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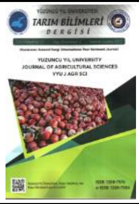

Araştırma Makalesi (Research Article)

Performance Evaluation of PR2 in Determination of Soil Water Content

Harun KAMAN*[1], Ömer ÖZBEK[2]

[1]Akdeniz University, Faculty of Agriculture, Department of Agricultural Structures and Irrigation, Antalya, Turkey
[2]Bati Akdeniz Agricultural Research Institute, Soil and Water Resources Department, Antalya, Turkey
[1]https://orcid.org/0000-0001-9308-3690 [2]https://orcid.org/0000-0001-6334-1222
*Sorumlu yazar e-posta: hkaman@akdeniz.edu.tr

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PR2,
Soil water content

Abstract: As it is known, drought is one of the most important issues of recent years. On the other hand, agriculture is the sector that uses the most water. The impact of drought can be reduced by reducing the water used in agriculture. Therefore, it is very important to determine the application time and amount of irrigation water for a successful agricultural irrigation management. One of the most important ways to achieve this success is to accurately determine and monitor the water content in the plant root zone. Soil water content can be determined in two ways; direct and indirect methods. The direct measurement method is tedious, laborious and time consuming. Instead, a large number of indirect measurement methods are developed. One of these indirect measurement methods is the PR2 Profile Probe method. In this study, the possibilities of using PR2 method under different soil water content conditions were investigated. First, the calibration of the PR2 method was made within 40 cm of soil depth. Then, the water content in the soil was monitored by the PR2 method under three different soil water content (100%, 75% and 50%) conditions. R^2 values for calibration relationships varied between 0.7947 and 0.9305. In the study, it was concluded that soil water content could be monitored with PR2 Profile Probe.

Toprak Su İçeriğinin Belirlenmesinde PR2'nin Performansının Değerlendirilmesi

Makale Bilgileri

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Anahtar Kelimeler
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PR2,
Sulama yönetimi

Öz: Bilindiği gibi kuraklık, son yılların en önemli konularının başında gelmektedir. Öte yandan, tarım en fazla suyu kullanan sektör konumundadır. Tarımda kullanılan suyun azaltılmasıyla kuraklığın etkisi azaltılabilir. Bu nedenle, başarılı bir tarımsal sulama yönetimi için sulama suyunun uygulama zamanı ve miktarının belirlenmesi çok önemlidir. Söz konusu başarıya ulaşmanın en önemli yollarından biri, bitki kök bölgesindeki su içeriğinin doğru bir şekilde belirlenmesi ve izlenmesidir. Toprak su içeriği doğrudan ve dolaylı yöntemler olmak üzere iki şekilde belirlenebilmektedir. Doğrudan ölçüm yöntemi yorucu, zahmetli ve zaman alıcıdır. Bunun yerine çok sayıda dolaylı ölçüm yöntemleri geliştirilmektedir. Söz konusu dolaylı ölçüm yöntemlerinden biri de PR2 Profile Probe yöntemidir. Bu çalışmada, farklı toprak su içeriği koşullarında, PR2 yönteminin kullanılma olanakları araştırılmıştır. İlk olarak, 40 cm toprak derinliği içinde PR2 yönteminin kalibrasyonu yapılmıştır. Daha sonra üç farklı toprak su içeriği (% 100, % 75 ve % 50) koşullarında PR2 yöntemiyle topraktaki su içeriği izlemeye alınmıştır. Kalibrasyon ilişkileri için R^2 değerleri 0.7947 ile 0.9305 arasında değişim göstermiştir. Araştırmada, PR2 Profile Probe ile toprak su içeriğinin izlenebileceği sonucuna varılmıştır.

1. Introduction

The soil is a dynamic and heterogeneous system in which all living things inhabit and plants are grown. Due to the fact that soil is the most important growing environment for plants, the knowledge of the basic soil-water relations in modern agriculture concerns not only those who deal with soil and irrigation but also a wide range of fields ranging from plant breeders to forestry, environment and civil engineering.

Accordingly, the measurement of soil water content is necessary for irrigation engineering, land and water conservation studies, many environmental and engineering studies (Çetin, 2003). One of the most important problems in the agriculture sector in the coming years is the sustainability of irrigated agriculture.

The studies on increasing the efficiency of the unit production and increasing the efficiency of the water used in the agricultural production are important issues for water saving. For this aim, determination and monitoring of soil water content in irrigation agricultural lands with effortless, fast and easy-to-use methods has become very important.

There are two basic methods to determine and monitor soil water content: 1) direct measurement and 2) indirect measurement. The direct method of measurement requires the gravimetrical removal of soil samples, spoiled or intact. This method is tedious and time-consuming. With indirect methods, soil water content cannot be measured directly. Here, another parameter that varies depending on the water content in the soil is measuring and calibrating the soil water content.

In calibration studies, R^2 is one of the most important parameters that show the linear relationship between directly measured soil water content and the other indirect measurement methods. It is desirable that the value of R^2 is close to 1. Because the value of R^2 takes a value close to 1, it increases the reliability/validity of the indirect measurement method in determining the soil water content.

Numerous studies have been carried out on the indirect measurement method of soil water content (eg, Tülün, 2005, Evett et al., 2006, Köksal et al., 2011, Kirnak and Akpinar, 2016). Sometimes different and sometimes parallel results emerged depending on other factors such as the method, soil properties, etc. studied in the research. Indirect methods include many methods such as neutron probe and TDR (Time Domain Reflectometry).

The Profile Probe method can also be counted among these. With the Profile Probe method, the water contents at different depths of the soil can be measured. For example, Ekinci and Başbağ (2019) measured the soil water content using the Delta T Profile Probe device. This article deals with the determination and monitoring of soil water content by the Profile Probe method, which has become very common in recent years.

This research has two aims: 1) the first was to investigate the possibility of using the Profile Probe Type PR2 in monitoring the water content of the plant root zone under greenhouse conditions, 2) the second aim of the study was to determine the possible changes in the water content of the plant root zone at three different irrigation water levels during the spring growth season.

2. Materials and Methods

2.1. Study area

The research was carried out in a greenhouse in the Research and Application Area of the Faculty of Agriculture at Akdeniz University. The survey area is located between 30 °C 38' 30''- 30 °C 39' 45'' east longitudes and 36 °C 53' 15''- 36 °C 54' 15'' north latitudes. The height of the study area is 54 m (Anonymous, 1998).

In the research area where the Mediterranean climate is dominant, summers are warm and dry, winters are warm and rainy. The average temperature in Antalya is 18.0 °C, the coldest month is January with 9.2 °C, and the warmest month is July with 28.2 °C. The annual average relative humidity is 63%, the average total precipitation is 1063.5 mm and the average total evaporation is 1 886.3 mm (Anonymous, 2000).

The soil in the research area consists of Gölbaşı series. The Gölbaşı series of soils, which developed on massive travertines, were included in the Entisol order due to their lack of profile development and young soil. All the profiles of this young series of soils with AC horizon possess clay-tin textures. They are located in almost flat and nearly flat topography (Sarı et al., 1993). Some soil characteristics of the greenhouse in which the survey was conducted are given in Table 1.

Table 1. Soil properties of the study site

Depth (cm)	Field capacity (cm^3 cm^{-3})	Wilting point (cm^3 cm^{-3})	Bulk density (g cm^{-3})
0-20	0.292	0.196	1.128
20-40	0.271	0.208	1.236
40-60	0.251	0.186	1.286

2.2. Calibration of Profile Probe Type PR2

The Profile Probe Type PR2 calibrations were first made in three different places in the greenhouse in the dimensions of 1×1 m. A large number of gravimetric soil samples were needed to perform an accurate calibration. In this case, a number of pits-holes may be formed around the PR2 access tube. For this reason, three square borders with soil embankments constructed (the soil pans) in order to avoid adversely affecting the calibration operation of cavities that may form around the PR2 access tube during the retrieval of a large number of gravimetric soil samples. At the same time, the calibrations performed in the three different places made it possible for the greenhouse soil to be better represented.

The PR2 access tube was placed in the middle of the soil pan. Then, the gravimetric soil samples (W, g g^{-1}) were taken from the depths of 10, 20, 30 and 40 cm from the first soil pan while the soil was dry. Simultaneously PR2 readings (mV) were made. The Gravimetric soil samples were taken from the second soil pan while the soil was partially wet one week later and again at depths of 10, 20, 30 and 40 cm. Simultaneous readings with PR2 were also recorded. One day later, gravimetric soil samples were taken from the third soil pan, which was completely saturated with water, again at the depths of 10, 20, 30 and 40 cm. Simultaneously PR2 readings were made. Gravimetric soil samples (W, g g^{-1}) and PR2 readings (mV) were repeated three times each time.

The water contents determined by the weight basis (W, g g^{-1}) of the gravimetric soil samples were converted to the volumetric water content (θ, cm^3 cm^{-3}) taking into account the soil unit volume mass (ρ, g cm^{-3}). Finally, a figure was made on the computer in such a way that the PR2 readings on the X axis and the volumetric water content of the soil were on the Y axis. Similarly, in a calibration study of the neutron probe, a figure was made on the computer (Soil Physics Laboratory, 1997) with the neutron probe count ratio on the X axis and the volumetric water content (θ, cm^3 cm^{-3}) on the Y axis. In another study by Kirnak and Akpinar (2016), TDR's measured dielectric constant (K) on the X axis and the volumetric water content (θ, cm^3 cm^{-3}) of the soil on the Y axis were included in the calibration process of TDR. Calibration process was completed by showing R^2 and equation on the figure.

2.3. Irrigation water for performance evaluation of PR2

The main aim of this article is only related to Profile Probe Type PR2 calibration and its possibilities for use. The irrigation water was obtained from the pumping system in the Research and Application Area at Akdeniz University.

The study lasted 129 days. A total of 24 irrigation applications were carried out beginning from the implementation of irrigation treatments. With the Profile Probe Type PR2, the water content of the root region of the plant was monitored at certain intervals throughout the season. Using the equation obtained from the Profile Probe Type PR2 calibration, the seasonal water content was also converted to the volumetric water content.

In this study, three irrigation treatments (T1, T2 and T3) were dealt with in order to check the Profile Probe Type PR2 measurements. T1 treatment was full irrigation. The remaining two irrigation treatments T2 and T3 were deficit irrigation treatment, which received 25% and 50% reduced amount of irrigation water, compared respectively to T1.

Two statistical parameters were used to compare predicted data from PR2 measurements with the observed gravimetric soil samples as (1) the coefficient of determination (R^2) and (2) mean value of data.

3. Results

3.1. Profile Probe Type PR2 Calibration

A total of 108 volumetric soil water samples and 324 times PR2 readings were used for the calibration. Three different figures were created for the calibration in the study.

In the first figure, the sampling values obtained in all the three of the dry, partly wet and full wet conditions were used (Figure 1). In Figure 2, the values in partially wet and full wet conditions were used. In Figure 3 shows the values regarding the dry and full wet conditions.

In the calibration studies, parameter R^2 is the linear relationship between the direct measurement and indirect measurement methods. It is desirable that the value of R^2 is close to 1. As seen in Figure 1, the R^2 value is 0.8625. In Figure 2, it can be seen that R^2 is 0.7947.

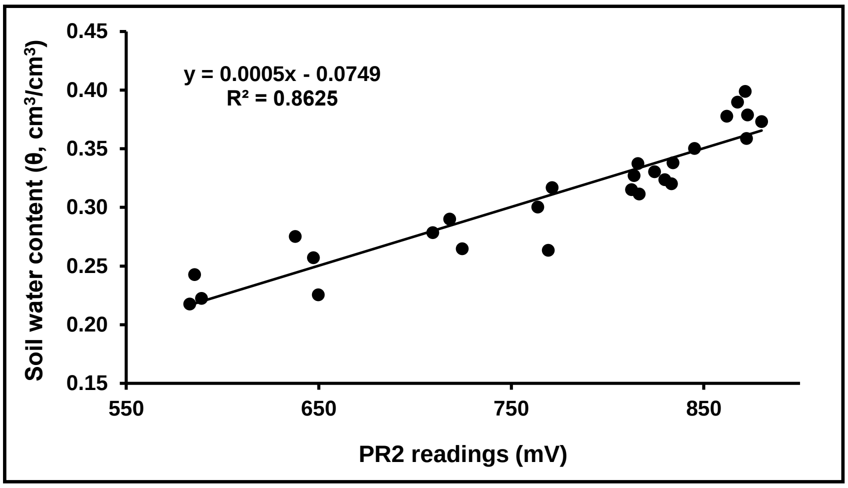

Figure 1. Profile Probe Type PR2 calibration curve in dry, partially wet and fully wet soil conditions.

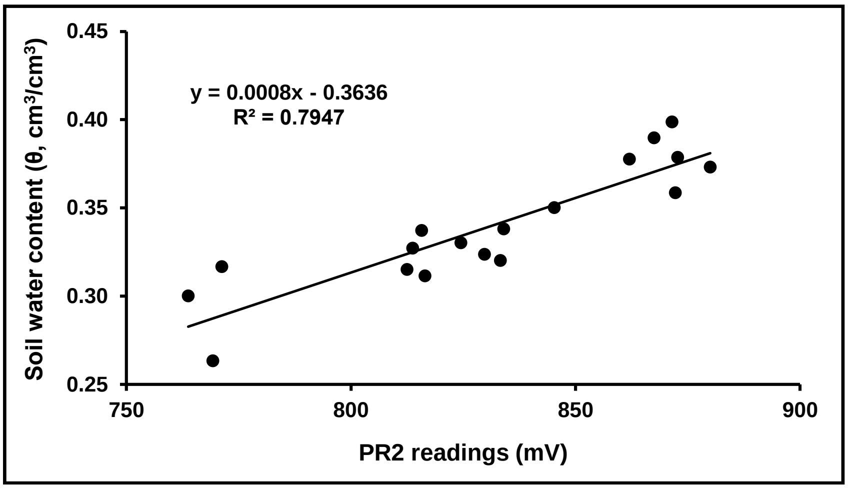

Figure 2. Profile Probe Type PR2 calibration curve in partially wet and fully wet soil conditions.

In Figure 3, the R^2 value is calculated as 0.9305. In these figures, the curve that best represents the PR2 reading with volumetric soil water is shown in Figure 3. For this reason, the PR2 readings were converted to volumetric water content using the calibration equation obtained from Figure 3. A figure of volumetric soil water and PR2 readings converted to volumetric water content can be seen in Figure 4.

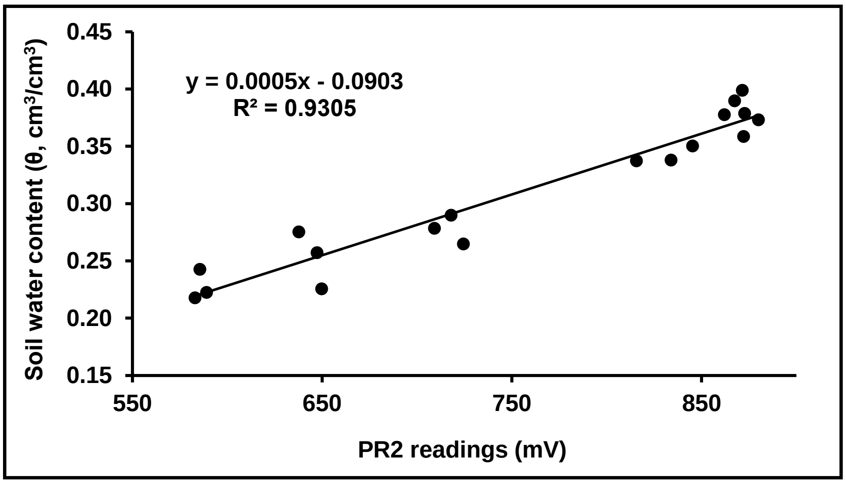

Figure 3. Profile Probe Type PR2 calibration curve in dry and fully wet soil conditions.

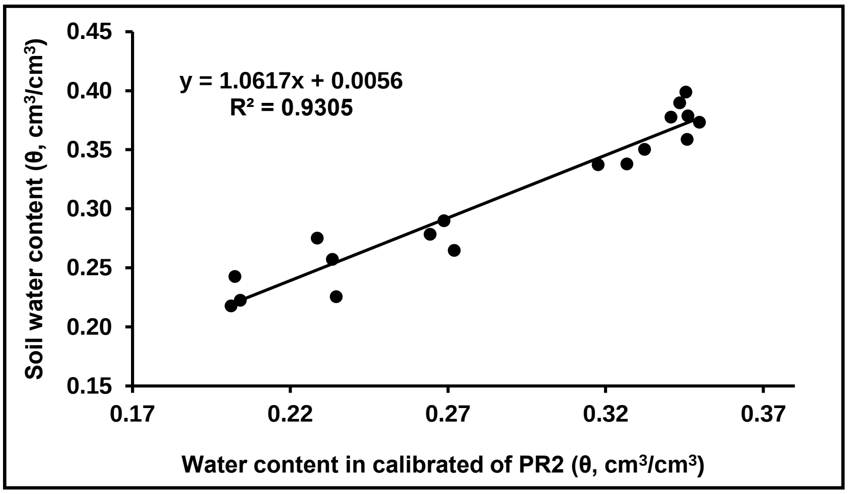

Figure 4. The relationship between calibrated volumetric water content of the Profile Probe Type PR2 reading and gravimetric water content.

3.2. Performance Evaluation of PR2 in soil water content

The change in soil water content during the season is given in Figure 5 and Figure 6. Figure 5 shows the variation of seasonal soil water content under T1 and T2. The amount of the irrigation water was about 25% less than that of T1. In the figure, it can be seen that the water content under the T2 treatment was less than the T1 treatment. This situation has come true as expected. As would be expected, the T1-rated soil water content had the highest values and the field capacity was close. In the case of a 50% deficit (T3) from the irrigation water (T1), the water content was clearly less than that of T1 (Figure 6). This shows that the research treatments discussed at the same time in this study were well planned and implemented correctly (Figure 5, Figure 6). In addition, Profile Probe Type PR2 reveals relatively accurate results for the soil water content measurement sensor.

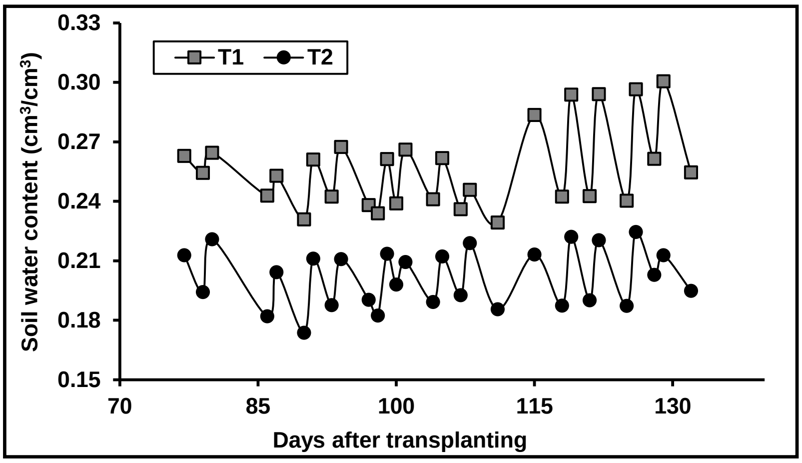

Figure 5. Seasonal variation of soil water content under T1 treatment and T2 treatment.

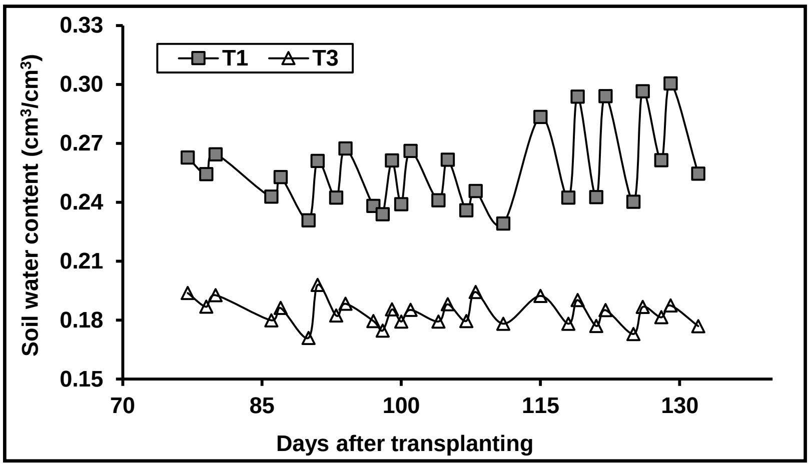

Figure 6. Seasonal variation of soil water content under T1 treatment and T3 treatment.

4. Discussion and Conclusion

Numerous studies have been conducted regarding the indirect measurement methods for measuring soil water content (eg, Tülün, 2005, Evett et al., 2006, Köksal et al., 2011, Kirnak and Akpinar, 2016).

The methods discussed in these studies have been somewhat different from one another depending on soil characteristics and other factors. Two of the most commonly used indirect measurement methods are neutron probe and Time Domain Reflectometry (TDR) methods in soil water content measurement studies.

One of the most important parameters showing the linear relationship between the direct measurement method (volumetric soil water content) and other indirect measurement methods is the R^2 value in the studies regarding calibration. For example, in a calibration study of the neutron probe, the R^2 value was found to be 0.58 for 15-165 cm soil profile depth (Soil Physics Laboratory, 1997). Another study of neutron probes showed that the calibration curve R^2 for 30 cm of different layers varied between 0.95 and 98 (Can and Kukul Kurttaş, 2009). In another study conducted by Köksal et al (2011), R^2 value; 0.86 for 0-30 cm soil depth, 0.82 for 30-60 cm soil depth, 0.81 for 60-90 cm soil depth and 0.92 for 90-120 cm soil depth. In the same study, it was found that the value of R^2 was very low (0.56) throughout the entire soil profile (0-120 cm soil depth) (Köksal et al., 2011).

Numerous studies have also been conducted on the indirect measurement of soil water content by TDR. For example, in the TDR calibration conducted by Kirnak and Akpinar (2016), the R^2 value was calculated as 0.80. Tülün (2005) found that the R^2 value varied between 0.8583 and 0.9986 in TDR calibration studies performed on different soil structures. In this study, R^2 values; 0.9716 for silty clay, 0.9797 for silty clay, 0.9986 for sand, 0.9344 for sandy clay, 0.9782 for clay, 0.8583 for clay and 0.9941 for clay.

In our study, the R^2 values for Profile Probe Type PR2 ranged from 0.7947 to 0.9305 (Figure 1, Figure 2, Figure 3). The values obtained from our Profile Probe Type PR2 study were in general parallel to the results of some neutron probe and TDR studies. However, Evett et al. (2006) report that Delta T PR1/6 was sensitive to temperature fluctuations. Evett et al. (2006) conducted a very detailed calibration study on EnviroSCAN, Diviner 2000, Delta-T PR1/6 and Trime T3 under laboratory conditions.

Our work is a more general and detailed work because our aim in this study was to measure the soil water content relative to the Profile Probe Type PR2. This situation, in fact, meets our needs. On the other hand, we think that it is necessary to study a more detailed calibration of the Profile Probe Type PR2, which takes into account the other factors such as temperature, salinity and so on.

In the study, it was determined that R^2 values for Profile Probe Type PR2 calibration varied from 0.7947 to 0.9305. These values were generally parallel to some other research results on neutron probe and TDR. On the other hand, we aimed to determine the use of the Profile Probe Type PR2 only when the soil water content was measured relatively in this study. For this aim, we think that we have achieved the goal because the results show that Profile Probe Type PR2 can measure soil water content relatively. In addition, we recommend taking into consideration the other factors such as temperature, salinity, etc. in a detailed calibration study of Profile Probe Type PR2. The water content in the root zone of the plant was highest in T1. In other parcels, soil water content was lower than T1. The lowest soil water content in the root zone of the plant was measured in terms of T3. The area with the highest water content was found to be in T1. The decrease in the content of soil water in the root zone of the plant can be seen due to the decrease in the amount of irrigation water.

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