Assessment of Genetic Diversity of Chinese Sand Pear Landraces (Pyrus pyrifolia Nakai) Using Simple Sequence Repeat Markers

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Abstract. The sand pear (Pyrus pyrifolia Nakai) is an important fruit crop in China. In this study, simple sequence repeats (SSRs) were used to estimate the level and pattern of genetic diversity among 233 sand pear landraces collected from 10 different geographic regions in China. The results demonstrated that the SSR technique is an effective tool for assessing genetic diversity and the geographic pattern of genetic variation among sand pear landraces of different origins. A total of 184 putative alleles was detected using 14 primer pairs with an average of 13.1 alleles per locus. The mean expected heterozygosity and observed heterozygosity across all loci were 0.705 and 0.671, respectively. High genetic diversity was found in all populations except for that originated from Jiangxi \((A_e = 3.149; H_e = 0.655)\), whereas at the regional level, those from central China were less diverse than those from other regions. Analysis of molecular variance showed that most genetic differences resided among landraces within populations. Additionally, un-weighted pair group with arithmetic average clustering and principal component analysis plotting based on Nei’s genetic distance revealed distinct gene pools in agreement with geographic distribution.

The sand pear (Pyrus pyrifolia Nakai) is one of the most important fruit tree crops in China and is extensively cultivated in central and southwest China. The species occurs naturally in southern and western China, recognized as the center of origin of the genus Pyrus (Rubtsov, 1944). There are very many landraces (local cultivars) of P. pyrifolia owing to nearly 3000 years of cultivation and the complex climatic and geographical variation in China. Many landraces have unique traits. For example, ‘Puguali’, from Zhejiang Province, is a large-fruited cultivar with a mean weight of 553 g and a maximum weight of 950 g. The skin is green when mature and covered with brown russet, which turns reddish brown when fruit are fully ripe. ‘Cangxili’, named after its place of origin, Cangxi county in Sichuan Province, is a traditional landrace with maximum fruit weight of 1850 g (average, 321.3 g), smooth skin, and crisp and tender flesh, which is sweet and juicy and of high quality. The rich genetic resources in sand pear provide great potential for cultivar improvement and enhancement of the sustainability of the pear industry. However, many traditional local cultivars have been threatened with extinction by the changes that have occurred in the modern Chinese fruit industry over the past three decades. There has been large-scale cultivation of a few elite cultivars and top-grafting or replacement of old cultivars or landraces. This genetic loss could lead to serious erosion of the gene pool of the cultivated sand pear. To conserve and manage the diversity of sand pear landraces and cultivars, the Wuhan Sand Pear Germplasm Repository (WSPGR) was established in 1986 as the national repository for sand pears, and since then, an exhaustive collection of local cultivars and landraces of Chinese sand pear has been assembled.

Molecular techniques are useful tools for evaluating genetic diversity and for defining genetic relationships in fruit tree crops. In pear, chloroplast polymerase chain reaction–restriction fragment length polymorphisms (RFLPs) were used to examine relationships between east Asian species (Iketani et al., 1998). Dominant nuclear markers, random amplified polymorphic DNA (RAPD), amplified fragment length polymorphism (AFLP), and intersimple sequence repeat (ISSR) were used in an investigation of genetic relationships among species and for pear cultivar fingerprinting (Cao et al., 2007; Shen et al., 2006; Teng et al., 2001, 2002; Zhang et al., 2007), and nuclear and chloroplast DNA sequences have been used to identify pear cultivars (Kimura et al., 2003; Lee et al., 2004). Of the DNA marker systems currently available, simple sequence repeat (SSRs) have been considered one of the most useful for assessment of genetic diversity and cultivar fingerprinting at the intraspecific level because of their abundance, hyperpolymorphism, and codominant inheritance (Morgante and Olivieri, 1993; Tautz, 1989). However, the published work to date reported the use of a set of SSRs isolated from apple for verifying the transferability of SSRs between apple and pear (Yamamoto et al., 2001) and the cultivar identification by SSRs in a limited number of cultivars developed in Japan (Kimura et al., 2002). SSR markers have been proved as a robust tool for revealing genetic diversity in sand pear (Cao et al., 2007; Kimura et al., 2002, 2003), red-skin sand pear (Zhang et al., 2007), and some other pears in west China (Fan et al., 2007).

Current germplasm evaluation in China mostly focuses on morphological descriptions and documenting pomological traits. The exchange of plants between repositories or commercial orchards raises problems in that some individual sand pear landraces or cultivars may be known by several different names or the one name may be used for different landraces or cultivars. The information from current evaluation of sand pears was not sufficient. Furthermore, detailed morphological descriptions and comparisons of plants are time-consuming and fruit-related traits cannot be observed until plants are mature to produce fruit. Genetic characterization of the gene pool of the cultivated sand pears in the WSPGR collection has not previously been attempted but is urgently needed for formulating management strategies for the WSPGR and for furnishing useful genetic information for future sand pear breeding efforts. This should provide a better understanding of the genetic diversity that exists in the gene pool of the cultivated sand pears and the diverse sources of useful genes in the germplasm repository. Therefore, the objectives of the present investigation were to determine the genetic diversity of the overall gene pool of sand pear landraces and assess the genetic variation among sand pear landrace groups in relation to their geographic distribution in China.

Materials and Methods

A total of 233 landraces originating from 10 provinces (designated as populations in this study) was obtained from the WSPGR...
Table 1. Chinese landraces of sand pear evaluated.

| Accession number | Landrace          | District | Province (population) | Region           |
|------------------|-------------------|----------|-----------------------|------------------|
| 001              | Fu’andaxuei       | Fu’an    | Fujian                | East China       |
| 002              | Qingpizhongli     | Jian’ou  | Fujian                | East China       |
| 003              | Aijiali           | Jianyang | Fujian                | East China       |
| 004              | Bingzili          | Jianyang | Fujian                | East China       |
| 005              | Huangpizhongli    | Jianyang | Fujian                | East China       |
| 006              | Chiupi            | Jianyang | Fujian                | East China       |
| 007              | Eli               | Jianyang | Fujian                | East China       |
| 008              | Pingguoli         | Jianyang | Fujian                | East China       |
| 009              | Shuli             | Jianyang | Fujian                | East China       |
| 010              | Bannamwuli        | Pingnan  | Fujian                | East China       |
| 011              | Mandingxuei       | Pucheng  | Fujian                | East China       |
| 012              | Puchengxuei       | Pucheng  | Fujian                | East China       |
| 013              | Puli              | Shouning | Fujian                | East China       |
| 014              | Liuyuehuangzongli | Shunchang| Fujian                | East China       |
| 015              | Muli              | Shunchang| Fujian                | East China       |
| 016              | Baiyu             | Jiujiang | Jiangxi               | East China       |
| 017              | Hehua             | Shangrao | Jiangxi               | East China       |
| 018              | Huangxiexiong     | Shangrao | Jiangxi               | East China       |
| 019              | Kuixingmake       | Shangrao | Jiangxi               | East China       |
| 020              | Xiuhapingtouqing  | Shangrao | Jiangxi               | East China       |
| 021              | Jiangwanxipili    | Wuyuan   | Jiangxi               | East China       |
| 022              | Bayuexue          | Wuyuan   | Jiangxi               | East China       |
| 023              | Wuyuanbali        | Wuyuan   | Jiangxi               | East China       |
| 024              | Wuyuanansli       | Wuyuan   | Jiangxi               | East China       |
| 025              | Wuyanxuei         | Wuyuan   | Jiangxi               | East China       |
| 026              | Yousi             | Wuyuan   | Jiangxi               | East China       |
| 027              | Danenl           | Leqing   | Zhejiang             | East China       |
| 028              | Dahuangren        | Leqing   | Zhejiang             | East China       |
| 029              | Huangqieli        | Leqing   | Zhejiang             | East China       |
| 030              | Juzhongli         | Leqing   | Zhejiang             | East China       |
| 031              | Puguali           | Leqing   | Zhejiang             | East China       |
| 032              | Yandangxuei       | Leqing   | Zhejiang             | East China       |
| 033              | Zhenxiangli       | Leqing   | Zhejiang             | East China       |
| 034              | Hanghong          | Unknown  | Zhejiang             | East China       |
| 035              | Huahong           | Unknown  | Zhejiang             | East China       |
| 036              | Yuanli            | Unknown  | Zhejiang             | East China       |
| 037              | Ruanxuei          | Unknown  | Zhejiang             | East China       |
| 038              | Sanhui            | Unknown  | Zhejiang             | East China       |
| 039              | Shanghaixuei      | Unknown  | Zhejiang             | East China       |
| 040              | Nuodaoli          | Yiwu     | Zhejiang             | East China       |
| 041              | Yiwulizi          | Yiwu     | Zhejiang             | East China       |
| 042              | Zaosanhua         | Yiwu     | Zhejiang             | East China       |
| 043              | Xihuaxuei         | Yunhe    | Zhejiang             | East China       |
| 044              | Yunshibianli      | Yunhe    | Zhejiang             | East China       |
| 045              | Yunhuxuei         | Yunhe    | Zhejiang             | East China       |
| 046              | Fengkaihuizouli   | Fengkai  | Guangdong            | South China      |
| 047              | Xinghuadayinli    | Fengkai  | Guangdong            | South China      |
| 048              | Yeshenli          | Fengkai  | Guangdong            | South China      |
| 049              | Hehuali           | Fengkai  | Guangdong            | South China      |
| 050              | Gaoyaoxshuili     | Gaoyao   | Guangdong            | South China      |
| 051              | Gaoyaohuangli     | Gaoyao   | Guangdong            | South China      |
| 052              | Gaoyaoqinli       | Gaoyao   | Guangdong            | South China      |
| 053              | Jianyeli          | Gaoyao   | Guangdong            | South China      |
| 054              | Huiyanghuangli    | Huiyang  | Guangdong            | South China      |
| 055              | Huiyangxuani      | Huiyang  | Guangdong            | South China      |
| 056              | Xihuahongli       | Huiyang  | Guangdong            | South China      |
| 057              | Xiangshuili       | Huiyang  | Guangdong            | South China      |
| 058              | Qinghui           | Lianzheng| Guangdong            | South China      |
| 059              | Sianjiangpili     | Lianzheng| Guangxi               | South China      |
| 060              | Beilihuangli      | Beilu    | Guangxi               | South China      |
| 061              | Beiliumili        | Beilu    | Guangxi               | South China      |
| 062              | Beiliquingli      | Beilu    | Guangxi               | South China      |
| 063              | Xiangjiaoli       | Debao    | Guangxi               | South China      |
| 064              | Huangpichangbatangli | Gongcheng| Guangxi | South China       |
| 065              | Huangpichuanli    | Gongcheng| Guangxi | South China       |
| 066              | Huangpixuei       | Gongcheng| Guangxi | South China       |
| 067              | Qingpisuani       | Gongcheng| Guangxi | South China       |
| 068              | Xipitangli        | Gongcheng| Guangxi | South China       |
| 069              | Cupitangli        | Guanyang | Guangxi | South China       |
| 070              | Guanyanghuangli   | Guanyang | Guangxi | South China       |
| 071              | Guanyangshuili    | Guanyang | Guangxi | South China       |
| 072              | Guanyangshuanli   | Guanyang | Guangxi | South China       |

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Table 1. (Continued) Chinese landraces of sand pear evaluated.

| Accession number | Landrace            | District  | Province (population) | Region  |
|------------------|---------------------|-----------|-----------------------|---------|
| 073              | Guanyangtangli      | Guanyang  | Guangxi               | South China |
| 074              | Guanyangxuexi       | Guanyang  | Guangxi               | South China |
| 075              | Guanyangzaoheli     | Guanyang  | Guangxi               | South China |
| 076              | Huangpieli          | Guanyang  | Guangxi               | South China |
| 077              | Quanzhoulou         | Guilin    | Guangxi               | South China |
| 078              | Yanshanhuangpixiao  | Guilin    | Guangxi               | South China |
| 079              | Yanshanliuyueyou    | Guilin    | Guangxi               | South China |
| 080              | Yanshangpingxuexi   | Guilin    | Guangxi               | South China |
| 081              | Hengxianjinpaoli    | Hengxian  | Guangxi               | South China |
| 082              | Hengxianlingshanli  | Hengxian  | Guangxi               | South China |
| 083              | Hengxiannili        | Hengxian  | Guangxi               | South China |
| 084              | Nanningdashali      | Hengxian  | Guangxi               | South China |
| 085              | Jingxuingzi         | Jingxi    | Guangxi               | South China |
| 086              | Jingxixuei          | Jingxi    | Guangxi               | South China |
| 087              | Shanggangli         | Leye      | Guangxi               | South China |
| 088              | Lipuhuangpili       | Lipu      | Guangxi               | South China |
| 089              | Lipuxuei            | Lipu      | Guangxi               | South China |
| 090              | Liuchengfengshanli  | Liucheng  | Guangxi               | South China |
| 091              | Liuchengxuexi       | Liucheng  | Guangxi               | South China |
| 092              | Sammenjianghuangli  | Liucheng  | Guangxi               | South China |
| 093              | Guihuali            | Longsheng | Guangxi               | South China |
| 094              | Huangyupili         | Longsheng | Guangxi               | South China |
| 095              | Huangxipili         | Longsheng | Guangxi               | South China |
| 096              | Napoqingpili        | Tianyang  | Guangxi               | South China |
| 097              | Bingtangli          | Unknown   | Guangxi               | South China |
| 098              | Bellihulou          | Wuming    | Guangxi               | South China |
| 099              | Cangwudashali       | Wuzhou    | Guangxi               | South China |
| 100              | Badongjingli        | Badong    | Hubei                 | Central China |
| 101              | Jianshichengtouli   | Jianshi   | Hubei                 | Central China |
| 102              | Jianshichixianfeng  | Jianshi   | Hubei                 | Central China |
| 103              | Jianshizaoquli      | Jianshi   | Hubei                 | Central China |
| 104              | Lichuaxiangshi      | Lichuan   | Hubei                 | Central China |
| 105              | Suizhouzaoquli      | Suizhou   | Hubei                 | Central China |
| 106              | Huishuqingjia       | Unknown   | Hubei                 | Central China |
| 107              | Houzuli             | Unknown   | Hubei                 | Central China |
| 108              | Huangpixiang        | Unknown   | Hubei                 | Central China |
| 109              | Make                | Unknown   | Hubei                 | Central China |
| 110              | Zaomili             | Wuhan     | Hubei                 | Central China |
| 111              | Wanyanjingxi        | Xianfeng  | Hubei                 | Central China |
| 112              | Xianfengbajie       | Xianfeng  | Hubei                 | Central China |
| 113              | Xianfengchentouli   | Xianfeng  | Hubei                 | Central China |
| 114              | Xianfenghongjili    | Xianfeng  | Hubei                 | Central China |
| 115              | Xianfengxuepingli   | Xianfeng  | Hubei                 | Central China |
| 116              | Xianfengyangdongli  | Xianfeng  | Hubei                 | Central China |
| 117              | Xueping             | Xianfeng  | Hubei                 | Central China |
| 118              | Xuanenchengtouli   | Xuan'ne    | Hubei                 | Central China |
| 119              | Xuanenxuei(2)       | Xuan'ne    | Hubei                 | Central China |
| 120              | Xuanenyangdongli    | Xuan'ne    | Hubei                 | Central China |
| 121              | Jinbangtou          | Yuan'an   | Hubei                 | Central China |
| 122              | Longtuani           | Yuan'an   | Hubei                 | Central China |
| 123              | Shilixiang          | Yuan'an   | Hubei                 | Central China |
| 124              | Suantianou          | Yuan'an   | Hubei                 | Central China |
| 125              | Wangshuihai         | Yuan'an   | Hubei                 | Central China |
| 126              | Huailuxiangshi      | Anjiang    | Hunan                 | Central China |
| 127              | Baojingyangdong     | Baojing   | Hunan                 | Central China |
| 128              | Daguoqing           | Jinxian   | Hunan                 | Central China |
| 129              | Tanghuangqiang      | Jinxian   | Hunan                 | Central China |
| 130              | Yadianqiang         | Jinxian   | Hunan                 | Central China |
| 131              | Gengzhouqiang       | Linwu     | Hunan                 | Central China |
| 132              | Qingli              | Linwu     | Hunan                 | Central China |
| 133              | Shexiangli          | Linwu     | Hunan                 | Central China |
| 134              | Xiangheli           | Linwu     | Hunan                 | Central China |
| 135              | Xianghuli           | Linwu     | Hunan                 | Central China |
| 136              | Zamali              | Linwu     | Hunan                 | Central China |
| 137              | Longhuqilu          | Longhu    | Hunan                 | Central China |
| 138              | Duanbazaos          | Yizhang   | Hunan                 | Central China |
| 139              | Qingqiao            | Yizhang   | Hunan                 | Central China |
| 140              | Tianxiaoli          | Yizhang   | Hunan                 | Central China |
| 141              | Metianjingai        | Meitan     | Guizhou               | Southwest China |
| 142              | Metianmugua         | Meitan     | Guizhou               | Southwest China |
| 143              | Fanli               | Weining    | Guizhou               | Southwest China |
| 144              | Weiningbajie        | Weining    | Guizhou               | Southwest China |

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Table 1. (Continued) Chinese landraces of sand pear evaluated.

| Accession number | Landrace            | District  | Province (population) | Region          |
|------------------|---------------------|-----------|-----------------------|-----------------|
| 145              | Weiningshugulian     | Weinig     | Guizhou               | Southwest China |
| 146              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 147              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 148              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 149              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 150              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 151              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 152              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 153              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 154              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 155              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 156              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 157              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 158              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 159              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 160              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 161              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 162              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 163              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 164              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 165              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 166              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 167              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 168              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 169              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 170              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 171              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 172              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 173              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 174              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 175              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 176              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 177              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 178              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 179              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 180              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 181              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 182              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 183              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 184              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 185              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 186              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 187              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 188              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 189              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 190              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 191              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 192              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 193              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 194              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 195              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 196              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 197              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 198              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 199              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 200              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 201              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 202              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 203              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 204              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 205              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 206              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 207              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 208              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 209              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 210              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 211              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 212              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 213              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 214              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 215              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |
| 216              | Weiningshiguli       | Weinig     | Guizhou               | Southwest China |

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found by Kimura et al. (2002), SSRs are particularly useful for assessing levels of genetic variation in cultivated sand pears. All except two of the primer pairs tested allowed reliable scoring of alleles across 233 landraces. The 14 primer pairs used all allowed reliable scoring of alleles across 233 landraces. The 14 primer pairs used all allowed reliable scoring of alleles across 233 landraces.

Fig. 1. Sixty-six geographic origins of 233 sand pear landraces evaluated in this study. 1) Yiwu; 2) Lishui; 3) Yunhe; 4) Leqing; 5) Shouning; 6) Fuan; 7) Pingnan; 8) Pucheng; 9) Jianyang; 10) Jianou; 11) Shunchang; 12) Jingjiang; 13) Jiujiang; 14) Wuyuan; 15) Yangling; 16) Lianping; 17) Huyang; 18) Gaoyao; 19) Fengkai; 20) Wuzhou; 21) Guanyang; 22) Gengchong; 23) Longsheng; 24) Guilin; 25) Lipu; 26) Belliu; 27) Liucheng; 28) Fengxian; 29) Wuming; 30) Leye; 31) Baise; 32) Tianyang; 33) Debao; 34) Jingxi; 35) Linwu; 36) Yizhang; 37) Longhui; 38) Jingxian; 39) Anjiang; 40) Baojing; 41) Wuhan; 42) Suzhou; 43) Yuanan; 44) Madong; 45) Jiangxi; 46) Xuanen; 47) Xinjiang; 48) Lichuan; 49) Meitan; 50) Zunyi; 51) Xingyi; 52) Weining; 53) Tongliang; 54) Cangxi; 55) Jianyan; 56) Jinchuan; 57) Luding; 58) Hanyuan; 59) Huili; 60) Lijiang; 61) Dali; 62) Fuyuan; 63) Mdu; 64) Kumming; 65) Chuxiong; 66) Chonggong.
Table 2. Estimates of genetic diversity of sand pear in different provinces and regions.

| Population       | N°   | A° ± se       | A° ± se       | H° ± se       | F ± se° |
|------------------|------|---------------|---------------|---------------|---------|
| East China       | 45   | 9.85 ± 0.694  | 5.08 ± 0.404  | 0.78 ± 0.027  | 1.824 ± 0.080 |
| Fujian           | 15   | 7.50 ± 0.511  | 4.76 ± 0.377  | 0.77 ± 0.018  | 1.716 ± 0.072 |
| Jiangxi          | 11   | 5.64 ± 0.038  | 3.14 ± 0.258  | 0.65 ± 0.027  | 1.322 ± 0.066 |
| Zhejiang         | 19   | 7.42 ± 0.500  | 4.58 ± 0.377  | 0.74 ± 0.018  | 1.641 ± 0.072 |
| South China      | 54   | 8.87 ± 0.653  | 5.24 ± 0.425  | 0.78 ± 0.036  | 1.794 ± 0.096 |
| Guangdong        | 13   | 6.07 ± 0.530  | 3.91 ± 0.380  | 0.71 ± 0.021  | 1.482 ± 0.085 |
| Guangxi          | 41   | 8.50 ± 0.532  | 5.07 ± 0.541  | 0.73 ± 0.024  | 1.765 ± 0.090 |
| Central China    | 41   | 8.785 ± 0.800 | 4.115 ± 0.437 | 0.73 ± 0.021  | 1.617 ± 0.086 |
| Hubei            | 26   | 7.857 ± 0.762 | 3.956 ± 0.511 | 0.71 ± 0.023  | 1.552 ± 0.088 |
| Hunan            | 15   | 6.429 ± 0.571 | 3.832 ± 0.369 | 0.706 ± 0.028 | 1.477 ± 0.093 |
| Southwest China  | 93   | 11.428 ± 0.850| 5.400 ± 0.507 | 0.78 ± 0.033  | 1.863 ± 0.099 |
| Guizhou          | 32   | 8.500 ± 0.769 | 4.953 ± 0.541 | 0.773 ± 0.024 | 1.675 ± 0.097 |
| Sichuan          | 26   | 8.286 ± 0.653 | 4.628 ± 0.546 | 0.742 ± 0.031 | 1.550 ± 0.099 |
| Yunnan           | 35   | 8.357 ± 0.427 | 4.380 ± 0.360 | 0.740 ± 0.033 | 1.651 ± 0.082 |

Table 3. Simple sequence repeat (SSR) primers and estimates of SSR polymorphism parameters based on 233 Chinese sand pear landraces.

| Locus code   | Size range (bp) | A° ± se | H° ± se | V ± se | PD ± se |
|--------------|-----------------|---------|---------|--------|---------|
| NH001c       | 118–160         | 9       | 0.661   | 0.500  | 0.154   | 0.88    |
| NH002b       | 148–200         | 13      | 0.718   | 0.733  | 0.152   | 0.92    |
| NH004a       | 78–130          | 17      | 0.748   | 0.844  | 0.124   | 0.86    |
| NH005b       | 304–350         | 9       | 0.527   | 0.554  | 0.136   | 0.77    |
| NH007b       | 120–152         | 15      | 0.679   | 0.738  | 0.130   | 0.88    |
| NH008b       | 188–215         | 10      | 0.747   | 0.669  | 0.120   | 0.93    |
| NH009b       | 138–170         | 16      | 0.694   | 0.518  | 0.136   | 0.92    |
| NH011b       | 151–196         | 18      | 0.736   | 0.695  | 0.133   | 0.94    |
| NH013a       | 190–225         | 12      | 0.695   | 0.451  | 0.105   | 0.90    |
| NH014a       | 60–130          | 21      | 0.825   | 0.802  | 0.097   | 0.97    |
| NH015b       | 100–136         | 13      | 0.715   | 0.740  | 0.116   | 0.94    |
| NH017a       | 88–120          | 13      | 0.717   | 0.731  | 0.156   | 0.94    |
| CH01F02*     | 163–184         | 12      | 0.743   | 0.672  | 0.106   | 0.95    |
| CH01H10°     | 97–123          | 6       | 0.666   | 0.747  | 0.136   | 0.90    |
| Mean         | 13.1            | 0.705   | 0.671   | 0.129   | 0.91    |

Table 4. Unique simple sequence repeat alleles in eight pear landrace populations.

| Population | Locus   | Allele (bp) | Landrace (no.) |
|------------|---------|-------------|----------------|
| Fujian     | NH004a  | 83          | Eli (007)      |
|            | NH014a  | 110         | Panli (013)    |
|            | NH009b  | 164         | Jiangwanzhipi (021), Yousu (026) |
|            | NH004a  | 130         | Jiuzhongli (030) |
|            | NH011b  | 172         | Zhenxingzhipi (033) |
| Guangxi    | NH008b  | 206         | Quanzhouli (077) |
|            | NH009b  | 148         | Cangwudashali (099) |
|            | CH01F02*| 176         | Yanshanhuangpixia (078) |
| Guizhou    | NH004a  | 98          | Weinigzaoli (167) |
|            | NH007b  | 146         | Weinxingzaoxiang (165) |
|            | NH009b  | 138         | Yingxi (170)   |
|            | CH01F02*| 172         | Weinigbaipili (144) |
| Hubei      | NH002b  | 148         | Make (109), Xianfengbaipili (112) |
|            | NH004a  | 123         | Xinianbaipili (112) |
|            | NH017a  | 120         | Lichuanxianshu (104), Wangshuibai (125) |
| Sichuan    | NH002b  | 160         | Hulixianghuang (188) |
|            | NH007b  | 136         | Hanyuanzhaobai (182) |
|            | NH015b  | 132         | Shangengzhipi (185) |
| Yunnan     | NH017a  | 117         | Dalisuanli (205), Miduahuangpi (225) |

In summary, the present study has demonstrated that SSR markers provide an effective tool for assessing genetic diversity and relationships within sand pear germplasm. Further work should focus on combining molecular data and pomological traits for delineating a core collection of sand pear and developing effective conservation strategies and breeding programs.
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Table 5. Genetic distance (D_A, Nei et al., 1983) matrix of 10 populations of Pyrus pyrifolia in China.

| Population | Fujian | Jiangxi | Zhejiang | Guangdong | Guangxi | Hubei | Hunan | Guizhou | Sichuan | Yunnan |
|------------|--------|---------|----------|-----------|---------|-------|-------|---------|---------|--------|
| Fujian     | 0.000  |         |          |           |         |       |       |         |         |        |
| Jiangxi    | 0.659  | 0.000   |          |           |         |       |       |         |         |        |
| Zhejiang   | 0.548  | 0.472   | 0.000    |           |         |       |       |         |         |        |
| Guangdong  | 0.603  | 0.792   | 0.555    | 0.000     |         |       |       |         |         |        |
| Guangxi    | 0.610  | 0.722   | 0.529    | 0.450     | 0.000   |       |       |         |         |        |
| Hubei      | 0.641  | 0.767   | 0.577    | 0.598     | 0.475   | 0.000 |       |         |         |        |
| Hunan      | 0.645  | 0.779   | 0.611    | 0.582     | 0.574   | 0.520 | 0.000 |         |         |        |
| Guizhou    | 0.562  | 0.744   | 0.505    | 0.575     | 0.544   | 0.522 | 0.619 | 0.000   |         |        |
| Sichuan    | 0.648  | 0.733   | 0.564    | 0.613     | 0.584   | 0.613 | 0.615 | 0.595   | 0.000   |        |
| Yunnan     | 0.535  | 0.744   | 0.527    | 0.541     | 0.519   | 0.549 | 0.567 | 0.506   | 0.465   | 0.000  |

Fig. 2. Unweighted pair group with arithmetic average dendrograms of 10 populations of sand pear based on Nei et al.’s (1983) genetic distance (D_A).

Fig. 3. Plot of first and second principal components of principal components analysis on 10 populations of sand pear, together accounting for 42.01% of the total variation.
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