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Water requirement pattern for tobacco and its response to water deficit in Guizhou Province

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Abstract

The water requirement pattern for tobacco (Yun 85) was identified based on analysis of data obtained from pot experiments in a canopy at the Xiuwen Irrigation Test Central Station in Guizhou Province, China. The results showed that the tobacco water requirement and the tobacco water requirement intensity throughout the growth period in pot experiments were significantly lower than those in field production. In pot experiments, the tobacco water requirement throughout the growth period ranged from 159.00 to 278.90 mm, with a reduction in the range of 241−441 mm, as compared with that in field production. Also, the average water requirement intensity at the vigorous growing stage was 1.97 mm/d, and the water requirement and water requirement module were 33.80−72.60 mm and 16.39%−33.09%, respectively, at the group stage, almost equal to their values at the vigorous growing stage. The patterns of the tobacco water requirement and water requirement module in pot experiments were different from those in field production. In pot experiments, the tobacco water requirement and water requirement module ranked the highest at the mature stage, followed by those at the group/vigorous growing and rejuvenation stages, while the water requirement intensity ranked the highest at the vigorous growing stage, followed by those at the mature, group, and rejuvenation stages. The pattern of the water requirement intensity in pot experiments was consistent with that in field production. In addition, the response of the tobacco water requirement to water deficit was also analyzed. Serious water deficit at the vigorous growing stage and continuous water stress at the group, vigorous growing, and mature stages can greatly influence the tobacco water requirement. Water deficit led to reductions in the water requirement and water requirement intensity at each growth stage. The vigorous growing stage exhibited the highest sensitivity to water deficit. The lower limit of moderate soil water stress at the vigorous growing stage was 65% of the field capacity. Results of this study can help to establish a reasonable irrigation schedule for tobacco production in Guizhou Province, China.

Keywords: Water requirement; Protected cultivation; Water deficit; Tobacco; Guizhou Province

1. Introduction

Tobacco (Yun 85) originated in South America but has now been cultivated around the world (FAO, 2001). China accounts for about 80% of worldwide total tobacco production and brings in significant income. Irrigation plays an important role in tobacco growth. Identification of the water requirement pattern is essential in water irrigation research (Romeroa et al., 2009). Many studies have been conducted on the water requirement patterns of rice and wheat (Wang et al., 2003; Bodner et al., 2007; Parent and Anctil, 2012), but studies on the tobacco water requirement are rarely reported. Clarification of the tobacco water requirement would be of great significance to water-saving irrigation due to the large amount of agricultural water consumption and low agricultural water use efficiency in karst areas in Guizhou Province.

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Related research on tobacco water requirements, yield, and quality has been performed by Orphanos and Metochis (1985) and Caldwell et al. (2010) in Nepal. Physiological characteristics of tobacco response to water deficit stress were clarified by Muthappa et al. (2010). Effects of different irrigation scheduling programs and water stresses on the maturity and leaf chemistry of Virginia tobacco at different growth stages have been studied in Ataturk soil by Cakir and Cebib (2010) at the Water Resources Research Institute in Kirklareli, Turkey. Effects of irrigation systems and fertilization on the growth, yield, and nicotine content of tobacco leaves have also been discussed by Ju et al. (2008). Cakir and Cebib (2010) concluded that irrigation scheduling programs and water stress at different growth stages could influence the ripening of Virginia tobacco, and severe water stress causes a delay in tobacco ripening. Muthappa et al. (2010) followed a stress imposition protocol that allowed plants to experience an initial gradual acclimation stress and, subsequently, severe stress for a definite period. However, there have been few studies on water requirements and effects of water supply on the growth, dry matter accumulation dynamics, yield of tobacco, and especially, the yield response to water deficit (Cakir and Cebib, 2006, 2009). Soil moisture dynamics, water use efficiency, and the relationship between soil moisture and tobacco transpiration have been examined in Henan, Jiangsu, Hunan, and Guizhou provinces, and a water production function of transpiration has been established (Wang et al., 2007; Hajiakbar et al., 2006; Gao and Gu, 2012). Moderate soil water stress can reduce excessive water consumption, thereby improving water use efficiency and enhancing crop quality and yield.

This study was based on experimental tobacco cultivation data from the Xiuwen Irrigation Test Central Station in Guizhou Province. The tobacco water requirement pattern and its response to water deficit were analyzed. The results can provide a scientific basis for the establishment of a proper irrigation schedule for tobacco and improvement of irrigation water use efficiency.

2. Materials and methods

2.1. Experimental site

Pot experiments were conducted in a canopy at the Xiuwen Irrigation Test Central Station (26°45′ to 27°12′N, and 106°22′ to 106°53′E) in Guizhou Province in southwest China. Guizhou Province is a region with typical karst landforms consisting of relatively low mountains and hills. The study area has a subtropical monsoon humid climate, with an average annual air temperature of 14.6°C and annual precipitation of 1 235 mm. The mean annual relative humidity is 77%, the annual sunlight is 1 021.5 h, and the frost-free growing season is 270 d per year. The experiments were performed on a plowed soil layer consisting of loess soil with an organic matter content of 33.69 g/kg, total nitrogen of 2.2 g/kg, total phosphorus of 0.3 g/kg, total potassium of 24.87 g/kg, dry density of 1.38 g/cm, and pH value of 7.0. The field capacities were 37.3%, 35.7%, and 33.6% for different soil layers at depths of 0−10 cm, 10−20 cm, and 20−40 cm, respectively.

2.2. Experimental design

Pot experiments were conducted in 2006 and 2007 to investigate the tobacco water requirement and the effect of water deficit on tobacco yield. To avoid the effect of precipitation, experiments were carried out in a canopy with two open ends. The canopy was 30 m long, 10 m wide, and 4 m high. To facilitate the experiment, tobacco was planted in plastic pots with a height of 40 cm and a diameter of 35 cm.

Tobacco seeds (Yun 85), the most popular cultivar in the region, were transplanted on April 25, 2006 with five various treatments (treatments 1 through 5) and on May 1, 2007 with nine various treatments (treatments 6 through 14). Treatment 5 was considered the conventional treatment. A randomized complete block experimental design with all the treatments described above and 15 repetitions for each treatment were adopted.

In contrast to the common classification of tobacco growth stages, including the elongation, vigorous growing, and mature stages, the whole growth period was classified into four growth stages in the experiments, including the rejuvenation, group, vigorous growing, and mature stages. In order to investigate the water requirement under various water stress levels, lower limits of soil water content at different growth stages were set for the 14 treatments involved in this study (Table 1).

2.3. Observation and calculation methods

Daily climatic parameters, mainly including precipitation, wind speed, temperature (maximum, minimum, and average), sunshine duration, relative humidity, and pressure, were measured at the Xiuwen Weather Station adjacent to the experimental site. Soil moisture was monitored at 8:00 am every day with a time-domain reflectometer (TDR; soil moisture meter, USA). The TDR was installed at different flow depths: 0−10 cm at the rejuvenation stage, 10−20 cm at the group and vigorous stages, and 20−40 cm at the mature stage. In pot experiments, water was discharged into pots through point-source irrigation until the soil moisture reached the lower limits of soil water content determined in Table 1. In this study, the water requirement intensity was defined as the ratio of the water requirement to the corresponding duration of time, and the water requirement module was defined as the ratio of the water requirement of a certain period of time to the water requirement throughout the growth period.

The tobacco water requirement (ET_t) at each growth stage was calculated with the field water balance equation:

$$ET_t = W_{0t} - W_t + P_t + I_t - S_t + K_t \quad (1)$$

where the subscript t means the growth stage t; W_{0t} and W_t are the water contents in the soil profile at the beginning and end of stage t, respectively; P_t is the precipitation; I_t is the amount of irrigation water; S_t is the percolation; and K_t is the