# DEVELOPMENT OF SEASON LONG DEFICIT IRRIGATION STRATEGIES FOR SUGARBEETS

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## Introduction:

Within the Western Sugar Cooperative growing region, surface water supplies for irrigation are limited whenever drought occurs. As a result, delivery of surface water may be delayed at the beginning of the season, restricted during the season, shut off before the irrigation season is over, or a combination of all of these situations. Because adequate water may not be available to meet total crop water needs, surface water users have a difficult decision to make in selecting which crop to irrigate.

For those growers that depend on ground water for irrigation, drought increases the amount of water they need to pump and results in increased pumping costs. However, in many areas pumping groundwater for irrigation has resulted in a decline in the groundwater table. As groundwater levels decline government regulatory agencies have imposed pumping restrictions as a method to reduce groundwater withdrawal in an attempt to extend the useful life of the aquifers into the future.

In the early 2000's when restrictions on ground water pumping were put in place and there was a lack of surface water due to drought, many producers had the feeling that sugarbeet production was a crop of the past. Without an abundant supply of water it would be unlikely that production levels could be maintained and a switch to other crops would be necessary.

Yet society is demanding irrigated agriculture use water for the production of all crops both effectively and efficiently throughout the season. With more limited supplies of water, the producer needs to decide which crop to grow and when to use the limited amount of water that is available. Water stress can occur anytime during the growing season and precipitation may also occur at anytime during the season, even immediately after an irrigation event. When excess water is applied, the result can be loss of water through deep percolation and at the same time use of a limited water supply when not needed.

Deficit irrigation strategies are being developed for many crops to deal with water shortages throughout the entire growing season. Season long deficit irrigation strategies for sugarbeets must be developed so that sugarbeet production can be maintained even though water supplies may be limited either now or in the future. The objective of this experiment was to evaluate the production of sugarbeets when irrigation water supply is limited and deficit irrigation must be used throughout the growing season.

## Procedure:

A small plot sprinkler irrigation system was used to compare nine irrigation treatments at the University of Nebraska Panhandle Research and Extension Center during the 2008 – 2010 growing seasons. Treatments were replicated six times in a randomized complete block design. Treatments were designed to compare with full irrigation and included:

1. 100% of full irrigation
2. 75% of full irrigation

3. 50% of full irrigation
4. 25% of full irrigation
5. 0% of full irrigation (no irrigation)
6. 100% of full irrigation until August 15 then 50% of full irrigation
7. 75% of full irrigation until August 15 then 25% of full irrigation
8. 50% of full irrigation until August 15 then 100% of full irrigation
9. 25% of full irrigation until August 15 then 75% of full irrigation

Two varieties Betaseed 66RR70 and Hilleshog/Syngenta 9027RR were planted. The small plot sprinkler system was installed immediately after planting. Due to a severe storm and frost that reduced stand in 2010, sugarbeets were replanted on 5/18 that year. Sprinkler irrigation treatments spanned the periods of June 30 – September 29, July 9 – September 25 and July 2 - September 24, for 2008, 2009 and 2010, respectively.

Approximately 7.7, 8.5 and 7.4 inches of rainfall was received during the 2008, 2009 and 2010 growing seasons, respectively. Table 1 gives rainfall amounts greater than 0.10 in. and the dates of occurrence. In 2008, rainfall was dispersed relatively even throughout the growing season. However in 2009 and 2010, rainfall primarily occurred during the early part of the growing season and prior to when irrigation began. In 2008 there was 4.8 in. of rainfall that occurred after the first irrigation event in the spring through harvest. For 2009 and 2010, there was only 2.2 in. and 1.8 in., respectively between the first irrigation event and harvest. In 2009 and 2010 1.2 in. and 0.4 in., respectively, of rain occurred two days after the first irrigation event. This resulted in only approximately 1.0 in. of rain for both 2009 and 2010 during the heavy water use months of July, August and September.

Table 1. Rainfall date and amount (inches) during 2008-2010 growing seasons.

| Year | Date | Rainfall | Date | Rainfall | Date | Rainfall |
|---|---|---|---|---|---|---|
| 2008 | 4/30 | 0.43 | 6/5 | 0.21 | 9/1 | 0.35 |
| | 5/7 | 0.33 | 6/20 | 0.36 | 9/5 | 0.30 |
| | 5/22 | 0.21 | 7/22 | 0.83 | 9/6 | 0.19 |
| | 5/23 | 0.24 | 8/3 | 0.11 | 9/7 | 0.13 |
| | 5/26 | 0.18 | 8/14 | 0.32 | 9/12 | 0.42 |
| | 6/1 | 0.19 | 8/15 | 1.36 | 10/11 | 0.23 |
| | 6/4 | 0.75 | 8/16 | 0.11 | 10/12 | 0.49 |
| 2009 | 5/10 | 0.23 | 6/10 | 1.35 | 7/11 | 1.17 |
| | 5/24 | 0.74 | 6/11 | 0.25 | 7/16 | 0.23 |
| | 5/25 | 0.14 | 6/14 | 0.63 | 7/28 | 0.11 |
| | 5/31 | 0.42 | 6/17 | 0.95 | 8/6 | 0.11 |
| | 6/3 | 0.29 | 6/23 | 0.12 | 8/8 | 0.30 |
| | 6/5 | 0.15 | 6/26 | 0.17 | 9/11 | 0.16 |
| | 6/7 | 0.32 | 7/1 | 0.11 | 9/21 | 0.16 |
| | 6/8 | 0.16 | 7/6 | 0.29 | | |
| 2010 | 5/18 | 0.26 | 6/9 | 0.2 | 7/4 | 0.37 |
| | 5/19 | 0.21 | 6/10 | 0.24 | 7/6 | 0.2 |
| | 5/24 | 0.47 | 6/11 | 1.6 | 7/10 | 0.17 |
| | 6/5 | 0.41 | 6/12 | 0.48 | 8/1 | 0.64 |
| | 6/6 | 0.5 | 6/18 | 0.16 | 8/16 | 0.27 |
| | 6/8 | 0.86 | 6/19 | 0.22 | 8/30 | 0.11 |

Table 2 gives, as an example, the 2010 irrigation schedule for the irrigation treatments tested. Irrigation application was limited to 0.8 in. every three days to simulate a 125 acre center pivot sprinkler having a 600 gpm well. All plots were irrigated on the same date at the desired level. Irrigation amount was varied by changing the size of nozzle in the sprinkler heads. The August 16 date in Table 2 reflects the date when application amounts compared to full irrigation for the split irrigation treatments changed.

Leaf area index and plant height were measured each season, Table 3. Leaf area index was determined by placing a light index meter within the plant canopy to determine the amount of intercepted light near the ground surface. Plant height was determined by measuring the height of the plant canopy as measured from the top of the soil ridge in the sugarbeet row to the average height of surrounding plant leaves. Leaf area and plant height were measured to determine influence of deficit irrigation on canopy development and architecture. Plots were harvested, Table 3, using a two row mechanical plot harvester. Sugarbeet samples were collected and sent to Western Sugar Cooperative to determine tare, sugar content and sugar loss to molasses (SLM).

A neutron probe was used to measure volumetric water content at 1 ft increments. Measurements were taken to a depth of 4 ft. The neutron probe measures the soil water content in approximately a 1 ft sphere of the soil profile. Neutron probe measurements were taken periodically throughout each growing season.

Table 2. Irrigation date and amount (inches) for the 2010 growing season.

| Date | 100% | 75% | 50% | 25% | 100/50% | 75/25% | 50/100% | 25/75% | 0% |
|---|---|---|---|---|---|---|---|---|---|
| July 2 | 0.8 | 0.6 | 0.4 | 0.2 | 0.8 | 0.6 | 0.4 | 0.2 | 0 |
| July 15 | 0.8 | 0.6 | 0.4 | 0.2 | 0.8 | 0.6 | 0.4 | 0.2 | 0 |
| July 19 | 0.8 | 0.6 | 0.4 | 0.2 | 0.8 | 0.6 | 0.4 | 0.2 | 0 |
| July 23 | 0.8 | 0.6 | 0.4 | 0.2 | 0.8 | 0.6 | 0.4 | 0.2 | 0 |
| July 28 | 0.8 | 0.6 | 0.4 | 0.2 | 0.8 | 0.6 | 0.4 | 0.2 | 0 |
| Aug 3 | 0.8 | 0.6 | 0.4 | 0.2 | 0.8 | 0.6 | 0.4 | 0.2 | 0 |
| Aug 6 | 0.8 | 0.6 | 0.4 | 0.2 | 0.8 | 0.6 | 0.4 | 0.2 | 0 |
| Aug 10 | 0.8 | 0.6 | 0.4 | 0.2 | 0.8 | 0.6 | 0.4 | 0.2 | 0 |
| Aug 16 | 0.8 | 0.6 | 0.4 | 0.2 | 0.4 | 0.2 | 0.8 | 0.6 | 0 |
| Aug 20 | 0.8 | 0.6 | 0.4 | 0.2 | 0.4 | 0.2 | 0.8 | 0.6 | 0 |
| Aug 23 | 0.8 | 0.6 | 0.4 | 0.2 | 0.4 | 0.2 | 0.8 | 0.6 | 0 |
| Aug 27 | 0.8 | 0.6 | 0.4 | 0.2 | 0.4 | 0.2 | 0.8 | 0.6 | 0 |
| Aug 30 | 0.8 | 0.6 | 0.4 | 0.2 | 0.4 | 0.2 | 0.8 | 0.6 | 0 |
| Sep 3 | 0.8 | 0.6 | 0.4 | 0.2 | 0.4 | 0.2 | 0.8 | 0.6 | 0 |
| Sep 7 | 0.8 | 0.6 | 0.4 | 0.2 | 0.4 | 0.2 | 0.8 | 0.6 | 0 |
| Sep 13 | 0.8 | 0.6 | 0.4 | 0.2 | 0.4 | 0.2 | 0.8 | 0.6 | 0 |
| Sep 15 | 0.8 | 0.6 | 0.4 | 0.2 | 0.4 | 0.2 | 0.8 | 0.6 | 0 |
| Sep 20 | 0.8 | 0.6 | 0.4 | 0.2 | 0.4 | 0.2 | 0.8 | 0.6 | 0 |
| Sep 24 | 0.8 | 0.6 | 0.4 | 0.2 | 0.4 | 0.2 | 0.8 | 0.6 | 0 |
| Total | 15.2 | 11.4 | 7.6 | 3.8 | 10.8 | 7.0 | 12.0 | 8.2 | 0 |

Table 3. Date of planting and harvest and date of measure for leaf area and plant height for 2008-2010.

| Year | Planting date | Leaf area | Plant height | Harvest date |
|---|---|---|---|---|
| 2008 | April 29 | October 10 | October 7 | October 17 |
| 2009 | April 30 | September 30 | September 23 | October 19 |
| 2010 | April 21(May 18) | September 23 | September 23 | October 8 |

**Results:**

Results from 2008 - 2010 for the nine irrigation treatments for leaf area index, plant height, tare, sucrose content, root yield, sugar yield and SLM is given in Table 3. Only minor visual differences were observed during the growing season among the nine water deficit treatments tested in the form of less plant canopy and water stressed leaves in the drier treatments. In particular, only the 25% and 0% treatments routinely showed visual signs of water stress. Leaf area index was statistically less than all other treatments for the 0% or no irrigation treatment. Leaf area index for the 0% irrigation treatment was approximately 17% less when compared to the average of all other water treatments. Plant height for the 0% irrigation treatment was 5.0 in. less compared to the 25% water treatment and nearly 9.0 in. less compared to the 100% irrigation treatment.

Tare tended to decrease as irrigation amount decreased. In the drier treatments, the lack of fine root hairs may have allowed for less soil to stick to the beet root and reduced tare. In addition, drier soil would tend to separate from the roots easier than soil with greater water content. Sucrose content for the three years ranged from an average low of 14.9% for the 0% irrigation treatment to a high of 16.0% for the 75%/25% irrigation treatment. Sucrose content was similar for all water treatments except the 50%/100% and 0% irrigation treatments which were statistically less than the other treatments, but similar to each other. These results would indicate that as soil water conditions become drier during the growing season, that sucrose content is also reduced.

Root yield decreased from a high of 31.1 t/ac for the 100% irrigation treatment to a low of 20.4 t/ac for the 0% irrigation treatment. Sugar yield was similar for the 100%, 75% and 50% irrigation treatments. Compared to the 100% irrigation treatment, sugar yield declined 14% and 38% for the 25% and 0% irrigation treatments, respectively. The split irrigation treatments that applied more water early in the growing season (100%/50% and 75%/25%) were statistically greater than the split irrigation treatments that applied similar amounts of water but had more water applied late in the growing season (50%/100% and 25%/75%).

SLM varied from a low of 1.2 for the 100% irrigation treatment to 1.7 for the 0% irrigation treatment. Average SLM was 1.3. For pounds of sugar per acre, there was no significant interaction found among the water treatments and varieties tested, therefore the varieties were combined for this analysis.

Table 3. Leaf area index, plant height and harvest yield results for deficit irrigation treatments during the 2008-2010 growing seasons.

| Treatment | Leaf Area Index | Plant Height | Tare | Sucrose Content | Root Yield | Sugar Yield | SLM |
|---|---|---|---|---|---|---|---|
| | | (in) | (%) | (%) | (t/ac) | (lbs/ac) | |
| 100% | 5.58ab* | 18.6ab | 3.7ab | 15.9a | 31.1a | 9880a | 1.2d |
| 75% | 5.65a | 18.4abc | 3.7a | 15.6a | 30.6ab | 9580a | 1.2d |
| 50% | 5.23b | 17.6bc | 3.1cd | 15.7a | 30.5ab | 9570a | 1.3cd |
| 25% | 5.41ab | 15.3e | 2.8d | 15.6a | 27.2d | 8540c | 1.4b |
| 0% | 4.61c | 10.2f | 2.3e | 14.9b | 20.4e | 6170d | 1.7a |
| 100%/50% | 5.8a | 17.0cd | 3.6ab | 15.7a | 31.0ab | 9730a | 1.2d |
| 75%/25% | 5.59ab | 15.9de | 3.3bc | 16.0a | 30.3ab | 9720a | 1.3cd |
| 50%/100% | 5.63ab | 19.3a | 3.6ab | 15.1b | 29.8bc | 8970b | 1.3bc |
| 25%/75% | 5.61ab | 17.9abc | 3.1cd | 15.7a | 29.0c | 9120b | 1.3cd |

*Values followed by the same letter indicate no significant difference at the 5% probability level.

Figures 1-3 show the total water held in a four foot soil profile for the uniform irrigation treatments during 2008-2010, respectively. During each year, soil water content can be seen to be drying out as the end of the season approaches. Average difference between the 100% irrigation treatment and the 0% irrigation treatment was over 3.5 inches of water in the soil profile.

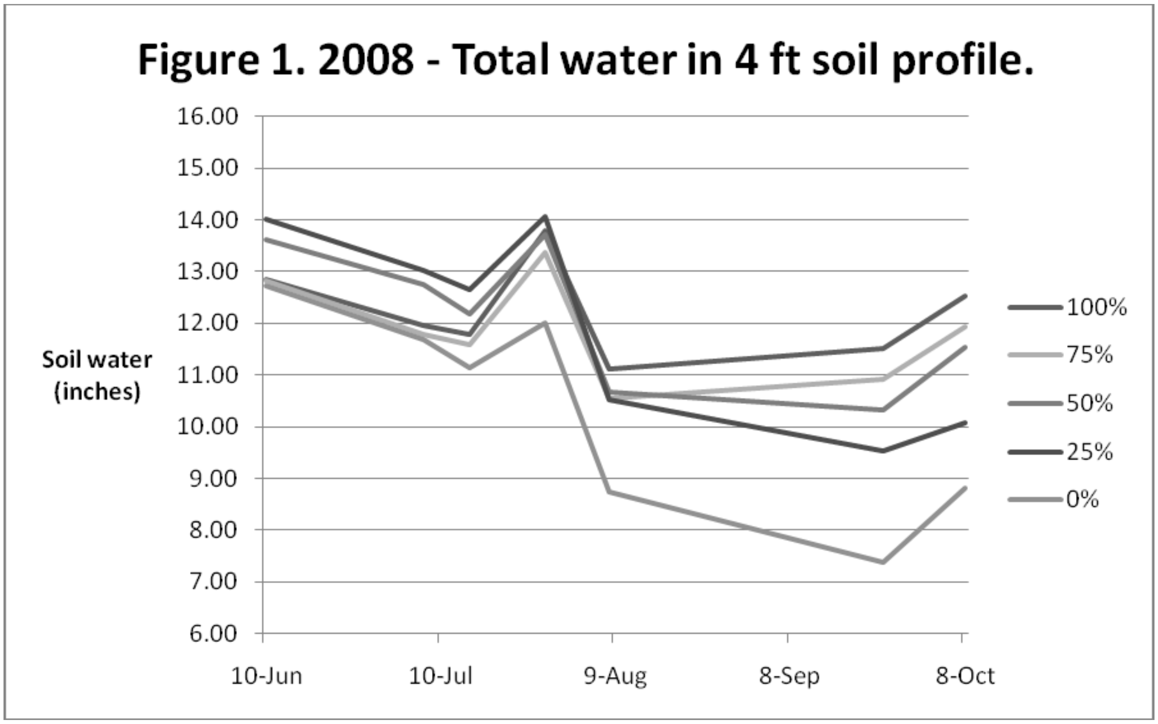
Figure 1. 2008 - Total water in 4 ft soil profile.
16.00
15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
Soil water
(inches)
10-Jun
10-Jul
9-Aug
8-Sep
8-Oct
100%
75%
50%
25%
0%

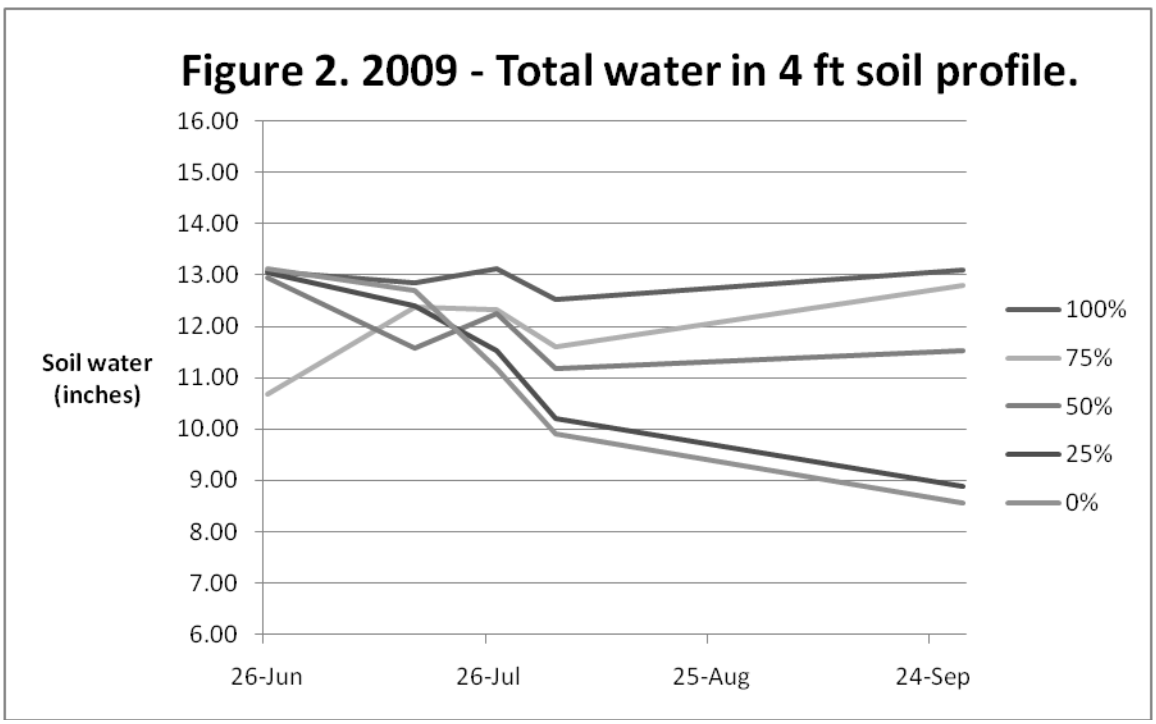
Figure 2. 2009 - Total water in 4 ft soil profile.
16.00
15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
Soil water
(inches)
26-Jun
26-Jul
25-Aug
24-Sep
100%
75%
50%
25%
0%

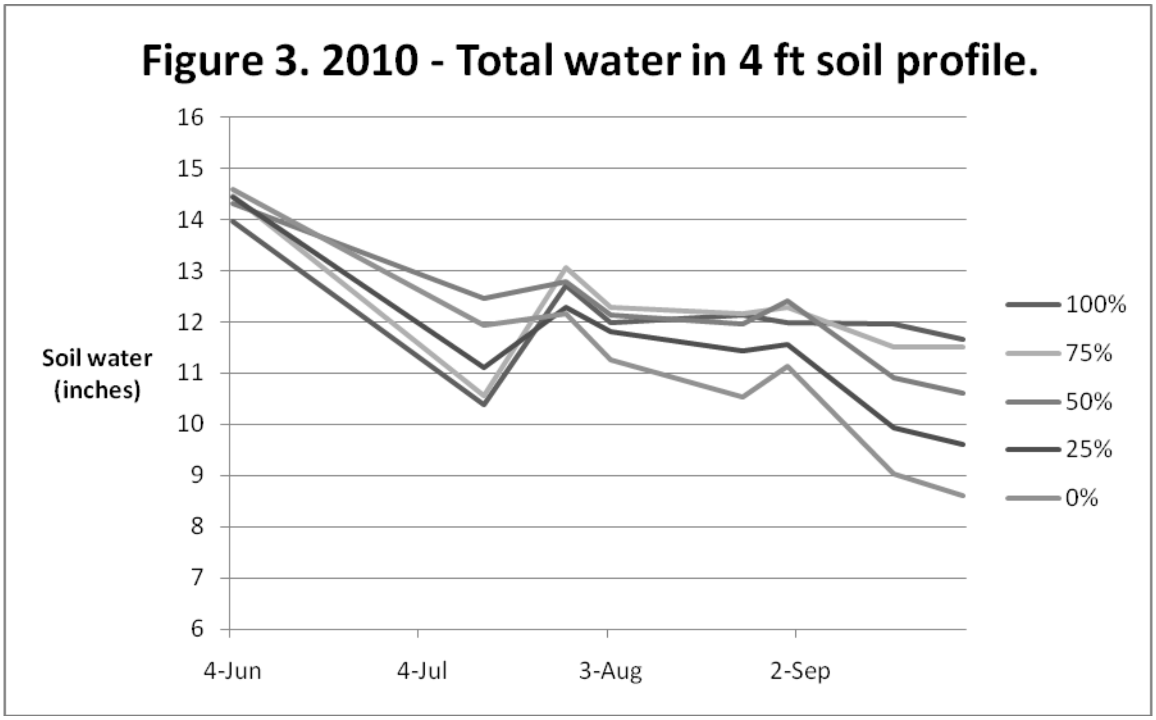
Figure 3. 2010 - Total water in 4 ft soil profile.
Soil water (inches)
16
15
14
13
12
11
10
9
8
7
6
4-Jun
4-Jul
3-Aug
2-Sep
100%
75%
50%
25%
0%