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SOIL MOISTURE DYNAMICS AND EVAPOTRANSPIRATION WATER CONSUMPTION IN SPRING MAIZE

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Abstract

In the present study the dynamics of soil reservoir and evapotranspiration in dry farmland were thoroughly analyzed based on the long-term positioning test and investigation of soil moisture dynamic changes of spring maize. It was found that the vertical distribution curve of annual average soil water content in spring maize field was "single peak and single valley" type. Compared with wet (high water) years, the regulation depth of soil reservoir in the field during the growth period of Spring Maize in dry years moved up and becomes shallow; The soil moisture of Spring Maize in dry (low water) years was more stable than that in wet years. Under the two precipitation years, the "water level" of soil reservoir showed the characteristics of first rising, then falling, and then rising patterns. This study clarified the water source of evapotranspiration water consumption during the growth period of spring maize, evaluated the water balance of farmland ecosystem, and a preliminary understanding of the formation and restoration process of soil dry layer, which provided data support and theoretical basis for improving the practice of existing knowledge of production practice and sustainable development of dry farming.

Introduction

Loess soil is loose and porous. It is the main place for storing natural rain water in this ecosystem, which meets the water demand of crop growth, and is very similar to the water storage function of surface reservoirs (Hessel *et al.* 2003): storing rain water for long-term preservation, regulating flood and drought, and continuously supplying water to plants (Zhu 2000, Li 1983a). The dynamics of soil reservoir includes the changes of soil water content, active layer and soil water storage, which reflect the infiltration regulation of water to soil reservoir to water and the dynamic changes of its filling and discharging process (Li 1983a, Li 1983b). The soil water cycle in the Loess Plateau is a relatively simple upward process of precipitation, infiltration and evaporation. Because the groundwater is buried deep and the Loess layer is also deep, rain water is stored in the soil, and finally reach to the deep water storage in the soil to cope with drought climate, but this soil reservoir effect is not exactly the same in the Loess Plateau, and it shows obvious regional differentiation due to the influence of precipitation and soil characteristics (Zhu 2006).

The drought caused by in sufficient rain and uneven inter annual and intra annual distribution on crop production in the semi-arid Loess Plateau has been alleviated and improved due to the regulation of soil reservoirs (Zhu 2006). Therefore, the research on the dynamics of dry land agricultural soil reservoirs in the Loess Plateau has gradually become a interesting field in the academic community. Zhang *et al.* (1990) found that there are great differences in the dynamics of soil reservoirs in different hydrological years, in which the change of soil moisture in normal

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water years is more active than those in dry and wet years. Deng *et al.* (2011) analyzed the dynamic recharge process of the soil reservoir and found that the water consumption in the seedling stage is mainly recharged by the shallow and middle soil, and the water consumption in the reproductive growth stage is mainly recharged by the middle and deep soil. The soil layer tends to deepen towards the later stage of growth. The soil water storage in different depths plays an important role, but the shallow and middle layer plays a prominent role.

Soil reservoir is an important indicator of the sustainability of regional water resources and the basis for the development of land use management strategies, especially in areas with soil water deficit (Zhao *et al.* 2017). Understanding the characteristics and dynamic laws of soil reservoir is a necessary basis for formulating scientific planting measures (Li 1982). The study of soil reservoir dynamics in the plateau area based on water balance is the main work of soil water availability evaluation in the study area, which can provide theoretical methods and data support for the rational development and utilization of arid agricultural water resources and the comprehensive study of eco hydrology in the semi-arid Loess Plateau area (Li *et al.* 2013).

Materials and Methods

The test area is located at the Qinling field monitoring center station in Shangwang village, Tangyu Town, Mei County, Baoji City, Shaanxi Province, China. The test area is located at east longitude 107°39′-108°00′ and north latitude 33°59′-34°19′. It is located in the west of Guanzhong plain, Shaanxi Province, adjacent to the Qinling Mountains in the South and the Weihe River in the north. It belongs to the Chuanyuan gully area in the middle reaches of the Yellow River. One ha corn field was selected as the farmland test sample, and the farming method was continuous cropping, which was a rain fed farmland; Field management is a traditional farming method, that is, ploughing before sowing, fertilizing once before sowing, and topdressing once after sowing; No irrigation measures has undertaken.

The precipitation (mm) during the study period is continuously monitored to the automatic weather station near the test sample site, and recorded once every 1 hr. The sum of the data recorded in the day is the daily precipitation. At the same time, in order to ensure the continuity of precipitation data, rain measuring cylinders were arranged in the test sample plot, and the precipitation and the start and end time of precipitation were recorded within 30 minutes after the end of a single precipitation event. In the present study, the middle-type precipitation less than 540.0 mm was taken at a dry year, and more than 628.0 mm was takend at a wet year, between which is a normal year (, Zhang *et al.* 2008, Chen *et al.* 2009, Wang *et al.* 2016).

The moisture measurement depth of the experimental farmland is 600 cm. Every 10 cm of 0 ~ 100 cm was taken at a layer, and 20 cm below 100 cm was taken at a layer. During the test, the neutron meter was used to measure the soil volume water content on the 15th and 30th day of each month. If the original sampling date meets continuous rainy days, it was appropriately delayed. The monitoring period was from September 15, 2018 to December 16, 2021. Formulas 1 and 2 were used to calculate the soil water storage, which is expressed by the depth of the water layer (mm). The calculation formula of soil water storage change is:

$$D_w = \Sigma\theta_i \bullet h_i \bullet 10^{-1} \qquad (1)$$

$$\Delta S = D_{w2} - D_{w1} \qquad (2)$$

where, D_w is the depth of water layer (mm); D_{w1} is the depth of water layer in the previous period (mm); D_{w2} is the depth of water layer in the later period (mm); h_i is the thickness of a soil layer (cm); θ_i is the volume water content of a soil layer (%).

The variation coefficient is used to characterize the variation degree of soil water content, and the calculation formula of variation coefficient is:

$$CV = s/m \quad (3)$$

where, s is the standard deviation of soil water content; m is the average value of soil water content.

In this study, a complete growth season was artificially determined, including the pre sowing leisure period and growth period of corn, and based on this, the crop growth season was divided and the phases of precipitation and precipitation year were calculated. Use Microsoft Excel 2010, Origin 8.0, ArcGis10.4.1 software were used to analyze the data statistically and the test data were charted.

Results and Discussion

The study period is three complete growth seasons of spring maize. In the first season (2019), which was a dry year, the precipitation for spring corn (477.4mm) did not meet the standard of normal wet year (540.0 mm). In the second season (2020), which was a wet year the precipitation for spring corn (638.2 mm) reached the standard of wet year (> 628.0 mm). In the third season (2021), which was a dry year the precipitation for spring corn (516.2 mm) did not meet the standard of normal water year (540.0 mm).

Table 1. Precipitation and yearly precipitation patterns in different growing seasons.

Growing season	precipitation(mm)	Precipitation year pattern
The first season	477.4	Dry year
The second season	638.2	Wet year
The third season	516.2	Dry year

Comparing the vertical distribution curve of annual average soil water content in the field during the growth period of Spring Maize in three seasons (Figure. 1), it can be seen that for the whole profile, the field soil water content in the second season was at the highest level, followed by the third season and the lowest in the first season, which is closely related to the precipitation year type. Compared to the dry year, the field soil water cycle in the wet year is maintained at a higher level, which can explain that after the dry year of spring maize. In wet years, the soil moisture in the field can be restored. The vertical distribution curve of annual average soil water content during the growth period of the three seasons of spring maize is in the shape of “single peak and single valley”, with the peak point at the layer of 10 ~ 20 cm and the valley point at about 50 cm; On the whole, the soil water content in the profile was lower in the 0 ~ 50 cm soil layer and higher in the 50 ~ 600 cm soil layer. In addition, the curve intersects at about 70 ~ 100 cm, and then there is no common intersection, indicating that the soil water content of this layer is relatively stable all year round. It can be inferred that this special layer is the result of the balance between precipitation, infiltration and soil evaporation, root water absorption.

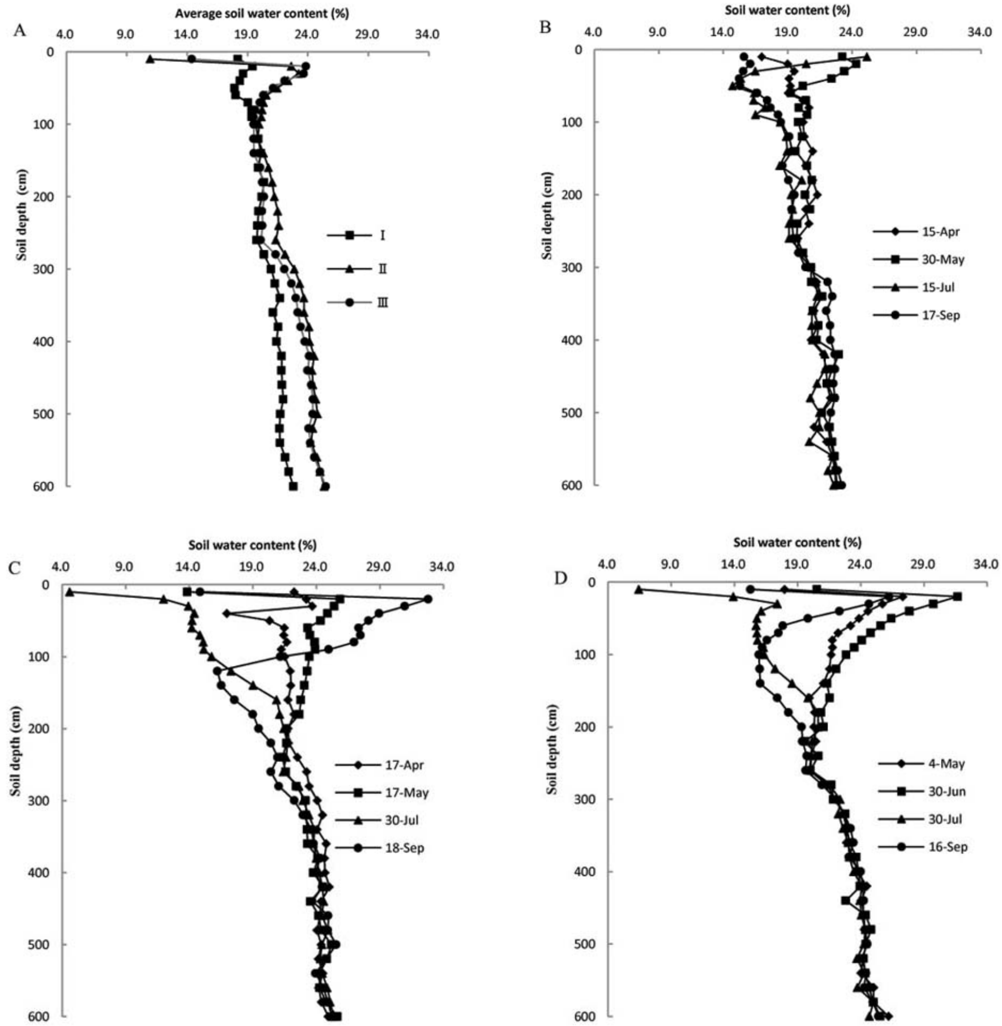

Fig. 1. Dynamics of soil moisture for different soil layers in spring corn field under different yearly precipitation patterns. A: Variation of average water content with depth in different growth seasons; B: Water content changes with depth at different times in the first season; C: Water content changes with depth at different times in the second season; D: Water content changes with depth at different times in the third season; I: The first season; II: The second season; III: The third season. The same below.

As shown in Fig. 1, the main regulation depth of the soil reservoir during the growth period of spring corn in the first season is 0 ~ 260 cm, 0 ~ 340 cm in the second season, and 0 ~ 260 cm in the third season, indicating that the main regulation depth of the soil reservoir is in dynamic change (Fig. 1). Compared with the wet years, the regulation ability of the soil reservoir to atmospheric drought in the dry years is reduced, which is manifested by the upward movement and shallowness of the main regulation depth. In addition, the soil water content of 0 ~ 300 cm soil layer changes greatly and varies significantly with different precipitation year types. The soil water content of 300 ~ 600 cm soil layer increases with the deepening of the soil layer, and the soil water content of this layer basically remains unchanged during the growth period of spring corn.

Fully grasping the variation characteristics of soil moisture in the vertical direction is helpful to understand the regulation function of soil moisture on the growth and development of surface plants and the link between surface water and groundwater (Wang *et al.* 2012). Figure 2 showed that the coefficient of variation of soil moisture in the field during the growth period of spring maize decreases in the 0 ~ 600 cm soil layer. Spring corn roots are mainly distributed in 0 ~ 100 cm. As the growth season of spring corn coincides with the rainy season, rain water is constantly consumed by crops. The annual rainfall infiltration depth in this area is mostly above and below 100 cm. The 70 ~ 100 cm soil layer is both the main water absorption layer of roots and the infiltration critical layer of rain water. Due to action of various factors, it may maintain the stability of water content. It is preliminarily verified that this special layer is the result of the balance between precipitation infiltration, soil evaporation and root water absorption. The specific mechanism needs to be further verified.

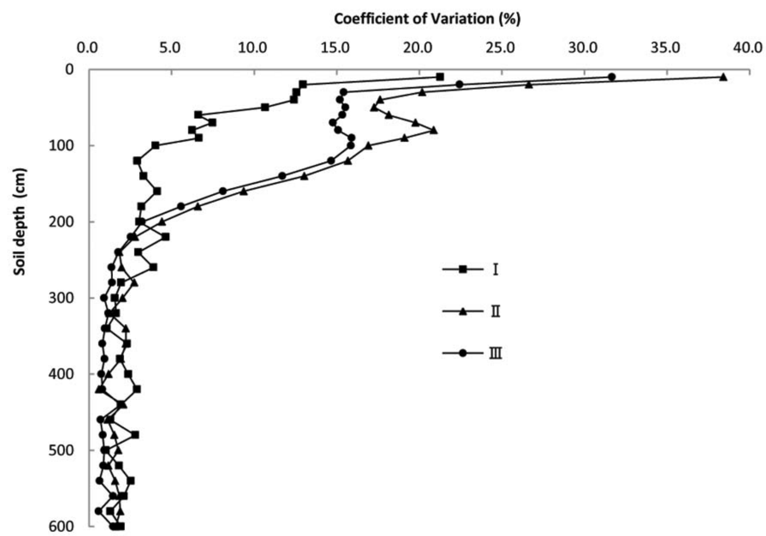

Fig. 2. Changes of soil water content for different soil layers in spring corn field. . A: Variation of average water content with depth in different growth seasons；B: Water content changes with depth at different times in the first season; C: Water content changes with depth at different times in the second season; D: Water content changes with depth at different times in the third season; I: The first season; II: The second season; III: The third season. The same below.

During the growth period of spring maize, the vertical distribution of soil moisture in the field has obvious hierarchical differences. The soil moisture in 0 ~ 140 cm soil layer changes rapidly, and the coefficient of variation of most sample points is greater than 10.0%, which belongs to medium variation; The change of soil moisture in 140 ~ 600 cm soil layer is not significant as a whole, and the coefficient of variation of the study sample points is less than 10.0%, which belongs to weak variation. The results showed that the precipitation year type had a significant effect on the vertical stratification of soil water. The active layer and sub active layer of soil water in the field during the growth period of Spring Maize in wet years moved downward and remain stable in dry years; For each soil layer of 0 ~ 200 cm, the coefficient of variation of field soil moisture in the growth period of Spring Maize in the second season is the largest, followed by the third season, and the first season is the smallest, indicating that the field soil moisture in the growth period of Spring Maize in dry years is more stable than that in wet years.

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