IMPROVED IRRIGATION MANAGEMENT THROUGH SOIL MOISTURE MONITORING

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ABSTRACT

Water is perhaps the single most important input to alfalfa production in the West. Despite its importance, it is one of the most difficult to manage. Research evaluated the usefulness of Watermark\textsuperscript{®} resistance blocks for irrigation scheduling in alfalfa. Watermark resistance block readings were closely correlated with neutron probe readings. The soil moisture content of several alfalfa fields was monitored for the duration of the irrigation season. Resistance block readings showed wide fluctuations in soil moisture during the season; the driest periods corresponded with alfalfa harvests. Soil moisture content varied greatly between growers reflecting individual irrigation practices. Soil moisture monitoring can be an effective method for scheduling alfalfa irrigations and improving irrigation management.

Key Words: Alfalfa, Medicago sativa, irrigation scheduling, water management, resistance blocks, neutron probe

INTRODUCTION

Proper irrigation management is critical to profitable alfalfa production in the West. However, effective water management is difficult. The ‘action’ occurs below the soil surface out of our view. Therefore, determining when to irrigate and how much water to apply are not simple tasks.

The decision of when to irrigate is ordinarily based on experience and past practices, weather-based information (crop evapotranspiration data), or soil-based measurements. Past practices may not be correct and often are not adjusted to account for changes in weather from year to year. It can be difficult to schedule irrigations based on crop evapotranspiration because, unlike other crops with a single harvest per season, the multiple harvests of alfalfa confound the process. Irrigation water cannot be applied too close to a cutting and fields obviously cannot be irrigated while the alfalfa is curing. Therefore, there is typically a 6- to even 20-day period during which fields cannot be irrigated. Scheduling irrigations around cuttings can be challenging.

Another difficulty using evapotranspiration data to schedule alfalfa irrigation is related to the fact that entire fields are usually not irrigated at once. This is especially true with sprinkler irrigation where fields are usually irrigated in sets. In theory, evapotranspiration would have to be monitored for each section of the field and each section irrigated accordingly.
SOIL BASED MEASUREMENTS

Soil-based measurements may be far more practical and easy-to-use for alfalfa producers. Soil moisture measurements can be used to schedule irrigations and/or assess the adequacy of current irrigation practices. Soil moisture content in alfalfa fields often goes unchecked. If soil moisture is monitored at all, it is usually only done using a shovel or soil auger. While somewhat helpful, using a shovel or auger is imprecise and is only useful for a gross evaluation of the soil moisture content in the upper foot or less.

Resistance blocks

Soil moisture sensors (also called gypsum blocks or resistance blocks) are an effective and relatively inexpensive method of monitoring soil moisture. They are not a new invention but recent advances have improved their accuracy and ease-of-use. Moisture blocks evaluate soil moisture by measuring the electrical resistance between two electrodes. The blocks take up and release moisture as the soil wets and dries. The higher the water content of the blocks, the lower the electrical resistance.

There are several manufacturers of resistance blocks. Of the ones tested, the Watermark® sensors were the most accurate (Hanson et al unpublished data). Some types of resistance blocks do not respond until the soil moisture content is relatively low. Watermark sensors were found to be more sensitive to moisture changes in the upper range of soil moisture.

The Watermark soil moisture sensor estimates soil moisture tension in centibars. The soil moisture tension refers to how strongly water is held on soil particles. Low soil moisture tensions indicate moist soil and high soil moisture tensions indicate dry soil.

Installation of sensors

Proper placement and installation of resistance blocks is important. It is recommended that growers install two or three sensors per evaluation site. One sensor should be located in the upper one quarter of the root zone of the crop. The other should be placed toward the bottom of the root zone. If three sensors are used, install them at 1 ft., 2 ft., and 3.5 or 4 ft (depending on the depth of the soil). The upper two sensors are used to determine when to irrigate. The deep sensor is useful to evaluate the depth reached by the last irrigation. The deepest sensor is also useful to make sure that you are not excessively depleting moisture reserves deep in the root zone of the crop.

The sensors must be installed in an area that is representative of the field (i.e., soil type typical of the field and an area that receives full sprinkler or flood-irrigation coverage). Two sites per field are recommended.

Since you don’t want to destroy the soil moisture sensors with a swather, it is advisable to make a buried reading station. A 4-6 inch length of 2-inch PVC with a screw-on cap works well to house the wire leads. A shallow (3-6 inch) trench is dug for the wire leads coming from each sensor to the PVC housing. You can color code the wires to keep track of the depth of the...
sensors by tying a small piece of colored wire to each lead. The sensor itself can also be glued onto a section of PVC pipe so they can be retrieved at a later date and reused. A more detailed explanation of the sensor installation procedure can be found in the literature from manufacturers.

Using the readings

The best way to apply soil-moisture measurements to irrigation scheduling is to plot the moisture values on a graph. The plotted data present a picture of how fast the soil is drying. As alfalfa grows, it draws on the soil-water and the moisture sensor readings begin to rise. After a few points have been plotted, you can estimate approximately how many days it will take for the soil to dry before irrigation is needed. For sandy soils irrigate when the upper sensor(s) reads 60-70 centibars. Clay soils retain more water and centibar readings over 100 can be obtained without a significant yield reduction.

DESCRIPTION OF SOIL MOISTURE STUDY

Watermark resistance blocks were installed in eight alfalfa fields in Scott Valley, Siskiyou County CA. The purpose was to assess current irrigation practices and evaluate the usefulness of Watermark sensors for irrigation management in alfalfa. Soil moisture levels were monitored weekly from spring through September. The sensors were installed at 1-foot increments down to 5 feet. A neutron probe access tube was also installed at each site, approximately 3 feet from the resistance blocks. A neutron probe is a more accurate and sophisticated instrument for estimating soil moisture content than are resistance blocks. However, a neutron probe is impractical for grower use because of the cost and licensing requirements. The soil moisture sensor readings correlated very well with the Watermark readings except in fields where there were dramatic changes in soil texture with depth.

RESULTS AND DISCUSSION

Before discussing the actual results, it is helpful to review what the Watermark readings mean. Remember that the readings are in centibars and measure soil moisture tension or suction. The higher the reading the lower soil moisture content and the lower the reading the higher the soil moisture content. When the soil profile is full (air spaces mostly filled with water) the Watermark reading is low, typically less than 5 to 10. As the soil dries the readings gradually increase. For the soils in the study, irrigation should occur when the centibar reading approaches 60 to 90. Following irrigation the readings should again drop to single digits. Readings that do not drop significantly following irrigation indicate that irrigation water was insufficient to reach that depth and refill the soil profile. Cases where the soil moisture tension readings never approach 60 to 90 indicate the field may be irrigated too often or with too much water per irrigation.

The Watermark readings were very useful to characterize the changes in soil moisture that occurred in the different fields. The three graphs that are presented in figures 1-3 represent the range of conditions found in the eight alfalfa fields. Soil moisture content fluctuated considerably over the season in most fields. As noted by the oscillation in the lines, there was far
more fluctuation in soil moisture at the shallow depths (1 and 2 feet) than at the deeper depths (3-
5 feet). This is logical in that the shallow depth is the zone of greatest root activity. Not surprisingly, soil moisture levels in all fields were high in early spring before crop transpiration depleted the soil moisture supplied by winter and spring rains. Soil moisture remained relatively high throughout spring in most fields; crop evapotranspiration is low and sporadic spring rains occur so irrigations usually keep pace with crop water needs. In June the soil moisture tensions start to increase significantly in most fields. The figures show a spike in soil moisture tension (very dry soil) in early June for most fields. This spike corresponds with first cutting. A spike in the sensor readings (low soil moisture levels) also occurred at each subsequent cutting.

The soil moisture contents encountered in this study varied considerably from grower to grower. Grower A (Figure 1) harvested 4 cuttings (note the peaks in soil moisture tension in late May, late-June, mid-July, and early September corresponding to each cutting). The soil moisture tension never went above 40 centibars until early August. This indicates more water than necessary was applied in spring through early summer. The number of irrigations or the irrigation set time could have been reduced. In contrast, Grower B (Figure 2) applied far less water than needed. Soil moisture was sufficient in spring up to first cutting in early June. From that point on the crop was stressed for moisture and water at the deeper depths was depleted. Only the one-foot sensor responded to irrigations (readings drop following an irrigation), indicating the water never reached the 2-foot sensor or below. Soil moisture was depleted even at the 5-foot depth.

For most of the season Grower C maintained soil moisture within an acceptable range (Figure 3) However, in mid June the soil moisture tension rose above 120 centibars. Rain occurred while the hay was curing, delaying the hay-making process. This postponed the irrigation that occurs after cutting. By the time the field was re-irrigated, excessive soil moisture depletion had occurred. The grower was able to ‘catch up’ and the Watermark readings returned to near zero.

This research clearly demonstrates the usefulness of monitoring the soil moisture content of alfalfa fields. Do you know which of these three graphs would depict the soil moisture status of your field? Soil moisture readings are particularly valuable to:

- **Determine when to begin irrigating in spring.** This is often a difficult decision. The soil profile is usually filled from winter rains. But, after alfalfa resumes growth in spring and the weather warms up, the grower must decide when the soil moisture is depleted enough to initiate irrigation.

- **Decide whether another irrigation is needed before cutting.** Alfalfa is most sensitive to water stress after cutting when the plants start to regrow. Resistance block readings help assess whether the soil-moisture content is sufficient to avoid water stress through the cutting and hay curing period until irrigation can be resumed. The sensors may indicate that alfalfa should be irrigated closer to a cutting or sooner after the bales are removed to avoid moisture stress to alfalfa regrowth.

- **Ascertain if the last irrigation was adequate to refill the soil profile.** Soil moisture sensors give an indication of the depth of water penetration. If the sensors do not respond
after an irrigation the water did not penetrate to the depth of the sensor. The soil-moisture readings indicate how many irrigations are necessary to refill the soil profile after cutting.

**Assess the deep-moisture status of a field.** The soil moisture sensors were extremely useful to assess the moisture status at the lower end of the alfalfa root zone. The lower half of the root zone supplies a moisture reserve and should not be excessively depleted.

**Evaluate current irrigation practices.** Soil moisture monitoring is helpful to verify that current irrigation practices satisfy, but do not exceed, the needs of the crop. Use the sensor readings to keep track of the soil moisture so that it can be maintained near optimum levels. The sensors may indicate the soil is getting excessively dry between irrigations. Or, soil moisture sensors may indicate that the soil has sufficient water even though an irrigation is planned. Irrigation can be skipped or delayed until soil moisture sensors indicate irrigation is needed.

It may be difficult to make major changes in irrigation practices because of the limited flexibility of most alfalfa irrigation systems (i.e., irrigations must be scheduled around cuttings, pump capacity is limited, the number of wheel lines per field are often fixed, etc.). However, in most cases it is not necessary to make major changes or to redesign an existing irrigation system. Relatively minor adjustments in irrigation practices could pay large dividends in increased yield or water savings. Soil moisture sensors have been proven to be very useful to diagnose the changes needed and fine-tune irrigation practices.

**SUMMARY AND CONCLUSIONS**

Watermark sensors were found to be a reliable tool to assist growers with irrigation scheduling and improve irrigation efficiency. It appears that, by using a tool such as soil moisture sensors, there is potential for improved water management and water conservation on some ranches. There were times in this study, especially in spring, when fields were irrigated when the soil moisture levels did not indicate irrigation was needed. Under irrigation occurred on other ranches, largely because the irrigation system was inadequate to meet peak crop needs in mid-summer. In conclusion, the soil moisture sensors employed in this study were found to be a very effective tool to determine when irrigation is needed and to help avoid over- or under-irrigation. Growers are encouraged to adopt the practice of soil moisture monitoring with resistance blocks to improve irrigation management.

**REFERENCES**


Figure 1. Seasonal changes in soil moisture content at five depths. Soil moisture readings taken with Watermark resistance blocks. (Alfalfa Grower A).

Figure 2. Seasonal changes in soil moisture content at five depths. Soil moisture readings taken with Watermark resistance blocks. (Alfalfa Grower B).
Figure 3. Seasonal changes in soil moisture content at five depths. Soil moisture readings taken with Watermark resistance blocks. (Alfalfa Grower C).