Mineral element composition of 27 Chinese dwarf cherry (Cerasus humilis (Bge.) Sok.) genotypes collected in China

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SUMMARY
Concentrations of ten mineral elements (P, S, K, Ca, Mn, Fe, Cu, Zn, Rb, and Sr) were determined in 27 genotypes of Chinese dwarf cherry using total reflection X-ray fluorescence spectrometry. The results indicated that Chinese dwarf cherry was a rich source of mineral elements, especially Ca, Fe, and Zn, with the highest concentrations being 524, 24.2, and 4.86 mg kg⁻¹ FW in genotypes C-12-5-7, A-9-1-3, and E-20-2-2, respectively. Among the 27 Chinese dwarf cherry genotypes examined, the coefficients of variation were > 30% for Rb, Fe, Ca, Sr, Zn, Mn concentrations, and 25 – 30% for P, S, K, and Cu concentrations. Principal components analysis was applied to the data matrix to evaluate the analytical results. Three principal components (PC1 – PC3) accounted for 75.6% of the total variance. The 27 Chinese dwarf cherry genotypes studied have potential benefits for human nutrition and healthcare research, as well as for genetic biodiversity research.

Mineral element compositions of fruit and vegetables are of significant interest for human health and nutrition. Essential mineral elements such as Mn, Fe, Cu, Zn, Ni, and Cr (minor and trace elements) and P, S, K, and Ca (major elements) are beneficial in crops (Calle et al., 2013). Fruit have been associated with reduced risks of some forms of cancer, heart disease, stroke, and other chronic ailments (Mitić et al., 2012). Daily consumption of fruit contributes significantly to the requirement for essential elements in humans (Mitić et al., 2012). The mineral element compositions of common fruit such as apple, grape, orange, cherry, strawberry, and plum have been investigated extensively (Liu et al., 2008; Provenzano et al., 2010; Sobukola et al., 2010; Mitić et al., 2012; Wasim et al., 2012). However, few data exist on the mineral element composition of Chinese dwarf cherry (Cerasus humilis (Bge.) Sok.).

Chinese dwarf cherry, a member of the family Rosaceae, originated in the North of China and is known for its resistance to drought, saline soils, alkaline soils, and cold, which allows it to grow vigorously on sandy wasteland and to help ecological restoration while producing delicious fruit (Song et al., 2011; Shao and Chu, 2008). Unfortunately, little research attention has been paid to Chinese dwarf cherry, although it has been grown in the wild for a long time. Chinese dwarf cherry germplasm has been collected and evaluated by the Beijing University of Chinese Medicine for > 10 years. However, the mineral elemental compositions of Chinese dwarf cherry genotypes have not yet been reported.

The aim of this study was to investigate the concentrations of P, S, K, Ca, Mn, Fe, Cu, Zn, Rb, and Sr in 27 genotypes of Chinese dwarf cherry, and to examine whether there was any correlation between the concentrations of these mineral elements using principal components analysis (PCA).

MATERIALS AND METHODS

Plant material
A total of 70 Chinese dwarf cherry (C. humilis (Bge.) Sok.) genotypes, with 30 trees per genotype, were planted in the orchard at the Xishan Experimental Forestry Centre, Haidian District, Beijing, P. R. China in Spring 2006. In this study, 27 of these genotypes of Chinese dwarf cherry were examined. The same irrigation, pruning, disease, and pest control management procedures were applied to all 27 genotypes. No fertiliser had been supplied since 2006.

Fruit were harvested manually at maturity from July–September 2011, based on ripening dates in 2010 and on fruit firmness. Samples of 250 g of fruit per tree were put into an ice box and immediately transferred to the laboratory and stored at −20°C until microwave digestion. Three replicates samples were collected for each genotype.

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Microwave digestion and mineral element concentration measurements

Ten fruit from each 250 g sample were washed in deionised water, then dried with filter paper. Pedicels and stones were removed and the flesh was ground in an agate mortar. Teflon reaction vessels were used for all digestion procedures and the reaction vessels were cleaned with 5 ml of concentrated nitric acid [65% (v/v); Merck, Darmstadt, Germany] before each digestion.

Four ml of 65% (v/v) HNO₃ was added to each 1.5 g sample of fruit flesh homogenate and kept at 25°C for 30 min, then 0.5 ml of 30% (v/v) H₂O₂ (Sinopharm Chemical Reagent Co., Ltd, Beijing, P. R. China) was added. Samples were digested in a microwave digestion system (MARS2006; CEM Co., Matthews, NC, USA) under the conditions listed in Table I. After the microwave digestion had finished, each sample was cooled and 0.5 ml of 30% (v/v) H₂O₂ was added. The liquid was separated from the solid phase by centrifugation at 5,000 × g for 2 min at 25°C and the supernatant was made up to 25 ml with deionised water. One ml of this was then poured into a 0.5 ml glass tube and 10 µl of 1.0 g l⁻¹ gallium internal standard solution (National Center of Analysis and Testing for Nonferrous Metals and Electronic Materials, Beijing, P. R. China) was added and vortex-mixed thoroughly for the measurements.

A sample (10 µl) of each diluted supernatant was placed in a quartz sample carrier and dried on a hot plate by vaporisation of the solvent prior to total reflection X-ray fluorescence spectrometry (Bruker AXS Microanalysis GmbH, Berlin, Germany). The spectrometer was equipped with a molybdenum tube (1,000 µA, 50 kV, 50 W), a multilayer monochromator, a silicon drift detector with an active area of 10 mm², and Spectra 6.1 software (Bruker AXS Microanalysis GmbH). Three replicates of each sample were measured.

### TABLE I

<table>
<thead>
<tr>
<th>Step</th>
<th>Temperature (°C)</th>
<th>Power (W)</th>
<th>Rate of temperature increase (°C min⁻¹)</th>
<th>Duration (min)</th>
</tr>
</thead>
<tbody>
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<td>1,600</td>
<td>3</td>
<td>3</td>
</tr>
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<tr>
<td>3</td>
<td>170</td>
<td>1,600</td>
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<td>3</td>
</tr>
<tr>
<td>4</td>
<td>190</td>
<td>1,600</td>
<td>5</td>
<td>10</td>
</tr>
</tbody>
</table>

### RESULTS AND DISCUSSION

**Mineral element concentrations**

A total reflection X-ray fluorescence spectrometer was used to measure the concentrations of ten mineral elements (P, S, K, Ca, Mn, Fe, Cu, Zn, Rb, and Sr) in the fruit flesh of 27 Chinese dwarf cherry genotypes. The results are shown in Table II.

Two different groups of mineral elements were established based on their concentrations. One group contained those mineral elements present in all fruit (i.e., P, S, K, and Ca). There were high variations in P and S concentrations among the 27 genotypes of Chinese dwarf cherry tested, ranging from 98 – 336 mg kg⁻¹ FW and from 18.6 – 53.4 mg kg⁻¹ FW, respectively (Table II). The highest P and S concentrations were 336 mg kg⁻¹ FW in genotype N3 and 53.4 mg kg⁻¹ FW in genotype H-9-1-1, respectively. Mean P and S concentrations were 198 mg kg⁻¹ FW and 35.7 mg kg⁻¹ FW, respectively (Table II). The coefficients of variation (CV) for all 27
genotypes of Chinese dwarf cherry were 27.6% for P concentration and 27.1% for S concentration (Figure 1).

Potassium (K) concentrations were highest among all mineral elements examined (Table II). K concentrations varied from 531 – 1,692 mg kg⁻¹ FW and the CV was 26.5% (Figure 1). The maximum and minimum K concentrations were 1,007 mg kg⁻¹ FW and 276.5% (Figure 1). The mean K concentration was 1,007 mg kg⁻¹ FW and the CV was 26.5% (Figure 1). The maximum and minimum K concentrations were observed in genotypes A-4-4-2 and E-20-2-3, respectively (Table II). The mean K concentration was 1,007 mg kg⁻¹ FW, which was higher than that in table grape (928.9 mg kg⁻¹ FW; Mitić et al., 2012), but lower than that in strawberry fruit (1,590 mg kg⁻¹ FW; Wasim et al., 2012) and in sea buckthorn (3,408.9 mg kg⁻¹ FW; Gutzeit et al., 2008).

Calcium (Ca) is required for normal growth and development in humans (Frossard et al., 2000). Calcium concentrations in Chinese dwarf cherry genotypes ranged from 103 – 524 mg kg⁻¹ FW with a CV of 41.6% (Table II; Figure 1). The maximum and minimum Ca concentrations were observed in genotypes C-12-5-7 and D-17-2-2, respectively (Table II). The mean Ca concentration found in this study was lower than those detected in wild myrobalan plum (Liu et al., 2008), and sea buckthorn (Gutzeit et al., 2008). We conclude that Chinese dwarf cherry is a good source of Fe among fruit species.

Copper (Cu) is an important co-factor for several key enzyme systems and is involved in the mobilisation and release of stored iron from the liver, in the formation of myelin and bone, and in the maintenance of elastin in the major blood vessels (Arvanitidou et al., 2007). In this study, Cu concentrations in Chinese dwarf cherry fruit ranged from 0.34 – 0.82 mg kg⁻¹ FW, and the lowest and highest values were found in genotypes F-3-3-1 and E-20-2-3, respectively (Table II). The mean Cu concentration in all 27 genotypes was 0.47 mg kg⁻¹ FW, with a CV of 32.5% (Table II; Figure 1). Mitić et al. (2012) reported that Mn concentrations ranged from 0.90 – 1.96 mg kg⁻¹ FW in table grape and from 0.46 – 0.56 mg kg⁻¹ FW in sour cherry. Zhang et al. (2008) reported Mn concentrations of 0.37 and 0.34 mg kg⁻¹ FW, respectively, for ‘Xinjiang’ wild apple and cultivated apple in China. However, the mean Mn concentration in Chinese dwarf cherry genotypes was lower than that in some fruit such as strawberry (Wasim et al., 2012), wild myrobalan plum (Liu et al., 2008), and sea buckthorn (Gutzeit et al., 2008).

Iron (Fe) is an essential mineral element and an important component of proteins involved in oxygen transport and metabolism (Aberoumand and Deokule, 2009). An approx. 6.7-fold difference in Fe concentration was found between the lowest and the highest ranked Chinese dwarf cherry genotypes. Concentrations ranged from 3.58 mg kg⁻¹ FW in genotype B-8-1-1 to 24.02 mg kg⁻¹ FW in genotype A-9-1-3 (Table II). The mean Fe concentration found in this study was lower than those measured in different fruit by other authors. Mitić et al. (2012) observed that Fe concentrations ranged from 7.62 mg kg⁻¹ FW in sour cherry to 8.15 mg kg⁻¹ FW in table grape. Zhang et al. (2008) showed that Fe concentrations reached 6.20 and 6.22 mg kg⁻¹ FW for ‘Xinjiang’ wild apple and cultivated apple, respectively, in China. In addition, the Fe concentration in Chinese dwarf cherry was significantly higher than that in strawberry (5.49 mg kg⁻¹ FW; Wasim et al., 2012), wild myrobalan plum (21.20 mg kg⁻¹ FW; Liu et al., 2008) and sea buckthorn (30.88 mg kg⁻¹ FW; Gutzeit et al., 2008). These results suggest that Chinese dwarf cherry can provide a significant source of Ca compared to other fruit.

The second group of mineral elements contained those known to be essential to living cells, (Mn, Fe, Cu, and Zn) in addition to two non-essential elements, (Rb and Sr). The concentrations of these mineral elements are shown in Table II. Mineral element concentrations in the second group were significantly lower than those in the first group (Table II).

Manganese (Mn) is an essential element for both animals and plants, and Mn deficiency results in severe skeletal and reproductive abnormalities in mammals (Sivaperumal et al., 2007). Mn concentrations varied from 0.62 – 2.11 mg kg⁻¹ FW, and the maximum and minimum values were observed in genotypes C-8-1-6 and B-4-5-1, respectively (Table II). The mean Mn concentration in all 27 genotypes was 1.20 mg kg⁻¹ FW, with a CV of 32.5% (Table II; Figure 1). Mitić et al. (2012) reported that Mn concentrations ranged from 0.90 – 1.96 mg kg⁻¹ FW in table grape and from 0.46 – 0.56 mg kg⁻¹ FW in sour cherry. Zhang et al. (2008) reported Mn concentrations of 0.37 and 0.34 mg kg⁻¹ FW, respectively, for ‘Xinjiang’ wild apple and cultivated apple in China. However, the mean Mn concentration in Chinese dwarf cherry genotypes was lower than that in some fruit such as strawberry (Wasim et al., 2012), wild myrobalan plum (Liu et al., 2008), and sea buckthorn (Gutzeit et al., 2008).

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kg\(^{-1}\) FW in genotype B-8-1-1 (Table II). The mean Zn concentration in all 27 genotypes was 2.33 mg kg\(^{-1}\) FW, with a CV of 35.9% (Table II; Figure 1). Mitić et al. (2012) observed Zn concentrations from 0.53 – 0.84 mg kg\(^{-1}\) FW in table grape and from 0.53 – 0.72 mg kg\(^{-1}\) FW in sour cherry. Zhang et al. (2008) recorded Zn concentrations of 0.27 and 0.20 mg kg\(^{-1}\) FW in Xinjiang wild apple and cultivated apple, respectively, in China. Zn concentrations in strawberry (Wasim et al., 2010), grape (Sobukola et al., 2010), and sea buckthorn (Gutzeit et al., 2008) were 0.86, 1.14, 0.04, 0.073, and 2.01 mg kg\(^{-1}\) FW, respectively. These results confirmed that Zn concentrations in Chinese dwarf cherry fruit were generally higher than in other fruit.

Significant differences in Rb (0.62 – 4.66 mg kg\(^{-1}\) FW) and Sr (0.45 – 2.24 mg kg\(^{-1}\) FW) concentrations were found among the 27 Chinese dwarf cherry genotypes (Table II). The CVs of all 27 genotypes were 55.3% and 40.7% for Rb and Sr concentrations, respectively (Figure 1). The mean concentrations of Rb (1.58 mg kg\(^{-1}\) FW) and Sr (1.10 mg kg\(^{-1}\) FW) were higher and lower than those in strawberry (Rb, 0.32 mg kg\(^{-1}\) FW; Sr, 2.01 mg kg\(^{-1}\) FW), respectively (Wasim et al., 2012).

**Correlation analysis**

Element-to-element correlation data, in terms of linear correlation coefficient values significant at the 95% and 99% confidence levels were examined. The Ca–Sr (0.90), P–K (0.76), K–Rb (0.75), K–Mn (0.73), P–Mn (0.60), P–Rb (0.66), Ca–Fe (0.57), Ca–Mn (0.54), Rb–Sr (0.54), P–Ca (0.54), Ca–Rb (0.53), K–Sr (0.53), Mn–Sr (0.52), K–Ca (0.51), Fe–Sr (0.49), P–Sr (0.49) and Mn–Rb (0.48) pairs of minerals showed high and significant correlations at the 99% confidence level. High correlation coefficients supported the assumption that the origins of the elements may be similar. While S showed a moderate correlation with Cu (0.41) at the 95% confidence level, Zn showed no correlation with any other element.

**Principal components analysis (PCA)**

A PCA was carried out on the correlation matrix using the PCA sub-routine in SPSS software Version 13. PCA was applied to the data matrix of total mineral element concentrations (ten elements × 27 genotypes) in Chinese dwarf cherry. Three PCs explained approx. 75.6% of the total variance among Chinese dwarf cherry genotypes, with the contribution of each PC being 42.6%, 17.5%, and 15.5%, respectively. The three principal components (PCs) and communalities are presented in Table III. The first (PC1) had high loadings for P, K, Ca, Mn, Rb, and Sr, and explained approx. 43% of the total variance. The second (PC2) accounted for 17% of the total variance and was highly positively correlated with S and Cu concentrations, while negatively correlated with Fe (−0.549). PC3 was dominated by Zn and explained 15% of the total variance. A 3-D plot of the PCA loadings is illustrated in Figure 2, where the relationships among the mineral elements can readily be seen.

**Table III**

Three principal components and communalities in 27 genotypes of Chinese dwarf cherry

<table>
<thead>
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<th>Mineral element</th>
<th>Principal component</th>
<th>Communalities</th>
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</thead>
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<tr>
<td></td>
<td>PC1</td>
<td>PC2</td>
</tr>
<tr>
<td>P</td>
<td>0.804†</td>
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</tr>
<tr>
<td>S</td>
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<tr>
<td>K</td>
<td>0.838</td>
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<tr>
<td>Ca</td>
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<tr>
<td>Mn</td>
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<tr>
<td>Fe</td>
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<tr>
<td>Cu</td>
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</tr>
<tr>
<td>Zn</td>
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<tr>
<td>Rb</td>
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<tr>
<td>Sr</td>
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</tr>
<tr>
<td>Variance explained (%)</td>
<td>42.6</td>
<td>17.5</td>
</tr>
</tbody>
</table>

†Bold values show loading coefficients >0.52 or <-0.52.

CONCLUSIONS

Ten mineral element concentrations in 27 genotypes of Chinese dwarf cherry were studied for the first time. The results indicated that Chinese dwarf cherry is a rich source of key mineral elements, especially Ca, Fe, and Zn, with the highest concentrations being 524, 24.2, and 4.86 mg kg\(^{-1}\) FW in genotypes C-12-5-7, A-9-1-3, and E-20-2-2, respectively. Among the 27 Chinese dwarf cherry genotypes examined, CV values among genotypes were calculated at > 30% for Rb, Fe, Ca, Sr, Zn, Mn concentrations, and 25 – 30% for P, S, K, Cu concentrations. PCA analysis showed the presence of three groups of minerals. The first group contained P, K, Ca, Mn, Rb, and Sr, the second group contained S, Cu, and Fe, and the third group included only Zn. The 27 Chinese dwarf cherry genotypes studied have potential for human nutrition, healthcare and genetic biodiversity research.

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REFERENCES


