A-250 (Revised)

SOYBEAN PRODUCTION

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Soybean is an important cash crop in the eastern third of North Dakota. The North Dakota Agricultural Statistics Service reported 6,000 acres of soybean harvested in 1946. In more recent years, however, acreage more than tripled from less than 200,000 acres in 1976 to a record 750,000 acres planted in 1984 and 1988 (Figure 1). As with other crops, acreage will fluctuate in response to the anticipated price-yield return ratio. In 1989, 650,000 acres were planted to soybean, whereas in 1991, 600,000 acres were reported planted. The state five-year average yield for 1986 through 1990 period was 26.7 bushels per acre. The state average yield for 1991 was 30.5 bushels per acre. The state-wide record yield of 35 bushels per acre occurred in 1986.

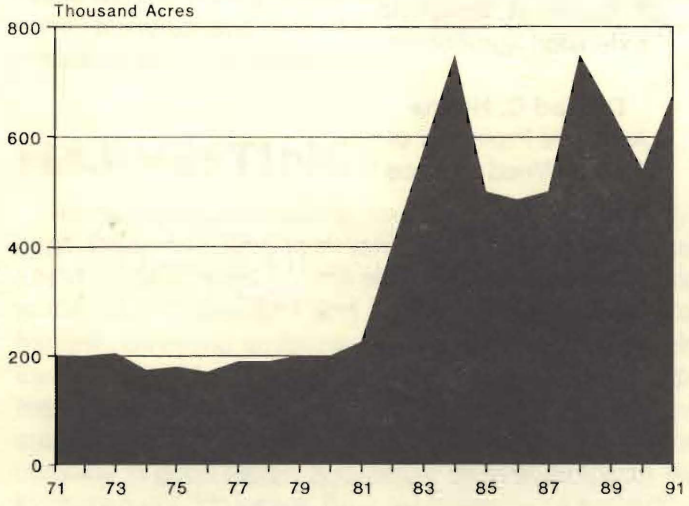

Figure 1. Soybean planted acres, North Dakota 1971-1991. Source: North Dakota Agric. Statistics No. 60, 1991.

ADAPTATION

Soybean is a full season crop primarily grown in southeastern North Dakota. However, increased acreage in Grand Forks, Walsh, Barnes, Griggs, Foster, Wells, Eddy, Stutsman, Pembina and LaMoure Counties suggests economic feasibility in those areas. The need for a long growing season and satisfactory soil moisture during flowering and pod filling may limit the westward expansion in the state with present varieties. However, soybean should be considered in the rotation when irrigation water is available.

SOIL REFERENCE

Soybean grows best under soil conditions favorable to corn. A fertile, medium-textured loam soil usually is best. Soybean can be produced on a wide range of soil types. Heavier, fine textured soils should have good drainage. Sandy loam soils warm up faster, allowing soybean to emerge sooner and develop rapidly. Soybean planted in soils with a pH greater than 7.5 or in high lime soils may have leaf yellowing due to iron chlorosis or other nutrient problems. Some varieties of soybean are more tolerant to high lime soils.

ROTATIONS

Soybean fits well in most eastern North Dakota crop rotations. Wheat yields at Fargo were 35 percent greater when planted on soybean land than when following wheat, surpassing other tested crops as a contributor to wheat crop yields the following year (Table 1). Also, no-till wheat yields following soybean were higher than following other previous crops. Studies from neighboring states have shown corn to yield better following soybean than following corn. Soybean, a legume, provides a break in the biological cycle of various cereal diseases, accounting for part of the recorded yield increases.

Soybean should follow corn, wheat, barley or other grass crops in a rotation. Soybean should not follow alfalfa, dry edible beans, canola, or sunflower where white mold disease (*Sclerotinia sclerotiorum*) has been detected. White mold has occasionally reduced soybean yield in North

Table 1. Effect of previous crop on wheat yields under no-till and conventional tillage systems at Fargo, N.D.

	Conventional Wheat Yield		TillageNo-Till Wheat Yield	
Previous Crop	Wheat Yield (bu/A)	Wheat on Previous Crop (%)	Wheat Yield (bu/A)	Wheat on Previous Crop (%)
Wheat	33.8	100	33.3	100
Soybean	45.3	134	44.9	135
Sugarbeet	40.8	121	38.8	117
Sunflower	39.3	116	39.1	117
Corn	38.6	114	37.3	112
Flax	38.0	112	37.5	113
Barley	37.0	109	36.0	108

Source: Dept. of Crop and Weed Science at North Dakota State University, Eight (8) years (1977-1984).

Dakota. White mold uses soybean as a host and this allows the organism to carry over to other susceptible crops. Broadleaf crops such as dry edible bean and sunflower should not follow soybean where white mold was present.

White mold usually has been observed in solid-seeded fields of soybean, but has seldom been reported in 30-inch rows or wider spaced plantings. If soybean is to be planted on white mold-infected land, planting in 30-inch or wider rows is recommended. This allows increased air movement and reduces the chance that the disease will develop to an economically damaging level. The risk of yield loss from white mold is greater with lodging susceptible varieties.

Soybean has limited crop residue levels after harvest and often causes the soil to be sufficiently mellow so that deep tillage for seedbed preparation is not necessary, except when weed infestation is serious. However, mellowing and low post harvest residues may make the soil vulnerable to additional erosion.

SOYBEAN VARIETY SELECTION

Soybean variety selection should be based on maturity, yield, lodging and disease reaction. Comparative maturity and yield of public and some private soybean varieties can be obtained from a current copy of Extension Circular A-843, "North Dakota Soybean Variety Performance Testing."

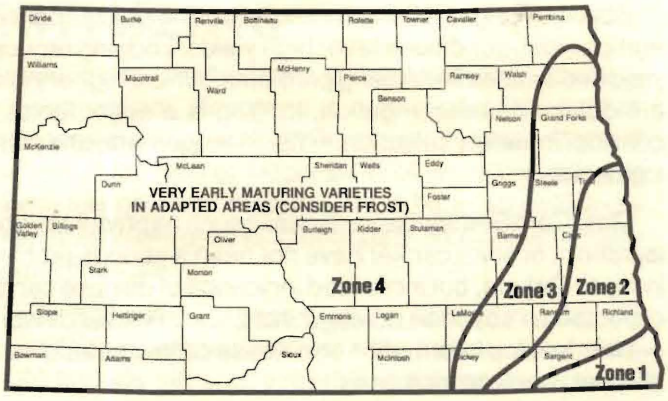

Figure 2. Maturity zones. Plant group 0 and 1 in Zone 1, Group 0 in Zone 2, Group 00 in Zone 3, and early group 00 in Zone 4.

Generalized areas of adaptation are indicated by zones in Figure 2. In general, seed maturity group 1 in Zone 1, maturity group 0 in Zone 2, maturity group 00 in Zone 3 and as early a group 00 as possible for Zone 4. When evaluating private company performance data and descriptions, make comparisons with public varieties grown for several years in your local area. Suggested public varieties are listed in Table 2.

Table 2. Agronomic characteristics on public soybean varieties suitable for North Dakota Production.

Variety*	Maturity Group	Fargo Relative Maturity	Height	Hilum Color	Zone**	Remarks***
Maple Ridge	000	v.early	v.short	yellow	3,4	
Maple Amber	000	v.early	v.short	brown	3,4	1,3
Maple Isle	00	v.early	short	yellow	3,4	
McCall	00	early med.	short	yellow	2,3,4	
Maple Glen	0	early med.	short	yellow	2,3,4	
Ozzie	0	med.	med.	yellow	2,3	
Evans	0	med.	med.	yellow	2,3	
Glenwood	0	med.	med.	dk.gray	1,2	
Dawson	0	med.	med.	yellow	1,2	2
Dassel	1	med.	med.	yellow	1,2	1
Kato	1	late	med.-tall	black	1	2,4
Sibley	1	late	med.-tall	yellow	1	4
Hodgson 78	1	late	med.-tall	buff	1	4

* Listed in order of maturity (earliest to the latest). Refer to NDSU Extension Circular A-843 for yield performance and additional agronomic information.

** Zone - see map - Fig. 2. for Soybean maturity zones.

*** Remarks: (1) Sensitive to Sencor/Lexone
(2) Good iron-chlorosis resistance
(3) Sensitive to iron-chlorosis on high pH soils
(4) Plant Early

Soybean lodging characteristics are an important consideration when conditions favor high yields. Lodging reduces yield and creates harvesting problems. Where higher yields are obtained under irrigation, lodging is a major factor to consider in variety selection, water management, and planting density.

Most Corn Belt soybean diseases such as phythium, phytophthora or stem canker have not been a serious problem in North Dakota, but increased incidence of disease can be expected as soybean acreage increases. Research workers will develop information on disease control strategies as disease pressure increases.

SEED QUALITY

Selection and use of high quality seed are basic keys to satisfactory soybean yield. Hot, dry conditions during development and maturation may reduce seed size, increase seed injury, and contribute to lowered germination.

Mechanical seed damage may be the greatest single cause of poor germination and low seedling vigor in soybean. Damage can occur at any point during harvesting, handling or seed processing. The least mechanical damage occurs at 12 to 14 percent moisture. Severe bruising and seed coat breakage may occur at higher or lower moisture content. Harvesting at a low moisture content (8 to 10 percent) following intermittent wet and dry periods can increase the amount of seed coat cracking. Frequent combine adjustments can compensate for changes in seed moisture during the day. Care must be taken during seed cleaning and conditioning to prevent seed damage. Use belt conveyors when possible, and if augers are used, keep them fully loaded. Seed should not be dropped onto bin floors or into steel truck boxes. Damage potential increases as temperature of the seed decreases.

The influence of soybean seed size on germination potential, early seedling vigor and crop yield is not always predictable. Seed of fairly uniform size with few very small or extremely large seed will reduce problems in precision planting.

Select soybean seed that is free of disease, seed coat cracking, splits and green immature seed. Use seed produced the previous crop year. Seed two years old or older usually has lower germination and less seedling vigor. Seedling vigor declines first when soybean seed deterioration occurs, then ability to establish a stand in the field declines, and finally germination percentage declines. Therefore, when soybean germination percentage is low, the seedlot should be discarded because of probable lower seedling vigor and reduced yield potential.

SEED TREATMENT

Treating soybean seed with a fungicide or fungicide plus insecticide generally does not increase yield when high quality seed is planted under North Dakota conditions. Seed treatment benefits seedlots that are damaged by disease, frost, excessive seed coat breakage and age. In most cases, seed lots that do not meet certification standards should not be planted.

Seed companies may routinely treat soybean seed with fungicides prior to bagging. Farmers planning to treat seed themselves should always follow fungicide/insecticide label directions as to rate and methods of treatment. Certain fungicides may injure or kill N-fixing rhizobia bacteria which are used for seed inoculation. Check NDSU Extension Circular PP-622, Field Crop Fungicide Recommendations, for recommendations on current registered seed treatments. Treated soybean seed can only be used for planting purposes.

INOCULATING SOYBEANS

Soybean has the ability to fix nitrogen from the atmosphere if properly nodulated. Nodulation requires the inoculation of the seed prior to planting with certain species of rhizobium bacteria specific for soybean. Or, if the field has a previous history of soybean production, the rhizobium bacteria may already be present in the soil. Seed inoculation is highly recommended for North Dakota soils with no previous history of soybean planting. Inoculation of seed for fields having prior soybean history is suggested if new strains of bacteria are to be introduced.

Several types of inoculum carriers are currently available for soybean seed treatment. Some of the oldest and very common are the peat-based materials. Peat is a good carrier for soybean inoculum but does not adhere to the seed as well as some other materials. For best results, peat-based materials should be applied as a slurry and mixed with the seed, particularly when planting into ground without a previous soybean history.

Clay-based materials can be applied dry and will stick to the seed. Clay-based materials become sticky when wet and can plug planters. Planter boxes should be left empty and cleaned each night when clay based inoculation products are used.

Granular inoculation materials can be applied separate from the seed through the granular insecticide hopper. Granular materials are more expensive but are usually very effective and are recommended for new soybean land.

Some liquid materials containing molybdenum plus a fungicide plus soybean inoculum are also being sold. Most fungicides reduce the viability of inoculum, and molybdenum is generally not considered necessary for North Dakota soils. Soybean inoculum is more tolerant to thiram fungicide than to most other fungicides; however, the length of time inoculum can survive in contact with thiram is not known. The advantage claimed for the liquid materials is the ease of application with a slurry seed treater. Soybean seed treated with carboxin should not be inoculated more than four hours prior to planting.

Some important factors that affect nodulation are the viability of the inoculum, the amount of rhizobium on the seed, and the soil nitrate level. The viability of the soybean inoculum depends on storage time and storage conditions. Many commercial inoculum containers list the expiration date for the inoculum. Inoculum should be refrigerated or stored in a cool place prior to and after purchase. Inoculum is easily killed by direct sunlight, so exposure of inoculated seed to sunlight or excessive heat should be avoided.

If peat based inoculum is used, a slurry should be made with materials such as sugar water or skim milk as a carrier. The slurry inoculum carrier should then be thoroughly mixed with the seed as close to planting time as possible. This method will greatly increase the number of rhizobium sticking to each seed.

Good nodulation usually will not occur in fields under extreme dry conditions or with high levels of residual soil nitrogen. Available soil nitrogen will be used in preference to the formation of nodules. Even so, seed planted in fields high in soil nitrate N should always be inoculated to provide a source of rhizobium for future crops.

SEEDBED PREPARATION

Soybean can be grown on a wide range of soil types under various cultural practices. Because of seed size and physiology, soybean seeds need to take up more moisture for germination than cereals do. Also, soybean is seeded only 1.5 to 2.0 inches deep. These factors explain why preparation of a firm, uniform seedbed is important for optimum stand establishment.

Shallow spring tillage to kill weeds, usually done just before planting, is effective on fall tilled fields. Several reduced tillage programs can be followed. Many farmers are growing soybean under a no-till program. Special planters or drills may be required to handle surface residue in no-till and some reduced tillage systems. Soybean, like other legume crops, has difficulty emerging through compacted layers and surface crusts.

FERTILIZING

Soybean does best in fertile soil and makes good use of carryover fertilizer. Response to commercial fertilizer has been inconsistent under North Dakota growing conditions. If a soil test of the field or response in other crops indicates distinctly low phosphate availability, a band application by planter attachment of 10 to 30 pounds of phosphate per acre may be beneficial.

Fields that have no prior soybean history may benefit from additional nitrogen fertilizer if the soil test shows less than 60 pounds per acre available in the top 24 inches at planting time. High nitrogen fertility circumvents the benefits of rhizobium bacteria as the bacteria will not convert atmospheric nitrogen when soil nitrogen is readily available to the plant.

Soybean without nodules or with ineffective nodules will respond to nitrogen like any other crop. Since legumes have the ability to fix nitrogen, inoculating soybean seed just before planting is important, especially on fields that have not recently been planted to soybean. Crop response to phosphorus and potassium are not always noticeable in the year of application.

Approximately 60 percent of the phosphorus and 50 percent of the potassium taken up by soybean plants is removed from the field when the seed is harvested. One bushel of soybean contains about three-fourths of a pound of P_2O_5 and over a pound of K_2O per bushel.

Starter fertilizer is best placed in a band 2 inches to the side and 2 inches below the seed. "Pop-up" fertilizer, a small amount of fertilizer placed in direct contact with the seed, **should not** be used on soybean because stand loss from fertilizer toxicity can result.

Micronutrient deficiency in soybean can be a problem on high pH soils. Iron chlorosis generally occurs on high-lime soils and is the most commonly reported trace element deficiency in North Dakota. The typical iron deficiency (chlorosis) symptom is yellow leaves with green veins.

Suggested foliar treatments to correct iron deficiency are 20 pounds of ferrous sulfate in 100 gallons of water applied at 10 to 20 gallons per acre, or 0.10 to 0.15 pounds per acre of iron as iron chelate applied in water carrier at the second trifoliolate leaf stage. These treatments will usually eliminate deficiency symptoms but may not result in a profitable yield increase. NDSU research showed that application at the fourth trifoliolate stage never resulted in a soybean yield increase. However, research in southern Minnesota showed economical yield increases from foliar application of iron. Selecting varieties tolerant of high-lime soils can help counteract iron chlorosis. Some varieties are quite susceptible to

iron chlorosis. Soybean has not responded to zinc fertilizer in eastern North Dakota and western Minnesota sites where the soil zinc level was above 1.0 ppm.

Soybean response to fertilizer has varied considerably. Experience on your farm is your best guide. Leave an unfertilized check strip for comparison. The use of foliar fertilization is not a substitute for a good soil fertility program of soil applied fertilizers and micronutrients. Consult NDSU Extension Service Circular SF-719, "Fertilizing Soybean," for additional information.

PLANTING

Soybean is susceptible to frost and prolonged exposure to near freezing conditions in spring and fall. Plant soybean after the soil has warmed to 50 F and air temperatures are favorable. Soybean planting generally should not be earlier than five days before the average last killing frost. This provides less than a 50 percent chance of frost killing the soybean. Delaying seeding until after the average last frost date allows time to kill early germinating weeds with tillage. Earlier planting in cool, wet soil may result in low germination, increased incidence of seedling diseases and poor stands.

Planting dates between May 10 and 25 appear to be favorable for higher yields with a reduced risk of frost injury. Plant as early as the frost date permits on fields where weeds are not a serious problem so soybean can take full advantage of the entire growing season and produce maximum yields. Earlier seeding allows the use of full-season varieties which typically yield more than shorter season varieties.

Four years' data from date-of-planting studies at the NDSU Fargo Experiment Station show that late plantings had lower seed yields, poorer seed quality, lower oil content, shorter plant height, and pods set closer to the ground as compared to optimum planting dates. However, late planting may be justified where weed control is of primary importance. Some early maturing varieties have had acceptable yields when weather factors like hail, late spring frost, floods, etc., necessitate very late planting or replanting.

Planting in rows is the most common method used and permits cultivation for weed control. Seeding can be done with row crop planters plus the proper plates, air planters, grain drills, and air seeders. The seed metering system of grain drills must be adjusted carefully to avoid seed damage. Plugging every other spout may be necessary with some drills to obtain uniform seeding of undamaged seeds. Plant to cover seed 1½ to 2 inches deep and place the seed in moist soil. Planting deeper than 2 inches or in a soil that crusts may result in poor emergence.

SEEDING RATE

Soybean yields have not varied significantly over a wide range of plant populations. A plant population of approximately 150,000 plants per acre is desirable regardless of row spacing. One pound of medium sized soybean will contain about 2800 seeds. A bushel of soybean will produce about 150,000 plants per acre assuming 90 percent germination. This would give plants about 1.5 inches apart within the row at a 30-inch row spacing. Seed per pound in currently available varieties ranges from 2200 to 3400. Seeding rates should be based on the number of viable seeds planted per foot of row (Table 3).

Table 3. Number of viable seeds per foot of row which will result in approximately 150,000 plants per acre.

Row Spacing (Inches)	Seed/ft. of row
40	12
36	10
30	9
24	7
20	6
15	5
12	4
10	3
6-7	2

High planting rates may cause yields to decrease in low rainfall years because of drought stress, and in good rainfall years high plant populations may lodge more than low populations. Low plant populations reduce lodging but contribute to low pod set and excessive branching. Extreme low seed number per foot of row may result in erratic stands due to a lack of seedling energy necessary to break the soil surface. This may be critical in solid seeded stands where soils are prone to crusting.

Seeding rates should be increased (5 to 7 percent) to compensate for unavoidable plant thinning such as with rotary hoeing for early season weed control. Slightly higher seeding rates may also be advantageous with June plantings or with no-till plantings, where soil temperatures are lower.

ROW SPACING

North Dakota soybean producers are planting soybean in narrower rows as a result of several NDSU research studies (1971-1986) at Casselton, Fargo, Oakes and northeastern North Dakota counties. The research demonstrated that higher yields of soybean can be obtained in narrow rows if stands are well established and weeds are adequately controlled (Table 4). These data demonstrate that narrow row soybean out-yielded wider spaced soybean by an average of 3 to 10 bushels per acre. Currently about 50 percent of soybean is planted in row spacings of 15 inches or less

The advantages for narrow row soybean are increased yield, reduced erosion, increased harvesting efficiency and early crop canopy closure to help control weeds, and the convience of using existing small grain equipment for some planting and harvesting operations. The primary disadvantages of narrow row production (solid seeding) are increased potential for weed and disease problems, seedling emergence problems if soil crusts easily, inability to use a row-crop cultivator and increased herbicide costs.

Close drilled or solid seeded soybean will produce satisfactory yields only if the land is relatively free of weeds, has good fertility and has adequate soil moisture during the pod filling portion of the growing season. Some weed control early in the season can be obtained with a harrow or rotary hoe, but mechanical weed control often is not satisfactory and chemical control is necessary for acceptable weed control in solid-seeded soybean. (See Weed Control section.)

WEED CONTROL

Soybean is a poor competitor with weeds when cool soil temperatures cause slow germination and reduced early season growth, but a good competitor in warmer soils when seed germination and seedling growth are rapid. Control of early weeds is one of the most critical components of a profitable soybean production system. Weed control during the first two to four weeks of the growing season is essential to maximize yield. Good cultural practices such as thorough seedbed preparation, adequate soil fertility, choice of a well-adapted variety, and use of good quality, high germination seed free of weed seeds all contribute to a soybean crop which will compete with weeds. Finish seedbed preparation immediately prior to planting the crop to kill germinating weeds.

A rotary hoe or harrow can be used in both wide row and narrow row soybean to control emerging weeds. These tillage tools can be used to control weed seedlings after planting but before soybean emerges or after emergence when soybean is in the one to two trifoliolate leaf stage. Avoid using the harrow or rotary hoe when soybean seedlings are just emerging (cracking stage). The rotary hoe is an effective and economical weed control method when the ground is not trashy, lumpy or wet and weeds are emerging (not more than 0.25 inch tall). If little or no precipitation has occurred to activate preemergence herbicides, a rotary hoe or harrow may elimate early flushes of weed seedlings and partially activate the herbicide to control subsequent flushes of weeds. Cultivation is most effective when soybean is slightly wilted during the warm part of the day. Cultivated at this time, soybean is less susceptible to breakage and the disturbed weeds will die quickly.

Many herbicides are available for weed control in soybean. Most are currently labeled for tank mixing with other herbicides for broad spectrum weed control. A number of commercial herbicide mixtures also are available for use in soybean.

Table 4. The effect of row spacing on soybean yields.

Location	Years	Row Spacing Comparisons	Wide Row Bu/A	Narrow Row Bu/A	Bu/A Increase	% Increase
Fargo	76-77'	30" vs. 6"	30.7	33.1	2.4	+8%
Casselton	75-76'	30" vs. 6"	17.1	22.0	4.9	+28%
Oakes*	71-72'	36" vs. 12"	34.6	45.6	11.0	+31%
N.E. N. Dak. **	84-86'	24" vs. 12"	24.4	28.1	3.7	+15%

* Oakes - Irrigated trials

** Six county sites - Walsh, Pembina, Cavalier, Ramsey, Nelson and Towner

An economical chemical weed control program involves a number of strategies and steps. These include: (1) Identify weed species present as seedlings, older plants or potential weeds based on previous weed infestation problems. (2) Evaluate soil type, texture and organic matter content of each field to help in determining rates of soil applied herbicides. (3) Inspect, adjust and calibrate all herbicide applicators or banding equipment to insure accurate herbicide application and even distribution. (4) Read and follow the label carefully when using herbicides for weed control.

Soybean is susceptible to injury from 2,4-D, MCPA, dicamba (Banvel), or picloram (Tordon); therefore, non-labeled herbicide drift into soybean fields should be avoided. Refer to NDSU Extension Circular W-253, "Agricultural Weed Control Guide," for current information on herbicide rates, mixtures and use. Always read and follow label directions when using pesticides.

HARVESTING

Timely, careful harvesting means extra bushels of soybean. Soybean is easy to thresh, but the challenge is to get all the soybean seed into the combine. Straight combining is the most satisfactory and commonly used method of harvest. Swathing soybean can result in excessive field losses (up to 25 percent) due to shattering. Use of equipment like floating headers, pickup reels, Love bars and row crop headers is helpful in reducing harvest losses. Keep the combine in good repair. A cutterbar in poor condition will increase gathering losses. Be sure knife sections and ledger plates are sharp, and that wear plates, hold-down clips and guards are properly adjusted. Proper reel speed in relation to ground speed will reduce gathering losses. Use a reel speed about 25 percent faster than ground speed. Operate the cutterbar as close to the ground as possible at all times. Keep forward speeds at or below 3 miles per hour. Slow down if stubble is high and ragged, or if separating losses are high. Approximately four beans or one to two pods per square foot represent a yield loss of **one bushel** per acre.

Harvest soybean when the plants are mature and the beans have approximately 14 percent moisture. Harvest may be started at 17 to 18 percent moisture when air drying is available. Harvest as much of the crop as possible above 12 percent moisture to avoid cracking seed coats and "splits." When soybean seed is extremely dry, (8 to 10 percent moisture), harvesting will cause more shattering and seed injury. Under these conditions, combine during morning or evening hours when relative humidity is higher and adjust the combine accordingly. Adjust cylinder concave clearance according to the operator's manual. When soybean plants and pods are tough, cylinder speed may have to be increased. Decrease cylinder speed as soybean seeds dry during midday to reduce breakage. Paraquat or sodium chlorate can be applied as a desiccant to aid harvesting if green weed growth delays harvest. Do not apply a desiccant until soybean moisture is under 30 percent and 65 percent of the seed pods have reached a mature brown color.

STORING

Soybean may be stored safely for short periods during cold weather with a moisture content as high as 14 percent. For safe storage during the spring or summer, soybean should not contain more than 12 percent moisture. An air screen cleaner to remove foreign material, weed seeds and fines should be used before applying air and heat to soybean. Sound beans, free of foreign material and splits, store better and stay in condition longer. The maximum drying temperature for soybean is about 140 ° F. When soybean is to be used for seed, the temperature should not exceed 105 ° F. A grower drying soybean is seldom confronted with removing more than 2 or 3 points of moisture.

UTILIZATION

The soybean seed contains about 20 percent oil and 40 percent protein. These two components determine the economic worth of the soybean seed. Soybean has been called the "Cinderella Crop" in the U.S. because of its rapid expansion the past 30 years. For over one hundred years soybean has been called "the meat of the fields" in the Orient.

Farmers and animal feeders worldwide have benefited from the expansion of soybean production, as people around the world strive to improve their diets. This is being accomplished through increased animal productivity and use of soy protein directly in human consumption. Availability of large supplies of soy oil helped the food industry develop and market many new food products.

Increased production the past few years suggests that soybean is a viable permanent crop in North Dakota. This unique cash crop fits well into North Dakota small grain and corn cropping rotations.

Helping You Put Knowledge To Work

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