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Genetic and fruit trait differences between Chinese elite lines/varieties and American varieties of processing tomato

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ABSTRACT

The history of processing tomato industry in China is short and the major variety being used in production to date is still Riegel 87-5, a variety released in 1996. To investigate the genetic and fruit trait differences between Chinese elite lines/varieties and American varieties, 51 including 24 recently developed Chinese elite lines, four Chinese varieties, and 23 American varieties were subjected to genotypic analysis using 547 InDel markers. The range of Nei's genetic distance was wider in Chinese elite lines (0.209–0.383) than in Chinese varieties (0.126–0.214) and American varieties (0.223–0.342). Cluster analysis indicated that the 51 varieties/lines could be classified into three groups without specific relationship between group and country. This was further supported by population structure analysis using the software STRUCTURE2.3.4. Fruit traits were collected from 51 tomato varieties/lines grown in 2013 and 2014. The average soluble solid content was lower, while the average fruit weight was larger, and the average color was relatively poorer in both Chinese elite lines and varieties than in the American varieties. However, some elite lines such as 9508-h and their progenies had relatively good fruit traits, and thus could be superior sources for processing tomato improvement. The experience of developing processing tomato industry in China could be of value to countries with similar situations.

1. Introduction

The earliest introduction and planting processing tomato in China occurred in Shanghai in 1960s, and the only processed product was highly concentrated paste (Xu and Li, 2007). The processing industry spread from the east coast to west and northeast in 1970s, and moved to northwest regions including Xinjiang, Gansu, Ningxia, and Hetao of Inner Mongolia. Due to the advantages of availability of vast fertile land, favorable weather, less cost for production, and better benefit for producer, these regions became the main production area in the late 1980s (Zhang et al., 2004; Xu and Li, 2007). Since 1990s, Xinjiang became the main production area with over 80% of the whole national production (Wu and Li, 2011; Zeng, 2015). In the past two decades, the processing tomato industry in Xinjiang developed rapidly and the paste production ranked the second in the world in 2003 (Li and Liu, 2009). However, the processing tomato production wandered or even declined in the last 10 years due to several factors including the weak demand of international market, simple production and processing system, the increase of labor cost, irrational expansion of tomato industries, and serious degeneration of varieties (Li and Liu, 2009; Wu and Li, 2011; Zeng, 2015; Kang et al., 2016).

Germplasm resources are the basis of genetic improvement. Since tomato is not a native plant species in China, the only approach for improving tomato cultivar is to use genetic resources imported from the center of origin or countries with strengths in breeding and production. The long history of processing tomato industry (Sims, 1980) and the steady increase of yield per unit since 1960s (Li and Liu, 2009) make the United States of America (USA) the leadership position in cultivar development, cultivation, and processing in the world (Sims, 1992; Li and Liu, 2009). Therefore, the USA is one of the most desirable countries for China to import processing tomato varieties. Many processing tomato varieties have been introduced from the USA into China particularly into Xinjiang for variety test and some of them (e.g. H9551, H8892, Medina) have been used in breeding programs to develop new varieties since 1990s. More than 50 new varieties have been released in China in the past 20 years. Unfortunately, this did not change the situation that the major variety being used in production to date is still Riegel 87-5, a variety derived from the variety Riegel through systemic selection (Jiang and Zhang, 1996). Approximately 80% of processing tomato acreage is used for planting this variety every year (Wu and Li,

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2011; Zeng, 2015). One of the reasons causing this situation is that most new cultivars/hybrids do not show significant performance improvement in terms of yield and quality (Li et al., 2013). It remains unclear why the use of foreign varieties as breeding materials does not show obvious success in new cultivar development.

In this study, genetic differences between 28 Chinese elite breeding lines/varieties and 23 American varieties were revealed by genotyping them with 547 InDel markers. Several fruit traits were also measured from all varieties and some progenies. The objective of this work was to explore the differences between Chinese and American processing tomato varieties for delineating the elite lines for future processing tomato breeding. The data will be used to illustrate the reason of poor variety improvement and propose strategies for processing tomato improvement in China and countries with the similar situation.

2. Materials and methods

2.1. Plant materials and experimental design

To compare genetic and phenotypic variation in processing tomato lines/varieties developed in China with varieties developed in the USA, a total of 51 processing tomato varieties or elite breeding lines consisting of 24 Chinese elite breeding lines, four Chinese modern varieties, and 23 American varieties (Table 1), were used in this study. The Chinese elite breeding lines and varieties being used in several breeding programs (Li et al., 2008b; Zeng et al., 2015) were collected from Xinjiang, where is the main processing tomato production area in China. The American varieties are mainly from three processing tomato grown regions including California, Ohio, and New Jersey in the United States. The 51 varieties/lines were grown in a randomized complete block design (RCBD) with three blocks containing each genotype in two independent experiments conducted at Shangzhuang Experimental Station of China Agricultural University (Beijing, China) in 2013 and 2014 for phenotypic data collection and DNA isolation. Plots of each genotype consisted of at least four plants. Eleven of 24 Chinese elite lines and six hybrid cultivars or inbred lines developed from some Chinese elite lines were grown in a RCBD with three blocks containing each genotype at Shihezi (Xinjiang, China) in 2014 or 2015 for agricultural traits evaluation. Plots of each hybrid consisted of 30 plants.

Tomato seeds used for all studies were sown in 128 cell flats filled with a mixture of peat and vermiculite (3:1) in a protected greenhouse. Greenhouse temperatures ranged from 22 to 30 °C with natural light. Seedlings were transplanted to field approximately 50 days after germination. Production practices, plant spacing, and row spacing were as recommended for commercial growers.

Table 1
Description of 51 processing tomato genotypes used in this study.

Genotype	Type	Country of origin	State/Provice of Origin
Hongfanbuluo 1	Variety	China	Xinjiang
Hongyu A	Variety	China	Inner Mongolia
Riegel 87-5	Variety	China	Xinjiang
Xinyin 98-1	Variety	China	Xinjiang
88-10-h	elite line	China	Xinjiang
9508-h	elite line	China	Xinjiang
NDM3373-h	elite line	China	Xinjiang
SF-18-h	elite line	China	Xinjiang
Sh-20-h	elite line	China	Xinjiang
TD-55C-h	elite line	China	Xinjiang
TD-91-1-h	elite line	China	Xinjiang
TY-01-h	elite line	China	Xinjiang
WTY09-04-h	elite line	China	Xinjiang
ZF044-h	elite line	China	Xinjiang
ZF071-1-h	elite line	China	Xinjiang
ZF084-1-h	elite line	China	Xinjiang
ZF086-2-h	elite line	China	Xinjiang
ZF087-h	elite line	China	Xinjiang
ZF088-h	elite line	China	Xinjiang
ZF089-4-h	elite line	China	Xinjiang
ZF103-2-h	elite line	China	Xinjiang
ZF107-1-h	elite line	China	Xinjiang
ZF112-h	elite line	China	Xinjiang
ZF117-h	elite line	China	Xinjiang
ZF120-h	elite line	China	Xinjiang
ZF125-2-h	elite line	China	Xinjiang
ZF-133-h	elite line	China	Xinjiang
ZF134-h	elite line	China	Xinjiang
Hunt 100	Variety	USA	–
E6203	Variety	USA	California
LA1500	Variety	USA	California
LA1502	Variety	USA	California
LA1563	Variety	USA	California
LA4104	Variety	USA	California
M82	Variety	USA	California
Pearson	Variety	USA	California
Peto95-43	Variety	USA	California
UC204C	Variety	USA	California
VF36	Variety	USA	California
Campbell 1327	Variety	USA	New Jersey
Campbell 31	Variety	USA	New Jersey
Campbell 34	Variety	USA	New Jersey
E3259	Variety	USA	Ohio
H1350	Variety	USA	Ohio
H1706	Variety	USA	Ohio
H722	Variety	USA	Ohio
OH7814	Variety	USA	Ohio
OH8245	Variety	USA	Ohio
OH88119	Variety	USA	Ohio
OH9242	Variety	USA	Ohio
Earliana	Variety	USA	Philadelphia

2.2. Genetic variation analysis

The 51 processing tomato lines/varieties were genotyped with 547 InDel markers (Supplementary material, Table S1) using the methods described by Yang et al. (2014). Nei's genetic distance (Nei, 1972) was calculated for each pair of genotypes and marker allele frequency was obtained using the software PowerMarker V3.25 (Liu and Muse, 2005). Unweighted Pair Group Method with Arithmetic Mean (UPGMA) cluster analysis was performed to develop a phylogenetic tree using the software PowerMarker and the tree was viewed in MEGA5 (Tamura et al., 2011). The stability of tree nodes was tested by bootstrap analysis with 100 replicates.

Population structure of the 51 processing tomato lines/varieties was determined using a free software package of STRUCTURE2.3.4 (Pritchard et al., 2000). Although the tomato lines/varieties had distinct origins, model without prior population information was used to assign individuals to population. Number of populations (K) and the best K were determined following the methods of Wei et al. (2012).

2.3. Phenotypic data collection and analysis

Phenotypic data including fruit weight (FW), soluble solid content (SSC) and color parameters of the 51 tomato lines/varieties grown in Beijing were collected from five to ten red ripe fruits at the same maturity stage. Mean FW for single fruit in each plot was obtained by dividing the total FW by the number of fruits. Objective measurement of color was conducted using the software Tomato Analyzer 3.0 (Brewer et al., 2006) following the description in Darrigues et al. (2008). The software generated a set of L*, a*, b*, hue, and chroma values representing absolute color for each fruit. SSC was measured using a WAY-2S digital ABBE refractometer (Shanghai Precision Scientific Instrument Company, Shanghai, China). Plot means for values of color parameters and SSC were calculated based on measurements of all fruits in each plot.

For tomato lines and hybrids grown in Shihezi; FW, SSC, pH, titratable acidity, and lycopene were measured from 30 red ripe fruits collected from plants in each plot. Mean FW for single fruit in each plot