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 at the Maricopa location.

Introduction

There are several important 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 first limiting factor and 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 much 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 inputs (irrigation and rainfall events) and water leaving the system (evapotranspiration). 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 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 is 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. PWP 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, including; 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. For Arizona crop production 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

Results from the 1997 study were very similar to the results found in the 1996 study (Norton and Silvertooth, 1997). In order to accomplish the stated objectives two separate studies were established, one at the University of Arizona Maricopa Agricultural Center on a Casa Grande sandy loam and the other was at the University of Arizona Marana Agricultural Center on a Pima clay loam (Table 2). Four blocks of 12, 40 inch rows extending the full length of the irrigation run (approximately 600 feet) were established at each location. Deltapine 33B was planted on 19 March and 17 April at Maricopa and Marana respectively. Two neutron probe access tubes were placed down the center of each block spaced approximately 200 feet apart at both locations. Neutron probe readings were conducted before and after each irrigation. Irrigations were terminated at different stages of growth for each of the four blocks. The first block received only a water-up at irrigation at Maricopa and only a pre-irrigation at Marana. 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 taken into cut-out before irrigations were terminated. Table 3 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

At the Maricopa location, values for volumetric soil water content varied according to stage of growth (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. These results demonstrate the importance of realizing from what depths the crop is extracting water at different stages of the season. Water extraction patterns at Marana differed slightly than those at Maricopa. An increase in depth of extraction was not observed as the crop increased in stage of growth. Several irrigations at Marana did not completely fill the profile. Water penetration during these irrigation events reached to approximately three feet. Since the fourth and fifth feet were very seldom replenished the effect of increasing depth of extraction was not observed. Tables 4 and 5 list the volumetric soil water content associated with the identification of PWP for each of the three treatments at Maricopa and Marana 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 Maricopa and Marana. Marana, Pima clay loam soil, has a much higher water holding capacity than the sandy loam at Maricopa. A comment should be made regarding PAW values at lower depths at Marana. It is possible that values for PAW are overestimated due to the extremely low water contents at the fourth and fifth foot depths (particularly treatment 2). If irrigations were being scheduled based on percent depletion of PAW an optimum irrigation regime would call for irrigations more frequently at Maricopa than Marana. This study will be continued at both Maricopa and Marana for the 1998 growing season.

References

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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. Soil classification and properties for both Marana and Maricopa.

Depth (ft)	Sand	Silt	Clay	pH	CEC	Organic C	K Total	K Exch
	———	%	———		cmol kg^{-1}	———	$g\ kg^{-1}$ ———	mg kg^{-1}
			Marana – *Pima (Typic Torrifluvent)*					
0 – 1	22	51	27	8.4	23.7	3.64	26	430
1 – 2	12	63	25	8.6	27.8	3.36	24.1	227
2 – 3	26	48	26	8.6	37.0	2.32	25.0	208
3 – 4	22	59	19	8.4	24.8	1.48	25.5	178
			Maricopa – *Casa Grande (Typic Natrargid)*					
0 – 1	64	21	15	8.2	10.9	1.60	29.9	560
1 – 2	68	18	14	8.5	9.1	1.00	30.8	373
2 – 3	72	15	13	8.5	8.3	0.72	29.5	271
3 – 4	58	25	17	8.5	9.1	0.56	24.4	250

Table 3. Irrigation events for all treatments for Maricopa and Marana, 1997.

Maricopa			
Treatment 1	**Treatment 2**	**Treatment 3**	**Treatment 4**
9 Arpil	9 April	9 April	9 April
	29 May	29 May	29 May
		9 June	9 June
		23 June	23 June
			2 July
			14 July
			23 July

Marana			
Treatment 1	**Treatment 2**	**Treatment 3**	**Treatment 4**
27 Maranach	27 Maranach	27 Maranach	27 Maranach
	29 May	29 May	29 May
	19 June	19 June	19 June
		3 July	3 July
			16 July
			31 July

Table 4. PWP and PAW values for each treatment at Maricopa, 1997.

Depth ft.	PWP Trmt 1	PWP Trmt 2	PWP Trmt 3	FC	Inches of Water PAW Trmt 1	Inches of Water PAW Trmt 2	Inches of Water PAW Trmt 3
	Volumetric Water Content						
1	0.16	0.17	0.19	0.33	2.0	1.9	1.7
2	0.18	0.22	0.19	0.33	1.8	1.3	1.7
3	0.22	0.24	0.19	0.33	1.3	1.1	1.7
4	0.27	0.27	0.21	0.33	0.71	0.71	1.4
5	0.28	0.27	0.22	0.34	0.71	0.83	1.4
				Total	**6.5**	**5.8**	**7.9**

Table 5. PWP and PAW values for each treatment at Marana, 1997.

Depth ft.	PWP Trmt 1	PWP Trmt 2	PWP Trmt 3	FC	Inches of Water PAW Trmt 1	Inches of Water PAW Trmt 2	Inches of Water PAW Trmt 3
	Volumetric Water Content						
1	0.22	0.21	0.24	0.39	2.0	2.1	1.8
2	0.24	0.23	0.29	0.39	1.8	1.9	1.2
3	0.21	0.17	0.19	0.35	1.7	2.1	1.9
4	0.18	0.13	0.16	0.37	2.2	2.8	2.5
5	0.18	0.14	0.18	0.37	2.2	2.7	2.2
				Total	**9.9**	**11.6**	**9.6**

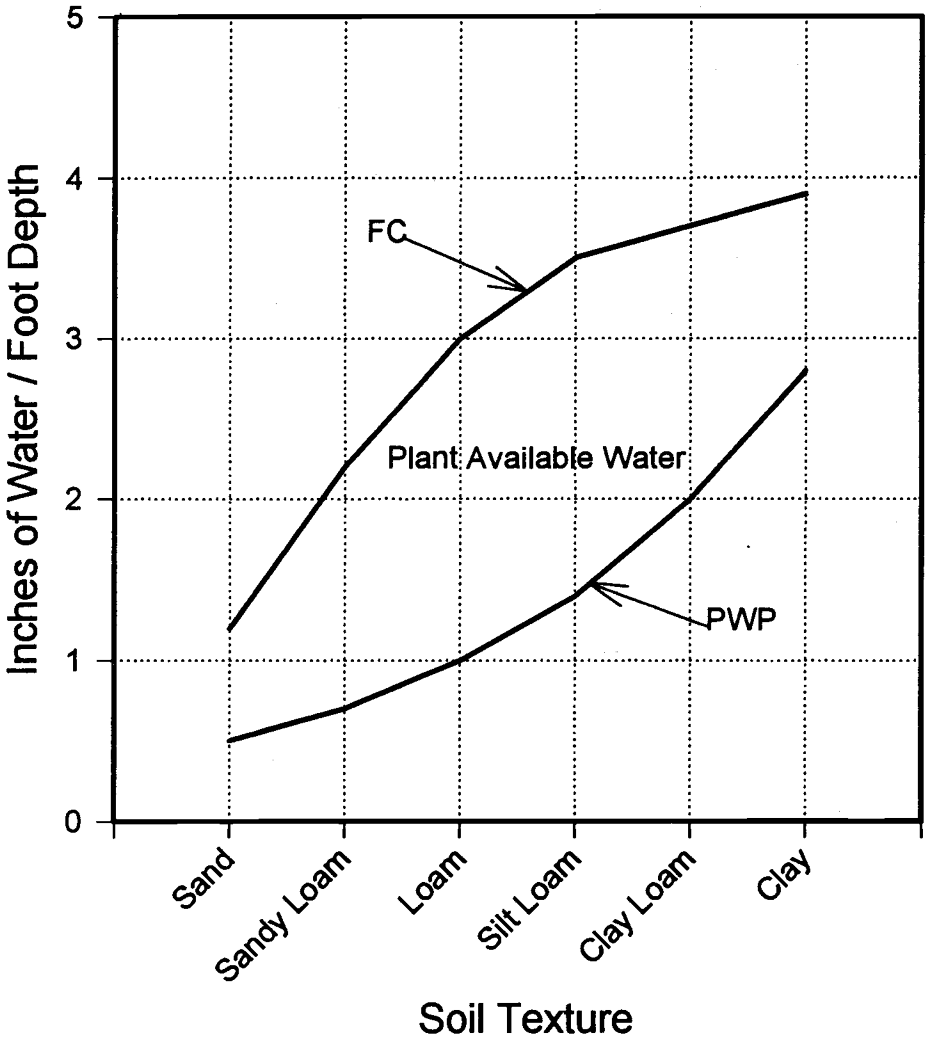

Figure 1. Graphical representation of PAW concept.

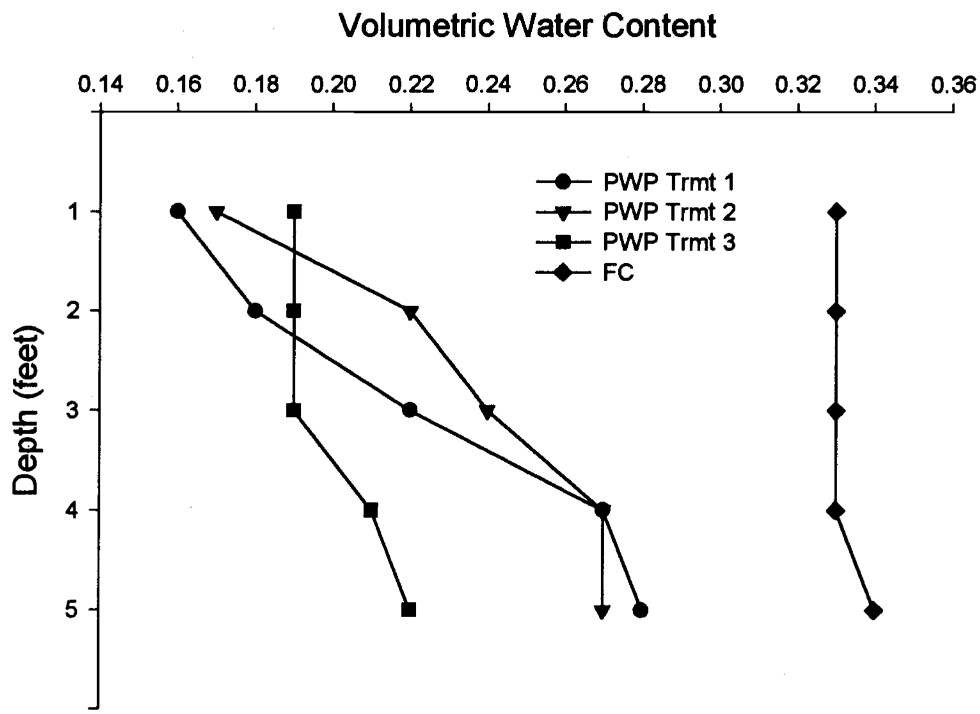

Figure 2. PWP for each treatment and FC for Maricopa, 1997.

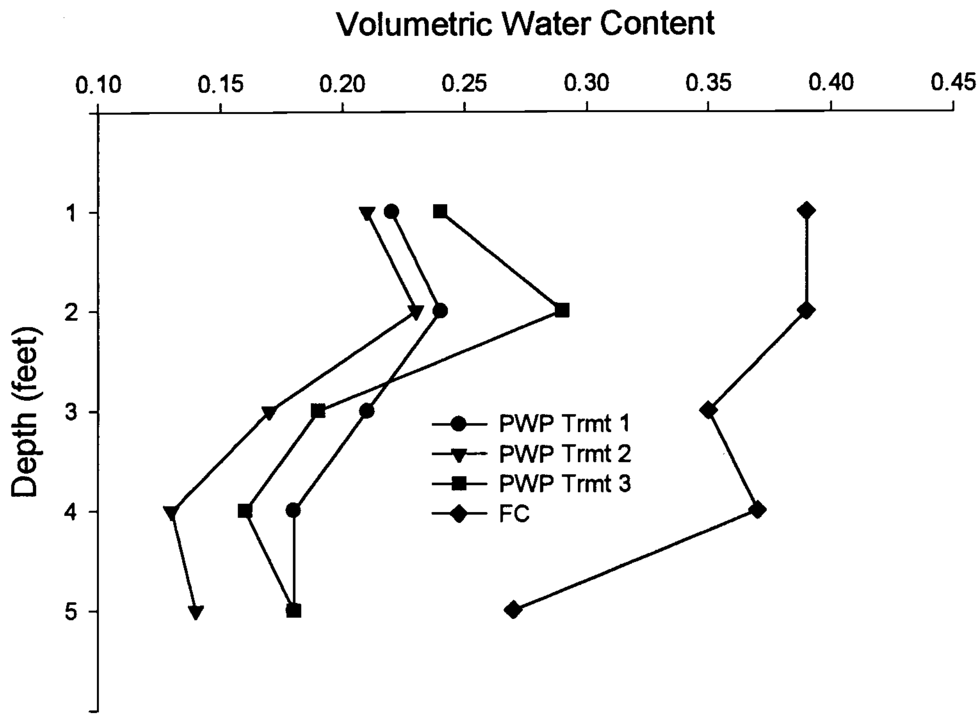

Figure 3. PWP for each treatment and FC for Marana, 1997.