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GROWTH, BIOMASS AND WATER POTENTIAL OF *PINUS YUNNANENSIS* FRANCH. SEEDLINGS UNDER DIFFERENT WATER TREATMENTS

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Abstract

To study the growth, biomass and water potential under different water control, two-year old *Pinus yunnanensis* Franch. seedlings were potted under four different water content levels: normal water content (T1), mild drought (T2) , moderate drought (T3) and severe drought (T4), which were controlled by weighing the soil. Results showed that: (i) when water stress became more severe, the heights, base diameters of the seedlings increased significantly, the soil and leaf water potential were decreased, the stem and leaf biomass percentage of the total were increased, the root biomass and root shoot ratio were increased. (ii) The height was positively correlated with diameter, and soil water potential was positively correlated with leaf water potential. Growth indexes are negatively correlated with water potential indexes for the most part. The growth and biomass index under four different water treatments was positively correlated, and the correlation relationship was significant.

Introduction

*Pinus yunnanen*sis (Franch.) was the main tree species and also the endemic species of south-west mountain of Yunnan, which was the distribution center (Jin *et al.* 2004). According to 1997 data, *Pinus yunnanensis* forest area was 1,812,800 hm^2, accounting for 29.98% of Yunnan land area (394000 km^2), that means nearly one-third of Yunnan province land area had *Pinus yunnanensis* woodland (the writing committee of Yunnan forest). However, the area of high quality *Pinus* forest was only 3,448,400 hm^2 in Yunnan province, which accounts for 29.19 per cent of forest area Yunnan, it means there were more than two-thirds of *Pinus* low-quality forest woodland in needs of reforestation. It shows that there were large area (8,364,400 hm^2) for woodland planting of *Pinus*, and the certified seeds of *Pinus* are in great demand in Yunnan (Dai and He 2006).

The hardening of seedlings of *Pinus* plantation in three years was serious, and the growth above the ground was extremely slow which restricted economic and ecological benefits of young generation. Earlier scientists had done a lot of research in genetics, breeding, seedling cultivation, yield cultivation techniques, allelopathy and other aspects at *Pinus* (Li *et al.* 2010, Ren *et al.* 2006, Zhu *et al.* 2009). But these studies were restricted only to the technical aspects, and the impacts on the hardening of seedling growth and biomass characteristics under different conditions are lacking (Tang 1983, Wang 2008, Li. 2010).

Therefore, the growth, biomass and water potential characteristics under different water control of *Pinus* seedlings were measured and analyzed (Xiao *et al*. 2004, Li *et al*. 2009, Wang 2007, Fu *et al.* 2005). The nursery technical measures and physiological indicators of *Pinus* seedlings were also linked to study, which aimed at providing a theoretical basis for the promotion and cultivation technologies of *Pinus*, and to finding the cause of hardening of seedlings and promoting healthy growth of *Pinus*.

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Materials and Methods

The study was done in the greenhouses and Plant Physiology laboratory of College of Forestry, South west Forestry University from April to October in 2014. The plant materials two-year potted *Pinus* seedlings were planted in clay, humus and cinders matrix, measured the leaves of robust and consistent growth under different water treatments.

A randomized complete block design was used. In all four, normal water (T1), mild drought (T2), moderate drought (T3) and severe drought (T4) water treatments gradient were set up, repeating three times for each treatment. Each treatment contain 25 pots; using weighing method for water control. The soil moisture of T1, T2, T3 and T4 were 75 to 80, 55 to 60, 40 to 45% and 25 to 30% of field water holding capacity, respectively. *Pinus* seedlings growth were measured using a measuring tape and a pair of slide calipers for the height (H, cm) and diameter (D, cm) at the level marked in each treatment, respectively.

Leaf and soil water potential were measured: using HR-33T dewpoint meter water potential instruments. HR-33T dew point microvolt meter was an embedded electronic systems, which can measure water potential by a thermocouple sensor.

Biomass measurement was done using the oven drying method of taproot, lateral root, root volume, stem, leaf by dry and fresh weight.

Excel, SPSS software was used for statistical analysis of data, processing of its data, and compared the difference of data among the treatments.

Results and Discussion

It can be seen from Fig. 1, with the increasing degree of water stress, the height and diameter of *Pinus* seedlings slowly increased; which were normal growth under different water conditions, and showed strong drought tolerance at early growth of *Pinus*. Between the height and diameter there existed a significant difference, N = 64, F = 6.891/F = 9.572, $p < 0.01$.

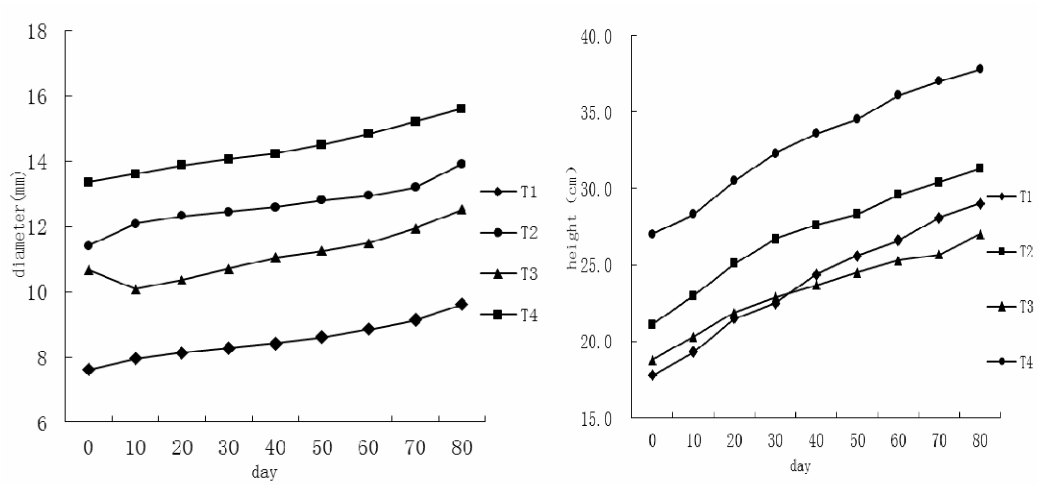

Fig. 1. Diameters and heights of the seedlings of *Pinus yunnanensis* under different water treatments.

The diameter and height of annual potted *Pinus* seedlings under different water gradient treatments showed a growth trend over time. Under the T2 water gradient condition, the diameter increased fastest over time, followed by the T1, T3 treatments, and the slowest was in T4. So the trends of diameter changes under four different kinds of water treatments conditions was as follows T2> T1> T3> T4 from the beginning to 90 days.

Among them, the height of *Pinus* seedlings increased fastest under the T1 water gradient control, followed by T2, and the height increased slowest under the T4 water control conditions. The height was measured from beginning to 90 days, and the trends of height changing extent was T1> T2> T4> T3.

Water potential is comprised of osmotic- and pressure potential. Pressure potential is an important indicator of measuring water status of seedlings, which is very sensitive to the response of water stress, almost all physiological processes *in vivo* seedlings will be reflected in the pressure potential, and dropped below a certain level, if the duration of water pressure potential was too long, it will produce permanent injury or even death to seedlings. Osmotic potential is a negative pressure, which is produced by integrating the solute and other substances into the zero potential of the pure water. The osmotic potential reduced with the increasing concentration of the solute, and becomes zero in pure water. Water potential varied with the seedlings and soil water absorption, dehydration. When the seedlings absorbed enough moisture, its water potential becomes zero. With the water loss, through the membrane, and solute was left behind, so the intracellular solute concentration increased, and osmotic potential reduced. Meanwhile, because the cells lost their original volume, the pressure potential also reduced ultimately, and the water stress of seedlings increased.

It can be seen from Fig. 2, the leaf water potential trend under four moisture gradient is T4>T3>T2>T1. The more arid is its condition, the more quick is the leaf water potential change. The changing trend of soil water potential is T3>T4>T2>T1 under different water gradients. However, the soil water potential was declining and becomes lower than at the beginning of the experiment. With the aggravation of drought, water potential was relatively large. So different water treatments had some effect on the water potential.

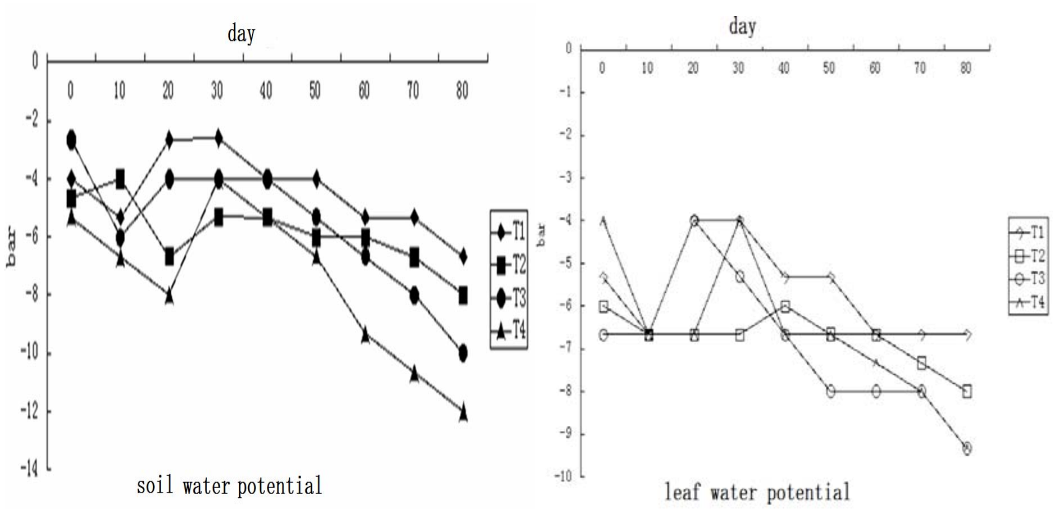

Fig. 2. Leaf and soil water potential of the *Pinus yunnanensis* seedlings under different water treatments.

As can be seen from Fig. 3, the root biomass in four water treatments were slowly increased with the extension of water stress, the percentages of root biomass increased were 26.97, 31.19, 33.15, 40.72%, and its order is: T4 > T3 > T2 > T1. It showed that the *Pinus* seedlings had some adaptability to drought environmental conditions under T3, T4 water treatments, and plants absorbed more water and nutrients under drought conditions, plant roots showed significant plasticity by extending around, roots allocated more biomass to roots growing preferentially in order to increase its drought tolerance.

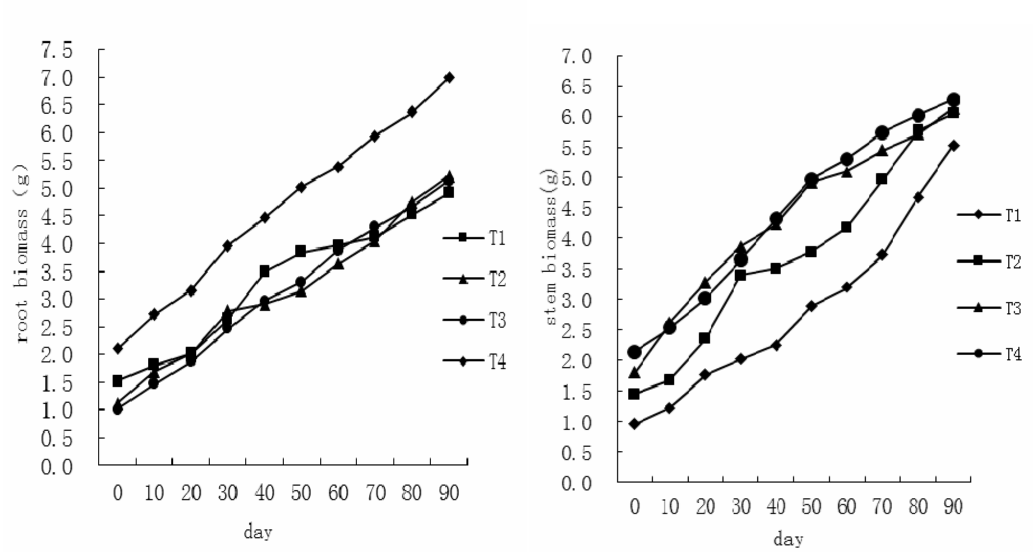

Fig. 3. Effects of different water treatments on the root and stem biomass.

The stem biomass in T1, T2, T3 and T4 water treatments slowly increased with the extension of water stress, but the rate of increase was slightly different. The percentage of stem biomass increments for T1, T2, T3 and T4 treatments were 36.34, 34.90, 34.78, 34.50%, and its order is: T1> T2 > T3 > T4, which showed that in stem the biomass accumulation is affected under drought conditions, and the biomass increment distribution in proportion to the stem decreased with the intensity of drought condition.

As can be seen from Fig. 4, the leaf biomass in T1, T2, T3, T4 four water treatments slowly increased with the extension of water control, but the rate of increase was different. The percentage in leaf biomass increment under four water treatment are 36.69, 33.91, 32.08, 24.77, and its order is: T1 > T2 > T3 > T4, and the percentage in leaf biomass increment under T1 water treatment was significantly larger than that of T4. It meant that T1 water treatment can promote the accumulation of leaf dry matter, and T3, T4 water treatments inhibit the growth and accumulation of leaf dry matter, with the increase of drought intensity. The findings indicated *Pinus* will slow down the growth rate of leaves and leaf dry matter accumulation in order to adapt to the arid environment, which reduced water, nutrients consumption and allocate more biomass to other organs such as root to increase the ability to adapt to drought conditions.

From Fig. 4, the variation of shoot ratio with the water control under four water treatments showed that it had little change in T1 before and after the water control, in the water treatments of T2 tended to increase after 60 days of water control, while it increased in T3, T4 water treatments over time, the shoot ratio after 90 days of water control was significantly higher than what was before the water control. It indicates that different water treatments has some impact on the shoot ratio of seedlings, the distribution of aboveground biomass and underground biomass under drought conditions, and the more biomass was allocated to the organ of the underground part, which was leading to the increasing trend of shoot ratio.

The correlation analysis in 15 samples of height, diameter, soil water potential, leaf water potential, root and stem biomass, shoot ratio were made, using SPSS 19.0 software for data processing of normal water (T1), mild drought (T2), moderate drought (T3) and severe drought (T4), which indicates that height and diameter had positive correlation under normal water conditions ($r = 0.969$, $p < 0.01$), leaf water potential and soil water potential have a positive correlation ($r = 0.951$), height, stem and leaf biomass (dry weight) are positively correlated (r = 0.970,0984), and reached a significant level of correlation ($p < 0.01$), positively correlated with root biomass reached significant level ($r = 0.882$, $p < 0.05$); the diameter and root, stem, leaf biomass (dry weight) also show a significantly positive correlation ($p < 0.01$).

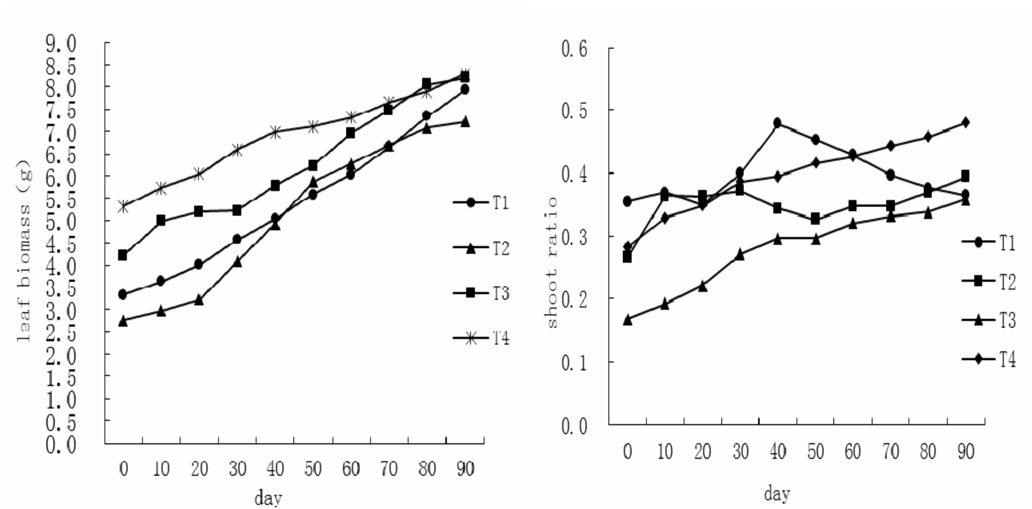

Fig. 4. Effects of water stress on the leaf biomass and distribution of root shoot ratio.

Under mild drought conditions the height and diameter, leaf water potential and soil water potential ($r = 0.955, 0.770$, $p < 0.05$) show a positive correlation, the height (or diameter) or leaf water potential and soil water potential are negatively correlated relationship. The height, stem and leaf biomass (dry weight) are positively correlated ($p < 0.01$), the height and root biomass reached significant levels of positive correlation($r = 0.842$, $p < 0.05$); the diameter and root, stem biomass (dry weight) are positively correlated, and the correlation is highly significant ($p <0.01$) shows positive correlation with leaf biomass ($r = 0.857$, $p < 0.05$).

Under moderate drought conditions the height and diameter are positively correlated ($r = 0.873$, $p < 0.05$), and a negative correlation between soil water potential is observed, and leaf water potential was no significant correlation; diameter and soil water potential, leaf water potential are negatively correlated; leaf water potential and soil water potential have a positive correlation. The height and root, stem and leaf biomass (dry weight) are positively correlated and the correlation is significant ($p <0.01$); the diameter and root biomass (dry weight) are significantly correlated ($r = 0.924$, $p < 0.01$), the stem and leaf biomass are positively correlated ($p < 0.05$).

Under severe drought conditions the height and diameter are positively correlated ($r = 0.837$, $p < 0.05$), height (or diameter) and soil water potential or leaf water potential have negative correlation, the soil water potential and leaf water potential has a positive correlation relationship. Height and root, stem, leaf biomass (dry weight) have positive highly significant correlation (p <

0.01); the diameter and root biomass (dry weight) have significant positively correlated (r = 0.980, p < 0.01), and stem biomass (dry weight) has significant positive correlation (r = 0.821, p < 0.05), and leaf biomass (dry weight) are positively correlated (r = 0.787, p < 0.05).

The height and diameter under four gradient water treatments continued to increase over time. However, the height and diameter growth relatively decreased from normal water, mild drought, and moderate to severe drought (Jing *et al*. 2005, Kang *et al*. 2007). The soil and leaf water potential showed a downward trend by two year *Pinus* seedlings. But the amount of soil water potential was always greater than the variation of leaf water potential in the same period, and soil water potential and leaf water potential had positive correlation. The above two points showed the change of soil water potential caused by the variation of leaf water potential, and which affected the growth of seedling to a certain extent.

Root, stem and leaf biomass increased differently with prolonging water stress (Wang *et al*. 2001), and the increment were different. The root-shoot ratio under water control after was greater than water control before significantly, and the root-shoot ratio increased with the enhancement of drought intensity. It showed the biomass increment proportional allocation to root organs increased with the drought intensity increasing, while the proportion of allocation to stem and leaf organs reduced. In order to meet the nutrient and water requirements of root priority growth under the condition of drought, the growth of stem and leaf will reduce water consumption of nutrient, thus promoted the growth of root system, which improved their ability to fight the drought through such an adjustment mechanism.

There is a strong correlation between the growth index and biomass index, the diameter and height (Qin *et al*. 2010, Huang *et al*. 2007). It showed that the moisture control has a certain impact on the correlation between the growth index, the growth and biomass index, but the correlation between the growth and biomass index is higher and reflects the coordination and integrity of biomass accumulation in dry matter and the growth of Pinus seedlings.

It can be concluded that the growth of *Pinus* seedlings through the protective enzyme system and osmatic adjustment substances could avoid water stress, which led to some tolerant ability to drought conditions. The biomass of *Pinus* seedlings roots increased, while the biomass allocated to stem and leaf organs decreased, which improved the drought resistance ability.

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