

# 不同授粉组合对苹果果实 ASA 含量及抗氧化协同酶、糖酸组分动态变化的影响

倪伟, 盖瑞, 于文章, 毛云飞, 刘青, 毛志泉, 陈学森, 沈向\*

(山东农业大学园艺科学与工程学院·作物生物学国家重点实验室, 山东泰安 271018)

**摘要:**【目的】讨论不同花粉授粉后的苹果果实在生长发育过程中抗坏血酸(ascorbic acid, ASA)含量、糖酸组分以及抗氧化协同酶活性的差异,明确高效授粉树花粉对苹果果实糖酸组分变化及抗氧化协同酶活性的影响,为高效授粉树的选育和提升苹果果实品质提供依据。【方法】采用自育高效授粉树 1379、1539、1-17 以及 3-21 的花粉,在‘富士’(*Malus domestica* Borkh. ‘Fuji’)、‘嘎拉’(*Malus domestica* Borkh. ‘Gala’)铃铛花期时进行授粉,以‘新红星’(*Malus domestica* Borkh. ‘Starkrimson’)花粉为对照,自授粉后 20 d 的幼果开始每间隔 20 d 进行连续采样,对苹果果实中 ASA 含量、有机酸中的草酸、酒石酸、苹果酸、乳酸、乙酸、琥珀酸、枸橼酸含量;可溶性总糖中葡萄糖、果糖、蔗糖以及山梨醇含量、抗氧化协同酶中超氧化物歧化酶(SOD)、过氧化物酶(POD)、过氧化氢酶(CAT)的活性和丙二醛(MDA)含量进行测定。【结果】不同花粉授粉后果实内 ASA 含量存在显著性差异,均高于对照。在果实生长发育过程中,SOD、POD 活性变化与果实内 ASA 积累量变化趋势相同,呈先降低、后升高、再降低的趋势;CAT 活性逐渐降低,MDA 含量变化呈先降低后升高的趋势,其中经过高效授粉树花粉授粉的果实内 MDA 含量均低于对照,而果实中抗氧化协同酶的活性均明显高于对照。在果实生长发育中后期,不同高效授粉树花粉授粉后的果实内总酸含量低于对照,而其中的草酸和酒石酸含量高于对照,苹果酸、枸橼酸和琥珀酸含量低于对照;糖组分含量均高于对照,其中果糖和蔗糖含量较对照有显著的提高,但不同授粉处理间的糖酸组分含量差异不显著。【结论】不同高效授粉树花粉均能显著提高苹果果实内 ASA 含量,但不同处理间 ASA 含量差异不显著;经过高效授粉树花粉处理的果实内草酸和酒石酸含量较对照有所提高,但是总酸含量较低;同时不同高效授粉树花粉授粉果实内的果糖和蔗糖含量较对照有显著的提高,但不同高效授粉树花粉授粉处理间的糖酸组分含量差异不显著。其中抗氧化协同酶活性与 ASA 积累量变化趋势相似,推测其活性与 ASA 含量具有一定的关系。

**关键词:** 苹果; 花粉; ASA 含量; 酶活性; 糖酸组分

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## Effects of different pollination combinations on ASA content, activity of antioxidant coordinating enzymes and dynamic changes of sugars and organic acid compositions in apple fruits

NI Wei, GE Rui, YU Wenzhang, MAO Yunfei, LIU Qing, MAO Zhiquan, CHEN Xuesen, SHEN Xiang\*

(College of Horticultural Science and Engineering, Shandong Agricultural University · State Key Laboratory of Crop Biology, Tai'an 271018, Shandong, China)

**Abstract:**【Objective】The metabolism of sugars and acids affects fruit development, antioxidation and dynamic changes of sugar/organic acid compositions in apple fruits. The antioxidant activity in the fruits is an important character for apple quality. This paper dealt with the differences of ASA (ascorbic acid, ASA) contents, sugars/organic acids composition and the activity of antioxidant coordinating enzymes in apple fruits during growth and development in relation to different pollination combinations.【Methods】

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作者简介: 倪伟,男,在读硕士研究生,主要研究方向为果树生理生化。Tel: 18805487881, E-mail: 747725820@qq.com

\*通信作者 Author for correspondence. E-mail: shenx@sdau.edu.cn

The flowers of 'Fuji' (*Malus domestica* Borkh.) and 'Gala' (*Malus domestica* Borkh.) were pollinated in belly stage of blooming by pollens collected from the pollination trees *Malus* spp. (1379, 1539, 1-17, 3-21), and 'Starkrimson' (*Malus domestica* Borkh.) as contrast. The fruit composition of acids including oxalic acid, tartaric acid, malic acid, lactic acid, acetic acid, succinate, citric acid, the composition of sugar including glucose, fructose, sucrose and sorbitol, and antioxidant enzymes including superoxide dismutase (SOD), peroxidase (POD), catalase (CAT) activity and malondialdehyde (MDA) content were determined during the fruit development every 20 days. The sugars and the organic acid were separated and quantified by HPLC analysis. The HPLC system contained a quaternary pump, an autosampler, and a reflective index detector (Waters 410) with HyperREZ XP Carbohydrate  $\text{Ca}^{2+}$  8  $\mu\text{m}$  column at 80 °C with a flow rate 0.5 mL · min<sup>-1</sup>. The mobile phase was performed with an isocratic elution of ultrapure water for peak separation. At last, the data were presented as the mean  $\pm$  standard deviation of triplicate. 【Results】Different pollens had different effects on the contents of the ASA in the fruits, and the contents of ASA increased significantly during 40-60 days after pollination. The content of the ASA in the fruits pollinated by the 4 tested pollinators was higher than that of the control obviously. The activity of superoxide dismutase (SOD), and peroxidase (POD) had the same changes as the ASA, that is, they decreased firstly, then increased, and decreased again at last. The catalase (CAT) activity decreased gradually while the content of malondialdehyde (MDA) increased at first, and then decreased. Activities of antioxidant isozymes in the fruits pollinated by the 4 tested pollination trees were higher than those of the control. In the late stage of the fruit growth, contents of total acids, the malic acid, citric acid and succinate in the fruits pollinated by the 4 tested pollination trees were lower than those of the control, while the contents of oxalic acid and tartaric acid in the fruits pollinated by the 4 tested pollination trees were higher than those of the control. The sugar content in the fruits pollinated the 4 tested pollinators was higher than that of the control, and the contents of fructose and sucrose in the fruits pollinated by the 4 tested pollination trees were significantly higher than those of the control. The contents of tartaric acid and oxalic acid in the fruits pollinated by the 4 tested pollination trees were higher than those of the control, but the total content of the acid in the fruits pollinated by the 4 tested pollination trees was lower than that of the control. Meanwhile, the contents of the fructose and sucrose in the fruit pollinated by the 4 tested pollination trees were significantly higher than those of the control, but the differences of sugar and organic acid compositions in the fruits pollinated by different pollen donors were not statistically obvious. 【Conclusion】The main soluble sugars in the fruits of the apple cultivars tested were glucose and fructose, the main organic acid was malic acid. The contents of the ASA in apple fruits could be significantly increased by using more suitable pollination trees, but the difference of the contents of the ASA in the fruits derived from the pollinating trees except for the control were not statistically significant. The contents of tartaric acid and oxalic acid in the fruits pollinated by the 4 tested pollination trees were higher than those of the control, but the total content of the acids in the fruits pollinated by the 4 tested pollination trees was lower than that of the control. Meanwhile, the contents of the fructose and sucrose in the fruits were significantly increased by using the pollinating trees except for the control. The change of the antioxidant activity was similar to the content of ASA, and it seems to be possible that that the antioxidant activity and the ASA content was related to each other.

**Key words:** Apple; Pollen; ASA content; Enzyme activity; Sugar and organic acid compositions

果实中糖酸的种类、含量及其动态变化是果实品质形成的重要基础,也是果实品质的关键研究指

标。有机酸作为一种酸性有机化合物,能够保持人体内酸碱环境的稳定,同时有机酸含量对果实的口