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Nitrogen metabolism of *Aloe vera* under long-term diluted seawater irrigation

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Abstract

Diluted seawater such as 10% (10 volumes of seawater and 90 volumes of freshwater), 25%, 50%, 75% and 100% were used to irrigate *Aloe vera* L. during four successive years in Ledong region, Hainan Province of China. The effect of seawater irrigation on nitrogen metabolism of aloe plant was studied. Total nitrogen content of aloe leaves ranged from 1.48 to 1.56 % of dry matter, and no significant differences were observed between control (freshwater irrigation) and seawater treatments. The total nitrogen content of *aloe* roots, in the range of 0.74 to 0.85 % of dry matter, was much lower than that in the leaves. There was no significant difference in total nitrogen content of roots between control and seawater treatments. It is suggested that seawater treatments do not affect nitrogen uptake and transport in aloe plant. The nitrate content in aloe leaves irrigated with seawater was much lower than that with fresh water irrigation, and a continuous decline in nitrate content was noted with increasing seawater concentration. The nitrate/total nitrogen ratio also tends to decrease in leaves suggesting that nitrate has been assimilated into osmoregulated substances under seawater stress. The amino acid content of aloe plant was not affected, while the ratios of amino acid/total nitrogen significantly increased under seawater stress as compared with control. The protein content and protein/total nitrogen ratios were not affected by seawater treatment except for 100%, suggesting that there was a favourable transformation from amino acids to proteins under salt stress. It is concluded that a long term irrigation by diluted seawater on leachable sandy soil with excessive annual rain precipitation could effectively maintain yield and improve the quality of aloe.

Key words: Amino acid, aloe qualities, nitrate, protein, total nitrogen

Introduction

The shortage of freshwater resources for irrigation is a well known problem of agriculture (Hamdy *et al*., 2005). The challenge is to maintain crop production without impairing the balance of good quality water: an obvious solution is consequently to explore the sustainable use of non-conventional water resources (Pereira, 2002). When freshwater supply is limited, there is an increasing demand for the use of non-conventional waters. Seawater, as an ample non-conventional water source, was proposed to be used for crop production along the coastal desert 40 years ago (Glenn, 1998).

aloe is commonly used to treat a number of skin irritations, such as dry skin and irritant contact dermatitis (West and Zhu, 2003), healing of burns (Visuthikosol *et al*., 1995) and cure of certain cancers. *aloe* is widely cultivated in coastal regions of southern China. Since several qualities of aloe plant were realised recently, aloe became a priority subject of many studies (Zheng, 2004; Liu, 2003; Sun *et al*., 2003; Wu *et al*., 2003). However, studies on nitrogen metabolism of aloe plant under salt stress are rare. The effect of seawater irrigation on nitrogen metabolism and qualities of aloe plant has not been studied.

The objectives of the present study were (1) to study the nitrogen metabolism of aloe plant under long-term irrigation with diluted seawater, and (2) to assess the qualities of aloe plant under seawater irrigation *vis a vis* increase/decrease of metabolic products.

Materials and methods

Study area and experiment layout: The experiments were conducted at the "863" Research Station, Ledong County, southeast of Hainan Province, China (18º9´N, 108º56´E). The climate is a tropical monsoon with mean annual temperature of 23-25ºC, mean annual precipitation 1000-1200 mm, most of which occurs from late May to October, and mean annual evaporation 2000-2200 mm.

A. vera used in this experiment has salt stress tolerance since the tissue cultured plants used for cultivation were from plants growing under seawater stress conditions. It was grown in 20 m^2 plots (5×4 m). The soil contained 69, 30 and 1% sand, silt and clay, respectively. The total soluble salts content and bulk density were 0.002% and 1.62 g cm^{-3}, respectively. There were six treatments *i.e.* CK (freshwater irrigation) and 10% (EC=4.2 dS m^{-1}), 25% (EC=10.9 dS m^{-1}), 50% (EC=19.1 dS m^{-1}), 75% (EC=28.4 dS m^{-1}) and 100% (EC= 39.2 dS m^{-1}) seawater

Table 1 Some chemical properties of the irrigation water[a)]

Warer used	pH	EC (dS m^{-1})	TN (mg L^{-1})	IN (mg L^{-1})	TP (mg L^{-1})	RP (mg L^{-1})
Seawater	7.8	39.2	1.28	0.43	0.76	0.30
Tap water	7.0	0.11	0.15	0.02	0.03	0.02

[a)] EC: Electrical conductivity; TN: Total nitrogen; IN: Inorganic nitrogen; TP: Total phosphorus; RP: Reactive phosphorus.

treatments, with a randomised complete block design, and each treatment had three replicates.

Seawater used for irrigation had a salinity of about 31.0 g L^{-1}. Prior to irrigation, the seawater and tap water were mixed in a tank, to which a compound fertilizer ($N:P_2O_5:K_2O$=15:15:15) was added to give the final concentration of 0.2%. The prepared mixtures were delivered to the experimental plots by plastic tubes. Basic chemical properties of irrigated water are shown in Table 1.

On August, 2001, plots were separated from each other with a deeply buried plastic film (40 cm depth) so as to prevent lateral permeation of seawater between plots. Before start, the experimental plots were pre-irrigated with sufficient freshwater to keep the soil field capacity moisture. Base fertilizers were applied at the rates of 600 and 75000 kg ha^{-1} for superphosphate and pig manure, respectively. Aloe was grown in the plots with 60 cm between rows and 50 cm between plants in the row. In one of the plots within the replicates, tensionmeter was installed at the depth of 0~40 cm. On December 10, the first irrigation was given using freshwater, and after that irrigation with the seawater treatments was done whenever soil water suction at a depth of 0~40 cm exceeded the value of 3.8 MPa. In all, 218 irrigations were given during the growth stages of aloe in 4 years. The total amount of water supplied in the irrigation reached about 1 m^3 per plot.

Sampling and analysis: Before irrigation, seawater and freshwater samples were analysed for electrical conductivity, pH, bicarbonate and levels of the ions: potassium, sodium, calcium, magnesium, chlorine and sulphate. Electrical conductivity and pH were measured in the field with EC 214 Conductivity Meter (HANNA instruments) and pH Meter (Cyerscan 510), respectively. Certain water parameters and initial soil samples which couldn't be measured in the field were analysed in the Resources and Environmental Laboratory, Nanjing Agricultural University (NJAU).

Aloe was harvested during late April 2004, and three individual plants in each plot were collected for analyzing plant biomass, total nitrogen, nitrite, amino acid and protein content. Analysis of amino acid and protein content was as per Li *et al.* (1999). All other analyses were according to Lu (1999).

Statistical methods: The analysis of variance was performed by the standard procedures using MS-EXCEL 2000 software. The means of different treatments were compared by applying Least Significant Difference Test (*P*=0.05) using SPSS 13.0 software.

Results and discussion

Effect of seawater irrigation on total nitrogen content in leaves and roots: Total nitrogen content in leaves and roots of aloe under seawater irrigation during four years are shown in Fig.1. The nitrogen content of aloe leaves ranged from 1.48 to 1.56 % of dry matter, and no significant differences were noted between CK- and seawater-treatments. The nitrogen content of aloe in roots, in the range of 0.74 to 0.85 % of dry matter, was much lower than that in leaves. There was no significant difference in nitrogen content of roots between the CK- and

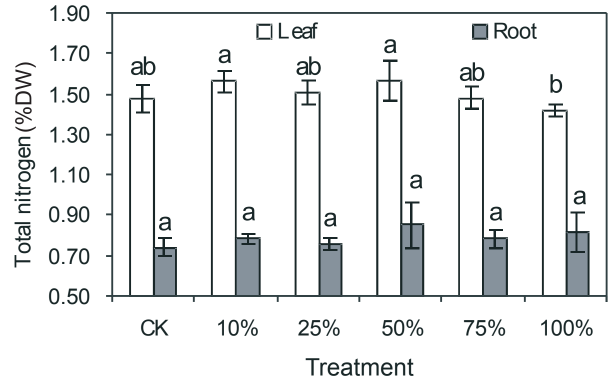

Fig. 1. The total nitrogen content in leaves and roots of *Aloe vera* under diluted seawater stress. CK represents freshwater (tap water) treatment, and seawater treatment, for example, 10% a mixture of 10% seawater and 90% fresh water on volume basis. The same letters on the bars are not significantly different (*P*=0.05) by Least Significant Difference Test.

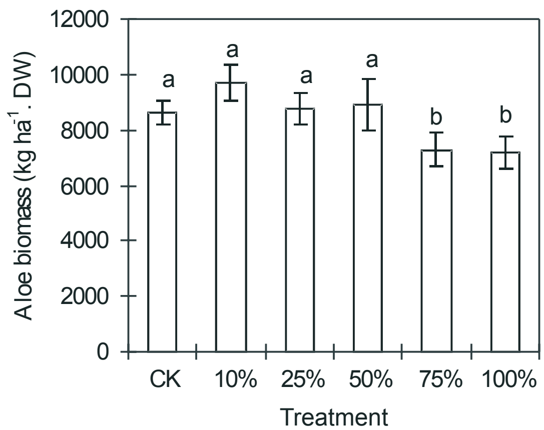

Fig. 2. The aloe biomass at harvest in 2004 under diluted seawater stress. CK represents freshwater (tap water) treatment, and seawater treatment, for example, 10% a mixture of 10% seawater and 90% fresh water on volume basis. The same letters on the bars are not significantly different (*p*=0.05) by Least Significant Difference Test.

the seawater- treatments. These results suggest that seawater irrigation didn't significantly influence the nitrogen uptake and transport. This may be attributed to high irrigation frequency and good water drainage in the sandy soil. Total nitrogen uptake by aloe plant decreased at 75 and 100% seawater treatments due to the decreased biomass under severe seawater stress (Fig. 2). These results are in agreement with earlier studies with different plants species, like Alfalfa (Khan *et al.*, 1994), pumpkin (Aroiee *et al.*, 2005) and bean (Rabie and Almadini, 2005) under salt stress conditions.

Effect of seawater irrigation on nitrate content and ratios of nitrate to total nitrogen in leaves of aloe: Seawater irrigation significantly decreased nitrate content in leaves of aloe when compared with the CK (Fig. 3A). Among the treatments, the highest value of nitrate content in leaves was obtained in 25%, followed by 10, 50, 75 and 100%. The ratio of nitrate/nitrogen in leaves are presented in Fig. 3B. Seawater irrigation markedly lowered the ratio of nitrate/total nitrogen in the leaves compared to the CK. With 10, 25, 50, 75 and 100% seawater irrigation, nitrate/nitrogen in leaves decreased by 20.8, 11.8, 22.9, 26.0 and 32.3%, respectively as compared to CK. Decrease in the nitrate level of leaves with increasing salinity could be attributed to a build-up of organic osmoregulatory substances. A decreased nitrate level in leaves may also be due to incorporation of nitrate in sugars and amino acid (proline) (Boggess *et al.*, 1976; Stewart, 1981; Rhodes *et al.*, 1986; Rhodes and Handa, 1989), and this transformation may be an adapting mechanism of plant for maintaining their normal growth under salt stress. It is also likely that an increase in Cl^- concentration in soil after seawater irrigation had reduced the nitrate uptake as reported for other plants (Weigel *et al.*, 1973; Kafkafi *et al.*, 1982; Elia *et al.*, 2004).

Effect of seawater irrigation on organic nitrogen and ratio of organic nitrogen to total nitrogen: Seawater irrigation resulted in a significant increase in amino acid concentration in aloe leaves. The highest content of amino acid was obtained in the 25% treatment. It was 1.16, 1.15, 1.07 and 1.04-folds respectively, when compared with the treatments 10, 50, 75 and 100% (Fig. 4A). Seawater irrigation had increased the ratio of amino acid to total nitrogen as compared with the CK (Fig. 4B).

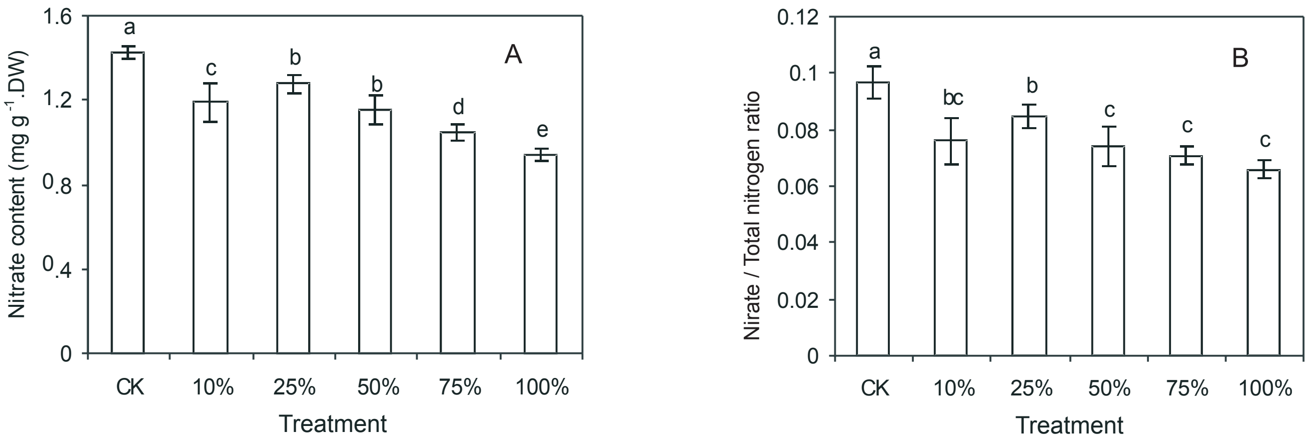

Fig. 3. The nitrate content (A) and the ratio of nitrate/total nitrogen (B) in aloe leaves under diluted seawater irrigation. CK represents freshwater treatment. Seawater treatment, for example, 10% is a mixture of 10% seawater and 90% fresh water on volume basis. The same letters on the bars are not significantly different (*P*=0.05) by Least Significant Difference Test.

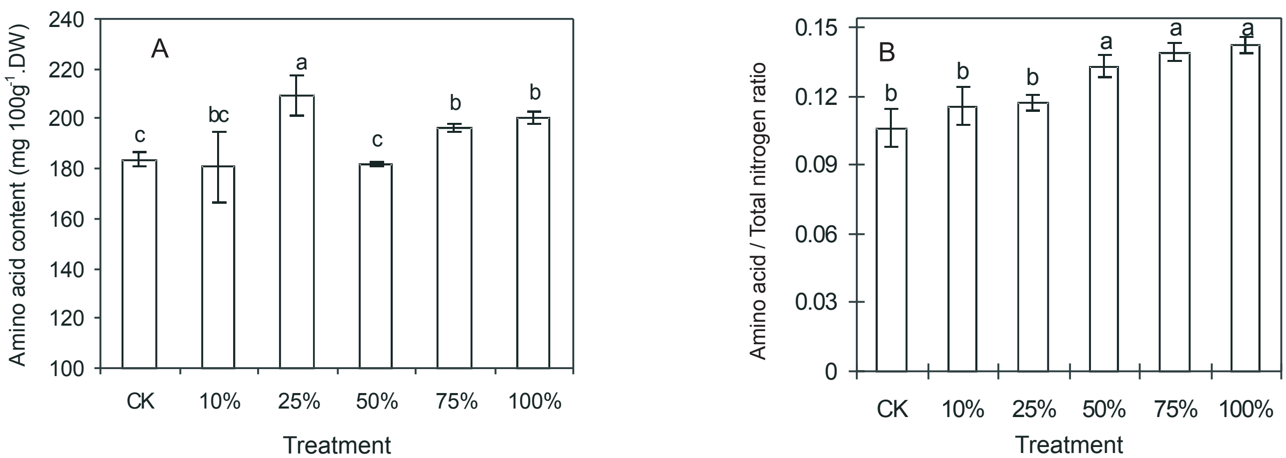

Fig. 4. The amino acid content (A) and the ratio of amino/total nitrogen (B) in aloe leaves under diluted seawater stress. CK represents freshwater treatment, and seawater treatment, for example, 10% is a mixture of 10% seawater and 90% fresh water on volume basis. The same letters on the bars are not significantly different (*P*=0.05) by Least Significant Difference Test.

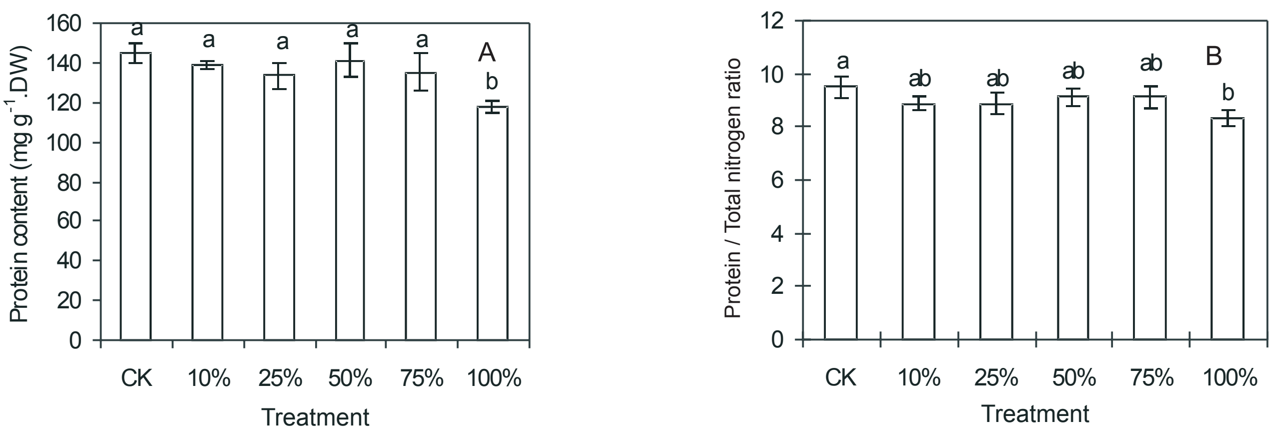

Fig. 5. The protein content (A) and the ratios of protein/total nitrogen (B) in aloe leaves under diluted seawater stress. CK represents freshwater treatment, and seawater treatment, for example, 10% is a mixture of 10% seawater and 90% fresh water on volume basis. The same letters on the bars are not significantly different (*P*=0.05) by Least Significant Difference Test.

Protein content: A significant increase in protein content of aloe leaves was observed under seawater treatments (except for 100%) indicating that the protein content had not been influenced under moderate seawater stress (Fig. 5A). Seawater irrigation enhanced the ratio of protein/total nitrogen as compared with CK (except for 100%) (Fig. 5B). It may be due to the fact that the presence of salt ions may activate the biosynthesis of glycinebetaine which in turn may improve the protein synthesis, a mechanism adopted by the plants against salinity stress as was suggested by Niazi *et al.* (2004).

Total nitrogen content of aloe did not decline under diluted seawater irrigation as compared to freshwater irrigation. However, nitrate content as well as the ratio of nitrate to nitrogen in aloe leaves was significantly reduced due to seawater stress, suggesting assimilation of nitrate into osmoregulatory substances like soluble sugars and organic acids. Subsequent results showed that seawater irrigation significantly increased the amino acid content of leaves suggesting that nitrate in leaves was largely assimilated into amino acid to resist severe salt stress. However, protein content of aloe in leaves was not affected by seawater except the pure seawater treatment, demonstrating that there is a transformation of amino acids into proteins under salt stress. This study demonstrates that a long term irrigation by diluted seawater on leachable sandy soil with excessive annual rain precipitation could effectively maintain yield and improve the quality of aloe.

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