Postprint: Seasonal Dynamics of Soil Moisture in Longdong Apple Orchard Grass-Intercropping System

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Abstract

The semi-arid region of the Longdong Loess Plateau is characterized by substantial interannual variation in rainfall and uneven intra-annual distribution. Optimizing orchard grass planting practices not only mitigates excessive soil water consumption by forage grasses during dry seasons but also enhances ecological conservation functions. To investigate the effects of planting different forage grasses on seasonal dynamics of soil moisture in rain-fed orchards, four treatments were established: inter-row planting of orchardgrass, white clover, and mixed forage grasses (orchardgrass and white clover) in apple orchards, and a clean-tilled orchard. The results indicated that: under mild spring drought conditions, orchardgrass and legume-grass mixed forage grasses reduced orchard soil moisture, whereas white clover had no significant effect; following prolonged summer drought, planting forage grasses significantly reduced water content across all soil layers; throughout the growing season, evapotranspiration in orchards planted with orchardgrass, mixed forage grasses, and white clover increased by 45.3 mm, 55.4 mm, and 0.7 mm, respectively, compared with the clean-tilled orchard. Consequently, in apple orchards of the semi-arid Longdong Loess Plateau, planting high water-consuming gramineous plants such as orchardgrass should be avoided, while water-efficient leguminous plants such as white clover can be adopted to improve orchard environments. These findings provide valuable guidance for optimizing grass planting practices in rain-fed orchards of the Longdong Loess Plateau.

Full Text

Seasonal Variation of Soil Moisture Content in Apple Orchard and Grass Intercropping System in Longdong

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Abstract

Precipitation in the semi-arid area of the Loess Plateau exhibits large interannual variability and uneven distribution within each year. Improvement of forage grass covering patterns could not only reduce water consumption during drought seasons but also promote ecological conservation benefits. The present work was conducted to investigate the effects of different grass species on soil water distribution in apple orchards. The field experiment was carried out at the Qingyang Grassland Agriculture Experiment Station of Lanzhou University under four treatments of different grass species: *Dactylis glomerata*, *Trifolium repens*, and mixed planting of these two species. Results showed that planting orchard grass and the mixture could reduce soil moisture content in different layers in the orchard under light drought in spring, but the effect of planting *T. repens* on soil moisture content was not significant. During the period with moderate or severe drought in summer, the soil moisture content under forage grass mulching treatment was significantly lower compared with that in the clean-tilled orchard. The evapotranspiration values of the planted *D. glomerata*, mixed planting, and *T. repens* orchard were 45.3 mm, 55.4 mm, and 0.7 mm higher respectively than that of the clean-tilled plots in the growing season, but the effect of planted *T. repens* on evapotranspiration in the growing season was not significant. Therefore, it is practical to plant species with low water consumption (such as *T. repens*) for improving the orchard environment instead of species with high water consumption (such as *D. glomerata*) on the semi-arid Loess Plateau.

Keywords: apple orchard; grass planting; soil moisture content; evapotranspiration; the Loess Plateau

1. Materials and Methods

1.1 Experimental Site The experiment was conducted at the Qingyang Grassland Agriculture Experiment Station of Lanzhou University (35°40 N, 107°51 E, 1297 m altitude). The site has a mean annual precipitation of 527.6 mm (1981-2014), mean annual temperature of 9.2°C, mean relative humidity of 61.8%, mean wind speed of 2.2 m · s ¹, and a frost-free period of 150–190 days. The soil is classified as loessal soil with uniform texture. Soil physicochemical properties in different layers are presented in .

1.2 Experimental Design The experiment was arranged in a randomized complete block design with four treatments and three replications. The treatments included: (1) clean tillage (control), (2) *Dactylis glomerata* planting, (3) *Trifolium repens* planting, and (4) mixed planting of *D. glomerata* and *T. repens* (2:1 ratio). Each plot measured 4 m × 4 m with 70 cm row spacing and 260 cm between rows. Grasses were sown in July 2014 at seeding rates of 15 kg · hm ^{2} for *D. glomerata* and 22.5 kg · hm ^{2} for *T. repens*.

1.3 Measurements and Calculations Soil moisture content was measured using a soil moisture monitoring system (Vantage Pro2, Davis Instruments, USA) at depths of 0–120 cm. Soil water storage was calculated using the formula:

$$W = \theta_g \cdot \gamma \cdot h$$

where θ_g is the gravimetric soil moisture content (%), γ is the soil bulk density (g · cm ^{3}), and h is the soil layer thickness (cm).

Evapotranspiration (ET) was calculated using the water balance equation:

$$ET_a = P + I + CR + W_1 - W_2 - R - DP$$

where ET_a is the actual evapotranspiration (mm), W_1 and W_2 are the initial and final soil water storage (mm), P is precipitation (mm), R is runoff (mm), I is irrigation (mm), CR is capillary rise (mm), and DP is deep percolation (mm). Due to the experimental conditions with flat terrain, no irrigation, and negligible capillary rise and deep percolation, the equation was simplified to:

$$ET_a = P + W_1 - W_2$$

2. Results

2.1 Soil Moisture Distribution During the growing season, soil moisture content varied significantly among treatments and soil depths. Under light spring drought conditions, grass planting reduced soil moisture content in the 0–20 cm layer, with the reduction being more pronounced in the *D. glomerata* treatment (18.7%–46.0% decrease) compared to *T. repens*. The mixed planting treatment showed intermediate effects.

During moderate to severe summer drought periods, all grass treatments exhibited significantly lower soil moisture content than the clean-tilled control throughout the 0–60 cm profile. The *D. glomerata* treatment showed the greatest reduction, followed by mixed planting, while *T. repens* had the smallest effect [Figure 3: see original paper].

2.2 Soil Water Storage Dynamics Soil water storage in different layers showed distinct seasonal patterns [Figure 4: see original paper]. In the 0–20 cm layer, water storage under grass treatments was consistently lower than the control, particularly during dry periods. The *D. glomerata* treatment reduced soil water storage by 430.1 mm, mixed planting by 440.2 mm, and *T. repens* by 385.5 mm over the growing season. Below 60 cm, differences among treatments diminished, indicating that grass effects were primarily confined to the upper soil profile.

2.3 Evapotranspiration Total evapotranspiration during the growing season was significantly higher in grass-planted treatments compared to clean tillage. The *D. glomerata* treatment increased ET by 45.3 mm, mixed planting by 55.4 mm, and *T. repens* by only 0.7 mm . The minimal increase in ET under *T. repens* suggests its water consumption was similar to the control, likely due to its shallow root system and lower transpiration rates.

3. Discussion

The results demonstrate that grass species selection critically influences soil water dynamics in apple orchards on the Loess Plateau. *Dactylis glomerata*, with its deep root system and high water demand, significantly depleted soil moisture throughout the profile, which could exacerbate water stress during drought periods. In contrast, *Trifolium repens* had minimal impact on soil moisture and evapotranspiration, making it suitable for orchard ground cover without compromising water availability.

The mixed planting treatment showed intermediate effects, suggesting that combining species may balance ecological benefits and water consumption. However, the higher ET in mixed plots compared to monocultures indicates potential competition for water resources.

These findings align with previous studies on the Loess Plateau, which reported that appropriate ground cover management can improve soil properties while maintaining water balance [**?**, **?**, **?**]. The negligible effect of *T. repens* on soil moisture suggests it can provide soil conservation benefits without significantly increasing water consumption, making it particularly suitable for semi-arid regions where water scarcity is a primary constraint.

4. Conclusion

For apple orchards in the semi-arid Loess Plateau, planting low water consumption species such as *Trifolium repens* is recommended for improving the orchard environment without exacerbating water stress. High water consumption species like *Dactylis glomerata* should be avoided, especially in areas with limited water resources. Mixed planting systems require careful management to optimize the trade-off between ecological benefits and water consumption.

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Note: Figure translations are in progress. See original paper for figures.