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Research Article

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Critical Period of Plant Water Relation Regulation in Water-Limited Regions

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Abstract

As plant grow, the plant water relation changed, which is not good for sustainable use of soil water resources and agriculture high-quality development. The plant growth and soil water change has been investigated and the plant water relation has been researched.in the semiarid region, Guyuan, China. The results showed that soil water resources reduced as plant grow. When the available soil water resources in maximum infiltration depth of soil are equal to the soil water resources use limit by plants, plant water relation enters the critical period of plant water relation regulation. The ending time of critical period of plant water relation regulation is the ineffective time of plant water relation regulation, such as fruit stopping expanding or vegetation stopping service. The plant water relation in critical period of plant water relation regulation is the most important time for ensuring plant grow well and getting the maximum yield and benefit in water-limited regions. However, there are few reports. This research, taking the caragana and red plum apricot as an example to investigate the precipitation, soil water and soil water suction, plant growth, soil water and plant growth and then determinate the Critical period of plant water relation regulation. The result showed that when soil water resources in the maximum infiltration are equal to the soil water resources use limit by plants, plant water relation enters the critical period of plant water relation regulation, the ending time is the ineffective period of plant water relation regulation, such as the 15 July, red plum apricot fruit stopping expanding and or caragana is the end of September. in the semiarid region.

Keywords: Water-Limited Regions, Plant Water Relation, Soil Water Resources, Soil Water Resources Use Limit by Plants, Maximum Infiltration Depth, Critical Period of Plant Water Relation Regulation

1. Introduction

In recent years, agricultural production activities have been strengthened to produce more and more products to meet the food needs of the world's growing population for a better life. As plant grow, the canopy and the roots develop, the interception by canopies increases and the roots of these plants grow quickly and thus take up more water from considerable soil depths, which reduces the soil water supply and increases soil water consumption. Consequently, the water used by plants increased, and interception and low infiltration capacity and soil water recharge rates has led to serious soil drying with times going by. The dried soil layers (DSL) appeared and then its thickness of DSL increased, and soil drying widespread. Serious drying of soil eventually and poor self-regulation of plant result in soil and vegetation degradation and agriculture failure, which have adverse effects on sustainable use of soil water resources and the stability of forest vegetation ecosystems [1]. Thus we should take effective measures to regulate the non-equilibrium relationship between soil water and plant growth by reducing the population quantity or plant density of indicator plants in a plant community based on soil water vegetation carrying capacity (SWVCC) on the Loess Plateau to balance the soil water recharge and soil water consumption in ecosystem because soil in this region ranges from 30 to 80 m from the surface and the groundwater table is also deep ,without irrigation [2-6].

Caragana is a good brush for soil and water conservation and red plum apricot is a deciduous fruit tree and the best cash forest in

semiarid loess hilly regions [4]. Since having been selected as good varieties to popularize in 1995, the distribution area of red plum apricot spreads from Guyuan county to the whole Ningxia, and then to Gansu province and so on in the most of the water-limited regions, China the yield, benefits and planting area of red plum apricot increase doubly. But along with the growth of red plum apricot and precipitation, sometime soil drying become severer. Once serious drying happens, which led to the change of red plum apricot tree leaf colour from green to yellow or croci and drop earlier of the leaf. If serious drying happens in the fruit expansion stage, the size of red plum apricot fruit cannot expand to normal size, which influence the yield, quality and economic benefits of red plum apricot forest. At this time, the relationship between the soil water and red plum apricot growth must be regulated on Soil Water Resources Use Limit by Plant and Soil Water Carrying Capacity for Vegetation to reduce or evade the bad influence of soil drought on the yield and benefits of red plum apricot [4,5]. However, there are few studies of Critical period of Plant water relation regulation in water-limited regions and Use Limit of Soil Water resources by red plum apricot.

2. Material and Methods

This study conducted at National high quality red plum apricot demonstration area,which is located at the Shanghuang Eco-experiment Station in the semiarid Loess hilly region (35°59′-36°02′N, 106°26′- 106°30′E) in Guyuan, Ningxia Hui Autonomous Region of China, Institute of Soil and Water Conservation of Chinese Academy of Sciences, with the altitude of the station ranges from 1,534 m to 1,824 m. Precipitation here is absent in the periods from January to March and from October to December, and the rainfall from June to September makes up more than 70% of the annual precipitation. 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 with wide distribution in the semiarid hilly region of the Loess Plateau. Red plum apricot tree is a kind of fine variety apricot (*Armeniaca vulgaris* Lam.). The experiment was conducted in 23-year-old red plum apricot garden planted in 1996 and 1-year-old red plum apricot garden planted 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, leaf of red plum apricot tree changes colour from green to yellow or croci, and drop earlier. The size of red plum apricot fruit is smaller than normal fruit, which influence the yield, quality and economic benefits of red plum apricot.

The experimental plots located in the 23-year-old red plum apricot tree planted in the bench terrace in 1996 and 1~2-year-old red plum apricot forest planted in the bench terrace in 2018. The sampling pits (soil profile) was dug in red plum apricot forest at the experimental site for investigating soil profile and sampling purposes, whose dimensions were $1m^2 \times 4$ m depth on the red plum apricot forest in April, 13, 2018. The undisturbed soil samples were collected for 3 times at different soil depth. At the same time the disturbed soil of about 100g at each depth was collected for determination of soil structure at the State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau.

Cutting ring was used to measure the bulk density, total porosity, capillary porosity, saturation moisture content at the different soil depths. 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°C, and the total porosity was calculated as 1-bulk density/soil particles density, assuming that the density of soil particles was $2.65g/cm^3$. Noncapillary porosity was the difference between total porosity and capillary porosity. Soil particles were measured with master sizer 2000 laser particle analyzer and grain size was graded on the USA standard. Soil water contents at different soil suctions were measured by a HITACHI centrifuge, made by Instrument Co., Japan.

Select 1-year-old and 23-year-old red plum apricot tree with average height and canopy as the sample of study. 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.

3. Results

3.1. Soil water contents and soil suctions

According to the relationship between soil water and soil suctions, the wilting point can be estimated when the soil suction is equal to the suction of -15 MPa [5-8]. Because the soil construction changes with the soil depth, see figure 1, the wilting coefficient changes with soil depth. 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 1. It can be seen from Figure 1 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 -1.5×10^6 Pa changes from 7.98 % in 0-10 cm to 6.68 % in 120 cm.

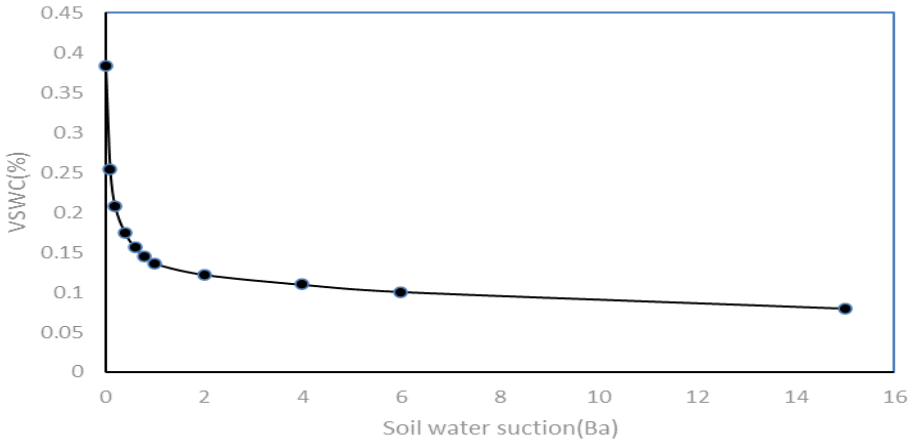


Figure 1: Volume Soil Water Content Change with Soil Water Suction

3.2. Infiltration Depth and Maximum Infiltration Depth

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 curves were 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. A lot of the crossover points at the same height in the soil profile makes up the wetting peak. The annual precipitation is 536.2 mm, which is 120.6 mm more than the mean precipitation 415.6 mm and close to the maximum rainfall record of 634.7 mm in the National high-quality red plum apricot demonstration area, see figure 1. After two effective rain events,

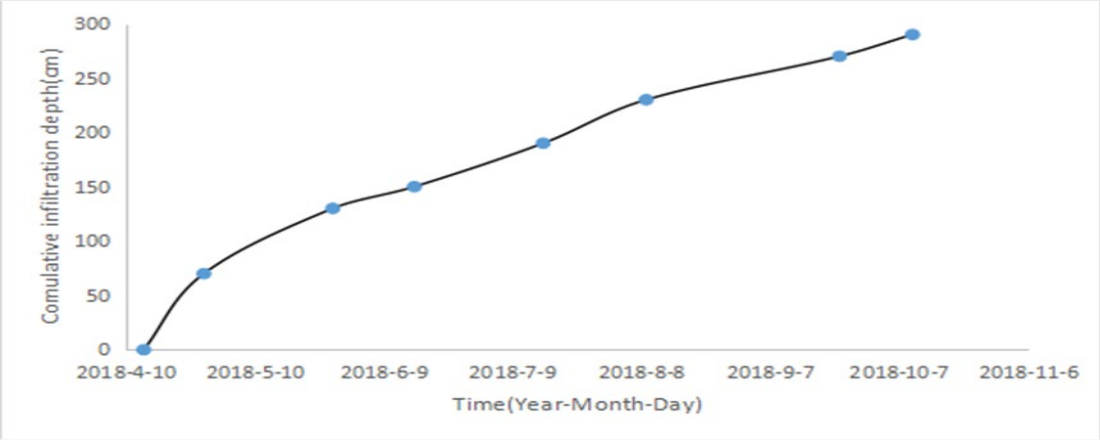


Figure 2: The Change of Precipitation (Photo above) and Soil Infiltration Depth (Picture below) with Time in Red Plum Apricot Orchard in 2018

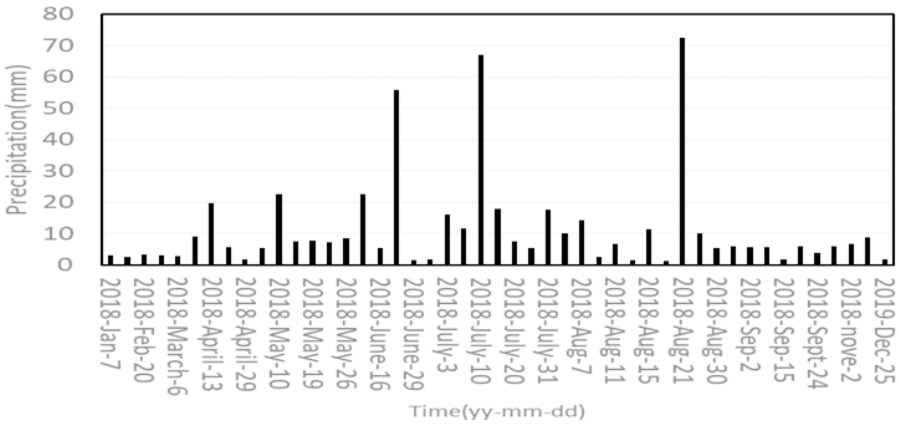


Figure 3: 9 mm in May 20 and 19.7 mm in April 13, Infiltration Depth Reaches to 70 cm on April 28, 2018, see figure 3

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 the cumulative infiltration or re-infiltration, 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 [9]. 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

3.3. Plant Water Relation

The concept of soil water resources come in 1985 after Lvovich MI proposed the concept of overall soil moistening in 1980 [10,11]. Soil water resources have different meaning in different field, such as Geology, Soil Science, Agriculture, Forestry and Animal Husbandry. To meet the need of different specialty, soil water resources can be classified into static soil water resources and dynamic soil water resources. Static soil water resources include generalized and narrow soil water resources. The generalized soil water resources 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 precipitation in the growing season for deciduous plant or a year for evergreen plants. Soil water resources are renewable water resources, a component of water resources [4].

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, flower in end of April and fruit mature in 15 July. Because some water irrigation and the precipitation in 2018 is 536.2, is 120.6 mm higher than the average of 415.6 mm. The volumetric water content in the 0 to 290cm soil profile is more than the wilting point and soil water resources in in the MID is more than the soil water resources use limit by plants, 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 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, 1~2-years-old red plum apricot tree grow well.

The 23~24-years-old red plum apricot tree start to bloom in the end of March and the flowers are in full bloom in the first ten-day period of April. The fruit is in the expansion period from the second ten-day period of May to the second ten-day period of June and mature in the in the first ten-day period of July. Unfortunately all of flowers wilt and die because of serious low 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, which cannot influence fruit develop because some water irrigation and the precipitation is high, the volumetric water content in the 0 to 290cm soil profile is more than the wilting point, and soil water resources in the MID is more than the soil water resources use limit by plant. The precipitation changes with time in 2019 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, plant water relation does not enter the Critical period of Plant water relation regulation, the Plant water relation does not need to be regulated on Soil Water Vegetation Carrying capacity for the sustainable use of soil water resources and high-quality production of red plum apricot in the period from 2018 to 2019[11].

If the plant density is more than soil water vegetation carrying capacity, the plant water relation regulation needs to be regulated to carry out sustainable use of soil water resources and agriculture high-quality development in water-limited regions [8-14].

If the soil water resources in the maximum infiltration depth are equal to the soil water resources use limit by plants, plant water relation enters the critical period of plant water relation regulation, which range from the moment soil water resources in the maximum infiltration is equal to the soil water resources use limit by plants to the ending time of the critical period of plant water relation regulation. The ending time of the critical period of plant water relation regulation for red plum apricot is the 15 July for red plum apricot because red plum apricot fruit stop expanding and mature in 15 July [15,16]. The ending time of the critical period of plant water relation regulation for caragana shrub is the end of September in the semiarid region of loess plateau, China because caragana shrub is soil and water conservation vegetation in this region [17]. In the end of September, raining season is stop and there is not soil and water loss happen [18-20]. At this period, the plant water relation regulation needed to be regulated by watering according to plant water requirement or reduce plant density or leaf amount according to the soil water vegetation carry capacity or suitable leaf amount in the critical period of plant water relation regulation to keep plant grow well and insure plant get quality fruit [3-14].

4. Conclusion

The critical period of plant water relation regulation is the most important theory for sustainable use of soil water resources and agriculture high-quality development in water-limited regions. If the soil water resources in the maximum infiltration depth are equal to the soil water resources use limit by plants, plant water relation enters the critical period of plant water relation regulation, which is from the moment soil water resources in the maximum infiltration is equal to the soil water resources use limit by plants to the ending time of the critical period of plant water relation regulation, which is ineffective time of plant water relation regulation. The ending time of the critical period of plant water relation regulation for red plum apricot is the 15 July, and the ending time of the critical period of plant water relation regulation for caragana is the end of September because it is the end of plant growth and raining season, the caragana stop service for soil and water conservation.

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