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Research Article

High-quality Production of Red Plum Apricot in Semiarid Loess Hilly Region of China

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Abstract

Red plum apricot is a deciduous fruit tree and the best cash crop in semi-arid loess hilly regions of China. Since 1995, the distribution area of the apricot has spread in most of the water-limited regions, China and the yield and benefits of red plum apricot increased dramatically. Since 2017, China has put forward high-quality development, and red plum apricot must carry out high-quality production. But, as the red plum apricot tree grows, Low temperature and frost, Hazards of heart-eating insects, and soil desiccation will appear, and seriously influence the yield's quantity, quality, and benefits of red plum apricot. However, there are few reports on the method for High-quality production of red plum apricot. In this study, the effectiveness of different methods of controlling Low temperature and frost, and the Hazards of heart-eating insects and soil desiccation were estimated. The results show that the greenhouse method was the most effective for controlling Low temperature and frost, spraying Beta-cypermethrin is still the better method for controlling Hazards of heart-eating insects. When the soil water resource in the maximal infiltration depth is lower than the soil water resource use limitation by red plum apricot, the plant water relationship enters the key period of plant water relationship regulation. The critical period ends when plant water regulation becomes ineffective of plant water relation regulation. When plant density exceeds the soil water vegetation carrying capacity, the plant water relation should be regulated, and then regulate the Vegetative growth and Reproductive growth on the appropriate leaf quantity when the plant density is equal to the soil water vegetation carrying capacity and the leaf fruit relation.

Introduction

The apricot (*Prunus armeniac*a L.) is a member of the Rosaceae. Apricot fruit is used as fresh, dried, or processed fruit, and is rich in many plant antioxidants and a good source of dietary fiber. Some of the applications of apricot in food technology are producing dried fruit, frozen apricot, jam, jelly, marmalade, pulp, juice, nectar, extrusion products, and so forth. Also, apricot is an economic fruit because its kernel is used for making oils, benzaldehyde, cosmetics, active carbon, and aroma perfume. In the year 2014, Iran's apricot production amounted to 252,747 tons per year, which came third after Uzbekistan and Turkey. The whole amount of apricot production was 3,365,738 tons [1].

The introduction experiment of fine fruit trees was carried out in Shanghuang Ecological Experimental Station in 1987. The improved plum apricot grown in Shanghuang Ecological Experimental Station was named red plum apricot and promoted on a large scale be-cause the plum apricot imported from Mei county, grew well and was redder in color than the plum apricot grown in Mei County, Mei County, China, and the quality of the plum apricot was better than that grown in Meixian County [2].

The red plum apricot fruit is large, beautifully round, and weighs approximately 60 grams per fruit. It is rich in juice, soluble solids content (14.3%), potassium (410.8 mg per 100 g), selenium, and Vc (8.3 mg per 100 g). The potassium content of red plum apricot is higher than that of apple (Malus domedtia), pear (Pyrus), peach (Amygdalus persica) and grape (Vitis vinifera). After a couple of years study from 1987 to 1991 in Shanghuang Eco-experimental Station, red plum apricot is selected and popularization because red plum apricot fruit is mature early, and fruit is larger, and quality is high, and production is stable [2,3]. Some 3-years-old red plum apricot begins to bear fruit, and 4-years-old Red plum apricot obtain higher yield planting in the station. It starts to germinate in March 28 [2,4] and expand leaf in the middle of April. Red plum apricot blooms from late March to early April and blooms, and bears fruit in mid-April. Fruit ripens in early July in the eco-experiment station, Guyuan County in the Ningxia Hui Autonomous Region. Red plum apricot is used as fresh food as well as raw material, such as making dried fruit by wind-drying.

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 in the key period of plant water relationship regulation [5]. Therefore, soil water management is very important in agricultural ecological systems [6].

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 [7]. Along with population increase in the water-limited regions, such as in the semi-arid 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 taken many measures since 1950, large-scale afforestation and fruit trees has been planted 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 to 0.31 billion tons in recent years from 1.6 billion tons in the 1970s, and the runoff has been halved.

Because soil in this region is very deep ranging from 30 to 80 m [8], and the groundwater table is deep [9], and without irrigation, soil water mainly comes from precipitation penetrating through the canopy. As canopy and the roots develop, the interception by canopies increases and the roots of these plants grow fast and thus take up water from the soil depths deeper than maximum infiltration depth, which reduces the soil water supply and increases soil water consumption. Consequently, the increased water use by plant and interception by crown and low infiltration capacity and soil water recharge rates has led to serious soil desiccation with times going by [10]. The dried soil layers (DSL) appeared and then its thickness of DSL increased, and soil desiccation widespread [11,12]. Serious drying of soil eventually and poor self-regulation of plant result in soil degradation, vegetation decline and agriculture fail-ure, which have adverse effects on sustainable use of soil water resources and the stability of forest vegetation ecosystems [13]. Thus we should take effective measures to regulate the nonequilibrium soil plant relationship by reducing the popula-tion 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 [14-16] because soil in this region range from 30 to 80 m from the surface [8], and the groundwa-ter table is also deep [9], without irrigation.

The concept of soil water resources come in 1985 [17,18] after Lvovich proposed the concept of overall soil moistening in 1980 [19]. 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 spe-cialty, 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 refer to 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 rainfall in the growing season for deciduous plant or a year for evergreen plants. Soil water resources are a component of water resources and renewable water resources [15].

The state of vertical distribution of soil water in the root soil zone influences plant growth. Because drought is a recurrent natural phenomenon, and the soil in which plant root dis-tribute resembles a reservoir and have the storage capacity of water, which have the buff-ering effect of soil desiccation on plant growth, the effects of water stress on plant growth vary with their gravity in these regions. Soil Water Resources Use Limit by Plant is the soil wa-ter storage in the Maximum Infiltration Depth (MID) when soil water content in all of the soil layers of the MID equals wilting coefficient [15,20]. 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 Plants because when soil water resources in the maximum infiltration depth equal Soil Water Resources Use Limit by Plant, soil water seriously in-fluence plant growth if the duration dry climate continue surpass the key period of plant water relationship regulation 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, Figure 1. 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 desiccation become severer. Low temperature and frost, Hazards of heart-eating insects and soil desiccation is the most important indicators influence high-quality production of red plum apricot, which led to size of fruit

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Figure 1: The shape of red plum apricot in semiarid region (Guyuan, China).

reduce, the quality reduce and the change of red plum apricot tree leaf color from green to yellow or saffron 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 relation-ship between the soil water and red plum apricot growth must be regulated on Soil Water Resources Use Limit by Plant and Soil Water Vegetation Carrying Capacity to reduce or evade the bad influence of soil drought on the yield and get the maximum yield and bene-fits of red plum apricot [5,16]. Red plum apricot is a deciduous fruit tree and the best cash forest in semi-arid loess hilly regions of China. Since 1995, later, the distribution area of the apricot spreads in the most of the water-limited regions, China. The yield and benefits red plum apricot increase dramatically. Since 2017, China put forward high-quality development, red plum apricot must carry out high-quality production. As the growth of red plum apricot tree, Low temperature and frost, Hazards of heart-eating insects and soil desiccation will appear, which seriously influence the yield quality and benefits of red plum apricot in turn. However, there are few studies of method of high-quality production of red plum apricot.

The high-quality development of agriculture is to take some measures and methods to make the land produce the maximum output and services to meet people's yearning for a better life and the needs of agricultural production services [21]. In the present work, the study aims at achieving these objectives: (1) the best method for controlling Low temperature and frost; (2) the best method for controlling Hazards of heart-eating insects; (3) the best method for controlling soil desiccation; (4) approach the method for the high-quality production of red plum apricot.

Materials and methods

Site description

This study was conducted at National Demonstration area of high-quality red plum apricot, 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 (Figure 2). This region receives minimal precipitation from January to March and 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 is a selected cultivar of *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 in 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 has reached a certain level after planting red plum apricot tree. An adult red plum apricot tree starts 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, the leaves turn from green to yellow or saffron, 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

Low temperature and frost: Because the harm of Low temperature and frost on the yield and quality of red plum apricot is that the temperature around the canopy of red plum apricot suddenly reduce to be-low 0 C° to -5 C°, which often stop the development of red plum apricot or cause red plum apricot death. The harm of Low temperature and frost often happens in the period of flowering and young fruit stage , which severely influence the yield and quality Since 2017, we drive on July around Guyuan county to investigate the influence of Low temperature and frost on the yield and quality of and compare the result of different method for controlling Low temperature and frost and then select the better method to control the influence of Low temperature and frost on yield and quality of red plum apricot.

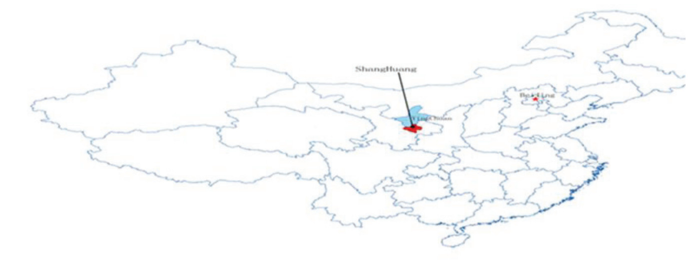

Figure 2: The study area of high-quality production of red plum apricot in Chinese loess plateau.

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Hazards of Peach fruit moth: In 2008, I encountered a Consumer in Shanghuang village, Guyuan City, Ningxia Hui Autonomous Region, the predecessor of the National high-quality red plum and Apricot Demonstration Base 100 kg of red plum apricot were picked from an orchard in Shanghuang Village, among which 77 kg of plum and apricot were damaged by peach fruit moth (*Carposina sasakii* Matsumura), and the fruit damage rate reached 67%, which showed that heart-eating insects did serious harm to red plum apricot. In 2009, we set up the heart-eating insects' control experiment in the Orchard in Shanghuang Village and carry out the experiment. In late May, when the temperature is high, the red plum and apricot expand to 0.8 ~ 1 cm in diameter, and the edible worm develops at this time. The insect lay eggs on the fruit surface for incubation, and the hatched larvae enter the young fruit. At this time, we use high efficiency, low toxicity and high efficiency chlorine Cypermethrin 2000 times solution for the control experiment of peach fruit moth, in order to kill the larvae, to ensure that the fruit without insect pests, medication There were 34 strains; However, 98% of the fruits of 1 unsprayed fruit tree and unsprayed red plum apricot were damaged by solid insect People ask; the effect of pesticide spraying was significant and the economic benefit is remarkable. To meet food safety needs, 2019 On July 19, we sampled the products of beta-cypermethrin for control of edible worms and shipped them to Xi 'an Guolian Quality Detection Technology Co., Ltd. for pesticide residue analysis.

Since 2008, I found the serious Hazards of peach fruit moth on the yield and quality of red plum apricot. A buyer picked up 100 kg of red plum apricot and found 33 kg of red plum apricots damaged by *Conogethes punctiferalis* larvae in an orchard. And then I found the method of spraying high-efficiency cypermethrin on the canopy and then popularize the method. Beta-cypermethrin should be used in the fruit expansion period one month before apricot ripening 1 week, the economic effect is significant [3]. Survey the area annually and the effect of spraying beta-cypermethrin. On July 19, 2019, we sampled the fruits of high-efficiency cypermethrin against heartworm and then sent the samples Xi'an Guolian Quality Detection Technology Co., Ltd. to analyzed the pesticide residues.

Even there are different kind of methods to kill heart-eating insects, such as using Sweet and sour sauce to kill heart-eating insects, but the best method is to spaying Be-ta-cypermethrin. Every year we drive 10 km around Shanghuang Station to survey the result of spraying high-efficiency cypermethrin.

Rainfall measurement: Rainfall at the study site was recorded using standard rain gauges positioned 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 con-tent, plant root distributions, and other plant growth parameters.

Physical characteristics of soil: 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 × 2m × 4m 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 (5 cm in height, 5 cm inner diameter and 100 cm 3 in cubage). At the same time, the disturbed soil of about 100 g 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 rings were 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 no capillary 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 2.65 g/cm^3. No capillary porosity was the difference between total porosity and capillary porosity. Soil particles were measured using a Mastersizer 2000 laser diffraction particle analyzer; grain size was classified 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 = 1.0 × 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 shrink amount of soil samples in the cutting ring by Vernier calipers at different soil suctions and then calculated the volumetric soil water content.

Soil water measurement: Select 1~2-year-old and 23~24-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 40 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 ra-dius of red plum apricot tree canopy, about 2 m away from the tree base (centre) to the ex-terior 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 [13,22,23]. Before measuring the volumetric soil water content (VSWC), the neutron probe was calibrated for the soil in the study area by using standard methods [24]. 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,

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in 2018 and 2019. 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. Secondly, 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 considered 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 orchards.

Plant growth measurement: 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 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.

Depth of infiltration and maximal infiltration depth

Two curves method was found by Guo in 2004 [25], and used to estimate the depth of infiltration by Guo and Shao in 2009 [26] and Guo in 2014 [15], and named by Guo in 2020 [27]. 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 were 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 and 2019.

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 lo-cation between two contiguous soil water distribution curves with depth in the soil profile at the beginning and the end of a period [26,27].

The change of wilting coefficient with soil depth

Because Gardner empirical formula can better describe the relationship between soil water content (w) and soil water suction (S), the wilting coefficient can be estimated by the Gardner empirical formula $w = a \cdot S^{-b}$ [26]. First the Gardner empirical formula were transform into $\ln(w) = a \times \ln(S) + b$, and then used to fit the relationship be-tween 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 coefficient, which is the volumetric soil water content (w) at 1.5 Mpa.

Soil water resources use limit by plants

The mathematical model for calculating SWRULP was showing as following:

$$\text{SWRULP} = \sum_{i=0}^{i=MID} \theta_W \times D$$

Here, SWRULP is Soil Water resources Use Limit by Plant, expressed in mm. MID is maximum infiltration depth. Owi is wilting coefficient at Layer i soil. Symbol i is layer i soil l and D is the thickness of the soil at layer i soil.

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 soil water content and moisture suction relationship, the relationship between the root density and soil depth using the least square method. Data were transformed where necessary to achieve linearity to gain a linear relationship.

Results

Method for controlling Low temperature and frost

There are different methods for controlling Low temperature and frost, such as irrigation in advance or covering with straw and son on. If a weather forecast predicts of Low temperature and frost, it is difficulty to irrigation in advance or covering with straw in large area. But, the best method of controlling Low temperature and frost is green house and spraying brassinolide. In addition, the method of green house is not good for promotion because the investment is too big, a 600 m^2 greenhouse needs 100,000 RMB per 666.7 m^2.

Since 2017, we investigate and compare the result of different method for Low temperature and frost and then found

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the better method to control the influence of Low temperature and frost on yield and quality of red plum apricot.

Method for controlling the Hazards of peach fruit moth s

According to the monitoring report (№ aff190702694) provided by Xi'an Guolian Quality Inspection Technology Co., Ltd., the target cypermethrin and beta cypermethrin were detected according to the national food safety standard maximum residue limits of pesticides in food (GB 2763 - 2016), and no cypermethrin and beta cypermethrin were detected (the detection limit was 0.003 mg / kg), showing high-efficiency cypermethrin against heartworm was a safe, reliable and effective method. At present, this practical technology has been widely popularized. Even there are other method for controlling the Hazards of peach fruit moth, I found the method of spraying high-efficiency cypermethrin on the canopy is the best method to controlling the Hazards of peach fruit moth. At present, this practical technology has been widely popularized. But the use of this method is influenced by the low temperature and frost control methods.

Method for controlling soil desiccation

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 functions. 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 be-tween two soil water distribution curves with depth measured in the soil profile before and after a rain event or several days. Numerous crossover points at similar depths 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 (Figure 1). After two effective rain events, 9 mm in May 20 and 19.7 mm in April 13, infiltration depth reaches to 70 cm on April 28, 2018 (Figure 3).

As time goes on, the cumulative infiltration depth increased with time in 2018 because the infiltration includes two stages: initial infiltration typically occurs during a rain event and the cumulative infiltration [28] or reinfiltration [29], 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 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 [26,30]. 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.

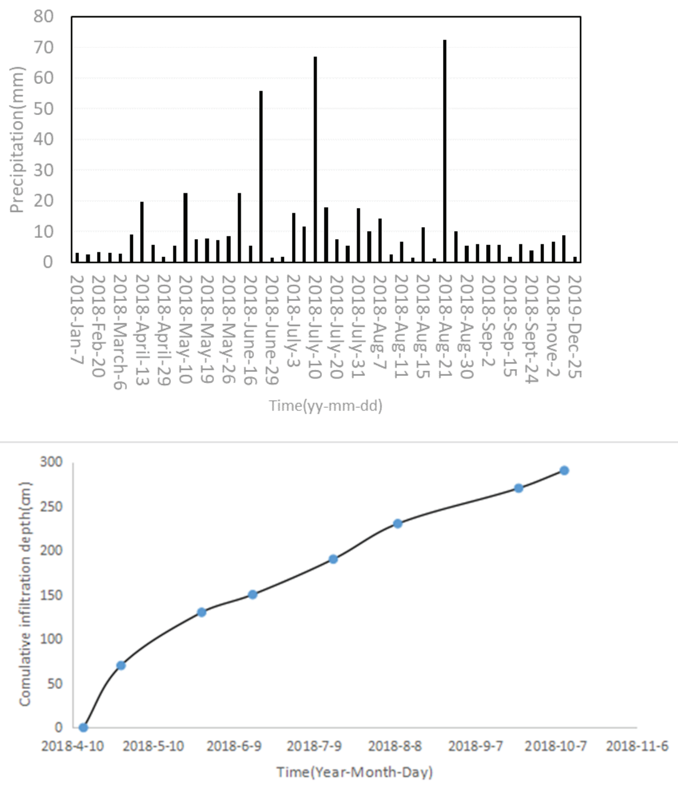

Figure 3: The change of precipitation and soil infiltration depth with time in red plum apricot orchard in 2018.

Water potential difference 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 [27]. That is to say, the maximum cumulative infiltration depth is the maximum infiltration depth. Cumulative infiltration depth reached 130 cm on May 28, up to 150 cm on June 16, reached 190 cm by July 16, and ultimately 290 cm. So, the maximum infiltration depth is 290 cm in red plum apricot forest (Figure 3), which is same as the maximum infiltration depth in caragana shrubland [27].

The change of wilting coefficient with soil depth: Plants absorb water from the soil, which cause soil water content root reduce. Soil desiccation 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 [9]. 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

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and below the permanent dried soil layer. So soil management should pay attention to soil water management 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 compete 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 sur-rounding the root reach balance with the water potential in plant root cell, and plant can-not 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: $w = aS^{-b}$, Where, θ is soil water constant and S is soil water suction (Figure 4). It can be seen that the volumetric soil water content dropping with the increasing soil water suction from 0.01 Ba, $1Ba = 1 \times 10^5$ 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.

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 cm - 180 cm soil layer to 0.991 in the 0 cm - 10 cm and 10 cm - 30 cm soil layer. The change of wilting coefficient with soil depth is shown.

In Figure 4. It can be seen 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 × 105 Pa drops from 7.98 % in 0 cm - 10 cm to 6.68 % in the 120 cm.

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 because soil water stress influence root growth and root water uptake. In order to express the stress of soil desiccation on plant growth, the term soil water resources use limit by plants was put forward [20,27]. If the soil water content in the MID is equal to wilting point and soil water storage (soil water resources) in the MID is equal to SWRULP. There is not enough water supply from precipitation, most red plum apricot changes the color 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 bene-fits 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.

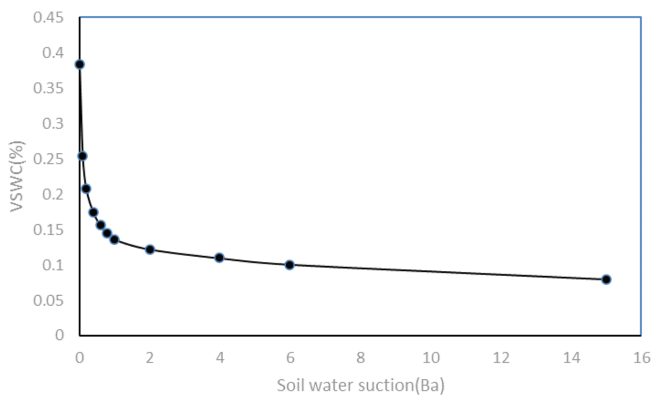

Figure 4: The relationship between Volume soil water content and soil water suction.

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 (Table 1), and the SWRLP in red plum apricot is 212.7 mm, 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 [30].

The term soil water vegetation carrying capacity was put forward in 2000 (Guo et al 2002), which is the ability of soil water resources to support vegetation, expressed by indicator plant. The soil water vegetation carrying capacity can be estimated by two lines method, and is the most important theory for sustainable use of soil water resources and high-quality and sustainable development of forest, grass and crop in the water-limited regions. The indicator plants of artificial vegetation such as artificial forests, grasses and crops are artificially cultivated trees or plants [15,27].

The critical period of plant water relation regulation is from the starting time the soil water resources in the maximum infiltration depth is equal to soil water resources use limit by plants [10] to the ending time plant water relation regulation is effective [5,21]. If the plant density is more than soil water vegetation carrying capacity in the critical period of plant water relation regulation, the plant water relation has to be regulated.as for fruit or crop, the The relationship between vegetative growth and reproductive growth of plants must be regulated according to the relationship between leaf amount in carrying capacity, suitable leaf amount and market demand for high-quality fruit to obtain maximum yield and effect.

The control of Soil drought based on the Use Limit of Soil Water Resources by red plum apricot and soil water vegetation carrying capacity.

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,

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is 120.6 mm higher than the average of 415.6 mm, (Figure 1), and the volumetric water content from 0 to 290 cm exceeded the wilting point (Figure 5) and soil water resources in the MID are greater than the soil water resources use limit by plant, the red plum apricot tree grows well. Up to June 16, new vimen grows up to 45 cm. By the end of the growing sea-son 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 (Figure 6).

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 floweres 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 290 cm 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 (Figure 7) and the 24-years-old red plum apricot tree grow well and red plum apricot mature because the soil water resources in the MID are more than SWRULP.

Discussion

Low temperature and frost, Hazards of heart-eating insects and soil desiccation is the most important indicators influence high-quality production of red plum apricot. Low temperature and frost often happen in the period of Red plum apricot flowering and Fruit setting period, and Hazards of heart-eating insects often happened in the Spring from first ten days in the month of May, in which young fruit stage, about May 20 in Guyuan, China, which is earlier than critical period of plant water relationship regulation. So, we can take effective method such as green house or smudging to reduce the influence of low temperature and frost after local weather report. The influence of heart-eating insects on the quality and yield of red plum apricot often happen on 20 may, we can spray 2000 time high-efficiency cypermethrin to the conopy of red plum apricot to reduce the Hazards of heart-eating in-sects on the quality and yield of Red plum apricot in the water-limited regions [3].

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 re-sources 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 desiccation and the dried soil layers in the soil profile [14,15]. Because soil desiccation has accumulative effect, as soil desiccation progresses, dried soil layers form. When the soil desiccation develop at stage, the permanent dried soil layers,

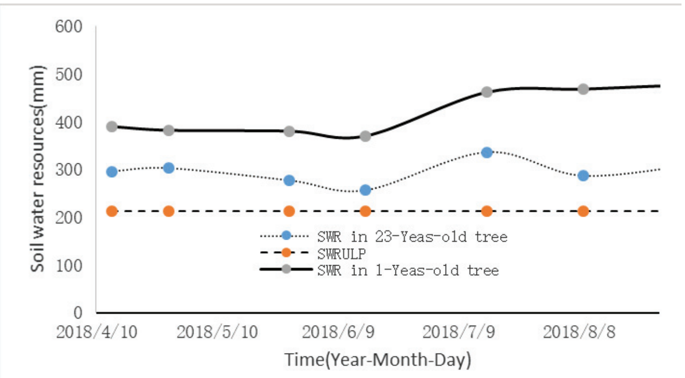

Figure 5: The relationship between soil water resources and the Use Limit of Soil Water Resources by red plum apricot in 1-year-old red plum apricot orchard.

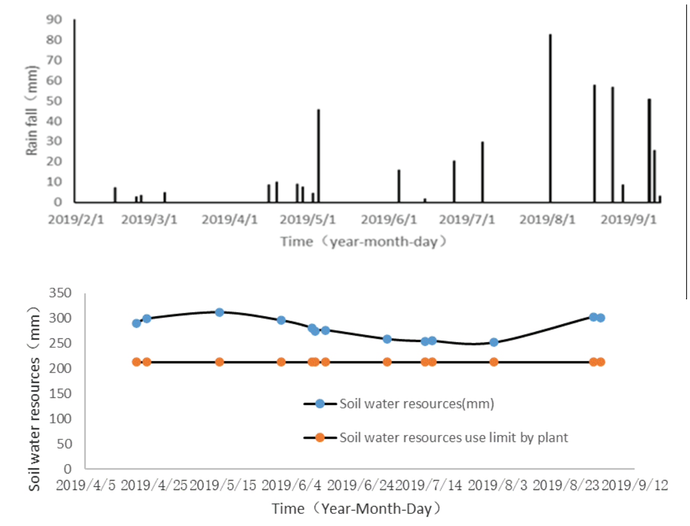

Figure 6: The relationship between Soil Water Resources in the MID and SWRULP in 2-year-old red plum apricot tree and 24-year-old red plum apricot tree.

Figure 7: Effects of low temperature and frost on red plum blossom before and after low temperature and frost event happened on April 14, 2020 in Nation high-quality red plum apricot demonstration area.

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the dried soil layers appears in the soil layer below the MID , the soil desiccation 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 disrupt water movement between soil above and below the MID, and affect water circle severely in land [31] 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, intervention is needed to regulate soil water use by red plum apricot forests, 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 desiccation before control soil degradation because soil drought is a natural phenomenon, it often happens and plants must adapt. Severe soil desiccation represents an ecological hazard, 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 [32], soil moisture deficit index, evapotranspiration deficit index, plant water deficit index [33]. These drought indices divide into meteorological, hydrological and agricultural drought index [34]. Because most of the drought indices are based on meteorological variables [35] or on a water balance equation, they do not account for water deficit accumulation or soil water storage [36], they are unsuitable for distinguishing between soil desiccation and soil drought from soil drought phenomenon in the red plum apricot forest in the water-limited regions because soil drought is a natural phenomenon, a water deficit accumulation or a decrease in soil water storage in a given soil depth. We have to develop a new index [37-52].

Because soil water resources are the soil water storage in soil root zone and can account for soil accumulation drought [15], we can use soil water resources in the MID under extreme condition, the soil water use control limit for red plum apricot serves as an indicator of severe desiccation 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 curve method was used to estimate the depth of in-filtration and soil water supply for a rain event proposed by Guo [25]. A series of two curve method for maximum infiltration depth for a long-time infiltration process [15,26,27].

SWRULP is the most important criteria for plants to use soil water rationally [15,16,20,21,26,27,], 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 key period of plant water relation regulation [5,16], the key period of plant water relation regulation is the ineffective time of plant water relation regulation, such as stopping expanding time of red plum apricot of Junly 15. The we should estimate the SWCCV, especially SWCCV in the kay period of plant water relation regulation [5,16] 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.

Soil water resources use limit by plants, soil water vegetation carrying capacity and the critical period of plant water relation regulation is the theory foundation for high-quality and sustainable development of forest, grass and crops in water-limited regions because when the plant density is equal to soil water vegetation carrying capacity and the critical period of plant water relation regulation, we can get the maximum yield and service [5,21].

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 relation. 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 severely dry soil.

The SWRULP can be served as a standard to determine whether or not plant have excessively used soil water resources as well as the theoretic base to determine start time of the critical period of plant water relation regulation. 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 and the soil water resources in the MID 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 regulate RBSWPG. When the soil water resources within the 290 cm MID have reached the threshold, the use of soil water resources by red plum apricot

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will reach its limit. We have to consider regulate the plant water relation and ensure sustainable utilization of soil water resources and maintain high-quality production of red plum apricot in water-limited regions.

Soil water resources use limit by plants, soil water vegetation carrying capacity and the critical period of plant water relation regulation is most important for the sustainable use of soil water resources and high-quality production of red plum apricot. Because the inter-annual and seasonal variation of precipitation is great and plant water relation is complex in the study site, and the study of High-quality development of Red Plum Apricot in semiarid loess hilly region need to be continue in order to achieve high quality development of plum apricot, it is necessary to regulate plant water relationship according to soil water carrying capacity for red plum apricot, and then regulate the relationship between reproductive growth and vegetative growth according to proper leaf quantity when plant density equal to soil water vegetation carrying capacity, and then regulate the relationship between leaf quantity and high-quality fruit to get maximum yield and benefit. The study needs to be continued because the soil water vegetation carrying capacity change with time(climate), and there is about 20-years cycle of precipitation in the study site. The investment in greenhouse control method is too big to promote and need to reduce.

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