Calibration & Testing of On-demand Irrigation Control Systems
Final Project Report

Submitted to

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Abstract
This project evaluated the accuracy of set points of soil moisture sensors for irrigation control on turfgrass. Four commercially available soil moisture sensors as part of a larger project have been installed on turfgrass plots at the University of Florida in Gainesville. Although initial results show that all of these sensors are capable of reducing irrigation water use, each sensor has an adjustable threshold to allow for different soil types, depth of probe installation, etc. The adjustable threshold is typically accomplished by some type of knob (Fig. 1) on the control mechanism of the device, while the sensor (Fig.2) that determines the moisture level in the soil is buried in the irrigated region. In the current project all soil moisture controller thresholds were set 24 hours after a significant rainfall event that filled the soil profile with water (i.e. field capacity). In every turfgrass plot an ECH_2O probe (Decagon Devices, Inc., Pullman, WA) was installed to monitor soil moisture content. Thus, each time one of the controllers was adjusted an independent measurement of soil moisture content was available from the ECH_2O probes. In a previous FNGLA funded project these ECH_2O probes were calibrated such that the soil moisture reading they provided was associated with the actual soil moisture with a high degree of confidence (Fig. 3). Overall, only one of the four controllers tested resulted in highly predicable relationships between soil moisture and the controller settings. Two of the controllers had knobs that were adjustable between "dry" and "wet" settings but did not produce results that were able to be replicated even during short periods of time such as a few minutes. Despite the non-predictability of controller threshold settings all but one controller reduced irrigation water 60-80% when compared to a conservative homeowner (i.e. twice per week adjusted by season) time based irrigation schedule (Cardenas-Lailhacar et al., 2005). It is unknown why controllers did not have reproducible set points, but part of the reason could be due to the design associated with inexpensive electronics.

Objectives
The objective of this research was to determine a relationship (if any) between actual soil moisture and the set point of four commercially available soil moisture controllers.

Methods

The controllers evaluated in this test were: Rain bird MCS100 (Rain bird, Inc., Glendora, CA), Acclima Model RS500 (Acclima, Inc., Meridian, ID), Water Watcher DPS-100 (Water Watcher, Inc., Logan, UT), and the Irrometer WEM (Irrometer Company, Inc., Riverside, CA). Soil moisture was measured independently by the ECH_2O probes in each plot. The soil moisture controllers are connected in series with typical residential irrigation controllers and treatments include irrigation windows of 1, 2, and 7 days per week. The set point on the controllers can be adjusted between "dry" and "wet" on the Rainbird (0-7) and WaterWatcher (-4 to 4). The Irrometer controller can be set at a specific soil tension (kPa) and the Acclima can be set directly to a specific soil volumetric water content (VWC, %). On the Rainbird and Water Watcher devices, the current soil moisture level can be found relative to the device setting by adjusting the dial (Fig. 1) until the LED turns off and on. On the Irrometer device an external hand held meter was used to determine the actual soil water tension from the probes; whereas, the Acclima device provided a direct readout of soil VWC (Fig. 1).

Results

The independent ECH_2O probe soil VWC was graphed against the readings produced by the various controllers. Overall, the Acclima controllers at 1, 2, and 7 days per week irrigation frequencies resulted in a more predictable response with soil moisture content than any other probe (Fig. 4). However, response from each probe (1, 2, and 7 day/wk) had substantially different slopes, which could indicate variability in the probes/controllers themselves or localized soil differences for each probe. The Rainbird controller resulted in slightly different threshold indications on the controller as the knob was adjusted each time. Figure 5 shows this variability plotted as the minimum, average, and maximum controller response points where the LED was "on" or "off". This type of response indicates a high intrinsic variability in the device which resulted in poor predictability of soil moisture at the 1 day/wk and 7 day/wk irrigation frequencies; however, the 2 day/wk frequency had an acceptable predictability of soil moisture content. The Irrometer device control dial relationship to soil moisture content had increased variability with increasing irrigation frequency (Fig. 6). We believe this response is due to a lag time of sensor output that is far slower than actual soil equilibrium conditions as has been noted in previous research (Irmak and Haman, 2001; Muñoz-Capena et al., 2005). Finally, the Water Watcher controller setting relationship with actual soil moisture conditions was not very strong (Fig. 7) and particularly bad for the 7 day/wk irrigation frequency.

Conclusions and Recommendations

Although this project has established the overall poor relationship between soil moisture controller set points and actual soil moisture conditions, irrigation water savings compared to time based treatments ranges from 60 to 80% (Cardenas-Lailhacar et al., 2005). This result suggests that while the resolution on the settings on the controllers is not fine, it is still lower than the potential difference between time based irrigation and sensor controlled irrigation. Future testing of these devices should include at least three controllers of each variety closely spaced together. This experimental design would allow the determination of variability between multiple devices of a single manufacturer. Thus the error attributable to soil variability or manufacturer variability could be determined.

References

Cardenas-Lailhacar, B., M.D. Dukes, and G.L. Miller. 2005. Sensor-based control of irrigation in bermudagrass. ASAE Paper No. 05-2180. American Society of Agricultural Engineers, St. Joseph, MI.

Irmak S. and D.Z. Haman. 2001. Performance of the Watermark granular matrix sensor in sandy soils. *Applied Engineering in Agriculture* 17(6):787-795.

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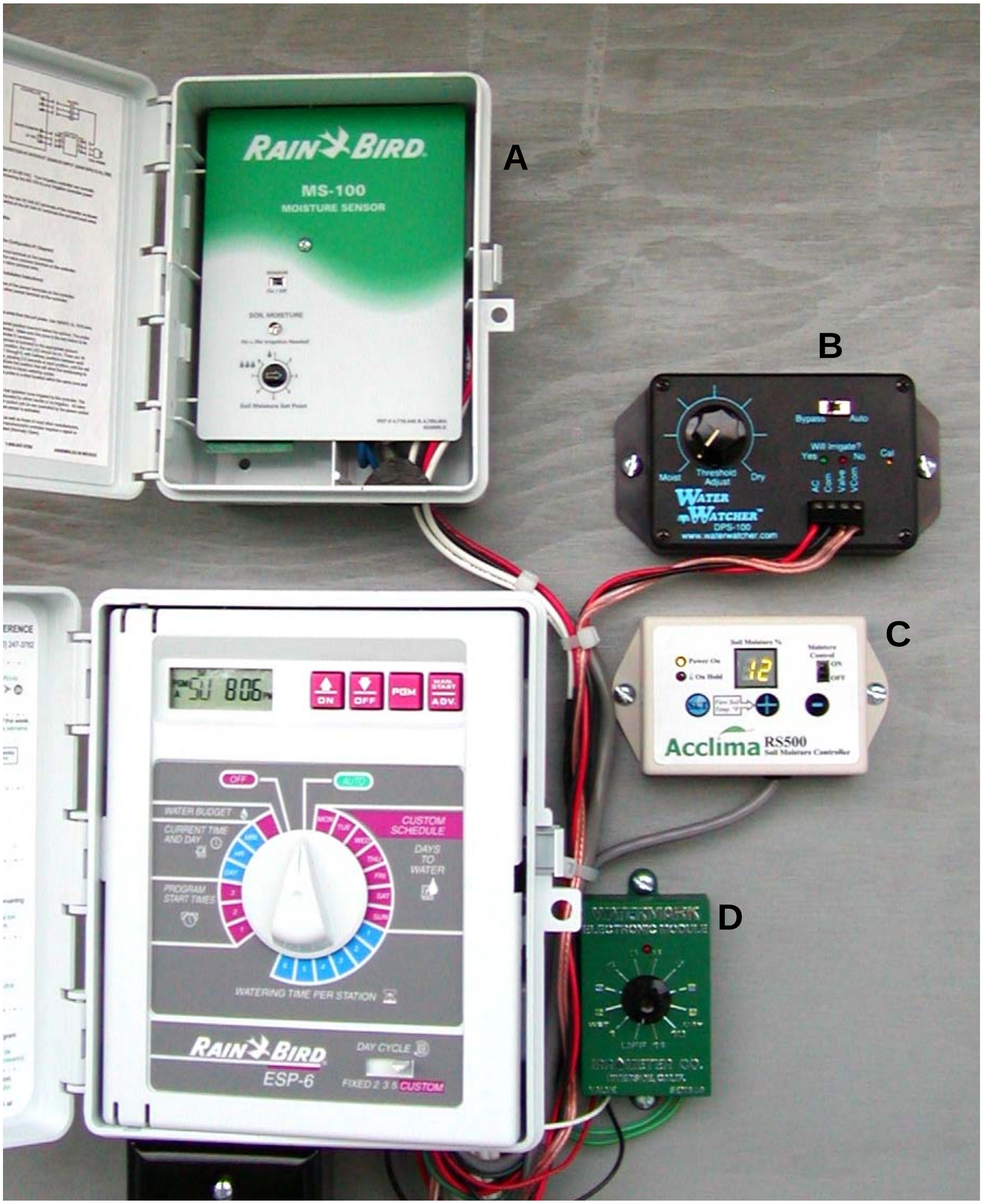

Figure 1. Soil moisture controllers tested: A)Rainbird, B)Water Watcher, C)Acclima, D)Irrometer.

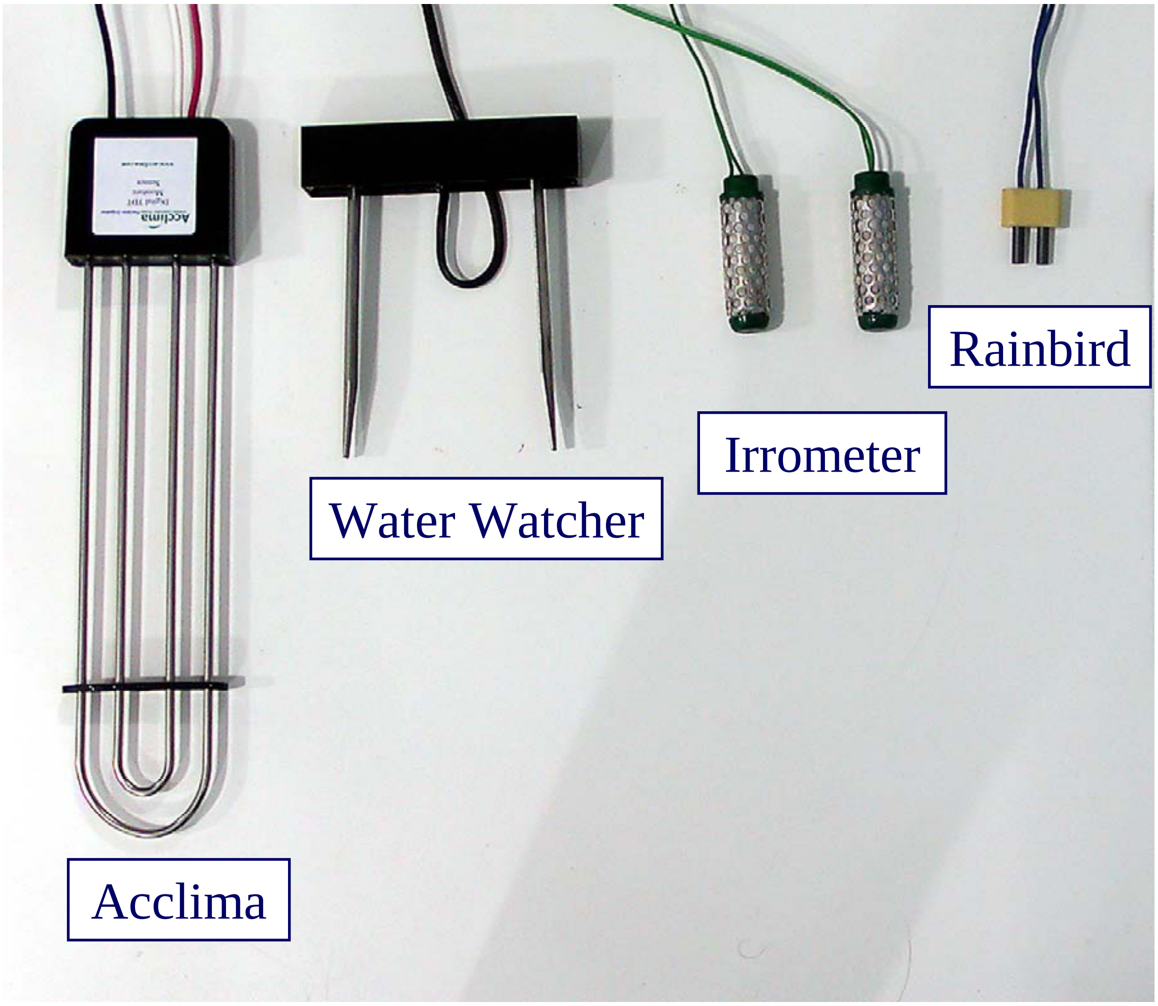

Figure 2. Soil moisture probes (paired with their matching controller) tested.

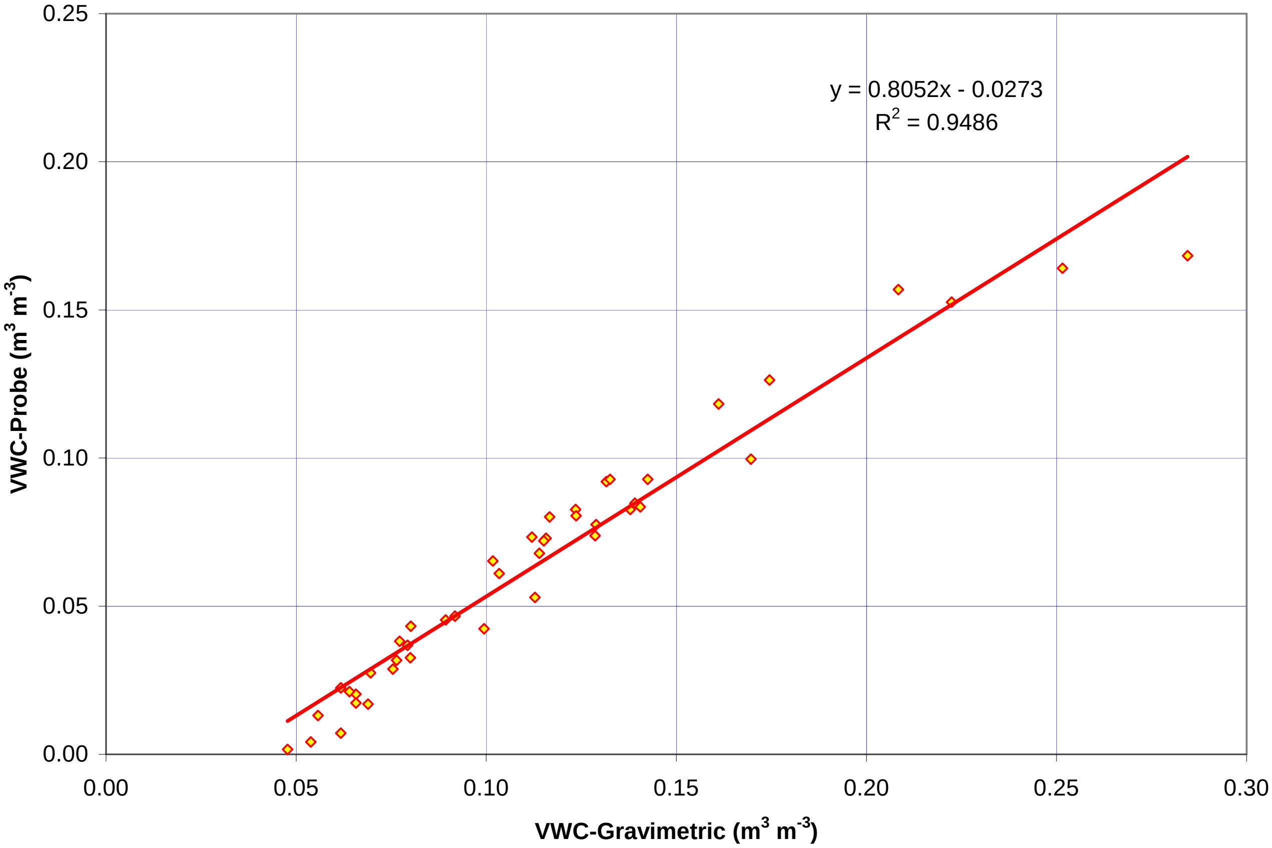

Figure 3. ECH_2O calibration results for an Arredondo fine sand.

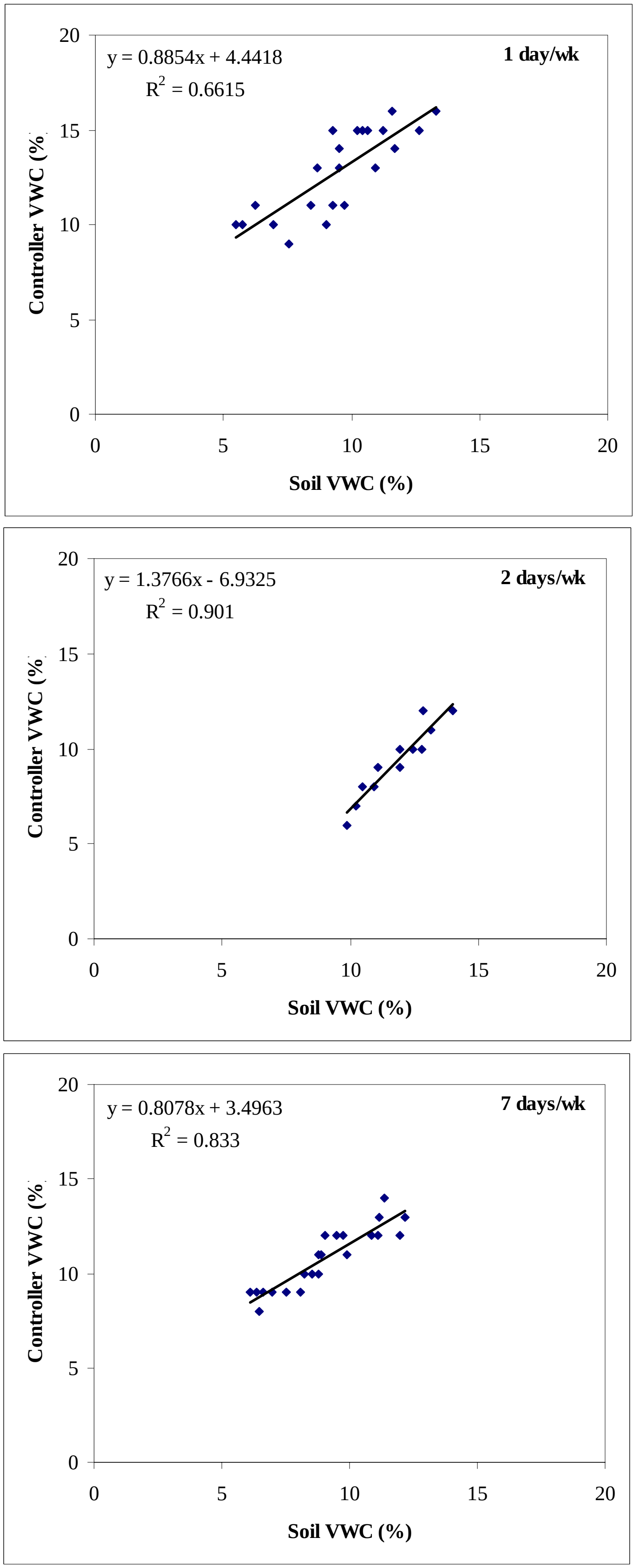

Figure 4. Acclima controller relationship between soil volumetric water content (VWC) and controller indicated VWC.

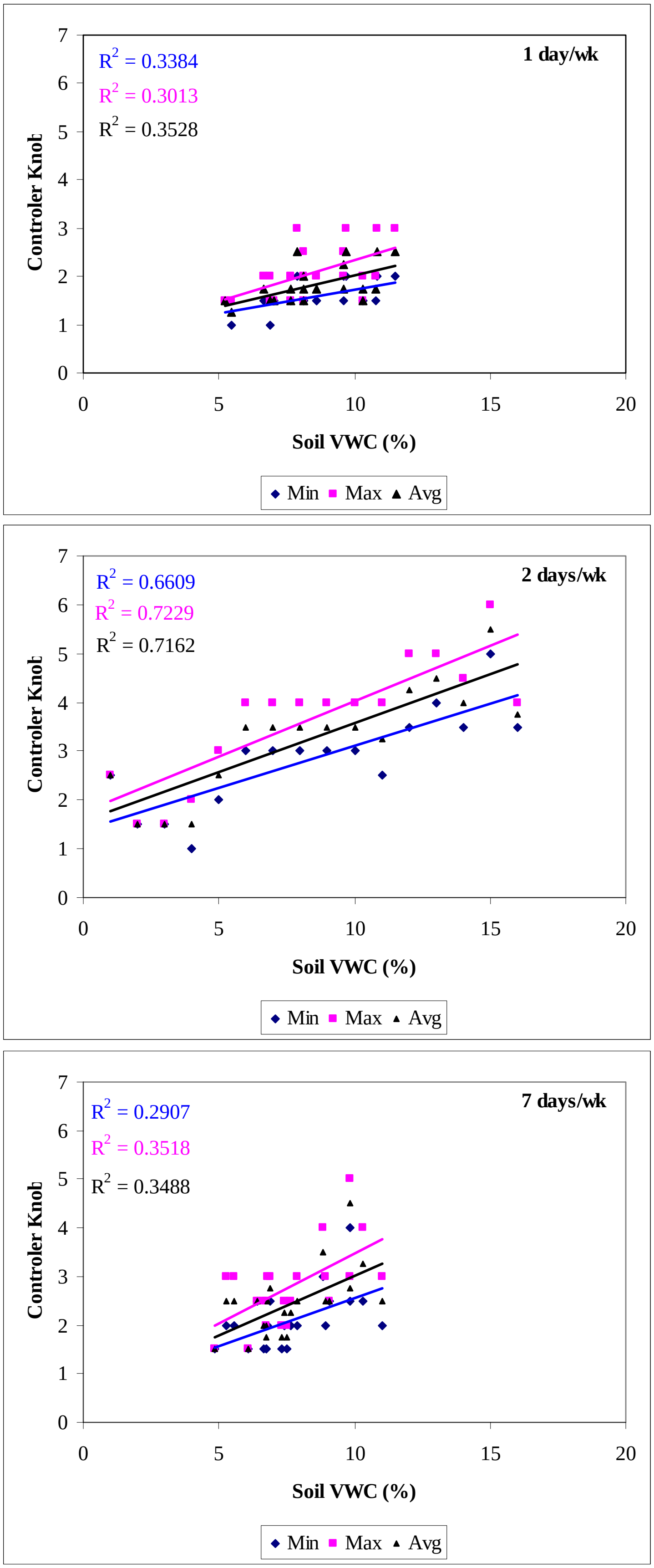

Figure 5. Rainbird controller relationship between soil volumetric water content (VWC) and controller setting.

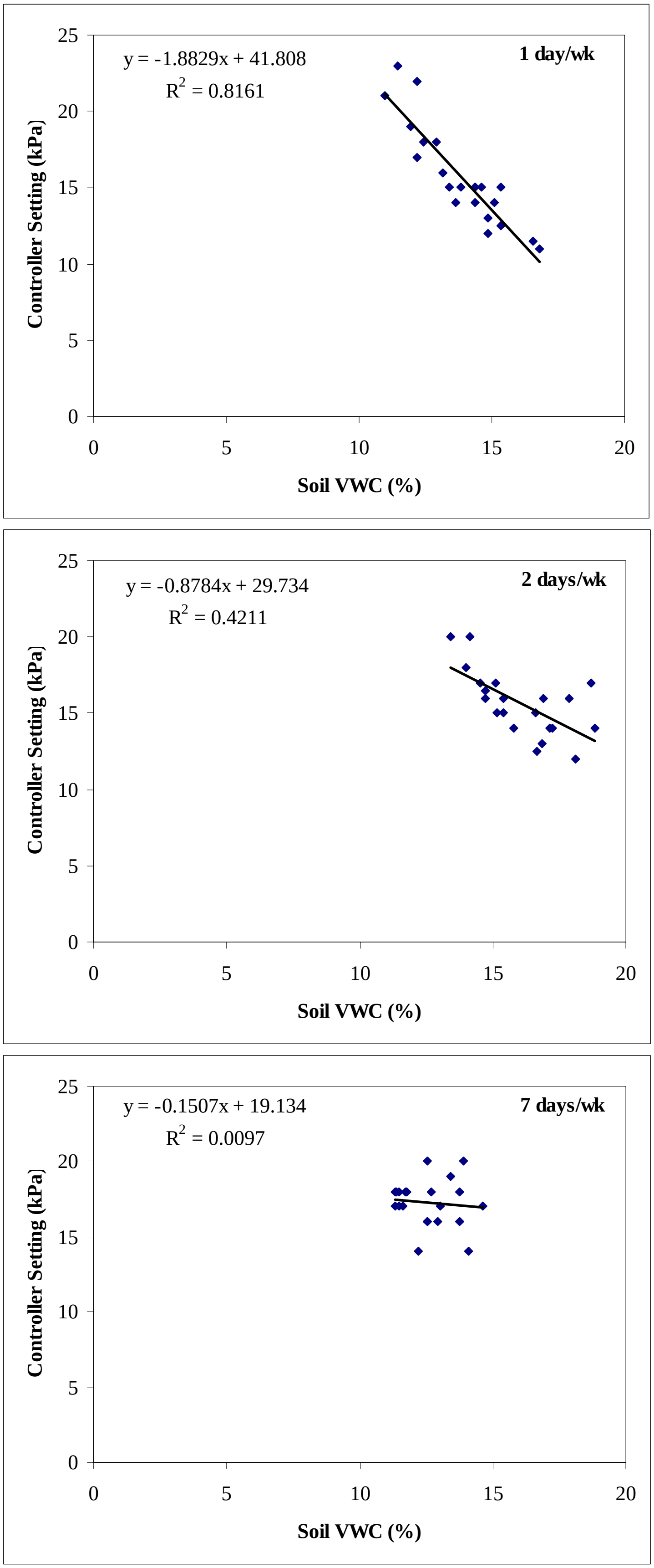

Figure 6. Irrometer controller relationship between soil volumetric water content (VWC) and controller soil tension setting (kPa).

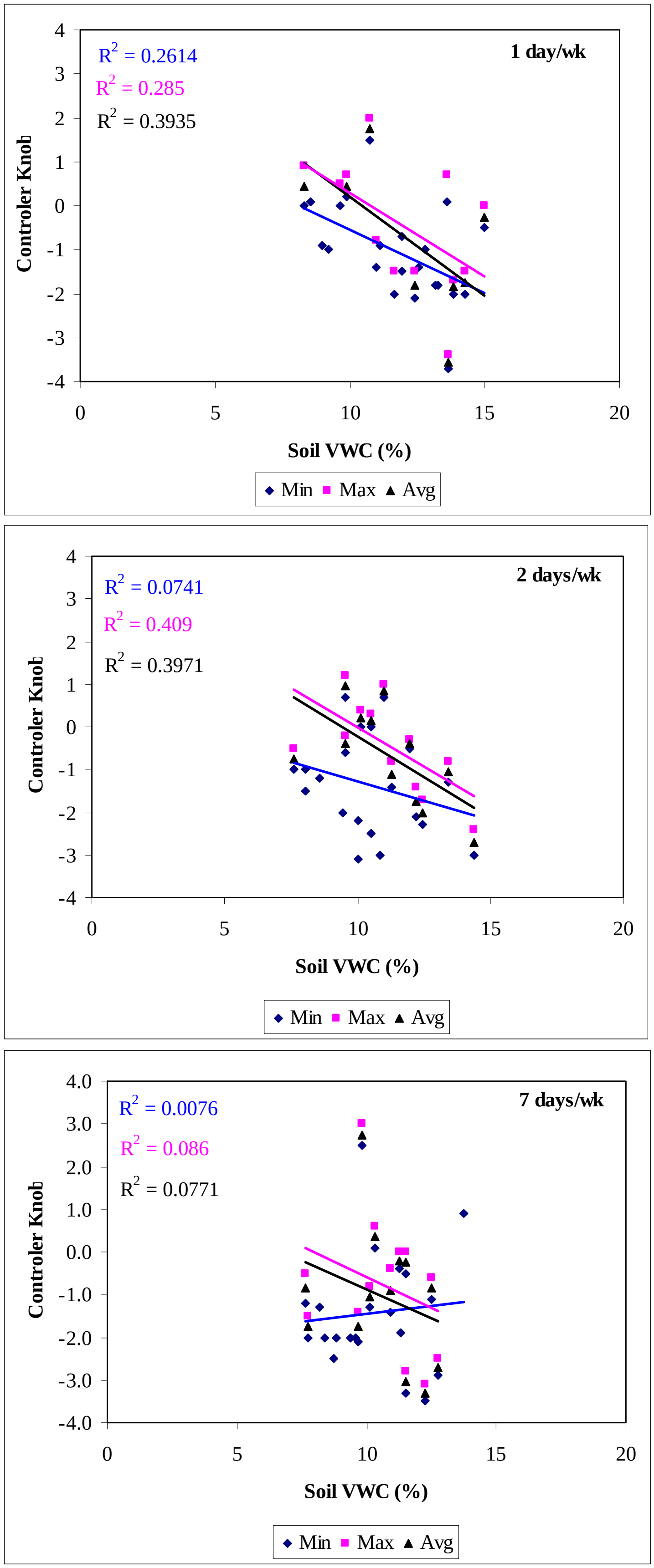

Figure 7. Water Watcher controller relationship between soil volumetric water content (VWC) and controller setting.