PHYSIOLOGICAL RESPONSES TO PRIMED ACCLIMATION IRRIGATION TREATMENTS: AN INITIAL STUDY

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Abstract

To maintain suitable yields in any crop and variety the first step is to ensure good stand establishment. Second is to promote vigorous above and below ground plant development to more efficiently utilize available resources for crop growth and yield. Studies have shown that controlled deficit irrigation treatments early in the season can help to promote below-ground plant development to a greater extent than above-ground development. These treatments have also been known to better prepare the plant for years with limited water. This irrigation strategy is known as Primed Acclimation (PA). The theory behind PA is to limit the soil moisture supply early season to promote deeper rooting depth and development. Increases in rooting development can provide increased resistance to dry periods later in the year. The goal of this project was to quantify the effects of primed acclimation irrigation treatments on cotton biomass and rooting development, and yield. Treatments were implemented at University of Georgia's Stripling Irrigation Research Park (UGA SIRP) under a variable rate center pivot irrigation system. The treatments were full irrigation, semi-primed, full primed, optimally primed, and dryland. Three Watermark moisture sensors installed in a probe (the UGA Smart Sensor Array (SSA)) were used to monitor soil tension. The UGA SSA's were used to trigger irrigation events at predetermined centibar readings, which correlated to the earlier mentioned treatments. Above ground biomass collections were collected at biweekly intervals beginning four weeks after emergence. Minirhizotron tubes were installed in each of the plots. Pictures were taken twice at the end of the season to determine if there were visible differences in the rooting differences between the irrigation treatments. While differences were observed between some of the irrigation treatments for plant growth factors such as crop growth rate, net assimilation rate, and leaf area index, lint yield between the treatments, with the exception of the dryland treatment, was found to be statistically similar.

Introduction

Primed acclimation is a term that is used to describe the imposition of water stress early during the development of a crop in order to induce stress responses that result in increased rooting depth and better utilization of available groundwater later during the season. This approach has been proposed as a means to aid the development of root growth to ensure the crop is better prepared for periods of limited water. Canopy development is considered more sensitive to water deficiencies than rooting development. Thus, early season root development might occur at the expense of early season canopy development. The ability of a plant to change its root distribution to exploit deeper stored soil water may be an important mechanism to avoid drought stress (Benjamin and Nielsen 2005). Cotton is one of the few crops that respond to water stress well by increasing rooting depth and density, making it an ideal target for water stress studies. However, drought stress in cotton can and will cause reductions in shoot and above ground biomass development, thus it is important to only stress the plants enough to ensure an increase in root development occurs while negligible effects are seen above ground. Pace et al. (1999) reported reductions in shoot to root ratio for plants that were drought stressed. However, after the plants were allowed a recovery period with ample irrigation the ratio increased to a similar level to non-water stressed plants. Consequently, it is important to characterize the above and below ground responses of cotton to primed acclimation while also directly measuring the stress level experienced by the crop. Primed acclimation irrigation triggers that do not penalize crop growth and yield must be clearly defined. A comprehensive analysis of above-ground and below-ground crop growth responses to primed acclimation is needed.

Objectives

The main objective of this study was to determine primed acclimation effects on crop growth and yield. The secondary objectives were to:

- Quantify biomass development above ground by collecting crop growth parameter data at regular intervals throughout the season.
- Determine the effects of primed acclimation treatment thresholds on end of season cotton lint yield.
- Determine the effects of primed acclimation on rooting development.

Materials and Methods

A site was selected under a variable rate center pivot irrigation system at UGA's Stripling Irrigation Research Park (SIRP) near Camilla, GA. Plots were established in a randomized complete block design and were planted in an arc planting pattern to match the travel pattern of the pivot. FiberMax 1944 GLB2 was the cultivar planted for this study. Five treatments were established and replicated four times (Table 1). Soil moisture sensors were installed in each of the treatments. The soil moisture sensors were the UGA Smart Sensor Array (SSA) system.

Table 1. Irrigation treatments and sensor reading thresholds for triggering irrigation events.

Irrigation Treatment	Pre-Bloom	First Bloom	Peak Bloom
Full Irrigation	40 cb	35 cb	35 cb
Semi Primed	70 cb	35 cb	35 cb
Full Primed	100 cb	35 cb	35 cb
Optimally Primed	No Irrigation	35 cb	35 cb
Dryland			

The UGA SSA's are a sensor probe with three of Irrometer's WaterMark sensors installed inline at depths of 12, 18, and 24 inches (Figure 1). Irrigation was triggered based on a weighted average centibar reading from the probe consisting of 50%, 30%, and 20% weight on the 12, 18, and 24 inch deep sensors respectively. Once the weighted average reached the thresholds listed in Table 1 irrigation was triggered and an amount of 0.75 inches was applied. This process continued until first bloom, when from then until irrigation termination all treatments were switched to a weighted average sensor trigger level of 35 centibars.

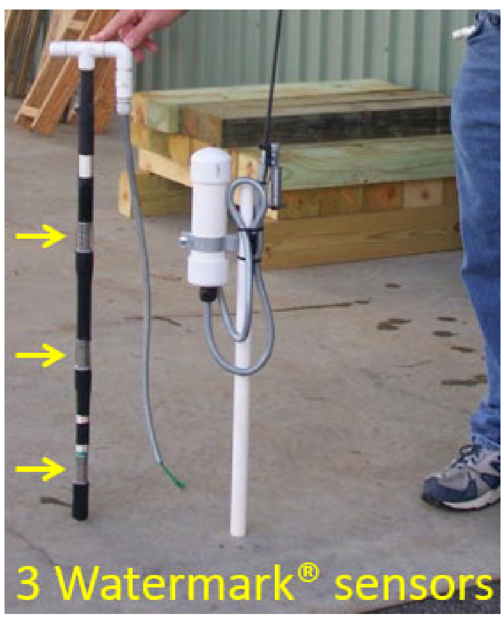

Figure 1. UGA Smart Sensor Array

Beginning at the six leaf stage crop growth data was collected. The crop growth data consisted of the number of plants in one yard length of row, the plants from that yard length of row, total weight from the yard length of row, plant height, number of nodes, number of reproductive structures (when relevant), the leaf area index, and the dry biomass weight. The cotton received 12.6 inches of rainfall throughout the season and the supplemental irrigation when triggered can be viewed in Table 2.

Table 2. Irrigation applied to, rainfall received by, and total water on each irrigation treatment.

Irrigation Treatment	Rainfall (in)	Irrigation (in)	Total Water (in)
Full Irrigation	12.6	6.9	19.5
Semi Primed	12.6	6.3	18.9
Full Primed	12.6	6.0	18.6
Optimally Primed	12.6	6.0	18.6
Dryland	12.6	0.0	12.6

MiniRhizotron tubes (Figure 2) were installed in each of the plots around canopy closure. Typically the tubes should be installed once a stand is established, but in this case since it was an initial study the tubes were installed to document the differences between treatments and were not used to actually track growth throughout the season. Pictures were collected (Figure 3) on August 5 and September 9.

Figure 2. MiniRhizotron Tubes installed in the cotton production field.

Figure 3. The MiniRhizotron camera (left) and image capture software (right).

Once the harvested plants were collected they were transported back to the lab for further analysis. Once the plants reached the lab plant height was measured, the number of nodes were counted, and the plants were stripped of all leaves and reproductive structures. The bare stalks were placed into an oven for drying. The leaves and reproductive structures were kept separate, the reproductive structures were counted and placed into an oven for drying. The leaves were processed through a leaf area index meter (LAI). Once each set of leaf samples were processed through the LAI meter they were placed into the oven. All of the samples were left in the oven for 48 hours. Once the samples were dried they were removed from the oven and weighed to obtain dry weight. The collected growth parameters were used to calculate crop growth rate, dry matter accumulation, net assimilation rate, and leaf area index.

Results and Discussion

Clear differences were observed throughout the season in the crop growth rate as presented in Figure 4. From Table 2, since the dryland (DL) only received 12.6 inches of rainfall the entire season this treatment quickly lagged behind in growth rate and even had a few collections that exhibited negative growth. The negative growth occurred during the hottest and driest part of the summer.

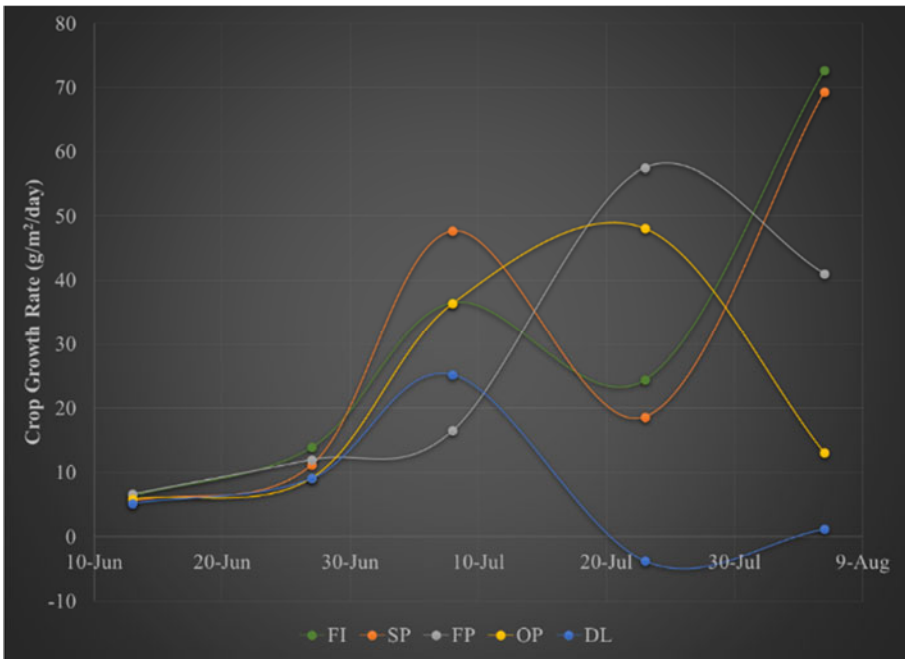

Figure 4. Crop growth rate of the five treatments throughout the growing season.

The first and second collections did not exhibit major differences between the treatments, however, as the season progressed differences became evident. The semi-primed (SP), full irrigation (FI), and optimally primed (OP) seemed to grow at a much higher rate than did the DL and full primed (FP). However, during the end of July, the early season limited moisture on both the FP and OP caused the growth rates to increase. This trend quickly changed during the beginning of August when it continued to remain hot and dry through the summer. The FI and SP, which had adequate moisture during the early season increased their growth rates at the end of the season while the other treatments did not.

Dry matter accumulation (Figure 5) began at a slow rate for all treatments but then picked up along a similar trend for each of the irrigation treatments. The DL treatment reached a peak of growth and then stayed constant for the rest of the season. This is the same trend observed from the growth rate. This means that there was no new growth added to the DL treatment from mid-July until the end of the season. There were no major differences between the other four treatments. The FI and SP had the highest accumulations of dry matter followed by FP and OP. This means that overall the PA treatments at the beginning of the season did have an effect on dry matter accumulation during the growing season and slightly reduced the amount of dry matter produced by the FP and OP treatments.

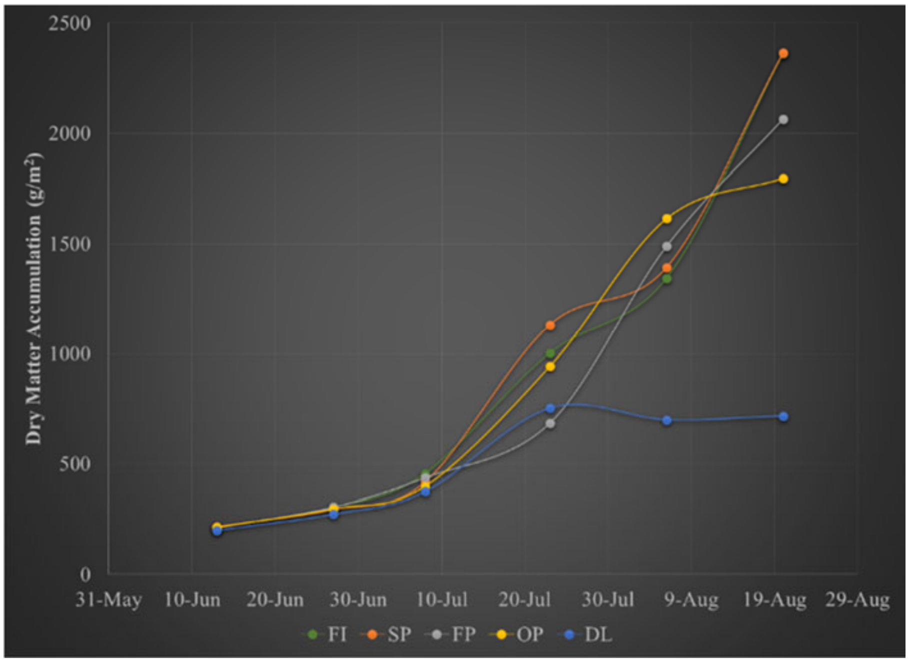

Figure 5. Dry matter accumulation from the throughout the season for the five PA treatments.

The net assimilation rate (Figure 6) or the mean rate of increase in total dry weight per unit leaf area, measured over a period of time, represents the excess of the rate of photosynthesis of the leaves over the rate of respiration of the whole plants, both expressed per unit leaf area had some major differences appear as the season progressed. Until the beginning of July all treatments responded similarly, however, as the season progressed the DL treatment dropped off in a very similar manner as it did in the crop growth rate.

Since the net assimilation rate is partially based on crop growth, it exhibits similar trends as did crop growth. The FI and SP had the highest assimilation rate at the end of the season showing that the adequate soil moisture early in the season had an effect on the end of the season. Just as with the crop growth rate, the lack of soil moisture or induced moisture stress early in the season reduced the net assimilation rate of the FP and OP treatments.

Leaf area index (Figure 7) did not follow any of the previous trends. All of the treatments had a sharp increase in leaf area index from early to mid-June. This is when the crop went through rapid canopy expansion and growth. However, after this time there were constant increases in all of the treatments except for DL. The DL treatment began to decrease in mid-July and continued to do so throughout the rest of the season. Again there was a slight penalty that developed in the OP treatment for having limited water at the beginning of the season. The reduction was not as significant as in some of the other growth parameters.

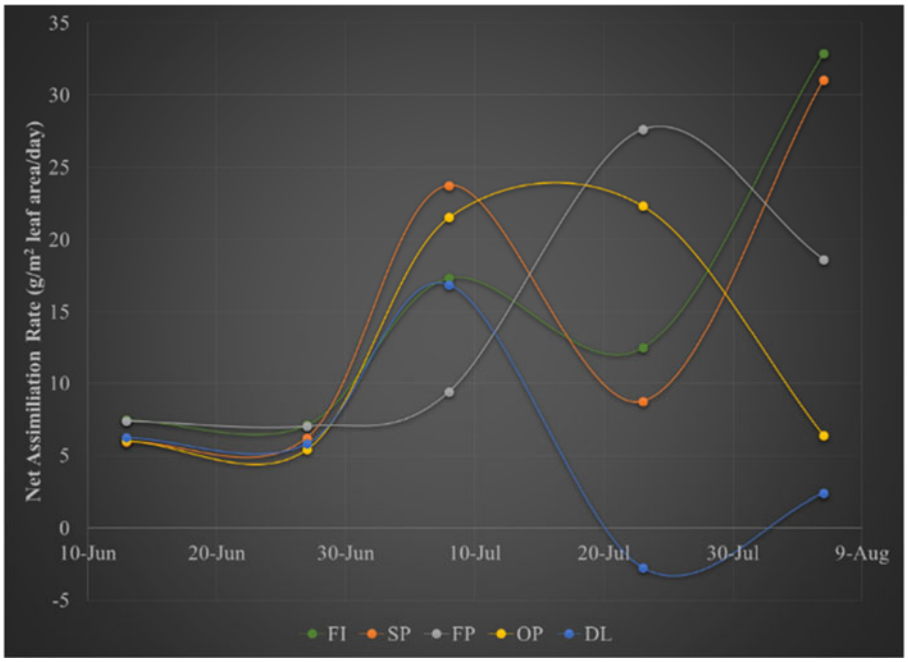

Figure 6. Net assimilation rate for the treatments throughout the season.

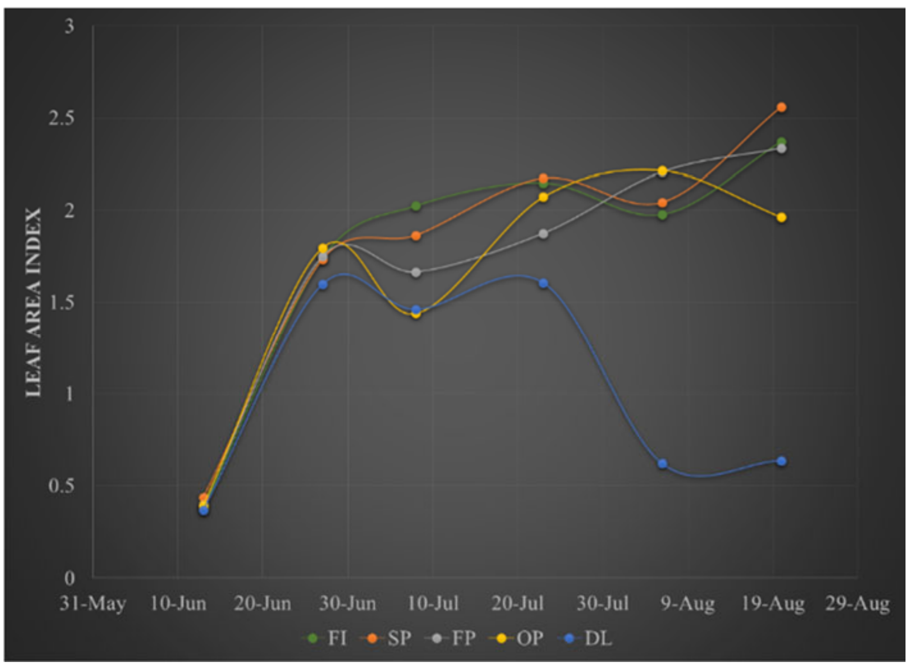

Figure 7. Leaf Area Index for the treatments throughout the season.

The reproductive structures on a cotton plant are some of the last structures to develop and that was evident in this study. No reproductive structures (Figure 8) were collected until the eighth of July. After this point all of the treatments added a significant amount of structures the next two weeks, the SP most of all. After the twenty third of July however, the DL began losing reproductive structures. All of the rest of the treatments kept increasing the number of reproductive structures at a high rate until the end of the season except for the OP treatment. OP was consistent with the other treatments until mid-August, at which it actually lost some of its reproductive structures.

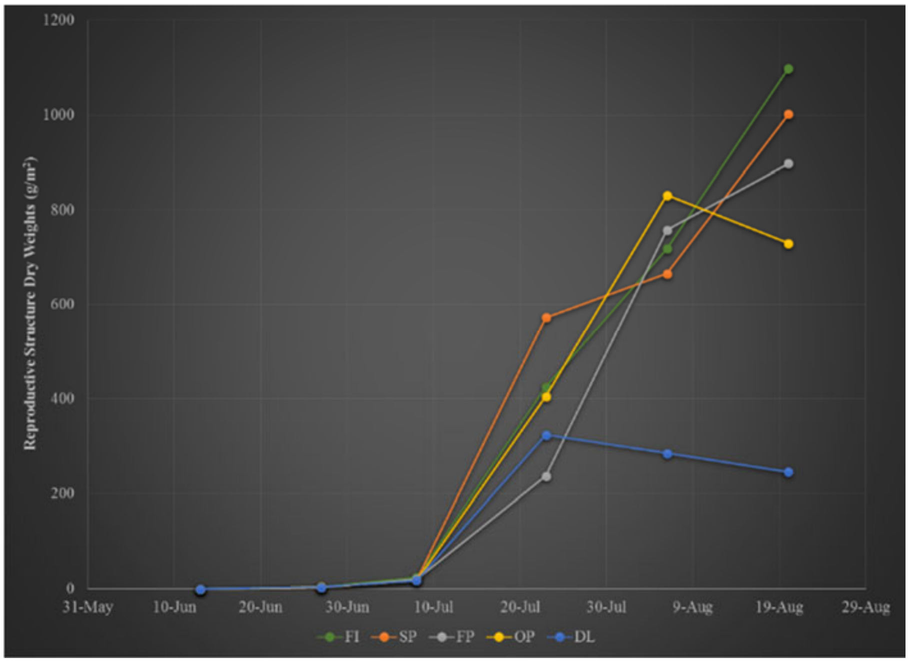

Figure 8. Reproductive structures for the treatments throughout the season.

Cotton plants typically lose reproductive structures when they are stressed. In this case the decline of reproductive structures is indicative of one of two things either sampling error or stress. The reduction of reproductive structures in the DL treatment can be directly attributed to plant stress. However, in the case of the OP treatment it could be sampling error, but more than likely it is crop stress. This can be verified by checking the other parameters presented in figures 4, 6, and 7. The OP treatment had decreases in all of these parameters, which were unrelated to reproductive structures but could be attributed to early season moisture stress.

Crop yield (Figure 9) is the final judgment of treatment effects. A productive canopy, high growth rate, high leaf area index, and increases in reproductive structures are required to maximize yield.

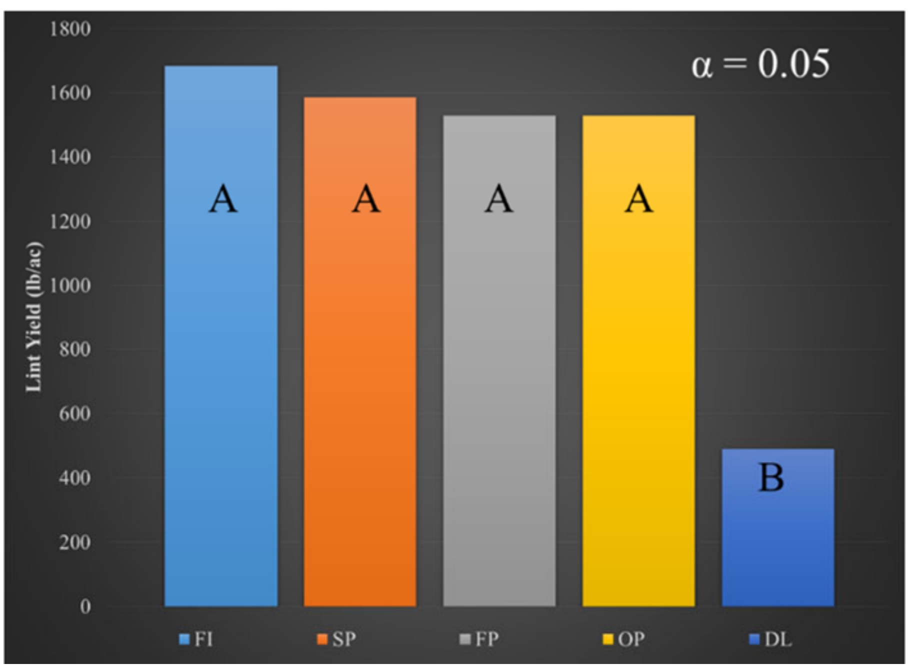

Figure 9. Lint yield for the treatments throughout the season.

Lint yield was statistically similar for all of the treatments except for DL. There was a yield penalty for increasing soil tension and decreasing early season irrigation however, the penalty was not statistically significant. The reduction that was seen in some of the other growth parameters did not have a significant effect on yield. Thus, it can be concluded that plants with early season moisture stress can recover if provided with adequate soil moisture at critical times during the season.

Figure 10 represents rooting pictures from about 2.6 feet below the soil surface. In each treatment the picture on the left is the one captured on August 5, before cutout and the picture on the right was captured on September 9, after cutout. Initial inspection of these images shows a dry down of all of the roots in both collections but it appears that the roots in the FP and OP dried down much more than the ones in the FI and SP. Too much early season stress caused these roots to stop growing sooner in the season. As discussed in the above-ground data, higher stress levels typically caused a reduction in growth and development. The same appears to be true in the below-ground data. The DL crop did not develop a substantial rooting system and roots were rarely found deeper than 0.1 ft. Even though the dryland crop performed similar to the irrigated treatments until mid-season the pictures do not show that it was able to develop a definitive rooting system. More in-depth analysis is needed of the rooting systems to determine full treatment effects of primed acclimation on root development.

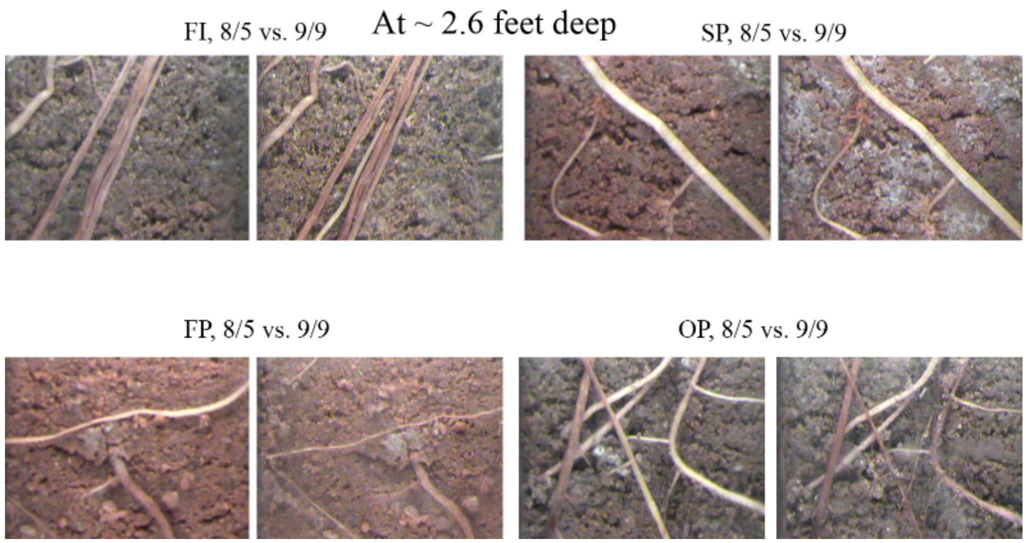

Figure 10. Images of the rooting system of the treatments that received irrigation.

Summary and Conclusions

Primed acclimation treatments were implemented in a cotton production trial at SIRP near Camilla, GA. There was rain early in the season that prevented treatments from being implemented as early as would be ideal. However, the production season turned off very hot and dry. Throughout the entire production season the trial only received 12.6 inches of rainfall. Crop growth parameters indicated that there were no differences between the FI and SP treatments. The FP treatment typically had slightly lower values than the FI and SP treatments. The OP treatment had lower growth rate and net assimilation rate. It was similar to the other irrigated treatments in dry matter accumulation and leaf area index. However, OP did have a reduction in reproductive structures late in the season which can be attributed to moisture stress early in the season. Lint yield was statistically similar for all four of the irrigated treatments. Statistically similar lint yield is significant because it means early season moisture stress did not have a significant effect on end of season productivity and lint yield. Even though the FP and OP treatments seemed to have slight reductions in some of the in-season crop growth parameters it did not have an effect on final yield. This means, the adequate irrigation treatments that were implemented beginning at first bloom allowed the plants to recover from early season moisture stress. This also indicated that mid-season irrigation rates and timing are more critical to crop growth, development and final yield than early season irrigation. The rooting data requires more in-depth analysis, but shows promise towards treatment differences in developing sound rooting systems. Corresponding root development pictures coupled with the above ground biomass collections, would aid to develop a relationship between above- and below- ground developments throughout the season.

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