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‘纽荷尔’脐橙及其芽变品种‘龙回红’脐橙的比较研究

袁高鹏[1],淳长品[1],彭良志[1*],黄宗俊[2],黄同麒[2],
杨惠栋[1],付行政[1],凌丽俐[1],曹 立[1]

([1]西南大学柑桔研究所·国家柑桔工程技术研究中心,重庆 400712;[2]江西省南康俊萍果树示范场,江西南康 341400)

摘 要:【目的】探究芽变品种‘龙回红’脐橙生物学特性、叶绿素含量、光合作用参数、营养元素、果实品质和产量等与其母本‘纽荷尔’脐橙的差异。【方法】在同一果园相同栽培管理条件下,对2个品种的植株生长特性、绝对叶绿素含量、光合作用参数、叶片营养元素含量和果实品质进行了对比研究。【结果】和‘纽荷尔’脐橙相比,‘龙回红’脐橙干周、树体高度和冠径差异较小,但春梢、夏梢和秋梢叶片厚度、长度和宽度均差异较大;‘龙回红’春梢、夏梢和秋梢叶片绝对叶绿素含量分别比‘纽荷尔’脐橙高37.7%、27.6%和16.5%,差异达显著水平。其中‘龙回红’脐橙春梢叶片的净光合速率(P_n)、气孔导度(G_s)、胞间CO_2浓度(C_i)和蒸腾速率(T_r)分别比‘纽荷尔’脐橙高33.4%、55.6%、20.9%和33.1%,大多数参数间的差异达显著水平。‘龙回红’脐橙叶片营养元素除P和Zn的含量显著低于‘纽荷尔’脐橙外,其他元素的含量均显著高于‘纽荷尔’脐橙;果实单果质量、纵径、横径、果形指数、果皮厚度、色差a/b值和固酸比显著高于‘纽荷尔’脐橙,而可滴定酸含量显著低于‘纽荷尔’脐橙。‘龙回红’脐橙单产比‘纽荷尔’脐橙高20%左右,且大多数果实品质指标优于‘纽荷尔’脐橙,特别是在果皮颜色和果型方面,优质果率明显提高。【结论】‘龙回红’脐橙是‘纽荷尔’脐橙的优良变异品种,具有很好的推广价值。

关键词:‘龙回红’脐橙;‘纽荷尔’脐橙;特性;光合参数;营养元素;品质;产量

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A study on the difference of ‘Newhall’ navel orange and its sport ‘Longhuihong’ navel orange

YUAN Gaopeng[1], CHUN Changpin[1], PENG Liangzhi[1*], HUANG Zongjun[2], HUANG Tongqi[2], YANG Huidong[1], FU Xingzheng[1], LING Lili[1], CAO Li[1]

([1]Citrus Research Institute, SouthwestUniversity · National Citrus Engineering Research Center, Chongqing 400712, China; [2]Nankang Junping Fruit Demonstration Farm of Jiangxi Province, Nankang 341400, Jiangxi, China)

Abstract:【Objective】Selective breeding of bud mutation is one of the most important methods for citrus new variety selection. Navel orange is a variety derived from bud mutation of sweet orange (*Citrus sinensis* Osbeck) in Brazil. At present, the southern region of Jiangxi province is the biggest navel orange production area in China, and ‘Newhall’ navel orange (*Citrus sineses* Osbeck, abbr. NH) covers more than 80% of the total plantation of navel orange. A mutant tree named ‘Longhuihong’ (*Citrus sineses* Osbeck, abbr. LHH) was found at the Ganliang navel orange orchard of southern region of Jiangxi province in the year 2000 followed a freezing injury (−6 to−9 ℃) in December 1999. LHH has many features diifferent from those of NH like leaf curvature, leaf vein herniation, cold-resistance, freezing-tolerance, less summer shoots and higher and more stable yield. Regional trials of southern region of Jiangxi province and Beibei district of Chongqing showed that LHH had better adaptability compared with NH. This study aimed to find the reasons of the difference between the NH and the LHH.【Methods】The growing characteristics of

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作者简介:袁高鹏,男,在读硕士研究生,主要从事果树栽培与生理研究。Tel:023-68249725,E-mail:770736470@qq.com

*通信作者 Author for correspondence. Tel:023-68247009,E-mail:penglz809@163.com

trees, the chlorophyll content, the characteristic of photosynthetic gas exchange of leaves, nutrient element content of leaves, fruit quality and yield were investigated for both NH and LHH grown in the same orchard. Five trees were randomly selected for measuring the perimeter of height of tree, crown diameter, trunk diameter, leaf length and width. Chlorophyll was extracted by 95% ethanol for twenty-four hours, and then the absorbency of chlorophyll a and chlorophyll b were detected under 665 nm and 649 nm by spectrometer. The photosynthesis (P_n), stomatal conductance (G_s), intercellular CO_2 concentration (C_i) and transpiration (T_r) of the leaves of spring shoots, summer shoots and autumn shoots were measured by portable LI-6400 photosynthesis measurement system. The internal and external qualities of fruits collected from the different directions of the tree were analyzed. Finally, nitrogen (N), phosphorus (P), kalium (K), Calcium (Ca), Magnesium (Mg), ferrum (Fe), ZIncum (Zn), manganum (Mn), copper (Cu) and borium (B) in the leaves of spring shoots were detected.【Results】The differences of trunk circumference, crown height and diameter of the trees between NH and LHH were not obvious. The thickness, length and width of the leaves of LHH in different seasons were significantly larger than those of NH. The chlorophyll contents of the leaves of LHH (2.63, 2.77 and 2.75 mg·g^{-1}) were significantly higher than those of NH (1.91, 2.17 and 2.36 mg·g^{-1}) in different seasons, respectively. The photosynthesis, stomatal conductance, intercellular CO_2 concentration and transpiration of the spring shoot leaves of LHH were significantly higher than those of NH, respectively. The nutrient element contents of LHH leaves were significantly higher than those of NH except for phosphorus and zinc. And the average weight, peel thickness, diameter, shape index fruits, the *a*/*b* value of chromatic aberration, and the ratio of total soluble solid to titration acid of LHH were significantly higher than those of NH, whereas the titration acid of LHH (0.54%) was significantly lower than that of NH (0.62%). The yield of LHH (61.3 kg) was higher than that of NH (51.0 kg), and most of the quality indexes of LHH fruits were better than those of NH, especially the skin color and fruit size.【Conclusion】The yield and quality of fruits of LHH are significantly higher than those of NH, LHH should be extended widely in the citrus area.

Key words: ‘Longhuihong’ navel orange; ‘Newhall’ navel orange; Characteristics; Photosynthesis parameters; Nutrient element; Fruit quality; Yield

芽变选种是世界柑橘选育种的主要方式之一，脐橙（*Citrus sinensis* Osbeck）最早在巴西由甜橙芽变产生，后传入美国并命名为‘华盛顿’脐橙（*Citrus sineses* Osbeck ‘Washington’），现大部分主栽脐橙品种均直接或间接来源于‘华盛顿’脐橙的芽变[1]。澳大利亚通过芽变选种获得了一些比‘华盛顿’脐橙晚熟的品种，如‘秋金’‘夏金’以及‘仓库’等；西班牙选育出了晚熟芽变品种‘里卡蕾特’；我国选育出了‘奉节72-1’‘丰脐’‘眉山9号’‘罗脐35号’‘奉晚’‘长红’‘纽荷尔’新系、‘良丰’‘新世纪’以及‘4号脐橙’等[2-3]。‘纽荷尔’脐橙（*Citrus sineses* Osbeck ‘Newhall’）原产美国，由‘华盛顿’脐橙芽变而成，1978年引进中国，由于外观美，成熟期早，品质优良，逐渐发展为主栽品种之一[4-5]。赣南是我国最大的脐橙产区，80%以上均为‘纽荷尔’脐橙[6]。

1999年12月赣南脐橙遭遇-6~-9 ℃冻害，翌年在南康区赣良‘纽荷尔’脐橙园发现1个变异株，叶片反卷，叶脉突出，变异特征十分明显（图1），表现抗寒耐冻。2001年从变异单株上采穗高接在温州蜜柑上，第二年开始结果，连续观察3 a，性状稳定；2004年从高接树上采集接穗嫁接在枳砧苗上，2005年将该批嫁接苗与同龄的枳砧‘纽荷尔’脐橙苗采用株间交替定植在南康市龙回镇岐岭村果园进行比较试验；2006—2012年在江西省南康区、信丰县、安远县、东乡县和重庆市北碚区进行栽培试验，结果表明，变异株系适应性强，多数性状均优于原有纽荷尔’脐橙，并于2012年12月通过江西省农作物品种审定委员会认定，定名为‘龙回红’[7]。笔者通过对‘龙回红’脐橙和其母本品种‘纽荷尔’脐橙的生物学性状、叶绿素含量、光合作用参数、叶片营养元素含量以及果实产量和品质进行对比研究，为探明2者之间的差异和‘龙回红’优良变异原因提供理论依据。

图1 ‘纽荷尔’(A)和‘龙回红’(B)脐橙叶片

Fig. 1 Leaves of ‘Newhall’(A) and ‘Longhuihong’(B) navel orange

1 材料和方法

1.1 材料

供试品种为‘龙回红’脐橙(*Citrus sineses* Osbeck‘Longhuihong’，简称LHH)和‘纽荷尔’脐橙(*Citrus sineses* Osbeck‘Newhall’，简称NH)，砧木均为枳[*Poncirustrifollata*(L.)Raf]，于2005年定植在赣州市南康区龙回镇岐岭村(试验园)，2个品种株间交替定植，采用相同的田间栽培管理方式。

1.2 植株生长量调查

2015年8月在试验园随机选取5株树进行树体生长量调查，单株重复，分别测量植株高度、冠径、干周、叶片长度和宽度等指标。

1.3 叶绿素含量的测定

于5月、7月和9月在测量生长量的植株上，分别采当年生春梢、夏梢和秋梢顶部从上往下数第3片叶，在树冠外围中部南面采8枚叶片(南部中部叶片受光充足，长势好)。采用李合生[8]的方法并有所改进：叶片擦净后去除主脉和叶片两端，然后剪碎、混匀，称0.1 g左右于15 mL塑料管中，用96%(φ)的乙醇加至15 mL刻度线处，3次重复。将处理好的样品置于黑暗环境中并经常摇动，直至叶片完全变白，分别在665 nm和649 nm处比色，记录吸光度值(A)。根据测量得到的665 nm和649 nm下的吸光度值代入公式(1)，计算出叶绿素的含量。

$$C_T = 6.63\times A_{665}+18.08\times A_{649} \quad (1)$$

式中，A665和A649分别是叶绿素溶液在665 nm和649 nm处的吸光度值，C_T是叶绿素总量的质量浓度(mg·L^{-1})。通过公式(2)计算后，换算为单位质量的叶绿素质量分数(mg·g^{-1})。

$$叶绿素总量=(C_T\times V)/(W\times 1\ 000) \quad (2)$$

式中，V表示提取液总体积(mL)，W代表叶片鲜质量(g)。

1.4 光合作用气体交换参数的测定

分别于5月、7月和9月在测量生长量的植株上，利用便携式LI-6400光合测定系统(LI-COR，USA)对植株春梢、夏梢和秋梢叶片进行光合测定，选取每株树冠南部中上部健康叶片10枚。测定800 μmol·m^{-2}·s^{-1}下的净光合速率(P_n，μmol·m^{-2}·s^{-1})、气孔导度(G_s，mmol·m^{-2}·s^{-1})、胞间CO_2浓度(C_i，μL·L^{-1})和蒸腾速率(T_r，mmol·m^{-2}·s^{-1})。测量过程中CO_2浓度的值控制为大气CO_2浓度值(约380±5 μmol·mol^{-1})，叶片温度控制在25 ℃，空气流速为500 mL·min^{-1}。

1.5 果品的测定

2015年12月果实成熟期统计其个数和产量，果实成熟时从5株树采集10个果实混为一个样品，每个品种3次重复，分析其品质。果实颜色采用L^*、a^*、b^*色度空间法进行描述，在每个果实赤道的5个部位，用日本美能达CR-10色差仪测定，其中L^*值表示黑白亮度，正值表示偏白，负值表示偏暗；a^*值表示红绿色差，正值表示偏红，负值表示偏绿；b^*值表示黄蓝色差，正值表示偏黄，负值表示偏蓝[9]；a/b值表示果实外观颜色，正值、负值和0分别表示果面为橙(红)色、黄色和绿色[10]。果汁可溶性固物(TSS)含量用PAL-1手持折光仪(日本ATAGO公司产)测定，可滴定酸(TA)含量用NaOH中和滴定法测定，维生素C含量用2，6-二氯靛酚滴定法测定[11]。单果质量用电子天平称量，果实纵横径用游标卡尺测量。

1.6 叶片采集和营养元素测定

2015年12月在进行生长量调查的植株上，采当年生春梢营养枝顶部从上往下数第3枚叶片，在每株树冠外围中上部东西南北4个方位采25~30枚

叶片，3株树共100~120枚叶片混为一个样品。所有样品装入有透气孔的干净塑料袋内，装入有冰袋的箱子中，迅速带回实验室，按凌丽俐等[12]的方法进行清洗和烘干等处理。营养元素氮（N）、磷（P）、钾（K）、钙（Ca）、镁（Mg）、铁（Fe）、锰（Mn）、锌（Zn）、铜（Cu）、硼（B）的含量参照凌丽俐[12]的方法进行测定。叶片营养元素营养诊断评价指标见表1，参照《DB36/T 625—2011脐橙叶片营养诊断标准》。

表1　赣南脐橙叶片营养诊断分级标准

Table 1 The classification of nutrient diagnosis of navel orange leaves in southern Jiangxi province of China

营养元素 Element	缺乏 Deficient	低量 Low	适量 Appropriate	高量 High	过量 Excess
ω(N)/%	≤2.50	> 2.50~2.70	> 2.70~3.00	> 3.00~3.20	>3.20
ω(P)/%	≤0.10	> 0.10~0.12	> 0.12~0.16	> 0.16~0.30	>0.30
ω(K)/%	≤0.70	> 0.70~1.20	> 1.20~1.70	> 1.70~2.00	>2.00
ω(Ca)/%	≤1.60	> 1.60~3.00	> 3.00~5.50	> 5.50~7.00	>7.00
ω(Mg)/%	≤0.20	> 0.20~0.25	> 0.25~0.50	> 0.50~0.70	>0.70
ω(Mn)/(mg·kg^{-1})	≤16.00	> 16.00~25.00	> 25.00~100.00	> 100.00~300.00	>300.00
ω(Zn)/(mg·kg^{-1})	≤16.00	> 16.00~20.00	> 20.00~100.00	> 100.00~200.00	>200.00
ω(Cu)/(mg·kg^{-1})	≤3.00	> 3.00~5.00	> 5.00~15.00	> 15.00~20.00	>20.00
ω(Fe)/(mg·kg^{-1})	≤35.00	> 35.00~60.00	> 60.00~120.00	> 120.00~200.00	>200.00
ω(B)/(mg·kg^{-1})	≤20.00	> 20.00~35.00	> 35.00~100.00	> 100.00~200.00	>200.00

2　结果与分析

2.1　‘龙回红’和‘纽荷尔’脐橙树体生物学性状差异

总体来讲，变异品种‘龙回红’与‘纽荷尔’相比，树体较小。其中干周差异不大，均为29.20 cm，树体高度为246.00 cm，比‘纽荷尔’低14.00 cm，南北向冠径均为200.00 cm，但东西向冠径‘龙回红’仅为288.00 cm，比‘纽荷尔’低57.00 cm。经方差分析表明，干周、树体高度和南北冠径差异不显著，而东西冠径有显著差异（表2）。

表2　‘龙回红’和‘纽荷尔’脐橙植株生物学特性

Table 2 Biological characteristics comparison of ‘Longhuihong’ and ‘Newhall’ navel orange

品种 Cultivar	干周 Perimeter/cm	树高 Height/cm	冠径 Crown/cm 南北向 North and South	冠径 Crown/cm 东西向 East and West
NH	29.20±1.92 a	260.00±32.40 a	200.00±0.00 a	345.60±24.63 a
LHH	29.20±5.26 a	246.00±21.62 a	200.00±0.00 a	288.00±39.15 b

注：小写字母表示在0.05水平差异显著。下同。

Note: The different small letters within the same column means significant difference at $P < 0.05$. The same below.

从表3可以看出，‘龙回红’的春梢、夏梢以及秋梢的叶片不论是在厚度、长度还是宽度，都要比‘纽荷尔’的大。其中，以‘龙回红’春梢叶片厚度、长度和宽度最为明显，分别比‘纽荷尔’叶片厚0.07 mm、长1.17 cm和宽4.72 cm，经方差分析表明叶片厚度、长度和宽度均有显著差异，但夏梢叶和秋梢叶的叶片厚度、长度和宽度差异不显著。

表3　‘龙回红’和‘纽荷尔’脐橙叶片指标

Table 3 Leaf indexes of ‘Longhuihong’ and ‘Newhall’ navel orange

品种 Cultivar	叶片厚度 Leaf thickness/mm			叶片长度 Leaf length/cm			叶片宽度 Leaf width/cm		
	春梢 Spring shoot	夏梢 Summer shoot	秋梢 Autumn shoot	春梢 Spring shoot	夏梢 Summer shoot	秋梢 Autumn shoot	春梢 Spring shoot	夏梢 Summer shoot	秋梢 Autumn shoot
NH	0.25±0.04 b	0.32±0.03 a	0.29±0.02 a	7.75±0.89 b	10.28±1.34 a	9.27±1.10 a	3.74±0.58 b	5.53±0.80 a	5.00±0.60 a
LHH	0.32±0.01 a	0.36±0.03 a	0.30±0.04 a	8.92±0.91 a	10.64±2.27 a	9.58±0.92 a	4.72±0.46 a	5.74±0.67 a	5.06±0.48 a

2.2　‘龙回红’和‘纽荷尔’脐橙叶绿素含量和光合作用参数差异

由表4可知，与‘纽荷尔’相比，‘龙回红’春梢、夏梢和秋梢叶片的绝对叶绿素含量均最大，分别比‘纽荷尔’的大37.7%、27.6%和16.5%。经方差分析表明，2个品种春梢、夏梢和秋梢叶片的绝对叶绿素差异均显著。

与‘纽荷尔’的净光合速率、气孔导度、胞间CO_2浓度、蒸腾速率等光合作用气体交换参数相比，‘龙回红’春梢、夏梢和秋梢叶的参数较大，以春梢为例，

表4　‘龙回红’和‘纽荷尔’脐橙绝对叶绿素含量

Table 4 The chlorophyll content of ‘Longhuihong’ and ‘Newhall’ navel orange

ω/(mg·g^{-1})

品种 Cultivar	春梢 Spring shoot	夏梢 Summer shoot	秋梢 Autumn shoot
NH	1.91±0.01 b	2.17±0.09 b	2.36±0.14 b
LHH	2.63±0.03 a	2.77±0.10 a	2.75±0.03 a

分别比‘纽荷尔’的大33.4%、55.6%、20.9%和33.1%。经方差分析表明,2个品种的大多数气体交换参数间的差异均达显著水平(图2)。

2.3 ‘纽荷尔’和‘龙回红’脐橙春梢叶片营养元素含量的比较

总体来讲,2个品种多数营养元素含量均在适

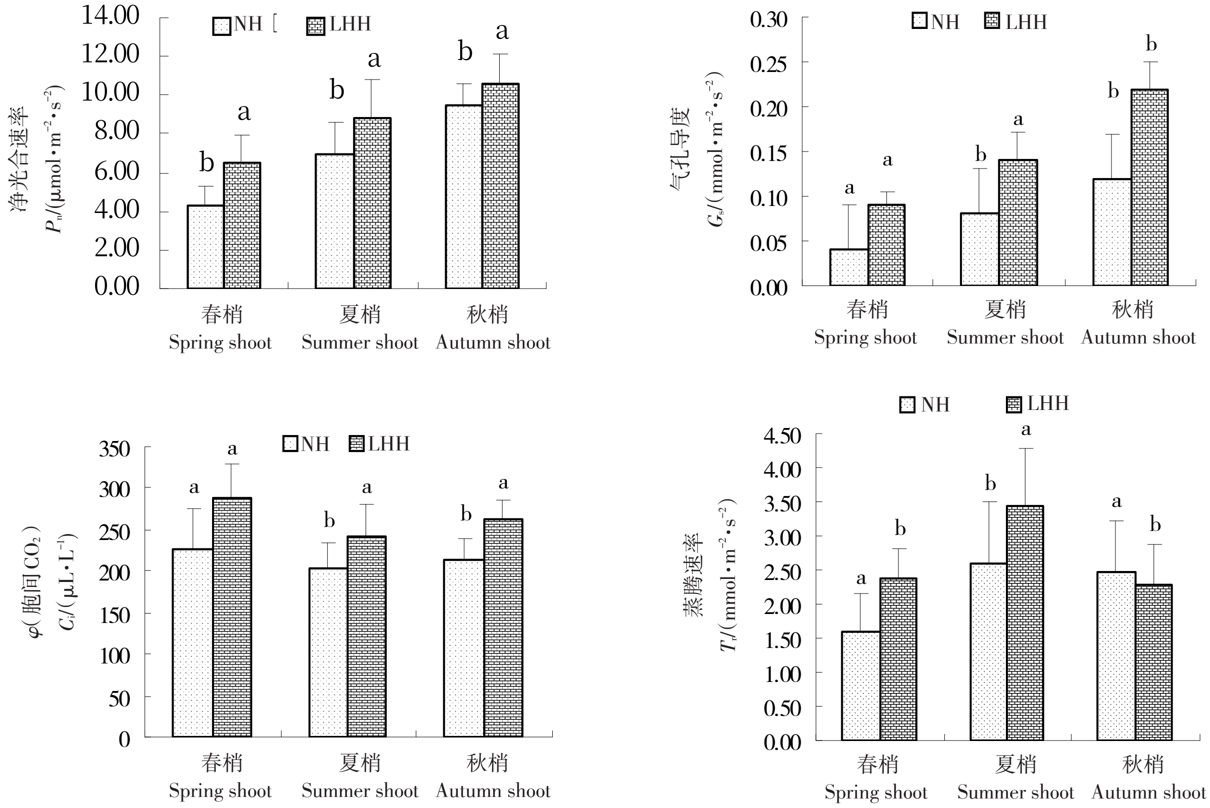

图2　‘龙回红’和‘纽荷尔’脐橙光合作用特性

Fig. 2 Photosyntheticcharacteristicsof of ‘Longhuihong’ and ‘Newhall’ navel orange

宜范围内,Fe含量处于高量范围,而Mg、Ca和Zn含量处于低量范围。除P和Zn外,‘龙回红’叶片营养元素含量高于‘纽荷尔’(表1),经方差分析表明,‘龙回红’叶片N、Ca、Fe、Cu、Mg、B含量显著高于‘纽荷尔’,K含量差异不显著,但P和Zn含量显著低于‘纽荷尔’脐橙(表5)。

表5　‘龙回红’和‘纽荷尔’脐橙叶片营养元素含量

Table 5 Nutrient element contentin leaves of Longhuihong’ and ‘Newhall’ navel orange

品种 Cultivar	ω(N)/%	ω(P)/%	ω(K)/%	ω(Ca)/%	ω(Mg)/%	ω(Fe)/(mg·kg^{-1})	ω(Zn)/(mg·kg^{-1})	ω(Cu)/(mg·kg^{-1})	ω(Mn)/(mg·kg^{-1})	ω(B)/(mg·kg^{-1})
NH	2.91±0.01 b	0.17±0.00 a	1.68±0.26 a	2.03±0.02 b	0.13±0.00 b	122.82±7.38 b	19.96±0.57 a	8.00±0.45 b	30.10±0.91 b	63.34±2.14 b
LHH	3.00±0.01 a	0.14±0.01 b	1.69±0.02 a	2.41±0.03 a	0.14±0.00 a	148.05±7.01 a	18.43±0.40 b	11.46±0.45 a	43.45±2.42 a	82.60±1.55 a

2.4 ‘龙回红’和‘纽荷尔’脐橙果实产量和品质差异

由图3可知,2个品种的单株果实个数无显著差异,‘纽荷尔’平均单株果实为224个,比‘龙回红’的多12个(5.6%);产量有显著差异,‘龙回红’单株产量为61.3 kg,比‘纽荷尔’的高10.3 kg(20.2%)。

从表6可知,‘龙回红’果实L^*值略低于‘纽荷尔’脐橙,a^*值、b^*值和a/b均高于与‘纽荷尔’脐橙,但2者差异不显著。

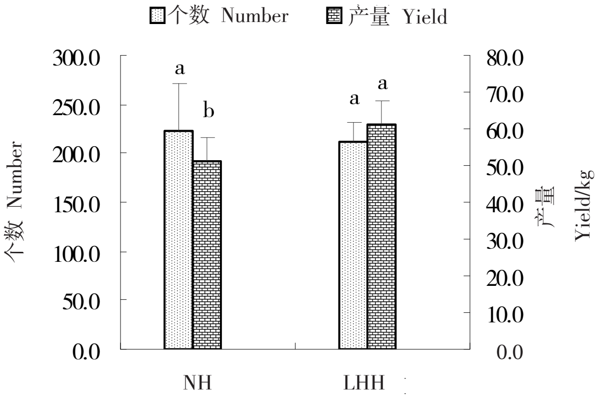

图3 ‘龙回红’和‘纽荷尔’脐橙产量的比较
Fig. 3 Yield comparison of ‘Longhuihong’ and ‘Newhall’ navel orange

表6 ‘龙回红’和‘纽荷尔’脐橙果实的色泽
Table 6 Fruit color comparison of ‘Longhuihong’ and ‘Newhall’ navel orange

品种 Cultivar	色差 Chromatic aberration			
	L^*	a^*	b^*	a/b
NH	65.10±0.70 a	24.35±2.77 a	63.87±1.62 a	0.38±0.04 b
LHH	63.82±1.01 a	27.97±0.27 a	63.53±0.90 a	0.44±0.01 a

‘龙回红’和‘纽荷尔’脐橙果形指数分别为1.08和1.04，均为椭圆形；‘龙回红’的单果质量、果皮质量、果皮厚度和可食率分别为279.72 g、84.63 g、6.26 mm和69.81%，分别比‘纽荷尔’脐橙的高37.5%，35.9%，19.0%和0.65%（表7）。方差分析表明，2者之间除可食率无显著差异外，其余指标均呈显著差异。

表7 ‘龙回红’和‘纽荷尔’脐橙果实的外观品质
Table 7 Fruit appearance quality comparison of ‘Longhuihong’ and ‘Newhall’ navel orange

品种 Cultivar	单果质量 Single fruit mass/g	果皮质量 Peel mass/g	果皮厚度 Peel thickness/mm	纵径 Vertical diameter/cm	横径 Transverse diameter/cm	果形指数 Fruit shape index	可食率 Edible rate/%
NH	203.46±8.06 b	62.29±0.76 b	5.26±0.22 b	7.70±0.07 b	7.43±0.10 b	1.04±0.01 b	69.36±1.16 a
LHH	279.72±14.48 a	84.63±10.41 a	6.26±0.39 a	8.90±0.23 a	8.23±0.07 a	1.08±0.02 a	69.81±2.44 a

‘龙回红’的可溶性固形物、可滴定酸和维生素C含量均低于‘纽荷尔’脐橙，但固酸比高于‘纽荷尔’。‘龙回红’的可溶性固形物、可滴定酸和维生素C含量分别为11.5%、0.54%和46.74 mg·100 mL^{-1}，分别为‘纽荷尔’的95.83%、87.10%和95.98%（表8）。经方差分析表明，可滴定酸含量和固酸比2者之间有显著差异，而可溶性固形物含量和维生素C含量差异不显著。

表8 ‘纽荷尔’和‘龙回红’脐橙果实的内在品质
Table 8 Fruit intrinsic quality comparison of ‘Longhuihong’ and ‘Newhall’ navel orange

品种 Cultivar	ω(可溶性固形物) TSS content/%	ω(可滴定酸) TA content/%	ρ(维生素C) Vitamin C content/ (mg·100 mL^{-1})	固酸比 TSS/TA
NH	12.0±0.44 a	0.62±0.02 a	48.70±2.71 a	19.47±0.69 b
LHH	11.5±0.15 a	0.54±0.02 b	46.74±1.38 a	21.37±0.64 a

3 讨 论

芽变在植物界普遍存在，属体细胞突变的一种[13]。柑橘枝条受到外界环境胁迫时容易使遗传物质发生改变，自然变异频繁，而脐橙又是柑橘中芽变发生频率很高的品种[14-16]。芽变发生后通常会与原品种之间形成较多的差异，在树势强弱、果实品质等形态方面和生理方面都有体现[17]。本试验‘龙回红’是在遭遇-6~-9 ℃冻害后选育出的脐橙新品种[7]。变异品种‘龙回红’在叶片上具有明显的特征，叶片反卷，叶脉突出。本研究结果也显示，‘龙回红’与‘纽荷尔’脐橙相比，叶片变大、变厚，颜色深绿。叶片营养元素含量多数指标‘龙回红’均高于‘纽荷尔’脐橙。

变异株系‘龙回红’与‘纽荷尔’果型也产生了较大差异[18-19]，‘龙回红’表现为果大，果实均匀，单产比‘纽荷尔’高20%以上。其原因可能与‘龙回红’的树体长势和营养有关，由于‘龙回红’夏梢抽得较少，树冠高度低于‘纽荷尔’。但赣南脐橙产区叶片最易缺乏的Mg、Ca和B含量却显著高于‘纽荷尔’[20-21]，且N含量也显著高于‘纽荷尔’（处于高量范围）。前人研究表明，植物的叶面积与净光合速率呈正相关[22]，叶片N含量和光饱和速率呈显著正相关[23]，适度提高叶片N水平能促进脐橙光合作用[24]，N素缺乏会导致柑橘光和叶面积显著下降，降低光合速率[25]；本试验研究结果也表明，‘龙回红’叶片的N素含量比‘纽荷尔’高3%，差异达显著水平，且叶片更大更厚，这在一定程度上增加了输送到果实的光合产物的量；也有研究结果表明，叶绿素含量与净光合速率呈正相关[26]，光合速率与作物产量也呈正相关[27-28]，本试验也有类似结果，‘龙回红’春梢的绝对叶绿素含量

和净光合速率分别比‘纽荷尔’高37.7%和33.4%,因而‘龙回红’果实更大,产量更高。

果实品质由外观和内质构成。外观品质主要由果皮光滑度和颜色决定[10],内在品质主要取决于果实可溶性固形物和酸含量,以及2者之间的比例。本研究表明,‘龙回红’果面较‘纽荷尔’粗糙,但果皮*a*/*b*值高,果面更红,而可溶性固形物和酸含量均较低,这可能与‘龙回红’树体营养有关。研究显示,‘龙回红’春梢、夏梢以及秋梢叶片的厚度、长度和宽度均比‘纽荷尔’大,N含量较高,可溶性固形物含量较低。但‘龙回红’的树体高度较‘纽荷尔’小,抽发夏梢较少,通风透光更好,光合产物积累较多,故‘龙回红’果面更红,酸含量更低[29-30]。

4 结 论

‘龙回红’脐橙单产比‘纽荷尔’脐橙高20%左右,且前者的树冠较小,叶片较大、颜色深绿,光合作用强,果实外观颜色和固酸比均显著优于‘纽荷尔’脐橙,果实单果质量较大,优质果率提高。因此,‘龙回红’脐橙是‘纽荷尔’脐橙的优良变异品种,具有很好的推广价值。

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