IPM Control of White Mold in Irrigated Dry Beans

by Richard A. Meronuck, Kasia Duellman, Linda Kinkel, Plant Pathology;
Jerry Wright, Biosystems and Agricultural Engineering;
George Rehm, Soil Water and Climate, and
Mel Wiens, Staples Plot Administrator, University of Minnesota

White mold continues to be a "pesky" yield limiting disease in dry beans everywhere the crop is grown. Refinements to three common production practices can help reduce white mold in irrigated dry edible beans grown on sandy soils by providing a more effective integrated pest management (IPM) program.

All classes of dry beans are susceptible to this disease. Although some varieties may show some tolerance when the disease pressure is high, all varieties will succumb and suffer severe yield loss. Planting upright varieties in wide rows and allowing three to four years between bean crops or other susceptible crops, such as sunflower and canola in a rotation will help reduce fungal inoculum. Small grain and corn are ideal non-host crops and are recommended in a rotation where dry beans are included.

White mold is caused by the fungus *Sclerotinia sclerotiorum* and develops as a white cottony growth on the stem, branches and pods of bean plants. Infected tissue becomes dry and has a chalky or bleached appearance (Figure 1). The fungus also produces black, hard mats of mycelium called sclerotia near these cottony growths. The sclerotia allows the organism to survive adverse conditions such as dry or cold for long periods of time.

The disease cycle (Figure 2) starts when the soil surface

Figure 1. Severe white mold infection showing the characteristic bleached, chalky colored stems.

IN PARTNERSHIP ...

College of Agricultural, Food, and Environmental Sciences
University of Minnesota

University of Minnesota Extension Service

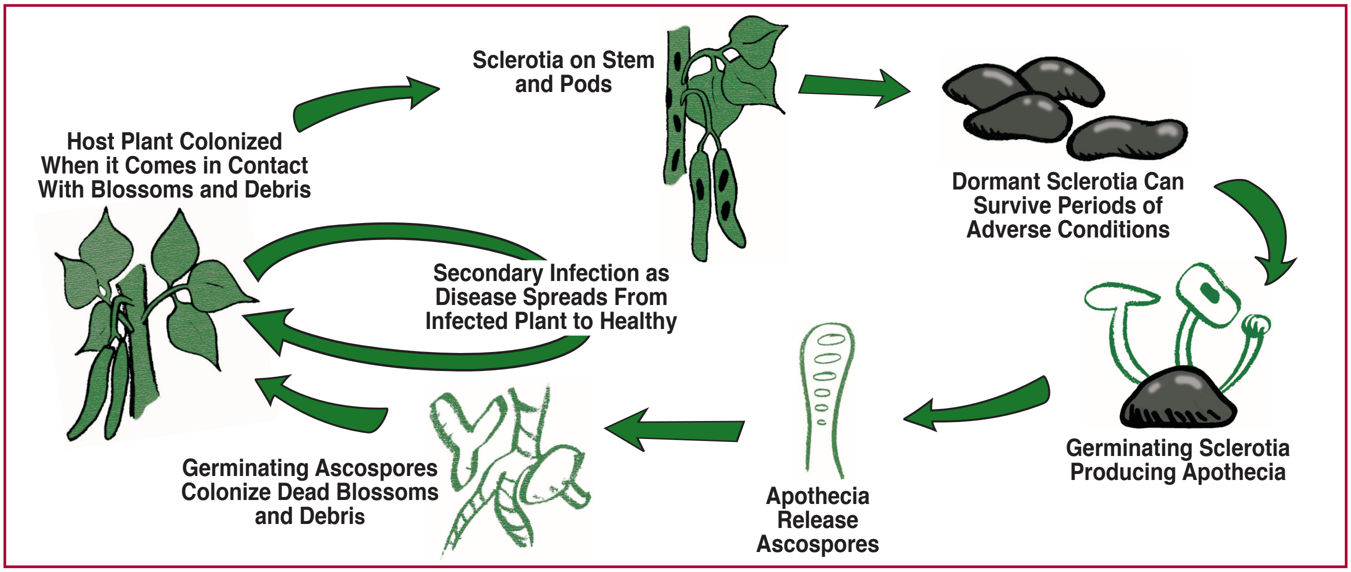


Figure 2. Life cycle of white mold *(Sclerotinia sclerotiorum)* on beans.

is cool but moist enough for the sclerotia to germinate. Soil moisture conditions near field capacity in the top 2 to 3 inches of the soil for 10 to 14 days and the soil temperatures between 59 and 65 degrees F during this same period favor sclerotia germination.

Upon germination, small mushroom-like bodies called apothecia appear in the soil surface under the crop canopy or in adjacent fields (Figure 3). Spores are produced by the apothecia and infect wilted flowers or other dead plant tissue (Figure 4). The infection then spreads to living plant tissue.

Infection kills some plants and severely reduces the yield of plants with pod infection. High humidity and air temperatures between 68 and 78 degrees F favor the spread of this disease.

Wet conditions during the period from June 1 to ten days after bloom onset can significantly increase the amount of white mold infection.

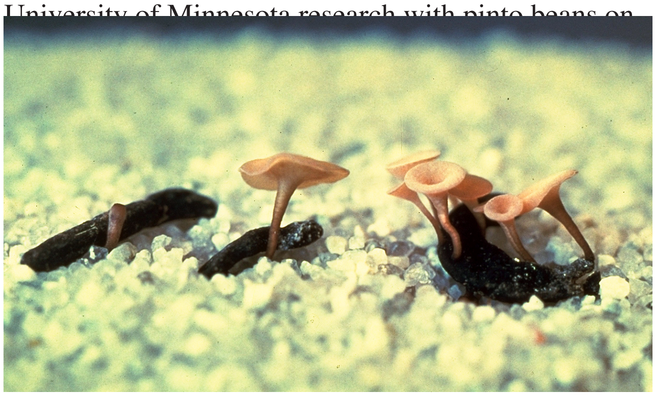


Figure 3. Apothecia stage of white mold.

Figure 4. Spores produced by Apothecia infects senescing flowers or other dead plant tissue.

University of Minnesota research with pinto beans on Verndale sandy loam soil at Staples, Minn., has shown (Table 1) that if a field has 3 to 5 inches of rain or irrigation between June 1 and ten days after bloom onset, there will be positive benefit to a spray program only 20 percent of the time. However, if the field receives 5 to 7 inches, economical benefit occurred 67 percent of the time; and when more than 7 inches fell, fungicide spraying showed a benefit 85 percent of the time. This spray decision aid is based on the assumption of a bean market over $.15/lb. and a canopy closure of 60% or greater within 7 days after bloom onset. Data input requires daily monitoring of in-field precipitation (rain and irrigation).

Wet conditions during the pre-bloom and bloom period create conditions for infection sites that will enlarge as the growing season progresses. The amount of leaf wetness after bloom influences the rate of spread of each infection site.

Table 1. Economic benefit to spraying at a bean price of $.15/lb. or greater.

Precipitation* Depth – Inches	Economic Spray Benefits
3 to 5	2 out of 10 years
5 to 7	6.7 out of 10 years
Over 7	8.5 out of 10 years

* Between June 1 and 10 days after bloom onset.

Benlate and Topsin M fungicides used in the University study, are two common fungicides used to control this disease. Our research was conducted with a ground rig using 40 gallons of water per acre delivered at 75 to 125 pounds of pressure with hollow cone nozzles. Banding or broadcast applications are effective. Two applications are economical in years of high disease pressure.

Always follow the label for proper timing and the amount of product to apply. Application by chemigation is also effective when applied with less than one-quarter of an inch of irrigation water. Information on chemigation safety, equipment and calibration is described in University of Minnesota Extension Service bulletin FO-6122.

A full canopy at bloom creates microclimate conditions favorable for white mold infection (Figure 5). Delaying full canopy development until after bloom will decrease the potential for damage from white mold. *Nitrogen (N) rate and timing can affect early canopy development*.

Split application of the required N fertilizer is a sound best management practice for the production of edible beans grown on irrigated sandy soils. For determining proper N rates for selected yield goals and soils refer to University of Minnesota Extension Service bulletin FO-6572. A typical recommendation for edible bean production on irrigated sandy soils would be 120 pounds of N per acre.

A study at Staples showed a yield increase of 250 pounds per acre in one of three years by delaying the second of two, 60 pounds of N per acre applications until two weeks after blooming. Split applications also decreased the number of plants with white mold infection. There was no change in yield in the other two years when N applications were delayed.

After applying 15 to 20 pounds per acre of N in the starter, apply half of the remainder of the recommended amount about two weeks after emergence. Apply the rest of the recommended amount as late as travel equipment in the bean field will allow. Another option for the split application is to apply the last portion of the recommended amount of N with the irrigation system if the center pivot is equipped with the necessary safety devices and permitted for chemigation by the Minnesota Department of Agriculture. This application can take place within two weeks after first bloom.

Application of N by chemigation should be done with $^1/_4$ to 1 inch of irrigation water. Information on nitrogen chemigation, safety equipment and N injection calibration is described in University of Minnesota Extension Service bulletin FO-6118.

The timing of this last application will be dictated by the growth of the crop. If ground equipment is used, the application will have to be made before canopy closure eliminates the possibility of using this equipment.

Irrigation scheduling is also another practice that can significantly reduce the amount of white mold in a field. Six years of research at Staples, on Verndale sandy loam soils, showed that scheduling irrigation events when the average soil water tension in the upper ten inches of the soil reached 65 to 75 centibars (cbs) could greatly reduce the potential for white mold development. Soil water tension was monitored at 4 and 10 inches depth by Watermark soil moisture sensors.

This irrigation strategy and the spray decision-aid were applied in a field of navy beans in 1997 near Wadena, Minn., that produced a net yield of 2,350 pounds per acre under severe disease pressure. The producer irrigated his field only when the soil water sensors indicated an average water tension around 75cbs. The spray decision-aid program suggested spraying and the producer applied two fungicide applications since the total precipitation was over 7 inches by early bloom.

Determining when to irrigate is best accomplished by using several in-field soil water tension sensors and/or a soil water accounting "checkbook" method. In 1998 four demonstration fields were managed using this irrigation scheduling program and the spray decision-aid (supported by an EQIP (Environmental Quality Incentive Program) educational grant.

Figure 5. Severe white mold in a crop with a dense canopy.

Disease pressure was light in 1998, hence only one grower applied a single fungicide application spray, resulting in a 28 pound yield per acre difference from the unsprayed check strip. University of Minnesota plot research at Staples over the past three years has shown that a single spray produced 587 to 924 pounds per acre over the unsprayed check.

Figure 6 shows the daily average soil water tension readings of four Watermark soil moisture sensors (two locations at two depths, 4 and 10 inches) taken in 1998 by one demonstration EQIP cooperator in Wadena County, Minn. Figure 7 shows when the rain events occurred and also when the cooperator initiated irrigation to prevent the soil profile and sensors from exceeding critical soil water levels. Note how the farmer applied each irrigation only when the soil water sensors averaged 60 cbs. or higher.

Figure 6 also shows how well the daily soil sensor readings trace the predicted daily soil water deficit (SWD) as estimated by the Minnesota Checkbook method (daily SWD was corrected five times during this period based on the soil water sensors readings).

Irrigation Scheduling Strategy

Soil moisture after planting and before flower initiation can generally be depleted to 50 to 60 percent of the total available water holding capacity within the root zone before an irrigation is necessary. Keeping it wetter may discourage adequate root development.

Dry beans have a normal effective rooting depth of two feet, but on many irrigated sandy soils in Minnesota, the rooting depth may only be 12 to 15 inches. It is estimated that 85 percent of the soil water used

Figure 6. Wadena County kidney beans, 1998. Watermark sensor readings compare well to estimated soil water deficit.

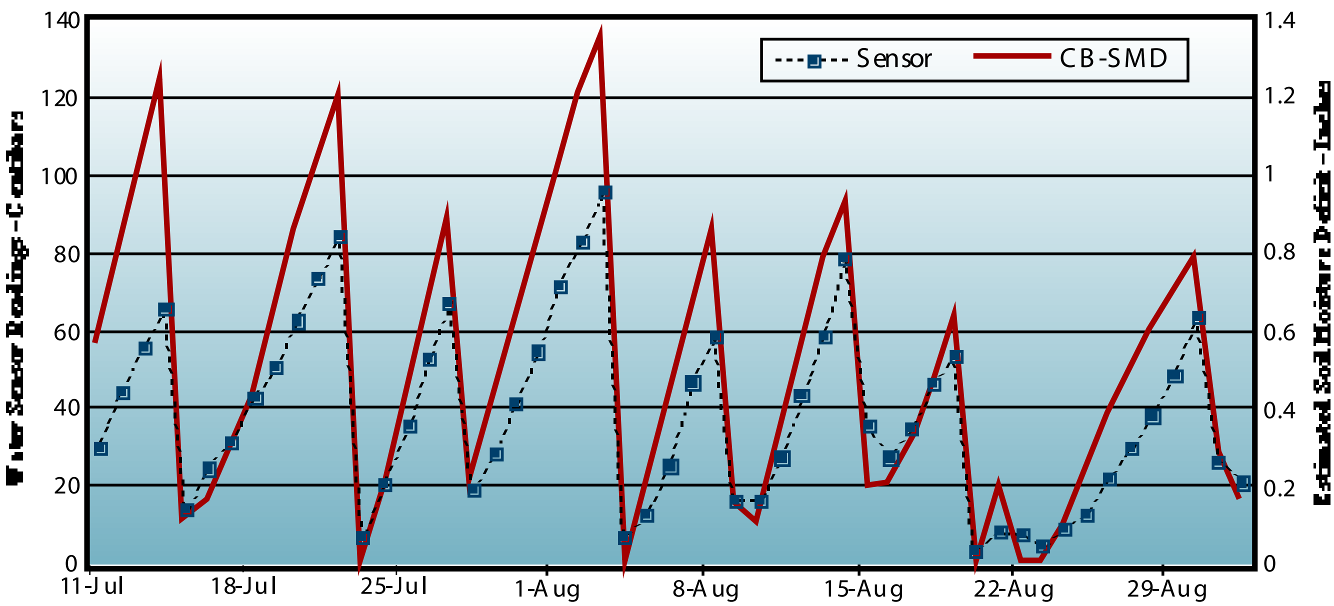
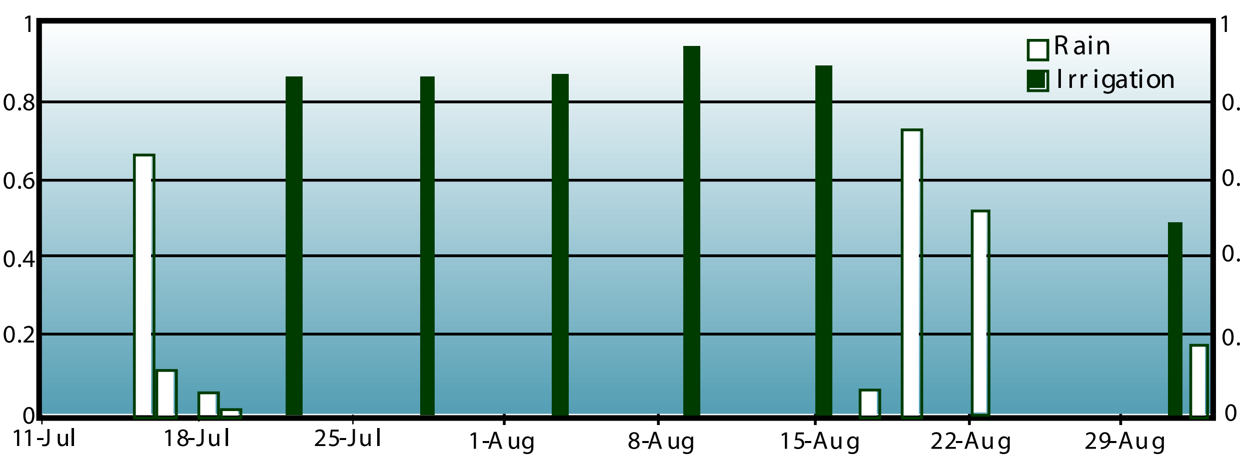


Figure 7. Rain events and irrigation depths, in inches, in 1998 in the Wadena County kidney bean field.



by the bean plant is taken from the top two-thirds of the rooting profile. This rooting depth is generally reached between 30 and 35 days after emergence.

Typically, the first irrigation will be needed about 5 to 10 days before flower initiation. At this time the soil profile should be completely recharged and then kept between field capacity and 40 to 50 percent depletion (60 to 70 cbs. of soil tension) until upper pod filling.

Additional irrigation during this period should be applied only when the soil dries to 40 to 50 percent depletion (60 to 70 cbs. of tension in top 12 to 15 inches of loamy sand or sandy loam soils). When the average of the sensors near the starting point in the field (Figure 11) reaches the desired level (60 to 70 cbs.) then irrigation should be initiated and enough water applied to replenish the soil profile.

If the soil is a very light texture, it may be necessary to start irrigator at a lower soil tension to avoid stressing the farthest end of the irrigated field. Initiating more frequent irrigations will maintain a too wet soil surface and wet foliage, which could cause greater incidences of white mold development.

When bean pods are nearly filled, soil water can be allowed to dry to 50 to 60 percent depletion before another irrigation is needed. Irrigation can typically be stopped when 50 percent of the leaves are yellowing on the plants. Once bean seeds have begun to dry in the pod, soil water is no longer taken up by the plant.

If the plants have a shallow root system because of root rot or other rooting barriers, the suggested irrigation scheduling strategy should be modified to encourage more frequent and lighter irrigation to meet the crop water needs.

Soil Water Monitoring Methods

Regular monitoring of the soil water status within the field is very necessary to assist an operator in deciding when to irrigate (Figure 8). The most common tools for estimating soil water depletion are (1) soil water tension sensors; (2) feel and appearance of the soil; and (3) soil water accounting by the "checkbook" method, where soil water deficit (SWD) is estimated by recording daily crop ET (evapotranspiration) and the amount of rainfall and irrigation.

Figure 8. Regular readings of in-field soil moisture sensors is one method of estimating soil water depletion.

Soil water tension can be monitored at given locations in the active root zone by electrical resistance soil water sensors or tensiometers (Figure 9). Soil tension or suction describes how tightly water is held to the soil particles and how much force plant roots need to remove water from the soil. Tension is usually expressed in centibars.

Table 2 shows estimated soil water deficit for several soil water tension levels and soil textures. Tensiometers directly measure the soil water tension between 0 and 80 cbs. and work best in sandy loam or lighter textured soil.

Resistance sensors work in a wider range of soil textures and soil water tensions. Some types, like the Watermark granular matrix sensor, operate as well as a tensiometer in sandy textured soils.

Table 2. Soil water deficit estimates for several soil textures and tensions.

Soil Texture	Soil water tension in centibars, cbs						
	10	30	50	70	100	200	1500**
	Soil water deficit – inches per foot of soil						
Coarse sand	0	0.1	0.2	0.3	0.4	0.6	0.7
Fine sand	0	0.3	0.4	0.6	0.7	0.9	1.1
Loamy sand	0	0.4	0.5	0.8	0.9	1.1	1.4
Sandy loam	0	0.5	0.7	0.9	1.0	1.3	1.7
Loam	0	0.2	0.5	0.8	1.0	1.6	2.4

***1500 cbs refers to the permanent wilting point, soil deficit equals the soil's available water capacity.*

Reading the installed sensors every 1 to 2 days is the best way to keep track of the soil water status. Figure 6 shows a good way to summarize the daily readings.

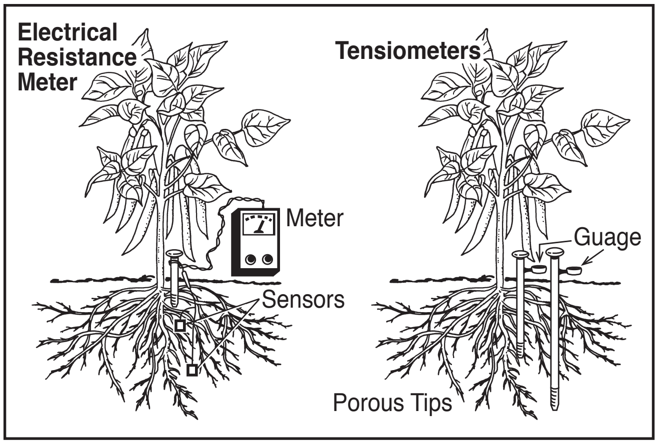


Figure 9. Positioning for use of two types of soil moisture monitors.

For additional information on sensors or their availability, contact your local irrigation supplier or consult an appropriate mail order product catalog.

The *feel/appearance* method involves collecting soil samples in the root zone with a soil probe or a spade. The soil water depletion of each sample can be estimated by feeling the soil and comparing its appearance to developed tables (such as that of Table 3).

Soil sampling should be taken from several depths in the root zone and at several locations across the field. Summing up the SWD estimations for a location from each depth will predict the total soil water depletion in the root zone at that site. This method requires frequent use by an operator to develop consistency in the art of estimating soil water status by feel. For assistance in determining total soil water capacity for the different soils in a field review a local soil survey atlas or contact the local Soil and Water Conservation District or Extension office.

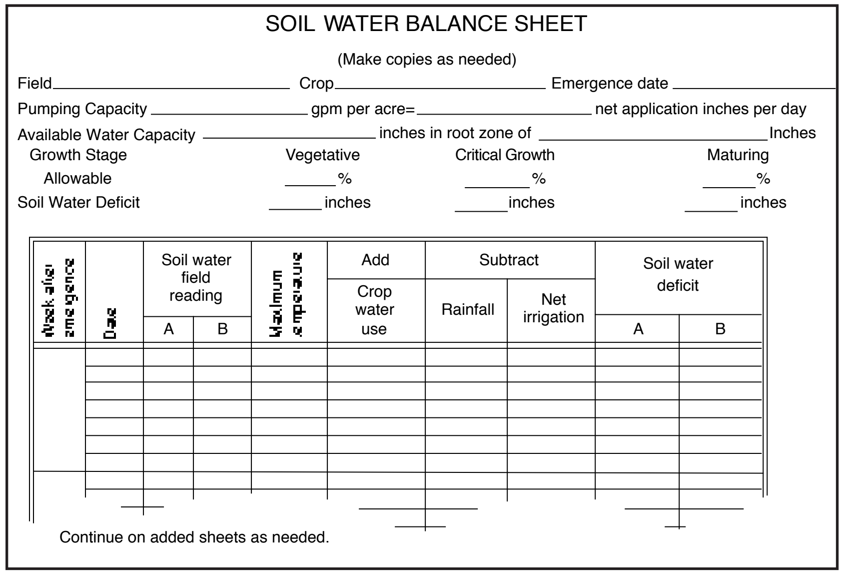
The *irrigation checkbook* accounting method involves keeping track of the estimated daily crop ET and measured rainfall and irrigation amounts within the field. These values are placed into a balance sheet (manual or computerized) to predict the soil water deficit (SWD) at the end of each day. Daily crop water use (ET) estimations for dry beans can be obtained by applying the values in Table 4 when the crop achieves full

Table 3. Guide for judging soil water deficit based on soil feel and appearance for several soil textures.

Soil Texture Classification					
Moisture deficiency	**Coarse (loamy sand)**	**Sandy (loamy sand)**	**Medium (loam)**	**Fine (clay loam)**	**Moisture deficiency**
in./ft.					**in./ft.**
.0	(field capacity) Leaves wet outline on hand when squeezed.	(field capacity) Appears very dark, leaves wet outline on hand, makes a short ribbon.	(field capacity) Appears very dark, leaves wet outline on hand, will ribbon out about one inch.	(field capacity) Appears very dark, leaves slight moisture on hands when squeezed, will ribbon out about two inches.	.0
.2	Appears moist, makes a weak ball.				.2
.4	Appears slightly moist, sticks together slightly.	Quite dark color, makes a hard ball.	Dark color, forms a plastic ball, slicks when rubbed.	Dark color, will slick and ribbons easily.	.4
.6	Appears to be dry, will not form a ball under pressure	Fairly dark color, makes a good ball.		Quite dark, will make thick ribbon, may slick when rubbed.	.6
.8		Slightly dark color, makes a weak ball.	Quite dark, forms a hard ball.		.8
1.0		Lightly colored by moisture, will not ball.	Fairly dark, forms a good ball.	Fairly dark, makes a good ball.	1.0
1.2	Dry, loose, single-grained flows through fingers. (wilting point)	Very slight color due to moisture, loose, flows through fingers. (wilting point)	Slightly dark, forms weak ball.	Will ball, small clods will flatten out rather than crumble.	1.2
1.4			Lightly colored, small clods crumble fairly easily.	Slightly dark, clods crumble.	1.4
1.6					1.6
1.8			Slight color due to moisture, powdery, dry, sometimes slightly crusted but easily broken down in powdery condition. (wilting point)	Some darkness due to unavailable moisture, hard, baked, cracked sometimes has loose crumbs on surface. (wilting point)	1.8
2.0					2.0

canopy closure shortly after first bloom. If the canopy shortly after bloom does not close completely, the estimated ET from Table 4 should be reduced by 10 to 15 percent depending on closure. Daily ET rate may also be available from a regional crop ET hotline service that is estimated from local weather station measurements. Crop ET may also be estimated from a daily ET potential map available on the internet at *http://bob.soils.wisc.edu/wimnext/* that is developed from local airport weather measurements and satellite imagery by the University of Wisconsin and supported by the University of Minnesota.

Predicted daily soil water deficit (SWD) from checkbook method should be in-field verified at least once every 7 to 10 days with a soil probe or soil water sensors and then the SWD on respective checkbook balance sheet adjusted accordingly (Figure 10).



SOIL WATER BALANCE SHEET

(Make copies as needed)

Field__________ Crop__________ Emergence date __________

Pumping Capacity __________ gpm per acre= __________ net application inches per day

Available Water Capacity __________ inches in root zone of __________ Inches

Growth Stage	Vegetative	Critical Growth	Maturing
Allowable	_____%	_____%	_____%
Soil Water Deficit	_____ inches	_____ inches	_____ inches

Week after emergence	Date	Soil water field reading A	Soil water field reading B	Maximum temperature	Add: Crop water use	Subtract: Rainfall	Subtract: Net irrigation	Soil water deficit A	Soil water deficit B

Continue on added sheets as needed.

Figure 10. A soil water balance sheet is used to track moisture levels using the irrigation checkbook accounting method. A full-size copy of the form can be found in University of Minnesota Extension Service publication FO-1332. The form is used in conjunction with an "average water use table."

Table 4. Estimated daily crop water use (ET) in inches/day for field beans in central Minnesota with normal sunshine.

Temp °F	Week after emergence: 1	2	3	4	5	6	7	8	9	10	11	12	13	14
50-59	.02	.03	.05	.06	.07	.08	.09	.10	.09	.09	.08	.06	.04	.02
60-69	.04	.04	.07	.08	.11	.12	.13	.15	.14	.13	.12	.09	.06	.03
70-79	.05	.06	.09	.11	.14	.06	.17	.19	.19	.17	.15	.11	.07	.04
80-89	.06	.07	.11	.13	.18	.20	.22	.24	.23	.22	.19	.14	.09	.04
90-99	.07	.09	.13	.16	.21	.24	.25	.27	.26	.25	.23	.17	.11	.05
Field beans Growth Stage				**2nd trifoliate**		**1st flower**			**seed filling**			**leaves yellowing**		

Figure 6 shows how well in-field daily soil sensor readings trace the predicted daily soil water deficit (SWD) as estimated by the Minnesota Checkbook method (daily SWD needed correcting five times during this period based on the soil water sensors readings) for a 1998 dry bean field in Wadena county.

Soil Moisture Sensor Installation

To install electrical resistance type soil water sensors like the Watermark soil moisture sensor or other similar devices follow the steps outlined below along with the instructions given by the respective sensor manufacturer. Sensors should be placed in a field within two weeks after plant emergence.

Soak each sensor in clean water for 1 to 2 hours to remove the air and then allow drying for 4 to 6 hours. Repeat this step two times more. Prior to placing sensors into the soil soak at least five minutes.

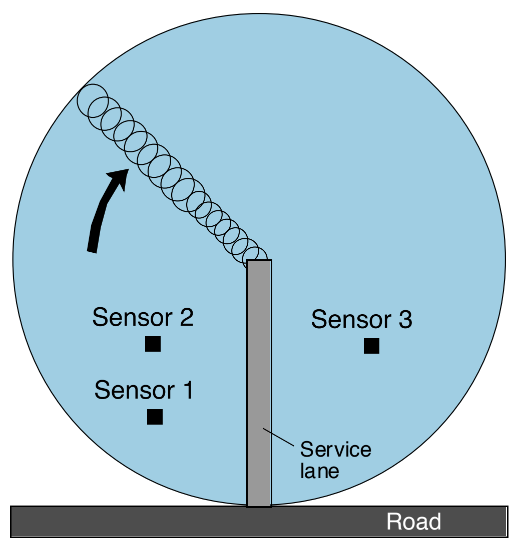


Figure 11. Typical locations for soil water sensor sites.

If the sensors were used in a previous season, evaluate for damage to the wire leads or the sensor surface and discard the sensor if surface looks plugged with soil or damaged.

Select two or more locations for the sensors in the first third of the irrigated field and one location in the last third of the field (Figure 11). All sensors should be located in a representative soil type in the field. Under a center pivot, the sensors should not be installed near pivot wheel tracks or other high traffic areas. The sensors should be placed somewhere between the second tower and the last tower. Each sensor should be positioned within the plant row near a healthy plant in a location with a normal plant population. At each site a sensor should be set 4 to 6 inches below the ground surface and another set at 9 to 12 inches below the surface.

To install a sensor in the soil, first make a hole with a soil probe or auger to a depth a little deeper than desired. To get good sensor contact with the soil, pour a little dry soil and water into the new hole. To position the sensor into the hole, draw the lead wire through the soil probe tube and hold the sensor on the end (Figure 12). Push the probe and sensor into the hole to the desired depth until set firmly. Fill the hole by adding some dry soil and a little water at a time and firm with a tamping stick until the hole is filled.

Figure 12. A soil probe is used to install a sensor.

Mark each sensor site with a colored flag or stake to locate the site easily. Wrap the extra lead wire around the stake. Mark each sensor's wire lead to indicate its depth with a tag or creating one or more knots near the wire end to indicate depth position (for example one knot means shallow and two knots means a deep sensor). At one or two of the locations near the start-up position of the irrigation cycle include a rain gauge with a 2-inch diameter or greater. Also place a marker at the end of each row or along the road to indicate the entrance path to the sensor site.

Wait to start taking readings until 1 to 2 days after installation to allow the added water to equalize with the surrounding soil moisture. Sensors should be read every two to three days and recorded in a notebook or spreadsheet to track the soil water changes in the soil profile throughout the growing season.

Remove sensors before harvest using a shovel. Clean soil from sensor surfaces with only water pressure and hang up to dry for use next year.

More information on the Checkbook method and in-field soil moisture monitoring tools can be found in University of Minnesota Extension Service bulletins Irrigation Scheduling Checkbook Method FO-1322 and Irrigation Water Management Considerations for Sandy Soils in Minnesota FO-3875. These are available at local county extension offices or can be ordered online at:

http://www.extension.umn.edu/

The research and demonstration studies mentioned in this bulletin were done at or near Staples, Minnesota. They received funding support over the years from the Northarvest Bean Growers Association, Irrigators Association of Minnesota, USDA-NRCS Environmental Quality Incentive Program (EQUP), Agricultural Utilization Research Institute (AURI), Elf Atochem, Dupont, and the University of Minnesota Agricultural Experiment Station.

For further information contact:

Richard Meronuck, (612-625-6290 or rmeronuck@extension.umn.edu), Department of Plant Pathology

Jerry Wright, (320-589-1711 or jwright1@extension.umn.edu), Department of Biosystems and Agricultural Engineering

George Rehm, (612-625-6210 or grehm@extension.umn.edu), Department of Soil, Water and Climate

Additional copies of this item can be ordered from the University of Minnesota Extension Service Distribution Center, 20 Coffey Hall, 1420 Eckles Avenue, St. Paul, MN 55108-6069, e-mail: order@extension.umn.edu or credit card orders at (800) 876-8636.

Produced by Communication and Educational Technology Services, University of Minnesota Extension Service.

BU-7397
1999