Review Article

High-quality production of red plum apricot in semiarid Loess Hilly region of China

Zhongsheng Guo[1,2]*

[1]Northwestern A & F University, Yangling, China

[2]ISWC, CAS & MWR, Yangling, China

https://www.agriscigroup.com

Check for updates

Abstract

Red plum apricot is a deciduous fruit tree and the best cash forest 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, in China, and the yield and benefits of red plum apricot increase dramatically. Since 2017, China put forward high-quality development, and red plum apricot must carry out high-quality production. But, as the red plum apricot tree grows, low temperatures and frost, hazards of heart-eating insects and soil drying will appear, which seriously influence the yield, quality, and benefits of red plum apricot in turn. 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 hazards of heart-eating insects and soil drying was estimated. The results show that the greenhouse method is the better method for controlling Low temperature and frost, spraying Beta-cypermethrin still is 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 ending time of the critical period of plant water relation regulation is the failure time of plant water relation regulation. When the current plant density is more than the soil water vegetation carrying capacity, the plant-water relation should be regulated, and then the vegetative growth and reproductive growth on the appropriate leaf quantity when the current plant density is equal to the soil water vegetation carrying capacity and the leaf fruit relation.

Introduction

The apricot (*Prunus armeniaca* 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. The applications of apricots in food technology are producing dried fruit, frozen apricots, 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 tones [1].

The introduction experiment of fine fruit trees was carried out in Shanghuang Ecological Experimental Station in 1987.

The improved plum apricot grown in the Station was named red plum apricot and promoted on a large scale because the plum apricot was imported from Mei County and grew well and was redder in color than the plum apricot grown in Mei County, China, and the quality of the plum apricot was better than that grown in Meixian County [2].

The shape of red plum apricot fruit is about round and looks beautiful. Red plum apricot fruit is big. The fruit weight of red plum apricot per single fruit weight is about 60 g. The apricot 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 of study from 1987 to 1991 in Shanghuang Eco-experimental Station, the red plum apricot was selected and popularization because red

001

plum apricot fruit mature early, and fruit is larger, and quality is high, and production is stable [2,3]. Some 3-year-old Red plum apricot begins to bear fruit, and 4-year-old Red plum apricot obtains higher yield planting in the station. It starts to germinate on March 28 [4] and expands 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 ripe 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 growth. Soil water equilibrium plays a vital role in 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 strengthened to meet the food needs of an increasing population worldwide, and the intensification of agricultural activity coexisted with negative environmental influence [7]. Along with population increase in the water-limited regions, such as in the semi-arid Loess hilly region of the Loess plateau, people need a lot of food, fruit, fiber, etc, and original vegetation is destroyed and changed into farmland. As a result, forests and vegetation were scarce, and the loss of soil and water in the Loess Plateau had become a serious environmental problem by 1949. Loss of soil and water eroded fertile surface soil and led to soil fertility and crop productivity reduction, which influence the quality of human life. In order to conserve soil and water loss, relieve destruction caused by sandstorms and haze weather, increase crop productivity, and the improvement of ecological environment, the government has taken many measures since 1950. Large-scale afforestation and fruit trees have been planted on the Loess Plateau. As a result of these efforts, great achievements have been made. The forest coverage quickly 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 the soil in this region is very deep, ranging from 30 m 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 the 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 the maximum infiltration depth, which reduces the soil water supply and increases soil water consumption. Consequently, the increased water use by plants interception by the crown, low infiltration capacity, and soil water recharge rates have led to serious soil drying with time going by [10]. The dried soil layers (DSL) appeared and then its thickness of DSL increased, and soil drying was widespread [11,12]. Serious drying of soil eventually and poor self-regulation of plants result in soil degradation, vegetation

decline, and agriculture failure, which have adverse effects on the sustainable use of soil water resources and the stability of forest vegetation ecosystems [13]. Thus we should take effective measures to regulate the nonequilibrium soil-plant relationship 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 [14-16] because soil in this region range from 30 to 80 m from the surface [8], and the ground water table is also deep [9], without irrigation.

The concept of soil water resources came in 1985 [17,18] after Lvovich proposed the concept of overall soil moistening in 1980. Soil water resources have different meanings in different fields, such as Geology, Soil Science, Agriculture, Forestry, and Animal Husbandry. In order to meet the needs of different specialties, soil water resources can be classified into static soil water resources and dynamic soil water resources. Static soil water resources include generalized and narrow soil water resources. Generalized soil water resources refer to the water storage in the soil from the surface soil to the water table, narrow soil water resources refer to the water storage in the root zone soil, and dynamic soil water resources refer to the antecedent soil storage plus the soil water supply from 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 the 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 has the storage capacity of water, which has the buffering effect of soil drying on plant growth, the effects of water stress on plant growth vary with their gravity in these regions. Soil Water Resources Use Limit by Plants (SWRULP) is the soil water storage in the maximum infiltration depth (MID) when the soil water content in all of the soil layers of the MID equals wilting coefficient [15,19]. We do not regulate the relationship as soil drought happens until the soil water resources reduce to a degree, SWRULP because when soil water resources in the maximum infiltration depth equal SWRULP, soil water seriously influences plant growth if the duration of dry climate continues to surpass the key period of plant water relationship regulation because plant have some self-regulation power.

The 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 apricots spread from Guyuan County to the whole of Ningxia, and then to Gansu Province and so on in most of the water-limited regions, China, the yield, benefits, and planting area of red plum apricot increase doubly. But along with the growth of red plum apricots and precipitation, sometimes soil drying becomes severe. Low temperature and frost, hazards of heart-eating insects, and soil dry are the most important indicators that influence the high-quality production of red plum apricot, which led to

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

the reduction in the size of fruit and quality and 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 influences 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 SWRULP and Soil Water Vegetation Carrying Capacity (SWVCC) to reduce or evade the bad influence of soil drought on the yield and get the maximum yield and benefits of red plum apricot [15,16]. The 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 has spread in most of the water-limited regions, in China. The yield and benefits of red plum apricots increase dramatically. Since 2017, China put forward high-quality development, and red plum apricot must carry out high-quality production. With the growth of the red plum apricot tree, low temperatures and frost, hazards of heart-eating insects and soil drying will appear, which seriously influence the yield, quality, and benefits of red plum apricot in turn. However, there are few studies of methods 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 need for agricultural production services [20]. 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 drying; (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. Precipitation here is absent in the periods from January to March and from October to December, and the rainfall from June to September makes up more than 70% of the annual precipitation. The mean rainfall measured between 1983 and 2001 was 415.6 mm with a maximum of 635 mm in 1984 and a minimum of 260 mm in 1991. The frost-free season is 152 days. The Huangmian soil having developed directly from the Loess parent materials, consists mainly of loamy porous Loess (Calcaric Cambisol, FAO 1988) with wide distribution in the semiarid hilly region of the Loess Plateau. The red plum apricot tree is a kind of fine variety apricot (*Armeniaca vulgaris* Lam.). The experiment was conducted in a 23-year-old red plum apricot garden planted in 1996 and a 1-year-old red plum apricot garden planted in 2018.

Generally, some 2-year-old red plum apricot trees start to bear fruit. The 3-year-old red plum apricot forest has some yield and the yield of the 4-year-old red plum apricot forest has reached a certain level after planting the red plum apricot tree. An adult red plum apricot tree starts to bloom at the end of March and is 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.

Observation items and determination methods

Low temperature and frost: The harm of low temperature and frost on the yield and quality of red plum apricots is that the temperature around the canopy of red plum apricots suddenly reduces to below 0 °C to -5 °C, which often stops the development of red plum apricots or causes red plum apricot death. The harm of low temperature and frost often happens in the period of flowering and young fruit stage, which severely influences the yield and quality Since 2017, in July we have driven 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.
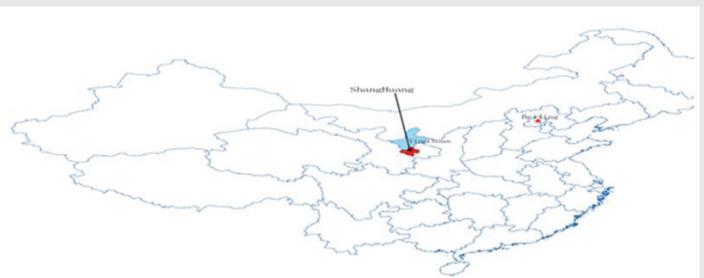

Figure 2: The study area of high-quality production of red plum apricots in the Chinese Loess plateau.

Hazards of peach fruit moth

In 2008, we 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 insect control experiment in the Orchard in Shanghuang Village and experimented. In late May, when the temperature is high, the red plum and apricot expand to 0.8 cm ~ 1 cm in diameter, and the edible worm develops at this time. The insect lays eggs on the fruit surface for incubation, and the hatched larvae enter the young fruit. At this time, we used high efficiency, low toxicity, and high-efficiency chlorine Cypermethrin 2000 times solution for the control experiment of edible worms, to kill the larvae, to ensure that the fruit was without insect pests, or 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 spraying fruit is very good 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, we found the serious hazards of heart-eating insects on the yield and quality of red plum apricots. A buyer picked up 100 kg of red plum apricots and found that there were 33 kg of red plum apricots injured by peach fruit moths in the 100 kg in an orchard. Then the method of spraying high-efficiency cypermethrin on the canopy was found and then popularized. 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 to Xi'an Guolian Quality Detection Technology Co., Ltd. to analyze the pesticide residues.

Even though there are different kinds of methods to kill heart-eating insects, such as using Sweet and sour sauce to kill heart-eating insects, the best method is to spray Beta-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 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 the 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.

Physical characteristics of soil

The experimental plots were located in the 23-year-old red plum apricot forest planted on the bench terrace in 1996 and the 1-year-old red plum apricot forest planted on the bench terrace in 2018. The sampling pits (soil profile) were dug in the red plum apricot forest at the experimental site for investigating soil profile and sampling purposes, whose dimensions were 1m×2m × 4 m depth on the red plum apricot forest on April 13, 2018. The undisturbed soil samples were collected 3 times at the depth of 0 to 5, 20 to 25, 40 to 45, 80 to 85, 120 to 125, 160 to 165, 200 to 205, 240 to 245, and 395 to 400 cm with cutting rings (a 5 cm in high, 5 cm in inner diameter and 100 cm3 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.

A cutting ring was used to measure the bulk density, total porosity, capillary porosity, and saturation moisture content. The core samples (undisturbed soil sample) collected were used with cutting rings to measure the soil bulk density, capillary porosity, and noncapillary porosity. The bulk density was determined by oven-drying the cores at 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/cm3. Noncapillary porosity was the difference between total porosity and capillary porosity. Soil particles were measured with a master sizer 2000 laser particle analyzer and grain size was graded on the USA standard. Soil water contents at different soil suction (0.1, 0.2, 0.4, 0.6, 0.8, 1.0, 2.0, 4.0, 6.0 bar, 1 bar = $1.0×10^5$ Pa) were measured by a HITACHI centrifuge, made by Instrument Co., Japan. Because Huangmian soil had been contracted when measuring with a centrifuge, the researchers measured the shrinking amount of soil samples in the cutting ring by vernier callipers 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 trees with average height and canopy as the sample of the study. Two holes 5.3 cm in diameter were made by holesaw in the place about 40cm 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 5.3 cm in diameter were made by holesaw in the middle of the radius of the 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 [14,21,22]. Before measuring the Volumetric Soil Water Content (VSWC),

the neutron probe was calibrated for the soil in the study area by using standard methods [23]. The calibration equation for this soil at the site is y = 55.76 x + 1.89, where y is VSWC, and x is the ratio of the neutron count in the soil to the standard count. The measuring depth ranged from 0 to 400 cm in the period from April to October, 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 depths, first put the probe into the aluminum access pipes and change the measuring line of the neutron probe to confirm whether or not the soil depth equals the planned depth of determination according to the display device of soil depth. Secondly, press the start button and then read and record the numbers of soil water content at different soil depths on the display screen of the neutron probe. The soil water content obtained for each measuring depth was taken to be representative of the soil layer that included the measuring point ± 10 cm depth, apart from that for the 5 cm depth, which was taken to represent the 0 to 10 cm soil. The measurements were also made before and after each rain event in the red plum apricot 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 colour of the leaf or the size of the 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 are approaching or smaller than SSWRULP in the 23-year-old red plum apricot tree. The measurements of red plum apricot tree growth were carried out in the time period from mid-April to October, and the measurements of precipitation and soil water were carried out from January to December 2018-2020.

Mathematical model

1) 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, the two-curve 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 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 the measuring line connected with the neutron probe sensor to the measuring soil depth according to the display device of soil depth in the neutron probe and measure and record soil water content at different soil depth and then draw the change of soil water content with soil depth before a rain event and after the rain event (two continuous soil water distribution curves or a

series of soil water distribution curves of soil water with soil depth at the same aluminum access pipes and there is a cross-location in the coordinate system in the soil profile before a rain event and after the rain event (or an infiltration process). The depth of infiltration during a rain event is equal to the distance from the surface to the joint location between two soil water distribution curves with soil depth. The MID, short for maximal infiltration depth is equal to the distance from the surface to the deepest joint lo-cation between two contiguous soil water distribution curves with depth in the soil profile at the beginning and the end of a period [13,24,25].

2) The change of wilting coefficient with soil depth: Because the 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 $w = a \cdot S^{-b}$ [24]. First, the Gardner empirical formula was transformed into $\ln(w) = a \times \ln(S) + b$, and then used to fit the relationship between soil water suction (S) and volumetric soil water content (w) at different soil depths, and then established the relationship between $\ln(w)$ and $\ln(S)$ by the least square method, and then estimate the wilting coefficient, which is the volumetric soil water content (w) at 1.5Mpa.

3) Soil Water Resources Use Limit by Plants (SWRULP): The mathematical model for calculating SWRULP is shown below:

$$SWRULP = \sum_{i-0}^{i-MID} \theta_w \times D$$

Here, SWRULP is Soil Water Resources Use Limit by Plant, expressed in mm. MID is maximum infiltration depth. Owi is the 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 the influence of the planting density on all the parameters measured and the effect of pipe position, planting density, and soil depth on soil water content. A regression analysis was then made to determine the different relationships, such as the soil water content and moisture suction relationship, and the relationship between the root density and soil depth using the least square method. Data were transformed when it was necessary to gain a linear relationship.

Results

Method for controlling low temperature and frost

There are different methods for controlling low temperatures and frost, such as irrigation in advance or covering with straw and so on. If we get the forecast of low temperatures and frost, it is difficult to irrigate in advance or cover with straw in large areas, but the best method of controlling low temperatures and frost is a greenhouse. In addition, the method of a greenhouse is not good for promotion because the investment is too big, a 600 m² greenhouse needs 100,000 RMB per 666.7 m².

Since 2017, we have investigated and compared the results of different methods for low temperature and frost and then found the better method to control the influence of low temperature and frost on the yield and quality of red plum apricot

Method for controlling the Hazards of peach fruit moth on fruit

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. However, the use of this method is influenced by the low temperature and frost control methods.

Method for controlling soil drying

The change of cumulative infiltration depths with time in red plum apricot forest: Infiltration is a process in which water enters the soil. The water infiltrated into soil has two functions. One is to increase soil water content in a soil layer, and another is to increase cumulative infiltration depth. The two curves method was used to estimate the depth of infiltration before and after a rain event or an infiltration process or several days. The infiltration depth for a rain event is equal to the distance from the surface to the crossover point between two soil water distribution curves with depth measured in the soil profile before and after a rain event or several days. A lot of the crossover points at the same height in the soil profile make up the wetting peak. The annual precipitation is 536.2 mm, which is 120.6 mm more than the mean precipitation of 415.6 mm and close to the maximum rainfall record of 634.7 mm in the National high-quality red plum apricot demonstration area, Figure 1. After two effective rain events, 9 mm on May 20 and 19.7 mm on April 13, infiltration depth reaches to 70 cm on April 28, 2018, Figure 3.

As time goes on, the cumulative infiltration depth increased with time in 2018 because the infiltration includes two stages: rainfall infiltration generally happening during a rain event, and cumulative infiltration [26] or reinfiltration [27], which occurs in the period between two rain events or a long-term period in which there are more than two rain events happens because there is a cumulative effect on the infiltration process. After a heavy rain event, a high water-bearing soil layer formed under the land surface. With time going by, the soil water content in the high water-bearing soil layer is reduced as it evaporates, 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 [24,28]. When the soil water content in the upper layer of the wetting peak is equal to the lower layer of the wetting peak, the cumulative infiltration process stopped because there is no infiltration force, the water potential difference and water

potential difference between the upper layer of the wetting peak and the lower layer of the wetting peak approaches zero. At this time, the cumulative infiltration depth is the maximum cumulative infiltration depth [25]. That is to say, the maximum cumulative infiltration depth is the maximum infiltration depth. The cumulative infiltration depth arrives at 130 cm on May 28, up to 150 cm on June 16, gets to 190 cm on July, 16, and finally to 290 cm. So, the maximum infiltration depth is 290 cm in red plum apricot forest, Figure 3, which is the same as the maximum infiltration depth in caragana shrubland [25].

The change of wilting coefficient with soil depth: Plants absorb water from the soil, which causes soil water content root reduce. Soil drying becomes severe and causes soil water stress in the soil layer near the root. At the same time, the water moves slowly from the soil layer nearest the root in the soil matrix driven by gravity and water potential gradients. The wilting coefficient for Huangmian Loess soil is the water content at -1.5 MPa in a given soil layer [9]. In the terraced land, 23-year-old red plum apricot tree root develops to a considerable soil depth and suck water in the dry year in the National high-quality red plum apricot demonstration area. Once a soil layer in which soil water content equals or is less than the wilting coefficient, the soil layer becomes a dried soil layer. The dried soil layer that happens in the soil layer deeper than the maximum infiltration depth is a 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 management should pay attention to soil water management in the soil layers from surface soil to maximum cumulative infiltration depth.
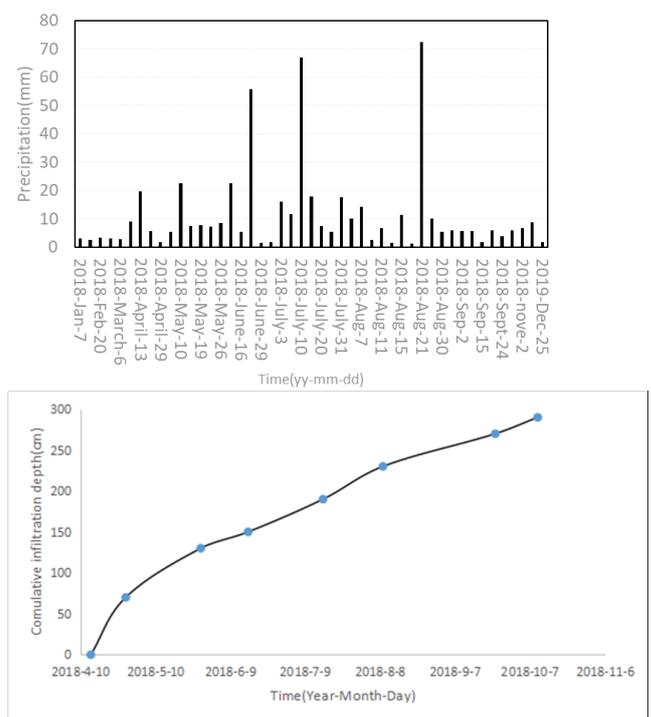

Figure 3: The change of precipitation (top) and soil infiltration depth (bottom) with time in the red plum apricot orchard in 2018.

006

Plant root water absorption is a process in which plant roots and soil particles contend for soil moisture. Along with plant growth and root water absorption, soil water content is reduced, and soil water stress increases in the soil around the root. When the soil water content in a soil layer reduces to a wilting coefficient, the soil water potential in a soil layer surrounding the root reaches balance with the water potential in the plant root cell, and the plant cannot absorb the water from the soil layer anymore. This balance point is the 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, See Figure 4. It can be seen that the volumetric soil water content drops with the increasing soil water suction from 0.01 Ba, 1Ba = 1×10^5 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 the 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 Figure 4. It can be seen from Figure 4 that field capacity at the suction of –0.33 MPa drops from 28.11% in 5 cm to 17.87 % in the 160 cm soil layer and then rises gradually to 21.82% in 400 cm with increasing soil depth. The wilting coefficient at the suction of $–15\times10^5$ Pa drops from 7.98 % in 0–10 cm to 6.68 % in 120 cm.

The Use Limit of Soil Water Resources by red plum apricot: The state of the vertical distribution of soil water in the root–soil zone space influences plant growth because soil water stress influences root growth and root water uptake. In order to express the stress of soil dry on plant growth, The term soil water resources use limit by plants was put forward [19,25]. If the soil water content in the MID is equal to the 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 colour of their leaf from green to yellow or croci and leaves fall earlier than usual time in the growing season. The red plum apricot tree almost ceased growing, and red plum apricot fruit does not expand, which influences the yield, quality, and economic benefits of red plum apricot fruit even if the roots extended to a depth of more than MID and could absorb some water from the soil layers more than 290 cm deep, suggesting that the total amount water that red plum apricot roots absorbed from the soil per unit time 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 Table 1, and the SWRULP in red plum apricot is 212.7mm, which is different from 252.8 in caragana shrubland at the middle and the top of
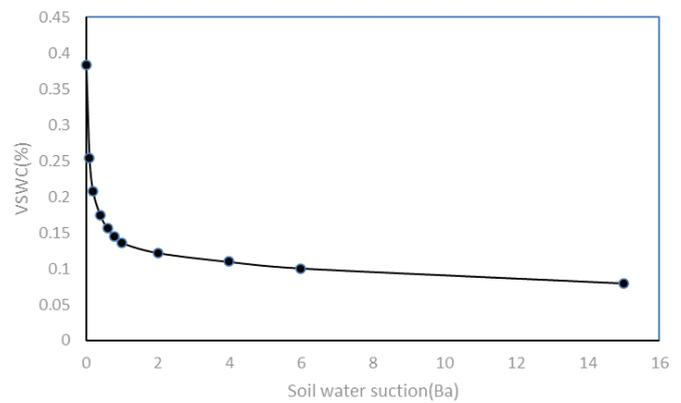

Figure 4: The relationship between the Volume Soil Water Content (VSWC) and soil water suction.

Table 1: The Use Limit of Soil Water Resources by red plum apricot in the semiarid region(guyuan,China).

Soil depth (cm)	Representative soil layer (cm)	Wilting coefficient (%)	Unavailable soil water storage (mm)
0	0-10	7.98	7.98
20	10-30	7.48	14.96
40	30-60	7.59	22.77
80	60-100	7.72	30.88
120	100-140	6.68	26.72
160	140-180	7.51	30.04
200	180-220	7.41	29.64
240	220-290	7.10	49.70
Use Limit of Soil Water Resources by plants	0-290		212.7

the Heici mountain and 220.8 mm in alfalfa grass, showed that the SWRULP changed with site condition and vegetation type [28].

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 plants. The soil water vegetation carrying capacity can be estimated by the two-curve method and is the most important theory for the sustainable use of soil water resources and the high-quality and sustainable development of forests, grass, and crops in water-limited regions. The indicator plants of artificial vegetation such as artificial forests, grasses, and crops are artificially cultivated trees or plants [14,25].

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 the soil water resources use limit by plants [10] to the ending time plant–water relation regulation is effective [16,20]. If the plant density is more than the 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 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 is based on the Use Limit of Soil Water Resources by red plum apricot and soil water vegetation carrying capacity.

As the air temperature increases 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 temperatures and frost, all the flowers of the red plum apricot tree froze to death on the morning of April 7. The red plum apricot tree germinates on April 30, and then spreads and grows. Because some water irrigation and the precipitation in 2018 is 536.2, is 120.6 mm higher than the average of 415.6 mm, Figure 1. and the volumetric water content in the 0 cm to 290 cm soil profile is more than the wilting point, Figure 5 and soil water resources in the MID is more than the soil water resources use limit by plant, the red plum apricot tree grows well. Up to June 16, new vimen grows up to 45 cm. By the end of the growing season in October, the width of a 1-year-old tree crown reached the range from 100 to 120 with an average of 110 cm in width, and the length of a 1-year-old tree crown reached the range from 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-year-old red plum apricot tree starts to bloom at the end of March and the flowers are in full bloom in the first ten-day period of April. The fruit is in the expansion period from the second ten-day period of May to the second ten-day period of June and matures in the first ten-day period of July. Unfortunately, all of the flowers wilt and died because of the cold temperature and frost on April 7, 2018. The 23-year-old red plum apricot tree began to spread leaf on April 30, and true leaf developed up to June 16 and grew well. The leaf dropped at the end of September because of some water irrigation and the precipitation was high, the volumetric water content in the 0 to 290cm soil profile was more than the wilting point, and soil water resources in the MID were more than the soil water resources use limit by the plant. The precipitation changed with time in 2019 (Figure 7) and the 24-year-old red plum apricot tree grew well and red plum apricot matured because the soil water resources in the MID are more than SWRULP.
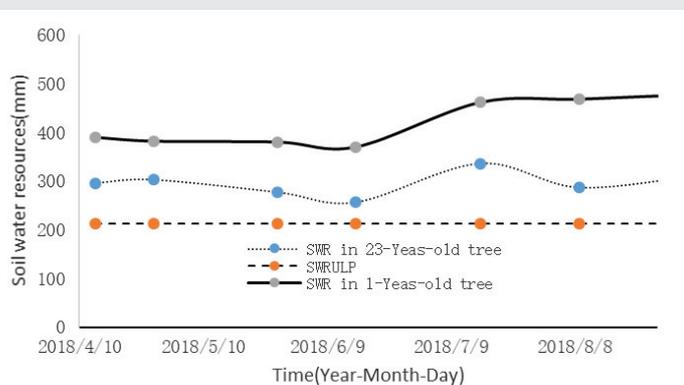

Figure 6: The relationship between Soil Water Resources in the MID and SWRULP in a 2-year-old red plum apricot tree and 24-year-old red plum apricot tree.

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 the Nation's high-quality red plum apricot demonstration area.

Discussion

Low temperature and frost, hazards of heart-eating insects, and soil dryness are the most important indicators that influence the high-quality production of red plum apricots. Low temperatures and frost often happen in the period of red plum apricot flowering and fruit setting period, and hazards of peach fruit moth often happen in the Spring from the first ten days in 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 methods such as a greenhouse or smudging to reduce the influence of low temperatures and frost after local weather reports. The influence of heart-eating insects on the quality and yield of Red plum apricots often happens by 20 May, we can spray 2000 times high-efficiency cypermethrin to the crown of Red plum apricots to reduce the hazards of heart-eating insects 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,

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.
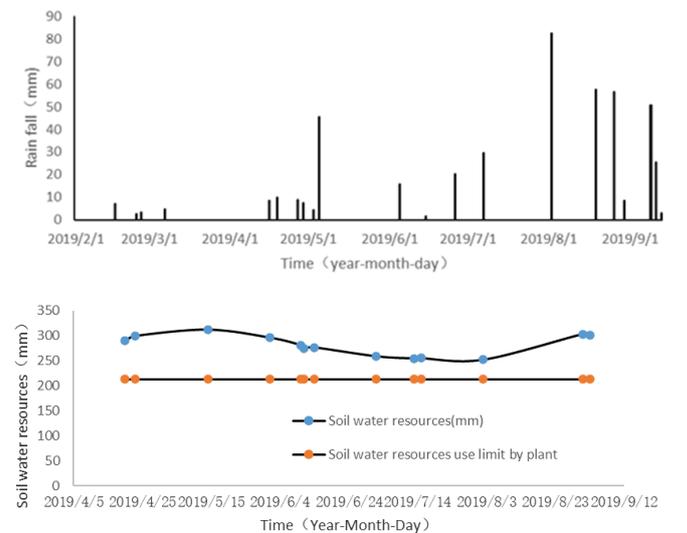
complicated, and important to effective water management, particularly soil water management in water-limited regions, such as the Loess Plateau in China. When planting red plum apricot trees, soil water content and the soil water resources in the soil root zone are high because the size of the canopy 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 taken up by plant roots would keep rising, which could cause a rapid decline of soil water content and soil water resources in the soil root zone even if there is some rise after a rain event, led to the appearance of soil drying and the dried soil layers in the soil profile [14,15]. Because soil drying has an accumulative effect, as the soil drying develops, dried soil layers develop. When the soil drying develops at this stage, the permanent dried soil layers, dried soil layers appear in the soil layer below the MID, the soil drying develops 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 the land [29] and sustainable use of soil water resources.

Because severe desiccation of soil and soil degradation harm the ecological and economic 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 the health of red plum apricot forest ecosystems in water-limited regions. Before controlling soil degradation, we should select a suitable index to differentiate 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 plans to accommodate it. 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 [30], soil moisture deficit index, evapotranspiration deficit index, and plant water deficit index [31]. These drought indices are divided into meteorological, hydrological, and agricultural drought indices [32]. Because most of the drought indices are based on meteorological variables [33] or a water balance equation, they do not account for water deficit accumulation or soil water storage [34], they cannot act as a suitable index for distinguishing severe drying of soil from soil drought phenomenon in the red plum apricot forest in the water-limited regions because soil drought is a nature phenomenon, a water deficit accumulation or a decrease in soil water storage in a given soil depth. We have to develop a new index.

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 conditions, soil water uses control limit by red plum apricot to express the severe drying of soil and act as a 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 the plant to avoid the form of permanent dried soil layers in the soil layers below MID.

The 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 natural soil profile because it destroys soil structure. The two-curve method was used to estimate the depth of infiltration and soil water supply for a rain event proposed by Guo [35]. A series of Two curve methods for maximum infiltration depth for a long-time infiltration process [15,24,25].

SWRULP is the most important criterion for plants to use soil water rationally [5,15,16,19,20,25,36-51], for it integrates 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 are equal to SWRULP, the plant-water relation enters the key period of plant-water relation regulation [5,16], we should estimate the SWCCV, especially SWCCV in the kay period of plant-water relation regulation [5,16] and regulate the plant water relation 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. Soil water in the key period of plant-water relation regulation seriously affects plant growth and maximum yield and beneficial results when the soil water resources in the MID are equal to or smaller than SWRULP.

SWRULP, 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 [5,20].

Conclusion

Soil desiccation is a natural phenomenon and often happens in water-limited regions. Soil desiccation and infiltration have an accumulative effect. When soil desiccation accumulates to a limit, it severely influences plant growth, causing soil degradation and threatening the quality and economic benefits of red plum apricots. 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 apricots, 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 plant water relation when soil desiccation develops to severely dry soil.

The SWRULP can serve as a standard to determine whether or not plants have excessively used soil water resources as well as the theoretic base to determine the start time of regulating plant water relation. The Soil Water Resources Use Limit by Red Plum Apricot is 212.7 mm. Because the annual precipitation in 2018 was 536.2 mm, which is 120.6 mm more than the mean precipitation and the soil water resources in the MID are more than the Soil Water Resources Use Limit by red plum apricot of 212.7 mm. When the red plum apricot grows well, we do not need to regulate plant water relations. When the soil water resources in the MID of 290 cm have reached the limit, the use of soil water resources by red plum apricots will reach their limit. We have to consider regulating the plant water relation and realize sustainable use of soil water resources and high-quality production of red plum apricots in water-limited regions.

Soil water resources use limit by plants is the sustainable use of soil water resources and high-quality production of red plum apricot, Because the interannual and seasonal variation of precipitation is great and plant water relation is complex in the study site, and the study of High-quality production of Red Plum Apricot in semiarid Loess hilly region need to continue to achieve high quality production of plum apricot, it is necessary to regulate peach fruit moth 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 Fruit setting period and the relationship between leaf quantity and high-quality fruit to get maximum yield and service. The study needs to continue because the soil water vegetation carrying capacity changes with time (climate), and there is about a 20-year cycle of precipitation in the study site. The investment in the greenhouse control method is too big to promote and needs to be reduced.

Acknowledgement

References

1. Khojastehnazhand M, Mohammadi V, Saeid M. Scientia Horticulturae. 2019; 251: 247-251.

2. Shi L, Guo Z. Journal of Ningxia agriculture and forestry science and technology. 1995; 1: 31-33.

3. Guo ZS. Industrial cultivation of orchard and garden economy in semiarid Loess hilly region. Practical forest technology. 2013; 9:82-85.

4. Guo ZS, Shi LM. The mathematical analysis of the production processes of fruit shoots. Chinese Journal of Biomass. 1993; 8(3):120-124.

5. Guo ZS.Soil water carrying capacity for vegetation. Land Degradation & Development. 2021; 32 (14) 3801-3811. https://doi.org/10.1002/ldr.3950.

6. Asgarzadeh H. Determination of soil available water for plants: Consistency between laboratory and field measurements. Geoderma. 2014; 226-227: 8-20.

7. Maharjan GR. Assessing the effectiveness of split fertilization and cover crop cultivation in order to conserve soil and water resources and improve crop productivity. Agricultural Water Management. 2016; 163(1):305-318.

8. Zhu XM. Soils of the Loess region in China. Geoderma. 1983; 29:237-55.

9. Yang WZ, Shao MA. Study on Soil Moisture in the Loess Plateau. Beijing, Science Press. 2000; 23-114.

10. Guo ZS, Li YL. Initiation stage to regulate the caragana growth and soil water in the semiarid area of Loess Hilly Region, China. Chin. J. Ecol. 2009; 29: 5721-29.

11. Li YS. The properties of water cycle in soil and their effect on water cycle for land in the Loess Plateau. Chinese Journal Ecology. 1983; 3: 91-101.

12. Chen HS. Soil desiccation in the Loess Plateau of China. Geoderma. 2008; 143:91-100.

13. Guo ZS, Shao MA. Impact of afforestation density on soil and water conservation of the semi-arid Loess Plateau, China. J. Soil Water Conserv. 2013; 58: 401-10.

14. Guo ZS, Shao MA. Carrying capacity of soil water for Vegetation in the Loess Plateau, In: Water-saving agriculture and sustainable use of water and land resources. Shaanxi Science and Technology Press, Xian. 2003; 704-11.

15. Guo ZS. Theory and Practice on Soil Water Carrying Capacity for Vegetation. Chinese Science Press: website at www.geobooks.com.cn. 2014.

16. Zhongsheng G. Soil Hydrology Process and Sustainable Use of Soil Water Resources in Desert Regions. Water. 2021; 13 (17) 2377. http://doi.org/10.3390/w13172377

17. Budagovski AI. Soil water resources and water supplies of plant cover, Vodnye. Resursy. 1985; 4:3-13.

18. Budagovski AI, Busarova OE. Basis of Method to Evaluate Changes in oil water resources and Rive Runoff for different Climate Change Scenarios, Resources, and Regime of Land Waters and Prediction of Their Change. Plenum Publishing Corporation, New York. 1992; 111-120.

19. Guo ZS. [Soil water resource use limit in semi-arid loess hilly area]. Ying Yong Sheng Tai Xue Bao. 2010 Dec;21(12):3029-35. Chinese. PMID: 21442986.

20. Guo Z. Agriculture High-quality development. Encyclopedic forum in Chinese. 2022; 01:64-66. https:// sns.wanfangdata.com.cn /sns/ perio/ bkltdzzz /?tabId=article&publishYear= 2022&issueNum=10&isSync=0&page=3

21. Wang GY, Shi XP, Zhang JH, Liang WL. A study on the comparison of measuring soil water content with TDR, neutron probe, and oven dry. Chinese Journal Agriculture University of Hebei. 2000; 23:23-26.

22. Evett SR. Soil water sensing for water balance, ET, and WUE. AGR. WATER MANAGE. 2012; 104:1-9.

23. Hauser VL. Neutron meter calibration and error control. Trans American Society Agriculture Engineering. 1984; 27:722-728.

24. Guo ZS, Shao MA. Soil water infiltrating process in afforested land on slopes of the semiarid region of Loess Plateau. Chin J. Soil Science. 2009; 46:953-58.

25. Guo Z. Estimating Method of Maximum Infiltration Depth and Soil Water Supply. Sci Rep. 2020 Jun 16;10(1):9726. doi: 10.1038/s41598-020-66859-0. PMID: 32546837; PMCID: PMC7297958.

26. Chowdary VM. Study of infiltration process under different experimental conditions. Agri. Water Manage. 2010; 83:69-78.

27. Corradini C. Modeling local infiltration for a two-layered soil under complex rainfall patterns. J. Hydrol. 2000; 237: 58-73.

28. Guo ZS. Utilization limit of soil water resources in water shortage areas. Proceedings of the Forum on Efficient Use of Water Resources and Water Saving Technology in China. 2017. https://kns.cnki.net/kcms2/article/abstract?v=lVku9qtM8H_EuZ2pWhXtelkgZiSuZg5U5uPDlI-IrH5KPU2hFxeOUa

29. Tian JL. Research on environmental effect of ecological and environmental construction on the Loess plateau, China Meteorological Press. Beijing. 2010; 88-98.

30. Palmer WC. Keeping track of crop moisture conditions, nationwide: the new crop moisture index. Weatherwise. 1968; 21:156–61.

31. Shi J, Li S, Zuo Q, Ben-Gal A. An index for plant water deficit based on root-weighted soil water content. Journal Hydrology. 2015; 522:285-94.

32. Mishra AK, Singh VP. A review of drought concepts. Journal Hydrology. 2010; 391:202-216.

33. McKee TB. The relationship of drought frequency and duration to time scales. In: Eighth Conference on Applied Climatology. American Meteorological Society, Anaheim, CA. 1993; 179-184.

34. Martínez-Fernández J, González-Zamor A, Sánchez N, Gumuzzio A. A soil water based index as a suitable agricultural drought indicator. Journal Hydrology. 2015; 522:265-273.

35. Guo ZS. Vegetation Carrying Capacity for Soil Water in A Semi-arid Region of Loess Hilly in the Loess Plateau, Dissertation for Doctoral Degree of Northwest Sci-Tech University of Agriculture and Forestry in. 2004; 74-79.

36. Arnold S. Effects of soil water potential on germination of co-dominant Brigalow species: Implications for rehabilitation of water-limited ecosystems in the Briga-low Belt bioregion. Ecol Eng. 2014; 70: 35-42.

37. Briggs LJ, Shantz HL. The wilting coefficient and its indirect determination. Botanical Gazette. 1912; 53:20-37.

38. Casadebaig P, Philippe D, Jrmie L. Thresholds for leaf expansion and transpiration response to soil water deficit in a range of sunflower genotypes. Eur J Agron. 2008; 28:646-54.

39. Guo ZS. A review of Soil Water Carrying Capacity for Vegetation in Wa-ter-limited Regions. Scientia Silvae Sinicae. 2011; 47(5):140-144.

40. Guo ZS. Introduction Experiment of High Calcium Tree Species, Saskatoon Berries in the Southern Part of the Ningxia Hui Autonomous Region of Semiarid Loess Hilly Areas. J. Soil and Water Conservation. 2016; 4:59-65.

41. Hao ZJ. Relationship between precipitation and the infiltration depth over the middle and lower reaches of the Yellow River and Yangtze-Huaihe River Valley. Prog. Nat. Sci. 2008; 18: 1123-28.

42. Ignaccolo M, Michele CD. A point-based Eulerian definition of rain event based on statistical properties of inter drop time intervals: An application to Chilbolton data. Advance Water Resource. 2010; 33:933-941.

43. Kramer PJ. Water Relations of Plant. Academic Press, New York, London, Paris, San Diego, San Francisco, São Paulo, Sydney, Tokyo, Toronto. 1983; 68-73.

44. Lvovich MI. Soil trend in hydrology. Hydrological Sciences Bulleting. 1980; 25: 33-45.

45. Ning T. Soil water resources use limit in the Loess plateau of China. Agriculture Science. 2013; 4: 100-5.

46. Araghi P, Mirlatifi SM, Dashtaki SG,Mahdian MH. Point estimation of soil water infiltration process using Artificial Neural Networks for some calcareous soils. Journal Hydrology. 2013; 481: 35-47.

47. Romano N. Soil moisture at local scale: Measurements and simulations. Journal Hydrology. 2014; 516:6-20.

48. Ungar ED. Transpiration and annual water balance of Aleppo pine in a semiarid region: Implications for forest management. Forest Ecology Management. 2013; 298:39-51.

49. Verma P. Root water compensation sustains transpiration rates in an Australian woodland. Advance Water Resource. 2014; 74:91-101.

50. Zhao L. A new plant height growth process model of Caragana forest in semi-arid Loess hilly Region. Chinese Journal Ecology. 2013; 33: 2093-103.

51. Corneo PE. Studying root water uptake of wheat genotypes in different soils using water δ18O stable isotopes, Agriculture. Ecosystems & Environment. 2018; 264(1):119-129.