Effects of potassium fertilizer on physiological and biochemical index of Stevia rebaudiana Bertoni

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Abstract

Potassium is a macronutrient essential to the performance of multiple plant enzyme functions. However, little is known about its impact on Stevia rebaudiana Bertoni. In the present study, we determined the Chlorophyll content, root activity, NR activity, invertase activity, SOD activity, MDA content of Stevia rebaudiana Bertoni subjected to five potassium levels (0, 90, 120 and 150 kg K2O/ha). Fertilization of potassium increased photosynthetic rate, the activities of nitrate reductase, invertase activity, root activity, stress resistance and malondialdehyde(MDA) content, especially under suitable potassium (120 kg K2O/ha). It is suggested that potassium promote plant status and provoke lipid peroxidation.

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Key words: Stevia rebaudiana Bertoni; Photosynthetic rate; Potassium; physiological and biochemical index

1. Introduction

Stevia rebaudiana Bertoni is a perennial herb belonging to the family Asteraceae, now being cultivated in many tropical and sub-tropical countries. The leaves of Stevia rebaudiana synthesize non-caloric thermo-stable intense sweeteners, mainly steviosides (the ent-kaurine glycosides) that find applications in food, pharmaceutical industries and agriculture[1-2]. Purified stevioside imparts about 300-times higher sweetness than sucrose [3]. Another glycoside, namely rebaudioside-A, which is about 400-times sweeter than sucrose is also present in Stevia leaves [4]. Therefore, there has been a large interest in Stevia

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although information concerning potassium nutrition in Stevia rebaudiana Bertoni and the effect on growth is lacking.

However, the Effects of potassium fertilizer on physiological and biochemical index of Stevia rebaudiana Bertoni in China have rarely been studied. Therefore, the goal of the present work was to determine the effects of potassium fertilizer on physiological and biochemical index of Stevia rebaudiana Bertoni of Chinese region.

2. Materials and Methods

2.1. Plant material, growth, and treatments

In 2007, experimental fields were laid out in Qingdao, Shandong Province, east China, with the varieties Qingtian bred by Qingdao Agriculture University and established. The fields were located on potassium deficient sandy soils of strongly moisture retaining capacity.

Base fertilizers given were 300 kg N and 90 kg P2O5/ha. Experimental fertilizer treatments were Control (CK, 0 K2O/ha), Treatment 1 (T1, 60 K2O/ha), Treatment 2, 90 K2O/ha), Treatment 3(T3, 120 K2O/ha) and Treatment 4(T4, 150 kg K2O/ha), given as sulphate, These treatments were distributed in a randomized block containing 3 repeats and each repeat was composed of 8 plants. All fields were in duplicate.

2.2. Methods

The physiological and biochemical indexes were measured in Stevia rebaudiana Bertoni leaves. Measuring root activity used TTC method; chlorophyll concentration [5]; NR activity [6]; SOD activity [7]; Invertase activities [8] and MDA content [9].

3. Result

3.1. Chlorophyll Content

Fig. 1 The influence of different potassium fertilizer horizontal on chl content in the leaf

Fig. 2 The influence of different potassium fertilizer horizontal on NR activity
Fig. 1 shows the Chlorophyll Content of Stevia rebaudiana leaf as a function of time for different potassium concentrations. Chlorophyll content increased at the early time and to the peak in 45 days after transplanting then decreased later. There was a significant difference in the chlorophyll content under different potassium nutrient. Compared with potash fertilizer treatment the CK has the highest chlorophyll content because of vigorous nitrogen metabolism before 30 days after transplanting. After 30 days after transplanting, Compared to CK chlorophyll content, which was relatively stable during the time course of the experiment, potassium treatment enhanced chlorophyll content. Chlorophyll Content of Stevia in the potassium treatment was, respectively, T3>T4>T2>T1>CK. And T3 was highest, achieved at 3.012mg.g⁻¹.

3.2. Activities of NR

We examined the activities of NR involved in nitrogen assimilation in the plants under potassium treatment. Fig. 3 shows the shoot NR activity as a function of time for different K levels. T1 did not significantly affect the activities of NR (Fig. 2), but T2, T3, T4 significantly increased it. Before 45 days after transplanting, NR activity increased with time at all K levels. The increase was rapid at the higher K levels of T3, T2 and T4. Plants grown at T3 attained NR activity of 6.02 μmol (NO₂⁻1) g⁻1 .DW.min⁻¹ at 45 d. Then the NR activity decrease sharply. A K treatment of T3 in the NR activity was sufficient for the maximum NR activity of Stevia.

3.3. Invertase activities

Invertase activity is closely related to carbon metabolism [10-12]. The invertase activities of plant with different treatments were measured in 30 and 60 days after transplanting (Fig. 3). Compared to CK invertase activity, Potassium clearly induced an increase of invertase activity throughout the experiment. However, the degree of increasing in the invertase activity when compared to the CK was greater in the T3 and T4 treatment than in the T1 and T2 treatment. Although no significant differences in invertase activity of stevia leaf were found between the T3 and T4 treatments, the T4 treatment consume more potassium fertilizer with high cost. Under the experimental conditions, the optimum treatment is T3.
3.4. Root activity

The root activity first increased and showed the highest activity in 30 days after transplanting then decreased over the growing period. Analyses of root activities demonstrated significant differences among different treatment, showing mainly increased activities under treatment of potassium. The highest root activity was measured in treatment of T3, in which root activity was 1.5 times higher than in CK, which revealed the lowest values (Fig. 4).

3.5. MDA content and SOD activity

The measurement of MDA content as parameters of oxidative stress showed significant differences between different treatments. MDA was higher in T3, T2, T4 and T1 than in CK (Fig. 5). Moreover, among all treatments T3 revealed significantly the highest MDA content, which were 2 times higher than in the CK. In parallel with the high amounts of MDA, SOD activity were significantly more pronounced in T3 and T2, whereas the CK had the lowest SOD activity (Fig. 6). Again, the T3 revealed significantly the highest value and its activity was 1.5 times higher than that in the CK.

Analysis of antioxidative enzyme (SOD) demonstrated significant difference in their activity among different treatments; the highest SOD activity was obtained in T3 at each time after transplanting, whose value was nearly one time higher than in the CK (Fig. 6). T2 had lower SOD activity than did T3 but significantly higher than T3 and T1. Excess fertilization results in a lower SOD activity in T4.

4. Discussion

Potassium is a macronutrient essential to the performance of multiple plant enzyme functions. Studies have indicated higher yield and disease resistance with increased levels of K in certain extent [13]. Although the mechanisms are not completely understood, this effect may be attributed to increased plant energy. In the experiment, application of potassium fertilizer had a positive effect on the physiological
status and improved the activity of the enzyme compared with CK, moreover, the T3 treatment had the best growth status in the experiment.

As NR activity is positively associated with photosynthesis [14], results obtained from the experiment showed that higher total chlorophyll content and NR activity observed in T3, T4, T2 and T1 compared to CK, therefore, potassium can increase both NR expression and its activity [6]. This is important, because photosynthetic capacity is closely associated with total chlorophyll content, and NR activity can be associated with amino acid conversion [14], and amino acid composition might be altered due to stress—or this combination—which could promote stress-resistance [15].

Invertase can be considered as a key enzyme in carbohydrate metabolism since it catalyses the irreversible reaction that converts sucrose into glucose and fructose. In contrast to CK, the effect of potassium on invertase activity was obvious, suitable potassium significantly increase invertase activity.

Results obtained from different treatments showed that higher MDA content observed in T3, T4, T2 and T1 compared to CK was associated with high activity of scavenging free radical, thus indicating that application of potassium can help plant against higher oxidative stress.

A clear relationship between stress and antioxidant enzymatic activities has been observed in shoots of Prunus avium [16], carnation [17], and Euphorbia milli [18]. The increased activity of SOD, a key enzyme involved in protecting the cells from oxidative stress by catalyzing the disproportion of O2- radical to H2O2 and O2, was observed in this experiment. Together with the appearance of new Cu/Zn-SOD and Fe-SOD isoforms, which have also been induced in chloroplasts of Mesembryanthemum crystallinum under oxidative stress [19], these findings suggest induction of a defense mechanism against oxidative damage in chloroplasts. Related to the increase in SOD activity was detected in T3, T4, T2 and T1, indicating activation of enzymes involved in scavenging H2O2. This could be connected with their role in scavenging increased H2O2. However, recently proposed that the concomitant presence of higher amounts of H2O2 [20], could induce a Fenton reaction generating extremely reactive hydroxyl radicals that can damage cell molecules, membranes, and other structures.

The increased activities of the antioxidative enzymes SOD and CAT in T3, T2, T4 and T1 suggest potassium can activated a defense mechanism against the increased production of ROS in the experiment. However, the increase in lipid peroxidation and carbonylation of proteins and oxidative damage to chloroplasts [21].

In collision, the application of adequate potassium was favorable to raise photosynthetic rate, promote the root activity, eliminate effectively oxygen free radical, increase stress resistance and promote plant growth activity.

Reference