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Effects of potassium deficiency on antioxidant metabolism related to leaf senescence in cotton (*Gossypium hirsutum* L.)

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ABSTRACT

In order to explore the changes in antioxidant metabolism related to leaf senescence under potassium (K) deficiency, field experiments were conducted in 2012 and 2013 with contrasting two cotton (*Gossypium hirsutum* L.) cultivars in low-K sensitivity (Simian 3, low-K tolerant and Siza 3, low-K sensitive) under three K levels (0, 150 and 300 kg K_2O ha^{-1}). Results showed that K deficiency enhanced the early season flowering rate, earliness, shedding rate and yellow leaf rate, and decreased leaf number, leaf area, boll number, seed cotton weight per boll and lint percentage. The premature senescence of leaf subtending the cotton boll (LSCB) induced by K deficiency was characterized by early chlorophyll degradation and negative chlorophyll fluorescence. Despite higher activity of hydrogen peroxide (H_2O_2) scavenging enzymes (catalase and peroxidase) and higher content of ascorbic acid (ASC) existed in the K-deficient leaf, higher H_2O_2 content was observed, which caused higher malondialdehyde content. Although lower dehydroascorbate reductase activity was observed under K deficiency, high ASC content was attributed to lower ascorbate peroxidase activity. The differences between Siza 3 and Simian 3 in response to K deficiency were that: (1) the seed cotton weight per boll and lint percentage in Siza 3 decreased more obviously, (2) higher leaf K concentration was needed for maintaining chlorophyll content for Siza 3, (3) Chlorophyll fluorescence parameters was more easily damaged in Siza 3, especially non-photochemical quenching, and (4) superoxide dismutase and glutathione reductase activities decreased markedly only in Siza 3.

1. Introduction

Potassium (K) is an important nutrient for plant growth and productivity, most of the K absorbed by plants is obtained from soil, however, K balance in soil declines significantly with time and has reached a negative value in many countries, although the K fertilizer is applied (Krauss, 2003). For example, China currently has a negative K balance of about −60 kg ha^{-1} year^{-1} and the trend is becoming more severe (Wang et al., 2012a). The negative K balance will lead to unavoidable K deficiency, which results in a lot of problems in plant growth and development, such as small plant (Pettigrew and Meredith, 1997), early maturity (Pettigrew, 2003) and premature senescence (Wang et al., 2012b). Premature senescence caused by K deficiency was initially reported in Alabama (Abaye, 1996), and then was reported in other countries, such as Australia (Bedrossian et al., 2000; Wright, 1998) and China (Xu et al., 2008; Zheng and Dai, 2000).

In cotton (*Gossypium hirsutum* L.), premature senescence induced by K deficiency usually develops during the flowering and boll development stage (Wright, 1999), which will decrease boll weight (Hu et al., 2016) and seed cotton yield (Li et al., 2012). In the underground, premature senescence caused by K deficiency is characterized by negative root growth (Li et al., 2012) and lower root vigour (Yu et al., 1996); On the ground, Reddy et al. (2000) indicated that the leaf growth is one of the most sensitive physiological process to K deficiency, and leaf senescence is

Abbreviations: CV, coefficient of variance; DPA, days post anthesis; LSCB, leaf subtending the cotton boll; *Fv*/*Fm*, the primary light energy conversion efficiency of PS II in the dark; Φ_{PSII}, quantum yield of PS II; qP, coefficient of photochemical quenching; qN, coefficient of non-photochemical quenching; ROS, reactive oxygen species; MDA, malondialdehyde; H_2O_2, hydrogen peroxide; ASC, ascorbate; GSH, reduced glutathione; CAT, catalase; POD, peroxidase; SOD, superoxide dismutase; APX, ascorbate peroxidase; DHAR, dehydroascorbate reductase; GR, glutathione reductase.

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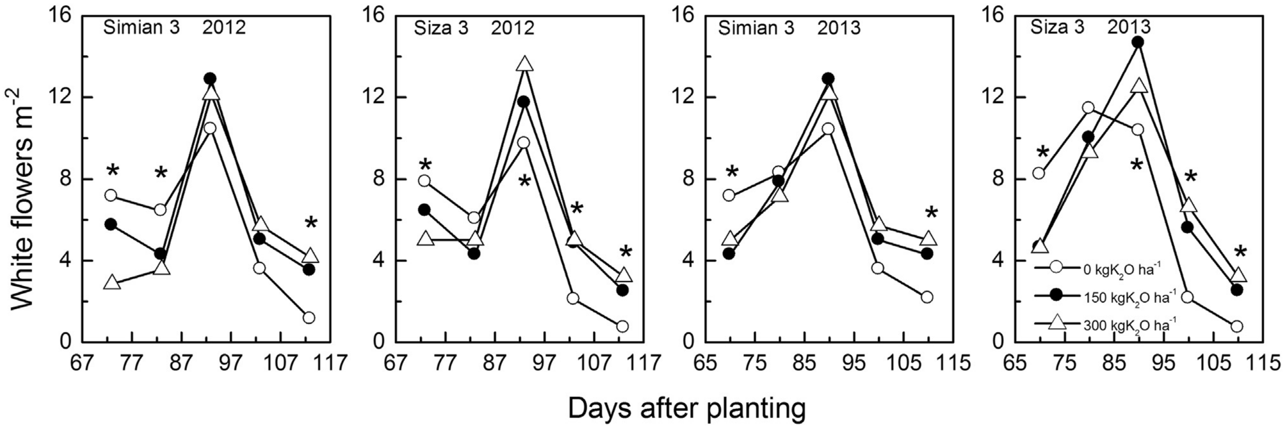

Fig. 1. Changes of white blooms (blooms at anthesis) number at various time of the calendar year in 2012 and 2013 under three potassium rates. Asterisks denote LSD values at the 0.05 level and are present only when the differences among the three potassium rates are statistically significant at the 0.05 level.

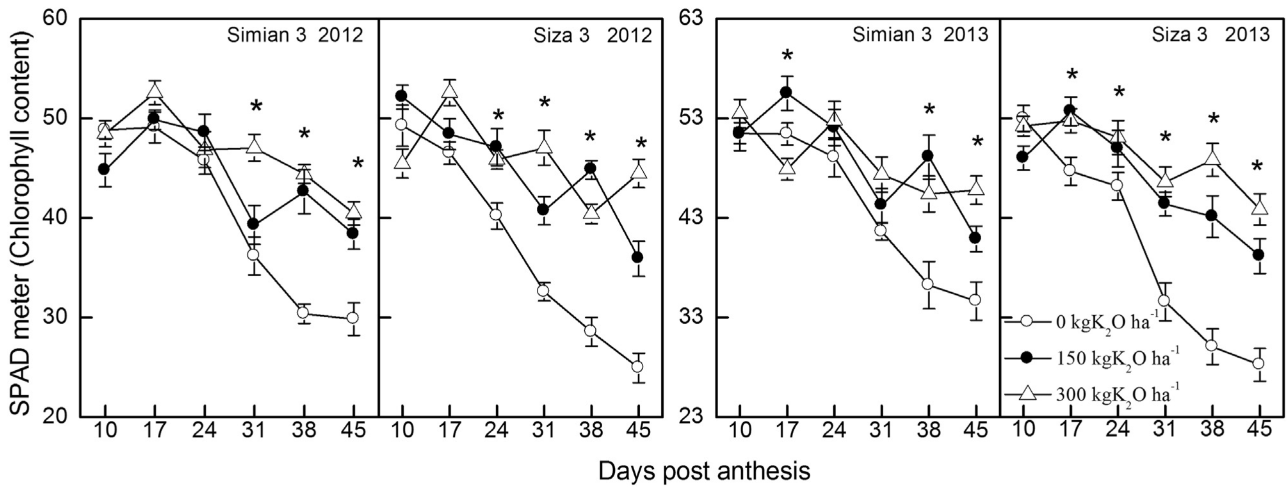

Fig. 2. Changes of SPAD meter in LSCB of Simian 3 and Siza 3 under three potassium rates in 2012 and 2013. Each value represents the mean of four replications. Asterisks denote LSD values at the 0.05 level and are present only when the differences among the three potassium rates are statistically significant at the 0.05 level.

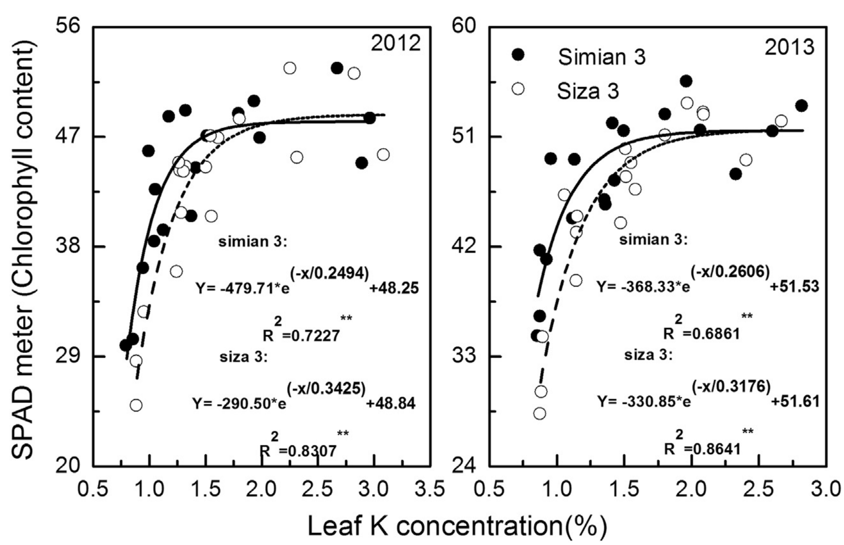

Fig. 3. Relationship between SPAD meter and leaf potassium concentration in LSCB of Simian 3 and Siza 3 in 2012 and 2013. The solid and dotted lines represent Simian 3 and Siza 3, respectively.

characterized by early chlorophyll degradation and decreased photosynthesis in mature leaves under K deficiency (Zhao et al., 2001, 2013), which would result in imbalance of photosynthate between sink and source (Pettigrew, 1999), and lower carbohydrate con-