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Evaluation of salt tolerance and contributing ionic mechanism in nine Hami melon landraces in Xinjiang, China

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ABSTRACT

Melon (*Cucumis melo* L.) is an important horticultural crop in the world. The objective of this work was to evaluate salinity stress tolerance and understand the ionic mechanism conferring this trait in nine Hami melon landracesfrom Xinjiang, China. Plants were grown in a potting mix (peat: vermiculite: perlite = 1:1:1, v/v) under glasshouse conditions and irrigated with Hoagland's nutrient solution containing either 0 (control) or 100 mM NaCl. Plant dry weight, single fruit weight, Na^+ and K^+ content of all leaves, stem and roots of the whole plant were measured at day 70 after commencing the treatment. Also, Na^+ and K^+ content of the second fully expanded leaf from the top were measured at day 20, 40 and 60 after stress onset. Net fluxes of K^+ and Na^+ were measured from plant roots in laboratory experiments using a noninvasive MIFE (microelectrode ion flux estimation) technique, and expression levels of the leaf tonoplast Na^+/H^+ antiporters (NHX) were investigated. Salt injury index and leaf chlorophyll content were also measured. The results showed that, according to the relative (NaCl/Control) plant dry weight and a single fruit weight, the salt tolerance of the nine landraces can be classified into three types: 'Huangdanzi', 'Zajiaojiashigua', 'Kalakesai' and 'Paotaihong' are salt tolerant; 'Laotiepi', 'Kaeryunxi' and 'Sairekekekouqi' are intermediate in salt tolerance; and 'Akekekouqi' and 'Paodangua' are salt sensitive. This conclusion was also supported by the results of measuring of the salt injury index and leaf chlorophyll content. The salt tolerance of landraces was positively correlated with the relative K^+ content of all leaves, but correlated negatively with the relative Na^+ content of the second fully expanded leaf, and relative K^+ content of the root. Compared with salt sensitive landraces, salt tolerant genotypes had significantly lower relative Na^+ content of the second fully expanded leaf, lower relative root K^+ content (except Paotaihong), and higher relative K^+ content of all leaves. They also displayed lower root net K^+ efflux and higher Na^+ efflux (except Zajiaojiashigua) capacity. The intermediate landrace 'Laotiepi' had very high Na^+ content and high level of *NHX2/3/6* expression in leaves but still possessed high chlorophyll content, suggesting that this landrace had an efficient vacuolar Na^+ sequestration mechanism in the leaf mesophyll. Taken together, our results showed that Hami melon landraces in Xinjiang showing significant difference in salt tolerance, and that K^+ retention in the shoot and Na^+ exclusion from young leaves are the main mechanisms conferring salinity stress tolerance of Hami melon landraces in Xinjiang.

1. Introduction

Soil salinity is a major environmental stress affecting agricultural production worldwide. More than 800 million hectares of agricultural land suffer from soil salinity (Rengasamy, 2010). To match the predicted population growth with a food supply, salt-tolerant cultivars have to be bred and recommended to growers.

Melon (*Cucumis melo* L.) is an important horticultural crop that belongs to the family of Cucurbitaceae. It is grown worldwide, with the melon production estimated around 31.2 million tons in 2016 for a

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cultured area of 1.3 million ha (FAO, 2016). China is the largest melon-producing country in the world.

Xinjiang occupies approximately one-sixth of the Chinese territory with some unique climatic characteristics, such as scant rainfall, large daily fluctuations of air temperature, strong sunshine, and long sunny days. These climatic conditions are advantageous for the cultivation of high-quality sweet and thick skinned melon, which has been called Hami melon since two hundred years ago (Zhang et al., 2017). With a total production of 1.1 million tons and a cultivation area of 41 thousand hectares annually, Hami melon is a local featured crop of economic important in Xinjiang, a major Hami melon producing province in China (Aierken et al., 2011). More than 100 landraces were distributed in Xinjiang and collected several decades ago (Wu, 1982). The local melon landraces in Xinjiang are very rich in phenotypic diversity, and the extent of morphological diversity between agro-ecological regions of Xinjiang is different (Zhang et al., 2012).

Melon is a salt sensitive crop. Several authors have studied the effects of salinity on the physiology of melon plants (Sivritepe et al., 2003; Kaya et al., 2007; Edelstein et al., 2011; Tedeschi et al., 2011; Zhang et al., 2011; Rouphael et al., 2012; Sarabi et al., 2017). They found that lower leaf Na^+ and higher K^+ accumulation is an important ionic mechanism for the salt tolerance in this species (Edelstein et al., 2011; Rouphael et al., 2012). Salt tolerance mechanisms are very complex and the tolerance trait is not always associated with less leaf Na^+ accumulation. It was shown that some genotypes of bread wheat (Genc et al., 2007) tomato (Gálvez et al., 2012), and pumpkin (Niu et al., 2017) had high leaf Na^+ content but also possessed high salt tolerance, suggesting an existence of an efficient tissue tolerance mechanism. However, the tissue tolerance mechanism has not been reported in melon yet.

Melon cultivation is often faced with salinity problems in Xinjiang (Tian et al., 2000). However, until now no studies have addressed the mechanism of salt tolerance in Hami melon landraces in Xinjiang. Also, most previous studies on salt tolerance in melon compared only few genotypes, while the salt tissue tolerance mechanism may be revealed using more genotypes, especially local landraces. Therefore, the aim of this work was to evaluate the salt tolerance and understand the ionic mechanism conferring this trait in various Hami melon landraces from Xinjiang. The selected salt tolerant landraces represent valuable resources and can therefore be used for improving salinity stress tolerance in melon.

Table 1
Melon landraces from Xinjiang province used in this study.

Landrace (full name)	Landrace (abbreviation)	Collecting sites	Botanical groups
Huangdanzi	HDZ	Turpan	*C. melo* var. *chandalak*
Zajiaojiashigua	ZSG	Jiashi	*C. melo* var. *inodorus*
Kalakesai	KKS	Jiashi	*C. melo* var. *inodorus*
Paotaihong	PTH	Shihezi	*C. melo* var. *inodorus*
Laotiepi	LTP	Shule	*C. melo* var. *ameri*
Kaeryunxi	KYX	Shufu	*C. melo* var. *inodorus*
Sairekekekouqi	SKQ	Hetian	*C. melo* var. *inodorus*
Akekekouqi	AKQ	Kashi	*C. melo* var. *ameri*
Paodangua	PDG	Hami	*C. melo* var. *ameri*

Plant designation indicates the common name and the botanical groups, according to Pitrat et al. (2000) and Yi et al. (2013).

2. Materials and methods

2.1. Plant material and treatments

In this study, nine Hami melon landraces ('Huangdanzi', 'Zajiaojiashigua', 'Kalakesai', 'Paotaihong', 'Laotiepi', 'Kaeryunxi', 'Sairekekekouqi', 'Akekekouqi' and 'Paodangua') from Xinjiang province were analyzed to evaluate the mechanism of salt tolerance in this species. All selected landraces are widely cultivated in Xinjiang. Table 1 provides the abbreviations and the collecting sites of these landraces. Fig. 1 shows the images of the landrace fruits.

The experiment was conducted using glasshouse facilities of the National Center of Vegetable Improvement in Huazhong Agricultural University, Central China (latitude, 30° 27′ N; longitude, 114° 20′ E; and altitude 22 m above sea level). The seeds were sown in the plug trays. When the third true leaf of plants emerged, seedlings were transplanted into plastic pots, each containing 10 L of substrate (peat: vermiculite: perlite = 1:1:1, v/v). Each pot contained one melon seedling. The pots were arranged at a 150 cm row spacing, spaced 50 cm apart. For the first week after transplanting, plants were irrigated with a full strength nutrient solution (Hoagland and Arnon, 1950) without salt. The composition of the Hoagland's solution was: 4 mM $Ca(NO_3)_2$, 6 mM KNO_3,

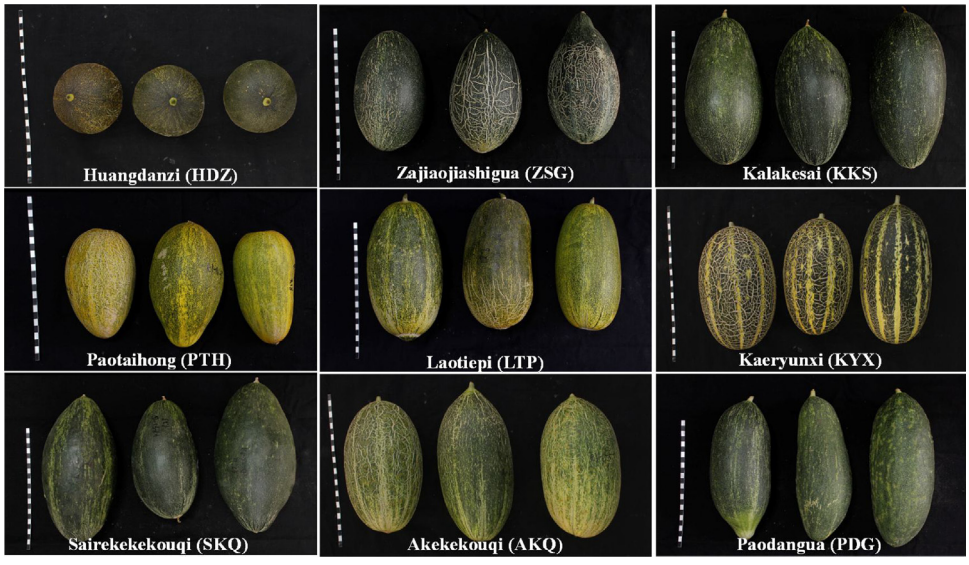

Fig. 1. Fruits of nine melon landraces. The scale bar in the figure is 25 cm.