarily foliage feeders, although under outbreak situations where plants are largely defoliated, larvae may feed on blossoms and newly set pods. There may be three to five generations each year, but the generation that occurs during August and early September is the most serious to soybeans. Seldom are larval populations so heavy that control measures are necessary. They are often naturally controlled by a fungus disease and by parasitic insects.

Green stink bugs and some other species of stink bugs and broad-headed bugs damage soybeans by inserting their beak through the pod and into developing to nearly mature seed. Damaged beans may be shriveled or show a small, sunken dark spot around the injury. Both nymphs and adults may cause injury and both may transmit yeast spores resulting in yeast spot disease. Stink bugs overwinter as adults and have at least one generation on other favored hosts before moving to soybeans. There are probably two generations over the northern half of Missouri while three generations occur over most of the southern half. Stink bug problems on soybeans reach a peak during August and early September.

Seed maggots, usually seed corn maggots, may destroy the seed before it germinates, particularly during cool, wet weather. Adult flies are attracted to and lay eggs in fields having large amounts of decaying organic matter on or near the soil surface. Stands are occasionally reduced to the point of replanting reduced tillage and no-till fields.

Striped blister beetles, and other blister beetle species, may occur in heavy numbers in localized areas of a soybean field during July and August resulting in rapid defoliation. Usually, by the time the infestation is noted, the damage has been done and the beetles have moved. Blister beetle larvae are predators of grasshopper eggs, populations are more abundant following a year of moderate to high grasshopper numbers.

Thrips are small, slender insects that feed by rasping the underside of leaves, usually close to a vein, and then sucking up the exuding sap. This feeding leaves a thin, narrow, silvered streaking visible on the leaf surface. Thrips are most common during the early growing season.

Two-spotted mites and other spider mite species may injure soybeans by sucking sap from underside of leaves resulting in foliage becoming light yellow to bronzy. Heavy infestations may cause defoliation. Tiny mites move into soybeans from surrounding weedy fence rows or adjacent red clover. Spider mites multiply rapidly during hot, dry weather; damage is most common during July and August.

White grub is the larval stage of the May beetle. Most species prefer roots of various grasses, but a few species are known to attack soybean roots. Most species require three years to complete their life cycle. Damage most usually occurs following planting of crop in soils previously in sod.

Beneficial Insects



Assassin bug



Ant lion



Lacewing



Ground beetle



Syrphid fly larva



Tobacco hornworm (parasitized by Braconid Wasp)





Ladybird beetle larva feeding on aphids (L) and typical adult (R)



Predaceous stinkbug (top) (ready to attack immature stinkbug)



Praying mantid

Nutrient Deficiencies



Nitrogen



Phosphorus



Potassium



Manganese



Sulfur



Iron



Zinc

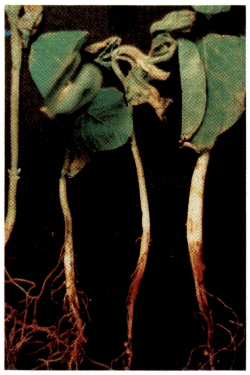


Magnesium

Diseases



Pythium seedling rot (fungus)



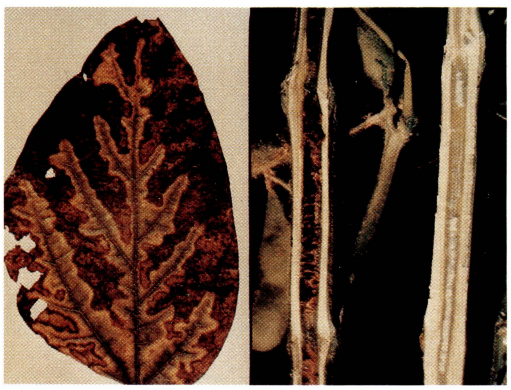
Rhizoctonia root rot (fungus)



Soybean cyst nematode field damage (L) and cysts on roots (R)



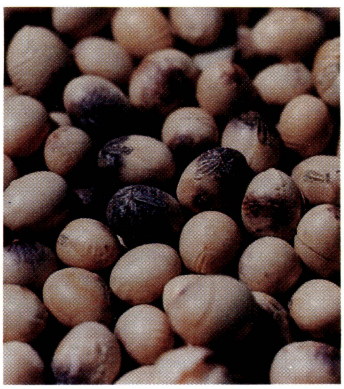
Phytophthora root and stem rot (fungus)



Brown stem rot (fungus)



Charcoal rot (fungus)



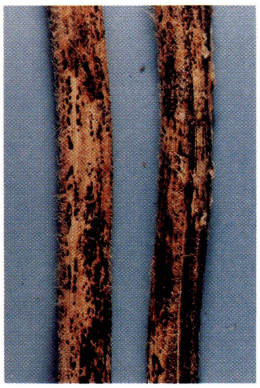
Purple seed stain (fungus)



Sudden Death Syndrome



Septoria brown spot (fungus)



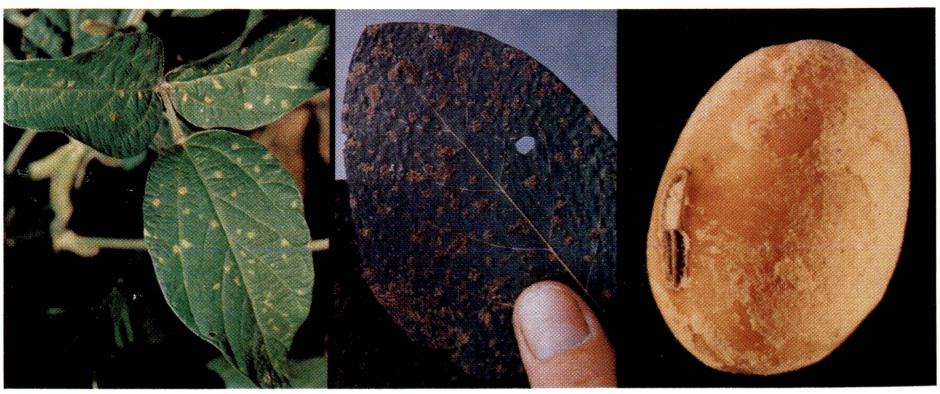
Anthracnose (fungus)



Stem canker (fungus)



Pod and stem blight: pycnidia on stems and pod (L) and infected seed (R) (fungus)

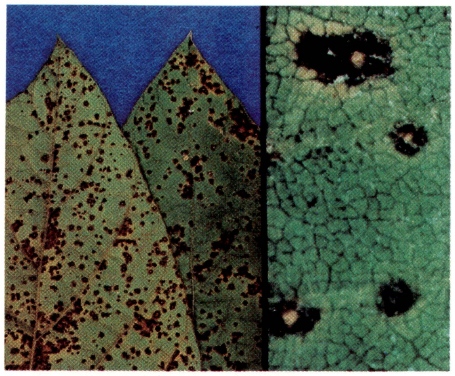


Downy mildew: upper (L) and lower (C) leaf surfaces, and infected seed (R) (fungus)

Diseases



Bacterial blight (bacteria)



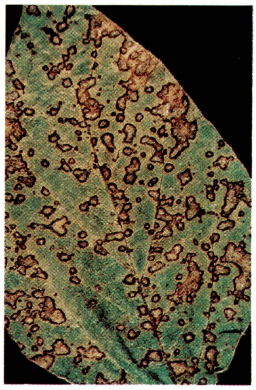
Bacterial pustule and (R) pustule close up (bacteria)



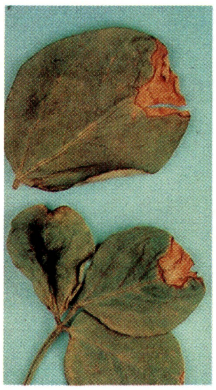
Wildfire (bacteria)



Alternaria leaf spot (fungus)



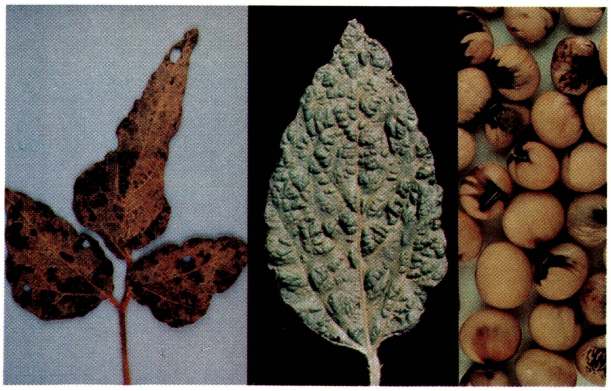
Frogeye leaf spot (fungus)



Phyllosticta leaf spot (fungus)



Sclerotinia stem rot: cottony mycelium (L) and sclerotia (R) (fungus)



Soybean mosaic leaf symptoms and (R) mottled seed coats (virus)



Yellow mosaic (virus)



Bud blight: necrosis of terminal buds (L) and blotches on pods (R) (virus)



Lightning damage



Southern stem blight (fungus)



Frost damage

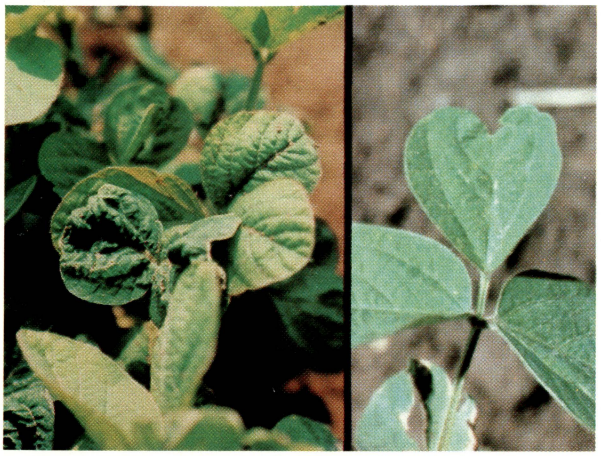


Fusarium root rot (fungus)



Bean pod mottle (virus)

Herbicide Injury



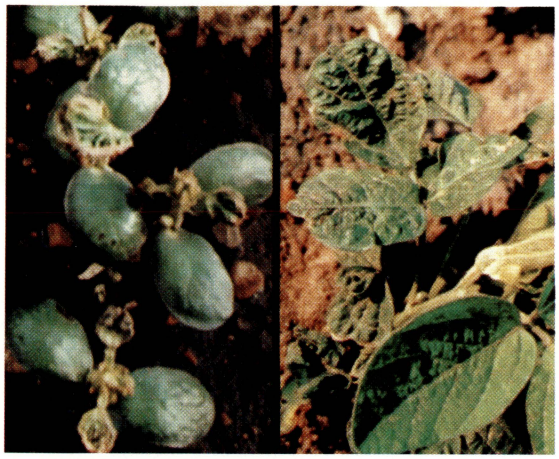
Lasso or Dual, preemergence



Dinitroaniline, preplant incorporated



Prowl, preemergence



Vernam, preplant incorporated



Lorox, preemergence



Sencor/Lexone, preplant incorporated



Atrazine carryover



Modown, preemergence



Amiben, preemergence





Hail injury

Herbicide Injury



Basagran, postemergence



Dinoseb, postemergence



Blazer, postemergence



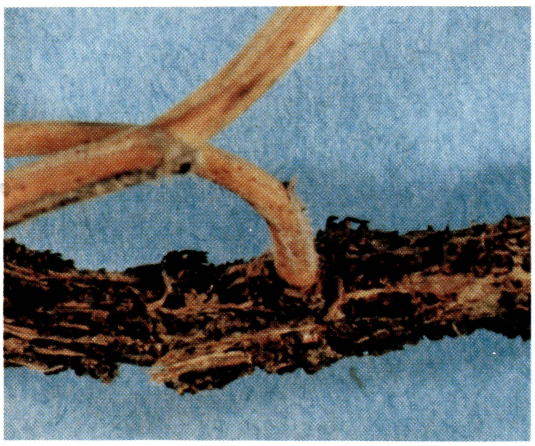
Alanap, postemergence



2,4-DB, postemergence



2,4-D, postemergence drift



2,4-D, "stem callus"



2,4-DM, "look-alike" injury (virus)

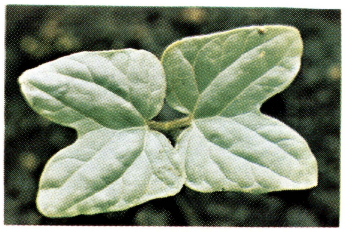


Banvel, postemergence drift

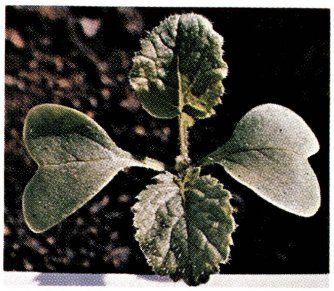
Grass and Broadleaved Weed Seedlings (including nutsedge)



Barnyardgrass



Bindweed, hedge



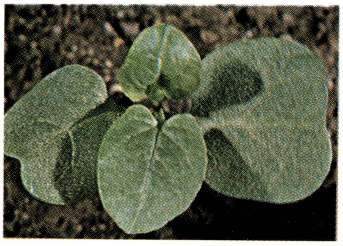
Mustard, wild



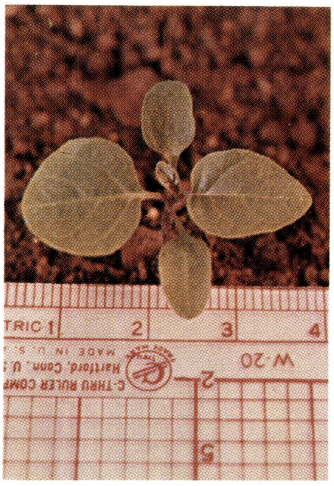
Smartweed, Pennsylvania



Crabgrass, large



Bindweed, field



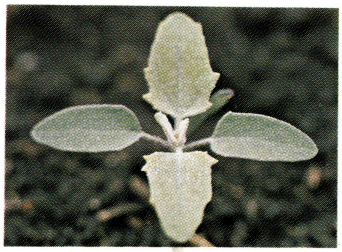
Nightshade, black



Sunflower, wild



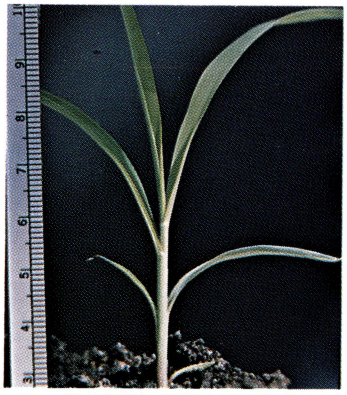
Buckwheat, wild



Lambsquarters, common



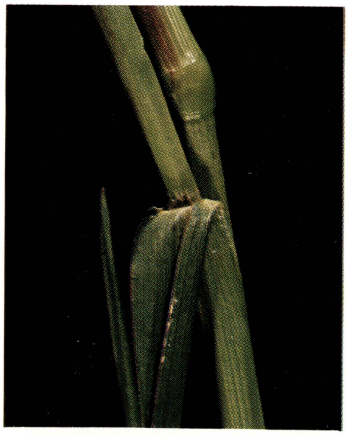
Pigweed



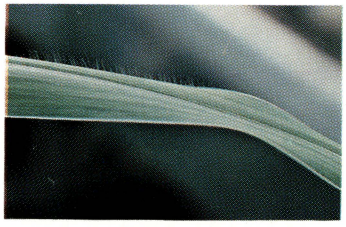
Foxtail, green



Nutsedge, yellow



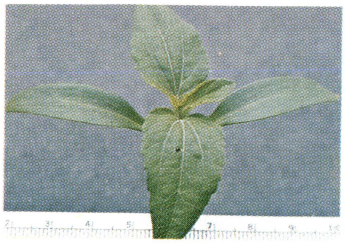
Panicum, fall



Foxtail, giant



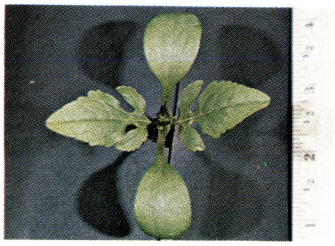
Ragweed, common



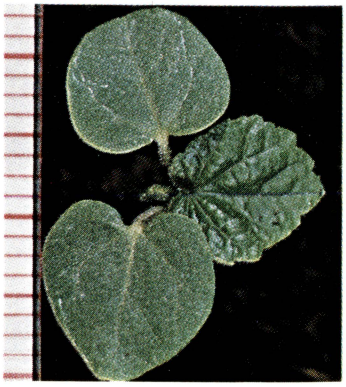
Cocklebur, common



Foxtail, yellow



Ragweed, giant



Velvetleaf

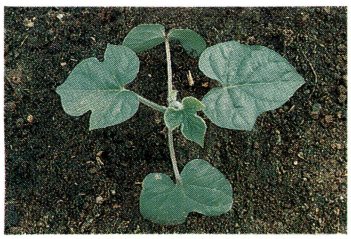
Annual Broadleaved Weeds



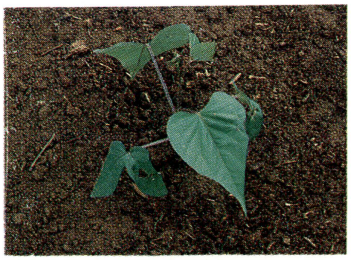
Jimsonweed — Cotyledon smooth and spindle shaped. Stems succulent and hollow. Leaves alternate, coarsely toothed, nearly smooth. Flower trumpet-shaped with white or purple color.



Jimsonweed (Mature) — Leaves alternate, smooth, with large triangular teeth; flowers white or purple, trumpet shaped. Unpleasant odor when bruised.



Morningglory, ivyleaf — Cotyledon moderately indented with rounded lobes. Leaves three-lobed, densely hairy. Flower blue.



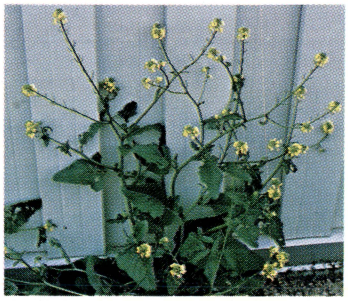
Morningglory, pitted — Cotyledon deeply indented with long, pointed lobes. Leaves smooth, heart shaped to basal lobed, may have purple margin. Flower white.



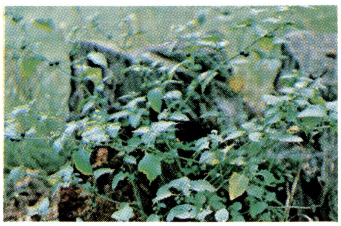
Lambsquarters, common — Leaves alternate, slightly toothed, white mealy.



Velvetleaf — Leaves alternate, heart-shaped with toothed margins, velvety soft hairy.



Mustard, wild — Leaves toothed, hairy, alternate.



Nightshade, black — Leaves alternate, dark green, veins prominent, petioles purplish.



Pigweed — Leaves alternate, indented at tip, midvein prominent, petioles purplish.



Ragweed, common — Leaves opposite at base, alternate above, and deeply lobed, rough hairy; stem densely hairy.



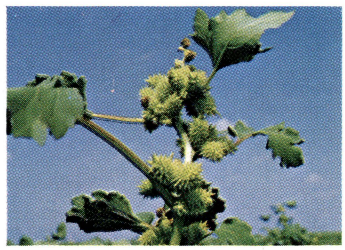
Ragweed, giant — Leaves deeply three-lobed, opposite, rough surfaced.



Smartweed, Pennsylvania — Leaves alternate, smooth, petiole bears ochrea without fringe of hairs at top.



Sunflower, wild — Leaves opposite at base of plant, alternate above, and rough hairy, toothed.



Cocklebur, common — Cotyledon lance shaped. Leaves alternate, triangular, lobed or toothed and rough. Seed enclosed in oval bur covered with hooked, stiff prickles.



Buckwheat, wild — Leaves alternate, heart-shaped or triangular; leaves bear ochrea at base of petiole; viny.

Annual Grasses and Perennial Weeds (including nutsedge)



Bindweed, field — Leaves alternate, arrowhead-shaped; flowers funnel-shaped, white to pinkish, 1 inch diameter, flower stalk bears pair of small green stipules; twining vine.



Bindweed, hedge — Leaves alternate, large arrowhead-shaped with cut-a-way corners at base; flowers white or pinkish, funnel-shaped, 2 inches diameter; twining vine.



Johnsongrass — Smooth, waxy leaf surface; large open panicle; prominent rhizomes.



Panicum, fall — Leaves smooth and relatively hairless; ligule a fringe of hairs; stems zigzagged, nodes prominent; spreading panicle.



Milkweed — Leaves opposite; milky sap in leaves and stem; a creeping perennial; spreads by wind blown seed.



Barnyardgrass — Leaves smooth; no ligule; spikelets bristly-hairy.



Foxtail, giant — Leaf blades pubescent on upper surface; ligule a fringe of hairs; cylindrical head; spikelets crowded, bristly.



Proso millet, wild — Leaves (sheath and blade) densely hairy; ligule a fringe of hairs; spreading panicle.



Foxtail, green — Leaf blades relatively hairless; ligule a fringe of hairs; cylindrical head, 3-4 inches long, droops or nods.



Cane, wild — Leaves similar to Johnsongrass; panicles vary from compact to loose; seeds large, black and shiny; no rhizomes.



Nutsedge, yellow — Leaves narrow, grass-like, mostly basal; flowers yellowish, small in narrow spikelets; roots bear small, round vegetative tubers.



Crabgrass, large — Leaves (sheath and blade) densely hairy, membranous ligule; finger-like panicle.



Foxtail, yellow — Leaf sheath flattened; leaf blades have long scattered whitish hairs near base; ligule a fringe of hairs; cylindrical head, 2-3 inches long; seed larger than giant or green foxtail.



Horsenettle — Leaves alternate deeply lobed, with star-shaped hairs and prickles along the midvein and petiole. Perennial with woody stems that have spines when matured. Flowers star shaped, white to pale purple. Berry fruit, smooth, usually yellow.



Hemp dogbane — Leaves smooth edged, opposite, elliptical. Perennial with upright woody based stem, exudes milky juice when broken. Flowers with greenish-white petals.

Chapter 10

Weed Control

Mike DeFelice and Barry Sims

Introduction

Weeds cause considerable economic loss to soybean farmers every year. Annual losses are estimated at 15% of yield in corn-belt states (including Missouri) despite the extensive use of herbicides. Losses result from inadequate weed control due to improper weed control practices or the lack of good control measures for specific weed problems.

Weed species vary in their ability to compete with soybeans to cause in yield reductions. A heavy cocklebur infestation can almost completely eliminate a soybean crop. Yield reductions of 30 to 80% have been reported for most of the weed species common to soybean fields. Weeds also cause economic losses through increases in tillage costs, cultivation, noxious weed seed content, foreign matter dockage, and interference with harvesting operations.

Weed control technology for soybean production has changed rapidly in recent years. New herbicides have been introduced by the agricultural chemicals industry, while changes in planting and tillage equipment have encouraged shifts toward reduced or no-tillage and narrower row spacing. Increased emphasis on soil conservation by farmers and government agencies has caused a greater reliance on herbicide technology for soybean weed control by reducing tillage options and causing some shifts in weed species.

Reduced or no-tillage tends to cause an increase in perennial weed problems and requires more consistent, residual weed control from herbicides. This chapter will attempt to summarize the factors and options currently influencing weed control practices and decisions for modern soybean production in Missouri.

Cultural Methods of Weed Control

Cultural methods of weed control can have a large influence on the timing and severity of weed problems encountered in soybean production. Deep-plowing in the fall or spring will reduce most perennial weed problems and in combination with secondary tillage with a disk or field cultivator provides a weed-free seed bed at planting. Although not as effective for controlling perennial weeds, reduced tillage practices such as the use of a chisel, disk, or field cultivator will also provide a clean seedbed at planting.

Producing soybeans in wide-rows (greater than 20 inches) using conventional tillage allows cultivation of weeds between-the-rows if you have enough equipment to cover all of your acreage while the weeds are small enough to control. However, grasses are not easily controlled by cultivation. A herbicide program is generally most effective for grass weed control in all but the lighest infestations.

Cultivation is also ineffective for controlling weeds growing directly in the row. Cultivator sweeps should be set to run as shallow as possible (one to two inches) while still controlling the weed infestation. Deeper cultivation will destroy a preemergence herbicide control layer and bring fresh weed seed up to the soil surface where it is more likely to germinate and cause a later flush. The use of a banded herbicide application in combination with cultivation is most effective and also reduces herbicide costs. Apply postemergence herbicides to the *first* flush when weeds are small and easy to control. Cultivation should be performed on the second flush when weeds are not as likely to germinate in the row where the sweeps are ineffective.

Greater reliance is usually placed on herbicides for weed control in drilled soybeans because postemergence cultivation is more limited. A timely rotary-hoeing early in the season can be effective. You will get best results with a rotary hoe when the crop has just emerged (just past the crook stage) and weeds are just emerging. The top 2 inches of the soil should be dry and the hoe should be operated at high speed. If a rotary hoe is used properly you should destroy less than 5 to 10% of a well-established soybean stand. Drilled or broadcast soybeans are also more competitive with weeds because of a more uniform crop distribution that forms a canopy earlier in the season.

Drilled or narrow-row soybeans can provide up to 30% weed control depending on the weed species. This is not enough to eliminate yield losses but can give considerable assistance to herbicides by reducing weed stands and preventing late season weed flushes.

Crop rotation can also be an important component of weed control programs. Some weeds that cannot be controlled with available soybean herbicides may be readily controlled with corn or grain sorghum herbicides. This rotation can break a long-term increase in a troublesome weed infestation although it usually takes many years to reduce a weed-seed soil pool.

Tillage rotation can also be used to manage weed problems. A deep tillage operation every three or four years in a no-tillage system may help to prevent significant build-up of perennial weed problems. Tillage rotation will also allow for some rotation in the type of herbicides you use. This may help to prevent weed resistance to herbicides in the long-run and can also help to minimize carry-over with some herbicides.

Herbicide Control

Herbicides are the primary method of weed control in modern soybean production. In 1978 (the last survey taken) 95% of Missouri soybean acres were treated with at least one herbicide application. Many new herbicides for soybean weed control have been introduced in the last few years. However, no single herbicide is yet capable of controlling all of the common weed problems encountered in Missouri soybean fields. In fact, many of the newer herbicides are more species specific in activity than previous herbicides. The choice of a herbicide program is even more critically tied to proper identification of problem weed species in the field and integration with the cultural methods being used to produce the crop.

A table of herbicide performance on the major problem weed species in Missouri is provided in this chapter to help you determine which herbicides might be right for your fields. This table is provided as a guide only. The University of Missouri does not warrant herbicide performance and herbicide effectiveness can vary due to differences in many environmental conditions. A more complete treatment of weed control options and herbicide combinations is provided in the "Weed Control Guide for Missouri Field Crops" (Guide No. MP575) which is updated annually and available at any County Extension Office.

Conventional and "Reduced" Tillage. Initial weed control is accomplished in conventional and most reduced tillage systems by the tillage operations performed just prior to planting. Herbicides used in conventional tillage are applied preplant, preplant incorporated or preemergence to provide residual control of weeds that have not emerged. Postemergence-overtop and postemergence-directed applications are made after crop and weed emergence.

In many cases a combination of herbicides will be required to control all of the weed species that occur in a field. This is particularly true because most herbicides specialize in controlling either grass or broadleaf weeds (see performance table). Tank-mixes of individual herbicides are now commonly available as package-mixes that have two herbicides in the same container. These can be a convenience but you should be sure the rates are right for your situation and that you are not paying a higher price than you would if you purchased the component herbicides separately. Be sure to consult the label for compatibility before mixing two herbicides together in the tank.

Multiple applications are also common. A preemergence herbicide is often followed with a postemergence herbicide application to control weed species missed by preemergence herbicides or to salvage an earlier application that failed to give good control due to misapplication or poor environmental conditions. Care should be used when choosing herbicides for a repeat application as crop injury is more likely when several herbicides are applied. This is especially true when soybeans are under stress.

Crop injury with some soybean herbicides can occur if herbicides are improperly applied or environmental conditions are stressing the soybean plant. Cool, wet conditions are particularly likely to cause injury problems with some herbicides. Off target drift of herbicides applied to nearby crops can also cause soybean injury. Be especially aware that many other factors can cause soybean stress and injury. Do not apply herbicides to soybeans that are already under stress from adverse weather, poor fertility, or other crop pests or pathogens until the problem has been corrected. Photographs of common herbicide injury symptoms caused by herbicides, other pathogens and environmental stress are included in this handbook to help you diagnose soybean injury in the field.

The cost of herbicide applications can be decreased by using band applications. Cultivation will be required in the area between-the-rows where no herbicide is applied. Banding is not recommended with narrow-row soybeans. It is virtually impossible to accurately apply herbicides in a band less than 10 inches wide due to the variability in band width that is caused by the rise and fall of the spray tip as you travel through the field.

No-tillage. Adoption of no-tillage practices in soybeans has been much slower than in corn production. The lack of good residual preemergence broadleaf herbicides has probably been the greatest impediment to adoption of no-tillage practices for soybeans. This situation is changing with the introduction of some of the new herbicide chemistry in the past two years. A gradual switch to narrow or drilled soybeans in no-tillage will also make weed control with preemergence and postemergence herbicides more effective.

Guide to Weed Response to Herbicides

	Barnyardgrass	Broadleaf signalgrass	Crabgrass	Fall panicum	Foxtails	Goosegrass	Johnsongrass (seedling)	Johnsongrass (rhizome)	Red Rice	Shattercane	Volunteer Corn	Yellow Nutsedge	Eastern Black Nightshade	Carpetweed	Cocklebur	Hophornbean Copperleaf	Jimsonweed	Hemp Sesbania	Common Lambsquarters	Entire and Ivyleaf Morningglory	Pitted Morningglory	Redroot and Smooth Pigweed	Prickly Sida	Common Ragweed	Giant Ragweed	Annual Smartweed Spp.	Spurred Anoda	Sunflower	Velvetleaf	Crop Response§
Preplant Incorporated																														
Command	9	9	9	9	10	9	—	—	—	—	—	—	5	4	6	—	9	4	9	4	5	5	9	—	—	—	7	5	10	0
Prowl	9	9	9	9	10	9	9	3	4	9	7	0	0	10	0	0	3	0	8	3	3	10	0	3	0	3	0	0	3	0
Sonalan	9	9	9	9	10	9	8	3	—	9	7	0	6	10	0	—	3	0	9	3	3	10	0	3	0	3	—	0	4	1
Treflan	9	9	9	9	10	9	9	3	4	9	7	0	0	10	0	0	3	0	9	3	3	10	0	3	0	3	0	0	3	0
Vernam	9	—	9	9	9	9	8	—	—	9	5	8	0	—	3	—	1	—	9	4	4	10	—	3	3	3	—	0	5	2
Preemergence																														
Amiben	7	7	7	7	7	—	6	0	—	6	3	3	7	—	4	—	5	—	8	5	5	8	8	7	6	7	—	3	7	0
Dual	8	7	9	9	9	9	6	0	9*	5	0	8	9	9	0	5	4	0	6	0	0	9	3	5	3	5	0	0	2	0
Lasso	8	7	9	9	9	9	6	0	9*	5	0	7	9	9	0	5	4	0	6	0	0	9	4	5	3	5	0	0	2	0
Lorox/Linex	6	6	6	6	6	6	4	0	—	0	0	0	4	9	6	—	5	—	9	5	6	9	8	8	6	7	—	6	6	1
Lorox +/Gemini	6	6	6	6	6	6	4	0	—	0	0	0	5	9	8	—	9	—	10	7	8	10	—	9	—	8	—	—	8	2
Preview/Canopy	7	6	7	7	7	7	5	0	—	1	3	2	5	9	9	9	9	9	9	8	9	10	9	9	—	9	9	8	8	2
Prowl	9	—	8	8	9	9	7	0	—	7	6	0	0	—	0	0	0	0	7	0	0	9	—	0	0	3	0	0	2	2
Scepter	6	6	6	6	6	6	6	2	5	—	—	4	8*	10	9	8	8	4	9	5	8	10	9	9	—	9	7	9	7*	2
Sencor/Lexone	7	6	7	7	7	7	5	0	4	1	2	2	5	9	7	9	7	9	8	2	7	9	9	9	7	9	9	7	7	2
Surflan	8	8	9	8	9	8	7	2	—	5	6	0	0	9	0	—	0	0	7	0	0	8	0	4	3	3	0	0	0	1
Postemergence-Overtop																														
Basagran	0	0	0	0	0	0	0	0	0	0	0	7	2	0	9	0	9	4	7	5	7	4	8	8	8	9	8	8	8†	0
Blazer/Tackle	2	2	2	4	4	0	4	0	2	5	4	2	9	10	7	9	9	10	6	8	9	10	2	9	8	8	2	6	7†	1
Blaz. + Basa.	2	2	2	3	4	4	4	0	0	4	2	4	8	10	9	9	9	10	7	8	9	10	8	9	8	9	8	8	8†	1
Classic	0	0	0	0	0	0	0	0	0	0	0	—	5	2	9	—	9	9	3	7	8	9	3	8	—	8	2	9	7	1
Cobra	2	2	2	4	4	1	4	0	2	5	4	2	9	10	9	—	9	9	5	7	8	10	6	9	—	7	—	—	7	2
Fusilade	8	8	8	8	9	9	10	9	6	10	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poast	9	10	9	9	10	9	10	8	7	9	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rescue	0	0	0	0	0	0	0	0	0	3	3	0	3	3	7	3	3	3	4	4	6	4	3	3	6	5	3	—	3	3
Rescue + Blaz.	1	1	1	2	2	0	2	0	1	2	2	1	—	3	8	—	—	—	—	6	7	6	3	—	—	5	—	—	5	3
Scepter	1	1	3	3	3	0	6	0	1	—	—	3	6	1	9	1	—	2	3	2	4	9	1	6	—	7	2	7	7	1
Whip	—	—	8	8	9	9	9	8	3	10	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Postemergence-Directed																														
Goal + 2,4-DB	4	4	4	—	6	4	4	0	4	—	—	2	—	10	9	9	8	9	—	9	9	9	8	9	—	9	8	—	9	2
Gramoxone	9	9	9	8	8	8	8	0	9	6	6	3	—	10	4	7	7	1	9	5	4	9	4	8	—	5	3	—	6	2
Lorox + 2,4-DB	7	7	8	7	7	7	7	0	6	—	—	2	—	10	9	9	8	8	—	10	9	9	8	9	—	7	8	—	7	2
2,4-DB	0	0	0	0	0	0	0	0	0	0	0	0	—	10	9	2	4	3	—	9	9	2	3	1	—	0	2	—	3	2

Weed control: 8 to 10 = Good 6 to 7 = Fair‡ Less than 6 = Poor — = No data available

* Shallow incorporation needed for this level of control.
† The addition of 28-0-0 liquid fertilizer required for this level of control.
‡ A weed control rating of 6 to 7 indicates partial control or suppression.
§ Crop response: A rating of 3 or less will not result in loss of crop yield under normal growing conditions.

Use this table as a guide for comparing the relative effectiveness of herbicides on individual weeds. Herbicides may perform better or worse than indicated due to extreme weather conditions and other variables. If you are obtaining satisfactory results under your growing conditions, changing products as a result of information in this table is not necessarily recommended.

Full-season no-tillage soybean production still represents only about one % of the total acreage in Missouri. Pressure from the public and government agencies will probably demand that more soybean acreage in Missouri switch to no-tillage practices in the future. Some of the new broadleaf herbicides make full-season weed control in no-tillage soybeans much more promising than in the past. These herbicides can be used early-preplant (up to 30 days prior to planting) or preemergence in combination with a burn-down herbicide such as Gramoxone or Roundup. A total-postemergence approach is also possible following a burn-down herbicide used at planting. Total-postemergence programs are generally more successful with drilled soybeans where early canopy formation can prevent later weed flushes.

No-tillage has been more successful to date in double-crop soybeans planted behind a winter wheat or other winter small grain crop. This practice conserves soil moisture at a time during the summer (late June to early July) when rainfall becomes more limiting. A preemergence burndown herbicide is usually necessary in double-crop soybeans unless weeds have been controlled with a herbicide application made in the winter grain crop. Narrow-rows are recommended for other reasons in addition to weed control.

A total postemergence program should be seriously considered in double-crop, drilled soybeans in Missouri (whether no-tilled or conventional tilled). Double-crop soybeans are planted during a period of low

rainfall, therefore, preemergence herbicides may not receive the rain they need for activation. In addition, dry weather frequently results in very little weed germination in a double-crop field. Some years you may find it unnecessary to apply a herbicide at all.

The choice of a preemergence versus a postemergence weed control approach in any soybean production system should be based on weed species present, the availability of equipment, and the likely ability to spray the entire acreage at the right weed stage without interference from adverse weather or other farm operations.

Specific Weed Problems: Perennials

Perennial weed species such as johnsongrass and field bindweed require a more planned approach to obtain satisfactory control. Perennial weeds reproduce and spread by seeds and vegetative reproduction from buds on their rhizomes or roots. Perennial weed seedlings are herbaceous and relatively easy to control with cultivation or herbicides. However, after three to six weeks most of these weeds will initiate perennial root structures and begin to store food reserves. The extensive root or rhizome systems of these weeds and the ability of small pieces of chopped roots to survive and produce new shoots make repeated cultivation and herbicide applications necessary to deplete stored food reserves.

There are a number of herbicides available for Johnsongrass control in soybeans. Roundup is effective preplant or applied postemergence with selective application equipment such as a rope-wick or a recirculating sprayer. The grass postemergence herbicides such as Fusilade, Poast and Whip also provide excellent control.

There are only a few herbicides that are effective for controlling perennial broadleaf weeds. The three herbicides available for use in field crops are 2,4-D, Banvel and Roundup. Unfortunately, soybeans are sensitive to all three of these herbicides. Roundup can be used preplant in the spring to control emerged perennial weeds. Application of 2,4-D can be made at least four weeks prior to planting soybeans.

Nothing available as a postemergence herbicide for soybeans is effective for control of perennial broadleaf weeds. A two percent Roundup solution can be used as a spot spray for light infestations or isolated plans but any crop plants that come in contact with the spray will be severely injured or killed. Selective application equipment such as rope-wicks, recirculating sprayers or roller applicators can be used with Roundup on hemp dogbane or common milkweed that are at least six inches above the soybean canopy. This height difference is likely to occur only briefly early in the growing season if at all.

Fall sprays are most effective for perennial weed control as the plants are transporting food supplies downward into the roots for storage during the winter. If perennial broadleaf weeds become a serious problem it may be necessary to rotate to corn, grain sorghum or winter wheat to allow the use of a more intensive herbicide control program.

Choosing a Weed Control Program

There is no simple solution to weed control in soybeans. The diversity of cropping systems, weed species and herbicides available creates a large number of possible approaches and needs for soybean weed control. The recent introduction of several new soybean herbicides has made the selection of a weed control program even more confusing. The herbicide performance chart provided can help you to narrow your choices based on the weed species you need to control. Proper identification of your particular weed problem is the most important step toward choosing a weed control program. Herbicides are now very specific for activity by weed species. Several pages of weed photographs are included in this handbook to help you properly identify the weeds in your field.

Other factors that should help you customize a weed control program for your fields are: tillage practices (incorporation or preemergence), row spacing (cultivation and banding, or broadcast), full season vs. double-crop, crop rotation (some herbicides will restrict rotational crop choices), dealer availability, equipment availability and herbicide price. Careful consideration should be given to the crop rotational restrictions common to most of the current soybean herbicides. Failure to follow the rotational restrictions on the herbicide label could result in loss or injury of the rotation crop.

A herbicide program that is cheap but does not control your specific weed problems will not be very economical. Proper herbicide application with well maintained and calibrated spray equipment is essential for good herbicide performance. Application timing is also critical with most of the current postemergence herbicides. Applications to small weeds less than 3 or 4 inches tall is far more likely to result in good weed control than application to larger weeds. Reviewing the herbicide label before use (or purchase) is important to ensure proper use and performance. With soybean prices likely to stay low in relation to production costs in the near future it is even more essential to obtain the maximum performance for your weed control investment by properly selecting and applying herbicides for your particular soybean production system and environment.

More weed control information can be obtained in the "Weed Control Guide for Missouri Field Crops" (Guide number MP575), and the "Perennial Broadleaf Weed Control in Missouri Field Crops" guide available at your local county extension office.

Chapter 11

Disease Control

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Soybeans were considered a disease free crop when they were introduced into the U.S.A. Within a short time the situation reversed. Soybean diseases are responsible for annual production losses ranging from 14% to 20%. Diseases cost soybean farmers in Missouri over $100 million each year. Most soybean diseases cause greater losses in wet seasons than in dry ones. Even in fields that appear relatively free of diseases, losses may occur. Damage produced by a succession of diseases is difficult to measure.

Soybean diseases are caused by pathogenic fungi, bacteria, viruses, and nematodes. Soybeans are also injured by herbicides and other factors. Interactions between non-parasitic disorders and diseases are also important to evaluating soybean problems.

Recognition of the most common and destructive diseases is important so that control measures can be applied. Refer to the picture pages on diseases in this publication.

One way to categorize soybean diseases is by: (1) seed and seedling diseases; (2) diseases of roots and stems; (3) diseases of pods and stems; (4) diseases of the leaves; (5) virus diseases; (6) non-parasitic disorders.

Seed and Seedling Diseases

Seed quality is closely related to several diseases and disorders. Low seed quality, whether due to physical damage or diseases, adversely affects germination and seedling vigor. Mechanical damage from rough handling during harvest and transport can fracture the seed coat through which seed-borne and soil-borne pathogens can enter and cause decay.

Prolonged storage, especially under high moisture conditions, reduces seedling vigor. Soybeans stored above 14% moisture will deteriorate rapidly, even under otherwise good storage conditions.

Deep planting and cold soils reduce seedling vigor and lead to exposure to several damping-off fungi.

If seed quality is low and/or seed coats are cracked, or if weather conditions are persistently cold and wet, fungicide seed treatment can increase emergence and vigor of young seedlings (see Chapter 3).

Pythium Seed and Seedling Rots

Causes: *Pythium ultimum* and *P. debaryanum* are soilborne fungi present in most agricultural soils. The fungi survive in the soil and in crop residues.

Symptoms: In cold, wet soils *Pythium* spp cause seedlings to be slow in development; sometimes to die prematurely. Lower tap roots develop soft, watery rots and often develop a "shoe string" appearance because of sloughed outer root tissues. Older plants may have water-soaked lesions at the ground line. Diseased plants may be single or in groups — randomly affected in a field or concentrated in wet areas. Symptoms are similar to *Phytophthora* root rot.

Control:

1. Use fungicide seed treatments with metalaxyl.
2. Use high-quality, high-germinating seed.
3. Avoid carryover seed or seed with damaged seed coats.
4. No specific varietal resistance is present.
5. Crop rotation is *not* especially useful.

Diseases of Roots and Stems

Rhizoctonia Root Rot

Cause: *Rhizoctonia solani* is a common soil fungus with a wide host range. It survives in the soil in crop residues, even in the absence of soybeans. It does not produce spores, but has resistant structures known as sclerotia or it may survive as mycelium.

Symptoms: The fungus causes a reddish-brown cortical rot (outer layer of the root) at the base of the stem near the soil line. Young plants can be seriously affected when the soil is wet. First symptoms are wilting plants that may die if the stem is girdled by the infection. Infected stems remain firm and dry. The disease patterns in the field may involve single plants, or a group of dead plants in the row, or in circular areas where the soils were wet in the early season.

Control:

1. Seed treatment fungicides improve emergence (see Chapter 3).
2. Ridge soil around the bases of plants when cultivating to stimulate root development.
3. Varieties do not have specific resistance; differences in susceptibility have been noted.
4. Soil drainage.

Nematode Diseases

The *soybean cyst nematode* is the most serious nematode problem on soybeans in Missouri. By attacking the roots, the nematode can seriously inhibit growth. Because of its unique importance, it is discussed in Chapter 8.

Other nematodes, i.e. *root knot nematode, root-lesion, sting, lance* are also discussed in Chapter 8.

Phytophthora Root and Stem Rot

Cause: *Phytophthora megasperma* var. *sojae* is a common soil fungus. It survives in soil and in buried crop residues. *Phytophthora* rot remains active throughout most of the growing season. It is most severe in heavy, *cold* and wet soils.

Symptoms: Soybeans may be infected at any stage of development. Seedlings may be attacked and die before or after emergence. Plants turn yellow, wilt, wither, and die at any age, leaving skips in the rows or in roughly circular areas. A dark brown root rot can be found on older plants, with a dull brown discoloration extending up the stem into the lower branches. Infection penetrates into the vascular cylinder and extends upwards in the stems.

Race 1 has been prevalent in Missouri. It is not known presently whether other races are important in our state, but there have been episodes of apparent Phytophthora infections that have suggested a changing race picture.

Control:

1. Plant varieties with resistance or with known field tolerance (Chapter 2).
2. Plant in warm, well-drained soils.
3. Crop rotation may be beneficial.
4. Use fungicide seed treatment with metalaxyl (Apron) to protect seedlings.
5. Extended-protection fungicides (e.g., Ridomil) have shown promise in row applications.

Fusarium Root Rot

Cause: *Fusarium oxysporum* and several other species, form species, and races are residents of most cultivated soils. These fungi survive in the soil or residues. The causal fungi infect seed, seedlings, and the roots and lower portions of stems.

Symptoms: Infected seeds may germinate poorly. Pre- and post-emergence damping off or late emergence and stunted plants may occur. Wilting is frequently observed in seedlings or young plants when roots are rotted and soil moisture is low — sometimes widespread in a field. The disease is often more severe in early-planted soybeans in heavy soils. Poor stands are usually associated with poor seed quality, heavy rains, soil compaction, and flooding just after planting. Older plants are seldom killed but they show wilting when soil moisture is low. They recover at night when moisture becomes adequate.

Control:

1. Plant high quality seed in warm, well-drained soil.
2. Delay cultivation until adequate soil moisture is available.
3. Ridge soil around base of plants to promote development of roots from the stem base.
4. All varieties are generally susceptible, but there are variations in responses.
5. Crop rotation is of little value in control.

Brown Stem Rot

Cause: *Phialophora gregata* (synonym *Cephalosporium gregatum)* is a soil-borne fungus. It survives in soybean residues for many years. Infection occurs through the roots and lower stem early in the growing season. It becomes most serious in fields where soybeans follow soybeans for several years. Yield reduction of 25% or more can occur when disease is widespread in a field. It is more prevalent in northern counties of Missouri than in central or southern counties.

Symptoms: Infected plants will have interveinal leaf tissues that turn brown and dry rapidly. Veins stay green for a while — usually about three weeks before maturity. Fields take on a brownish cast (like frost damage). These outer symptoms may not always be present. The lower stem should be split 10 to 30 days prior to maturity to check for symptoms. Healthy stems have white tissue in the center; infected stems have a brown pith with step-like characteristics. Severely diseased plants may lodge, and seed size is reduced. A brown pith can be associated with Fusarium and Charcoal Rot infections, and therefore, it is not a sure diagnostic symptom.

Control:

1. Crop rotation with corn or cereal. Infested field should not be planted to soybeans, alfalfa, or red clover for three years (the fungus is also pathogenic on those legumes).
2. Do not plant end rows of corn fields used in a rotation to soybeans.
3. Use commercial varieties with resistance, such as Chamberlain and Asgrow A3733 (Group III varieties). BSR 301 and 302 (Early Group III varieties) are available in Iowa and may fit in north Missouri.

Charcoal Rot

Cause: *Macrophomina phaseolina* is the fungus that

causes charcoal rot. It survives in the soil in residues of soybeans, corn, sorghum, alfalfa, and other plants as overwintering sclerotia (resistant fruiting bodies). The fungus is widespread in Missouri. Charcoal rot is increasing in severity and is considered to be a disease that causes significant losses every year because of root injuries. The fungus enters seedlings at an early stage, but is not easily recognized until near maturity.

Symptoms: Hot dry weather will accentuate charcoal rot symptoms because of water stress. When encountered after midsummer, prematurely yellow plants tend to retain leaves rather than follow normal abscission patterns. Roots and basal portions of stems have a grayish-black color when split. This is because of the large number of small black sclerotia embedded in the tissues. Weakened plants caused by crowding are more vulnerable to charcoal rot.

Control:

1. Follow fertility programs that encourage vigorous growth.
2. Avoid excessively high seeding rates.
3. Deep plowing.
4. Crop rotation may help somewhat, but the fungus has a wide host range, including corn and sorghum.
5. Practical field resistance has not been found, but there are degrees of susceptibility. Studies in the Dept. of Plant Pathology, UMC, indicate that seedling susceptibility to charcoal rot, in selected Missouri varieties, were ranked: **Beeson, Cutler, Amsoy 71, Calland,** and **Williams** (from least to most).

Southern Blight

Cause: *Sclerotium rolfsii,* a soil-borne fungus common to southern soybean areas, is adapted mainly to warmer temperatures and sandy soils. It has been prevalent in the Delta of Missouri. The fungus attacks a wide range of crops. It survives in the soil as large round sclerotia that develop on the lower stem.

Symptoms: The fungus produces a variety of symptoms on soybeans including pre- and post-emergence damping off and basal stem rot. On seedlings and stems the fungus produces a white, cottony mycelial growth over the stem surface. Infected seedlings or older plants are often killed prematurely. Eventually the fungus produces abundant globular, tan to reddish-brown or dark brown sclerotia about the size of mustard seeds. The sclerotia are embedded in the heavy mycelial growth on the stems.

Control:

1. Most commercial soybean varieties have some tolerance.
2. Rotation with less susceptible crops — grass family.
3. Deep plowing.

Sclerotinia Stem Rot

Sclerotinia sclerotiorum is a soil-borne fungus that can survive in the soil for long periods. It can cause pre- and post-emergence damping off of soybean seedlings. Older plants may become infected in wet weather, causing wilting and death. The disease is not prevalent in Missouri, but it is encountered occasionally, especially in wet years.

Diseases of Pods and Stems

Pod and Stem Blight

Cause: *Diaporthe phaseolorum* var. *sojae* is a fungus that overwinters in infected soybean residues or may be seed-borne. Spores developed in fruiting structures in stem and pod tissues, known as perithecia, are spread by wind. Pod and stem blight is widespread and destructive in most soybean fields in the entire state. Losses to both soybean quality and quantity can be very great in years of heavy dews and/or rainfall after pod set. As part of the "pod and stem complex," this disease represents one of the most serious chronic disease problems of soybeans. This disease causes multi-million dollar losses annually in Missouri.

Symptoms: Soybeans are infected early in the growing season, but symptoms on the pods and stems do not appear until the plants are mature. An identifying characteristic is the presence of small, black fruiting structures (pycnidia) arranged in linear rows on the stems. They are scattered on the pods. Infected seed may have white mold growth, or often dull, cracked, or shriveled. Such seed is weak or dead. Sowing diseased seed commonly results in seed decay, seedling blights, and poor stands.

Control:

1. Plant seed that is bright and vigorous.
2. Treat seed with an approved fungicide.
3. Apply a foliar fungicide to soybean fields if weather tends to be rainy. (Tables 11-1 and 11-2, Foliar Fungicides for Soybeans in Missouri and "How to Determine Whether Fungicide Application Should Be Made on Soybeans.")
4. Plow under crop residues.
5. Use crop rotation.
6. All varieties are more or less susceptible — several sources of resistant breeding material are available.

Stem Canker

Cause: *Diaporthe phaseolorum* var. *caulivora,* a close relative of the pod and stem blight fungus, has a similar life cycle. However, stem canker does not usually affect plants over large areas, but prematurely

kills occasional plants. The fungus overwinters on infected stems and seeds.

Symptoms: The disease usually appears in mid-July or early August and continues until plants mature. Brown, slightly sunken lesions appear at the base of branches or leaf petioles. Eventually, the stem is girdled from this canker and the upper part of the plant is killed. Dead plants with leaves still attached are characteristic of stem canker. After death, fruiting structures develop in stem tissues. Lesions are often near the soil line, thereby causing some confusion between *Rhizoctonia* root rot or *Phytophthora* root rot infections.

Control:

1. Plant disease-free seed.
2. Use fungicide seed treatment (Chapter 3).
3. Fall plow where feasible to hasten decay of infected residues.
4. Use crop rotation.
5. All varieties are more or less susceptible.

Anthracnose

Cause: *Colletotrichum dermatium* var. *truncata* and *Glomerella glycines* are the two fungi that cause anthracnose. The former fungus is more common in the Midwest, infecting plants of all ages. *G. glycines* only infects older plants. Both fungi overwinter either in infected seeds or as mycelium in soybean residues. Spores are produced from mycelium and infect healthy plants.

Symptoms: Both fungi produce similar symptoms. Indefinite, enlarging, reddish- or dark-brown areas develop on the stems and pods. Later, these areas develop black fruiting bodies (acervuli) that resemble tiny pin cushions with black spines (setae). They are easily seen with a hand lens. *C. dermatium* grows from infected cotyledons and may cause lesions that kill young plants. Stems, pods, and leaves may be infected without showing external symptoms until weather conditions become favorable for further disease development. Like the pod and stem blight fungus, infected seed may be shriveled and moldy, or may show no visible signs. It is usually not as destructive to germination as the Diaporthe pod and stem blight fungus.

Control:

1. Plant seed from fields with low infection.
2. Treat seed with an approved fungicide.
3. Apply foliar fungicides during the season if infection potential appears to be developing (Tables 11-1 and 11-2).
4. Use crop rotation.
5. Plow under infected residues if feasible.

Purple Seed Stain

Cause: *Cercospora kikuchii* is a fungus that overwinters as mycelium in infested seeds, stems, and leaves. It is a very common fungus in soybean fields, causing the characteristic purple discoloration of seed coats.

Symptoms: The most dramatic symptom is a pale to dark purple discoloration of the seed coats, but other parts of the soybean plants can be affected during the season prior to harvest. Infected seeds can produce diseased seedlings with cotyledons that are shriveled, purple in color, and fall prematurely. The fungus can grow into the stems and cause a girdling canker. Leaves may have a bronzed appearance in mid-season as a result of infection. When the fungus grows into the pods, seeds become infected. Yields are not reduced, but the value can be lowered from a grading standpoint. The purple discoloration does not seriously affect the quality of processed soybeans, since it disappears during heating.

Control:

1. Treat seed with an approved fungicide (Chapter 3).
2. In general, early maturing varieties are more susceptible than late maturing varieties.
3. Most varieties are susceptible; a few are moderately resistant.
4. Apply foliar fungicides at 60% of full pod set. (Tables 11-1 and 11-2).

Diseases of the Leaves

Brown Spot

Cause: *Septoria glycines* is a fungus that overwinters in resistant fruiting bodies (pycnidia) in tissues of fallen leaves and stems. The fungus is common to most soybean fields.

Table 11-1. Foliar Fungicides for Soybeans in Missouri.

Fungicide	Rates[1] and Remarks
Benlate (DuPont)	½ to 1 lb/A (WP) Do not apply within 35 days of harvest; do not graze or feed treated soybean vines or hay to livestock.
Mertect 340F (Merck)	6-10 fl. oz/A (flowable) Do not apply within 21 days of harvest. Do not graze or feed treated soybean vines or hay to livestock.
Bravo 500 (Fermenta)	2-3 pints/A (flowable) Do not apply within 6 weeks of harvest. Do not allow livestock to graze treated areas. Do not feed soybean hay or threshings from treated fields to livestock.
Topsin M (Pennwalt Corp.)	8-16 oz/A (WP) Do not make more than 2 applications per year. Do not graze or feed to livestock.

[1] Two applications — apply first when pods near top of plants are about ¼ to ½ inch (R4 — early pod stage) and a second application 2 weeks later (R5 — late pod stage). Proper application by aircraft requires minimum of 5 gallons of water per acre. Use a spreader-sticker adjuvant.

Symptoms: Small red-brown, angular spots appear first on primary leaves in early spring. Heavily infected leaves turn yellow, wither, and drop off. As the plants grow, fungus spores produced on the primary leaves spread and infect the trifoliate leaves, stems, and pods. Spores produced in the pycnidia are discharged during warm, moist weather. Greatest damage occurs when soybeans are planted every year in the same field.

Control:

1. Plant seed from disease-free plants.
2. Treat with approved fungicide (Chapter 3).
3. Apply foliar fungicides when weather conditions favor the disease.
4. Plow under crop residues when feasible.
5. None of the current varieties are resistant.

Downy Mildew

Cause: *Peronospora manshurica* is a fungus that overwinters in infected leaf residues or encrusted on infected seed or resistant spores (oospores). The disease is prevalent in soybeans, especially in wet seasons. Infected seed, when planted, serve as a primary source of field infection. The disease does not usually cause severe damage, but bears watching as there are variations in the fungus.

Symptoms: Early symptoms are indefinite yellow-green areas on the upper leaf surfaces. The spots enlarge, become grayish-brown to dark brown with yellowish-green margins. Grayish tufts develop on the lower side of the spots. Severe infections may result in premature leaf drop. Growth within pods results in whitish, crusty growth on seed, the resting spores (oospores).

Control:

1. Plant disease-free seed; treat with fungicide to improve emergence (Chapter 3).
2. Use crop rotation for one year or more.
3. Plow under infected residues.
4. None of the current varieties are resistant to all races of the fungus — varieties such as Calland, Dare, and Essex are moderately resistant.

Other foliar diseases caused by fungi

Several other diseases occur occasionally in Missouri, but for various reasons are of minor importance. Frogeye leaf spot, caused by *Cercospora sojina,* is not widespread because of the use of resistant varieties. Powdery mildew (*Microsphaera diffusa* and *Erysiphe polygoni*) and Phyllosticta leaf spot *(Phyllosticta sojaecola)* have not been prevalent in Missouri. Alternaria leaf spot (*Alternaria* sp) occurs late in the growing season and yield losses are considered minimal.

Table 11-2. How to Determine Whether Fungicide Application Should Be Made on Soybeans.

The following checklist may be useful in making a decision as to whether or not foliar fungicides should be used. Determining weather conditions prior to harvest, along with several other "risk factors," will help make a decision. Timely spraying and good coverage are essential to success. See Table 11-1 for fungicides labeled for soybeans and for rates and precautions.

Risk factors	Point value if the answer is yes
Rainfall frequency, dew and high humidity up to early pod set:	
Below normal	0
Normal	2
Above normal	4
Conservation tillage — debris on surface	1
Soybeans in field last year	2-3
Early maturing variety	2
Yield potential better than 35 bu/acre	2
Seed quality at planting less than 85% germination	1
Beans to be used or sold for seed	3
Leaves with brown spot symptoms	1
Pycnidia of pod and stem blight fungus visible on fallen petioles	2
Field relatively free of seed canopy	1
Other conditions that favor disease development (e.g., long-range weather forecast)	1-3

NOTE: If the total is 12 or more points for seed production fields or 15 or more for grain production fields, fungicide application may be justified.

Bacterial Blight

Cause: *Pseudomonas glycines* is a bacterium that survives in crop residues on or above the soil surface and in seed. Bacterial blight is one of the most widespread diseases in Missouri and appears early before flowering. It is most severe in periods of cool weather and frequent rain or dew in June and July.

Symptoms: Early symptoms on lower leaves are small, angular, yellow spots with "water-soaked" centers. Spots turn brown as tissues die and are surrounded by water-soaked, yellowish-green halos. Small infections often merge to form large, irregular dead areas. In windy and rainy weather the centers of older lesions drop out or tear away, giving the leaves a ragged and shredded appearance. Symptoms may appear about a week after a severe rain storm.

Control:

1. Plant disease-free seed.
2. Use crop rotation — at least one or two years between soybean crops.
3. Do not cultivate when foliage is wet.
4. Cover plant residues by fall plowing, if feasible.
5. No significant varietal differences.

Bacterial Pustule and Wildfire

Causes: Bacterial pustule, caused by *Xanthomonas phaseoli* var. *sojensis,* is not as prevalent as bacterial blight. Many commercial varieties have resistance. It appears occasionally in Missouri. Wildfire, caused by *Pseudomonas tabaci,* is almost always found associated with bacterial pustule.

Symptoms: Symptoms are similar to bacterial blight, except that small, raised pustules emerge from the leaf spots. When wildfire is present, a broad yellow halo surrounds the dark brown to black spots.

Control:

1. Same as for bacterial blight.
2. Several commercial varieties are resistant. See Chapter 2.
3. Wildfire has been greatly reduced as result of using varieties resistant to bacterial pustule.

Virus Diseases

Soybean Mosaic and Yellow Mosaic

Causes: Soybean mosaic and yellow mosaic are caused by the soybean mosaic virus and the bean yellow mosaic virus, respectively. The viruses are transmitted to soybeans by aphids. Soybean mosaic is seedborne, but seed transmission has not been reported for yellow mosaic.

Symptoms: Symptoms are variable, depending on the soybean variety and strains of the viruses. Stunted plants with crinkled and mottled leaves are characteristic of soybean mosaic. Conspicuous yellow mottling of leaves is characteristic of yellow mosaic. Mixed infections of these viruses plus other viruses are common but symptoms may vary.

Control:

1. Plant seed from disease-free plants and fields.
2. Rogue infected plants from seed-producing fields.
3. Practice good weed control.

Bud Blight

Cause: Bud blight is caused by the tobacco ringspot virus, which has a wide range of hosts. There are many strains of the virus. Several perennial legumes, such as alfalfa and red clover, are believed to serve as reservoirs for the virus. Transmission is by young thrips, grasshoppers, and probably other insects. Dagger nematodes are also vectors. There is some seed infection that can give rise to infected seedlings. The disease is serious and destructive in Missouri, but tends to be sporadic. Occasionally large parts of fields can be affected. It is frequently more severe in soybean fields adjacent to old stands of forage legumes or fence rows where legumes may be growing.

Symptoms: Symptoms of bud blight vary with the stage of development at which the plants are infected. When plants are infected before flowering, the terminal bud turns brown, dies, and curves downward to form a "shepherd's crook." Later, other buds turn brown, die, and become very brittle. Younger leaves often develop a rusty flecking. Plants are dwarfed and produce little or no seed. Sometimes there may be discoloration of the inside of the stems.

When infected during flowering, plants may not be stunted, but produce undeveloped pods. Infection after flowering results in poorly filled pods with dark blotches. The most conspicuous symptom expression is plants that remain green until frost — after other plants have matured and dropped leaves.

Bud blight usually starts along field margins and progress inward — following patterns of insect movement from legume sources.

Control:

1. Do not plant soybeans adjacent to other legume fields. A buffer strip of nonhost, such as corn, sorghum, or wheat, will help.
2. Control broadleaf weeds in noncrop areas close to soybean fields.
3. Rogue infected plants from seed fields.

Bean Pod Mottle

Cause: This disease is caused by the bean pod mottle virus. Yield losses by this virus vary from 10%-15% but are much higher in combination with soybean mosaic. The virus is spread in the field by the bean leaf beetle, farm machinery, and wind-carried soil or sand. Several legumes are susceptible.

Symptoms: Symptoms are most pronounced on young growing leaves during cool weather and appear as yellow-green mottle. The symptoms are masked during high temperatures and at maturity. Pod formation is much reduced if plants are under water stress. Infected plants yield smaller seed.

Control:

1. Crop rotation using nonlegumes is useful.
2. Remove infected plants when first noticed.
3. Insecticides to control leaf-beetles may prove economical where the virus is common.

Nonparasitic Disorders

Nonparasitic disorders are sometimes more destructive than diseases. Examples are nutrient deficiencies, imbalances or excess of soil nutrients, extremes in soil acidity or alkalinity, lack or excess of water, very high or low temperatures, air pollutants, mechanical injuries, hail injury, pesticide injury.

Severity and types of disorders vary with stage of maturity and plant parts involved. Some nonparasitic disorders are often confused with those caused by fungi, bacteria, viruses, and nematodes. Diagnosis is often complicated by presence of nonparasitic conditions and parasitic diseases.

Nutrient deficiencies are discussed in Chapter 5. Herbicide injuries are discussed in Chapter 10.

Chapter 12

Moisture Management

Zane R. Helsel, Jim Gregory, Calvin Jones and Dale Schnarre

Management of moisture during the growing season can significantly affect soybean productivity. Soybeans require about 18 to 22 inches of water for good development and maturation.

Missouri rainfall patterns are characterized by sufficient winter and early spring rainfall to fill and maintain the soil profile at near capacity until about June 1. During this period, excess moisture sometimes exists as puddled water or runoff. Crop water usage usually equals or exceeds rainfall in June, July, and August. During July and August, soybeans need about 1 to 2 inches of water per week, but receive on the average only 6/10 to 1 inch. Available soil water is normally depleted in these months. In the fall, rainfall normally increases, helping late-maturing crops.

The objective of good moisture management is to provide water to the soybean roots when needed by the plant to produce the most economical soybean yields. This chapter will evaluate suggestions for both drainage and irrigation.

Drainage

In most parts of Missouri excessive moisture occurs in most years from November through April. This rainfall (or snowfall) can produce both runoff and soggy, water-logged soil. As a result, many of the finer textured flatland soils, especially those with hardpans or claypans, are slow to drain in the spring.

Water-logged soils can delay spring tillage, reduce soil temperature, and cause planting delays that often result in decreased yields. These soils also require a larger set of tillage equipment to conduct field operations because more work must be done in the fewer available days for field work. If water-logging occurs during early plant development, diseases like pythium and other seedling rots can reduce population. Nitrogen fixation and nutrient uptake may be decreased. Iron and manganese may become more soluble at lower pH's, causing toxicities. Phytophthora root rot and other diseases may be encouraged.

Probably the most serious result of wet soils, however, is limited oxygen, which is needed for root growth and survival. Soybeans are rapidly damaged by flood waters. Under warm, sunny conditions, soybeans will continue to photosynthesize and respire, and will actually kill themselves within a few days. Soybeans may survive under water 3 or 4 days or more, if conditions are cool and cloudy. After draining of flood water, soybeans may be covered with mud, which will interfere with photosynthesis and respiration, and may cause leaf and plant death if not removed by rain in a few days.

Several methods are available to limit or remove excess water. Among them are tillage, tile drainage, and surface drainage, which includes land planing, drainage ditches and/or ridge planting.

Tillage. Compaction caused by poor tillage management can result in ponding and slow internal drainage of water. Limiting tillage passes, not using compacting tillage tools such as a disk, prohibiting the formation of a plow layer, conserving organic matter, and not working the soil when wet can help eliminate compaction.

Tile Drainage. Only a few soils in Missouri are suited for conventional tile drainage (tiles buried 2 ft. or deeper). Soils that are fine textured and have claypans near the surface are not suited for tile drainage. Unfortunately, many soils that need drainage in Missouri are of this type. When practical, tile drainage should be given priority over surface drainage because tile drains continue to remove excess water, even after surface water is removed.

Surface Drainage. Simple surface drainage ditches or grass waterways can improve the productivity of many fields. Soils that benefit most by surface drainage are those with 2% or less slopes and high in clay content or others that have a claypan near the surface.

On soils with less than 2% and with adequate topsoil, land planing (sometimes called land leveling, grading, or smoothing) can often be used to fill depressions that are small in area and less than 6 in. deep. This can also produce a uniform slope capable of

allowing slow water removal, uniform seed germination, comfortable machine operation, and reduced harvesting losses from low podding soybeans.

Drainage ditches, either on planed land or on fields where small depressions can be drained, can help move and direct water from wet areas. Broad, flattened V-shaped ditches can be constructed with snow plow-type tractor-mounted blades to allow for easy crossing of machinery. Dead furrows provide a good starting point for creating ditches. Slope of the ditch to outlet ditches should be about one-half foot per one hundred feet of length.

Ridge planting is a method of drainage that works both by elevating the plant on a soil ridge and by providing small drainage ditches on uniformly sloping land. Of course, ridge planting is necessary where furrow irrigation is used. Substantial time and labor is involved in developing, maintaining and restructuring ridges; but, when correctly used, they are effective in managing water movement and allowing for earlier planting on warmer, drier seed beds.

Where any significant land drainage structure and systems are to be developed, soil conservation specialists or area agricultural engineers can be consulted free of charge for recommendations and actual assistance in developing proper sizes, slopes, and configurations of the appropriate drainage system.

Irrigation and Water Management For Optimum Moisture Availability

To evaluate the need for additional water, or potential for water conservation the climate, soil, and plant characteristics must be known. Once need is established, the economics of supplying the additional water can be assessed.

Yield and Agronomic Performance. Expected yield increases from irrigation or other management practices vary because of yearly weather patterns, soil characteristics, and crop management. Supplemental water has increased yields up to 30 bu./A in a few cases and actually decreased yield by 10 bu./A in others. The large increases came on sandy soils in dry years, and the decreases came on over-irrigated soils followed by untimely, heavy rains. Studies from 1967 to 1974 in the Bootheel on Tiptonville loam, Sharky clay, and Waverly silt loam soils showed increases for full season varieties of +0.5, +2.1, and −0.2 bu./A, respectively. Yield increases were greater for short season varieties (+6.2, +5.1, and +8.9 bu/A, respectively, for the three soils). The lack of any large increase was because most years had adequate rainfall during the growing season. Also, no late season drought significantly influenced full season varieties. Yield increases from other studies in the Bootheel on sandy soils have shown yield increases of 8 to 15 bu.

A mid-Missouri survey of growers showed a 15-year average of 13 bu./A increase from irrigation of full season beans. A 10-year average increase of 13 + bu./A was also reported from irrigating double cropped beans. In Southwest Missouri, a 5-year furrow irrigation study demonstrated average yield increases of 4-7 bu./A for various irrigation treatments. A checkoff supported study in Barton County showed a range of 1-26 bu./A increase with a 13 bu./A average over 3 years. Results of a statewide grower survey are detailed in Chapter 14.

In addition to irrigation, soil profile modification may provide another way to improve moisture availability and soybean yield. Research in several states has periodically shown significant yield increases as a result of deep plowing, chiseling, or other types of mixing or breakage of a compacted soil zone. Studies conducted in eastern Missouri in 1980 showed a 7 bu./A yield increase over conventional tillage from deep mixing and adding of lime to a soil with a compacted acid sublayer.

Other production practices such as using long season varieties, good fertility practices, minimum or no tillage, and good weed control have all been shown to improve yield by conserving moisture during stress periods.

In addition to affecting yields, increased levels of moisture availability affect other agronomic characteristics of soybeans. Maturity of short- or mid-season varieties is only normally delayed about one to two days, unless added water is excessive. Maturity of full season varieties are normally not affected by additions of water. Height and lodging often increase under irrigation, particularly so if excessive irrigation and/or rainfall occur during vegetative development. Untimely or excessive irrigation can increase the incidence of leaf and root diseases; however, adequate moisture may often overcome some of the effect of root diseases and nematode damage by supplying moisture to the fewer viable roots.

Water Use. Water use patterns of the plant and the weather patterns during the growing season affect the potential performance, need and timing of irrigation. Lack of water during flowering and podding causes flower and pod abortion. Stress during pod development and early seed fill reduces the number of seeds per pod. Drought conditions during seed fill reduce seed size and thus final yields. The critical period of water need for indeterminate varieties is from late flowering through mid pod fill. For determinate varieties, such as those grown in the Bootheel, the period of greatest need begins earlier in the flowering stage. The new determinate semi-dwarf varieties show critical water needs at most stages of growth.

Water requirements are actually a function of plant needs for growth and that used for transpiration and evaporation from the plant and the soil. Evapotranspiration is affected by weather, location, and plant canopy; and is greatest during long, hot, dry and

Table 12-1. Available Soil Moisture for Various Soil Types.

Soil Type	Available Soil Moisture inches/foot of depth
Sands	0.5
Loamy sands	1.0
Sandy loams	1.5
Loams	2.0
Silt and clay loams	2.5
Clays	2.0

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windy days when plants are at full canopy. July and August are the months normally highest in evapotranspiration, sometimes reaching 0.4 in. per day. The planting date and maturity of the soybean variety grown result in it being in a critical stage of growth during periods of highest evapotranspiration. Early planted, short-season beans will be completing flowering and pod-filling at this time, resulting in decreased yields.

Full season varieties normally reach critical moisture needs when highest evapotranspiration is past. Double cropped soybeans encounter this period of highest evapotranspiration during vegetative growth when roots are shallow. This results in short plant height and, therefore, fewer podding sites. Less total water, however, is needed to achieve the maximum double crop yield.

Soil Characteristics. The inherent characteristics of soils affect root distribution and the ability of that soil to intercept, store and release moisture for plant growth. Available water-holding capacity is greater for medium to fine textured soils, as indicated in Table 12-1. Extremely fine clay soils hold more total water, but hold less available water. Carrying capacity indicates the number of days that water is available to a growing plant. Table 12-2 gives some examples of carrying capacity of soils. Finer textured soils and greater rooting depths provide for the greatest number of days between irrigation or needed rainfall. With greater carrying capacity, however, more water is needed to refill the profile once depleted. Carrying capacity is, of course, less when plants are young and have shallow roots, but in early summer it is not to the extent expected because of low evapo-transpiration during cooler, shorter days.

Many of eastern and southeastern Missouri soils have compacted sublayers of soil which restrict effective rooting depth; therefore, even though many of these soils are loams or clay loams, drought occurs quickly during periods of high water use.

The ability to intercept and conserve irrigation or rainfall water is affected by the slope and the infiltration rate of the soil. Increased slope, of course, increases runoff and soil erosion. Coarse textured soils and soils covered with residue have relatively high infiltration capacities. This high infiltration rate allows for more rapid sprinkler irrigation, but could seriously detract from the use of furrow or flood irrigation.

Production Practices Under Irrigation. Full season varieties planted early and grown with adequate water should provide the greatest soybean yields. Short season varieties, late planting, and double cropped beans normally achieve greater percentage increases in yields from irrigation, but total yields will be less than full season soybeans planted early. Fertilizer applications should be increased to allow for a 10-15 bu./A greater yield than obtained under non-irrigated conditions. If lodging has been a problem, seeding rates may need to be reduced by 10% for full season varieties under irrigation. Using a lodging resistant variety further helps reduce the chance of lodging.

The new determinate semi-dwarf and semi-determinate varieties perform extremely well under irrigation. Nebraska and Kansas have also developed common indeterminate varieties that are shorter and more lodging-resistant under irrigation.

The potential for many leaf diseases and some root rots is increased with irrigation, particularly under high humidity. In fields to be used for seed, a fungicide to control pod and stem blight and other seed-borne diseases may prove beneficial. Although insect and disease incidence may increase under irrigation, supplying adequate water to the plant when needed usually increases yields. Using pest-resistant varieties lessens concern for these potential problems under irrigation.

Water Sources and Quality. The three major sources of irrigation water are rivers, reservoirs, and wells. Deep wells normally provide the most dependable source of water, but capital investment and operating costs (depending on the depth of the well) are high for pumping. Rivers and reservoirs, although normally less expensive to use, are often at a low level when water is needed the most. Whatever the source

Table 12-2. Carrying Capacities of Soils in Days.

Soil Type	Evapo-transpiration (in/day)	Effective Rooting Depth 1′	2′	3′
Sands	.10	2.5	5.0	7.5
	.30	.8	1.6	2.4
Sandy loams	.10	7.5	15.0	22.5
	.30	2.5	5.0	7.5
Loams and Clays	.10	10.0	20.0	30.0
	.30	3.3	6.6	10.0
Silt and Clay loams	.10	12.5	25.0	37.5
	.30	4.1	8.3	12.5

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of water, the quality should be determined before selecting the source.

Water should not have toxic levels of micronutrients or be high in salts, particularly sodium. Some northern Missouri groundwater is high in sodium and should be avoided. It is preferable to have the pH of water above 6.5; river water and well water normally are about 8.0. With reservoir and river water, it may be necessary to check water more than once during the period of anticipated use.

Waste waters are beginning to be used for irrigation. These should be tested for salt and heavy metal content often to determine their feasibility as a source. Some waste waters may be high in nitrogen, which could stimulate excessive vegetative growth. Soil Conservation or Extension Specialists can offer assistance in determining the volume of water needed, the amount available from a particular source and the quality.

Irrigation Scheduling. With today's costs and narrow profit margins, no one can afford to schedule irrigation based on the guess method. By understanding the requirements of the plant, the soil characteristics and by monitoring rainfall and evapotranspiration, a good scheduling method can be developed. Different maturity groups of soybeans are known to require different amounts of water at various stages of growth in different locations across the state. These requirements must be met either from rainfall or supplemental water to achieve maximum yields. These requirements, however, must be timed to system capacity, soil relationships, and rainfall occurrences.

Determining how much water to apply is directly related to equipment capacity, soil texture and rooting depth. Soil survey maps from the Soil Conservation Service (and Table 12-1) give the inches of available water in the effective root zone. When soil moisture levels are depleted to about 50% (greater depletion will soon result in wilting), irrigation should begin. As an example, on a loam with a rooting depth of 2 feet, at 50% depletion, 2 inches of available moisture will remain and about 2 inches should be added by irrigation. In the early growing season, when water stress is less important to the plant and rainfall frequency is greater, it is often most efficient and economical to refill only about 80% of the total capacity. Thus, in the above example about 1.6 inches should be applied instead of 2 inches.

Several methods exist to determine when soil moisture depletion is at 50% or other levels. Three common ones are: 1) the hand or feel method; 2) use of tensiometers or moisture (gypsum) blocks, and 3) Blaney-Criddle or balance sheet method.

The feel or hand method involves the irrigator firmly squeezing a ball of soil in the hand and relating the consistency of the firmed ball to established descriptions. These descriptions are available from the SCS. An experienced irrigator will find this method fairly reliable; however, it is still quite variable, as the category descriptions are very general.

Instruments referred to as tensiometers and moisture (gypsum) blocks have been developed to indicate soil moisture status by the reading of a meter. Tensiometers are probes 1-2 feet long that are placed at random locations in a field when the profile is full of moisture, and remain there during the irrigation season. This instrument gives reading in centibars. In the early growing season (before mid- to full-flower for indeterminates, early flower for southern determinates), irrigation should begin at a reading of about 70 to 80 centibars. During flowering and pod fill, irrigations beginning at 50 centibars is suggested. Tensiometers have a moderate initial cost and require some time to initially set in the field. They are best adapted to coarse textured soils.

Moisture blocks, sometimes referred to as gypsum blocks or electrical resistance blocks, make use of stainless steel wire inbedded in gypsum. These blocks are placed in the soil at various locations and to a typical depth, like the tensiometers, of both 6 and 18 in. An electric resistant meter is connected to the lead wires. The resistance reading can be calibrated to soil moisture or to moisture tension. These are especially adapted to fine textured soils that do not encounter high salt content.

Several balance sheet methods are used in different regions throughout the United States. Most of these have been adapted to small computers and/or programmable computers to speed calculations. Missouri researchers and Extension personnel have developed a method referred to as the "modified (or 80%) Blaney-Criddle" method. This method is a modification of the method developed by Blaney, Criddle, and the SCS and uses concepts developed for corn by Woodruff. Information on geographic location and long-term weather data, along with information on planting date, variety, and available soil moisture-capacity are used to estimate potential evapotranspiration, water use, and recommended times for irrigation application. The irrigator must also keep records of amount of rainfall and irrigation water applied. The computer develops information for potential irrigation time intervals related to equipment design. The Blaney-Criddle balance sheet method requires little time for the grower to use and has been shown, when used in eastern Missouri, to produce among the highest yields of soybeans from any balance sheet method, while normally using less irrigation water.

Balance sheets, developed with the computer program AG0036, are available at County Extension Centers. Irrigators can obtain these balance sheets prior to the irrigation season.

MU Guide #4420, *Irrigating Soybeans,* can also provide more information on irrigation procedures.

Chapter 13

Harvest, Drying & Storage

William Hires, David Williams and Robert George

Harvesting

The high investment a farmer has in the soybean crop makes it necessary that he harvest all the highest quality soybeans possible from his fields. This chapter describes methods to minimize harvesting losses and increase return on the investment.

Losses from Poor Combine Operation and Adjustment

Harvesting losses cannot be reduced to zero, but a careful operator can reduce losses to an acceptable level without affecting the rate of working. No matter how careful, some soybeans will always be left in the field. Loss can occur on the ground before combining, from the machine because of cutting too high or poor driving and through the machine if the pods are not completely threshed, or the beans are thrown out of the machine.

Poor adjustment and operation of the combine may cause damaged grain that will lower the sale price, storage quality and germination of the soybean.

Operating the combine under poor conditions will increase wear on the machine, shorten the life of the combine, increase repair bills and require excessive amounts of power.

Losses occur in four separate areas of the combine — cutting and feeding, threshing, separating and cleaning they are known as *cutterbar, cylinder (rotor), rack* and *shoe* losses.

1. **Cutterbar Loss:** Tests on farmer operated combines have shown an average loss of 8 to 12% of the total crop including:
   a. Beans shattered onto the ground.
   b. Beans remaining in pods on the stubble.
   c. Beans remaining in pods on stalks which had been cut off but not fed into the machine.
   d. Beans in pods on lodged stalks.
   e. Modified sickle mechanisms (modified guards, double sickle) have been shown to reduce shatter losses in an Illinois study when beans were harvested at lower moisture content.
2. **Cylinder (Rotor) Loss:** Results have shown a loss of only 1%. Nearly all of the beans are threshed out by the cylinder or rotor.
   a. Percentage of splits is higher for conventional combines compared to rotary types.
   b. Properly adjusted conventional cylinders do not result in more splits than are allowed under current dockage levels.
   c. Germination tests show a higher percentage germination for rotary harvested soybeans.
3. **Rack and Shoe Loss:** Losses average 1.0% thus separating and cleaning losses are not serious.
4. **Preharvesting Losses:** Soybeans found on the soil surface before harvesting.

While the average loss is 13%, a good operator should be able to hold his losses at 3-5%. Every extra bushel saved at harvest is clear profit. With a harvesting rate of 2.5 A/hr. and soybeans having a value of $5.00 bu., the average farmer can gain $34 to $40/hr.

Measuring Soybean Harvest Losses

1. A average of 4 beans/sq. ft. equals about 1 bu./A loss.
2. Construct a rectangular frame that encloses an area of 10 sq. ft. and is equal in width to the combine header. See Table 13-1. A plastic clothesline taped to four wire pins made of No. 9 wire makes a handy measuring frame.

Table 13-1. Dimensions for Rectangular Frame.

Header Width (ft.)	Frame (in.)
8	15
10	12
12	10
13	9.25
14	8.6

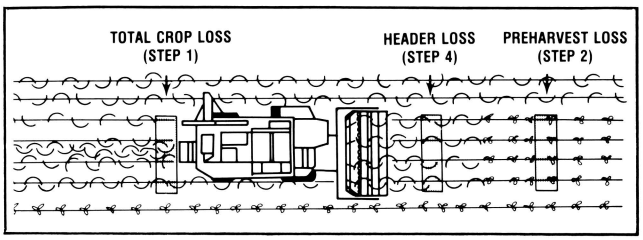


Figure 13-1. Placement of rectangular frame to count harvest losses.

3. Place the rectangular frame across the machine swath (Figure 13-1) and count seeds for total loss, header loss and preharvest loss.

The Procedure for determining losses (Table 13-2) is:

1. Stop combine at least 300 feet in from ends of field and where crop is typical of entire field. Back up combine about 15 feet. Place rectangular frame across swath harvested at rear of combine. Count all beans in frame and enter this count in Loss Data Table column 1-A. Divide this number by 40 and enter the bu./A loss in column 1-B. If loss is near 3% of yield, keep right on harvesting. If loss is greater, then determine the sources of loss.
2. Determine pre-harvest loss by placing rectangular frame in standing beans in front of combine. Count loose beans on ground and beans in pods laying loose on ground. Enter this number in column 2-A and then divide by 40 to get loss in bushels per acre. Enter this loss in column 2-B.
3. Machine loss is determined by subtracting the preharvest loss from the total crop loss. If machine loss is near 3% of yield or less, keep right on harvesting. If more, check gathering unit losses.
4. Gathering unit losses are determined by placing the rectangular frame in the space between the parked combine and the standing beans.
   a. Shatter loss — count all loose beans and loose pods on the ground. Enter this number in column 4a-A and enter the bu./A loss in column 4a-B.

Table 13-2. Harvest loss calculations.

Source of Loss	A Beans in 10 Sq. Ft.			B Your Bean Loss in Bu./A	C Acceptable Loss in bu/A (40 bu yield)
1. Total Crop	_____	÷ 40*	=	_____	1.3
2. Pre-Harvest	_____	÷ 40	=	_____	0.1
3. Machine	_____	÷ 40	=	_____	1.2
4. Gathering Unit	_____	÷ 40	=	_____	1.1
a. Shatter	_____	÷ 40	=	_____	0.4
b. Loose Stalk	_____	÷ 40	=	_____	0.2
c. Lodged Stalk	_____	÷ 40	=	_____	0.2
d. Stubble	_____	÷ 40	=	_____	0.3
5. Cylinder and Separation Loss	_____	÷ 40	=	_____	0.1

* Number beans to equal 1 bu./A loss.

   b. Loose stalk loss — count all beans in pods attached to soybean stalks that were cut but not gathered into machine. Enter number in column 4b-A and enter bu./A loss in column 4b-B.
   c. Lodged stalk loss — count all beans in pods attached to soybean stalks that were lodged and are still attached to the ground. Enter number in column 4c-A and enter bu./A loss in column 4c-B.
   d. Stubble loss — count all beans in pods still attached to stubble. Enter this number in column 4d-A and enter bu./A loss in column 4d-B.

   Total gathering unit loss is now obtained by adding the losses in column B for shatter, stubble, loose stalk and lodged stalk losses. Enter this number in column 4-B.
5. Cylinder and separation loss is now determined by subtracting the gathering unit loss from the machine loss. Enter this difference in column 5-B.

Note: Compare your harvest loss levels to those in column C. Then concentrate on machine adjustments and operating practices that will give the least total loss. Repeating these loss checks in different parts of the field will greatly increase their accuracy.

Tips for Keeping Combine Losses Low

1. Have the machine in good repair. Sharp knife sections and ledger plates are essential. Check combine for proper governed engine speed or PTO speed. This is basic.
2. Adjust reel speed to be 25% faster than ground speed, then strive to maintain that ground speed. A "variable reel speed drive" permits reel speed to be controlled "on the go" and matched to any ground speed. A six-bat reel feeds more even.
3. Position the reel so it enters the crop only enough to gain control. Hydraulic cylinders make it possible to change reel height while on the go. The reel axis should be 6 to 12 inches ahead of the knife.
4. Keep the seedbed level. Do not hill-up soil around beans when cultivating. Operate the cutterbar as close to the ground as possible. Studies indicate harvest losses with standard rigid grain heads of 8-10%, 6-8% for floating cutterbars, around 4% for flexible-floating cutterbars and about 2-4% for rowcrop heads.
5. A "pick up type reel" with "pick up guards" is recommended when beans are lodged and tangled. Row crop heads are used for this also.
6. Forward speed should be right at 3 mph on most machines to prevent stripping of beans from stalk. Check stubble height. If it is uneven and jagged, forward speed should be reduced.
7. Cylinder speed and clearance should be set according to the manual. Actually measure the clearance unless cylinder scale plate has been cali-

brated. In dry beans, the required cylinder-concave clearance may vary from ¼ to ⅜ inch depending on moisture. Closer clearances are used for damp conditions. Double the cylinder speed for early morning harvesting, or on misty, rainy days, when the bean pods are damp. Reduce cylinder speed to normal as bean pods dry. A variable speed drive for the cylinder makes this practice more feasible.

8. Set cleaning sieves and wind according to manual then note condition of beans in the grain tank. Separation loss is normally low, but in extremely weedy conditions, forward speed may have to be reduced to prevent overloading the rack and shoe.
9. Complete the harvest as quickly as possible after beans reach 15%. Take advantage of damp pod conditions, but use appropriate machine settings.
10. Proper combine operation, adjustment and maintenance is impossible without the operator's manual. The above recommendations should not supersede that.

Drying

Soybeans are a high oil content crop, containing about 18% oil. Oil contains no water, therefore, the water in soybeans is held in the other 85% of mass. The high oil content perhaps explains some interesting characteristics related to drying that are unique to soybeans.

Equilibrium Moisture Content of Soybeans

Soybeans are hygroscopic and give up or absorb moisture from air more easily than any other crop. The equilibrium moisture content is the moisture to which soybeans will dry or re-wet when exposed to air at a particular temperature and relative humidity for a long period of time. Data from Table 13-3 shows that at 70°F soybeans will dry to 15% moisture when subjected to 80% relative humidities and to 8.7% moisture with 50 relative humidity.

The equilibrium moisture content relationship explains why the moisture content of soybeans changes so rapidly in normal field conditions.

Soybeans dry rapidly in the field after maturity. Some data show beans will dry from 60% to 50% moisture in 16 days, and 50% to 10% moisture in 10 days. The last 10 days represent a 4% moisture change per day. Such rapid natural field drying makes it difficult to harvest a total crop early enough to minimize field losses due to overdrying.

Soybeans will change moisture content in the field between day and night after field drying to 13% and lower. Typical moisture changes can be from 16% at night to 9 to 10% during the hot, dry part of the days.

Table 13-3. Equilibrium Moisture Contents for Soybeans at 70°F

Relative Humidity	Percent Moisture (70°F)
20	4.0
30	5.5
40	7.0
50	8.7
60	10.4
70	12.5
80	15.0
90	18.6

Drying Specifications

Most drying systems can be used to dry soybeans if proper considerations are given to drying temperatures and relative humidities. The handling system on the drier should be evaluated for its potential to develop cracks and splits.

High Temperatures: Continuous flow driers have been used to dry soybeans. To avoid overdrying and cracking, temperature controls should be set at 110 to 130° and the pressure on the burner should be lowered. The drying air temperature for seed beans should not exceed 110°F. Check to see if the burner relights each time it cycles. The unloading auger speed may need to be increased to avoid overdrying.

Natural Air Systems: Natural air bin drying systems are very efficient for drying soybeans. Harvesting can proceed at normal rates until bins are full or until the total pounds of excess water in wet beans exceed the drying capacity of the system. Special attention should be paid to the management practices for drying soybeans when excessive moisture or adverse weather is encountered.

Sizing Natural Air Systems: The amount of water each cubic foot per minute of drying air can remove from soybeans is determined by the moisture content of the beans and the relative humidity of the air. The pounds of water to be removed are increased as bushels and depths are increased in bins. At the same time, drying rates are reduced because of increased depths reduce air flow rates from drying fans.

The problem is to match the pounds of water to be removed to the capacity of fans to remove the water before the grain is damaged by mold growth. Table 13-4 matches fan horsepower to bin diameters. The resulting air flows in cfm/ft² of floor are about equal for the combinations given.

Table 13-5 gives recommendations for maximum depths of soybeans at a given moisture content for safely drying when fans are matched as given in Table 13-4. Use 0 in the first column "depth of dried grain" for the initial fill for the given moisture. The top layers

Table 13-4. Fan horsepower requirements.

Fan Horsepower vs. Bin Diameter	
HP	Dia. (ft.)
5.0	24
7.5	27
10.0	30

of this initial fill *must* be dried to 15.5% before any additional grain can be added. The second fill can be determined from Table 13-4. After the top layers of the first fill is dried to 15.5%, the maximum depth of new grain can be determined from the depth of dried grain in the bin and the moisture content of the new grain. This second fill must be dried to 15.5% before additional grain can be added.

The initial fill should not be greater than 5 to 6 feet if the moisture is greater than 18% because of the delay in harvesting while waiting for the first fill to dry to less than 15.5%.

Supplemental Heat: The relative humidity of drying air will be reduced to 70% and lower early in the day on normal days when drying soybeans. Table 13-3 shows soybeans will dry to 12.5% if the relative humidity is 70%. It is easy to *over dry* soybeans.

Supplemental heat can be used during adverse weather. To avoid overdrying the temperature rise should not exceed 10°-15° above the average daily temperature. Run the fans continuously if moisture contents are above 16%.

The lower layer of beans will be overdried during normal daytime operation. These lower layers of overdried beans will absorb moisture from the air at night, and the dehydrated air will dry the wetter layer above. Cracks can result from drying soybeans at relative humidities below 40%. A good rule of thumb is that a 20°F temperature rise will cut relative humidity in half, e.g. If relative humidity is 80% a 20° temperature rise will reduce drying air relative humidity to 40%. It has been reported that 100% cracks can result in 5 minutes when drying below 40% relative humidity. Cracks will be generated when handling soybeans at 12% and lower.

Table 13-5. Natural Air Drying Schedule. (Based on fan-bin match in Table 13-4. Depths can be increased with larger fans.)

	% Moisture of Soybeans Added to Bin						
Depth (ft.) of Dried Grain (Less than 15.5%)	22	21	20	19	18	17	16
	Maximum Depth Added to Dried Depth						
0-(1st fill)	8.9	10.2	12	13.2	14.5	16	17.2
4	7.8	9.2	11	12.1	13.5	14.9	16.2
6	7.3	8.6	10.4	11.5	13.0	14.4	15.6
8	6.7	8.1	9.8	11.0	12.5	13.7	15.0
10		7.5	9.3	10.5	12.0	13.2	14.5
12			8.7	10.0	11.5	12.7	14.0
14					10.8	12.2	13.5
16							13.0

Management of Drying System

1. Following recommendations from Tables 13-3 and 13-4 will provide adequate and economical design for drying soybeans.
2. Do not overload bins. Excessive depths of wet grain will increase drying costs and delay harvests.
3. Level grain; unequal depths result in uneven drying.
4. Trash will affect drying. Uneven moisture gradients can result in hot spots during later storage.
5. Run fan continuously if grain is above 16% moisture. *DO NOT* turn off fan for periods of rain or bad weather.

Storage

Beans should be cooled in the fall to 40°F. The bins should be checked regularly during the winter. The grain should be warmed to 60°F in the early spring.

Efforts should be made to maintain not more than 15° difference between beans in storage and the average outdoor temperature.

Care should be used when warming beans in the spring. Start fans for cooling when the outdoor temperatures are about 10° warmer than grain temperatures. Forcing air warmer than 10° above grain temperatures can cause moisture condensation within the grain mass. This condensed moisture can cause beans to go out of condition later.

Soybeans that are heating or otherwise out of condition should be cooled regardless of weather conditions. Fans should be operated, under these conditions, until the cooling front has passed entirely through the mass of grain.

Comments are often made saying that beans will go out of condition easier than other grains. Beans stored at 13% moisture and allowed to heat to 70°F will have 72% relative humidity in the air surrounding the beans. 70°F temperatures and 72% relative humidity will support mold growth over time. The unique equilibrium moisture content characteristic of soybeans are the major reason beans can go out of condition easier than other grains.

Chapter 14

Economics

Herman E. Workman and Dale Schnarre

Growth of Soybeans in Missouri

Soybean acreage in Missouri has grown at an annual rate of over 100,000 acres per year since 1950. In the mid-1960s soybeans became the new king crop in Missouri as harvested soybean acreage surpassed corn. Since 1950, soybean yields have increased about 15 bushels per acre, while acreage has expanded over 3.6 million acres. Government programs to restrain corn and wheat acreages, together with low prices for other crops, and expanding world demand during the late 70s and early 80s helped stimulate the expansion of soybean output in Missouri. Table 14-1 reports five-year averages for soybean acreage, production, yield, and season average price for farmers since 1950.

Profitability of Soybeans on Missouri Farms

Comparing Soybeans with Other Crops

It is no accident that soybeans emerged as Missouri's top cash crop in the early 80s. In 1978, 1979, and 1980, Missouri farmers harvested over 5.5 million acres annually of soybeans valued at over one billion dollars each year. Records from farmers participating in the University of Missouri Mail-In Record (MIR) Program show how soybeans compared with other crops over the last few years. Table 14-2 compares the percent return to capital and management for the major crop enterprises since 1978. Soybeans were clearly the crop leader with an average of 12.0% return to operating capital and investment over the 1978-80 period. The profitability of soybeans on MIR farms compared to corn and wheat has declined substantially during the 1981-85 period. This decline reflects the continuing export problems and lower prices for soybean producers. At the same time, wheat and corn producers have had target price protection under government programs. However, the eight-year average in Table 14-2 shows soybeans a slight leader in profitability followed in order by wheat, corn, and grain sorghum.

Part of the high rating of soybeans was due to the consistency in yields over a period of years of variable weather patterns in Missouri. This is also shown in Table 14-2 where soybeans averaged 30.3 bu./A over the eight-year period 1978-85.

Corn enterprise often contributes to the profitability rating of soybeans but the opposite is also true. Corn contributes unused fertilizer to soybeans and reduces most disease pressure. The soybean contributes nitrogen to the soil and reduces the need for insecticides on corn. Because soybeans on hill land tend to promote soil erosion, unless conservation measures are taken, these losses may also offset some of the profits accrued to the soybean or other crop enterprise. Corn-soybean rotations are affected ultimately by price. When the price of soybeans is expected to be more than 2.6 times the price of corn, there is expansion of soybeans and a reduction of corn acres.

The pattern of the division of corn and soybean acres depends on other factors: the corn/soybean yield relationship, government programs, livestock on

Table 14-1. Missouri Average Acreage, Production, Yield, and Price for Soybeans.

Period	Acreage (000)	Production (000 bu.)	Yield (bu.)	Price ($)
1950-54	1,594.6	27,590.6	17.9	2.55
1955-59	1,968.4	42,400.0	21.4	2.02
1960-64	2,600.8	58,822.0	22.6	2.30
1965-69	3,328.6	84,284.2	25.4	2.40
1970-74	4,061.0	103,003.6	25.7	4.42
1975-79	4,918.0	137,591.0	27.2	6.27
1980-84	5,336.0	133,627.0	25.0	6.57
1985-86	5,265.0	178,993.0	34.0	4.73

Source: Missouri Farm Facts

Table 14-2. Percent Return to Capital and Management and Average Yield Per Acre for MIR Records, 1978-85.*

	1978-80	1981-83	1984-85	8-year average
Percent return to capital and management:				
Soybeans	12.0	4.9	3.1	7.1
Wheat	9.7	2.8	6.4	6.3
Grain Sorghum	6.7	2.6	3.5	4.4
Corn	6.5	5.1	7.0	6.1
Average yield (bu./A):				
Soybeans	32	30	28	30.3
Wheat	44	38	41	41.0
Grain Sorghum	75	65	72	70.5
Corn	83	92	101	90.9

* Data available through the cooperation of Missouri farmers who participated in the University of Missouri Mail-In Record Program.

farms, relative profitability of other crops (as in southeast Missouri), need to spread labor and machinery requirements at planting and harvesting, the effect on yields via pest control, and the need to reduce production and market risks.

Soybean Costs and Returns

Records from Missouri farmers participating in the MIR Program provide a history of costs to produce soybeans and other crops. Total costs to produce soybeans increased 48% in the five-year period from 1977 to 1981. However, total costs per acre declined 11% from 1981 through 1985 (Table 14.3). Total costs per acre include operating, ownership, and labor.

Operating or variable costs per acre are those costs that vary with the level of production each year. These items include: seed, fertilizer, chemicals, machinery repairs, fuel, interest, and miscellaneous out-of-pocket costs. These costs represent about 38% of the total costs to produce an acre of soybeans. For 1985 the average soybean operating cost per acre for MIR farms was $76.50, which represented an 11% decrease below 1981-82 operating cost. Operating cost for the corn enterprise decreased 6% for the same period.

Ownership or fixed costs per acre are those costs that do not vary with the level of production each year. These include: depreciation and interest on machinery, interest and taxes on land and other real estate, and possibly the cost of labor (operator's and/or other fixed labor expenses). These costs (including labor) represent about 62% of the total costs to produce an acre of soybeans. For the 1985 year, the average ownership and labor costs were $124.00 per acre. Spreading fixed costs per acre over more bushels by attaining higher yields offers the greatest opportunity for reducing per bushel costs and enhancing profits. Comparisons of similar per acre costs for corn are also shown in Table 14-3. This table also allows you to estimate your cost of production and compare it with the average returns of the MIR participants.

Economic Evaluation of Soybean Production Technology

Will a switch from a conventional soybean production technique or system be profitable? New soybean technologies or systems include: double-cropping, minimum tillage or no-till, irrigation, and narrow row or drilled seeding. In addition, selection and use of herbicides, fertilizer, varieties, etc., lend themselves to economic analysis.

Producers must weigh added benefits versus added costs. *Added benefits* may include: increased yields, reduced costs, reduced soil losses, higher quality, etc. *Added costs* may include: increased costs, risk of reduced yields, increased soil losses, lower quality, etc.

Double-Cropping Soybeans

Double-cropping means harvesting two crops (soybeans and wheat) from the same land in the same year. It has two special advantages for the farmer: (1) spreads part of the high fixed or ownership costs (more than 60% of the total costs) over more bushels — thus, reducing the average cost per bushel, and (2) spreads production and price risks over two crops in the same year. The practice of double cropping soybeans, however, has not increased in recent years. The primary reason has been the reduction of wheat acreage in Missouri due to adverse weather conditions at planting time. The Crop and Livestock Reporting Service estimated about 9% of Missouri's soybeans grown in 1985 were double-cropped compared to 10% in 1980.

Table 14-4 shows the projected added costs to produce an acre of double-crop soybeans. The table assumes a wheat crop was produced and includes only the extra costs of growing the soybean crop. The breakeven production level at 1987 costs is also shown. At $5.00 per bushel, it takes about 15 bushels of soybeans to pay for the added costs per acre. Additional yield above this provides an added return to land, management, overhead, and risk.

Irrigation

Does it pay to irrigate soybeans in Missouri? The answer depends in large part on the amount of rainfall and distribution in a particular area, expected yield increase from irrigation, amount of investment per acre, soil type, and management ability. Missouri precipitation averages from 37 inches in the Northwest

Table 14-3. Soybean and Corn Costs in Missouri.*

	Soybeans				Corn			
	1981-82	1983-84	1985	Your Farm	1981-82	1983-84	1985	Your Farm
Average yield per acre (bu.)	33.6	21.2	36.3	_____	109.9	71.7	113.2	_____
1. Average operating costs per acre:								
Seed	$ 11.75	$ 12.25	$ 10.25	_____	$ 17.00	$ 18.25	$ 16.50	_____
Plant food (fert. & lime)	8.00	5.50	4.25	_____	48.25	48.50	43.50	_____
Crop chemicals	19.25	21.25	19.00	_____	20.25	19.75	18.00	_____
Machine hire	5.00	4.00	5.50	_____	5.50	4.75	10.00	_____
Machinery fuel, oil, & repair	25.50	24.25	22.25	_____	31.50	30.00	28.50	_____
Miscellaneous	7.75	8.75	8.75	_____	13.50	13.50	13.75	_____
Operating interest	9.25	8.50	6.50	_____	10.50	10.00	8.00	_____
Total operating costs	$ 86.50	$ 84.50	$ 76.50	_____	$146.50	$144.75	$138.25	_____
2. Average ownership cost per acre:								
Crop machinery depreciation, and interest	$ 31.00	$ 31.75	$ 27.00	_____	$ 39.50	$ 41.25	$ 34.00	_____
Real estate depreciation, taxes and interest	87.50	86.25	78.00	_____	100.25	101.50	92.50	_____
Total ownership costs	$118.50	$118.00	$105.00	_____	$139.75	$142.75	$126.50	_____
3. Average labor costs per acre	$ 19.75	$ 21.00	$ 19.00	_____	$ 23.75	$ 24.50	$ 22.00	_____
Average number hours per acre	4.3	4.5	3.9	_____	5.3	5.4	4.5	_____
4. Average total costs per acre	$224.75	$223.50	$200.50	_____	$310.00	$312.00	$286.75	_____
5. Non-land costs per acre	$144.75	$130.25	$129.25	_____	$220.25	$221.00	$204.50	_____
6. Average total costs per bushel	$ 6.69	$ 10.54	$ 5.52	_____	$ 2.82	$ 4.35	$ 2.53	_____

* Summarized from enterprise records of Missouri farmers participating in UMC Mail-In Record Program. Two-year records were averaged 1981-82, 1983-84 and 1985.

to near 46 inches in the Southeastern corner. Response of soybeans to irrigation in Missouri has been erratic. Variability of yields (from annual farmer surveys) ranged from 15 bu./A for a ten-year period for irrigated beans and 30 bu./A for non-irrigated beans. In addition, these survey results show an average of 12.2 bu. difference between irrigated and non-irrigated beans. With an average added cost of $83.50 per acre (Table 14-4), irrigators need about $6.85/bushel to cover their added costs.

The response of soybeans to irrigation can be dampened with soils that have a good soil moisture holding capacity or with good precipitation during the pod filling stage. It is difficult to determine whether an irrigation system used only for soybeans will be economically feasible for a particular farm. However, if you have already invested in irrigation for corn, and other crops, you may have a better chance of making soybean irrigation pay than if you do not spread the investment over several crops.

Irrigation for Double Cropping

Proper irrigation can eliminate the most serious problem in double-crop soybeans, which is inadequate soil moisture to get the second crop established. If you already have an irrigation system, then double cropping should receive a high priority in a farm system. If you are not irrigating but considering it, the possibility of double cropping under irrigation should be taken into account when making the decision. For double-crop beans, the annual farmer surveys indicated an additional 12-bushel increase over non-irrigated beans over a ten-year period.

Decision to Irrigate

Table 14-4 shows the estimated per acre added operating, ownership, and labor cost for irrigating soybeans for an example system. The estimated added operating and labor costs are based on Missouri irrigation survey results. Added ownership costs are calculated based on $425 per acre added investment in an irrigation system that includes the cost of the water source. Source of water and acres irrigated can greatly affect this value. Breakeven analysis for soybean yields are shown. For a soybean price of $5.00, one would need to produce an additional 16.7 bu./A to cover all expected added costs.

If a producer is convinced that it will be profitable to install an irrigation system, an adequate source of good quality water must be available.

Some farmers are pumping their water from streams for irrigation. This can be a relatively good and low-cost source; but, of course, the stream, like a shallow well, may dry up in a dry year. Impounding surface

Table 14-4. Estimated Added Costs Per Acre

	Double-Crop[1]			Irrigated Single-Crop			Drilled	
	Example		Your Farm	Example		Your Farm	Example	Your Farm
1. Added operating costs per acre:								
Seed	$10.00						$ 2.50	
Fertilizer: P_2O_5 — @20¢	3.00	(15 lbs.)		$ 1.50	(8 lbs.)			
K_2O — @10¢	3.00	(30 lbs.)		1.50	(15 lbs.)			
Machinery operation and hire	20.00							
Herbicides							7.50	
Hauling				1.25				
Fuel for irrigation				10.75				
Irrigation repairs and maintenance				2.50				
Miscellaneous	6.50							
Operating interest (½ operating costs × 11%)	3.50			1.00			.50	
Total added operating costs	$66.00			$18.50			$10.50	
2. Added ownership costs per acre:								
Irrigation equipment, depreciation, taxes, and interest				60.00[2]				
3. Added labor costs per acre	8.00			5.00				
Total added costs per acre	$74.00			$83.50			$10.50	
4. Breakeven added double-crop soybean yields:[3]								
Soybean price/bu.	bu./A			bu./A			bu./A	
$4.50	16.4			18.6			2.3	
5.00	14.8			16.7			2.1	
6.00	12.3			13.9			1.8	
7.00	10.6			11.9			1.5	

[1] Table assumes a wheat crop was produced and includes only the extra cost of growing the soybean crop for double cropping.
[2] Irrigation investment per crop acre of $425, average 13-year life on equipment, taxes 1% of investment, and interest at 11%.
[3] Total added cost divided by expected average soybean price per bushel.

water is possible in many areas of the state, however, an appreciable loss may occur both from evaporation and seepage.

Drilled Soybeans

The main reason for planting soybeans to narrower rows (less than 15 inches) or to solid seed is the potential yield increase. Since 1981 acreage planted to narrow rows (rows less than 10 inches) has increased from 18.2% to 25.7%. This indicates that more farmers are planting soybeans to narrow rows. According to a mid-Missouri soybean study (non-replicated), an average of 2.8 bu. increase was observed on drilled soybeans when compared to 30-inch row planting in 1983-84.

To evaluate the feasibility of drilled soybeans, weigh the added benefits against the added costs. An example of such an analysis is illustrated in Table 14-4. Added operating costs include seed, fertilizer, post-emergent herbicide, hauling, and operating interest. Added ownership costs may involve a new drill to accommodate proper row width but part of its cost may be offset by use in planting wheat. In our example, the fixed or ownership cost are absorbed by the wheat enterprise.

The added benefits from drilled beans would be the additional yield increase, possible reduced cultivation, and reduced soil erosion.

The increase in yield necessary to cover the costs associated with switching to drilled beans will vary depending on the expected soybean price. The example used in Table 14-4 indicates that drilled beans would cost an additional $10.50 to produce over conventional row width beans. This means that for soybeans selling at $5.00 per bu. a net increase of 2.1 bu. would be needed to recover the added cost. Added costs per farmer will vary depending on current management practices and equipment being replaced.

Not all farmers should convert to narrow rows or drilled beans. Some farmers can boost yields more economically by improving their management on their current soybean system. Better variety selection, fertilizing economically, proper timing of planting and harvesting, and better weed control could increase yields by more than reducing row widths.

Other considerations such as type of farming lease arrangements could deter the added benefits gained from drilled beans. The owner-operator may be in a better position to change to drilled or narrow row beans than a renter or tenant. The tenant or renter could pay a larger share of the increased cost.

Chapter 15

Marketing

Richard K. Rudel

Supply and Demand

World and U.S. Soybean Supplies

The 1980/81 world soybean acreage was 136 million acres, 66 percent more than the 1972 acreage. Of the 1981 acreage, 86 percent was in the United States, Brazil and China, down from 90 percent in 1972. World soybean acreage has been declining in recent years. Between 1980 and 1986 acreage decreased by 5 percent, with the United States accounting for most of this adjustment.

Much of the United States decline in soybean output over the past several years has come from the decline in profitability of soybeans, relative to the government price support programs for other crops, such as feed grains and cotton. Soybeans have also faced increasingly stiff competition from South America as can be seen in Table 15-1.

Soybean Exports

The U.S. production of soybeans and products has increased at a much faster rate than domestic use or demand. In 1980 and 1981 the United States exported a total of 870 million bushels of soybeans, 1.6 billion pounds of soybean oil, and 6.8 million tons of soybean meal. By 1986 U.S. exports of soybeans, meal and oil had declined significantly as reported in Table 15-2. While most of the world markets for U.S. soybeans and products are in countries such as Europe (EEC, Western and Eastern), significant quantities of exports are made to Japan, Taiwan and other Asian countries. The recent declines in exports of soybeans and their products has been due to economic problems in many European countries, international political and trade disputes, and increasing competition.

Soybeans continue to play a major role in contributing positively to the U.S. trade balance. In 1981, U.S. soybean exports contributed slightly over $8 billion, and in 1986 soybeans contributed $4.7 billion.

Soybeans play a major role in Missouri's economy. In 1981, the value of soybeans and products exported

Table 15-1. World Soybean Acreage

Continent and Country	1980 Acreage (1,000 acres)	% of total	1986 Acreage (1,000 acres)	% of total
North America	75,313	55	61,317	47
United States	74,144	54	59,501	46
South America	28,857	21	33,460	26
Brazil	24,232	17	22,980	18
Argentina	5,022	4	9,020	7
Paraguay	1,404	1	1,460	1
Europe	1,463	1	1,905	1.5
Russia	2,190	2	1,853	1.5
Africa	224	*	677	*
Asia	25,679	19	28,678	22
China	19,710	15	20,361	15.7
Indonesia	2,079	2	0	*
WORLD TOTAL	136,188	100	129,307	100

* Less than 0.6 percent

Table 15-2. United States Soybean Exports

Item	1980	1986
Soybeans	1,000 Metric Tons	
European Community	10,721	8,863
Other Western Europe	2,668	186
Eastern Europe[1] + USSR	2,199	2,027
Other	8,230	9,063
Total	23,818	20,139
Soybean Meal		
European Community	3,836	2,632
Other Western Europe	198	10
Eastern Europe + USSR	1,599	255
Other	1,562	2,573
Total	7,195	5,450
Soy Oil		
Canada	13	6
Latin America	318	132
Western Europe	12	*
Eastern Europe	12	3
Asia	648	338
Africa	53	91
Other	40	*
Total	1,096	570

was $608 million; by 1986, however, the value of soybeans and products from Missouri decreased to $479 million. Soybeans are still the single most important agricultural export commodity in Missouri.

Soybean Price Structure

The primary pricing structure includes two segments: 1) the supply, demand and governmental programs that affect and shape the pricing behavior of the market, and 2) the market forces themselves which change and direct pricing behavior. The former is known as "price determination" and the latter as "price discovery."

Factors that influence soybean prices on the supply side and demand side are evident in Figure 15-1.

Factors that interact over time alter the supply and demand of soybeans, causing variations in price relationships between markets. Consuming regions develop rates of use relative to available supplies from year to year. For example, a major decline of two to four million metric tons in Brazil's soybean crop often can result in significant improvements in U.S. export markets for soybeans and soybean products and ultimately in soybean prices.

Variations in soybean prices also are caused by factors that alter the use and supply of soybean oil and meal. Supplies of the products are closely tied together. The economic forces determining the use for oil usually differ significantly from those for meal, resulting in variations in prices of soybeans.

Variations in farm prices of soybeans can also develop because of the relationship of quality factors to actual product value and to market prices of soybeans. Normally, soybeans are marketed on the basis of federally established grades and classes. Five grades and six classes of soybeans are recognized — 1, 2, 3 and 4, plus "sample grade." Price discounts or deductions from gross weight are imposed on beans that violate grading factors.

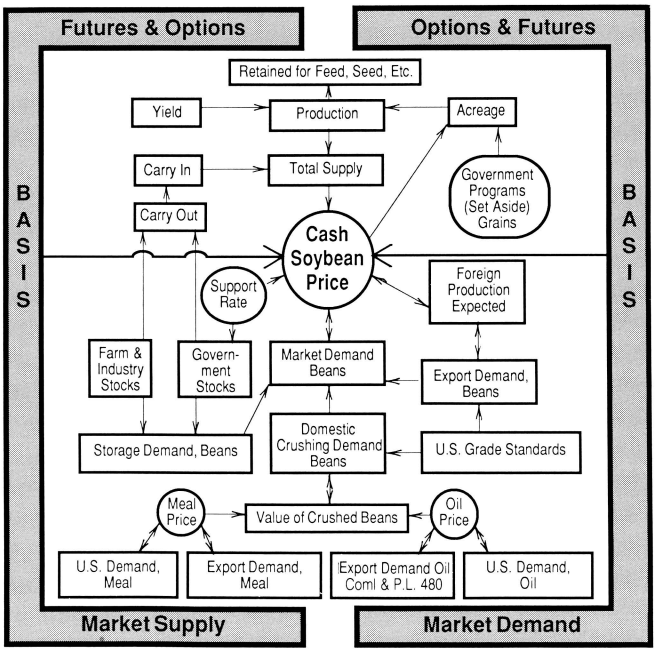


Figure 15-1. Price structure of the U.S. soybean market. Arrows indicate major directions of influence.

Producers Decision Making

Price is the hub of the system for the producer, regardless of whether soybeans are sold in the domestic or foreign markets. Price is generally governed by supply and demand, but neither domestic nor foreign markets operate in a freely competitive environment as government programs are often involved.

Producers can improve their marketing decisions and increase farm profits through proper use and analysis of marketing information and selection of better pricing and selling strategies when advantageous marketing opportunities exist.

Role of Fundamental Market Information

Market information is classified as current or historical. Current information is primarily used to adjust or update projections of supply, demand and use. Historical data is marketing information or statistics that provide estimates and projections of the supply and use of soybeans during past, current and future crop years.

Soybean price fluctuations are estimated by many sources using different forecasting techniques. USDA, for example, uses an economic model to predict average cash prices for soybeans each year. Note in Table 15-3 the differences in average prices between the selected crop years. Both large-scale and simple economic models are used by universities, private firms and individuals to project the change and level of price movements between years.

Although a producer can make an informed judgement of price trends by analyzing historical marketing information, many factors on which the estimates and projections were based are subject to change. Changes often result in price trends fluctuations and in revised price level projections.

Many factors that cause short run adjustments to supply and demand are recorded in current marketing information. Thus, it is advantageous for producers to include in their analysis current information such as that reported in Table 15-4. It includes exports, domestic crush, soy oil and soybean meal stocks data. Monthly soybean exports were averaging enough to meet and even exceed the total projected exports from the March 1986 supply and demand balance sheet shown in Table 15-3. Similarly, monthly crush data confirms that domestic processing was at a rate sufficient to meet the total projected crush for 1986. If these data, after adjustment for seasonal trends, indicate a sufficient deviation from the rate needed to meet the projections, the analysis would indicate po-

Table 15-3. Soybean Balance Sheet*

	1980-81 Estimates	1986-87 Projections
Acres		
Planted (million acres)	70.0	61.5
Harvested (million acres)	67.9	59.4
Yield/Harvest (bu./acre)	26.4	33.8
Supply (million bu.)		
Beginning Stocks	358	536
Production	1,798	2,007
Total Supply	2,156	2,543
Disappearance (million bu.)		
Crush	1,020	1,130
Exports	724	700
Seed, Ind., Res.	99	103
Total Disappearance	1,843	1,933
Ending Stocks (million bu.)	313	610
Average Season		
Farm Price/bu.	7.57	4.70

* Based on USDA Supply and Demand Projections as of March 1987.

tential price variations and/or potential adjustments to supply and use projections or estimates.

If the rates of export and/or domestic use are significantly above the rates needed to meet the projected levels of exports and use, a positive price impact could be expected. Vice versa would be true if export and/or domestic use rates are significantly below the rates needed to meet the projected levels of exports and domestic use. The producer must again place this information in perspective as a part of the total package of information and market analysis.

Table 15-4 also reports data on monthly stock levels of soybean meal and soybean oil. This information provides the current statistics needed to evaluate the composite impact of soybean oil and meal on soybean prices. Through December, 1986, monthly oil stocks were large. Large oil stocks in 1986 clearly indicated a major negative impact on soybean prices. Meal supplies followed a similar trend and were large enough to offer little support to soybean prices.

One set of marketing information is not enough to determine or analyze a trend. However, when information and analysis for each set of marketing information is arranged systematically and adjusted to new information, the composite provides significant evidence of price trend direction and magnitude.

Futures Market and Market Alternatives

Marketing and price discovery for soybeans and soybean products is facilitated by an organized futures market for beans, meal and oil. The major role of the futures trading in the soybean case is to promote the orderly movement of the commodity into domestic and foreign consumption channels throughout the marketing year. In addition, the futures market adds a time dimension to the pricing process and helps smooth out price changes due to short harvest or bumper crops, shifts in government price-support programs, changes in foreign markets, and governmental interference in trade agreements.

The futures market gives handlers, processors and producers of soybeans and their products an opportunity to obtain a return for the storage or processing. At the same time, they can avoid some risk associated with a possible adverse change in the product's price level. This risk of price changes is assumed by parties on the other side of a futures transaction.

Many soybean producers think of soybean futures markets as only a means of pricing grain. In fact, futures markets provide a significant set of statistics and data that can be analyzed by producers to determine how price trends achieve highs and lows. Data and statistics about the futures markets for soybeans includes daily and weekly price movements, recording of volume and open interest data, and the study of the actions of people that make up the futures market. Such information is published daily by the Chicago Board of Trade and is disseminated to the mass media, private and public agencies, and other sources. The term "technical analysis" describes the charting and analyzing of daily and weekly price gyrations and patterns, and the learning and recognizing of technical signals.

Information gained from the futures market can also provide a check and balance test for the evaluation of fundamental supply and demand information. The futures market records the overall evaluation of new information about supply and demand, thus providing producers a check against their own evaluation of the fundamental data. Soybean producers must be aware that often-times the futures markets will reach an evaluation of potential new information prior to the release of a report. This is commonly explained by the phrase: "the market had already built in the new information."

Table 15-4. Export Inspections, Crush, Oil and Meal Stocks, 1986

	Export Inspections[1]	Soybean Crush[3]	Oil Stocks[2]	Meal Stocks[2]
	— million bushels —		1,000 pounds	1,000 tons
Sept.	33	79.4	946.6	211.7
Oct.	115	107.0	963.6	218.0
Nov.	242	109.4	1,268.9	387.3
Dec.	310	107.6	1,506.5	240.3

[1] Accumulative totals to end of each month.
[2] Ending stocks at the end of each month.
[3] Monthly

Options Markets

Producers have an additional marketing alternative defined as a put or call option contract. A put option contract offers producers of soybeans protection against falling prices, while a call option contract offers protection against rising prices.

Options contracts differ from futures contracts in that futures contracts require margin deposits and the added risks of the additional costs of margin calls. On the other hand, options contracts require the payment of a premium associated with selected strike price for the option contract. Thus, a soybean producer using an option contract fixes and thereby limits his costs and risks to the amount of the premium in cents per bushel times the number of bushels in the contract.

Option contracts are traded in 5,000 bushel increments. Soybean option contracts are available for each of the futures contract months; however, option contracts expire in the month preceding the futures contract month (i.e. November soybean options expire in October).

To evaluate a put option contract a soybean producer can use the following formula:

Strike Price − Premium − Commission Fees − Interest Costs ± Basis

For the call option contract a soybean producer can use the following formula:

Strike Price + Premium + Commission Fees + Interest Costs + Basis

Mechanically options also differ from futures contracts in the way the producer can select to exit from his option contract. With an option contract the soybean producer has three means of exiting from the contract. The contract can be allowed to expire or it can be offset or exercised. If the market price moves up after the producer has purchased a put contract, the contract should be allowed to expire because it will be "worthless."

On the other hand, if the market price moves down after the producer has purchased a put contract, the contract should be either offset or exercised because it has "value."

For a call option contract the same exiting process is used; however, the price movements after the call option is purchased are reversed (i.e. for a call to have value the market price needs to rise).

Soybean producers who would like to obtain more information about option markets should contact the grain marketing specialists at their state universities.

Marketing Alternatives

Recognizing marketing opportunities is one thing, but being able to utilize different available marketing alternatives to take advantage of the marketing opportunities is another. Without a complete understanding of the basic mechanics, as well as the proper application of available marketing alternatives, soybean producers may find their marketing opportunities restricted.

Marketing alternatives available include:

1. Sell for cash at harvest.
2. Store at harvest and sell for cash later.
3. Forward price by contracting with a grain elevator, processor or other merchant.
4. Forward price by using the futures market or a put or call option contract.
5. Hedge stored soybeans by futures market selling or by buying a put option contract.
6. Transfer the risk of storage to the futures market by buying a futures contract or a call option contract.
7. Use delayed pricing contracts.
8. Use deferred payment contracts.
9. Use minimum price contracts.
10. Grain pooling agreements.
11. Use combinations of 1-10 above.

To illustrate the need to fully understand the mechanics and application of marketing alternatives, an example is developed from the 1981-82 soybean crop. Harvest of soybeans generally occurs in October and November. Producers can forward price soybeans, oftentimes 12 or more months prior to harvest. Thus, 1981-82 soybeans could have been priced in November of 1980. Using actual soybean futures and cash prices for November 24, 1980, resulted in the following application of forward pricing through the futures market.

Date	Cash	Futures
11/24/80	Local elevator price for Nov. 1980 soybeans $8.46	Chicago Board of Trade Futures for Nov. 1981 soybeans (selling one 5,000 bu. contract) $8.54
11/4/81	Local elevator price for Nov. 1981 soybeans $5.90	Chicago Board of Trade Futures for Nov. 1981 (buying back one 5,000 bu. contract) $6.55

Total Gross Price Received for 1981 Soybeans:	
Cash price received from local elevator:	$5.90
Gain from futures market forward price application ($8.54 − $6.55 = $1.99):	1.99
Gross Price Received Per Bushel:	$7.89

Net price would be gross price less commission fee and interest on margin deposits. In this example commissions and interest were about 6 cents per bushel resulting in a net price of $7.83 per bushel.

Locking in a price through futures markets can limit profits as well as losses. Selling a crop before it is actually produced also does not protect against the loss of a crop. Producers should compare current price expectations with future price expectations. Profit levels, cash flow needs, production decisions, and other personal attitudes and considerations can serve as guides selecting marketing alternatives.

Chapter 16

Processing

F. D. Harris

Oil-bearing seeds have been in demand for thousands of years. We have an equal demand for meal, the residual after the oil has been removed, since it is a high-protein food.

Oil seeds or beans are processed to remove the oil in such a way that both the oil and meal are of a quality that is suitable for intended uses. For human consumption, the processing is complex and regulated as for other food products. For other uses such as a fuel for internal combustion engines, the oil processing can be quite simple.

Oil Extraction Methods

Recovery of oil from oil seeds is done by several methods. The principal methods are expeller pressing and solvent extraction although a few selected seeds other than soybeans may still be processed with a hydraulic press.

Expeller. The expeller is a simple device as shown in Figure 16-1. Soybeans enter the expeller through the hopper and are forced toward the variable-area orifice at the left end of the screw. The barrel of the press shown in the figure is formed by a series of plates, each of which has a hole equal in diameter to the outside diameter of the screw. The plates are separated with shims in such a manner that the yield of oil can be maximized.

Large expellers capable of 10 to 100 tons per day use barrel-bars to form the barrel with the proper spacing in the circumferential direction. The bars are only a fraction of the length of the screw to allow a change in spacing with each new set of bars encountered as the beans progress toward the orifice. The variable-area orifice allows adjustment of the expression pressure, which also controls the flow rate of the beans through the press. The oil seeps through the open areas (spacings) of the barrel and the solids pass through the orifice; the resulting solids product is soybean meal. Meal from a mechanical expeller contains 8 to 12% oil.

Solvent. The solvent extraction process is preceded by a prepress with an expeller for high oil content seeds. For soybeans, which contain 18 to 20% oil, the extraction process is a direct process whereby a liquid material is introduced with the flakes, diffuses through, and dissolves the oil. The solvent and the solvent plus oil must be capable of diffusing through the structure of the bean flakes. The reduction of the seed to small particles or thin flakes facilitates the extraction process simply because diffusion is a property related to thickness.

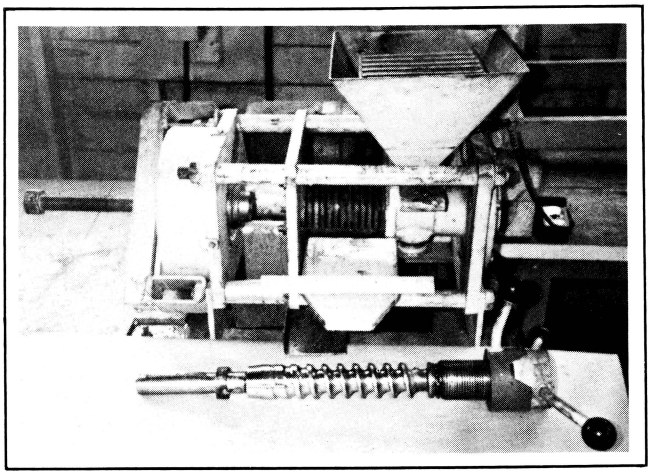


Figure 16-1. Mechanical screw press.

The most common solvent used for the extraction of soybean oil is n-hexane and the residue remaining on the meal is less than 0.002%. The work areas near the equipment cannot be maintained absolutely free of hydrocarbon vapors. There is high danger of fire. Allowable vapor concentrations are established by the Occupational Safety and Health Administration (OSHA).

The solvent extraction process consists of: a) preparation of the beans by cracking or flaking, b) extraction of the oil using a solvent, and c) reclamation of the solvent from the oil and the meal. The process and equipment associated with (a), (b) and (c) are dependent upon the production capacity, desired products and other factors, and will not be discussed here. Consult the references in this handbook. Typical

Table 16-1. Typical Yields from Large Pressing Plants

	Mechanical Expression	Solvent Expression
Oil (lb)	6	11
Meal (lb)	53 (10% oil)	48

yields of soybeans at 60 lb/bu, 20% oil content and 10% moisture are shown in Table 16-1.

The cost of manufacturing oil from soybeans is about 58 cents per bushel using the solvent extraction.

Processing

Figure 16-2 shows the processing required to produce basic edible soybean products. Processing eliminates "impurities" from the crude oil or basically alters the oil properties — flavor, color, thermal stability, odor and storage characteristics — so that the final product is market-acceptable. The impurities are solid particles, water, waxes, and oil-soluble impurities such as fatty acids, phosphotides, hydrocarbons, ketones and aldehydes. A major consideration during refining is exposure to air, particularly at high temperatures. Vegetable oil is susceptible to oxidation, which changes some desirable characteristics.

Several by-products from processing — lecithins and other hydrocarbons — are used extensively in food, health and beauty aids and other basic processing industries.

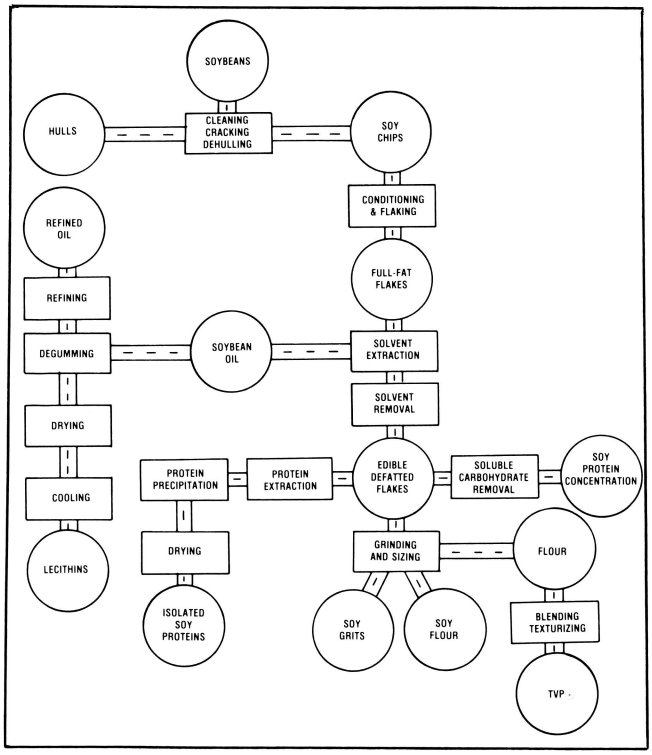


Figure 16-2. Soybean processing. Courtesy ADM, Inc.

Production of edible oil is accompanied by the production of a high protein (40%) food source for poultry, swine and some beef production. Products for human consumption can also be produced as indicated in Figure 16.2. From a bushel of soybeans, 17.8% by weight is used in the production of edible oil and 79.2% by weight is converted to meal. Soybean hulls, removed prior to the flaking process, are retained, cleaned, ground and mixed with the ground soybean meal. The addition of the hulls lowers the percent protein and adds fiber to the meal. The conversion of beans to final products is efficient, with only about a 3% loss. The oil sells for a higher price and the dollar value percentages are oil, 37% and meal, 63% (1987).

Vegetable Oil as an Alternative Fuel

Shortages and the high cost of petroleum fuels has caused greater interest in fuel alternatives or extenders. Popular alternative fuels are the alcohols, ethanol and methanol, and the vegetable oils. The future will probably include others such as higher alcohols, hydrogen and possibly others.

Vegetable oils such as soybean, sunflower, safflower, and peanut appear very promising for fuels because: a) the vegetable oils can be used directly or mixed with diesel fuel in unmodified compression-ignition engines (diesel), b) the processing required to convert the crude oil to fuel is a simple process (degumming), and c) the entire production process, i.e., growing soybeans to the production of fuel oil and meal, can be considered an on-farm process.

University of Missouri research has shown that soybean oil and diesel fuel blends do not lead to accelerated wear of engines. However, there remains the problem of injector coking, which should be solved to maintain engine power without excessive maintenance of the injection system. On-farm expression of soybean oil using a small screw press is simple and can be fully automated.

Once the oil is expelled it must be degummed and filtered. This can also be fully automated. Whereas the extraction process using a solvent such as hexane removes 98% of the oil from the soybean, the mechanical expeller will leave a significant amount of oil in the meal. Retention of oil in the meal is not a negative factor, provided the yield of oil is acceptable, because the oil provides energy in the animal diet.

Work at the University of Missouri has shown a yield of oil from unheated soybeans to be about 0.5 gal/bu, which represents 39% of the oil available. By heating the beans, a 15% increase in yield or 45% yield can be achieved.

If six gallons of fuel per acre are needed to produce all crops, with a 30 bu/A and 45% oil recovery, soybeans provide a three-to-one return. Or three acres of land can be farmed with fuel from one acre of land; or with 33% of the land in soybeans, all the land can be farmed with the fuel produced.

Chapter 17

Human Nutrition

Jean A. Ostasz and Nan Unklesbay

Soybeans have been used as foods in oriental cultures for centuries. But it was not until the beginning of the 1900s that the western world recognized soybeans for their human food value. Using soybeans and soybean products is a good way to lower the cost of serving flavorful nutritious meals and to provide variety in meals. Soybeans provide high quality protein and supplement the nutrients in other foods.

Nutritional Composition of Soybeans

Oil. Soybeans are rich in polyunsaturated oil, which is extracted for commercial use. The saturated fat content of soybean oil is lower than many other commercial oils while being comparable in total unsaturates (Table 17-1).

Many commercial vegetable oils contain soybean oil. Refined processed soybean oil is light in color. Soybean oil keeps best at refrigerator temperature after opening.

The soybean is processed into several forms that are used as ingredients in commercial foods. Soybeans contribute good quality proteins to a wide variety of processed and formulated foods. For example, through research sponsored by checkoff dollars they have been successfully used in pizza crusts and granola bars. Soybeans and soybean products may be used in every meal. Such products include main dishes, salads, soups, vegetables, breads, sauces, snacks, beverages and desserts such as ice cream.

Protein. A one-half cup serving of hulled soybeans contains as much protein as an eight ounce glass of milk or one and a half times as much protein as other dry beans. The protein in soybeans contains all the essential amino acids and is of good quality.

From a nutritional viewpoint, soybeans compare to meat or milk in amino acids, although they are slightly lower in the sulfur containing amino acids. Amino acids are the units of which protein is made. Our bodies require, but cannot make, some essential amino acids. Governments and international agencies continue to encourage production of legumes (e.g. soybeans) because they "fix" nitrogen, and because they make a special contribution to the diet of people unable to afford high levels of milk and other animal products. Soybean flour provides considerable amounts of protein when compared to various other flours (Table 17-2).

Carbohydrate and Fat. Although the carbohydrate content of (green) soybeans is less than an equivalent serving of lima beans, corn, or potatoes, the fat (oil) content in soybeans makes their caloric value approximately the same.

Table 17-1. Fat Content of Various Commercial Oils*

Oil (1 cup)	Total Fat (grams)	Total Saturated Fatty Acids	Unsaturated Fatty Acids	
			Oleic	Linoleic
Soybeans	218	31.4	49.7	111.2
Corn	218	27.7	52.7	126.5
Sunflower	218	22.5	42.6	143.3
Peanut	218	36.4	96.7	69.2
Cottonseed	218	56.4	37.1	112.4
Safflower	218	19.8	25.5	161.5
Sesame	218	30.9	85.6	90.1
Coconut	218	188.5	12.7	3.9
Palm	218	107.4	79.8	19.7

*Agriculture Handbook 8-4

Table 17-2. Protein Content of Various Flours

Flour (1 cup)	Protein (grams)
Soybean	31.2
Enriched Wheat	14.4
Rice	12.4
Corn	9.1

Agriculture Handbook No. 456

Vitamins and Minerals. Soybeans contain many vitamins and minerals including calcium, phosphorus, iron, vitamin A, thiamin and riboflavin (Table 17-3). However, a considerable portion of vitamin A is lost during processing. Research has reported that some of the minerals (e.g. iron and zinc) in soybeans may not be fully available for use in the body.

Soy protein either alone or as a partial source of protein can reduce the absorption of nonheme iron (iron from sources other than animal sources). USDA and other federal officials concerned about the nutritional impact of this product, give high priority to soy protein-iron research. They note that the iron-inhibiting effect of soy protein can be overcome by adding as little as 50 milligrams of vitamin C. This amount can be found in one medium orange, one-half cup orange juice or one and one-fourth cups tomato juice. The vitamin C source should be consumed at the same time as soy protein.

Protein Food Products

Four major types of defatted soy protein products are being used for human food. They are: flour and grits, concentrates, isolates and textured items. All four of these come from clean, dehulled soybeans. They differ from each other in protein content, physical and chemical properties.

Soy flour and grits — are simplest in form, and 40 to 55% protein. Soybean flour or grits vary in particle size. Soybean flour is added to various dishes and baked products largely to increase their nutritive value (e.g. bread, cakes, cookies, meat products etc.).

Soy protein concentrate — is manufactured from the flour simply by removing soluble carbohydrates. The resulting product is a 65-70% protein. It also retains the essential vitamins and minerals of the raw soybean. The concentrate is used extensively as a binder in meat products and in dry cereals.

Soy protein isolate — is produced by removing all the non-protein elements from the soybeans. This form contains at least 90% protein. It is bland in flavor and ideal for improving the nutritive content of food. It improves the moisture-retaining ability of foods. Soy protein isolates and concentrates are used in snack foods, dairy products, breakfast foods, diet drinks and even coffee whiteners.

Textured (vegetable) soy items — can be engineered to look and taste like bacon, ham, poultry, shrimp, crab, coconut, nuts, beef, pork and many other food products. Simulated meat products are made by extrusion or fiber spinning. In both processes, the basic ingredients are usually either soy flour or soy protein isolate or concentrates. In the Thermoplastic extrusion process, a mixture of soy, flour, water, flavoring, and coloring is subjected to heat and pressure for a predetermined time. This mass is extruded into the atmosphere or at a reduced pressure to allow expansion. Shape and size is determined by the size and shapes of the dies as well as by the frequency that the extruded material is cut from the dies by a revolving knife. At this point, the extruded material is still quite moist and further drying is necessary.

In the spun fiber process, fibers are prepared by extruding an alkaline dispersion of soy protein through spinnerettes into a coagulating bath. The resulting fibers are then stretched to impart a toughness or chewiness to the product. In the production of a simulated meat item, the fibers are combined with fat, coloring, flavoring, and heat-coagulable protein; they are then formed or shaped and cooked. After fabrication the product may be sliced, ground, or dried. It may be consumed as is, or processed further into frozen, canned, or dried products. The protein content of textured soy items varies from product to product (50-90% or higher). The protein and fat content can be controlled for the benefit of human nutrition.

Table 17-3 Nutritional content of soybeans (raw-dry and flour-full fat)

Nutrient	Soybean Flour (1 cup)	Raw-dry Soybean (1 cup)
Protein (gm)	31.20	71.60
Calcium (mg)	169.00	475.00
Phosphorous (mg)	474.00	1163.00
Iron (mg)	7.10	17.60
Vitamin A (I.U.)	90.00	170.00
Thiamin (mg)	.72	2.31
Riboflavin (mg)	.26	.65

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Nutrition Labeling

The U.S. Food and Drug Administration has established definitions and standards for labeling vegetable protein products (including soy-based proteins). The regulations establish protein content and the content of some vitamins and minerals that must be included if the food is to be considered to be nutritionally equivalent to the major protein foods such as meat or fish, for which it is a substitute. The U.S.D.A. authorized the voluntary use of textured vegetable protein fortified with minerals and vitamins in child feeding programs.

Chapter 18

Livestock Nutrition

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Soybean products are used in animal diets because of their low cost, high protein concentration and widespread availability.

Nutrients in Soybean Products

Solvent extracted soybean meal is the most common soybean product used in animal diets. Other products used include expeller extracted soybean meal, whole soybeans, soybean hulls and dehulled soybean meal. Levels of nutrients in these products are summarized in Table 18-1 and 18-2. Soybean hulls are high in crude fiber, dehulled soybean meal is low in crude fiber, and whole soybeans are high in oil (Table 18-1). Soybean hulls are lower in protein content than are other products. Whole soybeans are high in energy and TDN, due to high oil content, but soybean hulls are low in energy and TDN.

Amino acid content of soybean does not differ among extraction methods. Amino acid concentration is considerably higher in soybean meal than in alfalfa hay, corn or milk (Table 18-2). The proportion of amino acids is an important aspect of protein quality. Soybean products tend to be low in some amino acids, including methionine and cystine. Supplementation of ruminant diets containing soybean meal with amino acids or amino acid analogs (such as methionine analog), however, has not consistently benefited production.

Table 18-1. Nutrients in Soybean Products

	SBM Solvent Extracted	Soybean Seeds (whole)	SBM Expeller Extracted	Soybean Hulls (flakes)	SBM Dehulled Solvent Extracted
DM %	89.1	90.9	90.7	91.6	91.3
Protein %	46.7	37.9	42.4	11.3	50.8
EE %	1.2	17.4	4.7	2.5	1.1
CF %	5.2	5.3	6.1	33.1	2.9
NDF	14	10	14	67	8
ADF	10	8	10	50	6
Ca %	.30	.24	.28	.54	
P %	.65	.58	.59	.16	.65
Mg %	.27	.28	.25	—	—
K %	1.92	1.61	1.75	—	2.05
S %	.43	.22	.33	—	—
NEmaint	1.72	2.19	1.87	.90	—
NEgain	1.15	1.39	1.24	.06	—
NE lact	9.99	2.46	2.16	.82	—
ME (swine)	2051	3531	2947	—	3542
ME_n(poult)	2219	—	2379	12.0	2489
TDN cattle	73.3	83.1	77.0	58.8	76.3
TDN swine	75.7	91.4	77.2	—	71.2

* All nutrients except DM are on as as-fed basis. NRC-NAS. Atlas of Nutr. Data. 1971.

Solubility of Protein in Soybeans

Feedstuffs vary greatly in soluble and insoluble protein content. Many common ingredients of concentrates (corn, milo, cottonseed meal) are similar in soluble protein content (12-15% of total protein). Soybean meal is somewhat higher in soluble protein (24% of total). The solubility of protein in forage can vary from 22% in hay to about 60% in silages. Generally, wet silages have more soluble protein than dry silages.

Table 18-2. Amino Acid content of soybean meal, corn and alfalfa meal.

Amino acid	SBM solvent	Corn	Alfalfa hay	Carcass
	% of Dry Matter			
Arginine	3.28	.46	.70	3.89
Glycine	2.29	—	—	—
Serine	2.45	—	—	—
Histidine	1.15	.23	.30	2.06
Isoleucine	2.39	.46	.80	2.06
Leucine	3.52	1.03	1.00	5.54
Lysine	2.93	.23	.60	4.10
Methionine	.65	.11	.10	.79
Cystine	.69	—	—	—
Phenylalanine	2.27	.46	.60	2.93
Tyrosine	1.28	—	—	—
Threonine	1.81	.34	.70	2.61
Tryptophan	.62	—	—	—
Valine	2.34	.34	.70	4.56

* NRC-NAS Nutr. Req. of Domestic Animals 1. Nutr. Req. of Poultry. 1984.

Table 18-3. Protein in forages and grains.

Feedstuff	Total protein	Soluble protein	Insoluble unavail.	Insoluble avail.
	% of DM	% Total protein		
Concentrates				
Urea	281	100	0	0
Linseed meal	40	50	12	38
Distillers dried solubles	35	56	13	43
Wheat middlings	18	37	2	61
Oats	13	31	5	64
Soybean meal	52	24	2	74
Barley	13	17	5	78
Corn	10	15	5	80
Milo	12	15	5	80
Cottonseed meal	44	12	3	85
Brewers grains	29	6	13	81
Forages				
Legume hay	16	22	7	71
Grass hay	10	22	7	71
Legume silage (wet)	16	55	9	35
Legume silage (dry)	16	40	12	48
Corn silage (wet)	9	55	10	45
Corn silage (dry)	9	40	10	50
Corn silage (1% urea)	12	60	10	30

From Sniffen et al (1981) and other sources.

Silages to which ammonia was added at ensiling time tend to be higher in insoluble protein than nontreated silage. Table 18-3 presents solubility values for some common feedstuffs.

Soybean Products for Dairy Cattle

Soybean Meal. High producing cows past peak lactation and lower producers can utilize non-protein nitrogen supplements without adverse effects, provided dietary energy levels are adequate and adaptation is allowed.

Cows need increasingly higher levels of natural protein as milk production increases. For cows averaging above 60 lbs. per day during early lactation and peaking at 80 to 90 lbs. per day, 17% protein of the total ration is minimum and several trials suggest 18 or 19%. Heating protein supplements increases the insoluble protein fraction. Heated soybean meal has been shown to increase feed intake and milk yield in high producers.

The optimal amount of insoluble protein for high producing cows is not clearly known. Feed remains in the rumen a short period of time (18-25 hrs.) for high producing dairy cows eating large amounts. During this time there must be adequate levels of soluble nitrogen (protein) or rapidly digested insoluble protein to meet the immediate nitrogen needs of rumen microbes for digesting carbohydrates. Protein should be degradable enough that the insoluble fraction provides a uniform and adequate supply of nitrogen for digestion of the plant fiber. Soybean meal appears to fit these criteria reasonably well. Heated soybean meal appears to be a useful product, because insolubility is increased and rate of degradation is reduced, thereby increasing bypass potential.

Whole Soybeans. Whole soybeans can be fed to dairy cows; they are high in protein (38%) and the high oil is a beneficial energy source. In a California study cows fed rations containing heated whole soybeans produced 77 lbs. milk per day versus 71 lbs. per day for cows fed a control ration. There is a limit to the amount of whole soybeans that can be included in the ration. Cows fed 13 to 15 lbs. of whole soybeans per day (31% of ration) in a Pennsylvania study produced 75 lbs. milk versus 76 lbs. in control cows. However, the fat test was depressed (2.52% versus 3.50 for controls), caused by excessive amounts of oil, which upset rumen metabolism. It appears that 5 to 10 lbs. of whole soybeans (10-15% of the total ration) is sufficient for maximum production without jeopardizing milk fat.

Soybean Hulls contain 10-12% protein and approximately 67% fiber (cell wall). The digestibility of this fiber is similar to high quality forage or low quality grains. Hulls are apparently not an effective fiber for the ruminant because of their fineness. They may serve as a natural buffer when added to a high grain (starch) diet by reducing attendant acidosis and improving digestibility. For lactating dairy cows, feeding 5-10 lbs/day is generally recommended. Blending these palatable hulls is a good way to prevent over consumption. Blending is relatively easy since soybean hulls can be handled with conventional conveyers, storage bins, mixer wagons and front-end loaders.

Hulls are an excellent forage replacement for heifers and dry cows. They serve as an excellent energy supplement to roughages fed to beef cattle. Supplementing 3 to 4 lbs of soybean hulls per head daily for 400- to 600-lb calves on grass pastures or corn stalk fields has given equivalent performance to using an equal amount of corn. The soybean hulls are lower in energy than corn but they evidently are not reducing fiber digestion in the forage to the extent that corn does. The energy and protein concentrations of soybean hulls suggests an economic value similar to that of forage. This is illustrated in Table 18-4.

Soybean Oil. Soybean oil has potential as an energy source for dairy cows in early lactation, a time when energy intake often is inadequate. Research indicates that moderate levels (up to 6%) of fat or oils can im-

Table 18-4
Soybean meal price ($/T)

Corn price $/bu	140	160	180	200
	— value of soybean hulls ($/T) —			
1.50	49.74	51.42	53.09	54.76
2.00	62.42	64.10	65.77	67.44
2.50	75.10	76.77	78.45	80.12
3.00	87.78	89.45	91.12	92.80

prove milk yield or fat percent of higher producing cows. When fat content of the diet exceeds 6%, fiber digestion is depressed and fat test may decline. Feeding protected fat (covered with protein and indigestable in the rumen) may allow higher levels of fat in the diets of dairy cows (i.e., 10-20%); this would improve energy density and increase energy intake.

Soybean Meal Supplementation Versus Forage Base. The amount of soybean meal fed to dairy cows is dependent upon the forage and level of intake (Table 18-5). Alfalfa diets require little protein supplementation, as long as intake is adequate. Cows fed grass diets are unable to consume large amounts of forage; cows fed corn silage diets can consume large amounts of feed. In either case, high protein supplementation is necessary for optimal milk yield. Silage generally contains more soluble protein (30-50%) than hay (10-20%); cows fed silage-based diets may benefit more from insoluble protein supplements, such as heated soybean meal. High producing cows fed protein suplements in challenge or electronic feeders may also benefit from insoluble protein supplements.

Soybean Meal has been superior to non-protein supplements for beef cattle fed low energy rations and for new arrivals or cattle that have been kept off feed two or three days.

Plant protein supplements for the first 30 days cattle are on feed often removes the lag in daily gain that occurs when non-protein nitrogen supplements are used in starting rations. Cattle weighing less than 600 pounds have higher protein requirements than heavier cattle and show responses with increased gains to some "rumen by-pass" insoluble dietary protein.

Table 18-5. Soybean Supplementation in Forage-Based Diets.[a]

	Alfalfa forage	Grass forage	Corn silage
Forage			
DM (% BW)	1.8	1.6	2.0
DM (lbs)	22	19	24
As fed (lbs)	24	21	69
Energy intake (Mcal)	13.0	9.6	16
Protein intake (lbs)	4.0	2.3	2.4
Concentrate			
Energy to provide (Mcal)	20	23	17
Dm intake (lbs)	24	28	20
As fed intake (lbs)	26	31	22
Protein needed (lbs)	2.8	4.5	4.2
Protein (% of ration)	12	15	19
Concentrate formulation (minerals excluded)			
Ground corn (lbs/ton)	1850	1700	1500
SBM (lbs/ton)	150	300	500
SBM consumption (lbs/day)	2.0	4.2	5.5

[a] Based upon energy and protein requirements of a 1,200 lb cow producing 75 lbs of 3.5% milk

Whole Soybeans for Beef Cattle. Whole soybeans can be fed successfully to beef cattle within certain guidelines. Raw soybeans do not have to be heat treated for cattle. Most studies show raw soybeans give results comparable to heat treated soybeans in rations. Soybeans are usually ground or rolled for cattle but whole beans have been equivalent to processed beans in some comparisons.

Steer calves fed rations with 10% cottonseed meal or 10% raw soybeans had comparable rates and efficiencies of gain in a Louisiana study. When the level of raw soybeans was increased to 20 or 30% of the diets, there was progressive decline in performance.

Steers fed soybean meal, raw-ground, or micronized (infra-red heat treated) soybeans (Texas Tech Univ., 1972) gained as follows:

600 lb. Steers Fed 137 Days

	Meal	*Raw ground*	*Micronized*
Av. daily gain, lbs	3.33	2.93	2.93
Feed/gain, lbs	6.78	7.65	7.37

Feed intake and daily gain favored meal, but differences between treatments were not significant.

When a steer ration contained 20% soybeans (Univ. of Georgia), roasted and hot-rolled soybeans increased average daily gains by 11% and improved feed efficiency by 8% compared to raw-ground soybeans in bird resistant milo rations.

The protein in raw soybeans appears to be utilized as efficiently by beef cattle as the protein in soybean meal. Some studies indicate whole soybeans get better results with yearlings or older cattle than with calves. For best results, limit whole soybeans to 15% of the total ration dry matter. Higher levels of soybeans in a ration may cause scouring and otherwise decrease performance. Raw soybeans contain urease so they should not be mixed with urea in a ration. Urease will cause urea to break-down to ammonia in stored feed, which will result in low palatability of the feed and nitrogen losses. The urease in the raw soybeans can cause urea feeds to release ammonia faster in the rumen and increase the hazard of ammonia toxicity.

Ground soybeans become rancid quickly after grinding, especially in hot weather. In winter, rations with ground soybeans should not become rancid within 10 to 14 days. One advantage of roasting soybeans for cattle would be to inactivate the lipase enzyme and increase the storage length.

Soybean Products for Swine

Soybean Meal is widely used for a protein supplement in swine feeds. The amino acid content of soybean meal is well balanced to meet the deficiencies of

grains commonly used. Corn rations supplemented with soybean meal formulated to meet the protein requirements of growing and finishing hogs will adequately meet lysine needs.

Soybean meal is deficient in some of the B vitamins, particularly riboflavin, niacin, pantothenic acid and B_{12}. When these are added in the premix and the mineral needs supplemented, soybean meal can be used successfully as the only protein supplement in swine rations.

Whole Soybeans For Growing Swine Rations. Soybeans are unsatisfactory as supplemental protein in growing swine rations. Their poor nutritive value for swine appears to be caused by one or more of three factors: 1) Soybeans border on being deficient in methionine. 2) A trypsin inhibitor in raw soybeans. This inhibitor causes excessive excretion of essential amino acids. 3) A "growth inhibitor" (soyin), a toxic prohibitor in raw soybeans, diminishes feed intake. Soybeans cooked properly overcome these problems.

Two University of Missouri experiments determined performance in pigs fed cooked whole soybeans compared with regular corn-soybean meal rations. Rate of gain and feed efficiency were similar in the two trials with no consistent differences in carcass traits. Trials in Illinois with sows and in Kansas with barrows and gilts with heat-treated whole soybeans showed no difference in performance.

From these trials it appears that properly cooked whole soybeans are an excellent source of protein and similar performance in gains and feed efficiency can be expected compared to soybean-oil meal.

Cost of processing soybeans with farm-owned equipment is: (1) operating cost, primarily fuel; and (2) ownership costs. As a rule-of-thumb swine producers can assume they will use one ton of heat-treated soybeans per sow per year if they are on a farrow-to-finish program. Producers who purchase feeder pigs can calculate they will feed 100 pounds of heat-treated soybeans per hog.

Whole Soybeans for Sow Rations. Recent research from Nebraska and other Midwest Stations show that raw soybeans can be substituted for soybean meal satisfactorily in gestating sow rations. A slight improvement has been noted in piglet survival using raw beans. This has been attributed to the additional fat in the whole soybeans compared to soybean meal. Slightly more raw beans will be needed to formulate similar crude protein levels due to the lower protein content in whole beans relative to soybean meal.

Raw soybeans are not recommended for use in lactating sow rations.

Value of Whole Beans. The value of whole soybeans is based on their protein content relative to soybean oil meal and their energy value compared to corn. One way to determine the value of whole beans follows:

1. Whole soybeans contain 38% protein compared to 44% for soybean meal. As a protein source the whole grain is worth 0.86 the value of soybean meal (38 ÷ 44).
2. Soybeans contain 3,540 calories of metabolizable energy per pound, whereas corn has about 1,475 metabolizable calories per pound. Every pound of soybean oil fed would equal the energy of 2.4 lbs of corn (3,540 ÷ 1,475 = 2.4). Soybeans normally contain about 17.5% oil by weight. Soybean meal contains 0.5% oil by weight; therefore, the extra oil in cooked beans is 17%. A ton of soybeans contains 340 lbs of oil (2,000 x 17% = 340). The corn equivalent is 816 lbs (340 × 2.4 = 816).

Soybean Products for Poultry

Poultry in general require vitamins, minerals, energy, protein (amino acids) and water. In discussing soybean meal emphasis will be placed on protein and energy.

Energy. Various factors influence the amount of energy required per day — ambient temperature, activity, level of production, body weight, growth rate and availability of energy in dietary ingredients. The amount of feed that poultry will consume is primarily related to the energy requirement and the energy level of the diet. Other nutrients must be balanced in relation to energy in the diet.

Protein. Protein and amino acid requirements of poultry vary with the types of feedstuffs and activities of the chickens. These requirements are published in the National Research Council (NRC), 1977 publication. (See Tables 18-1 and 18-2 for feedstuff values.) Since poultry eat first to meet their energy needs, consideration to the calorie : amino acid ratio is a logical approach to meet their amino acid requirements. During the past 20 years literature reports on the lysine requirement of the laying hen ranged from 494 to 900 milligrams per hen. The most recent results on a corn gluten meal-soybean meal diet indicate that the daily lysine intake requirement is 700 milligrams.

Feedstuffs. Soybeans have been studied in numerous forms: raw; heated, unextracted and ground; heated, dehulled, and flaked; and expeller-soybean oil meal, and 44 to 49% soybean oil meal. In general raw soybeans and unextracted-ground soybeans were less satisfactory because of a poorer absorbability of the oil.

The major high-protein feedstuffs used in poultry diets are soybean meal and solvent-extracted whole or dehulled soybean meal. Hulls do not have an adverse effect on performance.

Subject and Problem Solving Index

A

Abortion, pod or flower, 3
Acreage, soybean, 69, 73
Aerial seeding, 26, 28
Air drying, 67
Amino acids, 79
Atrazine carryover, 53

B

Bacteria, disease, 59, CP
Beef cattle feedstuffs, 83
Beneficial insects, 42
Blends, variety, 8
Breeders seed, 12
Breeding, 5
Broadcast seeding, 26, 28

C

Calibration, planter, 25
Carrying capacity, 63
Cattle feedstuffs, 83
Certified seed, 12
Chemicals, herbicide, 52, 53
Chemicals, fungicides, 11, 12, 59
Chemicals, insecticides, 39
Claypan soils, 18, 61
Combines, adjustment, 10, 65, 66
Combines, rotary, 65, 66
Compaction, 16, 61
Conservation tillage, 17, 18, 26, 52
Cost of production, Ch 14
Crop injury, 4, 23, 26, 27, 53
Cultivation, 31, 51
Cyst nematodes, Ch 8, 44

D

Dairy cattle feedstuffs, 82
Damaged seed, 10, 11, Ch 13
Date of planting, 23
Deep tillage, 16
Determinate varieties, 2, 8, 30, 31
Disease control, Ch 11, CP
Disease, resistant varieties, 6, Ch 11
Dinitroanalines, 53
Double cropping, 18, 27
Double cropping economics, 70, 71
Double cropping fertilization, 22
Drainage, surface, 61
Drainage, tile, 61
Drilled soybeans, Ch 7
Drilled soybeans, economics, 72
Drought stress, 3, Ch 12
Drying, 11, 67
Dwarf varieties, 2, 8, 30, 31

E

Early planting, 24, 32
Economic threshold of insects, 39
Economics of drilled beans, 72
Economics of irrigation, 70, 71
Economics of double cropping, 70
Emergence, 1, 27
Erosion, 17
Expeller oil extraction, 77
Exports, 73

F

Fats, polyunsaturated, 79
Federal grain standards, 74, 75
Feed products, Ch 18
Fertilization, banding (row), 22
Fertilization, conservation tillage, 22
Fertilization, foliar, 22
Fertilization, liquid, 22
Fertilization, methods of, 22
Flooding, 61
Flowering, 2
Food products, 80
Forward pricing, 76
Foundation seed, 12
Frost damage, 2, 24
Fuel use, tillage, 15
Fuels from soy oil, 78
Fungicides, seed, 11, 12
Fungicides, plant, 59, 60
Fungus diseases, Ch 11, CP
Future market, 75

G

Germination, 1, 5, 27
Grading standards, 74, 75
Grain grading standards, 74, 75
Grits, soy, 80
Growth stages, 3, 4
Gumbo soils, 18

H

Hail damage, 4, 26, CP
Harvest losses, 65, 66
Harvest moisture, 4, Ch 13
Heat damaged protein, 81, 82
Heat damaged seed, 11, 67, 68
Herbicides, 31, 52, 53
Herbicides, carryover, 23, 27
Herbicides, contact, 52
Herbicides, injury, 26, 27, 53, CP
Hexane oil extraction, 77
Hogs, 83
Hulls for feed, 82

I

Incorporation of herbicide, 52
Indeterminate varieties, 2, 8, 30, 31
Inhibitors, trypsin, 84
Inhibitors, soyin, 84
Injury, herbicide, 26, 27, 53, 54, CP
Inoculant, 21
Insects, Ch 9, CP
Integrated pest management, 39
Intercropping, 28
Irrigation, Ch 12
Irrigation economics, 70

L

Land planing, 62
Late planting, 24, 27
Leaf loss, 4
Leaf yellowing, Ch 11, CP
Leaf damage, 4, 38, CP
Lecithin, 78
Liming, 19
Liquid fertilization, 22
Livestock feeding, Ch 18
Lodging, 7, 25, 30

M

Marketing, cash, 74, 76
Marketing, futures, 75
Maturity, varietal, 7, 23
Maturity, harvest, 4, Ch 14
Maturity, physiological, 4
Micronutrients, 20, CP
Minerals, 80
Minimum tillage, 18, 26, 52
Moisture, harvest, 4
Moisture, seed, 1, 10, 11, Ch 13
Moisture, soil, 16, Ch 12

N

Narrow rows, Ch 7
Natural air drying, 67
Nematodes, Ch 8
Nematode resistant varieties, 6, 34
Nitrogen, 21
Nitrogen fixation, 21
Nodules, 21, CP
No-till, 18, 26, 52
No-till economics, 70
No-till weed control, Ch 10
Noxious weeds, 13, 14
Nutrient, deficiencies, 20, CP
Nutrients, micro, 20
Nutrients, secondary, 20
Nutrient toxicities, 20
Nutrition, plant, Ch 5

CP = Color Photos pgs 40-50.

Nutrition, food, Ch 17
Nutrition, livestock, Ch 18

O

Off color soybeans, 75
Oil extraction, 77
Oil for fuel, 78
Oil processing, 77
Oil products, 78, 79, 82
Oil quality, 78, 79
Options, 76

P

Perennial Weeds, 54, CP
PH, 19
Phosphorus, 19, CP
Photoperiod, 2, 23
Planing, land, 62
Plant analysis, 21
Planter calibration, 25
Planting date, 23
Planting depth, 26
Planting method, 26
Planting rate, 25
Plant Variety Protection Act, 14
Pod damage, 39
Podding height, 25
Population, 24, 25, 31
Potash, 19
Potassium, 19
Poultry, 84
Pricing, 74
Production costs, Ch 14
Products, feed, 81, 82
Products, food, 80
Protein content, 79, 80
Protein, heat damaged, 81, 82
Protein, insoluble, 81, 82
Protein, soluble, 81, 82

R

Rainfall patterns, 61
Reduced tillage, 18, 26, 52
Registered seed, 12
Relay cropping, 28
Replanting, 26, 27
Residues, 17, 18
Resistant varieties, 6, Ch 11
Ridge planting, 62
Root knot nematodes, 35
Rotary combine, 65, 66
Rotary hoe, 25, 32, 51
Rotation, 23, 34, Ch 11

S

Scouting for pests, 37
Secondary nutrients, 20
Seed Act, 13, 14
Seed Certification, 12
Seed cleaning, 11
Seed filling, 3
Seed fungicides, 11, 12
Seed germination, 1, 9, 26, 27
Seed handling, 11, 67, 68
Seed inoculant, 21
Seed laws, 13, 14
Seed purity, 9
Seed size, 8, 25, 31
Seed splits, 11, Ch 13
Seed Testing Laboratory, 13, 14
Seed treatment, 11, Ch 11
Seed vigor, 9
Seedbed preparation, 15, 16
Seeding rates, 25
Seeding rates in narrow rows, 31
Semi-determinate varieties, 2, 8, 30
Semi-dwarf varieties, 2, 8, 30
Shattering, 8
Soil fertility, Ch 5
Soil testing, 19
Soil moisture, 16, Ch 12
Soil moisture carrying capacity, 63
Solvent extraction, 77
Soyin, 84
Soybean oil meal, 77, Ch 18
Sprayer calibration, 54
Standibility, 7, 25
Stand loss, 27
Statistics, Ch 14, 15
Stem damage, 38, Ch 11
Storage, 11, 68
Storage, insects in, 39
Stunted plants, Ch 8, CP, Ch 11
Subsoiling, 16
Surface drainage, 61
Swine, 83

T

Technical analysis, market, 76
Temperatures, high, 2, 23, 24
Temperatures, low, 2, 23, 24
Texturized vegetable protein, 80
Threshing, 65, 66
Tile drainage, 18, 26
Tillage, conservation, 16
Tillage, deep, 15
Tillage, fuel use, 15
Tillage, minimum, 18, 26
Tillage, no-till, 18, 26
Tillage, reduced, 18, 26
Tissue testing, 21
Trash, 16-18
Tryspin inhibitor, 84

V

Variety, blends, 8
Variety characteristics, 6
Variety development, 5
Variety, 5
Variety, for narrow rows, Ch 7
Variety selection, 6
Virus, Ch 11, CP
Vitamins, 80

W

Water quality, 63
Weed control, Ch 10
Weed control in narrow rows, 31
Weeds, CP
Weeds, noxious, 14
Weeds, perennial, 54, CP
Whole soybeans, Ch 18
World soybean production, 73

Y

Yellow leaves, CP

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Soybean Organizations

Missouri Soybean Merchandising Council, 915 S.W. Blvd., Suite K-2, Jefferson City, MO 65102
Missouri Soybean Association, 915 S.W. Blvd., Suite K-2, Jefferson City, MO 65102
American Soybean Association, 777 Craig Road, PO Box 27300, St. Louis 63141
National Soybean Crop Improvement Council, 211 S. Race St., Urbana, IL 61801

Credits

R. L. Bryan Co., Columbia, S.C., photos of beneficial insects, page 42, and striped blister beetle, looper and corn earworm, page 40.
Clemson Univeristy, photo of southern stem blight, page 44.
CSIRO, Melbourne, photo of sulfur deficiency, page 43, from An Atlas of Sulfur Deficiency in Commercial Plants.
Vernon Jones, UMC, Figures 6-1a, b, page 24.
Harold Kerr, Jimsonweed, large, page 49.
Illinois Voc. Agri. Services, Urbana, photos of diseases and herbicide injury, pages 44-47.
University of Illinois Bulletin 773, Marcos Kogan, principal author, and Circular 1200, photos of insects, pages 40 and 41.
University of Minnesota, photos of weeds, pages 48-50.
Potash and Phosphate Institute (N, Fe, P & Mg); The Fertilizer Institute (K); and David Whitney, Kansas State Univ. (Zn), photos of nutrient deficiencies, page 43.
Merle Shepard, Clemson Univ., photo of green clover worm, page 40.
Other photos furnished by authors.

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