Field and laboratory determination of potential crop yield/quality, irrigation system hydraulic properties, and soil improvement benefits of Magnetic Treated Water (MTW) under sprinkler irrigation in Southern Idaho

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SUMMARY

A Maximum H2O magnetic treatment unit was installed at the pivot point on one of 2 adjacent pivots planted to potatoes on a Declo loam soil east of American Falls, ID in 2021 (**Figure 1**). Although direct comparison of potato yield and quality between two adjacent was not valid due to fertilizer application differences, catch-can testing showed over 20% more water applied by the MTW pivot than the control during windy test conditions. Both pivots were designed to apply the same water depth and were operated the same. Post-season soil sampling to a depth of 5 feet showed 4.7 inches more water in the 2-5 ft depth for MTW than for the control pivot. This difference represents the seasonal average difference between the two treatments. Based on wetting patterns with depth, it is possible that on these fields, some water moved beyond 5 ft on the MTW field so actual difference in applied water might be greater than measured in the 0- 5-ft depth.

Initial tests of magnetically treated water's impact on water movement within the soil and sugar beet yield and quality relative to untreated canal water were conducted during the 2021 growing season at the Kimberly R&E Center on a deep Portneuf silt loam soil typically subject to surface sealing. Irrigation treatments of control and MTW-treated water at 100 and 125% of estimated crop water use (estimated Evapotranspiration or ET) were replicated 6 times. Beet yield was 4.2% greater for MTW than the control at the 100% ET irrigation level, and 4.4% greater at the 125% ET irrigation level. Stand count was 5% greater on the MTW plots than on the control plots.

Sprinkler throw distance, flow rate and sprinkler water distribution were also tested at another nearby site. Observations consistent across replications include throw distance of 6% greater on the MTW sprinklers and water volume applied was 9% higher for the MTW treatment.

Laboratory testing of specific gravity, dynamic viscosity, pH and surface tension for both un-treated well water and MTW water was also conducted. MTW well water was 0.45%, 50%, and 27% higher compared to un-treated well water for specific gravity, dynamic viscosity, and pH, respectively. Surface tension, using capillary rise as a proxy, was consistently higher (5.2cm or 11%) for MTW than for the un-treated control on the limited number of tests run.

OBJECTIVES

Based on the results of preliminary testing, personnel available, and early-season observations, the original objectives were modified to address the following issues in the 2021 growing season:

1. Determine the impact of magnetic treatment on surface sealing and seedling emergence of sugar beets (one of the most sensitive Southern Idaho crops to reduced crop stand due to surface sealing).
2. Measure differences in surface runoff and depth of water infiltrated due to magnetic treatment.
3. Measure differences in sugar beet yield and quality due to magnetic treatment.

4. Measure differences in relevant water quality concentrations with depth at the end of the season to evaluate leaching potential.
5. Measure differences in water throw distance and the distribution from sprinklers due to magnetic treatment.
6. Measure the impact of MTW on basic water physical properties such as density, dynamic viscosity, and surface tension.

BURT FEHRINGER POTATO FIELD, AMERICAN FALLS, ID

Materials and Methods

A magnetic treatment unit was installed at the pivot point on one of 2 adjacent pivots planted to potatoes on a Declo loam soil just east of American Falls, ID in 2021 (**Figure 1**). The USDA-NRCS Web Soil Survey [2] gives Field Capacity values of 24.3 to 22.6 % by volume for the 0-30- and 30-60-inch depths, respectively. Corresponding values for Wilting Point are 9.3 and 7.9 % by volume, respectively. Initial soil samples for water and nutrient content were taken at 3 locations on each pivot on May 17, 2021. Samples were taken for successive 6-inch intervals to a depth of 5 feet. Water content was determined by weighing and oven-drying. Nutrient analyses were performed by Stukenholz Labs, Twin Falls, ID.

Results and discussion

Although direct comparison of potato yield and quality between the two adjacent pivots was not valid due to unintentional fertilizer application differences, catch-can testing showed over 20% more water applied by the MTW pivot than the control during windy test conditions (**Figure 2**). Both pivots were designed to apply the same water depth and were operated the same. Maximum depth of root water uptake is typically 18-24 inches for potatoes. In this soil it appeared to be about 24 inches based on measured soil water content measurements. Post-season soil sampling to a depth of 5 feet showed 4.7 inches more water in the 2-5 ft depth for MTW than for the control pivot (**Figures 3-5**). This difference represents the seasonal average difference between the two treatments at depths unaffected by root water extraction. Part of the large difference in can catch between MTW and Control could be due to the increase in water density and viscosity on the MTW treatment (from laboratory testing discussed later in a later section of this paper). The change in these properties would cause the water droplets to be larger and less likely to evaporate or have excessive wind drift.

Additional water applied to the MTW pivot could move water-soluble nutrients downward below the root zone, potentially reducing some nutrients levels to below the critical threshold by mid-late season, reducing crop yield and quality. **Therefore, if MTW is used, it is critical to monitor water content carefully to take full advantage of higher water application rates and to avoid deep percolation of water-soluble nutrients below the active crop root zone.** This appears to be the case for Potassium and Phosphorus in the 0–6-inch depth. The general shape of the curves would also suggest more downward movement with MTW but the nutrient balance in the top 5 ft might not suggest that (**Figure 6**). Comparison of the shape of the Calcium curves with depth would suggest some downward movement of Calcium with MTW (**Figure 7**).

PLOT SPRINKLER TESTS, KIMBERLY RESEARCH AND EXTENSION CENTER (KREC), UNIVERSITY OF IDAHO

Materials and Methods

Plot sprinkler tests were conducted in Field 30 at the Kimberly Research and Extension Center during the 2021 growing season. The site was a 2-3% sloping eroded Portneuf silt loam soil. Field Capacity is approximately 31% by volume and Wilting Point 11% by volume. The eroded phase is particularly prone to surface sealing due to very low organic matter and high silt content. Treatments of Control, MTW and another treatment unrelated to this study were randomized within the 100 and 125 % ET blocks across the slope. Six replicates of this arrangement were developed in downslope tiers, with 10-ft alleys between reps, each containing a runoff collection ditch to assure that runoff from one set of plots did not enter the next set downslope. The magnetic treatment was produced with a single in-line "Maximum H2O" unit with 1-inch nominal diameter threaded connections.

Canal water was applied to 24 clean-tilled 22 x 35 ft plots (12 row of beets planted in the direction of slope) using square-pattern sprinklers with net application of about 0.8 inches per hour (**Figure 9**). Plots were irrigated once per week. One set of plots was irrigated to provide 100% of estimated AgriMet [1] ET and the other, 125% of estimated ET. Previous experience with these sprinklers on another eroded section of the same slope indicated that this soil tends to readily form a surface seal, followed by significant surface runoff.

Differences in geometry of the row/inter-row areas varied from plot to plot which made evaluation of surface runoff difficult to determine. Measurements taken were plant stand count at emergence for each plot (15 ft length), sprinkler throw distance, and post-harvest soil moisture sampling at 6-inch increments to 5-foot depth to evaluate total water infiltrated and the depth distribution of the water.

Results and discussion

Average stand count was 5% greater on the MTW plots than on the control plots. This is significant because beet yield is directly related to the number of beets emerged and growing during the season. **Beet yield was 4.2% greater for MTW** than the control at the 100% ET irrigation level, and **4.4% greater at the 125% ET** irrigation level (**Figure 10**). Differences between MTW and Control are larger on the first 3 replications because more of the topsoil has been eroded from the top of the field and deposited on the last 3 reps on the lower section of the field (**Figure 8**).

Nutrient and water movement within the soil are shown by pre-season and post-season soil water and nutrient sampling results with depth for MTW and Control (**Figures 11- 15**). **Figure 11** shows a small but consistent reduction in surface water content with MTW relative to Control for both 100 and 125% ET water application. In contrast, water content in the 36–42-inch layer and below were noticeably higher for MTW relative to Control for both irrigation levels. The pattern of water content with depth suggests that MTW modified the near-surface conditions to allow more downward water movement. The "extra" water applied through the MTW sprinklers (pressure and nozzle size were the same for MTW and Control but measured water application is typically 5-10% greater for MTW) moved downward giving the significant increase in water content below 36 inches for MTW vs. Control.

More downward water movement for MTW could also drive water-soluble nutrients such as potassium downward as well. This appears to be the case for water-soluble Potassium at the 0–6-inch depth (**Figure 12**), with essentially no difference at depths below 6 inches. Phosphorus (which may also move with water under some conditions) also shows a reduction at 0-6 inches and at lower depths for MTW, although it is not clear how the P in the MTW treatment could be lower at this depth. Calcium levels for MTW and Control with depth at 100% ET irrigation are essentially the same (**Figure 13**). At 125% ET irrigation, P did move downward and was higher below 30 inches for MTW relative to Control (**Figure 14**). Calcium levels were slightly lower at all depths for MTW than for Control at 125% ET irrigation (**Figure 15**). A second (and possibly third) year of testing with treatments applied to the same plots would assess the cumulative effects and might show larger differences if effects were indeed cumulative.

ADDITIONAL OFF-STATION SPRINKLER TESTING

Materials and Methods

Paired-sprinkler tests with impact sprinklers at 45 psi operating pressure were conducted in a wind-protected level, mowed pasture SW of Kimberly. This location was preferred over KREC because of the wind protection offered, the level area, and readily available clean water at any time. For each test one of two sprinklers was supplied with in-line magnetic treated water and the other with un-treated water. The treated and untreated sprinkler sites were reversed after each 1-hour run. Catch funnels for sprinkler distribution tests were placed at 10-foot intervals to 50 ft in each of 4 lines away from each sprinkler stand.

Results and discussion

Two consistent trends were observed in this testing:

- Magnetic treatment sprinkler throw was about 6% farther
- Water volume collected in treated and un-treated tests showed 9% greater water application for the MTW treatment
- More water was thrown to the outer edge of the wetted circle with magnetic treatment, providing more uniform water application as adjacent sprinklers overlap.

LABORATORY PHYSICAL PROPERTIES TESTING FOR MTW AND NON-TREATED WATER

A number of papers and testimonials report that magnetically treating water affects its physical and agronomical properties. If proven to be true and beneficial it could provide a simple and relatively inexpensive way to boosting agronomical efficiencies where appropriate. This portion of our work involved testing some basic physical properties that could provide insight into MTW's agronomic impact. Papers report that MTW shows changes in viscosity, surface tension [4][6][5] and/or density [6]. Most papers also report an increase in pH [5][6]

Materials and Methods

Both treated and un-treated water were obtained from a well-water outlet at KREC. The un-treated water was collected first. Then the MTW device was attached, and the treated water collected. Both water containers were transported to Artisan Labs, Hansen, ID where dynamic viscosity was determined using their equipment. Other tests were performed at KREC. Specific methods and equipment include:

- Dynamic viscosity was measured using a BROOKFIELD AMTEK DV-1 viscometer RV-02 at 20 rpm. Ten measurements were taken, and the average reported here (**Figure 16**).
- Density was assessed using a pycnometer method at 23°C. Ten measurements were taken, and the average reported here.
- pH was measured using METTER TOLEDO "FiveEasy Plus" pH meter. Ten measurements were taken, and the average reported here.
- Surface tension was assessed indirectly through the height of capillary rise of an initially air-dry soil placed in 4-cm ID polycarbonate tubes 76 cm in length. The soil-filled tubes were placed in shallow tubs filled with water to a depth of 4 cm with water maintained at that depth. Two tubes of each treatment were tested at one time. This process was repeated twice.

Results and discussion

MTW well water was 0.45%, 50%, and 27% higher compared to un-treated well water for specific gravity, dynamic viscosity, and pH, respectively. Surface tension, using capillary rise as a proxy, was consistently higher (5.2cm or 11%) for MTW than for the un-treated control on the limited number of tests run.

These changes in water properties would tend to form larger water droplets that would evaporate less and throw farther.

OVERALL CONCLUSIONS AND THEIR AGRICULTURAL PRODUCTION IMPACT

Laboratory testing showed that MTW increased water specific gravity, dynamic viscosity, pH, and surface tension relative to un-treated water. These changes and probably other unknown changes produced the following impacts relative to the Control treatment:

- Increased throw distance from impact sprinklers, and for individual plot sprinklers based on square-pattern spray nozzles at the Kimberly Research and Extension Center (KREC), **[reduced wind-skip problems]**
- Increased sugar beet seedling emergence rates and corresponding increase in beet yield on field plots at KREC, **[increased yield and profit]**
- Higher water application (with same nozzle size and pressure) on field plots at Kimberly and a potato field near American Falls **[higher irrigation system application rate possible with same hardware to better meet possible future increases in crop water use]**
- Increase in soil infiltration and decrease in soil Calcium levels in the top 0–6-inch layer at both Kimberly and American Falls, **[higher water application rates are not limited by current soil crusting and runoff problems Reduced Calcium / excess lime will also make Zinc and Iron in the soil more available to the crop]** **[Therefore, if MTW is used, it is critical to monitor water content carefully to take full advantage of higher water application rates and to avoid deep percolation of water-soluble nutrients below the active crop root zone.]**
- Slight reduction in P in the top foot with slight downward movement to 5 feet at KREC
- Slight reduction in P in the top 6 inches with slight downward movement to 30 inches near American Falls **[near surface reduction in P may be due to reduced Calcium / excess lime, by increased plant use, or a combination of both.]**

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- Garry Fenton, Maximum H2O for the use of their magnetic treatment device and financial support
- Ed Mathieu, Overland Distributing Company for his advice, support and insight into research methods and results from MTW testing

SOURCES

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2. USDA-NRCS. Web Soil Survey, Power County, Idaho.
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Figure 1. Overview of Fehringer potato field and the far part-circle center pivot. The MTW pivot irrigates the near half of the field, and the Control pivot the far half. Red circle is the pivot point for the N pivot.

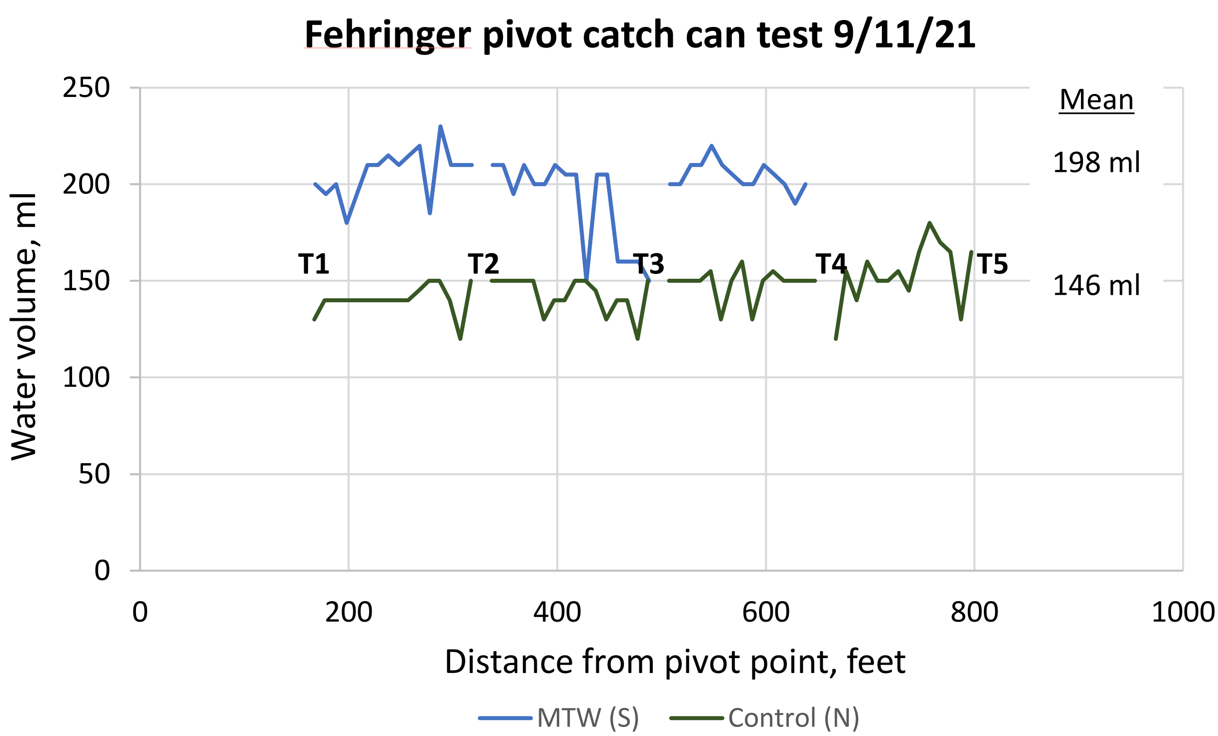

Figure 2. Results of catch can water distribution test on Fehringer Control and MTW pivots 9/11/21. T1..T5 are the locations of pivot towers 1..5. Measurements were taken between towers 1 and 4 on MTW and towers 1 to 5 on the Control pivot. Christiansen coefficient of uniformity is 93 for both pivots.

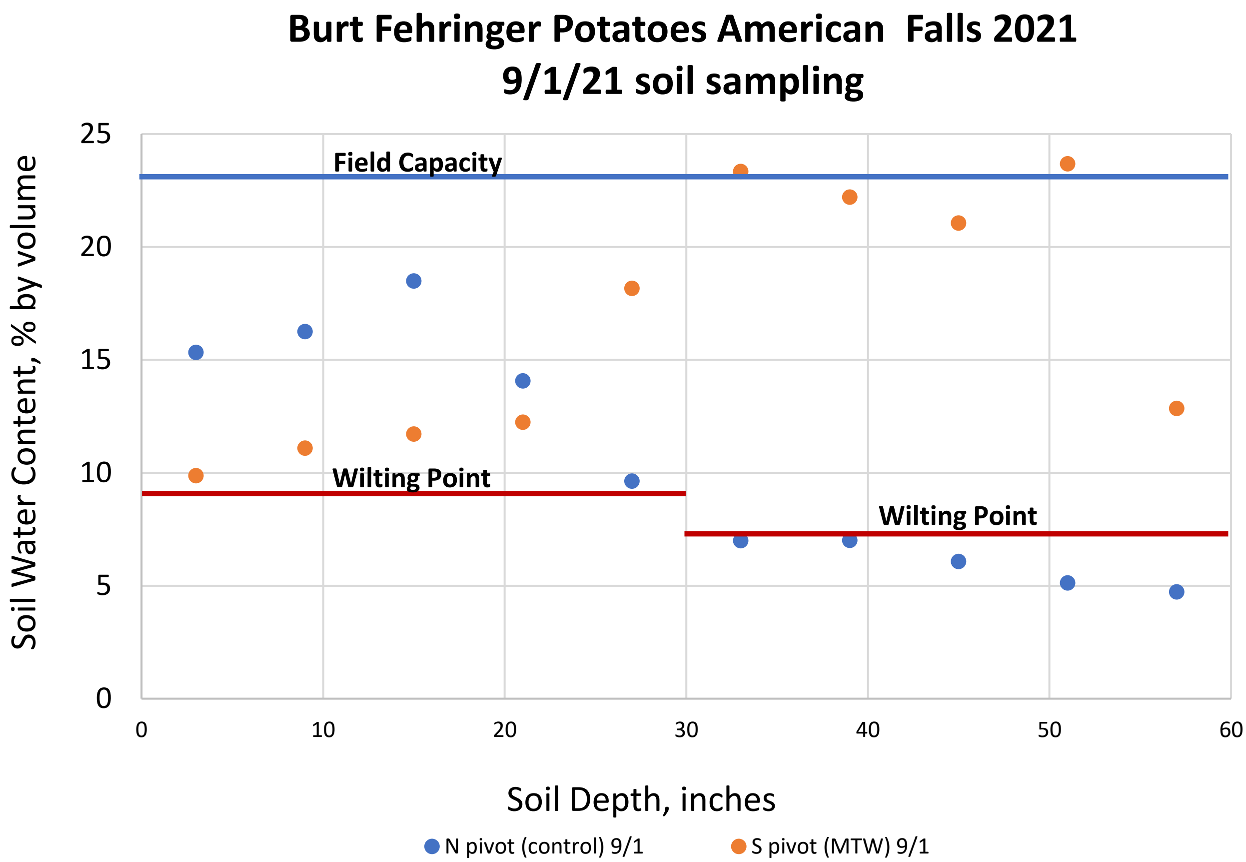

Figure 3. Post-harvest soil water content with depth for Control and MTW pivots. Wilting Point is lower for the 30-60 depth because the soil has a higher sand content.

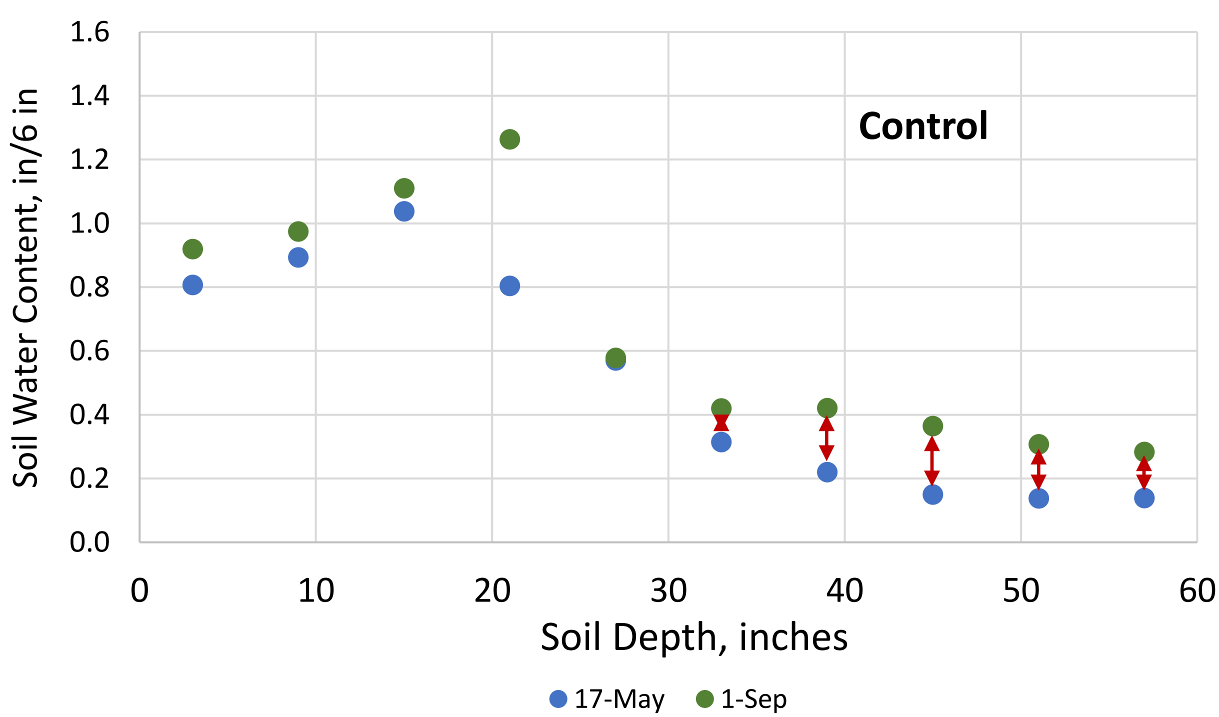

Figure 4. Early season and post-harvest soil water content with depth under Control pivot. Red arrows show the amount of soil water gain from May 17 to September 1 (0.83 inches) in the depth below the active potato root zone (approx. 24 inches max.)

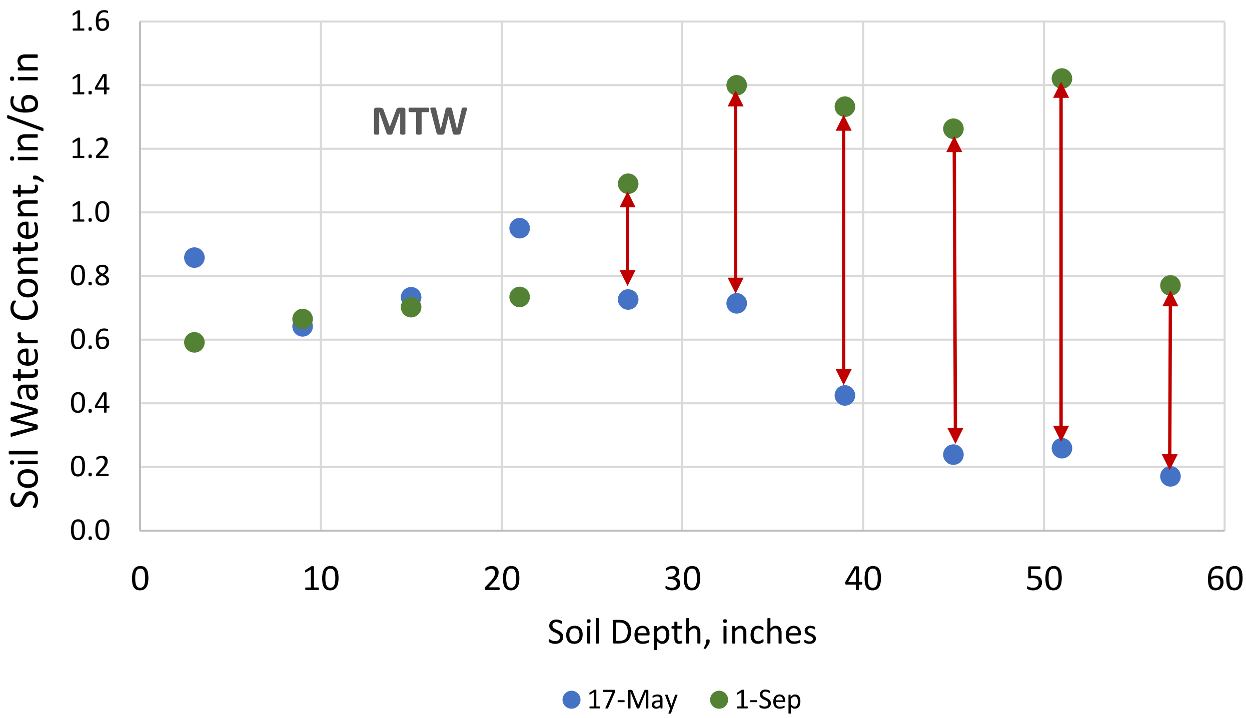

Figure 5. Early season and post-harvest soil water content with depth under MTW pivot. Red arrows show the amount of soil water gain from May 17 to September 1 (4.72 inches) in the depth below the active potato root zone (approx. 24 inches max.)

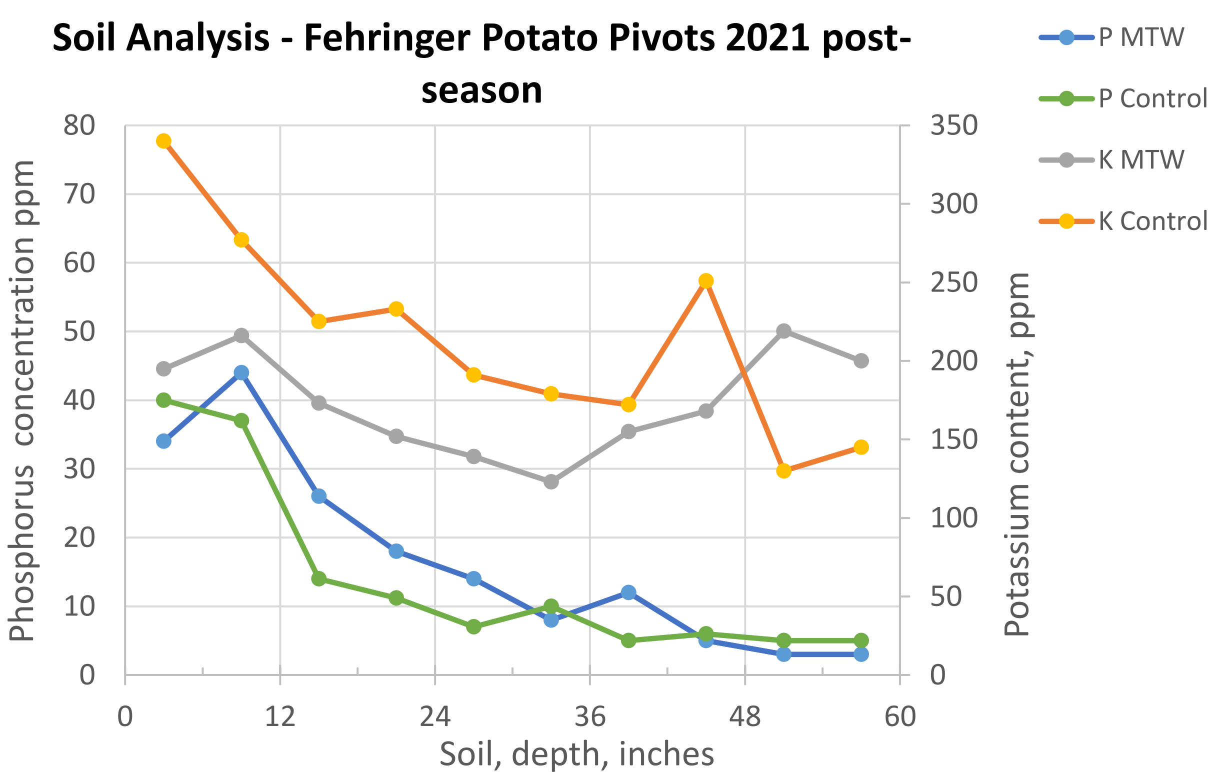

Figure 6. Phosphorus (P) and Potassium (K) concentration with depth for MTW and Control pivots.

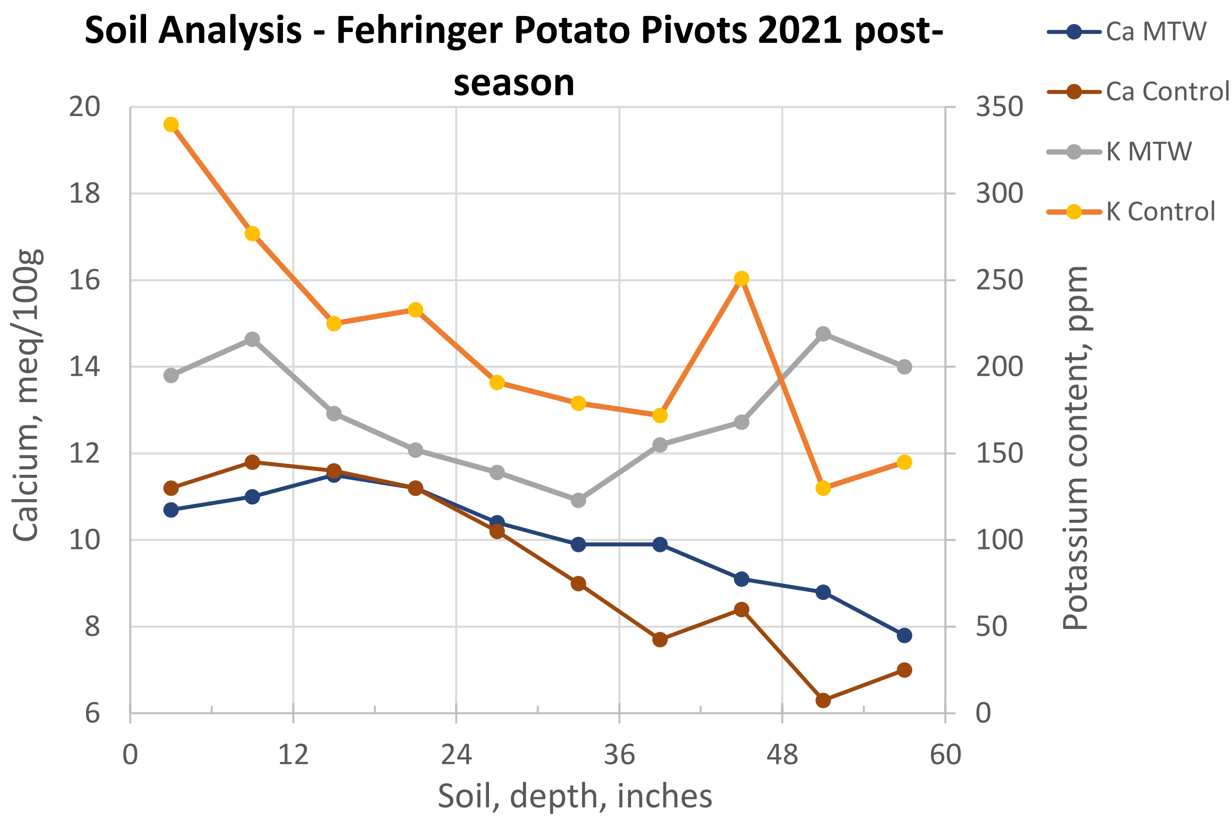

Figure 7. Calcium (Ca) and Potassium (K) concentration with depth for MTW and Control pivots.

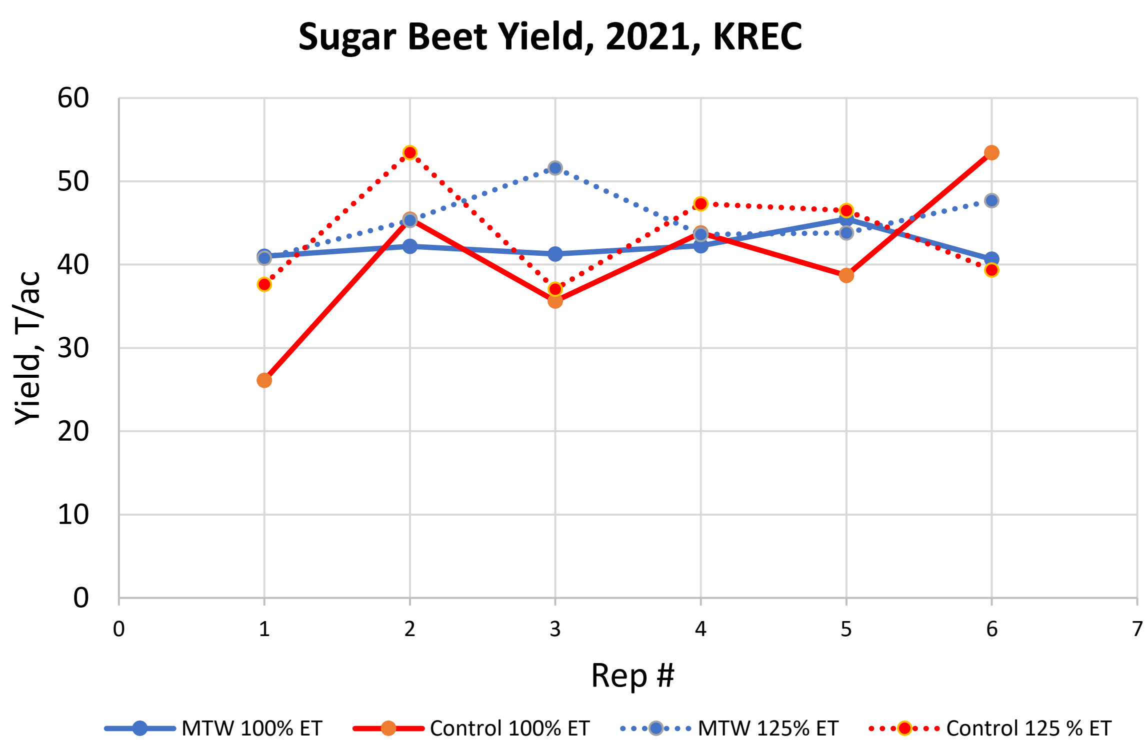

Figure 8. Comparison of sugar beet yield for all 6 replications of MTW and Control treatments.

Figure 9. Overview of KREC Field 30 with plot sprinklers. Magnetic device inserted at the circled location. The MTW submain then splits to provide water to MTW treatments in all 6 replications.

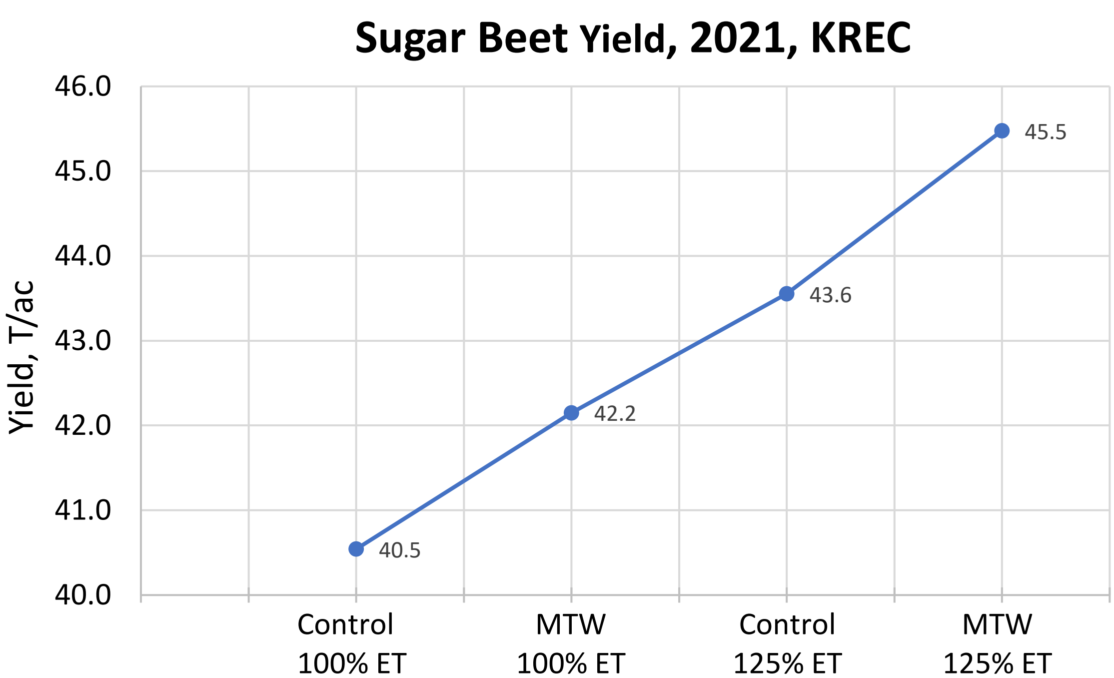

Figure 10. Average of 6 replications of each treatment after plot harvest length was corrected for blank areas or very weedy areas.

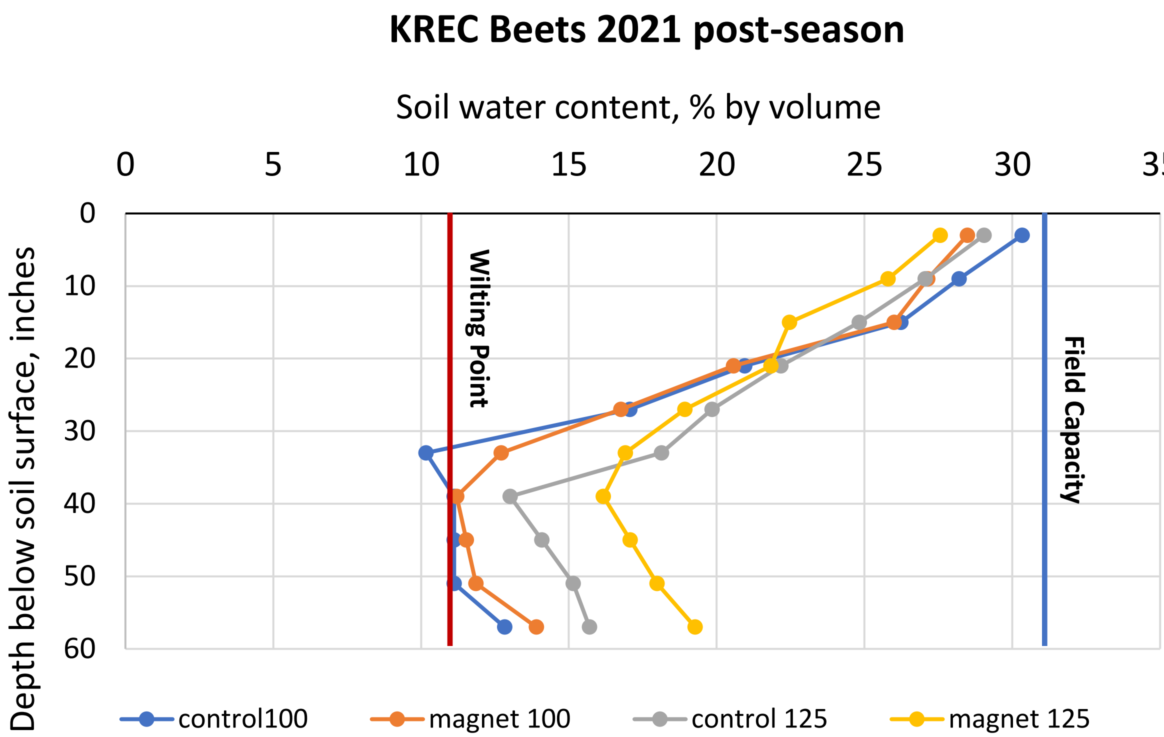

Figure 11. Post-harvest soil water content with depth for MTW and Control at 100 and 125 % ET.

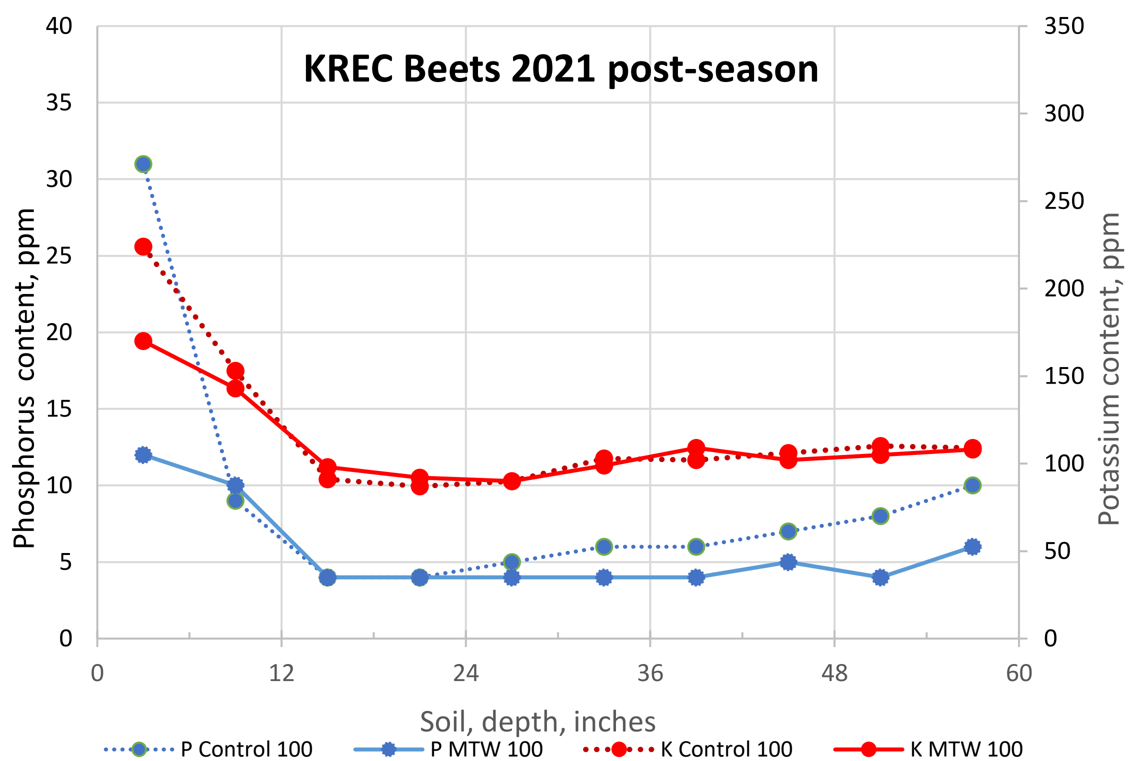

Figure 12. Comparison of Control and MTW treatments for Potassium (K) and Phosphorus (P) at the 100% ET irrigation level.

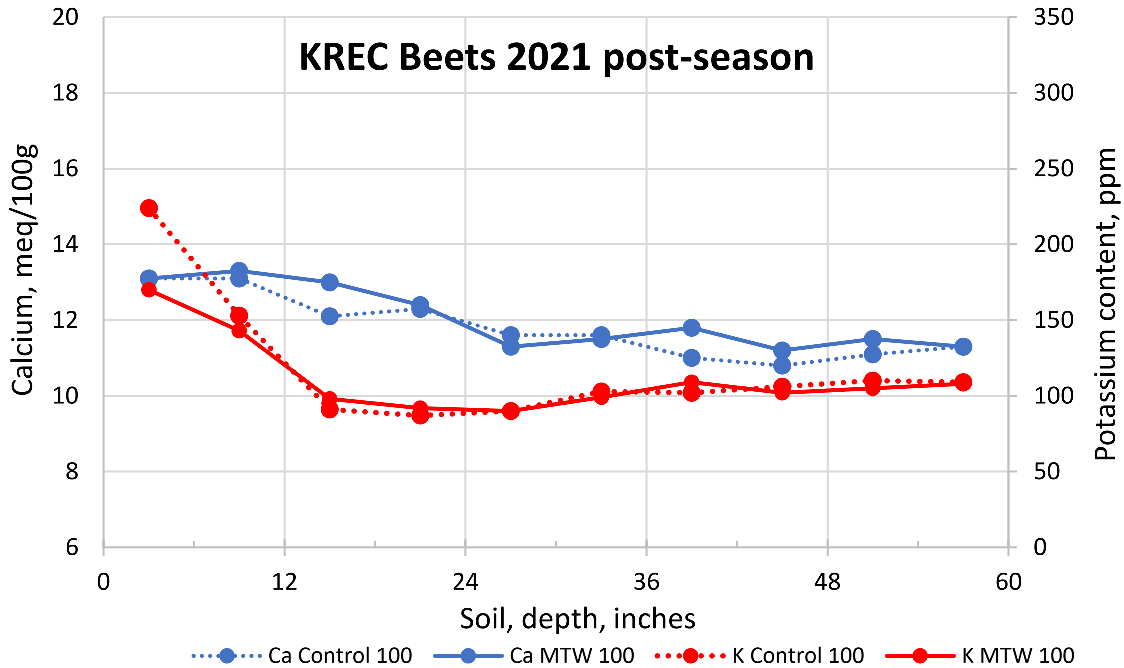

Figure 13. Comparison of Control and MTW treatments for Potassium (K) and Calcium (Ca) at the 100% ET irrigation level.

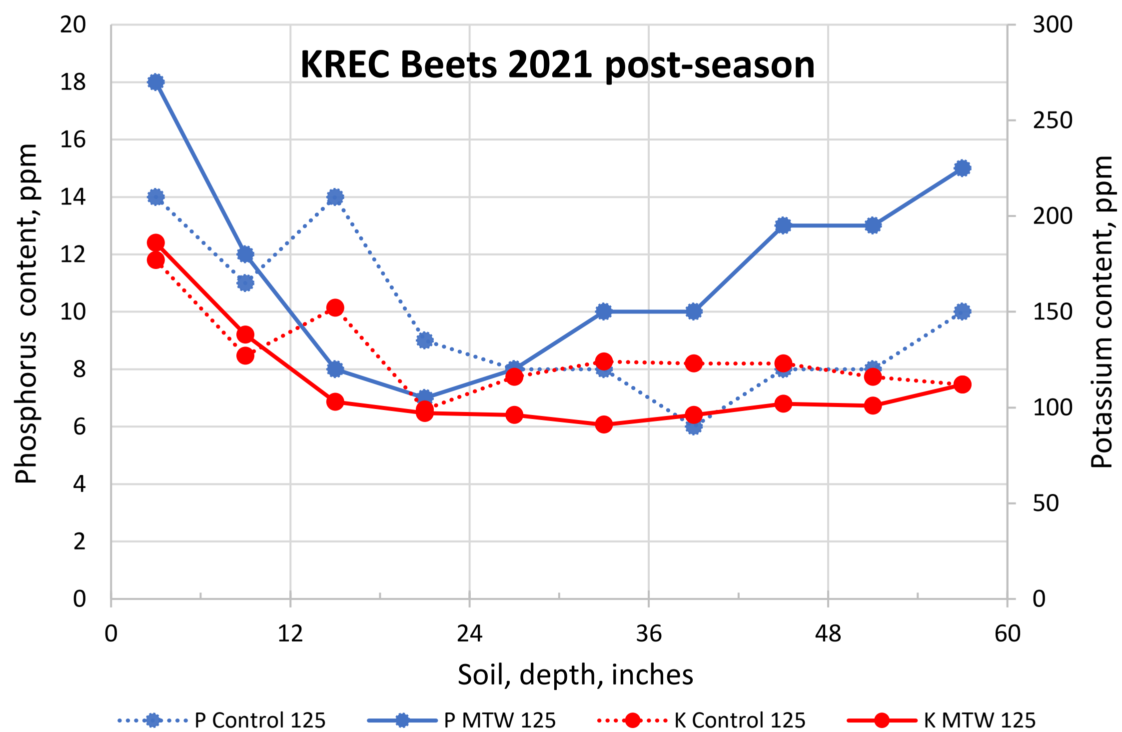

Figure 14. Comparison of Control and MTW treatments for Potassium (K) and Phosphorus (P) at the 125% ET irrigation level.

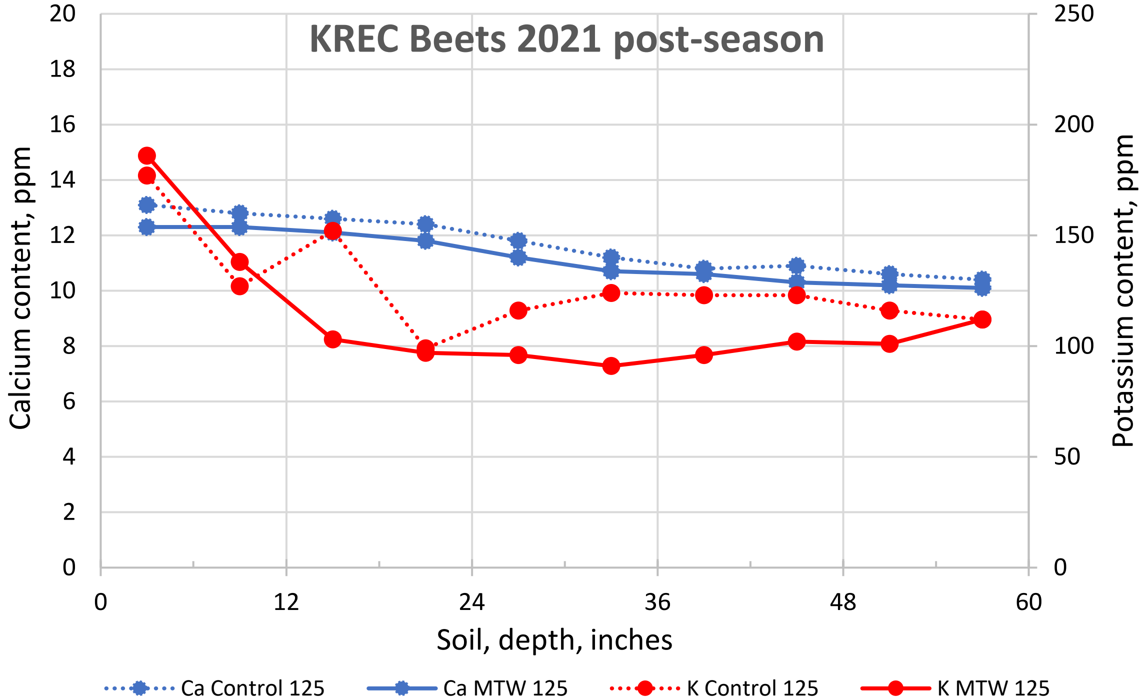

Figure 15. Comparison of Control and MTW treatments for Potassium (K) and Calcium (Ca) at the 125% ET irrigation level.

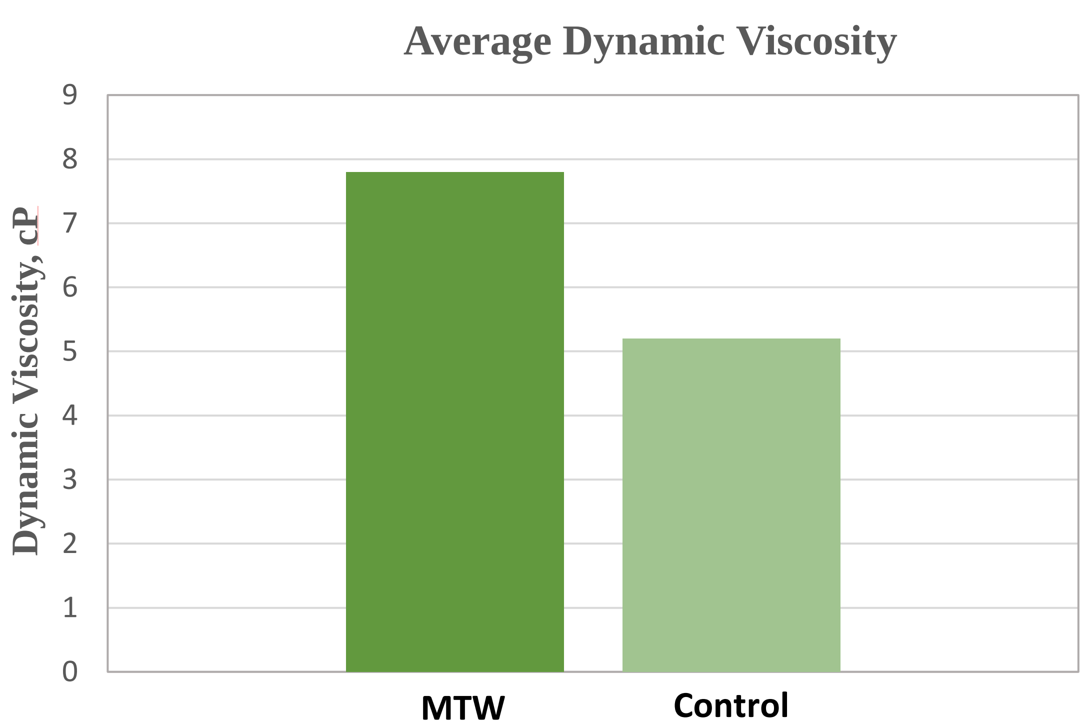

Figure 16. Average of 10 measurements for dynamic viscosity for both MTW (dark green) and Control (light green).