Soil Water Resources Utilization Limit by Red Plum Apricot

zhongsheng guo[1]

[1]Chinese Academy of Sciences and Ministry of Water Resources Institute of Soil and Water Conservation

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Abstract

:Red plum apricot is a deciduous fruit tree and the best cash forest in semiarid loess hilly regions. Since 1995, the distribution area of red plum apricot spreads in the most of the water-limited regions, China. The yield, benefits and plantation area of red plum apricot increase dramatically. But along with the growth of red plum apricot tree, soil drying appeared and sometime become sever,which influence the yield,quality and benefits of red plum apricot. At this time, the relationship between the soil water and red plum apricot growth must be regulated on Soil Water Resource Use Limitation by Plant and Soil Moisture Carrying Capacity for Vegetation. However, there are few studies on the regulation theory. In this study, daily precipitation, soil water suctions at different soil water content were measured, and the maximal infiltration depth and the soil water resource use limitation by red plum apricot was 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, and the maximal infiltration depth is 290 cm, and Soil Water Resources use limit by red plum apricot is 212.7 mm. When the soil water resource in the maximal infiltration depth is lower than the limit, the relationship between the soil water and red plum apricot vegetative growth must be regulated in Red Plum Apricot plantation for high quality production of red plum apricot.

Soil Water Resources Utilization Limit by Red Plum Apricot Zhongsheng Guo1,2 1,Institute of Soil and Water Conservation, Northwestern A & F University, 2,Institute of Soil and Water Conservation, CAS & MWR, Yangling, China; 26, Xinong Road, Yangling, Shaanxi Province 712100, P. R. China Tel. ++86-29-87012411 Fax. ++86-29-8701-2210 Corresponding Author: zhongshenguo@sohu.com

ABSTRACT:Red plum apricot is a deciduous fruit tree and the best cash forest in semiarid loess hilly regions. Since 1995, the distribution area of red plum apricot spreads in the most of the water-limited regions, China. The yield, benefits and plantation area of red plum apricot increase dramatically. But along with the growth of red plum apricot tree, soil drying appeared and sometime become sever,which influence the yield,quality and benefits of red plum apricot. At this time, the relationship between the soil water and red plum apricot growth must be regulated on Soil Water Resource Use Limitation by Plant and Soil Moisture Carrying Capacity for Vegetation. However, there are few studies on the regulation theory. In this study, daily precipitation, soil water suctions at different soil water content were measured, and the maximal infiltration depth and the soil water resource use limitation by red plum apricot was 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, and the maximal infiltration depth is 290 cm, and Soil Water Resources use limit by red plum apricot is 212.7 mm. When the soil water resource in the maximal infiltration depth is lower than the limit, the relationship between the soil water and red plum apricot vegetative growth must be regulated in Red Plum Apricot plantation for high quality production of red plum apricot.

Keywords: Red plum apricot growth; water-limited regions;soil drying; soil degradation; wilting coefficient; maximum infiltration depth; Use Limit of Soil Water Resources by Red plum apricot; high quality production of red plum apricot

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 growing. Soil water equilibrium plays a vital role for restoration rehabilitation. Therefore, soil water management is very important in agricultural systems (Asgarzadeh et al. 2014).

In recent years, agricultural production activity has been strenthened to meet the food need of an increasing population worldwide, the intensification of agricultural activity coexisted negative environmental influence (Maharjan et al. 2016). Along with population increase in the water-limited regions, such as in the semiarid loess hilly region of Loess plateau, People need a lot of food, fruit, fiber, etc, and original vegetation has been destroyed and change into farmland. As a result, forest and vegetation is scarcity, 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 quality of human life. In order to conserve soil and water loss, relief of 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 Three-North Shelter Forest Program sponsored in 1978 for 50 years, large-scale afforestation and fruit trees has been carried out on the Loess Plateau. As a result of these efforts, 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 soil in this region is very deep and in the range of 30–80 m from the surface (zhu et al. 1983), and the groundwater table is also deep (Yang and Shao, 2000), and without irrigation, soil water mainly comes from some precipitation penetrating through the canopy. Along with canopy and the roots development, the interception by canopies increase 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 increased water use by plants and interception and low infiltration capacity and soil water recharge rates has led to serious soil drying with times going by (Guo and Li 2009). The dried soil layers(DSL)appeared and then its thickness of DSL increased, and soil drying widespread (Li 1983; Chen et al. 2007). 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 sustainable use of soil water resources and the stability of forest vegetation ecosystems (Guo and Shao 2013). Thus we should take effective measures to regulate the nonequilibrium relationship between soil water and plant growth (RBSWPG) 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 (Guo and Shao 2003; Guo 2014,2021) because soil in this region range from 30 to 80 m from the surface (zhu et al. 1983), and the groundwater table is also deep (Yang and Shao 2000),without irrigation.

The concept of soil water resources come in 1985 (Budagovski 1985; Budagovski and Busarova 1992) after Lvovich proposed the concept of overall soil moistening in 1980. Soil water resources have different meaning in different field, such as Geology, Soil Science, Agriculture, Forestry and Animal Husbandry. In order to meet the need of different specialty, 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. The generalized soil water resources refers the water storage in the soil from surface soil to water table, and narrow soil water resources refers the water storage in the root zone soil, and dynamic soil water resources refers 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 (Guo 2014).

The state of 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 reservoirs 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 their gravity in these regions. Soil Water Resources Use

Limit by Plant is the soil water storage in the maximum infiltration depth(MID) when soil water content in all of the soil layers of the MID equals wilting coefficient (Guo 2010, 2014).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 surpass the key period of regulation of the relationship between soil water and plant growth because plant have some self-regulation power .

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 Ningxia, and then to Gansu province and so on in the 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, sometime soil drying become severer. Once serious drying happens, which led to the change of red plum apricot tree leaf colour from green to yellow or croci and drop earlier of the leaf. If serious drying happens in the fruit expansion stage, the size of red plum apricot fruit cannot expand to normal size, which influence the yield, quality and economic benefits of 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 to reduce or evade the bad influence of soil drought on the yield and benefits of red plum apricot (Guo 2014,2021). However, there are few studies of 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) 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 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'- 36deg02' N, 106deg26'- 106deg30' 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. 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 Huangmian 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. Red plum apricot tree is a kind of fine variety apricot (*Armeniaca vulgaris* Lam.). The experiment was conducted in 23-year-old red plum apricot garden planted in 1996 and 1-year-old red plum apricot garden planted 2018 .

Generally, some 2- year-old red plum apricot trees start to bear fruit. 3 -year-old red plum apricot forest has some yield and the yield of 4 -year-old red plum apricot forest have reached a certain level after planting red plum apricot tree. An adult red plum apricot tree start to bloom in 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 in the first ten-day period of July, and leaf drop in the middle and last ten-day period of September. Once serious drying happens in the Fruit expansion stage, leaf of red plum apricot tree change colour from green to yellow or croci, and drop earlier. The size of red plum apricot fruit is smaller than normal fruit, which influence 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 first-class high-quality red plum apricot Demonstration area, which was about 50 m from the Shanghuang Eco-experiment weather station, as a part of Guyuan Eco-experiment weather station under 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 in the bench terrace in 1996 and 1-year-old red plum apricot forest planted in the bench terrace in 2018. The sampling pits (soil profile) was dug in red plum apricot forest at the experimental site for investigating soil profile and sampling purposes, whose dimensions were $1m^2$ x 4 m depth on the red plum apricot forest in April, 13, 2018. The undisturbed soil samples were collected for 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 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 determination of soil structure at the State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau.

Cutting ring was used to measure the bulk density, total porosity, capillary porosity, 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 105-110, 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 master sizer 2000 laser particle analyzer and grain size was graded on the USA standard. Soil water contents at different soil suctions (0.1, 0.2, 0.4, 0.6, 0.8, 1.0, 2.0, 4.0, 6.0 bar, 1 bar = $1.0x10^5$ Pa) were measured by a HITACHI centrifuge, made by Instrument Co., Jappan. Because Huangmian soil had been contracted when measuring with a centrifuge, the researchers measured the shrink amount of soil samples in the cutting ring by vernier callipers at different soil suctions and then calculated the volumetric soil water content.

Select 1-year-old and 23-year-old red plum apricot tree with average height and canopy as the sample of study. Two holes with 5.3 cm in diameter were made by holesaw in the place about 40cm cm apart from the 1-year-old red plum apricot tree, and two 4-m long aluminum access pipes were placed in the holes with an interval of 1 m between them. Another two holes with 5.3 cm in diameter were made by holesaw in the middle of the radius of red plum apricot tree canopy, about 2 m away from the tree base (centre) to the exterior margin of the canopy in the 23-year-old red plum apricot tree 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 (Wang and others 2000; Evett and others 2012; Guo and Shao, 2013). Before measuring the volumetric soil water content (VSWC), the neutron probe was calibrated for the soil in the study area by using standard methods (Hauser 1984). The calibration equation for this soil at the site is $y = 55.76x + 1.89$, 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 depth, first put the probe into the aluminum access pipes and change the measuring line of the neutron probe to confirm the weather or not the soil depth equal 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 depth on the display screen of the neutron probe. The soil water content obtained for each measuring depth was taken to be representative for 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 colour of leaf or the size of fruit and the soil water was investigated and estimate the suitable amount of leaf and vimen when the soil water resources in the maximal infiltration depth is approach to or smaller than Soil Water Resources Use Limit by Plant in 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 in 2018 to 2020.

Mathmatical model

Depth of infiltration and maximal infiltration depth

Two curves method was found by Guo in 2004, and used to estimate the depth of infiltration by Guo and Shao in 2009 and Guo in 2014, and named by Guo in 2020. 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 used 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 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 (Guo and Shao 2009, 2013; Guo 2017).

2 **The change of wilting coefficient with soil depth**

Because Gardner empirical formula can better describe the relationship between w and S, the wilting coefficent can be estimated by the Gardner empirical formula w=a [?] S^{-b} (Guo and Shao 2009).First the Gardner empirical formula were transform into ln (w)=alnS+b, and then used to fit the relationship between soil water suction (S) and volumetric soil water content (w) at different soil depth, and then established the relationship between ln (w) and ln (S) by the least square method, and then estimate the wilting coefficent, which is the volumetric soil water content (w) at 1.5Mpa.

3 Soil Water Resources Use Limit by Plant

The mathematical model for calculating Soil Water Resources Use Limit by Plant (SWRULP) was showing as following:

SWRULP=

Here, SWRULP is Use Limit of Soil Water by Plant, expressed in mm. MID is maximum infiltration depth. Ow is wilting coefficient at soil depth of i, the symbol i is the number of soil layer 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 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, 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

1 The change of cumulative infiltration depths with time in red plum apricot forest

Infiltration is a process in which water enter soil. The water infiltrated into soil have two function. One is to increase soil water content in a soil layer, and another is to increase cumulative infiltration depth. The two curve 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. A lot of the crossover points at the same height in the soil profile makes up the wetting peak. The annual precipitation is 536.2 mm, which is 120.6 mm more than the mean precipitation 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 fig.1. After two effective rain events, 9 mm in May 20 and 19.7 mm in April 13, infiltration depth reach to 70 cm on April 28, 2018, see fig.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 the cumulative infiltration (Chowdary and others 2006) or reinfiltration (Corradini and others 2000), which occurs in the period between two

(Fig.1 Here)

(Figures 2 Here)

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 land surface. With time going by, the soil water content in the high water-bearing soil layer reduced because soil evaporate, plant root water absorption, or infiltrate into deeper soil layer and form another high water-bearing soil layer at deeper soil layer, and cumulative infiltration depth increases in the soil profile (Guo and Shao,2009; Guo 2017).When the soil water content in the upper layer of wetting peak is equal to the lower layer of wetting peak, the cumulative infiltration process stopped because there is not infiltration force, and water potential difference between the upper layer of 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 (Guo 2020).That is to say, the maximum cumulative infiltration depth is the maximum infiltration depth. The cumulative infiltration depth arrives in 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 red plum apricot forest, see Figure 3.

(Fig3 Here)

2 The change of wilting coefficient with soil depth

Plants absorb water from the soil,which cause soil water content root reduce. Soil dry become severe and soil water stress in the soil layer near root. At the same time, the water moves slowly from the from the soil layer nearest root to the soil layer near root in the soil matrix driven by gravity and water potential gradients. Wilting coefficient for Huangmian loess soil is the water content at -1.5 MPa in a given soil layer (Yang and Shao, 2000). In the terrace land, 23-years-old red plum apricot tree root develops to a considerable soil depth and suck water in the dry year on National high quality red plum apricot demonstration area. Once a soil layer in which soil water content equals or less than wilting coefficient, the soil layer become dried soil layer**,**The dried soil layer happened in the soil layer deeper than 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 root and soil particle contends for soil moisture. Along with plant growth and root water absorption, soil water content reduces and soil water stress increase in the soil around 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 plant root cell, and plant cannot absorb the water from the soil layer anymore. This balance point is 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 dropping with the increasing soil water suction from 0.01 Ba, 1Ba = $1x10^5$ 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 $0.01x10^5$Pa to $15.0x10^5$ Pa,.

(Figuer 4 Here)

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 MPa can be estimated. The determination coefficient, R^2, changes from 0.981 in 140-180 cm soil layer to 0.991 in the 0-10 cm and 10 -30 cm soil layer. The change of wilting coefficient with soil depth is shown in the Figure 5. It can be seen from Figure 5 that field capacity at the suction of -0.33 MPa drops from 28.11% in 5 cm to 17.87 % in 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 0-10 cm to 6.68 % in the 120 cm.

3 The Use Limit of Soil Water Resources by red plum apricot

The state of vertical distribution of soil water in the root soil zone space influence plant growth. Soil water stress influence root growth and root water uptake. If the soil water content in the MID is equal to 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 the colour of leaf from green to yellow or croci and leaves fall earlier than usual time in the growing season. Red plum apricot tree almost ceased growing, and red plum apricot fruit does not expanding, which influence 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 soil per unit time does 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 table1, 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 condition 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, 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 temperature and frost, all flowers of red plum apricot tree freeze to death on the morning of April 7. Red plum apricot tree germinates on April 30, and then spread and growth. 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 fig.1. and the volumetric water content in the 0 to 290cm soil profile is more than the wilting point, see fig.5 and soil water resources in 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 vimen grow up to 45 cm. By the end of the growing season on the October, the width of 1-year-old tree crown reached up to the range from 100 to 120 with an average 110 cm in width, and the length of 1-year-old tree crown reached up to the range from 120cm to 140 cm with average 130 cm, 1-years-old red plum apricot tree grow well, which lay the foundation for the next years blooming and fruiting.

(Fig.5 Here)

The 23-years-old red plum apricot tree start to bloom in 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 mature in the in the first ten-day period of July. Unfortunately, all of flowers wilt and die because of serious cool temperature and frost on the April 7, 2018. The 23-years-old red plum apricot tree begins to spreading leaf on April 30, and true leaf develop up to June 16, and grow well, leaf drop in the end of September because 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 precipitation changes with time in 2019 (Fig.6),and the 24-years-old red plum apricot tree grow well and red plum apricot mature because the soil water resource in the MID is more than SWRULP.

(Fig.6 Here)

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 (Guo and Shao 2003; Guo 2014). Because soil drying have accumulates effect, 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 (Tian 2010) and sustainable use of soil water resources.

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 (Palmer 1968) , soil moisture deficit index, evapotranspiration deficit index, plant water deficit index (Shi and others 2015) .These drought indices divides into meteorological, hydrological and agricultural drought index (Mishra and Singh 2010).Because most of the drought indices are based on meteorological variables (Mckee and others 1993) or on a water balance equation, they do not account for water deficit accumulation or soil water storage (Martinez-Fernandez and others 2015), they can not 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.

Because soil water resources are the soil water storage in soil root zone and can account for soil accumulation drought (Guo 2014),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 (2004), . A series of two curves methods for maximal infiltration depth for a long time infiltration process (Guo and Shao 2009, Guo 2014, 2020).

SWRULP is one of the most important criteria for plants to use soil water rationally (Guo 2010, 2014, 2020,2021a,2021b) , 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, we should estimate the SWCCV , especially SWCCV in the kay period of plant water relation regulation (Guo 2021a and 2021b) and regulate the RBSWPG 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 in the kay period of plant water relation regulation seriously affects plant growth and maximum yield and beneficial results when the soil water resources in the MID equals or smaller than SWRULP.

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 RBSWPG. For better management of soil water, control of soil degradation and realize sustainable use of soil water resources and high quality production 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 the key period of plant water relationship regulation and prepare to regulate the RBSWPG 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 RBSWPG. 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 RBSWPG. 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 consider regulate the RBSWPG 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 soil desiccation and soil degradation effect on red plum apricot need to be continue.

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Additional Information

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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There is not Competing Financial and non-financial interests

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