SDSU Extension

iGrow Soybean

BEST MANAGEMENT PRACTICES

Chapter 49: Soybean Irrigation

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Soybeans and corn require different irrigation management practices. These differences are the result of physiological differences between the plants. For soybeans, the most critical period is between R2 to R6 growth stages (Chapter 3). This chapter discusses when and how much irrigation water to apply and how to manage the salts contained in the water.

Irrigating soybeans

Irrigation or high rainfall that occurs during vegetative growth stages may not increase yields unless the soil water contents are extremely low. In many moderate- to fine-textured soils, early season irrigation can actually stimulate vegetative growth without increasing soybean yields (Kranz and Specht, 2012). Due to little available water in sandy soils, early season irrigations maybe required to germinate the seed and encourage growth. For soybeans, water stress between R2 to R6 (Chapter 3) can greatly reduce yields. Irrigation during this period of time typically increases the number of seeds per plant and yield per acre. However, it may also increase the disease potential. A good approach for irrigating soybeans is to match irrigation water with the most sensitive growth stages of plants.

Climatic conditions

In South Dakota, average annual precipitation ranges from less than 13 inches to nearly 30 inches, generally increasing from west to east (Fig. 49.1). However, all regions of South Dakota can experience drought. Irrigation can reduce a crop's dependence on natural rainfall and improve yields. If you are planning a new system or expanding an existing system, equipment and management options should be discussed with your local irrigation equipment dealer or Extension specialist. All irrigation systems in South Dakota using more water than 18 gpm require a water right permit pursuant to procedures in SDCL Chapter 46.2A. For permit requirements, contact the South Dakota Department of Environment and Natural Resources (http://denr.sd.gov/des/wr/watrightsapps.aspx).

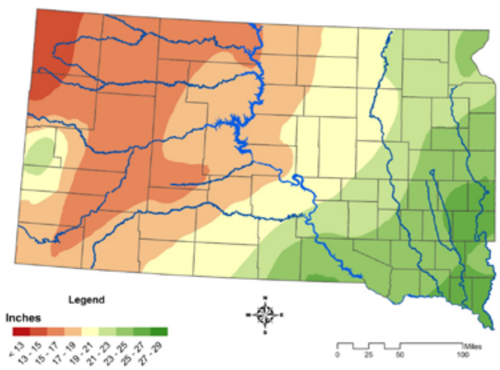

Figure 49.1. Average South Dakota annual precipitation in inches from 1977 to 2006.
(Map source: Kurt Reitsma, SDSU Extension)

Soil-water-plant relations

The amount of water retained and available for plant growth from the soil is dependent on the soil texture and organic matter content. Soil serves as a water storage reservoir for the plant, though not all soil water is available to the plant (Fig. 49.2).

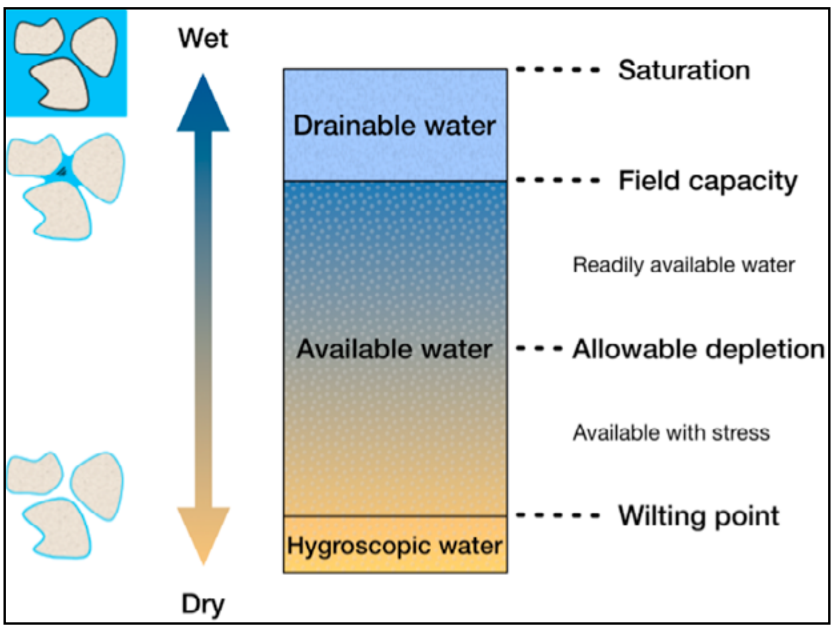

Figure 49.2. Soil water availability related to saturation, field capacity, and wilting point. The allowable depletion can vary based on growth stage and management considerations and is usually 50% or 70% of the available water. (Image courtesy of Gary Sands, University of Minnesota; and Chris Hay, SDSU Extension)

The water-holding properties of soil are similar to a sponge. When a sponge is placed in a bucket of water, all the pores in the sponge are filled to the saturation point with water. When the saturated sponge is removed from the bucket, some of the water freely drains out of the sponge. When soil is at its maximum water-holding capacity, soil is referred to as saturated. After water has drained freely from the soil for a couple of days, the soil water content reaches field capacity (Fig. 49.2). Water content can continue to decrease until permanent wilting point is reached. Water held by the soil between field capacity and permanent wilting point is called available water and varies by soil texture (Table 49.1).

Table 49.1. Ranges of available water for different soil textures. (Werner, 1993)

Soil Texture	Available Water, inch/foot of soil
Fine sands	0.7 – 1.0
Loamy sands	0.9 – 1.5
Sandy loams	1.3 – 1.8
Loams	1.8 – 2.5
Silt loams	1.8 – 2.6
Clay loams	1.8 – 2.5
Clays	1.8 – 2.4

As soil dries and approaches permanent wilting point, the remaining water becomes more difficult for the plant roots to extract. Soybean yield response to water stress will vary according to the growth stage of the plant.

To be most effective, water must be stored in the soil zone containing a majority of the soybean roots. Early in the growing season, the roots may be concentrated in the surface twelve inches. As the season progresses, roots can extend down to five feet. But irrigations should be scheduled to manage the water in the surface three feet unless local knowledge or experience suggests otherwise.

The relative amount of water lost from the soil to transpiration (water lost through the leaves to the air) and evaporation (water lost from the soil to the air) changes during the year. At planting, evaporation is the most important water-loss mechanism; however, when the crop canopy has fully developed, the major water-loss mechanism is transpiration.

Irrigation scheduling

Irrigation scheduling is the process of matching plant requirements to your ability to provide the water. The amount and timing of the irrigation is dependent on plant requirements as well as the irrigator preference, the amount of water contained in the soil, the soil characteristics, the water availability, the equipment capacity, and amount of water used since the most recent irrigation.

When scheduling irrigation, it is important to realize that heavy irrigations (saturating at least the top two feet of soil) are typically more effective and may take less time than several light irrigations. Wetting the soil to deeper depths also promotes deeper root development; light irrigations promote shallow rooting, which may lead to nutrient deficiency or lodging problems later in the season.

The most widely used approach for irrigation scheduling is called the Checkbook Approach (Werner, 1993). Whether using the checkbook approach or another method, soil water content should occasionally be measured.

The Checkbook Approach for irrigation scheduling

The Checkbook Approach is often called the Water Balance method. This method adds water received from rainfall and irrigation to the water balance and subtracts crop evapotranspiration (ETc). To maximize productivity, the field should be irrigated before readily available water has been depleted. Detailed information for this approach is available at https://openprairie.sdstate.edu/extension_circ/461/. There are many software implementations of the water balance method. Some of them are listed at http://irrigation.wsu.edu/Content/Resources/Irrigation-Scheduling-Aids-Tools.php.

The checkbook approach utilizes the following tools:

- a rain gauge to measure rainfall and irrigation
- estimated ETc values
- soil water balance worksheets
- soil water content measurements (to validate balances)

Evapotranspiration (ET), which is the loss of water from both evaporation and transpiration, is calculated using weather data (i.e., temperature, wind, and relative humidity) and crop information. Values of ETc vary by climate across South Dakota (Fig. 49.3 and Table 49.2). Daily values of soybean ETc are published on the South Dakota State Climatologist's website (http://climate.sdstate.edu/). If you are located close to a weather station, these are the most accurate estimates of ET. If a weather station is not located near your farm, ET can be estimated by measuring evaporation with an instrument such as an atmometer (Irmak et al., 2005). If neither method is available, long-term averages can be used (Werner, 1993).

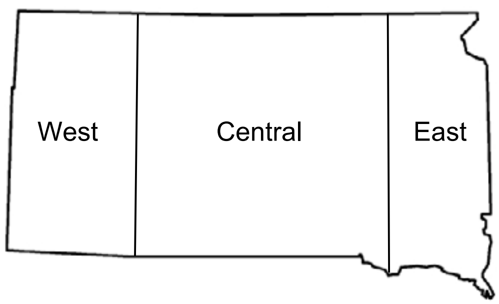

Figure 49.3. Evapotranspiration (ET) regions of South Dakota.

For irrigation planning, South Dakota can be divided into regions: West, Central, and East (Fig. 49.3). Daily water-use estimates are used to calculate water use over the season and are also used to estimate water use between irrigations for scheduling (Table 49.3). For example, to estimate seasonal irrigation requirements, daily water-use values (Table 49.2) are summed and compared with your field's expected rainfall estimates. The difference between daily water use and expected rainfall is the irrigation potential.

Table 49.2 Estimated soybean water use per day in South Dakota. (Werner, 1993)

Weeks After Emergence	Central Region			East Region		
	Maximum Temperature, °F					
	50-59	70-79	90-99	50-59	70-79	90-99
	Inches of water used/day					
1	0.02	0.04	0.07	0.02	0.04	0.06
3	0.02	0.05	0.08	0.02	0.05	0.07
5	0.04	0.08	0.13	0.03	0.07	0.11
7	0.07	0.14	0.24	0.06	0.13	0.20
9	0.10	0.19	0.33	0.09	0.18	0.29
11	0.10	0.21	0.36	0.09	0.20	0.31
13	0.09	0.19	0.33	0.08	0.18	0.28
15	0.06	0.11	0.20	0.05	0.11	0.17
17	0.03	0.06	0.10	0.03	0.06	0.09

Table 49.3. Irrigation scheduling example: Keeping the soil profile full.
This irrigated soybean field is near Beresford, SD. The rainfall and crop evapotranspiration (ET_c) data were retreived from http://climate.sdstate.edu. The field is irrigated with a center pivot. The soil in the field is an uniform silt loam with available water at 2.2 inches per foot. the irrigator manages the center pivot by setting the speed to make the full circle once every 4 days and apply 1 inch (gross irrigation) during that revolution. The application efficiency of the irrigation system is 85% so the net irragation is 0.85 inch for the gross irrigation of 1 inch.

The center pivot was started on July 31, 2011, and completely refilled the soil profile. That is, the soil water deficit was 0 after the center pivot passed over. The crop looks good and the irrigator wishes to keep the soil profile as close to field capacity (full) as possible. After the center pivot completes its circle on August 3, what whould the irrigator do on August 4? All All values are in inches.

Date	ET_c	Eff Rain	Gross Irrig.	Net Irrig.	Depletion
July 31, 2011	–	0	1	0.85	0
Aug. 1, 2011	0.42	0	–	–	0.42
Aug. 2, 2011	0.32	0	–	–	0.74
Aug. 3, 2011	0.23	0	–	–	0.97
Aug. 4, 2011	0.24	0	1	0.85	0.36

The crop has used enough water so the depletion is great enough to hold another entire irrigation. The irrigator can keep the center pivot running on August 4 without losing water to excessive runoff or drainage.

For the Checkbook Approach, rainfall should be measured at your location. The total (gross) rainfall should not be entered into the checkbook irrigation schedule. Instead, use effective rainfall, which is the amount of rain that actually soaked into the soil and is available to the crop. Effective precipitation can be estimated by measuring the gross rainfall and subtracting an estimate of how much of the rain ran on or off the field. The effective rainfall is usually less than the measured rainfall because more runoff leaves the field rather than running onto the field from a neighboring field.

One approach to estimating effective precipitation is to include all rainfall up to 0.2 inch then include 80% of any rainfall greater than 0.2 inch. If the crop is at full cover, a small amount (up to 0.05 inch for soybean or corn) may be subtracted for water intercepted and retained by the leaves. Additional details for estimating effective precipitation can be found at Cahoon et al. (1992).

Soil water measurement

Checkbook balances should be periodically checked against measured soil water content. Soil water status can be 1) estimated by the "hand-feel" method, 2) measured from soil samples by calculating the gravimetric water content, or 3) monitored with sensors.

1. The hand-feel method is fast and inexpensive (NRCS, 1998). This method involves "feeling" a soil of known water content and comparing that to a soil with unknown water content; available water is estimated by how the soil "feels" in your hand. Note that a "same" amount of available water for different soil textures will "feel" different, so you need to "calibrate" your feel to the different soil textures that are found in your fields. Obviously, hand-feeling is the least accurate method, but it can be effective with some practice.

   Samples should be collected from areas of the field with soil types that represent a majority of the field. Enough samples should be tested to get a consistent sense of the average conditions in the field. If the soil and water content are consistent, two or three samples may be adequate. Samples should be collected from enough depths to adequately represent the root zone. Use a hand soil probe or trenching spade to collect samples deeper than the top few inches

2. Gravimetric water content is measured by collecting samples and calculating the weight difference between wet and oven-dried samples. The problem with oven drying samples is that drying may take several days. This problem can be overcome by using a microwave oven to dry the samples (Schneekloth et al., 2007). Drying with a microwave oven is much quicker than drying with a conventional oven and can provide water percentage estimates within an hour of collecting the sample. Samples should be collected from areas with representative soil types, similar to sampling with the hand-feel method. The depths of sampling should reflect the root zone of the soybean (as deep as three feet). The percent water is calculated with the following equation:

$$\% \text{ water} = \frac{(\text{wet weight of soil} - \text{dry weight of soil}) \times 100\%}{\text{dry weight of soil}}$$

3. Soil water content or status can also be measured with sensors placed in the soil. Three commonly used sensors are gypsum blocks (Werner, 2002), granular matrix blocks (e.g., WaterMark®, Irmak et al., 2006), or tensiometers (Kranz et al., 1989). Gypsum or granular matric blocks measure soil water content or provide readings that are correlated to soil water content. Tensiometers provide readings of soil water potential, or energy with which the water is held to the soil particles.

   For irrigation scheduling, sensors should be placed at multiple depths (6", 18", and 30") at both the start and endpoint of the irrigation system. That requires a minimum of two locations in a pivot-irrigated field. It is preferable to have more locations to average out some of the soil variability. Additional sensors might be required to monitor soil water in an area of different soil types (e.g., a sandy area) if the area with the different soil type is large. When placing a soil water sensor, push a soil probe into the soil to the desired depth. With soil from that depth, make a thin slurry with soil and water, insert the sensor into the hole, and pour the slurry into the hole. The slurry helps ensure good contact between the soil and the sensor.

Table 49.4. Irrigation scheduling example: Saving room to capture rainfall.
For the same field near Beresford, the irrigator wishes to wait as long as possible to utilize any rainfall, but not let the depletion exceed 50%. The available water in the 3-foot root zone is 6.6 inches so the allowable depletion is 3.3 inches. All values are in inches.

Date	ET_c	Eff Rain	Gross Irrig.	Net Irrig.	Depletion
July 31, 2011	–	–	1	0.85	0
Aug. 1, 2011	0.42	–	–	–	0.42
Aug. 2, 2011	0.32	–	–	–	0.74
Aug. 3, 2011	0.23	–	–	–	0.97
Aug. 4, 2011	0.24	–	–	–	1.21
Aug. 5, 2011	0.13	–	–	–	1.34
Aug. 6, 2011	0.22	–	–	–	1.56
Aug. 7, 2011	0.22	–	–	–	1.78
Aug. 8, 2011	0.27	–	–	–	2.05
Aug. 9, 2011	0.22	–	–	–	2.27
Aug. 10, 2011	0.22	–	–	–	2.49
Aug. 11, 2011	0.29	0.4	–	–	2.38
Aug. 12, 2011	0.24	–	–	–	2.62
Aug. 13, 2011	0.23	–	–	–	2.85
Aug. 14, 2011	0.26	–	–	–	3.11
Aug. 15, 2011	0.28	–	–	–	3.39

The irrigator can wait until August 15. The depletion at the end of August 14 was 3.11 inches, and it is likely that the depletion will exceed the maximum of 3.3 inches on August 15.

Another way to describe soil water is to consider soil water depletion. Soil water depletion is the amount of water required to bring the root zone back to field capacity. When the soil is at field capacity, depletion is zero. Optimal irrigation efficiency is realized when irrigation water is applied in the amount equal to depletion. Runoff and deep drainage can result when water is applied in excess of depletion. Excess irrigation water application not only diminishes irrigation efficiency, but also can result in soil, nutrient, and pesticide losses from runoff and leaching.

Critical plant growth stages

Adequate soil water is needed for germination; therefore, if the soil is dry, irrigation may be needed to improve germination and seedling vigor. As the crop develops, moist soil is needed for root development. Check your fields by probing to discover if there are any layers of dry soil in the profile. Irrigation may be needed earlier than expected to wet deeper soil layers. Most irrigation systems cannot keep up with crop water demands during the later critical growth periods when the weather is often warmer and drier (Werner, 1993); therefore, some planning with estimated water use values (Table 49.2) can be beneficial.

Soybean is most sensitive to water stress from the beginning of flowering all the way through pod filling. Soil water depletion should not be allowed to exceed 50% after flowering begins. Soybean is less susceptible to water stress during the early stages of growth and development, prior to flowering. Soil water depletion up to 70% is allowable during vegetative growth prior to flowering.

At the end of the growing season, it is wise to deplete as much water as possible from the root zone. Depleting soil water at the end of the season minimizes the risk of nutrient leaching, allows you to take advantage of any off-season precipitation, and allows for surface-soil drying prior to harvest.

Table 49.5. Irrigation scheduling during wetter, cooler weather.
During 2010, rain was more plentiful. The same irrigated field near Beresford received a 2-inch rain that refilled the soil profile on July 30. When should the producer irrigate again to keep the soil profile full but not waste water? All values are in inches.

Date	ET_c	Eff Rain	Gross Irrig.	Net Irrig.	Depletion
July 30, 2010	–	2.0	–	–	0
July 31, 2010	0.21	–	–	–	0.21
Aug. 1, 2010	0.26	–	–	–	0.47
Aug. 2, 2010	0.12	0.45	–	–	0.14
Aug. 3, 2010	0.12	0.20	–	–	0.06
Aug. 4, 2010	0.23	–	–	–	0.29
Aug. 5, 2010	0.21	–	–	–	0.50
Aug. 6, 2010	0.23	–	–	–	0.73
Aug. 7, 2010	0.28	–	–	–	1.01
Aug. 8, 2010	0.21	0.70	–	–	0.52
Aug. 9, 2010	0.14	–	–	–	0.66
Aug. 10, 2010	0.20	0.25	–	–	0.61
Aug. 11, 2010	0.25	–	–	–	0.86
Aug. 12, 2010	0.26	–	–	–	1.12

The small rainfall amounts on August 2 and 3, coupled with the lower values of ETc because of the cooler weather, resulted in depletions of less than an inch until August 7. The irrigator might have started the pivot on or about August 7. Given the cool, wet weather, the irrigator might have waited until August 12 or later.

Monitoring soil water content can provide valuable information related to when to terminate irrigations. Rather than terminating irrigation at a given date, you should monitor weather forecasts, crop development, and soil water content to estimate how much water will be required to get the crop to maturity. Terminating irrigation early does not promote early maturing and dry-down of the grain (Werner, 1993).

Irrigation systems

Surface irrigation systems have been used for millennia. Surface irrigation uses the soil surface for water conveyance and the soil profile for water storage (http://waterquality.colostate.edu/CornBook/64Irrigationd.pdf). Water is available to infiltrate into the soil longer at the top of the field, so more water is stored in the soil profile in that area.

The uniformity of water distribution can be improved by minimizing the length of run. Short runs that reduce the difference of infiltration time between the top and bottom of the field can improve water-distribution uniformity. An alternative is to optimize the uniformity by increasing the water inflow rate to a maximum, without causing excessive soil erosion at the top of the field. This advances the water as quickly as possible across the field and reduces the difference in infiltration time. Other methods for increasing uniformity include surge irrigation, cutback irrigation, furrow packing (usually for the first irrigation), and the use of polyacrylamide (PAM) soil amendments.

Sprinkler systems, including center pivots, are the most popular irrigation systems in South Dakota. Center pivot systems can reduce labor requirements (compared to surface irrigation), increase distribution uniformity and irrigation efficiency (potentially, for the latter), and allow the effective application of fertilizer or pesticides with the irrigation water. With center-pivot systems, nozzles can be placed either on the pipe or near the soybean canopy.

Historically, sprinkler irrigation systems had high operating pressures, wide sprinkler spacings, and sprinklers that were mounted well above the crop canopy. These systems generally had low application rates. To reduce energy costs, many high pressure systems have been replaced with low pressure systems. Low pressure systems have closer nozzle spacings that often are nearer to the ground.

In many fields, drop hoses or pipes can be used to lower the nozzles to just above or even into the crop canopy. Where water supplies are greatly diminished and irrigation systems have limited capacity, nozzles have been installed as low as two feet above the soil surface. In some cases, the pipe has been covered with a sock that drags on the ground so that water is applied directly to the soil surface.

Placing the nozzles near to the soil surface reduces the amount of water that might be lost to wind drift or evaporation. The danger of this approach is that runoff can be increased. If you are considering installing nozzles near the soil surface, be sure that your soils have high infiltration rates (>0.25"/hr). In addition, nozzles must be spaced more closely together (approximately five feet apart).

Many irrigated fields will be in a corn-soybean crop rotation. Installing nozzles near the top of a mature corn canopy (approximately seven feet) is a good compromise in those situations. This allows for a wider spread of water from the nozzles while still reducing wind drift and droplet evaporation.

Subsurface drip irrigation (SDI) is a type of microirrigation system. SDI systems have high water-use efficiency and have been used to irrigate many different crops in the central and southern high plains of the United States. A disadvantage with these systems is that they are expensive to install. They are not commonly used in South Dakota, but may be an option for areas poorly suited to center-pivot irrigation (e.g., some field shapes, small field sizes, and so on) and for high value crops.

Managing salinity and sodium problems

Salts most often interfere with crop water uptake and can reduce yields and crop quality. To prevent salt accumulation in irrigated systems, monitor the salinity (i.e., total salt content—measured as electrical conductivity) and sodium content of water and soil. Salt accumulation can be hastened when several small irrigations are applied rather than fewer, deeper irrigations. Yield impacts from salts (salinity) vary greatly with management, soil type, and weather conditions. If salinity or sodium problems are suspected, consult with a crop consultant or an Extension specialist.

When preparing to irrigate, a water sample should be collected and analyzed for salts (electrical conductivity) and sodium (Na) content. A good lab should be used to analyze the salinity of the water sample, address the compatibility of the water and soils for irrigation, and provide recommendations to manage the salinity.

Salt problems often occur in soils with poor internal drainage. Layers of low permeability restrict the flow of water "out the bottom" more slowly than evapotranspiration removes water from the upper profile. To avoid the accumulation of salts in irrigated situations, the soil must have adequate drainage capacity, even if your water quality is relatively good. Water must move freely through the soil, leave the root zone, and carry with it some salts. Without adequate drainage capacity, salts will build up over time and cause problems with soil nutrient holding capacity and stunted crop growth. In poorly drained situations, select salt-tolerant crops and/or install artificial drainage to remove excess water and salts from permeable soils. County, district, federal, or state drainage laws may apply to artificial drainage systems.

Salt accumulation in the soil profile can also be managed by applying extra water to leach the salts from the soil profile. The amount of water needed is referred to as the leaching requirement (LR).

$$LR = \frac{\text{irrigation water EC (dS/m)}}{\text{acceptable deep drainage EC (dS/m)}}$$

Leaching can occur naturally when the soil is wet enough for water to move downward, driven by gravity. This happens most often during spring snowmelt and thaw. It can also happen during the growing season if a large rainfall occurs when the soil water content is already high.

Soybean is considered moderately tolerant to salinity, but the tolerance can vary widely among varieties. A deep drainage EC threshold of 5 dS/m has been reported for soybean, above which yield loss occurs. For each 1 dS/m increase of deep drainage EC, approximately 20% of the yield will be lost.

Table 49.6. Example of calculating the leaching requirement.

A water sample is collected and analyzed by a reputable lab. They report the EC of the irrigation water as 2 dS/m. You know that the deep drainage EC threshold for yield loss for soybean is 5 dS/m. Thus, the leaching requirement (LR) for your situation is = 2 dS/m divided by 5 dS/m, or 0.4. That is, the water application amount should be 40% greater than the crop water needs to help leach salts out the bottom of the root zone. If the soil salinity increases enough so that the deep drainage EC is greater than 5 dS/m, soybean yield will be decreased.

Extreme care must be used in soils with high sodium (Na) contents or when the irrigation water has high sodium concentration. Sodium destroys soils by dispersing soil colloids and destroying soil structure. In addition, high sodium concentrations reduce water infiltration rates and permeability. Irrigating with water that had high sodium concentrations has rendered some land in South Dakota useless. Sodium-affected soils often have very poor drainage, and sodium-sensitive plants experience reduced growth. Nutrient-deficiency symptoms (resulting from high pH) and poor soil physical conditions are often observed in high-sodium situations.

More information for managing saline soils and information about acceptable deep drainage EC values are provided in Bischoff and Werner (1999). For further information related to salinity and sodium, see Chapter 48.

Chemigation

One advantage of irrigation is the ability to apply fertilizers or pesticides through the irrigation system. This practice is commonly referred to as chemigation. Fertilizer applied through an irrigation system must remain soluble in the irrigation water because nozzles, emitters, and fittings can become clogged by precipitates from fertilizers. After fertilizer application, a short irrigation may be used to wash the fertilizer off the plant and lessen the possibility of fertilizer burn. If applying pesticides, the pesticide must be labeled both for use in soybean and for application with the irrigation system.

When chemigating you must also protect the water supply. Backflow into a well or other water supply can have serious consequences for other users and make the water unusable for their applications. State law requires the use of an anti-backflow device when chemigating. Examples of anti-backflow devices include such things as check valves and low-pressure relief valves (SDCL §34A-2A-3). Always read and follow the instructions on the product label and take precautions to protect yourself and others from exposure to chemicals.

When using chemigation, to apply liquid nitrogen or other chemicals, you may not need water at the time you want to apply the chemicals. Apply the chemicals in a timely fashion, but use the least amount of water possible. High-capacity injection equipment, along with an irrigation system that can cover the field in the shortest period of time, is desirable for chemigation.

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49-434