

5种植物生长调节剂对灰枣果实品质的影响

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摘要:【目的】以灰枣为试验材料, 对其进行5种植物生长调节剂喷施处理, 筛选出可促进灰枣果实生长的植物生长调节剂, 为提高灰枣果实品质奠定基础。【方法】利用不同浓度的胺鲜酯(diethyl aminoethyl hexanoate, DA-6)、氨基寡糖素(oligochitosan, AS)、复硝酚钠(sodium nitrophenolate, CSN)、苯胺腈酸(phthalanilic acid, PA)和宛式拟青霉提取物(paecilomyces variotii extracts, ZNC)等5种植物生长调节剂, 于脆熟期对灰枣叶片进行喷施, 以喷施清水为对照, 探究不同植物生长调节剂对灰枣果实生长发育及品质的影响。【结果】不同植物生长调节剂对果实表型及内在品质有不同程度的改善效果。1200倍液苯胺腈酸(PA)处理在果实形态和总黄酮含量方面表现优异, 果皮总黄酮含量较对照显著提高了146.01%, 果肉总黄酮含量较对照显著提高了15.26%; 30 mg·L⁻¹的胺鲜酯(DA-6)处理对果实形态、可溶性固形物含量、可溶性蛋白含量等多个指标有较大提升, 其中可溶性固形物含量较对照提高了1.6个百分点, 可溶性蛋白含量较对照显著提高了7.25%。【结论】1200倍液苯胺腈酸和30 mg·L⁻¹的胺鲜酯在改善灰枣果实品质方面效果较为突出, 为灰枣生产合理选用植物生长调节剂提供了理论参考。

关键词: 灰枣; 植物生长调节剂; 果实品质

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Effects of five plant growth regulators on fruit quality of *Ziziphus jujuba* 'Huizao'

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Abstract: 【Objective】Huizao is an important variety of red Chinese jujuba (*Ziziphus jujuba*) in Xinjiang. Improvement of yield and fruit quality will increase economic benefits and market competitiveness. Plant growth regulators have shown unique advantages in regulating crop growth and development, enhancing resistance and improving quality. The study aimed to screen out the effective plant growth regulators that could improve the fruit quality of Huizao. 【Methods】This experiment was carried out in the Chinese Jujuba Germplasm Resource Collection of Kashgar Mageti County, Fruit and Vegetable Research Institute, Xinjiang Uygur Autonomous Region Academy of Agricultural Sciences. The Huizao trees were used as the test material, and five plant growth regulators, namely, Diethyl aminoethyl hexanoate (DA-6), Oligochitosan (AS), Sodium Nitrophenolate (CSN), Phthalanilic acid (PA), and Paecilomyces variotii extracts (ZNC), were sprayed during the period of fruit expansion. 15 treatment groups were set up with different concentration gradients for each regulator, and a clear water control (CK) was set up. We selected the test trees with good growth, consistent flowering and growth, and sprayed the leaves evenly with different agents and concentrations, 2 L liquid sprayed for each treat-

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ment. The first spray was made in July 10, and the second spray was made 10 days later. During the fruit ripening period, the morphological indexes (single fruit mass, single kernel mass, longitudinal and transverse diameter of fruit, longitudinal and transverse diameter of jujube kernel, etc.), nutrient content (soluble solids, soluble sugar, soluble protein, vitamin C, titratable acid, etc.) and key secondary metabolites (anthocyanin, total phenolics, total flavonoids, etc.) were measured, and correlation analyses were carried out on the various indexes, and the affiliation function method was used to calculate the integrated scores. The correlation analyses of each index were conducted, and the scores were calculated using the affiliation function method to comprehensively evaluate the fruit quality. **【Results】** In terms of fruit morphology, the differences in the edible rate (95.11%–97.31%) and fruit shape index (1.38–1.54) among treatments were not significant, but the kernel shape index of ZNC T1 (2000 times $250 \text{ mg} \cdot \text{L}^{-1}$ ZNC), CSN T2 ($20 \text{ mg} \cdot \text{L}^{-1}$ CSN) and ZNC T2 (1500 times $250 \text{ mg} \cdot \text{L}^{-1}$ ZNC) treatments were significantly higher than that of the control. In terms of nutrient content, the DA-6 T1 ($20 \text{ mg} \cdot \text{L}^{-1}$ DA-6) and DA-6 T2 ($30 \text{ mg} \cdot \text{L}^{-1}$ DA-6) treatments significantly increased soluble solids content, and the CSN T2 and AS T3 (600 times 5% AS) treatments had the highest SSC content. The DA-6 T3 ($25 \text{ mg} \cdot \text{L}^{-1}$ DA-6) treatment had the highest soluble sugar content, but the difference with the control was not significant; and several treatments significantly increased soluble protein content, the DA-6 T2 and CSN T3 ($25 \text{ mg} \cdot \text{L}^{-1}$ CSN) treatments increased by 7.285% and 5.16%, respectively, compared with the CK; vitamin C content was significantly higher than that of the control in all treatments except CSN T3, of which the vitamin C contents of the AS T1 (1000 times 5% AS), AS T3 and ZNC T1 treatments were the highest, increased by 89%, 77% and 89%, respectively, compared with the CK. The DA-6 T2 and ZNC T3 (1000 times $250 \text{ mg} \cdot \text{L}^{-1}$ ZNC) treatments significantly increased the content of titratable acid. In terms of key secondary metabolites, DA-6 T3, ZNC T2, and ZNC T3 treatments significantly increased anthocyanin content, with ZNC T3 treatment having the highest anthocyanin content. The CSN T1 ($15 \text{ mg} \cdot \text{L}^{-1}$ CSN), PA T2 (1200 times 20% PA), and ZNC T1 treatments had the highest total pericarp phenol content. The DA-6 T3 treatment had the highest total phenolic content in the pulp, which was enhanced by 83% compared with the CK. The PA T2 treatment significantly enhanced the total flavonoid content in the pericarp, and the AS T3 treatment significantly enhanced the total flavonoid content in the pulp. The correlation analysis between the indicators showed that fruit transverse diameter and fruit longitudinal diameter, kernel longitudinal diameter and kernel weight, and kernel transverse diameter and kernel weight were all highly significantly and positively correlated ($P < 0.01$), i.e., an increase in kernel weight was often accompanied by an increase in kernel longitudinal and transverse diameter. And the kernel longitudinal diameter and fruit weight, kernel transverse diameter and anthocyanin content, were significantly and positively correlated with kernel transverse diameter ($P < 0.05$). Through the comprehensive evaluation of the affiliation function method, the comprehensive score of fruit quality of each treatment ranged from 0.293 to 0.722, with the PA T2 treatment scoring the highest, followed by DA-6 T2 and ZNC T2, and the order of the comprehensive score was PA T2 > DA-6 T2 > ZNC T2 > AS T3 > ZNC T3 > ZNC T1 > CSN T2 > PA T1 (1400 times 20% PA) > DA-6 T3 > PA T3 (1000 times 20% PA) > CSN T3 > CK > AS T2 (800 times 5% AS) > CSN T1 > DA-6 T1 > AS T1. **【Conclusion】** The five plant growth regulators had certain regulatory effects on the fruit quality of Huizao, among which PA T2 treatment had the most prominent effect in improving fruit quality. DA-6 T2 also had a more satisfactory effect. Therefore, it would be recommended to choose PA T2 treatment to effectively improve the fruit quality of Huizao and enhance its market competitiveness.

Key words: Huizao; Plant growth regulator; Fruit quality

枣(*Ziziphus jujuba* Mill.)是鼠李科枣属植物,原产于中国,是中国重要的经济林树种之一^[1]。其中,新疆是红枣主要的种植地之一,产量占据全国的一半,凭借着优异的自然条件和得天独厚的地理位置,生产的红枣具有较高的营养价值和保健功效^[2-3]。枣果实营养丰富,富含糖类、维生素、矿物质等营养成分,具有很高的食用价值和药用价值^[4]。随着红枣产量的剧增和消费者需求标准的提高,红枣的品质变得尤为重要。新疆红枣产品在国内外知名度较高,品牌优势明显,然而枣产品以初加工为主,精深加工产品转化能力不足^[5]。

植物生长调节剂是一类能够调节植物生长发育的化学物质,具有用量少、效果显著、作用快等特点^[6],在作物生产中发挥着重要作用,不仅能提高作物产量,还能增强作物抗性和改善作物品质,在延长产品保质期和促进植物育种方面也发挥着重要作用^[7]。王铤等^[8]以桃品种胭脂脆为试验材料,喷施0~40 mg·L⁻¹胺鲜酯(diethyl aminoethyl hexanoate, DA-6),结果表明,喷施胺鲜酯对桃果实表型指标及风味品质、营养价值均有促进作用,且以30 mg·L⁻¹处理效果最佳。王荣山等^[9]以宁杞7号叶片为试验材料,结果表明,喷施5%的氨基寡糖素(oligochitosan, AS)800倍液可显著提高叶片的叶绿素含量、超氧化物歧化酶(superoxide dismutase, SOD)和过氧化物酶(peroxidase, POD)活性,促进总酚和黄酮类化合物的积累。屈旭等^[10]用不同浓度的复硝酚钠(sodium nitrophenolate, CSN)处理辣椒种子,结果表明,10~70 mg·L⁻¹ CSN处理对提高辣椒幼苗质量和壮苗指数的作用比较显著。褚素芬等^[11]研究苯胺胺酸(phthalanilic acid, PA)对苹果树产量和品质的影响,结果表明,PA显著提高苹果可滴定酸、可溶性糖、可溶性固形物含量和果实硬度,随浓度的增加呈先升高后降低的趋势,在浓度为180 mg·L⁻¹时效果最好。王珊珊等^[12]在生姜幼苗期和旺盛生长期分别喷施不同质量浓度的宛氏拟青霉提取物(*paecilomyces variotii* extracts, ZNC),研究其对生姜生长特性、产量、品质的影响,结果表明,喷施ZNC处理的生姜,在幼苗期和旺盛生长期的株高、主茎粗、分枝数及维生素C、可溶性糖、可溶性蛋白含量均有所增加。前人研究表明,果实膨大期是果实快速生长以及品质形成的关键时期,在此阶段采取减少灌溉、控制氮肥、增加磷钾肥及微量元素、调节通风透光条件

的方式可提高果品品质^[13]。当前,红枣产品以粗加工的干枣为主,精深加工产品少^[14],新疆灰枣大多用于制干,但灰枣在脆熟期采摘有制作为灰枣浓缩汁、熬粥煮汤、泡茶泡酒等多种用途^[15-16]。为探究灰枣脆熟期果实特点,提高脆熟期灰枣果实品质,植物生长调节剂的应用尤为重要。植物生长调节剂对果实品质具有重要作用,在果树栽培中应用广泛,但针对灰枣的研究较少^[17-18]。笔者以灰枣为试材,探究不同浓度的DA-6、AS、CSN、PA和ZNC对脆熟期灰枣果实生长发育及品质的影响,旨在探讨不同种类及不同浓度的植物生长调节剂对灰枣果实品质的改善效果,以期为灰枣优质栽培提供理论依据与技术支持。

1 材料和方法

1.1 试验地概况

试验地位于新疆维吾尔自治区农业科学院果蔬研究所喀什麦盖提县枣种质资源圃,该区域属于温带大陆性干燥气候,海拔1 180.58~1 181.19 m,研究区域最低、最高和平均温度分别为-12℃、41℃和15.7℃,年降水量为70.7 mm,多年平均日照时数为2 806.3 h。

1.2 材料

本试验以灰枣为研究对象,供试品种树砧木均为15年生的酸枣,株行距为1.5 m×4 m,试验地水肥管理一致。每个处理通过从试验地东西南北中部各个方向选择生长状况良好、花期和长势一致的3株试验树,每株试验树选择3个枣头,于灰枣幼果期(6月中旬)进行挂牌标记,于果实膨大期(7月10日)对灰枣叶片进行人工喷施药剂处理,不同药剂、不同浓度均喷施2 L,隔10 d后(7月20日)再喷施1次,共喷施2次。

1.3 方法

1.3.1 植物生长调节剂处理 供试的植物生长调节剂有DA-6、5% AS、CSN、20% PA以及250 mg·L⁻¹ ZNC。试验共设置15个处理,以喷施清水为对照,详细配比见表1。

1.3.2 果实形态指标的测定 在果实脆熟期,每株树上挂牌标记的枝干东西南北方向随机摘取30个果实,单果质量及单核质量用电子天平(0.001)测量;枣果实纵径和横径及枣核纵径和横径使用电子游标卡尺(0.001)测量。可食率/%=(枣果实可食部分/不可食部分)×100,果形指数=果实纵径/果实横

表 1 不同处理浓度配比

Table 1 Concentration ratios for different treatments

处理 Treatment	20%苯胺胺酸 20% PA	胺鲜酯 DA-6	5%氨基寡糖素 5% AS	复硝酚钠 CSN	宛式拟青霉提取物 ZNC(250 mg·L ⁻¹)
对照 Control(CK)	清水 Water	清水 Water	清水 Water	清水 Water	清水 Water
T1	1400 倍液 1400 times liquid	20 mg·L ⁻¹	1000 倍液 1000 times liquid	15 mg·L ⁻¹	2000 倍液 2000 times
T2	1200 倍液 1200 times liquid	30 mg·L ⁻¹	800 倍液 800 times liquid	20 mg·L ⁻¹	1500 倍液 1500 times
T3	1000 倍液 1000 times liquid	40 mg·L ⁻¹	600 倍液 600 times liquid	25 mg·L ⁻¹	1000 倍液 1000 times

径,核形指数=果核纵径/果核横径。

1.3.3 果实营养物质及关键次生代谢物含量的测定 于果实脆熟期每株树上挂牌标记的枝干东西南北方向随机摘取30个果实测定果实营养物质指标:可溶性固形物含量的测定用数显糖度计;可滴定酸含量的测定采用氢氧化钠滴定法^[19];维生素C含量的测定采用钼蓝比色法^[20];可溶性糖含量的测定采用蒽酮比色法^[21];可溶性蛋白含量的测定采用考马斯亮蓝 G-250 染色法^[22],总黄酮含量的测定采用亚硝酸钠-硝酸铝-氢氧化钠比色法^[23];总酚含量的测定采用福林酚法^[24];花青素含量的测定采用紫外-可见分光光度法^[25]。

1.3.4 综合隶属函数值的计算 隶属函数法是在多指标测定的基础上客观分析评价的一种重要方法,隶属函数值越大,表明该品种的综合品质越好。通过计算不同植物生长调节剂处理下枣果实品质相关指标的隶属函数值,对各处理综合品质进行排序。

$$\text{隶属函数计算公式}^{[26]}:U(X_i)=\frac{X_i-X_{\min}}{X_{\max}-X_{\min}}。$$

式中, X_i 为各指标中第*i*个测定值; $X_{\min}$ 为各指标中的最小值; $X_{\max}$ 为各指标中的最大值。

1.4 数据处理

使用 Microsoft Excel 2020 整理数据,使用 SPSS 17.0 软件进行单因素方差分析,采用 Duncan's 多重极差检验分析样本间差异显著性($P<0.05$),用 Person 相关分析描述不同处理之间主要经济性状的相关性,用隶属函数法分析评价各个指标。

2 结果与分析

2.1 不同植物生长调节剂对灰枣果实形态指标的影响

如表2所示,所有处理的可食率范围为95.114%~97.313%,均与CK无显著差异,其中AS T1可食率最高,PA T1可食率最低。果形指数范围为1.376~1.542,各处理与对照之间并无显著差异,其中PA T3

处理果形指数最大,DA-6 T1处理果形指数最小。核形指数范围为3.184~4.207,ZNC T1核形指数最大,ZNC T3处理核形指数最小,其中,ZNC T1、CSN T2及ZNC T2处理较CK分别显著提高17.19%、16.04%和14.85%。

2.2 不同植物生长调节剂对灰枣果实品质的影响

2.2.1 不同植物生长调节剂对灰枣可溶性固形物含量的影响 由图1可知,所有处理的可溶性固形物含量范围在27.8%~35.9%,其中,DA-6 T1、DA-6 T2、AS T3、CSN T2、PA T1、PA T3处理的可溶性固形物含量高于CK,但差异不显著,CSN T2及AS T3处理含量最高,较CK增长了2.8个百分点。而PA T2、AS T2、CSN T3、ZNC T1、ZNC T3均显著低于CK,其中,CSN T3最低,为27.8%,较CK显著降低了5.3个百分点。

2.2.2 不同植物生长调节剂对灰枣果实可溶性糖含量的影响 由图2可知,AS T1、AS T3、CSN T1、CSN T2、PA T2、ZNC T2、ZNC T3处理的可溶性糖含量均显著低于CK,其中AS T1最低,为10.42%,较CK降低了5.29个百分点;而DA-6 T3、PA T1处理的可溶性糖含量较CK有一定的增长,但差异不显著,其中,DA-6 T3的可溶性糖含量最高,达到16.63%,比CK增长了0.92个百分点。

2.2.3 不同植物生长调节剂对灰枣果实可溶性蛋白含量的影响 由图3可知,DA-6 T1、DA-6 T2、AS T1、CSN T1、CSN T2、CSN T3、PA T1、PA T2、ZNC T2、ZNC T3处理的可溶性蛋白含量均显著高于CK,其中,DA-6 T2处理最高,为4.14 mg·g⁻¹,较CK显著提高了7.25%;而PA T3处理可溶性蛋白含量最低,为3.78 mg·g⁻¹,较CK显著降低了2.07%。

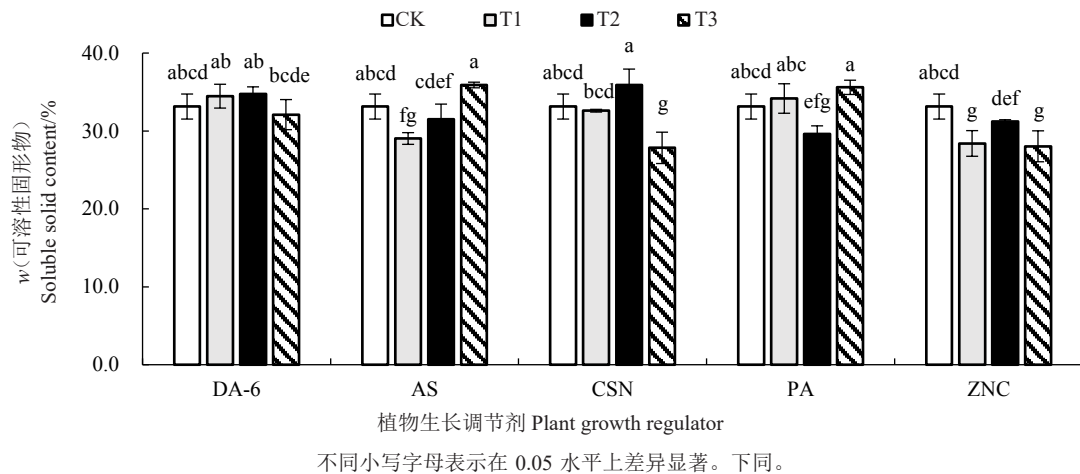
2.2.4 不同植物生长调节剂对灰枣果实维生素C含量的影响 由图4可知,除CSN T3处理的维生素C含量相较于CK无显著差异外,其他处理均显著高于CK,其中,AS T1、AS T3和ZNC T1处理的维生素C含量较高,分别为253.60、237.84、253.60 mg·100 g⁻¹,

表 2 不同植物生长调节剂对灰枣果实形态指标的影响

Table 2 Effects of different plant growth regulators on morphological indexes of Huizao fruits

处理 Treatment	果实质量 Fruit mass/g	核质量 Nuclear mass/g	可食率 Palatability/%	果实横径		果形指数 Fruit shape index	核纵径		核横径 Nuclear transverse diameter/mm	核形指数 Nuclear index
				Longitudinal diameter of fruit/mm	Transverse diameter of fruit/mm		Nuclear longitudinal diameter/mm	Nuclear transverse diameter/mm		
对照 CK	9.03 ± 1.213 de	3.19 ± 0.088 g	95.835 ± 0.924 abc	36.08 ± 1.287 bcde	24.48 ± 1.181 bc	1.476 ± 0.075 abc	18.19 ± 1.922 cd	5.09 ± 0.284 c	3.590 ± 0.471 cde	
DA-6 T1	8.24 ± 0.352 e	3.17 ± 0.083 g	96.334 ± 0.484 abc	32.90 ± 2.234 f	23.95 ± 1.716 c	1.376 ± 0.064 c	18.21 ± 1.236 cd	5.10 ± 0.423 c	3.582 ± 0.281 cde	
DA-6 T2	10.21 ± 0.298 abc	3.86 ± 0.080 c	95.450 ± 0.858 bc	35.28 ± 2.743 cde	24.99 ± 1.688 abc	1.412 ± 0.047 bc	20.56 ± 2.021 b	5.50 ± 0.502 bc	3.758 ± 0.484 abcd	
DA-6 T3	9.20 ± 0.338 cde	3.21 ± 0.086 g	95.891 ± 1.289 abc	36.05 ± 1.168 bcde	25.45 ± 1.002 abc	1.418 ± 0.077 bc	17.95 ± 2.360 d	5.45 ± 0.434 bc	3.339 ± 0.676 de	
AS T1	10.74 ± 0.929 a	2.77 ± 0.082 i	97.313 ± 0.463 a	36.18 ± 2.573 bcde	25.97 ± 2.138 ab	1.396 ± 0.066 bc	18.21 ± 2.734 cd	4.91 ± 0.621 c	3.715 ± 0.420 bcd	
AS T2	9.69 ± 0.962 bcd	3.32 ± 0.095 ef	95.356 ± 0.7 bc	35.14 ± 2.752 cde	25.09 ± 1.308 abc	1.400 ± 0.059 bc	19.44 ± 2.881 bcd	5.18 ± 0.399 c	3.765 ± 0.588 abcd	
AS T3	9.71 ± 0.844 bcd	3.67 ± 0.082 d	96.649 ± 1.145 ab	36.44 ± 1.514 bcd	25.24 ± 0.818 abc	1.446 ± 0.094 abc	20.31 ± 2.236 bc	5.30 ± 0.797 c	3.873 ± 0.458 abc	
CSN T1	9.11 ± 0.659 de	3.22 ± 0.101 g	96.587 ± 0.359 abc	34.89 ± 1.669 cdef	24.38 ± 1.013 bc	1.433 ± 0.088 abc	18.63 ± 1.311 bcd	5.35 ± 0.492 c	3.524 ± 0.526 cde	
CSN T2	8.87 ± 1.112 de	3.02 ± 0.047 h	96.273 ± 1.534 abc	36.15 ± 2.257 bcde	23.95 ± 1.877 c	1.515 ± 0.188 ab	20.36 ± 2.171 bc	4.90 ± 0.386 c	4.166 ± 0.438 ab	
CSN T3	10.78 ± 0.618 a	3.34 ± 0.106 e	96.344 ± 1.053 abc	34.22 ± 1.790 def	24.03 ± 0.985 c	1.425 ± 0.065 abc	18.73 ± 1.792 bcd	5.37 ± 0.792 c	3.519 ± 0.335 cde	
PA T1	10.30 ± 0.939 abc	4.10 ± 0.134 a	95.114 ± 0.875 c	33.95 ± 1.773 ef	24.35 ± 0.683 bc	1.396 ± 0.090 bc	20.07 ± 1.049 bcd	5.97 ± 0.593 ab	3.380 ± 0.267 cde	
PA T2	9.67 ± 0.865 bcd	3.40 ± 0.204 e	96.745 ± 0.569 ab	39.12 ± 2.215 a	26.25 ± 1.651 a	1.494 ± 0.104 abc	19.55 ± 2.260 bcd	5.10 ± 0.403 c	3.853 ± 0.485 abc	
PA T3	10.35 ± 1.087 ab	3.24 ± 0.105 fg	96.412 ± 1.672 abc	37.62 ± 2.108 ab	24.97 ± 3.724 abc	1.542 ± 0.293 a	18.91 ± 2.418 bcd	5.20 ± 0.761 c	3.684 ± 0.511 bcd	
ZNC T1	11.18 ± 1.783 a	3.68 ± 0.078 d	96.549 ± 1.419 abc	38.10 ± 3.065 ab	25.53 ± 1.650 abc	1.492 ± 0.059 abc	22.57 ± 2.795 a	5.37 ± 0.511 c	4.207 ± 0.420 a	
ZNC T2	10.96 ± 1.800 a	4.02 ± 0.084 ab	95.873 ± 0.264 abc	36.64 ± 1.840 bc	24.98 ± 1.391 abc	1.471 ± 0.110 abc	22.45 ± 2.276 a	5.48 ± 0.435 bc	4.123 ± 0.567 ab	
ZNC T3	8.94 ± 1.363 de	3.99 ± 0.100 b	95.688 ± 0.976 bc	34.93 ± 2.580 cdef	25.38 ± 1.637 abc	1.379 ± 0.112 c	19.52 ± 1.531 bcd	6.26 ± 1.012 a	3.184 ± 0.528 e	

注: 同列数据后不同小写字母表示在 0.05 水平上差异显著。
Note: Different small letters in the same column indicate significant difference at 0.05 level.



Different small letters indicate significant difference at 0.05 level. The same below.

图 1 不同植物生长调节剂处理下灰枣果肉可溶性固形物含量

Fig. 1 Soluble solids content of Huizao pulp under different plant growth regulator treatments

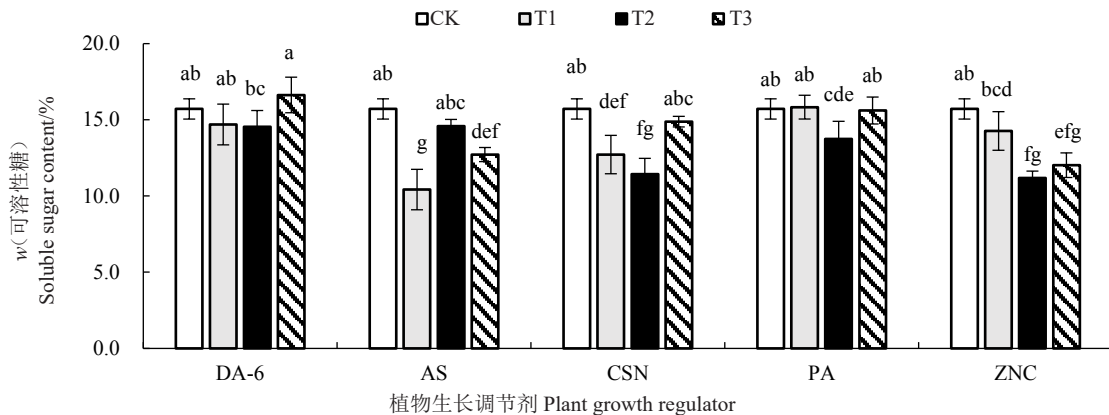


图 2 不同植物生长调节剂处理下灰枣果肉可溶性糖含量

Fig. 2 Fruit pulp soluble sugar content of Huizao under different plant growth regulator treatments

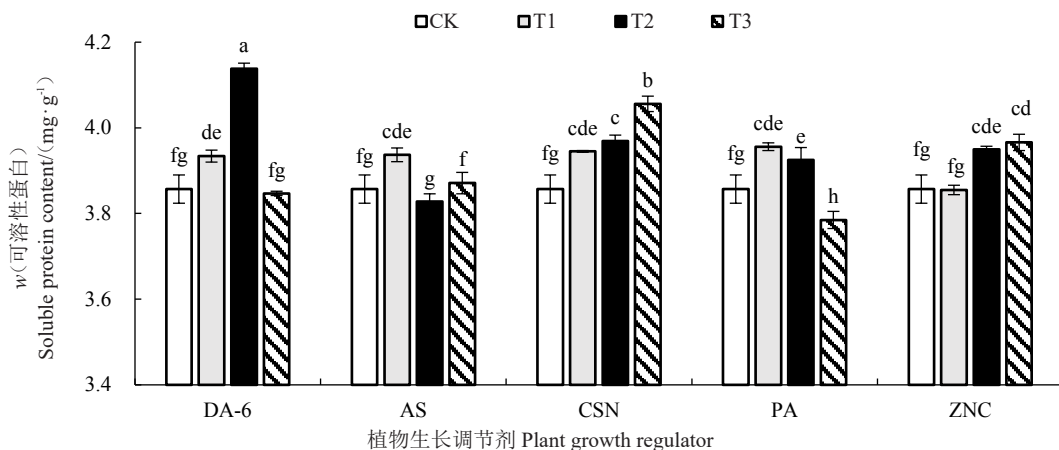


图 3 不同植物生长调节剂处理下灰枣果肉可溶性蛋白含量

Fig. 3 Fruit pulp soluble protein content of Huizao under different plant growth regulator treatments

较CK分别显著提高了88.93%、77.19%和88.93%；而CK和CSN T3处理的维生素C含量较低，分别为134.23、138.74 mg·100 g⁻¹。

2.2.5 不同植物生长调节剂对灰枣果实可滴定酸含量的影响 由图5可知，DA-6 T2和ZNC T3处理的可滴定酸含量较CK均显著提高0.05百分点，而

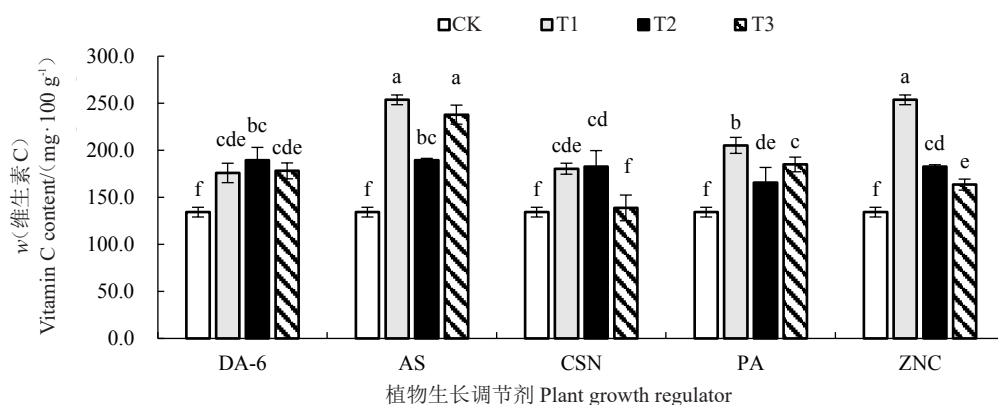


图4 不同植物生长调节剂处理下灰枣果肉维生素C含量

Fig. 4 Vitamin C content of Huizao fruit pulp under different plant growth regulator treatments

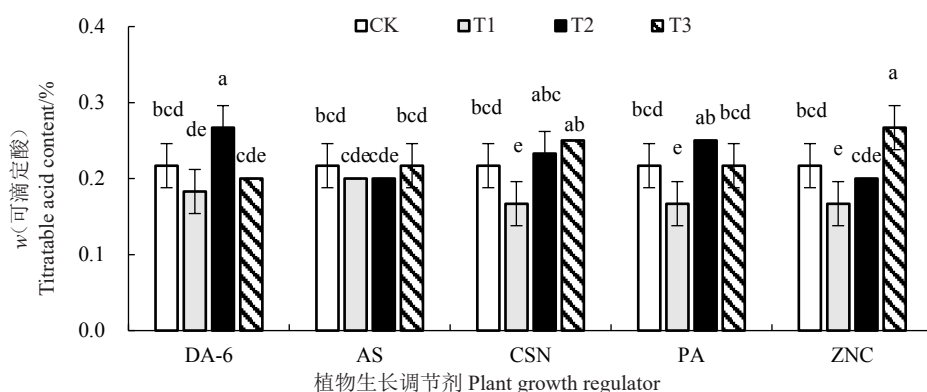


图5 不同植物生长调节剂处理下灰枣果肉可滴定酸含量

Fig. 5 Titratable acid content of Huizao pulp under different plant growth regulator treatments

CSN T1、PA T1及ZNC T1较CK均显著降低0.05百分点,其他处理与CK之间无显著差异。

2.3 不同植物生长调节剂对灰枣果实关键次生代谢物含量的影响

2.3.1 不同植物生长调节剂对灰枣果实花青素含量的影响 由图6可知,DA-6 T3、ZNC T2、ZNC T3处理的花青素含量(b,后同)均显著高于CK,分别为

1.82、1.67和3.86 $\mu\text{mol}\cdot\text{g}^{-1}$ 。其中ZNC T3处理花青素含量最高,较CK显著提高199.22%;而DA-6 T2、AS T3、CSN T3、PA T1、PA T3处理的花青素含量较CK显著降低,分别为0.94、0.88、0.71、0.87、0.85 $\mu\text{mol}\cdot\text{g}^{-1}$,其中CSN T3最低,较CK显著降低了44.96%。

2.3.2 不同植物生长调节剂对灰枣果实总酚含量的影响 由图7可知,所有样品果皮总酚含量在0.64~

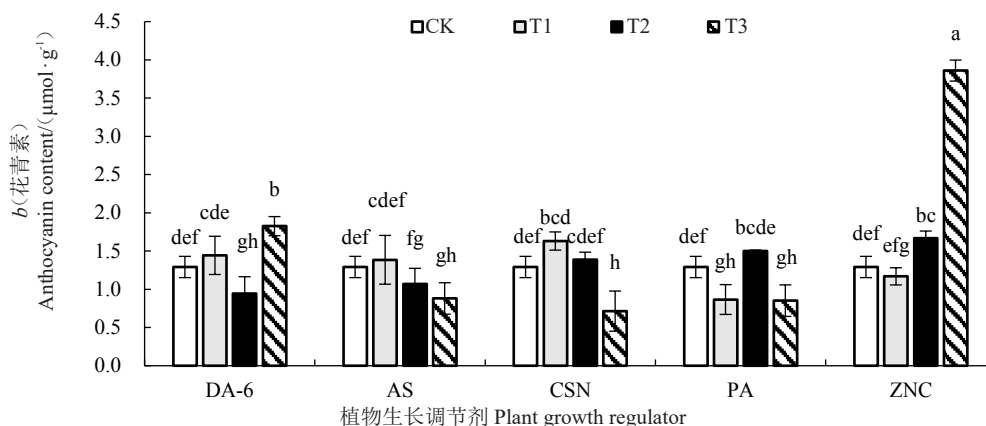


图6 不同植物生长调节剂处理下灰枣果皮花青素含量

Fig. 6 Anthocyanin content of Huizao pericarp under different plant growth regulator treatments

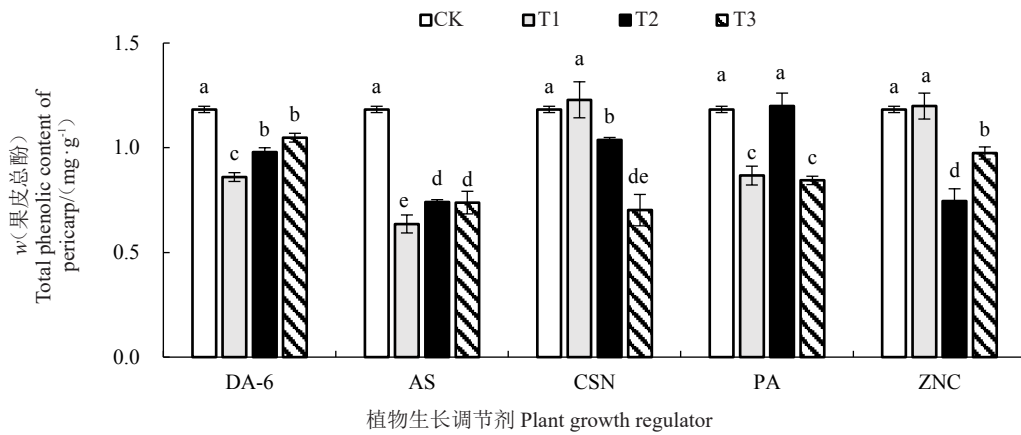


图 7 不同植物生长调节剂处理下灰枣果皮总酚含量

Fig. 7 Total phenolic content of Huizao pericarp under different plant growth regulator treatments

1.23 $\text{mg} \cdot \text{g}^{-1}$ 之间,其中,CSN T1、PA T2和ZNC T1果皮总酚含量较高,分别为1.23、1.20、1.20 $\text{mg} \cdot \text{g}^{-1}$,相较CK分别提高了4.24%、1.69%、1.69%;其他处理均比CK显著降低,其中AS T1和CSN T3处理较低,分别为0.64、0.70 $\text{mg} \cdot \text{g}^{-1}$,较CK分别显著降低了45.76%、40.68%。由图8可知,所有样品果肉总酚含量在

0.73~1.34 $\text{mg} \cdot \text{g}^{-1}$ 之间,所有处理均显著高于CK,其中,DA-6 T3处理最高,较CK显著提高了83.56%。

2.3.3 不同植物生长调节剂对灰枣果实总黄酮含量的影响 由图9可知,枣皮总黄酮含量范围为3.08~9.25 $\text{mg} \cdot \text{g}^{-1}$,DA-6 T1、DA-6 T2、AS T1、AS T3、CSN T1、CSN T2、CSN T3、PA T2、ZNC T2、ZNC T3均显

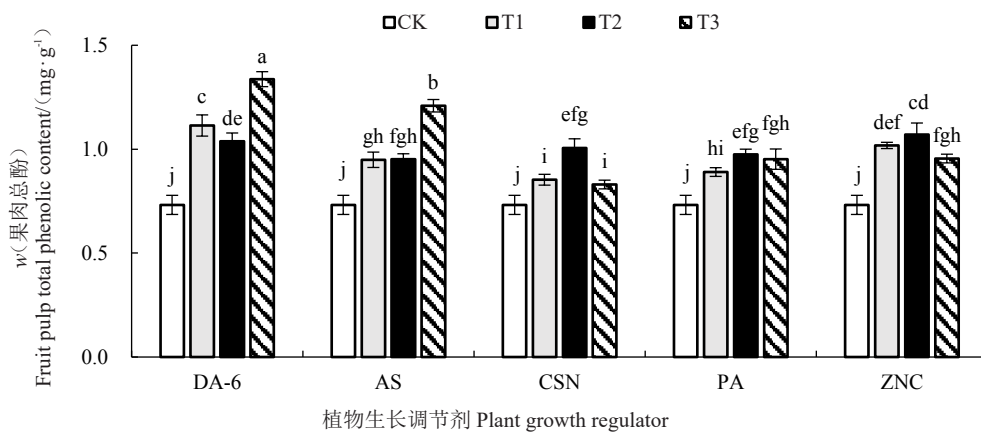


图 8 不同植物生长调节剂处理下灰枣果肉总酚含量

Fig. 8 Total phenolic content of Huizao pulp under different plant growth regulator treatments

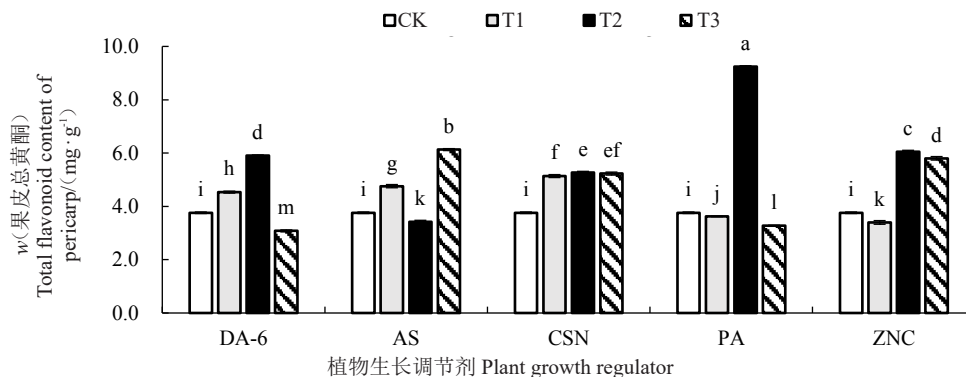


图 9 不同植物生长调节剂处理下灰枣果皮总黄酮含量

Fig. 9 Total flavonoid content of Huizao pericarp under different plant growth regulator treatments

著高于CK,其中,PA T2处理最高,为9.25 mg·g⁻¹,相较CK显著提高了146.01%,而DA-6 T3、AS T2、PA T1、PA T3、ZNC T1均显著低于CK,其中DA-6 T3最低,较CK显著降低了18.08%。枣肉总黄酮含量范围为0.51~2.52 mg·g⁻¹,其中DA-6 T1、AS T1、CSN T3、PA T3、ZNC T1相较于CK均显著降低,AS T1最低,比CK显著降低了73.16%,而DA-6 T3、AS T2、AS T3、CSN T2、PA T1、PA T2处理均显著高于CK,

AS T3处理最高,比CK显著提高了32.63%(图10)。

2.4 不同植物生长调节剂对灰枣果实品质影响的综合评价

2.4.1 灰枣果实主要经济性状之间的相关性分析
从图11中可知,灰枣果实部分性状间存在显著关联。果实横径与果实纵径、果核纵径与果核质量、果核横径与果核质量均呈极显著正相关,表明果核质量的增大往往伴随着果核纵横径的增加。而果核纵

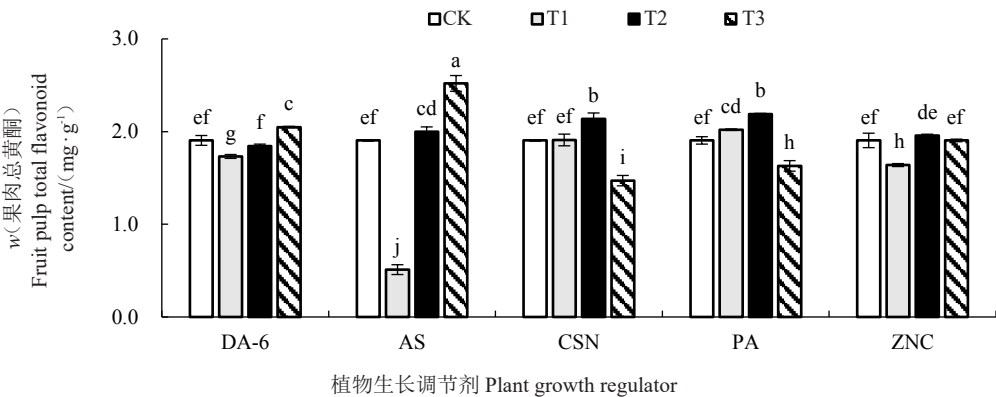
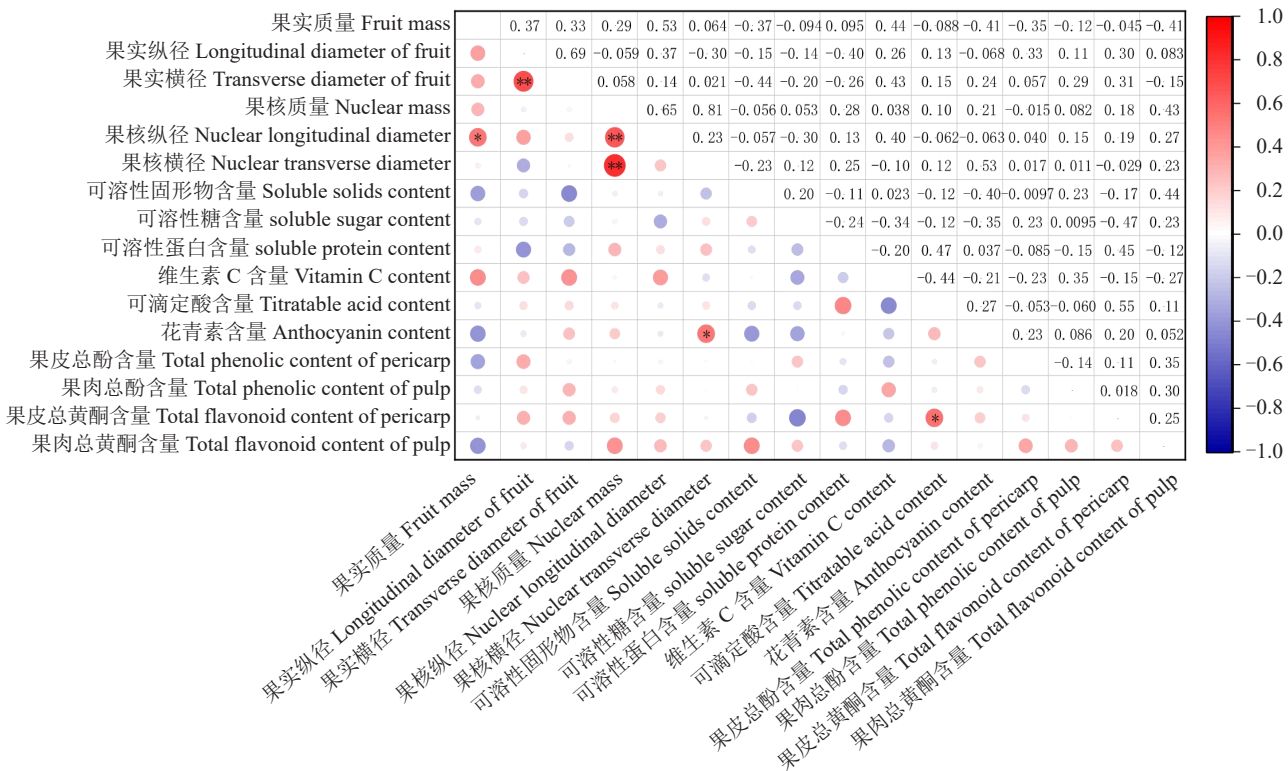


图 10 不同植物生长调节剂处理下灰枣果肉总黄酮含量
Fig. 10 Total flavonoid content of Huizao pulp under different plant growth regulator treatments



*和**分别表示显著相关(P<0.05)和极显著相关(P<0.01)。
* and ** indicate significant correlation (P<0.05) and extremely significant correlation (P<0.01), respectively.

图 11 灰枣果实主要经济性状之间的相关性分析
Fig. 11 Correlation analysis between major economic traits of Huizao fruits

径和果实质量、果核横径和花青素含量均呈显著正相关。这些相关性反映了果实各经济性状并非独立,对了解果实生长发育规律及品质形成机制有重要意义,可为果实品质改良提供理论参考。

2.4.2 基于隶属函数法的不同处理灰枣果实品质综合评价 通过计算不同处理灰枣果实品质相关指标的隶属函数值,并对综合品质进行排序。由表3可知,各处理果实品质综合隶属函数值在0.293~0.722之间,利用各指标隶属函数的均值,来对其优良性进行综合排序,其排序结果为PA T2>DA-6 T2>ZNC T2>AS T3>ZNC T3>ZNC T1>CSN T2>PA T1>DA-6 T3>PA T3>CSN T3>CK>AS T2>CSN T1>DA-6 T1>AS T1。从数据可知,不同植物生长调节剂及浓度处理对灰枣果实品质综合得分影响显著,PA T2处理得分最高(0.722),排名第一,说明此处理提升果实品质效果最佳;DA-6 T2和ZNC T2分列二、三位,也有较好效果。而AS T1处理得分最低(0.293),排名末位,对比各处理可知,并非同一种调节剂浓度越高得分越高,不同调节剂的适宜浓度存在差异,研究结果为筛选合适的植物生长调节剂及浓度提供了参考。

表3 不同植物生长调节剂处理的灰枣果实品质综合得分

Table 3 Composite score of fruit quality of Huizao with different plant growth regulators

处理 Treatment	综合得分 Aggregate score	排名 Ranking
PA T2	0.722	1
DA-6 T2	0.648	2
ZNC T2	0.618	3
AS T3	0.609	4
ZNC T3	0.571	5
ZNC T1	0.559	6
CSN T2	0.504	7
PA T1	0.501	8
DA-6 T3	0.485	9
PA T3	0.483	10
CSN T3	0.466	11
对照CK	0.461	12
AS T2	0.443	13
CSN T1	0.420	14
DA-6 T1	0.350	15
AS T1	0.293	16

3 讨 论

营养生长和生殖生长的平衡一直是果树生产中

应注意的问题^[27],植物生长调节剂是一类具有生理活性的物质,通过影响植物内源激素的平衡来起到调控植物生长发育的作用^[28]。喷施植物生长调节剂可调控果树生长发育,也可控制植株生理生化及器官形成的过程,塑造理想的个体造型和合理的群体结构,是果树生产中控制树体生长、提高果品品质的重要技术措施^[29]。研究不同处理枣果实主要经济性状之间的相关性具有重要意义,其结果可以为不同植物生长调节剂优良性评价提供理论依据。前人研究表明,喷洒适宜浓度的DA-6可提高果实质量、纵径、横径、可溶性固形物含量、可溶性总糖含量、可滴定酸含量、维生素C含量,并促进果实中某些营养物质的积累^[30]。本研究结果显示,DA-6 T3处理(胺鲜酯40 mg·L⁻¹)显著提高了枣果肉总酚含量,DA-6 T2处理(胺鲜酯30 mg·L⁻¹)显著提高了可溶性蛋白和可滴定酸含量,这与邱玉宾等^[31]的研究结果基本一致。总黄酮含量是衡量水果抗氧化能力的重要指标,具有很高的营养价值和保健药用价值^[32]。Ma等^[33]对豇豆叶面喷洒PA,发现PA正调节生长和发育,提高果实品质和产量,尤其是在200 mg·L⁻¹时表现更为优异。本试验结果显示,PA T2处理(苯胺胺酸1200倍液)显著提升了枣果实黄酮含量。这一结果与张欧等^[34]关于辣椒的研究结果有一定差异,这一现象可能是不同植物对苯胺胺酸响应机制存在差异,辣椒与枣的代谢、生理特性不同,导致促进总黄酮积累的最佳喷施浓度各异。王胤等^[35]研究了5% AS喷施黄瓜种子,结果表明,用5% AS 800倍液处理组的黄瓜种子发芽旺盛,发芽率最高,发芽势最强,黄瓜植株生长旺盛,长势良好,叶色深绿。周旭红等^[36]研究CSN对香石竹生长发育的影响,结果表明,施加0.03 g·L⁻¹ CSN对提高花的品质有一定效果。郭梅燕等^[37]在烟草不同生长期喷施ZNC,分析其诱导烟草抗病效果及对烟草生长发育的影响,结果表明,50 ng·mL⁻¹和500 ng·mL⁻¹处理较CK增产较多。本试验研究发现,灰枣果实在AS 600倍液和AS 1000倍液处理下,分别对可溶性固形物和维生素C积累有良好的促进作用,在ZNC 2000倍液处理下,维生素C含量有较高的提升作用。

隶属函数是一种广泛应用于多标准决策的综合评价方法,可以避免单一指标对试验评价结果的偏差^[38]。试验结果表明,不同植物生长调节剂及浓度处理对灰枣果实品质均有一定的调控作用,多数呈

现促进效果。其中,PA T2处理综合得分最高(0.722),提升果实品质效果最佳,DA-6 T2和ZNC T2也有较好表现。总体而言,PA系列处理对果实品质产生了较为明显的正面影响。笔者在本研究仅采用5种植物生长调节剂的有限浓度梯度进行试验,存在一定的不足之处,如不同浓度的AS、CSN等调节剂处理效果有待深入探究。后续研究会增加调节剂种类,设置更精细的浓度梯度试验,综合研究其对果实营养成分、口感等方面的影响,以确定提升灰枣果实品质的最佳调节剂及浓度。

4 结 论

综上所述,5种植物生长调节剂的综合处理效果为PA T2>DA-6 T2>ZNC T2,其中PA T2处理效果最好,显著提升果实总黄酮含量等指标;DA-6 T2(胺鲜酯30 mg·L⁻¹)次之。建议在灰枣生产中选用PA T2处理,以提高灰枣果实品质。

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