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花粉直感对杨梅果实品质及不同蔗糖代谢酶活性的影响

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摘 要:【**目的**】探究杨梅的花粉直感效应。【**方法**】以'东魁''荸荠种'为母本,选用黄岩、舟山的雄株作为花粉源进行人工授粉,并以自然授粉为对照,观察其对当年果实品质的影响,并且测定2个不同发育时期的杨梅果实蔗糖磷酸合成酶(SPS)和蔗糖合成酶(SS)的活性。【**结果**】以'荸荠种'为母本的授粉组合中,单果质量比对照低6.5%~18.6%,果实纵径比对照低4.62%~9.16%,亮度比对照低5.1%~16.4%,总糖含量比对照低14.17%~16.67%,维生素C含量比对照低6.73%~10.3%,可滴定酸含量比对照高17.1%~20.3%。以'东魁'为母本授粉组合中,与自然授粉相比,果实质量、果实横纵经、可食率等方面差异不显著,色差比对照低8.1%~9.3%,'东魁'×黄岩花粉可溶性固形物含量、总糖含量和可滴定酸含量分别比对照高31.95%、3.06%、25.39%。杨梅人工授粉不同雌雄组合表现出花粉直感现象。SPS活性在5月19日和6月19日最高的分别是'荸荠种'×舟山花粉和'东魁'×舟山花粉。SS活性在5月19日和6月19日最高的分别是'荸荠种'×黄岩花粉和'东魁'×黄岩花粉。【**结论**】'荸荠种'×舟山花粉、'东魁'×黄岩花粉为最佳组合,'荸荠种'和'东魁'都与黄岩和舟山的杨梅花粉有亲和力。从容易取材及品质改良两方面综合考虑,黄岩和舟山的杨梅雄株在品质改良中有着一定的优势,舟山的杨梅花粉为'荸荠种'授粉对品质的改良更好,黄岩的杨梅花粉为'东魁'授粉对品质的改良更佳。

关键词:杨梅;花粉直感;果实品质;蔗糖代谢酶
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Effect of xenia on fruit quality and sucrose metabolism enzyme activity in red bayberry

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Abstract:【Objective】Xenia is a phenomenon that pollen source influences fruit traits, including color, size, soluble solids, seed size and so on. In this study, we evaluated different pollination combinations in improving fruit quality.【Methods】Pollens from different parent cultivars were collected from Huangyan and Zhoushan counties in Zhejiang province before the male flowers opened and stored under −20 ℃. Female flowers were selected from 15-year-old trees of *Myrica rubra* 'Biqizhong' and 'Dongkui' in Haining county, Zhejiang province. The pollination combinations included natural pollination of 'Biqizhong' (CK1), 'Biqizhong' × Huangyan(BH), 'Biqizhong' × Zhoushan (BZ), natural pollination of 'Dongkui' (CK2), 'Dongkui' × Huangyan (DH), 'Dongkui' × Zhoushan (DZ). The fruit weight, size, color, hardness, TSS, total sugars, titratable acids, and vitamin C were tested. Fruit weight was measured using a balance, size with a caliper, color parameters detected with a spectral photometer (HITACHI307), hardness using a texture analyzer and TSS with a saccharimeter. The contents of total sugars, titratable acids, and vitamin C were determined with alkaline acid solution method, sodium hydroxide solution method, and 2, 6-dichlorine indophenol solution, respectively. Sucrose phosphate synthase (SPS) and sucrose synthase (SS) catalyze the synthesis of sucrose in plants. The activities of both enzymes on May 19 and Jun 19 were deter-

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mined to understand sucrose synthesis in bayberry trees. Data collected were analyzed with SPSS 17.0 to do analysis of variation and multiple comparison for significance of difference. 【Results】The fruit weight, size, appearance, hardness and color had significant differences among different pollination combinations. The fruit weight in BH and BZ was lower than in CK1 by 6.5% and 18.6%, respectively. BZ had the heaviest fruit mass (7.9 g) among the artificial pollination combinations. The fruit transverse and longitudinal diameters in BH were 4.3% and 7.6% smaller than those in CK1, respectively, and those in BZ were shorter by 4.62% and 9.16%, respectively. However, fruit weight, and transverse and longitudinal diameters in pollination combinations with 'Dongkui' had no significant difference compared with CK2. The flesh recovery had no significant difference among all the pollination combinations with both female parent cultivars. The hardness of BZ and BH fruit was significantly higher than that of CK1 by 7.81% and 18.47%, respectively. The fruit hardness in DH and DZ was also higher than that in CK2. The fruit brightness in BH and BZ was significantly lower than that in CK1 by 5.1% and 16.4%, respectively, and the yellow index in BH and BZ was 6.43% and 20.30% lower, respectively. The red index of BZ fruit was the highest among the six combinations, being 4.8% higher than CK1. The fruit brightness in DH was significantly and 5.75% lower than that in CK2, but that in DZ significantly and 5.87% higher. However, the yellow index of 'Dongkui' fruit produced from different pollen sources was significantly different with that of CK2 fruit, but red index had no difference. The content of soluble solids was different in different pollination combinations. Soluble solids in BH and DZ fruits were 0.17% and 3.24% lower than the controls, respectively, but those of BZ and DH fruits were significantly higher than that of the control by 7.14% and 31.95%, respectively. The total soluble sugars in all the cross pollination combinations were lower than in the controls, but the content titratable acids was higher. The vitamin C in the fruits generated from cross pollination combinations with 'Biqizhong' as the female parent was lower than that in CK1, but that in the fruits from the pollination combinations with 'Dongkui' was higher than that in CK2. The contents of soluble sugars in BH and BZ were 14.17% and 16.67% lower than that in CK1, but DH had a significantly (3.06%) higher content of soluble sugars than CK2. The titratable acids in BH and BZ fruit were 20.30% and 16.99% higher than that in CK1, respectively. In addition, the titratable acids in DH dramatically increased by 25.39% compared with CK2, but those in DZ decreased by 2.73%. The contents of vitamin C in BH and BZ were 10.3% and 6.73% lower than those in CK1, respectively. However, the content of vitamin C in DH and DZ was higher than that in CK2, with that in DZ being 8.63% higher than that in CK2. The SPS activity in the six pollination combinations on May 19 and June 19 were measured. The results indicated that SPS activities in all pollination combinations on June 19 were higher than those on May 19. The enzyme activity in BZ and DZ increased greatly. SPS activity in BH and BZ on May 19 increased by 82.55% and 87.06% compared with CK1, respectively, and that on June 19 increased by 28.8% and 37.08%, respectively. SPS activity in BZ was 47.7 $mg \cdot g^{-1}$ (expressd by the sucrose content) on May 19 and 57.75 $mg \cdot g^{-1}$ on June 19. In DH and DZ, the enzyme activity was increased by 28.20% and 35.33% respectively on May 19, and by 31.62% and 44.77% respectively on June 19, compared with CK2. SPS activity in DZ was 41.75 $mg \cdot g^{-1}$ and 58.24 $mg \cdot g^{-1}$ on May 19 and June 19, respectively, which was higher than that in DH. The SS activity in BH and BZ was higher than in CK1, being 99.81% and 115.89% higher on May 19 and 76.49% and 105.98% higher on June 19, respectively. The enzyme activity in BH was 77.71 $mg \cdot g^{-1}$ on May 19 and 66.86 $mg \cdot g^{-1}$ on June 19, which was the highest among all the pollination combinations. The SS activity in DH was 52.14 $mg \cdot g^{-1}$ and 66.64 $mg \cdot g^{-1}$ on May 19 and June 19, respectively, which was higher than that in CK2. However, the enzyme activity in DZ on May19 was lower than that in CK2.【Conclusion】‘Biqizhong’ and ‘Dongkui’ displayed a high pollination compatibility with the cultivars in Huangyan county and Zhoushan county. The fruit weight, transverse and longitudinal diameters and SS activity in DH were the highest among the six pollination combinations. However, the fruit hardness, TSS and SPS activity in BZ were higher compared with those of the other treatments. It was clear that the quality of DH and BZ fruit had improved greatly and that pollen source significantly influenced the quality of fruit. The results provided information for pollination combination selection to improve fruit quality via artificial pollination. The results showed that the male plants in Zhoushan had a better effect in improving quality of ‘Biqizhong’, while those in Huangyan seemed better for ‘Dongkui’.

Key words: Bayberry; Pollen xenia; Fruit quality; The Enzymes for sucrose metabolism

杨梅(*Myrica rubra*)是我国亚热带特色水果之一，为杨梅科(Myricaceae)杨梅属(*Myrica*)植物，其果实甜酸适口，风味独特，营养价值和经济价值极高，树体经济寿命长并且具有固氮功能，常被人们誉为“绿色企业”和“摇钱树”，在国内外享有盛誉。截止2015年，全国杨梅种植面积达到33.4万hm^2，其中浙江省的杨梅种植面积就达到8.7万hm^2，产量50多万t，年产值达50多亿元，在全国乃至世界居于首位。

花粉直感现象是指花粉落到雌蕊柱头上完成授粉受精以后，由于父本花粉的作用通过种子对果实产生影响，主要表现在当年形成果实的色泽、大小、可溶性固形物含量和种子大小等方面的影响[1]。花粉直感影响果实产量品质，该现象的研究对果树产业有着重要的现实意义[2]。糖分含量是果实品质的重要指标，糖分的积累既由遗传因素所控制，也受环境影响。蔗糖磷酸合成酶(sucrose phosphate synthase，SPS)和蔗糖合成酶(sucrose synthase，SS)是高等植物中与糖代谢密切相关的酶，SPS催化6-磷酸果糖和尿苷二磷酸葡萄糖（UDPG)反应生成6-磷酸葡萄糖和尿苷二磷酸（UDP)，SPS催化蔗糖生成是不可逆的[3]，SS既可催化蔗糖合成又可催化蔗糖分解，SS催化果糖和UDPG反应生成蔗糖和UDP。SS在蜜柑[4]果实发育后期蔗糖积累中可能起重要作用，且SS对蔗糖积累的贡献大于SPS。对杨梅的研究表明，在成熟杨梅果实中SPS的活性与蔗糖的积累密切相关，其活性的变化与蔗糖积累的趋势一致[5]。笔者通过‘荸荠种’自然授粉、‘荸荠种’×黄岩花粉、‘荸荠种’×舟山花粉、‘东魁’自然授粉、‘东魁’×黄岩花粉、‘东魁’×舟山花粉组合，研究测定当年的果实品质及不同发育时期的杨梅果实蔗糖磷酸合成酶(SPS)和蔗糖合成酶(SS)的活性，旨在为杨梅人工授粉设计不同的亲本组合，为改良果实品质提供理论基础。

1　材料和方法

1.1　材料

在雄花尚未开放时于浙江省杨梅主产区黄岩（2015年3月24日，树体12 a生）、舟山(2015年4月2日，树体10 a生）的雄株采集杨梅雄花枝（花色红)，花粉的收集及保存参考谢小波等[6]的方法。在浙江省海宁县黄湾镇钱江村各选5株15 a生‘东魁’‘荸荠种’进行人工套袋授粉。在杨梅雌花尚未开放时使用硫酸纸袋套雌花枝，每株套袋400个，选择晴天的上午在雌花开放初期轻轻打开纸袋，用毛笔蘸取花粉轻轻抖至雌花序上，随即用回形针夹牢袋口。自然授粉设为对照，雌花开放完毕，用硫酸纸袋套花枝。待果袋内果实完全成熟(2015年6月25日)时采摘果实测定果实品质，需要检测酶活性的果实样品采后立即放入液氮罐内保存，带回实验室转移至-80 ℃冰箱备用。‘荸荠种’为母本的组合以‘荸荠种’的自然授粉为对照，授粉组合为‘荸荠种’×黄岩、‘荸荠种’×舟山；‘东魁’为母本的组合以‘东魁’自然授粉为对照，授粉组合为‘东魁’×黄岩、‘东魁’×舟山。

1.2　色差、质量、大小、硬度、可溶性固形物含量测定

果实成熟时采收，每个授粉组合测15个果实。采用色差自动检测计(HITACHI307光谱光度计，北京辰泰克仪器技术有限公司)测定每个果实赤道部位4个方向的a^*(红色饱和度)、b^*(黄色饱和度)、L^*(光泽明亮度)。

用电子天平测定单果质量，用游标卡尺测量纵横径，用质构仪(Brookfield CT3 texture analyzer，Brookfield Engineering Laboratories，Inc. 11 Commerce Boulevard Middleboro，MA 02346 USA)测定硬度(平板探头TA-CTP，测试速度1 mm·s^{-1}，触点负载

为20 g,测试的目标值距离为8 mm),用手持糖度计(Pocket refractometer pal-1)测定可溶性固形物含量。

1.3 总糖的提取及测定

采用蒽酮比色法测定总糖含量,称取5.00 g果肉,用组织搅碎机搅碎后,置于50 mL三角瓶中,加沸水25 mL,加盖,超声提取10 min,冷却后过滤,残渣用沸蒸馏水反复洗涤并过滤,滤液收集在50 mL容量瓶中,定容至刻度,得提取液。吸取提取液2 mL,置于另一个50 mL容量瓶中,用蒸馏水稀释定容,摇匀。吸取1 mL已稀释的提取液于试管中,加入4 mL蒽酮试剂,迅速浸于冰水浴中冷却,管口加盖,准确煮沸10 min取出,用冰浴冷却至室温后测620 nm吸光值。空白管以等量蒸馏水取代提取液。试验3次重复。

1.4 维生素C的提取及测定

称取可食部果肉100 g(精确到0.01 g)放入组织捣碎机中,加100 mL浸提剂(2%偏磷酸,或者2%草酸),迅速捣成匀浆。称20 g浆状样品,用浸提剂将样品移入100 mL容量瓶,并稀释至刻度,摇匀过滤。若滤液有色,可按每g样品加0.4 g白陶土脱色后再过滤。吸取10 mL滤液放入50 mL锥形瓶中,用已标定过的2,6-二氯靛酚溶液滴定,直至溶液呈粉红色15 s不褪色为止。3次重复,同时做空白试验[7]。

1.5 可滴定酸的提取及测定

称取组织搅碎机搅碎的果肉样品10 g(精确到0.01 g)于100 mL烧杯中,加入双蒸水50 mL,置于沸水浴中煮沸30 min,取出冷却至室温(约20 ℃),用100 mL容量瓶定容,摇匀、过滤,滤液收集于250 mL锥形瓶中备用。吸取滤液10.00 mL置于150 mL三角瓶中加2滴酚酞指示剂,用0.1 mol·L^{-1} NaOH标准溶液滴定至微红色且15 s不褪色,记录消耗氢氧化钠标准溶液的体积,3次重复,同时做空白试验[8]。

1.6 酶的提取及测定

酶的提取参考Souleyre等[5]的方法并进行改进,即称取1.0 g杨梅果肉,加入提取缓冲液(2.5 mL 1 mol·L^{-1} Hepes-NaOH,0.25 mL 1 mol·L^{-1}氯化镁,0.1 mL 0.5 mol·L^{-1} EDTA,5.0 mL 0.01 mol·L^{-1} EGTA,5.0 mL纯甘油,0.05 mL Triton×100,0.25 mL 1 mol·L^{-1} DTT,2.5 mL 0.01% PMSF,1 mL PVPP,去离子水补齐至50 mL)5 mL,且在4 ℃冰上研磨至匀浆,然后在4 ℃条件下13 000 r·min^{-1}离心20 min,取上清液,即为粗酶液,4 ℃保存备用。测定2个不同发育时期(5月19日和6月19日)杨梅果实蔗糖磷酸合成酶(SPS)和蔗糖合成酶(SS)的活性。

SPS活性测定参照Lowell等[9]的方法,并加以改进。70 μL反应体系:3.5 μL 1 mol·L^{-1} Hepes-NaOH(pH 7.5),1.05 μL 1 mol·L^{-1}氯化镁,0.14 μL 0.5 mol·L^{-1} EDTA,3.5 μL 0.1 mol·L^{-1} NaF,14 μL 0.1 mol·L^{-1} 6-P-葡萄糖,2.8 μL 0.1 mol·L^{-1} 6-P-果糖,11.2 μL 0.1 mol·L^{-1} UDP-葡萄糖,10 μL酶提取液,补加去离子水至70 μL。30 ℃反应30 min,最后加入2mol·L^{-1} NaOH 0.1 mL,沸水浴10 min后,冷却至室温,再加3.5 mL 30%HCl,1 mL 0.1%间苯二酚,摇匀,80 ℃水浴10 min,冷却后在480 nm测定OD值。对照不加6-P-葡萄糖和6-P-果糖。3次重复。

SS酶活性测定参考Hubbard等[10]的方法,并加以改进。70 μL反应体系:5.6 μL 1 mol·L^{-1} Hepes-NaOH,3.5 μL 0.1 mol·L^{-1} NaF,43.4 μL 0.1 mol·L^{-1} 6-P-果糖,10.5 μL 0.1 mol·L^{-1} UDP-葡萄糖,7 μL酶提取液,对照体系不加6-P-果糖,用去离子水补充。30 ℃水浴反应30 min,最后加入5 mol·L^{-1} NaOH 70 μL,沸水浴10 min后,冷却至室温,再加3.5 mL 30%HCl,1 mL 0.1%间苯二酚,摇匀,80 ℃水浴10 min,冷却后在480 nm测定OD值。3次重复。

1.7 数据统计分析

应用SPSS 17.0软件对所有试验数据进行方差分析(ANOVA),用Duncan多重比较分析差异的显著性。

2 结果与分析

2.1 果实品质

2.1.1 外观、质量、硬度和色差 不同授粉组合对杨梅果实的外观、单果质量、硬度和色差都有较显著的影响。‘荸荠种’为母本的授粉组合的果实质量都相对较低,比对照低6.5%~18.6%,其中‘荸荠种’×舟山的果实质量最大,为7.9 g;果实横径和纵径都比对照小,分别比对照低4.3%~7.6%和4.62%~9.16%。‘东魁’授粉组合果实质量、横纵径等方面与对照差异不显著。2个品种可食率均无显著性差异。‘荸荠种’×舟山硬度显著比对照高,‘荸荠种’×黄岩显著比对照低,分别比对照高7.81%和低18.47%。‘东魁’授粉组合果实硬度均高于对照,其中‘东魁’×舟山硬度比对照高8.45%。‘荸荠种’授粉组合果实的亮度均显著低于对照(P<0.05),比对照低5.1%~16.4%,‘荸荠种’×黄岩、‘荸荠种’×舟山的黄色数值

均显著高于对照,比对照高6.43%~20.30%；‘荸荠种’×舟山的红色指标最高,比对照高4.80%。‘东魁’×黄岩的果实亮度显著低于对照,比对照低5.75%；‘东魁’×舟山显著高于对照,比对照高5.87%。‘东魁’授粉组合果实黄色指数差异显著,而红色指数差异不显著(表1)。

表1 ‘荸荠种’和‘东魁’为母本的授粉组合对果实品质的影响

Table 1 Effect of the artificial pollination with ‘Biqizhong’ and ‘Dongkui’ as female parent on bayberry fruit quality

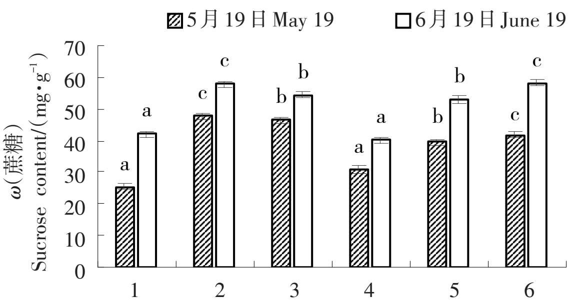
母本 Female parent	父本 Male parent	单果质量 Fruit mass/g	果实横径 Transverse diameter/mm	果实纵径 Longitudinal diameter/mm	可食率 Edible rate/%	ω(可溶性固形物) Soluble solids content/%	硬度 Firmness/g	L^*	a^*	b^*	ω(总糖) Total sugar content/(mg·g^{-1})	ω(可滴定酸) Titratable acid content/%	ω(维生素C) Vitamin C content/(mg·100 g^{-1})
荸荠种 Biqizhong	自然授粉 Natural pollination	8.45±0.74 b	23.49±0.88 c	24.90±1.31 c	94.56±0.04 a	11.49±0.33 a	2 355.73±276.92 b	25.68±2.1 c	54.10±6.29 a	34.98±19.68 a	2.40±0.003 c	6.65±0.012 a	2.23±0.03 b
	黄岩 Huangyan	6.88±0.97 a	21.71±1.13 a	22.62±0.38 a	94.33±0.05 a	11.47±0.68 a	1 920.47±435.32 a	24.36±0.63 b	54.38±1.39 a	42.08±0.87 c	2.00±0.06 a	8.00±0.03 c	2.00±0.07 a
	舟山 Zhoushan	7.90±0.79 b	22.49±1.09 b	23.75±1.21 b	94.05±0.05 a	12.31±0.38 b	2 539.33±397.16 b	21.48±1.19 a	56.70±1.65 a	37.23±1.96 b	2.06±0.06 b	7.78±0.023 b	2.00±0.03 a
东魁 Dongkui	自然授粉 Natural pollination	17.14±2.57 a	30.42±2.32 a	30.23±1.95 a	93.99±0.07 a	9.89±0.62 a	2 261.47±428.49 a	24.19±1.18 b	52.02±1.46 a	41.7±2.05 c	2.29±0.02 a	6.97±0.05 a	3.13±0.03 a
	黄岩 Huangyan	17.93±1.97 a	30.85±1.45 a	30.77±1.36 a	94.37±0.09 a	13.05±0.88 b	2 335.6±576.37 a	22.8±1.23 a	47.93±10.37 a	13.05±0.88 b	2.36 ±0.07 b	8.74±0.02 b	3.20±1.00 a
	舟山 Zhoushan	17.58±2.71 a	29.96±2.94 a	30.12±1.86 a	94.31±0.07 a	9.57±0.45 a	2 452.13±538.37 a	25.61±2.26 c	47.47±3.64 a	9.57±0.45 a	2.32 ±0.06 ab	6.78±0.02 a	3.40±0.06 b

2.1.2 可溶性固形物、总糖、可滴定酸、维生素C含量 不同花粉对‘东魁’‘荸荠种’授粉组合的果实可溶性固形物含量有一定影响。‘荸荠种’×黄岩和‘东魁’×舟山的果实可溶性固形物含量低于对照,分别比对照低0.17%和3.24%；而‘荸荠种’×舟山和‘东魁’×黄岩果实的可溶性固形物含量都显著高于对照,分别比对照高7.14%和31.95%(表1)。

‘荸荠种’授粉组合果实的含糖量显著低于对照,低14.17%~16.67%,以‘东魁’为母本的授粉组合中,‘东魁’×黄岩果实显著高于对照,高3.06%。以‘荸荠种’为母本的授粉组合果实可滴定酸含量显著高于对照,‘荸荠种’×黄岩和‘荸荠种’×舟山的可滴定酸含量分别比对照高20.30%和16.99%。‘东魁’×黄岩的可滴定酸含量比对照显著高25.39%,‘东魁’×舟山比对照低2.73%。不同花粉对‘东魁’‘荸荠种’的维生素C含量有影响,‘荸荠种’×舟山和‘荸荠种’×黄岩授粉组合果实的维生素C含量显著低于对照,分别比对照低6.73%和10.3%,‘东魁’×黄岩和‘东魁’×舟山维生素C含量均高于对照,其中‘东魁’×舟山的维生素C与对照有显著差异,比对照高8.63%(表1)。

2.2 不同授粉组合酶活性

2.2.1 不同授粉组合蔗糖磷酸合成酶(SPS)活性分析 对5月19日和6月19日6个授粉组合的SPS活性进行测定,6月19日的酶活性与5月19日的相比,每个授粉组合的SPS酶活性均升高,其中‘荸荠种’×舟山与‘东魁’×舟山增加幅度最大。以‘荸荠种’为母本的授粉组合2个时间的SPS酶活性均显著高于对照,分别比对照高82.55%~87.06%和28.8%~37.08%,其中‘荸荠种’×舟山的SPS酶活性最大,为47.7和57.75 mg·g^{-1}(以鲜质量计)。以‘东魁’为母本的授粉组合2个时间的SPS酶活性都显著高于对照,分别比对照高28.20%~35.33%和31.62%~44.77%,其中‘东魁’×舟山的SPS酶活性最大,为41.75和58.24 mg·g^{-1}(图1)。



1. 荸荠种自然授粉；2. 荸荠种×舟山；3. 荸荠种×黄岩；4. 东魁自然授粉；5. 东魁×黄岩；6. 东魁×舟山。下同。

1. Natural pollination of Biqizhong；2.Biqizhong×Zhoushan；3. Biqizhong×Huangyan；4. Natural pollination of Dongkui；5. Dongkui×Huangyan；6. Dongkui×Zhoushan. The same below.

图1 杨梅不同授粉组合蔗糖磷酸合成酶活性

Fig. 1 SPS enzyme activity in the different pollination combinations of bayberry

2.2.2 不同授粉组合蔗糖合成酶(SS)活性分析 对5月19日和6月19日的6个授粉组合的SS酶活性进行测定，2个时间‘荸荠种’为母本的授粉组合的SS酶活性均显著高于对照，分别比对照高99.81%~115.86%和76.49%~105.98%，‘荸荠种’×黄岩的酶活性最大，分别为77.71和66.86 mg·g^{-1}。2个时间段‘东魁’×黄岩SS酶活性都显著高于对照，分别是52.14和66.64 mg·g^{-1}。但是‘东魁’×舟山SS酶活性5月19日低于对照，6月19日高于对照(图2)。

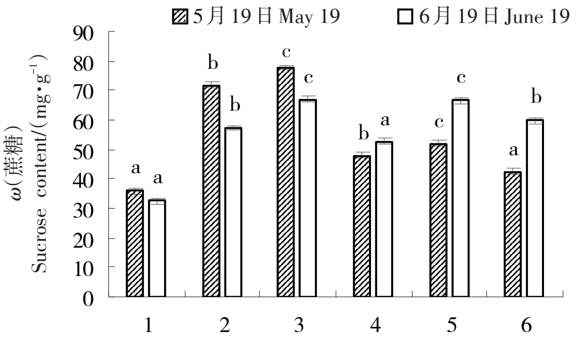


图2 杨梅不同授粉组合蔗糖合成酶活性

Fig. 2 SS enzyme activity in the different pollination combinations of bayberry

3 讨 论

不同地区的杨梅雄株花粉对果实品质有影响。对单果质量、横纵径、可溶性固形物含量等方面果实品质的影响，在火龙果[11]、猕猴桃[12]、苹果[13]、仰韶杏、贵妃杏[14]、山核桃[15]、猕猴桃[16-17]、枸杞[18]、蓝莓[19]等水果上都有报道。花粉直感对桔橙[20]果实质量、果形指数和蔗糖含量均表现为显著提高。荔枝[21]在果实纵径、果形指数、单果质量、可溶性固形物、糖、可滴定酸、维生素C含量方面都表现出花粉直感的显著差异。在‘黑宝石李’[22]、‘京白梨’[23]、罗汉果[24]、锥栗上也存在这种影响。不同的花粉授粉结实会影响杨梅果实形状、颜色、硬度、可溶性糖、可滴定酸、维生素C以及可溶性固形物含量，本试验说明杨梅在授粉组合结实中存在着明显的花粉直感现象，主要表现在果实总糖、维生素C、可滴定酸的含量方面，以‘东魁’‘荸荠种’为母本的授粉组合果实的含量和对照有显著差异。

很多水果糖分积累以蔗糖为主要成分，其次是果糖和葡萄糖，近几年人们对杧果[17]和柑橘[18]的研究表明，蔗糖代谢相关酶与果实糖积累之间存在密切联系。在苹果[19]和葡萄[20]果实发育早期，蔗糖含量与转化酶活性呈负相关；在成熟香蕉[21]和猕猴桃[22]等果实中SPS活性的升高与蔗糖的积累密切相关；SS在桃果实发育后期蔗糖积累中可能起重要作用[23]。在Vizzotto等[24]的研究中，草莓果实中蔗糖浓度升高时，SPS和SS的活性都上升，说明几种蔗糖代谢相关酶可能同时对果实糖积累产生影响。杨梅这种蔗糖型的果实中，SS和SPS的活性与蔗糖合成有关。在杨梅果实发育过程中，其中以‘东魁’为母本的授粉组合中‘东魁’×黄岩的SS活性最高，以‘荸荠种’为母本的授粉组合中‘荸荠种’×黄岩的SS活性最高。因此‘东魁’×黄岩和‘荸荠种’×黄岩的蔗糖含量大于其他授粉组合。但SS和SPS如何协调促进杨梅果实蔗糖的积累仍需要进一步研究。

从本文研究结果可见，‘荸荠种’和‘东魁’与黄岩和舟山的杨梅花粉都有亲和性。在‘荸荠种’授粉组合果实中，与‘荸荠种’自然授粉相比，‘荸荠种’×舟山授粉组合的硬度、可溶性固形物含量、色差a^*最大，SPS酶活性最高；在‘东魁’授粉组合果实中，与‘东魁’自然授粉相比，‘东魁’×黄岩授粉组合的果实质量、横径、纵径最大，SS酶活性最高；这说明不同花粉对杨梅果实品质有显著影响。将为筛选改善杨梅果实品质的授粉组合提供参考。从容易取材及品质改良2方面综合考虑，黄岩和舟山的杨梅雄株在授粉组合中有着一定的优势，舟山的杨梅花粉为‘荸荠种’授粉对品质的改良更好，黄岩的杨梅花粉为‘东魁’授粉对品质的改良更佳。

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