

不同树形对早实核桃‘鲁光’坚果产量和品质的影响

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摘要:【目的】探索适宜‘鲁光’核桃优质高产的树形。【方法】以‘鲁光’核桃树为研究对象, 分析主干分层形、开心形和自然圆头形3种树形的结构参数、坚果产量和品质, 并进行主成分分析。【结果】主干分层形的树高、基径、骨干枝数、单株平均坚果产量、树冠投影面积平均产量、单果质量、仁质量、种仁粗脂肪和抗坏血酸含量最高; 开心形的坚果壳厚最小, 出仁率和种仁蛋白质含量最高; 自然圆头形的总糖和氨基酸含量最高。坚果外观形状无显著的树形间差异。主成分分析表明主干分层形有利于产量的形成, 开心形有利于品质的形成, 3种树形的综合排名顺序为主干分层形>开心形>自然圆头形。【结论】济南市章丘区‘鲁光’核桃的适宜树形为主干分层形。

关键词:核桃;树形;产量;品质;主成分分析

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Effects of different tree shapes on yield and quality of ‘Luguang’ walnut

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Abstract:【Objective】The major objectives of this work are to (1) select the most suitable tree shape for high nut yield and quality in early-fruiting walnut ‘Luguang’ from the 3 commonly used tree shapes including trunk-layered shape, open centre shape and natural round shape; (2) provide references and technical guidance for the cultivation and maintenance of the most suitable tree shape of this walnut variety.【Methods】5-year-old early-fruiting walnut variety ‘Luguang’ trees were used as the experimental materials to comparatively analyze the canopy structural parameters, average yield per plant, average yield per unit canopy projection area, morphological indexes and nutritional components of walnut from trees with the above mentioned three canopy shapes. The tree height was measured from the ground to the top of the crown with a tower ruler; the trunk base diameter was measured with a tape 20 cm from the ground; and the crown width was measured with a meter ruler at the east-west and north-south directions of the vertical projection edge of the crown. The vertical diameter, transverse diameter and lateral diameter of the nut were measured with a digital caliper. The average fruit weight, kernel weight and yield per plant were determined with an electronic scale. The contents of protein, crude fat, ascorbic acid, total sugar and amino acid were measured using kjeldahl method, soxhlet extraction method, 2, 4-dinitrophenylhydrazine method, reducing sugar release method, and automatic amino acid analyzer, respectively. Principal component analysis (PCA) was used to comprehensively evaluate the different tree shapes.【Results】Results from one-way ANOVA showed that tree shape had significant influence on tree height ($p \leq 0.01$), trunk diameter ($p \leq 0.05$), number of skeleton branches ($p \leq 0.001$), average yield per plant ($p \leq 0.001$), average yield per unit canopy projection area ($p \leq 0.001$), average

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fruit weight ($p \leq 0.001$), kernel weight ($p \leq 0.01$), shell thickness ($p \leq 0.001$), kernel rate ($p \leq 0.001$), protein content ($p \leq 0.05$), crud fat content ($p \leq 0.05$), ascorbic acid content ($p \leq 0.01$), total sugar content ($p \leq 0.05$) and total amino acid content ($p \leq 0.05$), but no significant effect of tree shape was observed ($p > 0.05$) on canopy width, fruit vertical, transverse and lateral diameters, fruit shape index, contents of the 17 amino acids and total essential amino acid, and the percentage of essential amino acids. Trees with trunk-layered shape had the highest tree height (4.55 m), trunk diameter (11.31 cm), number of skeleton branches (6.25) and average yield per plant (7.12 kg), which were significantly higher than that of the trees with natural round shape (3.78 m, 10.49 cm, 5.25 and 6.47 kg, respectively). Tree height, trunk diameter, number of skeleton branches and average yield per plant of the tree with open centre shape were 4.05 m, 10.79 cm, 5.00 and 6.72 kg, respectively. Trees with open centre shape had the highest canopy width (4.08 m, 4.05 m), followed by trees with natural round shape (4.00 m, 3.88 m) and trunk-layered shape (3.78 m, 3.65 m). The average yield per unit canopy projection area in trees with trunk-layered shape and natural round shape was 0.61 and 0.59 kg·m⁻², respectively, both being significantly higher than that in trees with open centre shape (0.51 kg·m⁻², $p \leq 0.05$). The highest values in average fruit weight (17.00 g) and kernel weight (9.79 g) were observed in trees with trunk-layered shape, which were significantly higher than those in the round shaped trees (16.03 g and 9.25 g, respectively) ($p \leq 0.05$). The average fruit weight and kernel weight of walnut in trees with open centre shape was 16.50 g and 9.70 g, respectively, which had no significant difference from those in trees with the other two shapes. Trees with open centre shape showed the lowest shell thickness (1.01 mm) and the highest kernel coverage (58.72%), which were significantly lower and higher respectively than those in trees with trunk-layered shape (1.06 mm and 57.61%, respectively) and natural round shape (1.06 mm and 57.81%, respectively) ($p \leq 0.05$). Trees with open centre shape were highest in kernel protein content (172.97 mg·g⁻¹), which was significantly higher than that in trees with natural round shape (165.09 mg·g⁻¹) and trunk-layered shape (160.96 mg·g⁻¹) ($p \leq 0.05$). Trees with trunk-layered shape had the highest values in crude fat content (676.93 mg·g⁻¹) and ascorbic acid content (2.95 mg·g⁻¹), followed by trees with open centre shape (668.99 and 2.72 mg·g⁻¹, respectively) and natural round shape (660.92 and 2.40 mg·g⁻¹, respectively). The total sugar content in the kernel from trees with natural round shape was the highest (17.18 mg·g⁻¹), followed by those in the open centre shape (16.64 mg·g⁻¹) and trunk-layered shape (15.90 mg·g⁻¹). Seventeen amino acids were determined in ‘Luguang’ walnut kernel, among which the seven essential amino acids were detected with a total content in the range from 44.62 to 48.36 mg·g⁻¹, accounting for 28.26 to 29.32% of the total amino acids. The total amino acids content in the kernel of ‘Luguang’ walnut was 153.02-164.92 mg·g⁻¹, and glutamate showed the highest content (29.67-32.29 mg·g⁻¹), followed by arginine (19.35-21.76 mg·g⁻¹) and aspartate (16.99-17.58 mg·g⁻¹), while methionine had the lowest content (1.36-1.60 mg·g⁻¹). The results of PCA showed that the order of productivity potential among different tree shapes was trunk-layered shape > open centre shape > natural round shape, while the order for quality formation was open centre shape > trunk-layered shape > natural round shape.【Conclusion】Taking productivity and quality into account, the best tree shape for ‘Luguang’ walnut is trunk-layered shape, followed by open centre shape and natural round shape.

Key words: Walnut; Tree shape; Yield; Quality; Principal component analysis

树形结构决定了树冠的冠层结构特点和树冠微域环境,直接影响树体对光的截获与利用及水肥的吸收、运输与利用,进而影响树木的生长、逆境适应

能力、果实产量和品质的形成^[1-7]。因此,研究果树树形结构对树体生长、果实产量和品质形成的影响,对评价树体生长与生产状况、整形修剪、激素调控效

果、完善树形培养与维护技术体系、选育优良品系均具有重要意义。不同树形结构的构建与调控在苹果、梨、樱桃等树种上已经得到了较为广泛和深入研究^[8],有关核桃树形结构的构建与调控技术的研究鲜有报道。

核桃(*Juglans regia* L.)是重要的坚果和木本油料树种,广泛种植于山区、丘陵和田园等地,其常用树形有主干分层形、开心形和自然圆头形3种。常月梅^[9]对比分析了‘中林1号’核桃自然圆头形和疏散分层形2种树形树冠不同部位的微域环境及其对叶片光合速率、养分积累和枝条干枯的影响,结果表明,与自然圆头形相比,疏散分层形树冠内通风透光性好,叶片光合能力高,有利于叶片光合同化产物的合成和枝条营养物质的积累,增强了抗性能力,减少了枝条干枯的发生。郭众仲^[10]对比分析了6 a(年)生‘新温185’核桃主干形和自然圆头形2种树形的冠层结构特性、冠层微环境、叶片光合特性、坚果产量与品质发现,与自然圆头形相比,主干形树高较高,冠幅较小,短果枝率较高,有效光区比例高且有效相对光照强度分布相对均匀,叶片光合能力强,有利于坚果产量的形成和品质的提高。谭岷山等^[11]在‘华宁大砂壳’核桃上的研究表明,主干分层形的叶面积指数、冠层截获的总辐射能和单株产量均显著高于开心形和自然圆头形。刘伟伟^[12]研究表明,‘新温185’核桃疏散分层形树冠不同部位间的冠内光分布、坚果产量和品质均存在显著差异,坚果产量和品质在树冠垂直方向(从上到下)和水平方向(从外到内腔)均呈逐渐减小趋势,坚果品质的格局变化与冠内光分布特征呈显著正相关。此外,研究表明,不同方位、不同冠层的光照强度差异亦诱导核桃果实内果皮中木质素含量及相关酶活性的差异^[13]。

早实核桃良种‘鲁光’是由山东省果树研究所以新疆无性系品种‘卡卡孜’作母本,以早实核桃品种‘上宋6号’作父本杂交育成,目前在华东、华北、西北核桃种植区均有栽培。本研究以5 a生‘鲁光’核桃树为研究对象,对比分析了主干分层形、开心形和自然圆头形3种树形的结构参数、单株产量、坚果形态和种仁营养成分,并采用主成分分析法对3种树形进行综合评价,筛选出有利于该品种产量和品质形成的最佳树形,以期为该品种通过整形修剪技术培养和维护合理树形结构,改善果实品质,保持连年

优质高产提供科学的理论依据。

1 材料和方法

1.1 试验地概况

试验地设在山东省林业科学研究院试验基地,位于济南市章丘区三德范村,地处泰沂山脉,海拔563.5 m,属暖温带半湿润大陆性季风气候,四季分明,雨热同季。春季干旱多风,夏季雨量集中,秋季温和凉爽,冬季雪少干冷。年平均日照2 647.6 h,平均气温12.8 ℃,平均降水量600.8 mm,年平均相对湿度为65%,无霜期平均192 d。试验园区土壤为褐土,土层深厚,土质疏松,管理水平中等。

1.2 试验材料

试验材料为早实核桃品种‘鲁光’,树龄为5年,株行距4.0 m×4.0 m,南北行向。于定植后,分别定干培养主干分层形、开心形和自然圆头形3种树形。随机选取立地条件相同、长势良好、树形标准的3种树形的‘鲁光’核桃树进行树体结构、坚果产量和品质的调查分析。以单株为1个重复,每个树形6次重复。

1.3 试验方法

1.3.1 树形结构参数 于7月中旬新梢停长后,分别对3种树形的骨干枝数、树高、基径和冠幅进行测定。树高用塔尺(0.01 m)从地面至树冠顶端测量,基径用胸径尺(0.01 cm)在树干距离地面20 cm处测定,冠幅用米尺(0.01 m)分别在树冠垂直投影边缘的东西方向和南北方向测量。

1.3.2 单株产量 9月上旬核桃果实成熟后,将3个树形各个试验单株的果实分别采收,去青皮,晾干,用电子秤(1.00 g)称重即得单株坚果产量,并计算树冠投影面积平均产量(树冠投影面积平均产量=单株坚果产量/单株树冠投影面积)。

1.3.3 坚果形态指标 每个单株随机选取30粒坚果,用数显游标卡尺(0.01 mm)测定纵径、横径、侧径和壳厚,用电子天秤(0.000 1 g)测定单果质量和仁质量,并计算果形指数和出仁率。

$$\text{果形指数} = \text{纵径}/[(\text{横径}+\text{侧径})/2]。$$

$$\text{出仁率} \% = \text{种仁质量}/\text{坚果质量} \times 100。$$

1.3.4 种仁营养成分 30粒坚果去壳取种仁,测定其营养成分,蛋白质含量采用凯氏定氮法测定(GB/T 5009.5—2003),粗脂肪含量采用索氏抽提法测定(GB/T 5009.6—2003),抗坏血酸含量采用2,4-二硝

基苯肼法测定(GB 12392—90),总糖含量采用还原糖法测定(GB/T 5009.7—2008),氨基酸种类及含量采用氨基酸自动分析仪测定(GB/T 18246—2000)。

1.4 数据分析

采用Excel 2010进行常规数据统计分析,采用SPSS 20.0数据处理系统进行单因素方差分析(One-way ANOVA)和主成分分析(Principal Component Analysis,PCA)。

2 结果与分析

2.1 不同树形冠层结构

如表1所示,方差分析结果表明,树形对树体的

树高($p \leq 0.01$)、基径($p \leq 0.05$)和骨干枝数($p \leq 0.001$)均有显著影响,而对冠幅无显著影响($p > 0.05$)。主干分层形的树高和基径均最大,分别为4.55 m和11.31 cm,均显著高于自然圆头形(分别为3.78 m和10.49 cm, $p \leq 0.05$),而两者与开心形(分别为4.05 m和10.79 cm)无显著差异($p > 0.05$)。主干分层形的骨干枝数最多,为6.25,显著高于自然圆头形(5.25)和开心形(5.00)($p \leq 0.05$)。3种树形间冠幅无显著差异($p > 0.05$),且东西冠幅大于南北冠幅。开心形的冠幅最大(4.08 m,4.05 m),其次是自然圆头形(4.00 m,3.88 m)和主干分层形(3.78 m,3.65 m)。

表1 不同树形结构参数
Table 1 Structure parameters of different tree shapes

树形 Tree shape	树高 Tree height/m	基径 Base diameter/cm	骨干枝数 Number of skeleton branches	冠幅 Crown width/m	
				东-西 East-west	南-北 North-south
自然圆头形 Natural round shape	3.78±0.13 b	10.49±0.48 b	5.25±0.75 b	4.00±0.35 a	3.88±0.21 a
开心形 Open centre shape	4.05±0.18 ab	10.79±0.88 ab	5.00±0.50 b	4.08±0.33 a	4.05±0.23 a
主干分层形 Trunk-layered shape	4.55±0.20 a	11.31±0.50 a	6.25±0.75 a	3.78±0.21 a	3.65±0.10 a
F	11.647**	5.792*	83.170***	2.226	1.871

注:同一列中不同小写字母表示不同树形间同一指标间的差异显著($p \leq 0.05$)。显著水平:^{*} $p \leq 0.05$,^{**} $p \leq 0.01$,^{***} $p \leq 0.001$ 。下同。

Note: Values in the same column with different small letters are significantly different ($p \leq 0.05$). Level of significance: ^{*} $p \leq 0.05$, ^{**} $p \leq 0.01$, ^{***} $p \leq 0.001$. The same as following.

2.2 不同树形单株产量与树冠投影面积产量

如表2所示,方差分析结果表明,树形对单株平均坚果产量和树冠投影面积平均产量有显著影响($p \leq 0.001$)。主干分层形单株平均坚果产量最高,

表2 不同树形的单株平均坚果产量和
树冠投影面积平均产量

Table 2 Average yield per plant and average yield per unit canopy projection area in walnut trees with different canopy shapes

树形 Tree shape	单株平均坚果产量 Average yield per plant/kg	树冠投影面积平均产量 Average yield per unit canopy projection area/ (kg·m ⁻²)	坚果果形指数		
			纵径	横径	侧径
自然圆头形 Natural round shape	6.47±0.62 b	0.59±0.08 a	0.60	0.58	0.55
开心形 Open centre shape	6.72±1.09 b	0.51±0.07 b	0.62	0.55	0.52
主干分层形 Trunk-layered shape	7.12±1.20 a	0.61±0.04 a	0.65	0.60	0.58
F	126.726***	47.450***	1.01	0.98	0.95

为7.12 kg,显著高于自然圆头形(6.47 kg)和开心形(6.72 kg)($p \leq 0.05$)。主干分层形和自然圆头形树冠投影面积平均产量无显著差异(分别为0.61 kg·m⁻²和0.59 kg·m⁻², $p > 0.05$),显著高于开心形(0.51 kg·m⁻², $p \leq 0.05$)。

2.3 不同树形坚果形态特征

如表3所示,树形对‘鲁光’核桃坚果外观形状无显著影响($p > 0.05$),3种树形间坚果纵径、横径、侧径和果形指数均无显著差异($p > 0.05$)。‘鲁光’核桃3种树形坚果果形指数均大于1,果实为长圆形。

如表4所示,方差分析结果表明,树形对‘鲁光’核桃平均单果质量($p \leq 0.001$)、仁质量($p \leq 0.01$)、壳厚($p \leq 0.001$)和出仁率($p \leq 0.001$)均有显著影响。主干分层形的平均单果质量和仁质量最大,分别为17.00 g和9.79 g,均显著高于自然圆头形(分别为16.03 g和9.25 g, $p \leq 0.05$),开心形居中(分别为16.50 g和9.70 g)。开心形的坚果壳厚最小,为1.01

表3 不同树形坚果外观形状

Table 3 Morphological characters of nuts from trees with different tree shapes

树形 Tree shape	纵径 Vertical diameter/mm	横径 Transverse diameter/mm	侧径 Lateral diameter/mm	果形指数 Fruit shape index
自然圆头形 Natural round shape	42.14±0.94 a	38.51±0.82 a	36.07±0.72 a	1.13±0.02 a
开心形 Open centre shape	42.83±0.15 a	39.13±0.57 a	36.32±0.40 a	1.14±0.04 a
主干分层形 Trunk-layered shape	42.37±0.25 a	39.30±0.27 a	36.83±0.38 a	1.12±0.03 a
F	0.871	1.437	1.012	0.451

表4 不同树形坚果平均单果质量、仁质量、出仁率和壳厚

Table 4 Average single fruit weight, kernel weight, kernel recovery and shell thickness of walnut from trees with different tree shapes

树形 Tree shape	平均单果质量 Average single fruit mass/g	仁质量 Kernel mass/g	壳厚 Shell thickness/mm	出仁率 Kernel rate/%
自然圆头形 Natural round shape	16.03±1.11 b	9.25±0.53 b	1.06±0.03 a	57.81±1.21 b
开心形 Open centre shape	16.50±0.64 ab	9.70±0.54 a	1.01±0.07 b	58.72±2.14 a
主干分层形 Trunk-layered shape	17.00±0.44 a	9.79±0.25 a	1.06±0.09 a	57.61±1.60 b
F	21.635***	10.766**	100.285***	62.192***

mm, 显著小于自然圆头形(1.06 mm)和主干分层形(1.06 mm)($p \leq 0.05$)。开心形的出仁率最高, 为58.72%, 显著高于主干分层形(57.61%)和自然圆头形(57.81%)($p \leq 0.05$)。

2.4 不同树形坚果种仁营养成分

如表5所示, 树形对‘鲁光’核桃种仁蛋白质($p \leq 0.05$)、粗脂肪($p \leq 0.05$)、抗坏血酸($p \leq 0.01$)和总糖($p \leq 0.05$)含量有显著影响。开心形的种仁

蛋白质含量最高, 为172.97 mg·g⁻¹, 显著高于自然圆头形(165.09 mg·g⁻¹)和主干分层形(160.96 mg·g⁻¹)。主干分层形的种仁粗脂肪和抗坏血酸含量最高, 分别为676.93 mg·g⁻¹和2.95 mg·g⁻¹, 其次是开心形(分别为668.99 mg·g⁻¹和2.72 mg·g⁻¹)和自然圆头形(分别为660.92 mg·g⁻¹和2.40 mg·g⁻¹)。自然圆头形的种仁总糖含量最高, 为17.18 mg·g⁻¹, 其次是开心形(16.64 mg·g⁻¹)和主干分层形(15.90 mg·g⁻¹)。

表5 不同树形核桃种仁蛋白质、脂肪、抗坏血酸和总糖含量

Table 5 Contents of protein, crude fat, ascorbic acid and total sugar in walnut kernel from trees with different tree shapes

树形 Tree shape	w(蛋白质) Protein content/ (mg·g ⁻¹)	w(粗脂肪) Crude fat content/ (mg·g ⁻¹)	w(抗坏血酸) Ascorbic acid content/ (mg·g ⁻¹)	w(总糖) Total sugar content/ (mg·g ⁻¹)
自然圆头形 Natural round shape	165.09±1.64 b	660.92±0.20 b	2.40±0.02 c	17.18±0.01 a
开心形 Open centre shape	172.97±2.25 a	668.99±0.01 ab	2.72±0.20 b	16.64±0.01 ab
主干分层形 Trunk-layered shape	160.96±1.18 b	676.93±0.39 a	2.95±0.15 a	15.90±0.01 b
F	8.901*	5.761*	17.308**	4.754*

如表6所示, ‘鲁光’核桃种仁检测出17种氨基酸, 其中必需氨基酸7种, 含量(w, 后同)为44.62~48.36 mg·g⁻¹, 占氨基酸总量的28.26~29.32%。方差分析结果表明, 树形对种仁氨基酸总量有显著影响($p \leq 0.05$), 而对17种氨基酸的含量、必需氨基酸含量及其比例无显著影响($p > 0.05$)。‘鲁光’核桃种仁氨基酸总量为153.02~164.92 mg·g⁻¹, 其中谷氨酸含量最高, 为29.67~32.29 mg·g⁻¹, 其次为精氨酸(19.35~21.76 mg·g⁻¹)和天冬氨酸(16.99~17.58 mg·g⁻¹); 蛋氨酸含量最低, 为1.36~1.60 mg·g⁻¹。

2.5 主成分分析

如表7所示, 将反映核桃坚果产量和质量的14个指标转化为14个主成分, 进行主成分分析, 提取特征值大于1的主成分2个, 累计方差贡献率达96.991%, 综合反应核桃坚果产量和品质, 作为树形评价的综合指标。第1主成分的特征值为8.425, 方差贡献率为60.179%, 综合了单株平均坚果产量、树冠投影面积平均产量、平均单果质量、仁质量、壳厚、出仁率和果形指数7个指标的信息, 主要反映坚果产量和外在品质; 第2主成分的特征值为5.575, 方

表 6 不同树形核桃种仁氨基酸组成

Table 6 The amino acid compositions in kernels of the walnuts from trees with different canopy shapes (mg·g⁻¹)

氨基酸组成 Amino acid compositions		树形 Tree shape			F
		自然圆头形 Natural round shape	开心形 Open centre shape	主干分层形 Trunk-layered shape	
必需氨基酸 Essential amino acid	苏氨酸 Threonine (Thr)	6.27±0.24 a	6.12±0.56 a	6.75±0.38 a	0.417
	缬氨酸 Valine (Val)	6.98±0.17 a	7.55±1.02 a	7.87±0.69 a	1.022
	蛋氨酸 Methionine (Met)	1.36±0.05 a	1.60±0.14 a	1.56±0.32 a	0.359
	异亮氨酸 Isoleucine (Ile)	5.67±0.33 a	5.53±0.51 a	5.90±0.61 a	0.812
	亮氨酸 Leucine (Leu)	11.05±0.46 a	10.47±0.29 a	11.50±1.16 a	0.293
	苯丙氨酸 Phenylalanine (Phe)	8.73±0.50 a	9.07±0.68 a	9.92±0.75 a	1.127
	赖氨酸 Lysine (Lys)	4.56±0.29 a	4.44±0.70 a	4.86±0.58 a	2.101
非必需氨基酸 Non-essential amino acid	天冬氨酸 Aspartate (Asp)	17.58±1.08 a	16.99±0.72 a	17.06±2.26 a	1.665
	丝氨酸 Serine (Ser)	7.21±0.25 a	6.87±0.83 a	7.89±0.80 a	1.241
	谷氨酸 Glutamate (Glu)	31.75±2.16 a	29.67±3.27 a	32.29±2.74 a	0.659
	甘氨酸 Glycine (Gly)	7.68±0.34 a	7.42±0.61 a	8.00±0.72 a	0.447
	丙氨酸 Alanine (Ala)	5.04±0.29 a	4.67±0.17 a	4.63±0.33 a	0.056
	胱氨酸 Cysteine (Cys)	2.30±0.47 a	2.21±0.30 a	2.38±0.21 a	0.271
	酪氨酸 Tyrosine (Tyr)	7.89±0.54 a	8.02±0.53 a	9.11±0.63 a	1.323
	组氨酸 Histidine (His)	3.56±0.07 a	3.42±0.28 a	3.72±0.19 a	0.085
	精氨酸 Arginine (Arg)	19.54±2.90 a	19.35±1.42 a	21.76±2.27 a	1.263
	脯氨酸 Proline (Pro)	10.70±0.67 a	9.62±0.23 a	9.72±0.88 a	0.257
氨基酸含量总和 Total amino acid		157.87±9.22 b	153.02±6.56 b	164.92±7.19 a	5.916*
必需氨基酸含量 Total essential amino acid		44.62±7.47 a	44.78±3.02 a	48.36±4.27 a	1.2
必需氨基酸比例 Essential amino acid ratio/%		28.26±5.11 a	29.26±2.27 a	29.32±3.60 a	1.573

表 7 主成分的特征值、方差贡献率、累计方差贡献率及各成分因子的载荷矩阵

Table 7 Eigenvalue, variance contribution rate, cumulative variance contribution rate and component matrix of the first 2 principal components

指标或参数 Index or parameter	主成分 Principal components	
	1	2
单株平均坚果产量 Average yield per plant	-0.951	-0.317
树冠投影面积平均产量 Average yield per unit canopy projection area	-0.931	0.364
平均单果质量 Average single fruit weight	0.987	0.164
仁质量 Kernel weight	0.853	0.522
壳厚 Shell thickness	-0.983	0.181
出仁率 Kernel rate	0.939	-0.345
果型指数 Fruit shape index	-0.942	0.335
蛋白质含量 Protein content	-0.503	0.864
粗脂肪含量 Crude fat content	0.186	0.983
抗坏血酸含量 Ascorbic acid content	0.273	0.962
总糖含量 Total sugar content	-0.092	-0.996
氨基酸总含量 Total amino acid content	0.052	-0.999
必需氨基酸含量 Total essential amino acid	-0.299	0.954
必需氨基酸比例 Essential amino acid ratio	0.774	0.633
特征值 Eigenvalue	8.425	5.575
方差贡献率 Variance contribution rate/%	60.179	36.812
累计方差贡献率 Cumulative variance contribution rate/%	60.179	96.991

差贡献率为 36.812%，综合了蛋白质、粗脂肪、抗坏血酸、总糖、总氨基酸和必需氨基酸含量 6 个指标的信息，主要反映核桃种仁内在营养品质。

各个指标的原始数据标准化后，将各主成分相应的因子得分乘以相应方差的算术平方根，分别计算出不同树形核桃坚果产量和品质的综合评价得分值(Y)；各得分值与相应特征值的方差贡献率的乘积累加得出不同树形的综合评价指数(S)，以此评价不同树形的综合优劣。如表 8 所示，有利于产量形成的树形顺序依次为主干分层形、开心形和自然圆头形；有利于品质形成的树形顺序依次为开心形、主干分层形和自然圆头形；综合坚果产量和品质两方面因素，3 种树形的优劣顺序依次为主干分层形、开心形和自然圆头形。

3 讨 论

果树树形根据其形成方式分为自然生长树形和人工培育树形，自然生长树形由树体的遗传基因控制，未经人工整形修剪，其形成与维护简单，但由于长期的放任生长，致使果树树体枝叶量过大，影响叶片对太阳辐射能的截获与利用，降低了叶片光合能力，不利于树体和果实生长发育，导致果实产量和品

表8 不同树形结构的主成分值与综合评价指数值

Table 8 Values of principal components and synthetic analysis indexes of different tree shapes

树形 Tree shape	主成分值 Value of principal components, Y		综合评价指数 Synthetic analysis indexes, S	排名 Order
	Y_1	Y_2		
自然圆头形 Natural round shape	-2.550 830	-1.768 490	-2.239 300	3
开心形 Open centre shape	-0.607 400	2.681 218	0.702 162	2
主干分层形 Trunk-layered shape	3.158 232	-0.912 730	1.537 134	1

质降低,降低了果园经济效益^[1,8]。因此,根据不同果树、不同品种的生长生理特性、种植区域的立地条件及栽植方式,培养和维护合理的树形结构是保障果树连年优质高产的基础和关键。笔者以早实核桃良种‘鲁光’为试验材料,构建了主干分层形、开心形和自然圆头形3种树形,对比分析了3种树形的树形结构、坚果产量和品质特点,综合评价3种树形的优劣,筛选出适宜该品种的最佳树形,对该品种优质高产树形的培养和维护有重要的理论参考和技术指导意义。

不同果树种类或同一种类的不同品种在不同栽培条件下的适宜树形的冠层结构存在较大差异^[14-18]。树高、基径、骨干枝数和冠幅等冠层结构特征指标是影响核桃单株产量的重要因子,常用来评价核桃树体的生长势和生产潜力^[19-21]。本研究中5 a生‘鲁光’核桃3种树形间的树高($p \leq 0.01$)、基径($p \leq 0.05$)和骨干枝数($p \leq 0.001$)均存在显著差异,主干分层形的树高、基径和骨干枝数均明显高于开心形和自然圆头形;开心形的冠幅最大,其次是自然圆头形和主干分层形。与自然圆头形和开心形相比,主干分层形树体生长势较强,树冠相对较大,其骨干枝多且分层着生,树冠内通风透光性较好,树体生长发育旺盛,生产潜力强。研究结果与谭岷山等^[11]在10 a生‘华宁大砂壳’核桃及高山等^[22]、郭众仲^[10]和刘伟伟^[12]分别在4、6和10 a生‘温185号’核桃上的研究结果基本一致。

大量研究表明,果树不同树形因其枝类组成和空间分布特征的不同,影响树冠内的枝叶量及其空间分布,导致树冠微域环境的不同,影响树体对光照、水、肥的利用率,最终对树体生长发育、产量与品质的形成产生不同程度的影响^[23-25]。本研究中5 a生‘鲁光’核桃主干分层形的单株产量最高,其次是开心形和自然圆头形。研究结果与谭岷山等^[11]在10 a生‘华宁大砂壳’核桃上的研究结果一致。此外,笔者发现‘鲁光’核桃不同树形间的坚果品质存在显著

差异,主干分层形的单果质量、仁质量、种仁粗脂肪和抗坏血酸含量最高;开心形的坚果壳厚最小,出仁率和种仁蛋白质含量最高;自然圆头形的总糖和氨基酸含量最高。与开心形和自然圆头形相比,主干分层形的骨干枝和结果枝量较大,冠层结构呈立体状且分层明显,叶面积指数较大,树冠内通风透光性好,能够截获更多的光辐射能,增强叶片的光合能力,促进营养物质的积累,有利于产量的形成和品质的提升^[11,22]。

主成分分析是通过降维将多个指标简化为少量综合指标,用少数变量反映多个初始变量信息的一种统计分析方法^[26],目前已成为作物种质资源^[27-28]、抗逆性^[29-30]及果实品质^[31-32]综合评价的主要方法之一。笔者对反映核桃坚果产量和品质的14个指标进行主成分分析,提取了特征值大于1的2个主成分,反映初始变量的96.991%的信息;主成分1主要反映不同树形的单株产量和坚果外在品质特征,主成分2主要反映不同树形的核桃种仁内在品质(营养组成)特征;分别计算出反映不同树形核桃坚果产量和品质的主成分得分及不同树形的综合评价指数,对5 a生‘鲁光’核桃的3种树形进行了综合评价。结果表明,主干分层形有利于产量的形成,开心形有利于坚果品质的提升;3种树形的坚果产量和品质综合排名优劣顺序为主干分层形、开心形和自然圆头形。主成分分析结果与3种树形的生长与生产状况及坚果品质表现基本一致,表明主成分分析可以用来综合评价不同树形的优劣,提高了树形优劣评价的准确性和方便性,为不同树形优劣综合评价体系的构建提供了基础。

4 结 论

5 a生‘鲁光’核桃主干形树体骨干枝数较多,树冠较小,有利于产量的形成;开心形树体骨干枝数较少,树冠较大,有利于果实品质的提升;3种树形优劣的综合排名顺序为主干分层形>开心形>自然圆头形。

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