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Research Article

Use limitation on soil water resource by red plum apricot

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Abstract

Since 1995, the yield, benefits, and plantation area of red plum apricot have increased dramatically. But as red plum apricot trees' canopy and roots grew, soil drying appeared and sometimes become severe in a wet year. The severe soil drying influence the yield, quality and benefits of red plum apricot because precipitation is small and with a big season change. At this time, the plant-water relationship has to be regulated on Soil Water Resource Use Limitation by Plant and Soil Moisture Vegetation Carrying Capacity. However, there are few studies on the utilization limit of soil water resources by red plum apricot forest land. In this study, daily precipitation, and soil water suctions at different soil water content are measured, and the maximal infiltration depth and the soil water resource use limitation by red plum apricot were estimated. The results show that wilting coefficient varies with soil depth from 7.98 in surface soil to 7.1% in 240 cm soil depth, the maximal infiltration depth is 290 cm and the Use Limit of Soil Water Resources by red plum apricot is 212.7 mm. When the soil water resource in the maximal infiltration depth is lower than the limit, the regulation of the plant-water relationship must be considered.

Introduction

Soil water limits the ecological situation where plant roots grow, especially in water-limited regions where climate and soil characteristics set the limits of available water for plant growth. Soil water equilibrium plays a vital role in restoration rehabilitation. Therefore, soil water management is very important in agricultural systems [1].

In recent years, agricultural production activity has been strengthened to meet the food need of an increasing population worldwide, and the intensification of agricultural activity coexisted with negative environmental influence [2]. As the population increase in the water-limited regions, such as in the semiarid loess hilly region of the Loess plateau, People need a lot of food, fruit, fiber, and so on, but primitive plants cannot meet their needs. So, most of the primitive vegetation has been destroyed and changed into farmland. As a result, forest and vegetation is scarce, and the loss of soil and water in the Loess Plateau had become a serious environmental problem by 1949. Loss of soil and water eroded fertile surface soil and led to soil fertility and crop productivity reduced, which influence the quality of human life. In order to conserve soil and water loss, relieve destruction caused by sandstorms and haze weather, increase crop productivity, and the improvement of ecological environment, the government has been taking many measures since 1950. In particular, with the implementation of the Three-North Shelter Forest Program sponsored in 1978 for 50 years, large-scale afforestation and fruit trees have been carried out on the Loess Plateau. As a result of these efforts,

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great achievements have been made. The forest coverage fast increased and annual sediment discharge on the Loess plateau has been reduced from 1.6 billion tons in the 1970s to 0.31 billion tons in recent years, and the runoff has been halved.

Because the soil in this region is very deep and in the range of 30–80 m from the surface [3] and the groundwater table is also deep [4] and without irrigation, soil water mainly comes from some precipitation penetrating through the canopy. Along with the canopy and the development of the root, the interception by canopies increases and the roots of these plants grow quickly and thus take up water from considerable soil depths, which reduces the soil water supply and increases soil water consumption. Consequently, the combination of increased water use by plants and interception and low infiltration capacity, and soil water recharge rates has led to serious soil drying with time going by [5]. The dried soil layers (DSL) appeared and then its thickness of DSL increased, and soil drying was widespread [6,7]. Serious drying of soil eventually and poor self-regulation of plant result in soil degradation, vegetation decline, and agriculture failure, which have adverse effects on the sustainable use of soil water resources and the stability of forest vegetation ecosystems [8]. Thus we should take effective measures to regulate the nonequilibrium relationship between soil water and plant growth by reducing the population quantity or density of indicator plants in a plant community on Soil Water Carrying Capacity for Vegetation (SWCCV) on the Loess Plateau to balance the soil water recharge and soil water consumption in plantation [9,10] because the soil in this region ranges from 30 m to 80 m from the surface [3], and the groundwater table is also deep [4], without irrigation.

The concept of soil water resources come in 1985 [11] after Lvovich proposed the concept of overall soil moistening in 1980. Soil water resources have different meanings in different fields, such as Geology, Soil Science, Agriculture, Forestry, and Animal Husbandry. In order to meet the need of different specialties, soil water resources can be classified into static soil water resources and dynamic soil water resources. Static soil water resources include generalized and narrow soil water resources. Generalized soil water resources refer to the water storage in the soil from the surface soil to the water table, narrow soil water resources refer to the water storage in the root zone soil, and dynamic soil water resources refer to the antecedent soil storage plus the soil water supply from precipitation in the growing season for deciduous plant or a year for evergreen plants. Soil water resources are renewable water resources, a component of water resources [12].

The state of the vertical distribution of soil water in the root-soil zone space influence plant growth. Since drought is a recurring natural phenomenon, and the soil in which plant root distribute resembles a reservoir and have the storage capacity of water, which have the buffering effect of soil drying on plant growth, the effects of water stress on plant growth vary with the gravity in these regions. Soil Water Resources Use Limit by Plants is the soil water storage in The Maximum Infiltration Depth (MID) when the soil water content in all of the soil layers of the MID equals wilting coefficient [12-14]. We do not regulate the relationship as soil drought happens until the soil water resources reduce to a degree (Soil Water Resources Use Limit by Plant) because when soil water resources in the maximum infiltration depth equal Soil Water Resources Use Limit by Plant, soil water seriously influence plant growth if the duration dry climate continue to surpass the key period of regulating the relationship between soil moisture and plant growth because the plant has some self-regulation power.

The red plum apricot is a deciduous fruit tree and the best cash forest in semiarid loess hilly regions. Since having been selected as good varieties to popularize in 1995, the distribution area of red plum apricot spreads from Guyuan county to the whole of Ningxia, and then to Gansu province and so on in most of the water-limited regions, China, the yield, benefits, and planting area of red plum apricot increase doubly. But along with the growth of red plum apricot and precipitation, sometimes soil drying become severer. Once serious drying happens, which led to the change of red plum apricot tree leaf color from green to yellow or croci and drops earlier of the leaf. If serious drying happens in the fruit expansion stage, the size of red plum apricot fruit cannot be expanded to normal size, which influences the yield, quality, and economic benefits of the red plum apricot forest. At this time, the relationship between the soil water and red plum apricot growth must be regulated on Soil Water Resources Use Limit by Plant and Soil Water Carrying Capacity for Vegetation [12,15] to reduce or evade the bad influence of soil drought on the yield and benefits of red plum apricot. However, there are few studies on the Use Limit of Soil Water by red plum apricot.

In the present work, the study aims at achieving these objectives: (1) the changes of cumulative infiltration depths with time and the maximum cumulative infiltration depth in the red plum apricot forest; (2) the Change of wilting coefficient with soil depth up to maximum infiltration depth and (3) Use Limit of soil Water by red plum apricot.

Methods

Site description

This study was conducted at the National high-quality red plum apricot demonstration area, which is located at the Shanghuang Eco-experiment Station in the semiarid Loess hilly region (35°59′- 36°02′ N, 106°26′- 106°30′ E) in Guyuan, Ningxia Hui Autonomous Region of China, Institute of Soil and Water Conservation of Chinese Academy of Sciences, with the altitude of the station ranges from 1,534 m to 1,824 m. Precipitation here is absent in the periods from January to March and from October to December, and the rainfall from June to September makes up more than 70% of the annual precipitation. The mean rainfall measured between 1983 and 2001 was 415.6 mm with a maximum of 635 mm in 1984 and a minimum of 260 mm in 1991. The frost-free season is 152 days. The Hungarian soil having developed directly from the loess parent materials consists mainly of loamy porous loess (Calcaric Cambisol, FAO1988) with wide distribution in the semiarid hilly region of the Loess Plateau. The red plum apricot tree is a kind of fine variety apricot (*Armeniaca vulgaris* Lam.). The experiment was conducted in a 23-year-old red plum apricot garden planted in 1996 and a 1-year-old red plum apricot garden planted in 2018.

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Generally, some two-year-old red plum and apricot trees begin to bear fruit. 3 -year-old red plum apricot trees have some yield and the yield of 4 -year-old red plum apricot trees has reached a certain level after planting the red plum apricot tree. An adult red plum apricot trees start to bloom at the end of March and are in full bloom in the first ten-day period of April, red plum apricot fruit is in the expansion period of fruit from the second ten-day period of May to the second ten-day period of June, and fruit mature between the first 10 days and the second 10 days of July and leaf drop in the middle and last ten-day period of September. Once serious drying happens in the Fruit expansion stage, the leaves of a Red Plum apricot tree change color from green to yellow or croci and drop earlier. The size of red plum apricot fruit is smaller than normal fruit, which influences the yield, quality, and economic benefits of red plum apricot.

Observation items and determination methods

Rainfall at the study site was measured with standard rain gauges placed in the center of the National Quality red plum apricot Demonstration Zone, which was about 50m from the Shanghuang Eco-experiment weather station, as a part of the Guyuan Eco-experiment weather station under the Institute of soil and water conservation of Chinese Academy of Sciences. The study also included the determination of the soil moisture content, plant root distributions, and other plant growth parameters.

The experimental plots were located in the 23-year-old red plum apricot forest planted on the bench terrace in 1996 and the 1-year-old red plum apricot forest planted on the bench terrace in 2018. The sampling pits (soil profile) were dug in the red plum apricot forest at the experimental site for investigating soil profile and sampling purposes, whose dimensions were 1m^2 × 4 m depth on the red plum apricot forest on April 13, 2018. The undisturbed soil samples were collected 3 times at the depth of 0 to 5, 20 to 25, 40 to 45, 80 to 85, 120 to 125, 160 to 165, 200 to 205, 240 to 245 and 395 cm to 400 cm with cutting rings (a 5 cm in high, 5 cm in inner diameter and 100 cm^3 in cubage). At the same time the disturbed soil of about 100g at each depth was collected for the determination of soil structure at the State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau.

A cutting ring was used to measure the bulk density, total porosity, capillary porosity, and saturation moisture content. The core samples (undisturbed soil sample) collected were used with cutting rings to measure the soil bulk density, capillary porosity, and noncapillary porosity. The bulk density was determined by oven-drying the cores at 105ºC-110ºC and the total porosity was calculated as 1-bulk density/soil particles density, assuming that the density of soil particles was 2.65g/cm^3. Noncapillary porosity was the difference between total porosity and capillary porosity. Soil particles were measured with a master sizer 2000 laser particle analyzer and grain size was graded on the USA standard. Soil water contents at different soil suction (0.1, 0.2, 0.4, 0.6, 0.8, 1.0, 2.0, 4.0, 6.0 bar, 1 bar = 1.0×10^5 Pa) were measured by a HITACHI centrifuge, made by Instrument Co., Japan. Because Huangmian soil had been contracted when measuring with a centrifuge, the researchers measured the shrinking amount of soil samples in the cutting ring by vernier calipers at different soil suctions and then calculated the volumetric soil water content.

Select a 1-year-old and 23-year-old red plum apricot tree with average height and canopy as the sample of the study. Two holes 5.3 cm in diameter were made by a hole saw in the place about 40cm apart from the 1-year-old red plum apricot trees, and two 4-m long aluminum access pipes were placed in the holes with an interval of 1 m between them. Another two holes 5.3 cm in diameter were made by the hole saw in the middle of the radius of the red plum apricot tree canopy, about 2 m away from the tree base (center) to the exterior margin of the canopy in the 23-year-old red plum apricot trees planted in the bench terrace in 1996. The interspaces between access pipes and soil were filled with some fine earth in case water might flow through the interspaces. A neutron probe, CNC503A (DR), made by Beijing Nuclear Instrument Co., China, was used for long-term monitoring of the field soil water content because of its high precision in situ [7,16,17]. Before measuring the Volumetric Soil Water Content (VSWC), the neutron probe was calibrated for the soil in the study area by using standard methods [18]. The calibration equation for this soil at the site is $y = 55.76\ x + 1.89$, where y is VSWC and x is the ratio of the neutron count in the soil to the standard count. The measuring depth ranged from 0 to 400 cm in the period from April to October 2018. Measurements were made with 15-day intervals in time and 20 cm intervals in depth. Measurements were made every 15 days to a depth of 4 m in increments of 20 cm starting at the 5 cm depth. When measuring soil water content at different soil depths, first put the probe into the aluminum access pipes and change the measuring line of the neutron probe to confirm whether or not the soil depth equals the planned depth of determination according to the display device of soil depth. Second press the start button and then read and record the numbers of soil water content at different soil depths on the display screen of the neutron probe. The soil water content obtained for each measuring depth was taken to be representative of the soil layer that included the measuring point ± 10 cm depth, apart from that for the 5 cm depth, which was taken to represent the 0 to 10 cm soil. The measurements were also made before and after each rain event in the red plum apricot forest.

Height, diameter at the base and size of the canopy of the 1-year-old red plum apricot tree growing on the plots were investigated and measured and estimate the maximal infiltration depth and Soil Water Resources Use Limit by Plant. the relationship between the color of a leaf or the size of fruit and the soil water was investigated and estimate the suitable amount of leaf and even when the soil water resources in the maximal infiltration depth is an approach to or smaller than Soil Water Resources Use Limit by Plant in the 23-year-old red plum apricot tree. The measurements of red plum apricot tree growth were carried out in the time period from mid-April to October, and the measurements of precipitation and soil water were carried out from January to December 2018 to 2020.

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Mathematical model

Depth of infiltration and maximal infiltration depth: Two curves method was found by Guo in 2004 [9] and used to estimate the depth of infiltration by Guo and Shao in 2009 [19] and Guo in 2014 [12], and named by Guo in 2020 [14]. In this study, two curves method was used to estimate the depth of infiltration and soil water supply for a rain event or some days and a series of two curves methods for users to estimate the depth of infiltration for a long time infiltration process, such as the time period from mid-April to October in 2018.

When estimating the depth of infiltration and soil water supply for a rain event or some days, first put the probe into the aluminum access pipes and change the length of the measuring line connected with the neutron probe sensor to the measuring soil depth according to the display device of soil depth in the neutron probe and measure and record soil water content at different soil depth and then draw the change of soil water content with soil depth before a rain event and after the rain event (two continuous soil water distribution curves or a series of soil water distribution curves of soil water with soil depth at the same aluminum access pipes and there is a cross-location in the coordinate system in the soil profile before a rain event and after the rain event (or an infiltration process). The depth of infiltration during a rain event is equal to the distance from the surface to the joint location between two soil water distribution curves with soil depth. The MID, short for maximal infiltration depth is equal to the distance from the surface to the deepest joint location between two contiguous soil water distribution curves with depth in the soil profile at the beginning and the end of a period [7,19].

The change of wilting coefficient with soil depth: Because Gardner's empirical formula can better describe the relationship between w and S, the wilting coefficient can be estimated by the Gardner empirical formula $w=a\cdot S^{-b}$ [19]. First, the Gardner empirical formula was transformed into $\ln(w)=a\times\ln S+b$, and then used to fit the relationship between soil water suction (S) and volumetric soil water content (w) at different soil depths, and then established the relationship between ln (w) and ln (S) by the least square method, and then estimate the wilting coefficient, which is the volumetric soil water content (w) at 15Mpa.

Soil water resources use limit by plant: The mathematical model for calculating Soil Water Resources Use Limit by Plant (SWRULP) was showing as follows:

$$\mathrm{SWRULP} = \sum_{i=0}^{i=MID} O_w \times D_i$$

Here, SWRULP is the Use Limit of Soil Water by Plant, expressed in mm. MID is maximum infiltration depth. O_w is wilting coefficient at a soil depth of i, i is the number of the soil layers and D is the thickness of the soil at i soil layer

Statistical analysis

With the help of ANOVA coupled with SPSS 13.0 software, an analysis was made concerning the significance of the influence of the planting density on all the parameters measured and the effect of pipe position, planting density, and soil depth on soil water content. A regression analysis was then made to determine the different relationships, such as the relationship between soil water content and moisture suction, and the relationship between the root density and soil depth using the least square method. Data were transformed when necessary to obtain a linear relationship.

Results

Changes of accumulative infiltration depth of red plum apricot over time

Infiltration is a process in which water enters the soil. The water infiltrated into the soil have two functions. One is to increase soil water content in a soil layer, and another is to increase cumulative infiltration depth. The two curves method was used to estimate the depth of infiltration before and after a rain event or an infiltration process or several days. The infiltration depth for a rain event is equal to the distance from the surface to the crossover point between two soil water distribution curves with depth measured in the soil profile before and after a rain event or several days [14]. A lot of the crossover points at the same height in the soil profile make up the wetting peak. The annual precipitation is 536.2 mm, which is 120.6 mm more than the mean precipitation of 415.6 mm and close to the maximum rainfall record of 634.7 mm in the National high-quality red plum apricot demonstration area, see Figure 1. After two effective rain events, 9 mm on May 20 and 19.7 mm on April 13, infiltration depth reaches to 70 cm on April 28, 2018, see Figure 2.

As time goes on, the cumulative infiltration depth increased with time in 2018 because the infiltration includes two stages: rainfall infiltration generally happening during a rain event, and cumulative infiltration [20] or infiltration [21], which occurs in the period between two rain events or a long-term period in which there are more than two rain events happens because there is a cumulative effect on the infiltration process. After a heavy rain event, a high water-bearing soil layer formed under the land surface. With time going by, the soil water content in the high water-bearing soil layer is reduced because

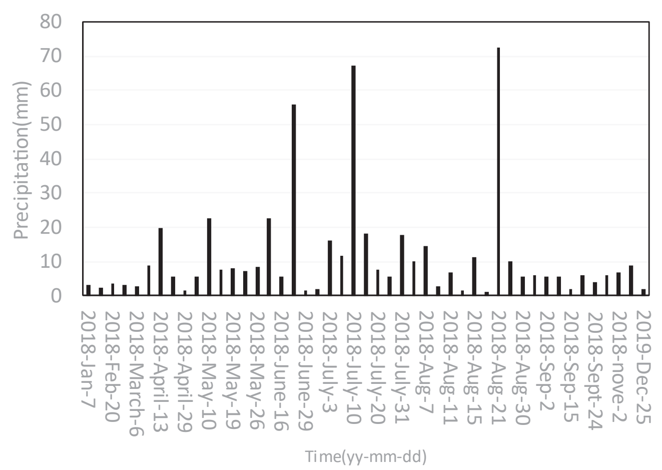

Figure 1: The changes of precipitation with time in the National high quality red plum apricot demonstration area.

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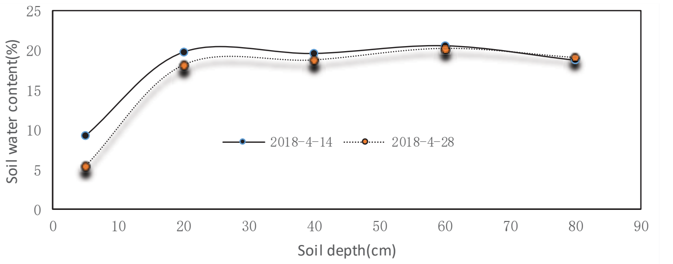

Figure 2: Change of Infiltration depth in red plum apricot plantations with time from 14 to 28 April 2018.

soil evaporates, plant root water absorption, or infiltrates into the deeper soil layer and forms another high water-bearing soil layer at deeper soil layer, and cumulative infiltration depth increases in the soil profile [19]. When the soil water content in the upper layer of the wetting peak is equal to the lower layer of a wetting peak, the cumulative infiltration process stopped because there is no infiltration force, and water potential difference between the upper layer of the wetting peak and the lower layer of wetting peak approaches to zero. At this time, the cumulative infiltration depth is the maximum cumulative infiltration depth [14]. That is to say, the maximum cumulative infiltration depth is the maximum infiltration depth. The cumulative infiltration depth arrives at 130 cm on May 28, up to 150 cm on June 16, get to 190 cm on July, 16, and finally to 290 cm. So, the maximum infiltration depth is 290 cm in the red plum apricot forest, see Figure 3.

The change of wilting coefficient with soil depth

Plants absorb water from the soil which causes soil water content root to reduce. Soil dry becomes severe and soil water stress in the soil layer near the root. At the same time, the water moves slowly from the soil layer nearest the root to the soil layer near the root in the soil matrix driven by gravity and water potential gradients. The wilting coefficient for Huangmian loess soil is the water content at -1.5 MPa in a given soil layer [10]. In the terraced land, 23-year-old red plum apricot tree root develops to a considerable soil depth and suck water in the dry year in a National high-quality red plum apricot demonstration area. Once a soil layer in which soil water content equals or is less than wilting coefficient, the soil layer become dried soil layer, the dried soil layer happened in the soil layer deeper maximum infiltration depth is permanent dried soil layer in which the soil water cannot be recovered. The permanent dried soil layer reduces the soil moisture mobility and blocks up the intercourse between soil water in the soil layer upper and below the permanent dried soil layer. So soil water management should pay attention to soil water in the soil layers from surface soil to maximum cumulative infiltration depth.

Plant root water absorption is a process in which plant roots and soil particles contend for soil moisture. Along with plant growth and root water absorption, soil water content reduces, and soil water stress increase in the soil around the root. When the soil water content in a soil layer reduces to wilting coefficient, the soil water potential in a soil layer surrounding the root reach balance with the water potential in the plant root cell, and the plant cannot absorb the water from the soil layer anymore. This balance point is a wilting coefficient. The relationship between volumetric soil water content, w, and soil water suction, S, is determined as $w = aS^{-b}$, See Figure 4. It can be seen that the volumetric soil water content drops with the increasing soil water suction from 0.01 Ba, $1\text{Ba} = 1\times10^5$ Pa, to 15.0 Ba, such as in the 10 cm soil layer, volumetric soil water content dropping from 38.37% to 7.98% with the increasing soil water suction from 0.01×10^5 Pa to 15.0×10^5 Pa.

Where θ is soil water constant and S is soil water suction. According to the relationship between θ and S, the wilting point at the suction of -15×10^5Pa can be estimated. The determination coefficient, R^2, changes from 0.981 in the 140 cm - 180 cm soil layer to 0.991 in the 0-10 cm and 10 -30 cm soil layers. The change of wilting coefficient with soil depth is shown in Figure 5. It can be seen from Figure 5 that field capacity at the suction

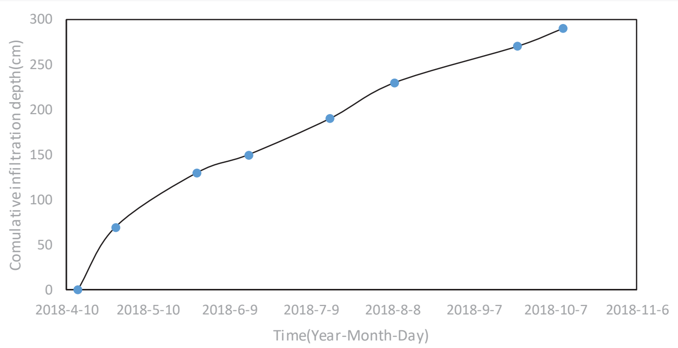

Figure 3: The Change of Cumulative infiltration with time in red plum apricot forest, 2018.

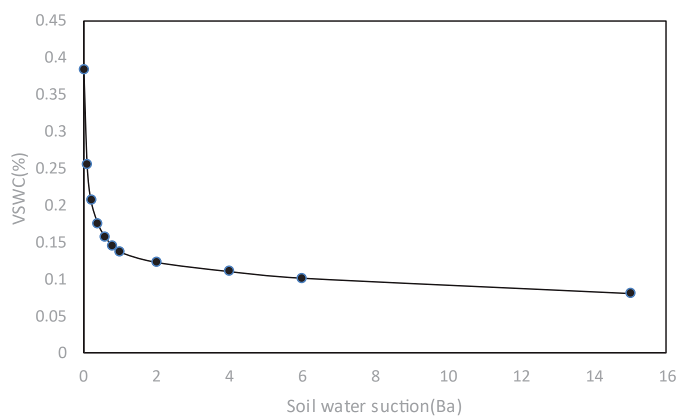

Figure 4: The relationship between Volumetric soil water content (VSWC) and soil water suction(s) in red plum apricot forest.

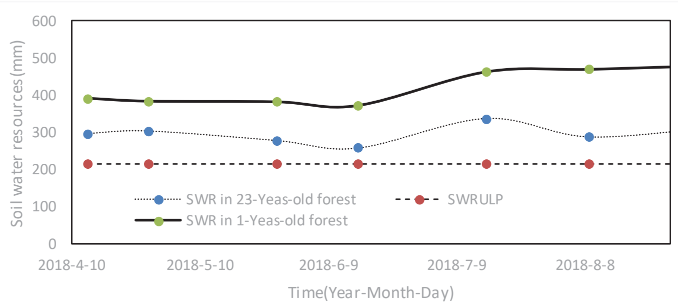

Figure 5: The relationship between Soil Water Resources in the MID and SWRULP in 1-year-old red plum apricot forest and 23-year-old red plum apricot forest.

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of -0.33×10^5 Pa drops from 28.11% in 5 cm to 17.87 % in the 160 cm soil layer and then rises gradually to 21.82% in 400 cm with increasing soil depth. The wilting coefficient at the suction of -15×10^5 Pa drops from 7.98% in 0 cm - 10 cm to 6.68 % in 120 cm.

The use limit of soil water resources by red plum apricot

The state of the vertical distribution of soil water in the root-soil zone space influence plant growth. Soil water stresses influences root growth and root water uptake. If the soil water content in the MID is equal to the wilting point and soil water content in the MID is equal to SWRULP, and there is not enough water supply from precipitation, most red plum apricot changes color leaf from green to yellow or croci and leaves fall earlier than usual time in the growing season. The red plum apricot tree almost ceased growing, and red plum apricot fruit does not expand, which influences the yield, quality and economic benefits of red plum apricot fruit even if the roots extended to a depth of more than MID and could absorb some water from the soil layers more than 290 cm deep, suggesting that the total amount water that red plum apricot roots absorbed from the soil per unit time do not satisfy the need of plant transpiration and fruit development in the semiarid loess hilly region.

SWRULP is the limit of plants in using soil water resources. It can be defined as the soil water storage in the MID when all of the soil layers in the MID become DSLs. The soil depth, representative soil layer, and Wilting coefficient see Table 1, and the SWRLP in red plum apricot is 212.7mm, which is different from 252.8 in caragana shrubland at the middle and the top of the Heici Mountain and 220.8 mm in alfafa grass, showed that the SWRULP changed with site and vegetation type.

The control of soil drought and the use limit of soil water resources by red plum apricot

As the air temperature increase in the spring, a red plum apricot tree planted in the spring begins to bloom on the last teen-day of March and the first teen-day of April. Because of low temperatures and frost, all flowers of the red plum apricot tree froze to death on the morning of April 7. The red plum apricot tree germinates on April 30 and then spread and grows. Because some water irrigation and the precipitation in 2018 is 536.2, is 120.6 mm higher than the average of 415.6 mm, see Figure 1 and the volumetric water content in the 0 to 290cm soil profile is more than the wilting point, see Figure 5 and soil water resources in the MID is more than the soil water resources use limit by plant, the red plum apricot tree grow well. Up to June 16, new men grow up to 45 cm. By the end of the growing season in October, the width of a 1-year-old tree crown reached the range from 100 to 120 with an average of 110 cm in width, and the length of a 1-year-old tree crown reached the range from 120 cm to 140 cm with average 130 cm, 1-years-old red plum apricot tree grows well, which lay the foundation for the next years blooming and fruiting.

The 23-year-old red plum apricot tree starts to bloom at the end of March and the flowers are in full bloom in the first ten-day period of April. The fruit is in the expansion period from the second ten-day period of May to the second ten-day period of June and matures the in the first ten-day period of July. Unfortunately, all of the flowers wilt and die because of serious cool temperatures and frost on April 7, 2018. The 23-years-old red plum apricot tree begins to spread leaf on April 30, and true leaf develops up to June 16 and grows well, leaf drop at the end of September because of some water irrigation and the precipitation is high, the volumetric water content in the 0 to 290cm soil profile is more than the wilting point, and soil water resources in the MID is more than the soil water resources use limit by plant. The 24-years-old red plum apricot tree grow well and red plum apricot mature because the soil water resource in the 0 cm to 290 cm soil layer is more than SWRULP.

Table 1: The Use Limit of Soil Water Resources by red plum apricot.

Soil depth (cm)	Representative soil layer (cm)	Wilting coefficient (%)	Unavailable soil water storage (mm)
0	0-10	7.98	7.98
20	10-30	7.48	14.96
40	30-60	7.59	22.77
80	60-100	7.72	30.88
120	100-140	6.68	26.72
160	140-180	7.51	30.04
200	180-220	7.41	29.64
240	220-290	7.10	49.70
Use Limit of Soil Water Resources by plant	0-290		212.69

Discussion

Governed by atmospheric demand, soil water and plant characteristics, plant water relationship is dynamic, complicated, and important to effective water management, particularly to the soil water management in the water limited regions, such as Loess plateau in China. When planting red plum apricot trees, soil water content and the soil water resources in soil root zone are high because the size of canopy and the root system of red plum apricot tree is small. As the trees grow, the leaf area index increases and height growth increases. At the same time, the amount of soil water took up by plant roots would keep rising, which could cause rapid decline of soil water content and soil water resources in the soil root zone even if there are some rise after a rain event, led to the appearance of soil drying and the dried soil layers in the soil profile [7,12]. Because soil drying has accumulate, as the soil drying develop, dried soil layers developed. When the soil drying develop at stage, the permanent dried soil layers, the dried soil layers appears in the soil layer below the MID , the soil drying develop into severe desiccation of soil and red plum apricot cannot extract enough water from the soil to meet the transpiration of the plant, which ultimately resulted in soil degradation and influence the quality and effective of red plum apricot because permanent dried soil layers may cut off the link between soil waters in the soil layers upper than MID and soil layers deep than MID and affect water circle severely in land [22] and sustainable use of soil water resources.

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Because severe desiccation of soil and soil degradation does harm to ecological and economy benefit of red plum apricot forest and it is not good for sustainable use of soil water resources and sustainable produce of red plum apricot forest in water-limited regions, we should interfere and control the degree red plum apricot forest use soil water, and evade the severe drying of soil and soil degradation and ensure health of red plum apricot forest ecosystems in water limited regions. Before control of soil degradation, we should select a suitable index to difference severe drying of soil from soil drying before control soil degradation because soil drought is a natural phenomenon, it often happens and we have to make plant to accommodate. Severe drying of soil is a disaster, which causes severe soil degradation and vegetation decline, we have to control it.

There are some soil water deficit indices, such as crop moisture index [23], soil moisture deficit index, evapotranspiration deficit index, plant water deficit index [24]. These drought indices divides into meteorological, hydrological and agricultural drought index [25]. Because most of the drought indices are based on meteorological variables [26] or on a water balance equation, they do not account for water deficit accumulation or soil water storage [27-37], they cannot act as a suitable index for distinguishing severe drying of soil from soil drought phenomenon in the red plum apricot forest in the water-limited regions because soil drought is a nature phenomenon, a water deficit accumulation or a decrease in soil water storage in a given soil depth. We have to develop a new index [38-40].

Because soil water resources are the soil water storage in soil root zone and can account for soil accumulation drought [12] we can use soil water resources in the MID under extreme condition, soil water use control limit by red plum apricot to express the severe drying of soil and act as an suitable soil water management index, that is to say, when the soil depth of DSL equals MID in which soil water resources equal SWRULP, we reduce soil water use by plant to avoid the form of permanent dried soil layers in the soil layers below MID.

Digging method can measure the infiltration depth in farmland, but it cannot be used to determine the depth of infiltration and maximal infiltration depth in the nature soil profile because it destroy soil structure. Two curves method was used to estimate the depth of infiltration and soil water supply for a rain event proposed by Guo [9]. A series of two curves methods for maximal infiltration depth for a longtime infiltration process [12,14,19].

SWRULP is one of the most important criteria for plants to use soil water rationally [12,13,15] , for it integrate soil depth, infiltration depth, wilting point and soil water management requirement and better difference the serious drying of soil from light drying of soil in the forest land. When the soil water resources in the MID equal to SWRULP, the plant water relation enters the critical period of plant water relationship regulation, which decide the plant growth and maximum yield and services. We should study and estimate SWCCV in the critical period of plant water relationship regulation and regulate the water plant relationship because the environment in which plants are growing is complex and roots distribution varies with soil depth, and plants absorb water from different soil depth at the same time, and soil water deficit index cannot describe this kind of severe drying of soil. And soil water seriously affects plant growth when the soil water resources in the MID equal plant water relationship and plant water relation enter the critical period of plant water relationship regulation [41-44].

Conclusion

Soil desiccation is a natural phenomenon and often happens in water-limited regions. Soil desiccation and infiltration has an accumulative effect. When soil desiccation accumulates to a limit, which severely influences the plant growth, causing soil degradation and threatening the quality and economic benefits of red plum apricot. At this time, we should regulate the plant water relationship. For better management of soil water, control of soil degradation and realize sustainable use of soil water resources and sustainable produce of red plum apricot, we must have a better understanding of the difference between soil desiccation and serious desiccation of soil and determine Soil Water Resources Use Limit by Plant and SWCCV in critical period of plant water relationship regulation and prepare to regulate the water plant relationship when soil desiccation develops to serious desiccation of soil.

The SWRULP can serve as a standard to determine whether or not plant have excessively used soil water resources as well as the theoretic foundation to determine start time of regulating plant water relationship. The Soil Water Resources Use Limit by red plum apricot is 212.7 mm. Because the annual precipitation in 2018 is 536.2 mm, which is 120.6 mm more than the mean precipitation 415.6 mm and the soil water resources is more than the Soil Water Resources Use Limit by red plum apricot of 212.7 mm and red plum apricot grow well, we do not need to regulating plant water relationship. When the soil water resources in the MID of 290 cm has reached the limit, the use of soil water resources by red plum apricot will reach their limit. We have to regulate the plant water relationship and realize sustainable use of soil water resources and high-quality production of red plum apricot in water-limited regions. Because the interannual and seasonal variation of precipitation is great in the study site, and the study of sustainable use of soil water resources and high-quality production of red plum apricot need to be continue.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author contribution statement

Zhongsheng Guo wrote the paper.

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