Field Determination of Permanent Wilting Point

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Abstract

Water is a vital resource for cotton production in the desert Southwest. One method of managing irrigation water is through the use of a "checkbook" approach to irrigation scheduling. This involves irrigating based upon the percent depletion of plant available water (PAW) from the soil profile. In order to effectively utilize this method of irrigation scheduling soil water content values at field capacity (FC) and permanent wilting point (PWP) must be defined. In this study the PWP values were characterized for two different soil types, one at Maricopa, AZ and another at Marana, AZ. The possibility of having different values for PWP as a function of crop stage of growth was also investigated in this study. Results demonstrated differences in both FC and PWP values between the two locations. Differences were also observed as a function of crop growth stage in the pattern of soil water extraction.

Introduction

Irrigated agriculture in the desert Southwest is a very intensive, high input, high output production system. There are several important crop inputs that go into producing a successful crop of cotton. In order to attain maximum economic yield all inputs must be managed in an optimal fashion. The single most critical input in desert agriculture is water. If water is not managed in an optimum fashion, management of other inputs such as fertilizers, PGR's, insecticides, etc. become less significant. The goal in managing irrigation water is to apply a sufficient amount at the proper time to meet crop needs. There are several different approaches that can be taken to schedule irrigation events. The use of infra-red thermometry, pressure-bomb readings, computer models, etc. are all methods that have been used in scheduling irrigations. In this study we wanted to investigate some important parameters used in what is called a "checkbook" method to determine irrigation timing.

The "checkbook" method is based upon a very simple premise. The amount of water entering and leaving the system is monitored by keeping track of irrigation and rainfall events which are inputs and then by subtracting rates of evapotranspiration (ET), which is water leaving the system through the soil and plants. Irrigation events are then scheduled based upon a percent depletion of the plant available soil water (PAW). A very important point to remember is that the total amount of water applied to the system is not necessarily the amount of water that is available to the crop. Due to the physical nature of the soil, the amount of PAW is usually much less than the total, and is highly dependent on soil texture. Plant available water (PAW) is commonly defined as the difference between field capacity (FC) and permanent wilting point (PWP). In general terms, PAW is defined (Miller and Donohue, 1995) as the difference between soil water held at -33 kPa (FC) and -1500 kPa (PWP). However, PWP iw more functionally defined as the point (i.e. soil water content) at which plants wilt but do not recover overnight (Taiz and Zeiger, 1991). These terms are very general and will actually differ among soil types. The FC however, is more easily determined and is essentially the soil water content directly after an irrigation when gravity has drained water out of the profile. The PWP is a point that is somewhat more difficult to identify. Since PWP is best defined by the condition of the plant, there are several factors that could affect PWP, some of which include; crop species, soil type, and crop stage of growth. In order to effectively use the checkbook method for scheduling irrigations PAW and thus the FC and PWP points must be clearly identified. Once these points are identified, then irrigations can be scheduled based upon a percent depletion of PAW. Depletion or evapotranspiration can be calculated from a reference ET multiplied by the appropriate crop coefficient resulting in a crop ET. Crop ET values can be obtained from local AZMET weather stations maintained by the University of Arizona. This method for irrigation scheduling is used quite extensively in crop production situations. It has even been taken to level of computer automation in programs like AZSCHED that was developed at the University of Arizona (Fox et al., 1992). The information generated by this type of research could easily be used to improve and validate such computer models. Table 1 outlines some general PAW values for several different soil types and Figure 1 graphically represents this concept. The objectives of this study were to identify PWP soil water content values for two different soil types and to identify how these values might change as a function of crop stage of growth.

Materials and Methods

In order to accomplish the stated objectives two separate studies were established, one at the University of Arizona Maricopa Agricultural Center (MAC) on a Casa Grande sandy loam and the other was at the University of Arizona Marana Agricultural Center (MAR) on a Pima clay loam. Four blocks of 24, 40 inch rows extending the full length of the irrigation run (approximately 600 feet) were established at each location. Deltapine (DP) 5415 was planted on 19 March and 17 April at MAC and MAR respectively. Four neutron probe access tubes were placed down the center of each block spaced approximately 100 feet apart at both locations. Neutron probe readings were conducted before and after each irrigation. Each of the four blocks had irrigations terminated at different stages of growth. The first block received only a water-up at irrigation at MAC and only a preirrigation at MAR. The second block was terminated just prior to first bloom and received no further irrigations. The third block was terminated after peak bloom receiving no more irrigations. The fourth block was allowed to complete the season and was terminated according to UA recommendations. Table 2 provides a list of irrigation events for all treatments at each location. PWP was identified visually for each block. PWP is defined by Taiz and Zeiger (1991) as the point at which the plant does not recover overnight from a water stress induced wilt. This was the criteria used to identify PWP. Soil water content was then identified at that point for each block using neutron probe readings.

Results and Discussion

Values for volumetric soil water content varied according to stage of growth. This was particularly evident at the MAC location (Figure 2). Treatment 1, which reached PWP just prior to first bloom still had a high volumetric water content below 2 feet. As treatments 2 and 3 were brought to PWP, more of the soil water below 2 feet was extracted. The same trend was observed at the MAR location (Figure 3) but not to such a dramatic extent. These results demonstrate the importance of realizing from what depths the crop is extracting water at different stages of the season. Tables 3 and 4 list the volumetric soil water content associated with the identification of PWP for each of the three treatments at both MAC and MAR, respectively. Also shown in these tables is the calculated PAW based upon FC and PWP for each of the three treatments. The first and most obvious result to notice is the differences in the amount of PAW between MAC and MAR. MAR, Pima clay loam soil, has a much higher water holding capacity than the sandy loam at MAC. If irrigations were being scheduled based on percent depletion of PAW an optimum irrigation regime would call for irrigations more frequently at MAC than MAR. If irrigations are being scheduled at 50% depletion of PAW and crop ET values are approximately 0.33 inches/day (mid-season) irrigations will need to be scheduled on approximately 7-day intervals. This was the first year of this study. It will be continued at both MAC and MAR, and a location will be added at Yuma for the 1997 growing season.

References

Fox Jr., Fred A, T. Scherer, D.C. Slack and, L.J. Clark. 1992. AZSCHED Arizona Irrigation Scheduling. User's Manual. The University of Arizona. Cooperative Extension. Agricultural and Biosystems Engineering. Version 1.01.

Miller, R.W. and, R.L. Donahue. 1995. Soils In Our Environment. Prentice Hall Inc. A Simon and Schuster Co. Englewood Cliffs, NJ.

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Table 1. General values of soil water holding capacity for several soil textures.

	Water per 1 foot of Soil Depth		
	PWP	FC	PAW
Soil Texture	**inches**	**inches**	**inches**
medium sand	0.28	1.2	0.9
fine sand	0.39	1.5	1.1
sandy loam	0.59	1.9	1.4
fine sandy loam	0.79	2.6	1.8
loam	1.2	3.1	2.0
silt loam	1.4	3.4	2.0
clay loam	1.8	3.7	2.0
clay	2.6	3.9	1.4

Table 2. Irrigation events for all treatments for MAC and MAR, 1996.

Maricopa			
Treatment 1	**Treatment 2**	**Treatment 3**	**Treatment 4**
21 March	21 March	21 March	21 March
	22 May	22 May	22 May
	12 June	12 June	12 June
		24 June	24 June
		8 July	8 July
			18 July
			1 August
			15 August
Marana			
Treatment 1	**Treatment 2**	**Treatment 3**	**Treatment 4**
27 March	27 March	27 March	27 March
	10 June	10 June	10 June
		1 July	1 July
		17 July	17 July
			30 July
			13 August
			28 August

Table 3. PWP and PAW values for each treatment at MAC, 1996.

Depth		PWP		FC		Inches of Water PAW	
ft.	Trmt 1	Trmt 2	Trmt 3		Trmt 1	Trmt 2	Trmt 3
	Volumetric Water Content						
1	0.11	0.15	0.16	0.25	1.7	1.2	1.1
2	0.15	0.21	0.19	0.27	1.4	0.7	1.0
3	0.20	0.23	0.18	0.26	0.7	0.4	1.0
4	0.23	0.22	0.19	0.26	0.4	0.5	0.8
5	0.23	0.21	0.19	0.26	0.4	0.6	0.8
				Total	**4.6**	**3.4**	**4.7**

Table 4. PWP and PAW values for each treatment at MAR, 1996.

Depth		PWP		FC		Inches of Water PAW	
ft.	Trmt 1	Trmt 2	Trmt 3		Trmt 1	Trmt 2	Trmt 3
	Volumetric Water Content						
1	0.20	0.21	0.22	0.32	1.4	1.3	1.2
2	0.14	0.14	0.18	0.33	2.3	2.3	1.8
3	0.15	0.12	0.12	0.32	2.0	2.4	2.4
4	0.16	0.14	0.17	0.26	1.2	1.4	1.1
5	0.15	0.13	0.17	0.27	1.4	1.7	1.2
				Total	**8.3**	**9.1**	**7.7**

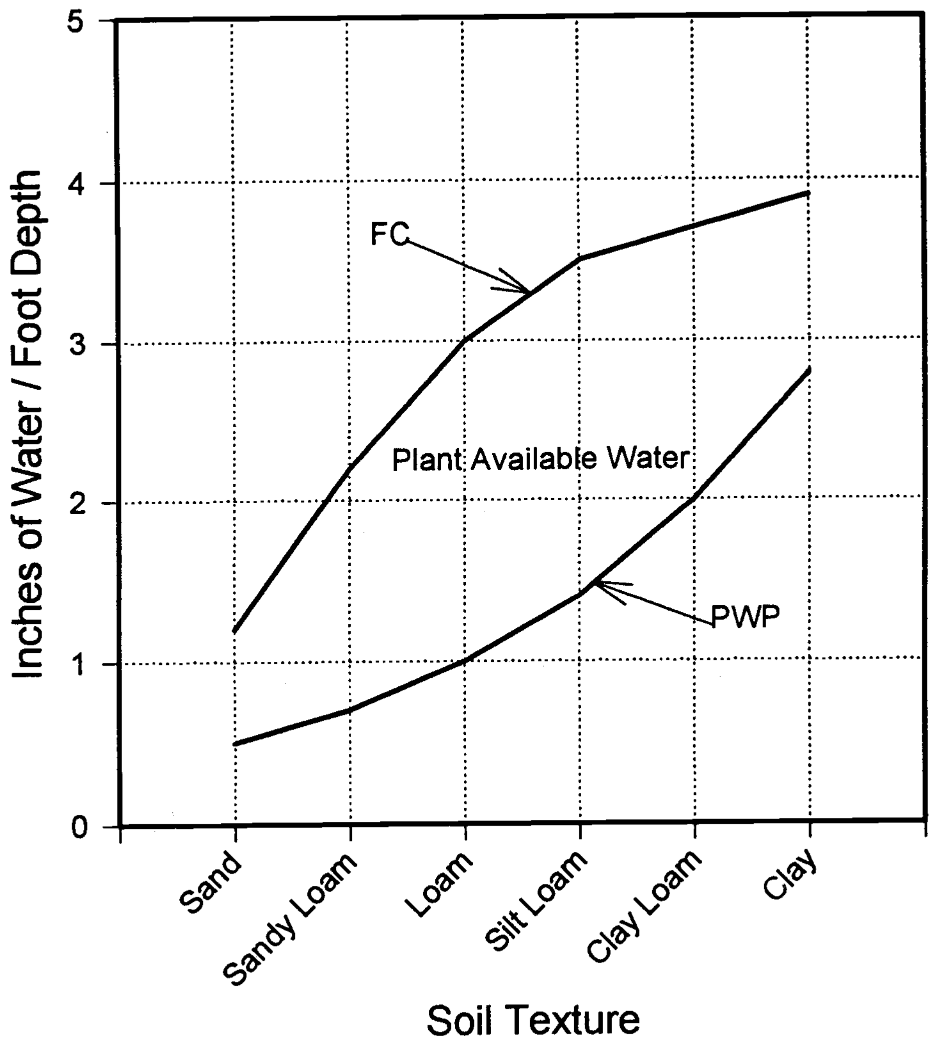

Figure 1. Graphical representation of PAW concept.

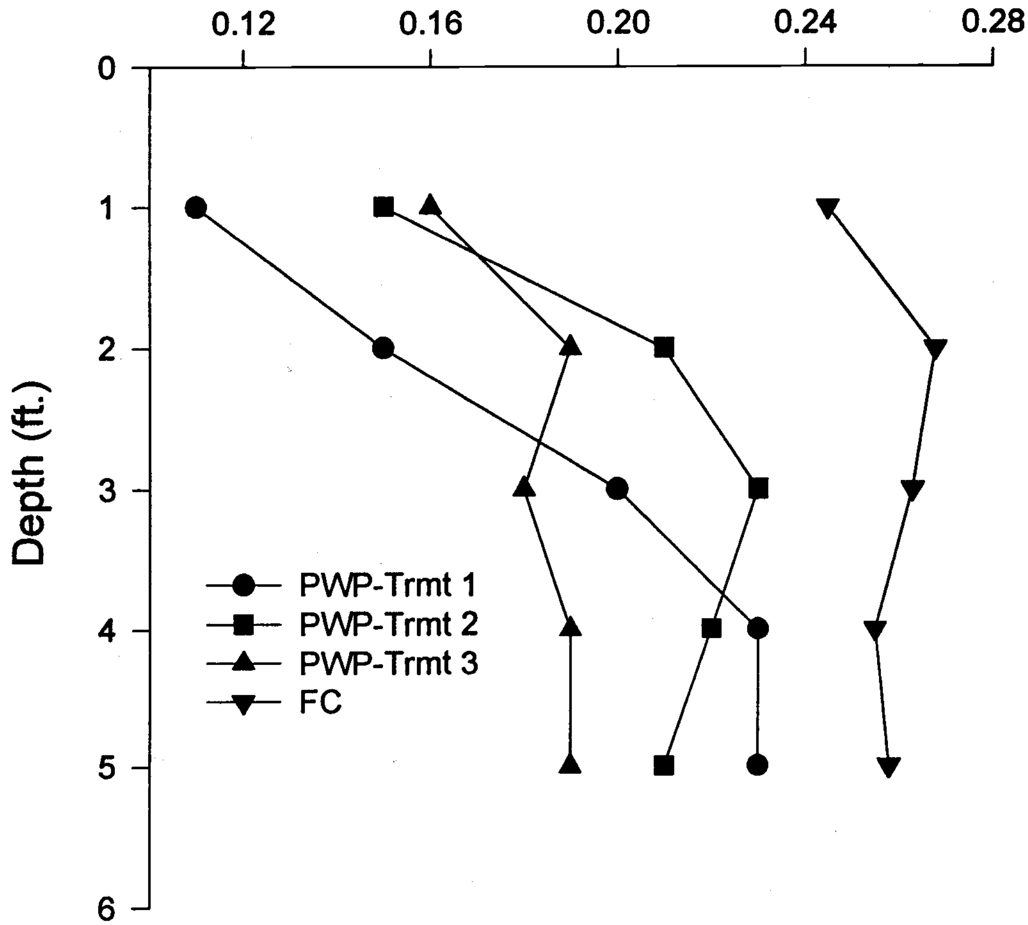

Figure 2. Soil moisture and plant-available water profiles for Maricopa, 1996.

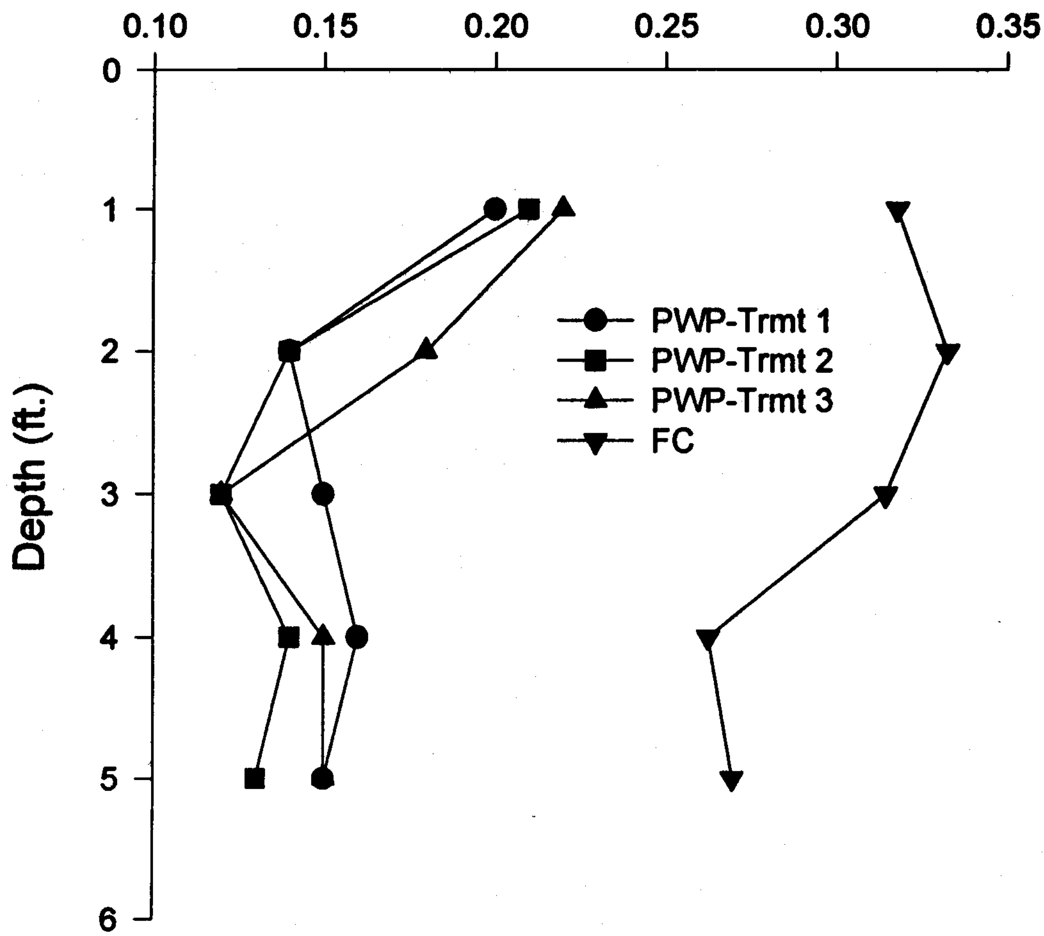

Figure 3. Soil moisture and plant-available water profiles for Marana, 1996.