

中国板栗 9 个结果母枝相关表型性状遗传多样性研究

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摘 要: 以中国 10 个省份 (群体) 的 164 份板栗种质为材料 (种植在立地条件相同的同一地块, 连续 3 年采用相同的修剪技术和标准修剪), 对母枝结果枝数、雄花枝数、纤弱枝数、结果枝长度、果前梢长度、结果枝节间长度、结果枝粗度、结果枝节位数和结果枝结苞数等 9 个表型性状量化赋值后进行系统分组设计、方差分析和聚类分析。结果显示: 结果母枝的 9 个表型性状值在群体间和群体内差异均达极显著水平, 说明这些性状在群体间和群体内均存在丰富变异; 9 个表型性状平均变异系数为 19.4% ~ 64.0%, 其中母枝上雄花枝数、纤弱枝数和果枝结苞数的变异系数 > 40%, 说明这 3 个性状改良潜力较大; 9 个表型性状在群体间表型分化系数为 65.9%, 群体内为 34.1%, 说明这些表型性状的变异主要来源于群体间; 通过系统聚类, 依据表型差异可将 10 个群体划分为 4 大类群, 基本按地理距离而聚类。

关键词: 板栗; 表型性状; 群体间; 群体内; 多样性

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Genetic Diversity Analysis of Several Phenotypic Traits Related to Biennial Bearing Branch in Chinese Chestnut

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Abstract: For further enriching genetic diversity information of phenotypic traits on Chinese chestnut germplasm resources, 9 phenotypic traits related to biennial bearing branch of 164 Chinese chestnut germplasms from 10 provinces (as 10 populations) were designed with hierarchical classification and then were done with analysis of variance and systematic cluster analysis. The results showed that differences among and within populations of 9 phenotypic traits value were highly significant, indicating a wide range of variation existed in these two levels. The average variation coefficient of the 9 phenotypic traits was 19.4% – 64.0%, especially, variation coefficient concerning 3 of the 9 traits including the average male flower shoot number/biennial bearing branch, the delicate shoot number/biennial bearing branch and the average bur number/branch, reached > 40%, which suggested that the germplasms had a great potential of genetic breeding in the 3 phenotypic traits. The average of phenotypic differentiation coefficient among populations and within populations were 65.9% and 34.1%, respectively, illustrating that the variation

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among populations was the leading source of trait variation. The systematic cluster analysis showed that 10 populations can be divided into 4 groups based on the variation of phenotypic traits, which indicated that the phenotypic traits of Chinese chestnut populations were basically clustered according to geographical distance.

Keywords: chestnut; phenotypic traits; within populations; among populations; diversity

板栗 (*Castanea mollissima* Bl.) 原产于中国, 以其独特的抗病性和高品质特征成为世界上其他栗种抗病育种和品质改良的重要基因来源 (杨阳 等, 2017)。遗传多样性研究是种质创新的基础 (Campbell, 2009; 胡标林 等, 2012), 而表型性状遗传多样性是种质整体遗传多样性的一个重要组成部分 (Mitchell-Olds et al., 2007; García-Verdugo et al., 2009, 2010), 对种质的性状表型值进行科学统计分析, 揭示表型性状在群体间和群体内的遗传规律及变异大小, 有助于了解其遗传稳定性和选择潜力, 对发掘利用和创新现有种质具有重要指导意义。

有关中国板栗表型遗传多样性的研究已有一些报道, 涉及叶片、果实、刺苞、品质等 (周连第等, 2005; 马玉敏 等, 2008; 王广鹏 等, 2009; 刘国彬 等, 2011, 2013; 江锡兵 等, 2014)。板栗叶片大小、叶柄长度和粗度以及果实形状、大小等形态性状的变异系数均在 10% 以上, 表现出丰富的遗传多样性, 其中以叶面积及单粒质量变异最大, 而果形指数变异最小, 且中国板栗叶片从南到北大致呈现出从长椭圆形到椭圆形变化的趋势, 同时南方板栗果实大于北方板栗。从板栗果实和叶片的 12 个性状表型分化系数来看, 种群内变异是板栗表型变异的主要来源, 种群内品种间的多样性大于种群间 (兰彦平 等, 2007; 江锡兵 等, 2014)。在板栗众多的表型性状中, 与结果母枝相关的表型性状遗传变异程度, 直接体现基因与环境效应对树体生长势和产量潜力的影响, 极具育种参考价值, 但至今仍缺少这方面的研究报道。

本研究中以中国 10 个板栗主产区省份 (群体) 的 164 份种质资源为对象, 其定植在立地条件基本相同的同一地块, 每年采用相同的修剪技术, 修剪枝量也执行同一标准 (王广鹏 等, 2016), 使人为因素的影响相同 (通过 3 年人工修剪后各材料间枝条性状值的差异趋势相同, 即枝条性状差异是其自身特性的差异), 对其结果母枝 9 个表型性状进行遗传多样性及变异水平分析, 旨在进一步解析中国板栗表型性状遗传多样性信息, 为板栗种群划分、品种创新和种质科学保护提供理论依据。

1 材料与方法

1.1 试验材料

以源自 10 个板栗主产区省份 (群体) 的 164 份种质资源为试验材料 (表 1)。试材定植于河北省昌黎果树研究所板栗种质资源圃 (东经 119°15', 北纬 39°72', 属温带半湿润大陆性气候区, 年平均气温 11 °C, 无霜期 186 d, 年降水 638 mm)。2004 年试材嫁接于 3 年生砧木, 株行距 4 m × 4 m, 树体整形修剪均采用王广鹏等 (2016) 的方法, 即轮替更新修剪法, 留枝量保持在 6 ~ 9 条·m² 之间, 其他管理措施一致。每份种质选取 3 株生长状况基本一致的健康树体, 2014—2016 年连续 3 年分别测量各单株结果母枝相关表型性状。

1.2 结果母枝和树势相关表型性状测定

结果母枝长度和粗度、果前梢长度、果枝结苞数按照刘庆忠等 (2006) 的方法测定。母枝上结

果枝数、雄花枝数和纤弱枝数按照张宇和等（1989）的方法测定。在树体休眠期测定结果枝节位数：随机选择单株树冠外围由顶芽抽生的 1 年生结果枝 30 条，调查其上节位数，取平均值。结果枝节间长度测定：结果枝节间长度 = 结果枝长度/ 结果枝节位数。

1.3 数据分析

采用系统分组设计方差法分析各性状，建立线性模型： $Y_{ijk} = \mu + S_i + T_{(ij)j} + \varepsilon_{(ij)k}$ 。式中： Y_{ijk} 为第 i 个群体第 j 个资源第 k 个观测值， μ 为总均值， S 为群体效应（固定）， $T_{(ij)j}$ 为群体内资源效应（随机）； $\varepsilon_{(ij)k}$ 为试验误差。 V_{ST} 为表型分化系数，表示群体间变异占遗传总变异的百分比（葛颂 等，1988；江锡兵 等，2014）， $V_{ST}(\%) = [\delta_{2tS} / (\delta_{2tS} + \delta_{2S})] \times 100$ 。式中： δ_{2tS} 为群体间方差分量， δ_{2S} 为群体内方差分量。用性状变异系数（ CV ）表示性状离散程度， $CV(\%) = s / \bar{x} \times 100$ （江锡兵 等，2014）。式中： \bar{x} 为性状平均值， s 为标准差。

采用 Excel 2010 和 SPSS 20 统计软件对各性状进行方差分析、Duncan’s 多重比较及聚类分析。

2 结果与分析

2.1 结果母枝相关表型性状在群体间的变异特征

由表 1 ~ 表 4 可见，板栗结果母枝相关的 9 个表型性状在群体间和群体内的差异均达到极显著水平，说明各表型性状在群体间和群体内均存在着广泛变异。板栗同一表型性状在不同群体间变化明显，说明长期环境异质可导致群体表型的差异明显。在 10 个群体间仅结果枝粗度无显著差异；广西、安徽、江苏和浙江群体普遍表现出结果母枝节位数少、节间长的特征；广西群体的结果母枝上雄花枝数和江苏群体母枝上纤弱枝数显著高于其他群体；北京、河北和山东群体普遍具有结果母枝上结果枝数量多、结苞数多的特征。

表 1 板栗 164 份种质结果母枝相关表型性状值
Table 1 Data of phenotypic traits of biennial bearing branch of 164 resources in chestnut

群体 Population	种质 Germplasm	数量 Number					长度/cm Length			
		结果枝数 Bearing shoot	雄花枝数 Male flower shoot	纤弱枝数 Leptos shoot	结果枝节位数 Node order/branch	每果枝结苞数 Bur/branch	结果枝 Bearing shoot	果前梢 Tailed twig	结果枝节间 Internode	结果枝粗度/mm Bearing shoot width
北京 Beijing	燕丰 Yanfeng	3.3 ± 0.6	1.0 ± 0.0	4.7 ± 0.6	11.2 ± 2.1	1.9 ± 0.9	45.7 ± 8.2	18.7 ± 5.5	4.4 ± 0.3	7.2 ± 2.1
	燕昌 Yanchang	3.3 ± 0.6	2.0 ± 1.0	2.3 ± 1.2	10.2 ± 2.0	1.9 ± 0.6	37.0 ± 4.9	12.1 ± 3.4	3.8 ± 0.5	7.5 ± 1.7
	燕红 Yanhong	4.3 ± 1.5	0.3 ± 0.6	1.3 ± 0.6	7.6 ± 1.9	1.9 ± 0.9	34.0 ± 8.3	4.8 ± 1.8	4.5 ± 0.4	5.4 ± 1.2
	燕平 Yanping	2.3 ± 0.6	1.0 ± 0.0	1.3 ± 1.2	28.0 ± 8.3	2.1 ± 1.5	42.6 ± 6.2	23.4 ± 4.0	2.0 ± 0.2	8.3 ± 0.9
	良乡 1 号 Liangxiang 1	2.7 ± 0.6	2.0 ± 0.0	3.7 ± 1.2	29.8 ± 4.7	1.8 ± 0.9	44.9 ± 7.6	19.5 ± 3.4	1.5 ± 0.1	6.8 ± 1.4
	北京 8 号 Beijing 8	3.0 ± 1.0	1.3 ± 0.6	0	25.9 ± 7.3	4.1 ± 1.8	35.9 ± 9.2	19.2 ± 5.3	1.9 ± 0.2	7.1 ± 1.6
	黑 8 Hei 8	4.3 ± 1.2	1.7 ± 1.5	0.7 ± 0.6	21.1 ± 4.1	1.9 ± 1.1	39.5 ± 10.4	11.0 ± 5.7	2.0 ± 0.4	6.1 ± 1.3
	京暑红 Jingshuhong	4.7 ± 1.2	0.7 ± 0.6	1.3 ± 0.6	20.5 ± 4.0	3.1 ± 1.4	38.2 ± 6.5	6.4 ± 2.1	1.9 ± 0.2	5.6 ± 0.7
	BJHW	3.7 ± 0.6	3.7 ± 1.5	1.3 ± 0.6	19.8 ± 5.0	2.0 ± 0.6	38.0 ± 7.9	7.6 ± 4.2	2.0 ± 0.3	5.2 ± 1.3
	短花 Duanhua	1.0 ± 0.0	4.7 ± 1.2	1.0 ± 1.0	22.0 ± 5.2	2.0 ± 1.0	44.7 ± 14.2	14.0 ± 1.7	2.0 ± 0.2	5.8 ± 1.3
河北 Heibei	怀丰 Huai feng	2.0 ± 0.0	2.0 ± 1.0	1.7 ± 1.2	31.3 ± 6.5	3.2 ± 1.3	51.5 ± 6.3	22.0 ± 2.6	1.8 ± 0.1	7.8 ± 1.4
	前 3 Qian 3	2.3 ± 0.6	1.7 ± 0.6	6.0 ± 1.0	9.9 ± 6.1	2.7 ± 1.7	42.7 ± 14.4	12.7 ± 5.4	5.2 ± 2.5	7.0 ± 1.4
	遵化短刺 Zunhua Duanci	2.3 ± 0.6	3.0 ± 1.0	6.7 ± 2.1	5.7 ± 1.5	1.7 ± 0.8	30.1 ± 6.0	5.4 ± 2.4	5.5 ± 1.0	5.3 ± 0.8
	抚宁薄皮 Funing Bopi	7.3 ± 0.6	1.0 ± 0.0	1.0 ± 0.0	6.1 ± 1.6	3.1 ± 1.1	32.6 ± 6.0	7.3 ± 2.1	5.4 ± 0.7	5.9 ± 1.2
	变异燕明 Bianyi Yanming	3.0 ± 1.0	0.7 ± 0.6	1.3 ± 0.6	9.9 ± 5.3	1.8 ± 1.1	36.6 ± 15.7	16.8 ± 6.4	4.0 ± 0.9	6.3 ± 1.5
	替码燕明 Tima Yanming	3.3 ± 0.6	1.7 ± 1.2	1.3 ± 1.2	7.9 ± 1.8	1.4 ± 0.5	41.9 ± 8.4	10.1 ± 3.7	5.4 ± 0.5	6.0 ± 1.2

续表 1

群体 Population	种质 Germplasm	数量 Number					长度/cm Length			
		结果枝数 Bearing shoot	雄花枝数 Male flower shoot	纤弱枝数 Leptos shoot	结果枝节位数 Node order/branch	每果枝结苞数 Bur/branch	结果枝 Bearing shoot	果前梢 Tailed twig	结果枝节间 Internode	结果枝粗度/mm Bearing shoot width
	后南峪垂枝 Hounanyu Chuizhi	3.0 ± 0.0	1.3 ± 0.6	0.7 ± 1.2	8.4 ± 1.9	2.1 ± 1.1	46.3 ± 13.5	10.8 ± 4.3	5.4 ± 1.2	5.8 ± 1.3
	邢台薄皮 Xingtai Daopi	4.0 ± 0.0	2.3 ± 1.2	4.3 ± 1.2	24.5 ± 4.8	2.3 ± 1.2	38.8 ± 10.1	12.8 ± 5.3	1.6 ± 0.2	6.0 ± 1.4
	西寨 1 号 Xizhai 1	3.0 ± 1.0	2.0 ± 1.0	2.3 ± 0.6	13.5 ± 9.7	1.6 ± 1.0	40.6 ± 16.0	11.3 ± 4.8	4.3 ± 2.1	5.5 ± 1.6
	西寨 2 号 Xizhai 2	2.7 ± 0.6	0.7 ± 0.6	2.0 ± 1.4	6.6 ± 1.5	2.9 ± 1.2	38.6 ± 7.8	3.6 ± 1.0	5.9 ± 0.7	6.8 ± 1.2
	燕奎 Yankui	3.0 ± 1.0	2.3 ± 0.6	2.3 ± 0.6	20.7 ± 4.8	1.8 ± 0.7	42.7 ± 17.3	12.9 ± 5.8	2.0 ± 0.4	5.9 ± 1.2
	邢台垂枝 Xingtai Chuizhi	3.7 ± 0.6	1.0 ± 1.0	2.7 ± 0.6	6.3 ± 3.0	1.8 ± 0.8	34.2 ± 10.6	8.8 ± 2.9	5.8 ± 1.5	5.2 ± 1.5
	X28-11	4.0 ± 1.0	2.3 ± 1.5	3.7 ± 1.5	24.0 ± 8.1	2.8 ± 1.5	45.1 ± 17.5	20.2 ± 6.9	1.9 ± 0.3	4.9 ± 1.0
	燕明 Yanming	3.7 ± 0.6	0.7 ± 1.2	1.0 ± 0.0	17.0 ± 3.9	1.7 ± 1.0	40.9 ± 16.8	12.7 ± 4.4	2.4 ± 0.8	6.4 ± 2.0
	替码珍珠 Tima Zhenzhu	4.0 ± 1.0	1.7 ± 1.2	2.0 ± 1.0	19.5 ± 3.8	3.1 ± 1.2	39.5 ± 8.4	7.4 ± 2.8	2.1 ± 0.4	5.5 ± 0.9
	燕兴 Yanxing	4.3 ± 1.2	2.7 ± 0.6	1.5 ± 0.7	18.3 ± 4.9	1.6 ± 0.5	26.4 ± 7.8	5.8 ± 2.2	1.5 ± 0.4	4.7 ± 0.9
	M19-4	3.0 ± 1.0	1.7 ± 1.2	6.3 ± 0.6	16.4 ± 2.9	2.1 ± 1.2	38.2 ± 11.8	10.6 ± 3.5	2.3 ± 0.5	5.7 ± 1.2
	青龙白 Qinglongbai	3.0 ± 1.0	2.3 ± 1.5	2.3 ± 1.2	16.6 ± 2.0	1.4 ± 0.7	33.3 ± 5.9	6.7 ± 1.7	2.0 ± 0.3	5.2 ± 0.9
	迁西早红 Qianxi Zaohong	3.1 ± 1.0	1.7 ± 0.6	2.0 ± 1.0	21.8 ± 2.1	2.3 ± 1.0	40.0 ± 4.5	8.1 ± 2.0	2.0 ± 0.2	7.1 ± 0.4
	燕紫 Yanzi	2.3 ± 0.6	1.7 ± 1.2	3.7 ± 1.5	24.6 ± 5.3	1.6 ± 0.5	56.0 ± 10.6	15.6 ± 3.9	2.2 ± 0.1	5.9 ± 1.2
	H4-24	1.7 ± 0.6	3.3 ± 1.5	4.7 ± 1.2	17.0 ± 3.1	1.8 ± 0.8	39.2 ± 11.9	11.0 ± 3.2	2.3 ± 0.3	6.2 ± 1.4
	X12-55	2.0 ± 0.0	0.7 ± 0.6	5.3 ± 0.6	18.8 ± 5.1	1.7 ± 0.5	42.7 ± 14.9	11.5 ± 3.5	2.3 ± 0.3	6.4 ± 1.4
	XL-001	2.7 ± 0.6	3.7 ± 1.2	4.7 ± 1.2	39.3 ± 5.5	1.4 ± 0.7	58.5 ± 9.2	27.5 ± 7.0	1.9 ± 0.2	7.5 ± 1.5
	XL-002	2.3 ± 0.6	0.5 ± 0.6	1.7 ± 0.6	23.8 ± 5.3	1.3 ± 0.5	44.9 ± 11.7	20.8 ± 7.3	1.9 ± 0.3	6.0 ± 1.5
	迁西壮栗 Qianxi Zhuangli	3.0 ± 1.0	2.0 ± 1.0	3.0 ± 1.0	20.1 ± 3.9	2.3 ± 1.3	36.0 ± 9.3	6.8 ± 1.7	1.8 ± 0.2	6.1 ± 1.5
	达 1-3 Da 1-3	3.0 ± 0.0	1.3 ± 0.6	4.0 ± 1.0	17.8 ± 4.1	1.9 ± 0.5	34.2 ± 11.3	8.4 ± 3.3	1.9 ± 0.5	5.5 ± 0.9
	紫珀 Zipo	2.0 ± 0.0	1.3 ± 1.5	0.7 ± 1.2	19.0 ± 4.6	2.5 ± 1.4	41.5 ± 20.2	11.2 ± 6.8	2.1 ± 0.5	6.4 ± 2.0
	燕光 Yanguang	3.3 ± 1.5	1.7 ± 0.6	1.0 ± 1.0	20.3 ± 4.4	2.7 ± 1.6	31.7 ± 7.6	5.0 ± 2.2	1.6 ± 0.1	5.4 ± 1.2
	燕山短枝 Yanshan Duanzhi	2.3 ± 0.6	1.3 ± 0.6	0.7 ± 0.6	18.7 ± 4.3	1.6 ± 1.1	39.4 ± 16.0	9.6 ± 3.8	2.0 ± 0.4	6.2 ± 0.8
	大官 10 Daguan 10	3.0 ± 0.0	3.7 ± 1.2	2.7 ± 1.2	24.7 ± 3.9	1.9 ± 0.9	43.1 ± 8.9	15.3 ± 4.2	1.7 ± 0.2	7.1 ± 1.6
	燕晶 Yanjing	2.0 ± 0.0	3.0 ± 1.7	1.7 ± 0.6	23.2 ± 5.6	2.3 ± 1.0	43.8 ± 12.2	13.5 ± 5.5	1.9 ± 0.2	7.4 ± 1.2
	84-2	3.3 ± 0.6	2.3 ± 2.1	0.7 ± 1.2	18.1 ± 4.4	1.7 ± 0.9	30.4 ± 11.9	11.1 ± 4.4	1.6 ± 0.3	5.8 ± 1.6
	东陵明珠 Dongling Mingzhu	4.3 ± 1.2	3.0 ± 2.0	3.3 ± 1.5	22.2 ± 3.6	2.4 ± 1.4	38.7 ± 7.8	11.1 ± 4.3	1.8 ± 0.3	6.3 ± 1.4
	燕山早丰 Yanshan Zaofeng	4.3 ± 0.6	0.7 ± 0.6	2.0 ± 1.7	23.0 ± 4.7	3.2 ± 1.8	35.2 ± 6.0	7.0 ± 2.5	2.0 ± 0.3	6.5 ± 1.2
	大板红 Dabanhong	3.7 ± 0.6	2.3 ± 1.5	3.3 ± 0.6	22.8 ± 5.4	2.4 ± 1.4	38.3 ± 10.7	14.1 ± 5.7	2.0 ± 1.1	6.9 ± 1.4
	龙湾 5 号 Longwan 5	3.3 ± 0.6	4.7 ± 0.6	2.0 ± 1.0	22.3 ± 4.4	1.6 ± 1.0	37.6 ± 10.7	10.4 ± 3.4	1.6 ± 0.3	5.4 ± 0.9
	龙湾 1 号 Longwan 1	2.3 ± 0.6	1.3 ± 1.5	2.7 ± 2.1	19.9 ± 2.9	2.1 ± 1.5	24.1 ± 5.5	6.4 ± 2.9	1.2 ± 0.2	5.8 ± 1.4
	沙坡峪 3 号 Shapoyu 3	2.7 ± 0.6	3.3 ± 1.5	4.3 ± 1.5	23.1 ± 4.9	3.3 ± 0.7	37.8 ± 9.0	8.0 ± 2.9	1.6 ± 0.1	6.2 ± 0.7
	干 2-2 Gan 2-2	2.3 ± 0.6	0.3 ± 0.6	1.7 ± 0.6	25.6 ± 2.1	2.4 ± 0.5	39.9 ± 5.6	6.9 ± 1.3	1.6 ± 0.2	5.1 ± 0.6
	侯庄 2 号 Houzhuang 2	2.3 ± 0.6	1.7 ± 0.6	2.3 ± 0.6	18.6 ± 4.3	1.9 ± 0.7	34.4 ± 13.3	7.3 ± 2.4	1.8 ± 0.5	6.3 ± 1.6
	徐家 1 号 Xujia 1	2.3 ± 0.6	0.7 ± 0.6	2.7 ± 1.5	23.9 ± 9.1	1.9 ± 0.9	40.4 ± 19.8	19.0 ± 9.2	1.6 ± 0.2	5.7 ± 1.0
	杨家峪 13 Yangjiayu 13	3.3 ± 1.2	1.3 ± 1.5	5.3 ± 1.5	21.7 ± 4.6	1.6 ± 0.8	32.2 ± 12.6	7.6 ± 2.8	1.5 ± 0.4	5.8 ± 2.2
	刑丰 1 号 Xingfeng 1	4.7 ± 0.6	2.0 ± 1.0	1.0 ± 1.0	20.7 ± 3.6	1.7 ± 0.6	33.7 ± 6.9	5.1 ± 2.4	1.6 ± 0.2	5.4 ± 1.2
	X12	3.3 ± 1.5	0.7 ± 0.6	1.3 ± 1.5	19.2 ± 4.1	3.6 ± 2.0	36.8 ± 9.5	3.9 ± 1.7	1.9 ± 0.4	6.8 ± 1.4
	上庄 52 Shangzhuang 52	2.7 ± 0.6	3.0 ± 0.0	2.3 ± 0.6	17.9 ± 3.4	2.3 ± 0.9	35.8 ± 7.4	4.8 ± 1.8	2.0 ± 0.3	5.6 ± 1.1
	燕金 Yanjin	3.0 ± 0.0	1.7 ± 1.5	3.0 ± 1.0	19.1 ± 3.1	2.7 ± 1.3	39.4 ± 11.4	9.2 ± 3.7	2.0 ± 0.4	6.3 ± 1.4
	杨家峪 5 号 Yangjiayu 5	1.7 ± 0.6	1.0 ± 1.7	4.0 ± 1.7	29.4 ± 8.3	2.0 ± 1.6	49.2 ± 17.6	20.4 ± 5.9	1.6 ± 0.3	7.2 ± 1.5
	大碌洞 Daludong	3.0 ± 1.0	5.3 ± 0.6	1.3 ± 1.5	22.6 ± 5.3	2.0 ± 0.7	53.0 ± 12.5	8.7 ± 4.7	2.4 ± 0.3	6.1 ± 1.4
	东沟峪 Donggouyu	2.0 ± 0.0	3.7 ± 2.1	1.7 ± 0.6	21.0 ± 3.0	1.3 ± 0.5	35.3 ± 10.9	9.0 ± 3.7	1.7 ± 0.3	5.1 ± 0.7
	牛 1 Niu 1	2.3 ± 0.6	1.7 ± 1.5	3.7 ± 1.2	21.5 ± 4.8	2.3 ± 1.2	34.6 ± 7.2	8.9 ± 2.9	1.6 ± 0.3	5.1 ± 0.8
	何家坟 5 Hejiafen 5	3.3 ± 0.6	2.0 ± 2.0	3.3 ± 1.5	18.6 ± 3.0	2.0 ± 0.7	36.9 ± 9.1	6.1 ± 2.6	2.0 ± 0.3	5.4 ± 1.5
	无花栗 Wuhuali	3.0 ± 1.0	6.7 ± 1.5	1.3 ± 0.6	20.2 ± 4.0	1.0 ± 0.0	44.0 ± 10.1	11.8 ± 4.5	2.2 ± 0.2	5.4 ± 1.0
	M 18-16	3.3 ± 0.6	4.0 ± 1.7	2.7 ± 1.2	23.1 ± 4.4	2.4 ± 1.2	43.0 ± 10.9	7.8 ± 2.7	2.0 ± 0.3	5.7 ± 1.3
	冀栗 1 号 Jili 1	4.0 ± 1.0	2.7 ± 2.1	2.0 ± 1.0	20.8 ± 3.7	1.8 ± 0.7	43.6 ± 11.3	17.1 ± 5.9	2.1 ± 0.3	5.4 ± 0.9
	X 52-58	3.7 ± 1.5	1.7 ± 1.2	0.3 ± 0.6	19.7 ± 3.4	1.5 ± 0.8	51.1 ± 4.3	13.8 ± 3.0	2.6 ± 0.3	5.5 ± 0.9
	H 7-5	2.3 ± 0.6	2.3 ± 2.1	3.3 ± 1.5	23.1 ± 3.1	1.7 ± 0.8	41.6 ± 13.8	17.7 ± 7.2	1.8 ± 0.4	6.0 ± 0.9

续表 1

群体 Population	种质 Germplasm	数量 Number					长度/cm Length			结果枝 粗度/mm Bearing shoot width
		结果枝数 Bearing shoot	雄花枝数 Male flower shoot	纤弱枝数 Leptos shoot	结果枝 节位数 Node order/ branch	每果枝 结苞数 Bur/ branch	结果枝 Bearing shoot	果前梢 Tailed twig	结果枝 节间 Internode	
	后南峪丰收 1 号 Hounayu Fengshou 1	2.7 ± 0.6	0.7 ± 1.2	1.3 ± 0.6	21.1 ± 4.5	2.6 ± 1.7	41.9 ± 9.5	8.4 ± 2.3	2.0 ± 0.2	6.2 ± 1.4
	桑 1 Sang1	2.0 ± 0.0	4.0 ± 1.7	5.3 ± 1.2	28.2 ± 3.1	1.5 ± 0.8	59.3 ± 13.3	20.8 ± 8.1	2.1 ± 0.3	7.4 ± 1.8
	长南庄 2 号 Changnanzhuang 2	3.0 ± 1.0	0.7 ± 0.6	2.7 ± 1.5	22.8 ± 3.6	2.4 ± 1.0	43.9 ± 5.3	9.8 ± 2.5	2.0 ± 0.3	5.8 ± 0.8
	塔 14 Ta 14	2.7 ± 0.6	5.3 ± 1.2	3.0 ± 2.0	19.0 ± 4.0	1.6 ± 0.7	30.9 ± 7.0	3.4 ± 1.2	1.7 ± 0.4	6.0 ± 0.6
	燕宝 Yanbao	4.0 ± 1.0	1.3 ± 1.5	3.7 ± 0.6	24.2 ± 4.2	1.9 ± 0.7	48.8 ± 10.0	13.5 ± 4.7	2.0 ± 0.3	5.6 ± 1.2
	石场子 2-2 Shichangzi 2-2	4.3 ± 1.5	1.0 ± 1.0	4.3 ± 1.5	20.1 ± 3.4	3.5 ± 1.3	37.5 ± 10.5	7.8 ± 3.9	1.9 ± 0.3	6.2 ± 1.0
	关堂 64 Guantang 64	2.3 ± 0.6	2.7 ± 1.5	4.7 ± 2.5	26.4 ± 1.4	1.5 ± 0.5	52.0 ± 9.3	7.6 ± 2.1	1.9 ± 0.3	5.7 ± 0.5
	岔 3 Cha 3	2.3 ± 0.6	1.0 ± 0.0	8.7 ± 1.2	26.3 ± 2.6	3.1 ± 0.9	49.3 ± 9.9	15.9 ± 5.6	1.9 ± 0.3	7.1 ± 0.6
	贾庄 1 号 Jia Zhuang 1	3.3 ± 0.6	1.3 ± 0.6	0.7 ± 1.2	19.7 ± 3.3	2.3 ± 1.1	28.9 ± 7.0	6.2 ± 2.5	1.5 ± 0.2	6.6 ± 1.1
	西沟 7 号 Xigou 7	2.7 ± 0.6	2.0 ± 1.0	2.0 ± 1.0	18.8 ± 1.7	2.6 ± 0.7	31.4 ± 6.9	5.0 ± 1.5	1.7 ± 0.4	5.5 ± 0.8
	塔 54 Ta 54	4.7 ± 1.5	1.3 ± 0.6	5.0 ± 1.7	23.8 ± 2.5	2.8 ± 1.2	34.4 ± 6.7	8.8 ± 2.9	1.4 ± 0.2	5.5 ± 0.8
	下庄 4 号 Xia Zhuang 4	5.1 ± 1.2	2.3 ± 1.2	2.7 ± 1.5	20.1 ± 3.6	2.6 ± 1.1	31.7 ± 7.8	5.0 ± 2.6	1.6 ± 0.2	5.0 ± 1.0
	淳 1 Bo 1	2.0 ± 0.0	3.0 ± 1.0	5.3 ± 1.5	17.5 ± 3.6	1.7 ± 0.5	35.7 ± 9.5	9.2 ± 2.6	2.0 ± 0.2	6.2 ± 1.5
	凤 2 Feng 2	3.0 ± 0.0	1.3 ± 0.6	5.0 ± 1.7	24.4 ± 6.8	2.1 ± 0.9	42.8 ± 14.3	14.2 ± 5.7	1.7 ± 0.2	6.3 ± 1.7
	杨家峪 1 号 Yangjiayu 1	3.3 ± 1.2	0.3 ± 0.6	2.3 ± 1.2	20.1 ± 3.0	2.5 ± 1.4	29.4 ± 10.7	4.5 ± 1.8	1.4 ± 0.4	6.0 ± 1.3
	M17-21	3.7 ± 0.6	2.0 ± 1.0	4.3 ± 1.2	24.9 ± 2.9	3.4 ± 1.7	38.5 ± 7.9	6.2 ± 2.8	1.5 ± 0.2	5.8 ± 0.8
	波叶栗 Boyeli	2.3 ± 0.6	0.7 ± 0.6	6.7 ± 1.2	24.2 ± 6.4	3.0 ± 0.9	37.7 ± 5.0	10.4 ± 3.2	1.6 ± 0.3	5.7 ± 1.2
	1209	2.0 ± 1.0	2.7 ± 1.2	1.7 ± 1.2	19.5 ± 3.8	2.5 ± 1.4	38.5 ± 7.8	9.8 ± 3.8	2.0 ± 0.2	5.3 ± 0.5
	D 5-50	1.7 ± 0.6	2.3 ± 0.6	0.3 ± 0.6	18.6 ± 2.2	1.6 ± 0.9	41.0 ± 9.5	6.4 ± 3.2	2.2 ± 0.2	5.6 ± 0.6
	周家峪 6 号 Zhoujiayu 6	2.7 ± 0.6	1.3 ± 0.6	2.3 ± 1.5	22.4 ± 3.3	2.6 ± 1.4	45.0 ± 10.7	12.3 ± 4.5	2.0 ± 0.2	6.4 ± 1.1
	园门实生	1.3 ± 0.6	1.3 ± 0.6	3.0 ± 2.0	28.0 ± 8.5	2.3 ± 1.3	60.5 ± 19.9	24.5 ± 3.9	2.2 ± 0.1	6.2 ± 1.0
	杨家峪 1-6 Yangjiayu 1-6	4.0 ± 1.0	1.0 ± 1.0	12.3 ± 0.6	19.1 ± 4.9	2.9 ± 1.6	29.5 ± 11.9	7.1 ± 2.4	1.5 ± 0.4	5.2 ± 1.3
	桑 6 Sang 6	2.7 ± 0.6	2.3 ± 0.6	2.7 ± 0.6	18.8 ± 3.4	2.0 ± 0.8	37.5 ± 7.3	6.5 ± 1.8	2.0 ± 0.3	6.2 ± 1.0
	沙坡峪 1 号 Shapoyu 1	2.0 ± 0.0	2.0 ± 1.7	2.3 ± 1.5	22.4 ± 3.6	1.3 ± 0.5	38.3 ± 9.0	12.8 ± 3.5	1.7 ± 0.2	6.0 ± 1.4
	早 1 Zao 1	3.3 ± 0.6	2.0 ± 1.0	2.3 ± 0.6	12.8 ± 11.5	2.6 ± 1.4	50.4 ± 11.2	14.8 ± 4.9	2.1 ± 0.3	7.8 ± 1.8
	早 2 Zao 2	3.3 ± 0.6	0.7 ± 0.6	3.7 ± 1.5	23.6 ± 2.8	2.1 ± 1.1	40.1 ± 9.1	7.4 ± 2.7	1.6 ± 0.3	6.7 ± 1.3
	早 3 Zao 3	3.7 ± 1.2	2.7 ± 1.2	1.5 ± 1.3	5.6 ± 2.1	2.6 ± 1.3	44.5 ± 10.8	11.3 ± 3.7	1.8 ± 0.3	6.7 ± 1.5
	迁早 1 Qianzao 1	3.3 ± 0.6	2.0 ± 1.0	0.7 ± 0.6	24.7 ± 3.6	3.3 ± 1.3	44.4 ± 3.5	8.8 ± 1.1	2.0 ± 0.2	6.4 ± 1.1
	迁早 2 Qianzao 2	4.3 ± 0.6	1.3 ± 1.2	2.3 ± 0.6	22.7 ± 2.9	3.3 ± 1.7	44.0 ± 9.8	10.2 ± 3.7	2.7 ± 0.1	6.5 ± 1.1
	D6-87	2.0 ± 0.0	3.3 ± 0.6	3.3 ± 1.2	16.5 ± 3.4	1.7 ± 0.8	58.3 ± 9.8	23.0 ± 7.2	2.3 ± 0.4	6.0 ± 1.2
	X8-53	2.3 ± 0.6	3.3 ± 1.2	1.7 ± 0.6	25.1 ± 3.0	1.6 ± 0.8	36.7 ± 9.7	11.8 ± 4.9	1.7 ± 0.3	6.0 ± 1.2
	邢台短枝 Xingtai Chui zhi	4.0 ± 1.0	1.3 ± 1.2	6.3 ± 1.5	21.3 ± 4.9	2.4 ± 1.0	32.1 ± 5.9	4.7 ± 1.8	1.7 ± 0.2	5.4 ± 0.9
	宽城下六 Kuancheng Xialiu	5.0 ± 1.7	1.0 ± 0.0	0.3 ± 0.6	18.5 ± 3.6	2.0 ± 0.8	43.3 ± 8.7	12.2 ± 3.6	1.9 ± 0.4	6.7 ± 0.8
	宽城大屯 Kuancheng Datun	3.3 ± 0.6	1.7 ± 0.6	4.0 ± 1.0	22.4 ± 2.5	2.7 ± 0.8	13.8 ± 4.8	7.3 ± 2.6	1.1 ± 0.3	4.3 ± 0.5
	三色栗 Sanseli	3.0 ± 1.0	1.3 ± 1.5	4.3 ± 2.3	12.6 ± 1.6	1.3 ± 0.7	36.6 ± 7.1	11.6 ± 3.6	1.9 ± 0.3	6.1 ± 1.4
	X 19-94	3.7 ± 1.5	2.0 ± 1.0	2.0 ± 1.0	19.5 ± 3.0	1.5 ± 0.7	53.6 ± 13.7	19.6 ± 6.4	2.3 ± 0.2	5.8 ± 1.5
	南垂 5 号 Nanchui 5	3.0 ± 1.0	3.3 ± 1.5	3.3 ± 0.6	22.8 ± 4.8	2.3 ± 1.0	41.0 ± 11.1	6.5 ± 3.6	3.0 ± 0.4	5.2 ± 0.6
	明丰 2 号 Mingfeng 2	2.0 ± 0.0	2.0 ± 1.0	0.7 ± 0.6	13.5 ± 2.7	1.7 ± 0.8	54.8 ± 12.8	17.7 ± 8.6	2.6 ± 0.3	5.6 ± 1.5
	毛栗 Maoli	2.0 ± 0.0	3.0 ± 2.0	1.3 ± 0.6	21.5 ± 4.5	1.5 ± 0.5	38.1 ± 12.3	11.5 ± 4.2	1.8 ± 0.4	5.4 ± 1.0
	平泉 (葛) Pingquan(ge)	3.3 ± 1.2	3.0 ± 0.0	2.3 ± 1.2	21.7 ± 8.0	2.2 ± 1.0	37.9 ± 10.2	4.2 ± 2.0	2.6 ± 0.3	6.0 ± 1.3
	去暑红 Qushuhong	3.7 ± 1.5	2.3 ± 1.5	2.7 ± 1.5	20.6 ± 4.3	2.5 ± 1.7	38.0 ± 9.6	10.0 ± 3.9	2.3 ± 0.3	5.8 ± 1.3
	熊 84 Xiong 84	3.0 ± 0.0	0.7 ± 1.2	2.0 ± 1.7	16.7 ± 2.8	2.0 ± 1.0	38.0 ± 9.6	10.0 ± 3.9	2.3 ± 0.3	5.8 ± 1.3
陕西	长安夹栎栗 Changan Jiajianli	2.0 ± 1.0	2.0 ± 1.7	5.3 ± 2.5	23.7 ± 3.3	1.7 ± 1.0	46.2 ± 5.9	17.7 ± 2.5	2.0 ± 0.1	6.3 ± 5.8
Shaanxi	长安明栎栗 Changan Mingjianli	1.0 ± 0.0	1.3 ± 1.5	1.3 ± 1.2	21.3 ± 4.0	1.3 ± 0.6	40.7 ± 10.0	9.0 ± 2.0	1.9 ± 0.2	5.9 ± 1.7
广西	广西油栗 Guangxi Youli	3.7 ± 0.6	1.7 ± 1.2	2.3 ± 0.6	7.3 ± 2.4	2.2 ± 1.2	39.3 ± 12.8	5.6 ± 2.5	5.5 ± 0.6	6.3 ± 1.7
Guangxi	广西玉林 Guangxi Yulin	4.0 ± 1.0	2.3 ± 1.5	2.3 ± 1.2	7.0 ± 1.9	1.8 ± 1.1	34.6 ± 5.0	8.1 ± 2.6	5.2 ± 1.2	7.0 ± 1.3
	广西 14-1 Guangxi 14-1	3.3 ± 1.2	2.3 ± 1.2	3.3 ± 2.1	16.5 ± 3.8	1.6 ± 0.7	32.7 ± 9.3	11.9 ± 3.9	2.0 ± 0.3	4.7 ± 1.1
	广西 14-2 Guangxi 14-2	1.0 ± 0.0	4.0 ± 1.0	2.3 ± 0.6	19.7 ± 2.1	1.0 ± 0.0	42.7 ± 3.8	18.0 ± 2.6	2.1 ± 0.5	4.6 ± 0.2
	广西 14-4 Guangxi 14-4	1.7 ± 0.6	6.0 ± 1.7	3.3 ± 1.2	15.6 ± 3.8	1.4 ± 0.5	34.4 ± 3.6	13.0 ± 3.7	2.0 ± 0.4	4.6 ± 0.4
	融水优株 Rongshui Youzhu	3.7 ± 1.5	6.7 ± 1.2	6.3 ± 2.1	19.1 ± 3.0	1.1 ± 0.3	34.3 ± 10.1	14.5 ± 6.0	1.8 ± 0.3	6.0 ± 0.9

续表 1

群体 Population	种质 Germplasm	数量 Number						长度/cm Length			结果枝
		结果枝数 Bearing shoot	雄花枝数 Male flower shoot	纤弱枝数 Leptos shoot	结果枝 节位数 Node order/ branch	每果枝 结苞数 Bur/ branch	结果枝 Bearing shoot	果前梢 Tailed twig	结果枝 节间 Internode	粗度/mm Bearing shoot width	
安徽	大红袍 Dahongpao	2.3 ± 0.6	1.7 ± 0.6	2.3 ± 1.5	11.1 ± 5.5	2.0 ± 0.8	38.4 ± 10.0	9.4 ± 3.6	3.7 ± 0.9	6.4 ± 1.5	
Anhui	粘底板 Niandiban	3.0 ± 1.0	1.7 ± 1.5	3.3 ± 1.5	9.1 ± 3.0	1.6 ± 1.0	30.2 ± 7.0	5.6 ± 1.9	3.5 ± 0.7	5.3 ± 1.3	
	AH-1	2.4 ± 0.8	1.5 ± 0.6	2.8 ± 1.6	12.4 ± 6.0	2.0 ± 1.2	29.9 ± 5.0	8.0 ± 3.7	3.6 ± 0.6	6.0 ± 1.7	
	AH-9	2.9 ± 0.7	1.9 ± 1.0	2.9 ± 1.2	7.1 ± 1.2	1.5 ± 0.8	35.8 ± 12.1	6.8 ± 2.9	3.6 ± 0.9	5.2 ± 0.6	
江苏	重阳蒲 Chongyanpu	2.7 ± 0.6	1.3 ± 0.6	5.3 ± 1.5	7.6 ± 2.4	1.6 ± 0.7	31.7 ± 12.3	9.3 ± 4.9	3.1 ± 1.1	4.6 ± 0.9	
Jiangsu	九家种 Jiujiazhong	3.3 ± 1.5	0.7 ± 0.6	4.0 ± 1.7	7.3 ± 3.8	1.9 ± 0.7	35.9 ± 11.0	11.2 ± 4.7	3.8 ± 1.5	7.2 ± 1.9	
	青毛软刺 Qingmao Ruanci	2.3 ± 0.6	1.3 ± 0.6	6.5 ± 0.7	11.0 ± 2.8	1.9 ± 0.9	41.3 ± 11.3	6.4 ± 2.6	3.8 ± 0.7	7.1 ± 1.3	
	J-002	2.8 ± 1.0	1.1 ± 1.0	5.1 ± 1.0	7.9 ± 3.5	1.8 ± 0.6	36.2 ± 12.0	8.9 ± 4.2	3.5 ± 0.7	6.2 ± 0.9	
湖北	DL-1	3.0 ± 1.7	2.0 ± 1.0	1.3 ± 1.5	21.1 ± 5.3	1.2 ± 0.4	47.0 ± 5.4	12.7 ± 3.8	2.4 ± 0.7	5.2 ± 1.3	
Hubei	DL-2	2.0 ± 1.0	2.7 ± 1.5	2.0 ± 1.7	22.7 ± 3.3	1.8 ± 0.8	53.5 ± 11.9	16.5 ± 5.8	2.3 ± 0.2	6.0 ± 1.2	
	DL-3	3.7 ± 1.2	1.0 ± 0.0	2.3 ± 0.6	29.5 ± 8.9	2.0 ± 1.0	62.5 ± 20.2	30.3 ± 9.9	2.1 ± 0.4	7.2 ± 1.5	
	DL-4	2.3 ± 0.6	1.0 ± 1.0	3.0 ± 1.0	21.4 ± 5.5	1.7 ± 0.5	52.1 ± 11.4	26.7 ± 9.8	2.5 ± 0.4	6.5 ± 1.5	
	罗田乌壳栗 Loutian Wukeli	2.7 ± 0.6	1.0 ± 1.0	4.7 ± 2.1	21.0 ± 6.7	1.5 ± 0.7	31.0 ± 6.3	7.1 ± 3.2	1.6 ± 0.8	5.5 ± 1.0	
	罗田林科所 Loutian Linkesuo	5.1 ± 0.8	1.3 ± 1.5	2.0 ± 1.0	6.5 ± 3.6	1.3 ± 0.5	31.7 ± 10.9	11.3 ± 5.8	5.5 ± 1.8	5.5 ± 1.2	
湖南	焦扎 Jiaozha	2.3 ± 0.6	2.0 ± 2.0	1.3 ± 0.6	17.3 ± 2.0	1.4 ± 0.5	30.7 ± 4.8	8.0 ± 2.2	1.8 ± 0.3	5.4 ± 0.8	
Hunan	安优 1 号 Anyou 1	1.3 ± 0.6	1.7 ± 1.5	1.3 ± 1.2	21.8 ± 4.6	1.5 ± 0.6	53.3 ± 16.8	23.8 ± 6.8	2.4 ± 0.4	7.7 ± 2.3	
	步城优株 Bucheng Youzhu	1.3 ± 0.6	2.3 ± 1.5	3.0 ± 1.7	20.5 ± 3.7	1.0 ± 0.0	40.8 ± 11.2	15.0 ± 5.4	2.0 ± 0.5	7.0 ± 2.2	
	黄花优株 Huanghua Youzhu	1.0 ± 0.0	4.3 ± 1.5	1.7 ± 1.2	13.0 ± 6.1	1.3 ± 0.6	27.3 ± 16.3	7.3 ± 1.5	2.0 ± 0.3	6.7 ± 0.7	
	石门优株 Shimen Youzhu	2.0 ± 0.0	1.7 ± 1.2	3.7 ± 2.1	16.7 ± 3.2	1.5 ± 0.5	27.5 ± 3.9	5.8 ± 1.2	0.7 ± 0.2	6.0 ± 0.4	
	新田优株 Xintian Youzhu	1.7 ± 0.6	5.7 ± 1.5	2.0 ± 2.0	17.6 ± 3.8	1.4 ± 0.5	35.8 ± 15.6	12.4 ± 4.0	1.9 ± 0.5	5.9 ± 1.2	
	临湘优株 2 号 Linxiang Youzhu 2	1.0 ± 0.0	2.0 ± 0.0	4.0 ± 2.0	28.5 ± 5.5	1.0 ± 0.0	48.0 ± 17.0	23.0 ± 7.0	1.6 ± 0.4	7.4 ± 2.7	
	桐优 33 Tongyou 33	1.3 ± 0.6	3.3 ± 0.6	1.0 ± 0.0	25.3 ± 10.8	1.8 ± 0.5	51.0 ± 15.5	17.8 ± 4.9	2.2 ± 0.7	6.9 ± 0.9	
	林场优株 Linchang Youzhu	3.3 ± 0.6	0.7 ± 1.2	1.0 ± 1.0	17.1 ± 2.7	2.3 ± 0.9	28.6 ± 5.0	5.5 ± 1.4	1.7 ± 0.2	5.8 ± 1.1	
浙江	上光栗 Shangguangli	1.3 ± 0.6	1.3 ± 1.2	3.7 ± 0.6	21.0 ± 0.8	1.5 ± 1.0	38.0 ± 7.1	12.0 ± 4.3	1.8 ± 0.3	7.1 ± 2.2	
Zhejiang	双季栗 Shuangjili	3.0 ± 1.0	2.0 ± 1.0	2.3 ± 1.5	20.4 ± 5.8	1.6 ± 0.5	40.9 ± 7.7	8.3 ± 3.5	2.1 ± 0.7	6.3 ± 1.4	
	浙江魁栗 Zhejiang Kuili	3.7 ± 1.2	3.3 ± 1.2	4.5 ± 1.7	7.9 ± 1.8	1.5 ± 0.7	35.9 ± 10.0	10.1 ± 3.2	5.7 ± 0.6	6.4 ± 0.9	
	Z-01	2.7 ± 1.0	2.2 ± 1.2	3.6 ± 0.9	12.6 ± 3.4	1.5 ± 0.6	36.8 ± 6.4	9.7 ± 3.7	4.0 ± 0.3	6.5 ± 0.9	
山东	红栗 Hongli	3.7 ± 0.6	3.0 ± 0.0	0.7 ± 0.6	20.9 ± 4.7	2.1 ± 0.9	36.7 ± 12.6	6.5 ± 3.3	1.7 ± 0.3	4.9 ± 0.7	
Shandong	华丰 Huafeng	2.7 ± 0.6	1.7 ± 0.6	2.7 ± 2.1	25.5 ± 6.7	1.6 ± 0.9	42.1 ± 13.6	17.4 ± 6.8	1.6 ± 0.2	6.8 ± 1.6	
	野杂 Yeza	6.3 ± 2.3	3.0 ± 1.7	0.7 ± 0.6	16.4 ± 3.8	1.8 ± 0.7	28.0 ± 8.0	7.2 ± 3.7	1.7 ± 0.2	4.4 ± 1.1	
	沂蒙短枝	3.3 ± 0.6	1.0 ± 1.0	3.7 ± 2.1	19.9 ± 3.8	1.7 ± 0.7	27.85 ± 8.7	8.0 ± 3.2	1.4 ± 0.3	6.4 ± 1.5	
	Yimeng Duanzhi										
	金丰 Jinfeng	3.0 ± 1.0	0.7 ± 0.6	2.0 ± 1.7	18.2 ± 3.8	2.9 ± 0.9	31.6 ± 11.0	6.6 ± 2.7	1.7 ± 0.3	6.5 ± 1.6	
	泰安薄壳 Tai'an Boke	3.0 ± 1.0	2.0 ± 0.0	5.3 ± 0.6	26.4 ± 5.6	1.9 ± 1.2	52.1 ± 14.7	25.1 ± 9.3	1.9 ± 0.3	6.6 ± 1.5	
	山东早实丰	3.3 ± 1.2	2.7 ± 1.2	2.7 ± 0.6	17.6 ± 3.3	1.7 ± 0.9	36.7 ± 9.1	9.1 ± 3.1	2.1 ± 0.3	5.0 ± 0.8	
	Shandong Zaoshifeng										
	华光 Huaguang	2.7 ± 0.6	3.0 ± 1.7	2.3 ± 2.1	11.4 ± 1.5	1.6 ± 0.5	29.6 ± 4.2	4.5 ± 1.7	2.6 ± 0.4	5.0 ± 0.7	
	黄棚 Huangpeng	4.0 ± 1.0	1.3 ± 1.2	1.7 ± 1.2	16.8 ± 3.3	1.9 ± 0.8	32.1 ± 8.6	5.5 ± 2.2	1.9 ± 0.5	5.9 ± 1.0	
	泰栗 1 号 Taili 1	3.3 ± 0.6	0.3 ± 0.6	4.3 ± 1.5	24.7 ± 4.0	1.6 ± 0.5	37.2 ± 7.0	15.0 ± 2.8	1.5 ± 0.2	6.5 ± 0.9	
	红光 Hongguang	3.3 ± 1.0	0	4.3 ± 1.5	17.7 ± 3.1	3.3 ± 1.5	31.8 ± 10.0	5.3 ± 2.1	1.8 ± 0.4	6.4 ± 1.3	
	郯城 3 号 Tancheng 3	2.3 ± 0.6	2.3 ± 1.5	3.3 ± 1.5	23.6 ± 4.5	2.4 ± 1.5	43.7 ± 10.3	18.0 ± 3.0	1.9 ± 0.4	7.3 ± 1.5	
	大粒 Dali	2.0 ± 0.0	0.7 ± 0.6	2.7 ± 1.2	23.1 ± 4.8	1.2 ± 0.4	42.3 ± 15.7	12.9 ± 5.6	1.8 ± 0.3	5.2 ± 1.1	
	东岳早丰	3.0 ± 0.0	0.3 ± 0.6	2.7 ± 1.5	23.8 ± 6.2	2.0 ± 0.5	45.8 ± 17.8	15.0 ± 6.3	2.2 ± 0.4	6.0 ± 1.1	
	Dongyue Zaofeng										
	尖顶油栗 Jianding Youli	3.3 ± 0.6	1.3 ± 1.5	3.7 ± 0.6	7.0 ± 2.6	1.7 ± 0.7	38.4 ± 12.5	6.6 ± 2.6	5.4 ± 0.6	5.5 ± 1.1	
	黑烟青 Heiyanqing	2.3 ± 0.6	1.0 ± 1.7	1.0 ± 1.0	20.6 ± 4.4	2.0 ± 0.8	39.0 ± 10.5	11.7 ± 4.1	1.9 ± 0.2	5.8 ± 0.8	
	烟泉 Yanquan	4.0 ± 1.0	3.0 ± 2.0	4.0 ± 1.0	26.3 ± 4.6	1.4 ± 0.5	41.2 ± 9.2	16.7 ± 6.6	1.6 ± 0.3	6.5 ± 1.3	
	烟青 Yanqing	4.3 ± 1.2	0.3 ± 0.6	4.7 ± 0.6	20.3 ± 2.8	3.0 ± 1.2	42.1 ± 11.9	15.7 ± 5.9	2.1 ± 0.5	6.1 ± 1.6	
	杂 35 Za 35	4.3 ± 1.5	0.3 ± 0.6	2.0 ± 1.0	15.5 ± 4.4	3.0 ± 1.4	20.1 ± 5.6	2.9 ± 1.7	1.3 ± 0.2	4.8 ± 1.2	
	金平 Jinping	2.7 ± 0.6	2.3 ± 2.1	7.7 ± 3.1	22.0 ± 3.8	2.0 ± 0.7	59.3 ± 9.0	28.6 ± 5.5	1.6 ± 0.3	7.4 ± 1.2	
	新选 1 号 Xinxuan 1	3.0 ± 0.0	3.7 ± 2.1	2.7 ± 0.6	27.1 ± 2.5	2.1 ± 1.4	42.4 ± 10.7	15.3 ± 8.0	2.3 ± 0.4	5.6 ± 0.9	

表 2 板栗 10 个群体结果母枝表型性状平均值和方差分析
Table 2 Mean value and variance analysis of biennial bearing branch traits for 10 populations of chestnut

群体 Population	数量 Number					长度/cm Length			结果枝 粗度/mm Bearing Shoot width
	结果枝数 Bearing shoot	雄花枝数 Male flower shoot	纤弱枝数 Leptos shoot	结果枝 节位数/ Node order branch	每果枝 结苞数 Bur/ branch	结果枝 Bearing shoot	果前梢 Tailed twig	结果枝 节间 Internode	
北京 Beijing	3.2 ± 1.3 c	1.8 ± 1.5 a	1.8 ± 1.5 a	19.4 ± 8.7 de	2.3 ± 1.3 b	40.0 ± 9.0 abc	12.9 ± 7.3 bc	2.6 ± 1.1 a	5.7 ± 2.1 a
河北 Hebei	3.1 ± 1.1 c	2.0 ± 1.5 a	2.9 ± 2.2 ab	19.6 ± 6.6 de	2.2 ± 1.2 ab	39.4 ± 12.4 abc	10.2 ± 6.0 abc	2.3 ± 1.3 a	5.9 ± 1.3 a
广西 Guangxi	2.9 ± 1.4 bc	3.8 ± 2.3 b	3.3 ± 1.9 ab	13.0 ± 6.1 b	1.6 ± 0.9 a	35.6 ± 9.1 abc	10.7 ± 5.3 abc	3.5 ± 1.8 b	5.9 ± 1.5 a
安徽 Anhui	2.7 ± 0.8 abc	1.7 ± 1.0 a	2.8 ± 1.5 ab	10.0 ± 4.3 ab	1.8 ± 0.9 ab	33.8 ± 9.2 a	7.3 ± 3.4 a	3.6 ± 0.7 b	5.8 ± 1.4 a
江苏 Jiangsu	2.8 ± 1.0 bc	1.1 ± 0.9 a	5.1 ± 1.6 b	8.4 ± 3.4 a	1.8 ± 0.8 ab	35.4 ± 11.9 ab	9.2 ± 4.6 ab	3.6 ± 1.2 b	6.3 ± 1.8 a
浙江 Zhejiang	2.7 ± 1.3 abc	2.2 ± 1.3 a	3.6 ± 1.6 ab	14.8 ± 7.4 bc	1.5 ± 0.7 a	38.2 ± 9.1 abc	9.8 ± 3.6 ab	3.2 ± 1.7 b	6.5 ± 1.3 ab
陕西 Shaanxi	1.5 ± 0.8 a	1.7 ± 1.5 a	3.3 ± 2.8 ab	22.9 ± 3.5 e	1.6 ± 0.9 a	44.3 ± 7.4 bc	14.8 ± 4.9 cd	1.9 ± 0.2 a	6.2 ± 1.7 a
湖北 Hubei	3.1 ± 1.4 c	1.5 ± 1.2 a	2.6 ± 1.6 a	20.9 ± 9.0 de	1.6 ± 0.7 a	45.0 ± 17.1 c	17.1 ± 10.8 d	2.6 ± 1.5 a	6.0 ± 1.4 a
湖南 Hunan	1.7 ± 0.9 ab	2.6 ± 1.9 ab	2.1 ± 1.6 a	19.0 ± 5.6 d	1.6 ± 0.7 a	35.7 ± 13.6 abc	11.3 ± 7.3 abc	1.9 ± 0.4 a	6.3 ± 1.4 a
山东 Shandong	3.3 ± 1.2 c	1.6 ± 1.5 a	3.2 ± 2.1 ab	19.9 ± 6.3 de	2.0 ± 1.1 ab	37.2 ± 13.4 abc	11.5 ± 7.8 abc	2.0 ± 0.9 a	5.8 ± 1.4 a
平均值 Mean	3.0 ± 1.2	2.0 ± 1.7	2.9 ± 2.1	19.0 ± 7.0	1.8 ± 3.1	38.9 ± 12.4	11.0 ± 6.9	2.7 ± 1.1	5.9 ± 1.5
群体间 <i>F</i> 值 Among populations <i>F</i> value	5.3**	4.5**	3.1**	18.4**	6.0**	4.1**	9.0**	13.8*	2.7**
群体内 <i>F</i> 值 Within populations <i>F</i> value	3.6**	3.3**	5.6**	13.5**	2.9**	4.9**	14.7**	31.4**	3.1**

注：同列不同小写字母表示群体间差异达到显著水平（ $P < 0.05$ ），表中平均值为总数据均值。* $P < 0.05$ ，** $P < 0.01$ 。

Note: The lowercase letters in the same column mean significant difference among populations at 0.05 level. The mean in the table is total number average. * $P < 0.05$ ，** $P < 0.01$.

2.2 结果母枝相关表型性状在群体内的变异特征

由表 3 可知，板栗结果母枝相关 9 个表型性状平均变异系数值差异较大，介于 19.4%~64.0%，其中母枝上雄花枝数、纤弱枝数和结苞数变异系数平均值均达到 40%以上，说明这 3 个性状多态性程度相对较高，具有较大的遗传变异潜力。

表 3 板栗 10 个群体结果母枝表型性状平均变异系数
Table 3 Coefficients of variation (CV) of biennial bearing branch for 10 populations of chestnut %

群体 Population	结果枝数 Bearing shoot number	雄花枝数 Male flower shoot number	纤弱枝数 Leptos shoot number	结果枝 长度 Bearing shoot length	果前梢 长度 Tailed twig length	结果枝节 间长度 Internode length	结果枝 粗度 Bearing shoot width	结果枝 节位数 Node order number/ branch	每果枝 结苞数 Bur number/ branch	平均值 Mean
北京 Beijing	19.7	51.0	51.4	20.0	29.3	10.6	20.6	21.1	46.8	30.1
河北 Hebei	21.8	65.0	53.9	25.7	36.2	17.3	19.6	21.6	46.3	34.2
广西 Guangxi	25.3	42.6	55.1	20.8	32.5	15.4	16.0	22.3	37.4	29.7
安徽 Anhui	29.0	63.1	55.6	24.7	36.8	20.5	23.5	42.6	53.0	38.8
江苏 Jiangsu	30.8	57.7	27.6	35.1	45.4	33.5	21.1	40.3	44.4	37.3
浙江 Zhejiang	36.0	57.1	39.9	21.7	36.6	25.3	22.5	18.5	48.3	34.0
陕西 Shanxi	25.0	82.3	66.9	18.7	18.2	9.1	28.5	16.4	52.6	35.3
湖北 Hubei	30.2	70.3	59.0	23.7	38.4	25.7	21.5	30.3	40.2	37.7
湖南 Hunan	22.8	64.3	57.1	30.6	27.6	19.4	20.1	24.0	29.2	32.8
山东 Shandong	22.2	86.3	49.7	27.8	38.1	16.7	19.6	20.6	43.7	36.1
平均值 Mean	26.3	64.0	51.6	24.9	33.9	19.4	21.3	25.8	44.2	34.6

各群体内各表型性状变异系数均值存在明显差异，表明各群体的性状表型多样性存在明显差

别, 其中安徽群体的各性状的平均变异系数均值最大, 为 38.8%, 表明该群体表型多态性较为丰富; 而广西群体的各性状平均变异系数均值最小, 为 29.7%。依据各表型性状变异系数平均值的均值来看, 不同群体内表型性状多态性丰富程度为: 安徽 > 湖北 > 江苏 > 山东 > 陕西 > 河北 > 浙江 > 湖南 > 北京 > 广西。

2.3 结果母枝相关表型性状群体间表型分化

按系统分组设计方差分量比组成计算出各方差分量占总变异的比例(表 4)。在板栗各表型性状中群体遗传组成均有较大差异, 方差分量百分比在群体间和群体内的范围分别是 47.2% ~ 74.5%和 23.3% ~ 43.9%。根据 9 个表型性状的平均值, 群体间的方差分量占总变异的 61.7%, 群体内占 31.9%。群体间 9 个表型性状的表型分化系数(V_{st})值介于 51.8% ~ 75.9%之间, 平均为 65.9%, 即群体间的平均表型变异约占总变异的 2/3, 群体内约占 1/3, 说明就这 9 个表型性状而言, 群体间变异是表型变异的主要来源。

表 4 板栗结果母枝表型方差分量和群体间表型分化系数
Table 4 Variance portions and differentiation coefficients of biennial bearing branch phenotype traits among and within populations of chestnut

性状 Trait	方差分量 Variance components			方差分量百分比/% Percentage of variance components		表型分化 系数/% V_{st}
	群体间 Among populations	群体内 Within populations	随机误差 Random errors	群体间 Among populations	群体内 Within populations	
结果枝数 Bearing shoot number	7.394	2.453	0.685	70.2	23.3	75.1
结果枝长度 Bearing shoot length	571.301	532.026	107.694	47.2	43.9	51.8
结果枝粗度 Bearing shoot width	10.342	5.520	2.108	57.6	30.7	65.2
果前梢长度 Tailed twig length	393.990	262.959	17.915	58.4	39.0	60.0
雄花枝数 Male flower shoot number	10.497	4.407	1.354	64.6	27.1	70.4
每母枝上纤弱枝数 Leptos shoot number	13.238	9.570	1.719	53.8	39.0	58.0
结果枝节位数 Nodeorder number	812.345	258.574	19.189	74.5	23.7	75.9
平均每果枝结苞数 Bur number	7.720	3.072	1.066	65.1	25.9	71.5
结果枝节间长度 Internode length	21.987	11.920	0.380	64.1	34.8	64.8
平均值 Mean	205.424	121.167	16.901	61.7	31.9	65.9

2.4 结果母枝相关表型性状聚类分析

采用系统聚类法, 对 10 个群体 164 份板栗资源依据表型性状进行聚类分析, 结果见图 1。

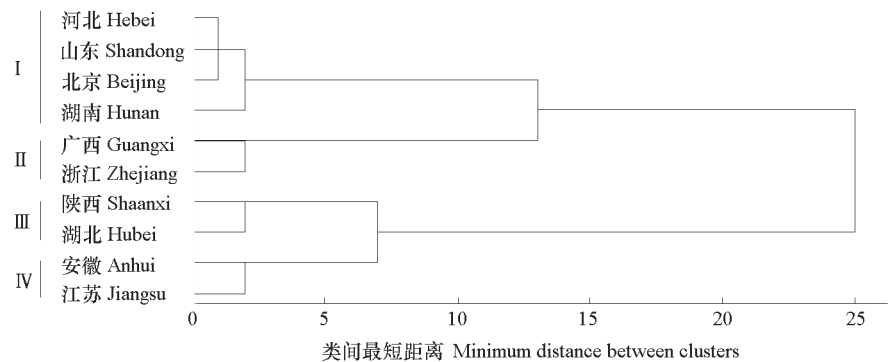


图 1 板栗群体树状聚类图(组间联接)
Fig. 1 Cluster tree of chestnut populations (average linkage between groups)

在欧式距离 5 时 10 个板栗群体被聚为 4 大类, 北京、河北、山东和湖南群体聚为一类, 其中北京、河北和山东群体地理位置毗邻, 均位于北方属于华北板栗品种群, 其性状遗传上聚在一起与其地理位置相吻合, 这 3 个群体随后又与湖南群体聚为一类, 但其遗传距离与地理距离无明显的相关关系。安徽和江苏群体聚为一类, 二者地理位置紧密相连, 位于东南部地区, 均属于长江中下游板栗品种群, 其遗传距离也相近。陕西和湖北群体聚为一类, 二者地理位置相邻, 均位于中西部地区。广西和浙江群体聚为一类, 其遗传距离与地理距离无明显的相关关系, 但均属于南方板栗群。

3 讨论

植物表型多样性是其遗传多样性的重要部分(李斌 等, 2002), 种质的遗传多样性是育种工作的基础(Li et al., 2009; 张向前 等, 2010)。矮化、高产是目前果树育种的一个重要目标, 板栗结果母枝性状与植株矮化程度和产量之间有密切关系(王广鹏 等, 2004)。本研究结果显示, 板栗结果母枝的 9 个表型性状在群体间和群体内均存在极显著差异, 这与一些学者(马玉敏 等, 2008; 王广鹏 等, 2009; 刘国彬 等, 2011; 江锡兵 等, 2014)对板栗叶片、坚果和总苞等性状遗传多样性的研究结果相似, 说明板栗结果母枝相关性状在群体间和群体内均存在丰富变异, 表型多样性水平很高, 育种选择潜力巨大, 预示着通过现有个体选择来改良(提高或降低)这些性状进而实现矮化高产是可以取得成功的。但是板栗这 9 个性状表型值的变异幅度不尽相同, 这说明通过选择手段来改良这些性状特征的难易程度会因性状而异, 变异系数大小揭示的性状选择改良潜力依次是每母枝上雄花枝数 > 纤弱枝数 > 结苞数 > 果前梢长度 > 结果枝数 > 结果母枝节位数 > 结果母枝长度 > 结果母枝粗度 > 结果枝节间长度, 可依据各性状改良潜力合理设定选种目标。

变异系数越大, 则性状离散程度越大, 可用它来比较衡量不同的性状之间的变异程度(孔繁玲, 2006)。本研究中, 不同地区来源的群体间的各性状表型值和变异系数有一定差异, 同一群体不同性状间的变异程度亦有所不同, 说明不同的群体其基因型和环境异质导致群体表型变异的差异, 体现了群体间种质在育种上的不等值性。一般各性状变异系数平均值高的群体预示着具备选种有利性状的个体出现的频率高, 因而育种价值也高, 如山东群体最具有选出母枝上结果枝比例高品种的潜力, 北京群体最具有选出结苞数高品种的潜力。但是, 本研究中单一性状最突出的个体不是必然出现在平均表现值最高的群体中, 如河北群体平均母枝上结果枝数(3.1 条)小于山东群体(3.3 条), 但是却出现了所测定 164 份种质中结果母枝上结果枝数最高的个体; 河北群体的平均结果母枝长度偏低, 但却出现了所有种质中结果枝长度位居第 2 的个体。一些学者在对不同群体银杏、油茶表型性状遗传变异的研究中也发现了相同的现象(张云跃 等, 2001; 黄勇 等, 2011)。这些现象提示在制定板栗育种改良计划时, 既要考虑群体的平均表现, 又要充分关注群体内极性个体, 并将之作为特异基因型来加以选用, 以此来提高选种改良效率, 尤其在杂交育种时, 具极端性状基因型种质的利用比对现有综合性状表现优良基因型种质选择更为重要。

生物群体间的变异反映了地理、生殖隔离上的差异, 是一个生物多样性的的重要组成部分(王娅丽 等, 2008), 它反映了群体在不同环境中的适应状况, 其大小在某种程度上说明了该生物对不同环境适应的广泛程度, 值越大适应的环境越广(李斌 等, 2002)。中国板栗 9 个结果母枝相关表型性状的平均表型分化系数(V_{st})值介于 51.8%~75.1%之间, 平均为 65.9%, 群体内的变异为 34.1%, 说明板栗群体间多样性程度大于群体内多样性, 表型变异以群体间为主, 反映出板栗具有广泛的环境适应性和表型性状可塑性(基因与环境互作复杂性)。此研究结果与江锡兵等(2014)基于板栗叶

片、果实性状群体间、群体内的平均表型分化系数提出的群体内变异远高于群体间变异的研究结果不同,其原因可能是用于分析的性状不同。

本研究中,除湖南、广西和浙江群体外,板栗群体表型特征基本上按地理距离而聚类,揭示了群体间表型性状变异的连续性。之前,江锡兵等(2014)依据叶片、坚果性状表型特征将中国板栗山东、河北、湖北、安徽、江苏和河南6个中北部群体聚为1大类,本研究结果与之有一定相似性。这些聚为一类的群体,地理位置相临或相近,相似的自然条件和栽培耕种史、频繁的品种交换,都会造成这些地区的资源在遗传组成上趋同(兰彦平等,2010)。湖南、广西和浙江板栗群体,发生未按地理距离而聚类的情况,其原因可能是本研究中这些群体的试材由于长期引种驯化、变异,导致与原产地的性状表现有所不同,或者这些群体的野生种质遗传变异较大,与其他种质在遗传关系上较远,还有可能是上述群体的试材(样本)相对较少,不足以代表各自群体种质多样性水平。

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