

# NaCl胁迫对番茄嫁接苗根系多胺含量的影响

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**摘要:** 以耐盐番茄品种‘影武者’为砧木, ‘宝大 903’为接穗, 研究了  $100 \text{ mmol} \cdot \text{L}^{-1}$  NaCl胁迫 10 d条件下, 嫁接苗与自根苗生长和根系不同形态(游离态、结合态和束缚态)多胺含量的变化。结果表明: 嫁接苗的生物量显著高于自根苗; 在整个胁迫期内嫁接苗根系 3种形态的腐胺和精胺含量呈上升趋势, 3种形态的亚精胺含量呈下降趋势; 自根苗根系游离态和结合态精胺含量在胁迫第 6天达到峰值后下降; 束缚态精胺含量变化不明显, 3种形态的腐胺、亚精胺含量在整个胁迫期内呈下降趋势。以上结果表明, 腐胺和精胺在番茄嫁接苗根系耐盐性方面发挥着重要作用。

**关键词:** 番茄; NaCl胁迫; 嫁接; 多胺

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## Effects of NaCl Stress on Contents of Polyamines in Roots of Grafted Tomato Seedlings

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**Abstract:** Using Kagemusya (*Lycopersicon esculentum* Mill.), a salt tolerant cultivar, as rootstock and Baoda 903 as scion, grafting was made to compare the differences in plant growth and contents of different forms (free, conjugated and bound) of polyamines between grafted and own-rooted tomato seedlings under  $100 \text{ mmol} \cdot \text{L}^{-1}$  NaCl stress for 10 days. The results showed that the biomass production in grafted seedlings was significantly higher than that of own-rooted seedlings. The contents of three forms of putrescine (Put) and spermine (Spm) in roots of grafted seedlings increased significantly during NaCl treatment, while the contents of three forms of spermidine (Spd) decreased continuously. The contents of free and conjugated Spm in roots of own-rooted seedlings reached the highest value on the 6th day of treatment and then decreased slowly. No significant difference was observed in bound Spm. The contents of three forms of Put and Spd decreased significantly during NaCl treatment. These results indicated that the Put and Spd played important roles in the roots of grafted tomato seedlings for salt tolerance.

**Key words:** Tomato; NaCl stress; Grafting; Polyamines

多胺 (Polyamines, PAs) 是近年来研究较多的一种植物生长发育调节物质, 广泛分布于植物体内, 在植物生长发育以及对环境的应激反应中发挥重要作用。在植物体内多胺主要以游离态、结合态和束缚态 3种形式存在。当植物遭受非生物逆境时, 不同种类、不同形态的多胺相互转化, 从而改变植物的抗逆性。近年来, 我国设施土壤次生盐渍化现象日益严重, 嫁接栽培成为克服设施土壤次生盐渍化的一条有效措施。陈淑芳等 (2006) 报道了番茄嫁接苗和自根苗叶片游离态多胺含量的变化与耐盐性的关系。但尚不清楚根系内不同形态多胺含量的变化与嫁接番茄耐盐性之间的关系。作者以番

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茄嫁接苗和自根苗为试材, 研究 NaCl胁迫下, 两者根系内 3种形态多胺含量的变化, 以进一步探明不同形态多胺在嫁接番茄耐盐性方面所起的作用。

## 1 材料与方法

供试的番茄 (*Lycopersicon esculentum* Mill) 砧木是日本设施栽培专用的耐盐品种‘影武者’, 接穗为‘宝大 903’。嫁接与嫁接苗的培育按陈淑芳等 (2005) 报道的方法进行。当幼苗具有 8~9片真叶时进行 NaCl胁迫处理。为防止盐激, 开始处理浓度为  $50 \text{ mmol} \cdot \text{L}^{-1}$ , NaCl直接溶于 1/4 浓度日本园试营养液中 (EC值为  $4.85 \text{ dS} \cdot \text{m}^{-1}$ ), 2 d后浓度增到  $100 \text{ mmol} \cdot \text{L}^{-1}$  (EC值为  $8.76 \text{ dS} \cdot \text{m}^{-1}$ ), 此时定为 NaCl胁迫处理开始, 处理时间持续 10 d。设 4种处理: 营养液栽培自根苗, 营养液栽培自根苗 +NaCl, 营养液栽培嫁接苗, 营养液栽培嫁接苗 +NaCl。每处理 7株, 3次重复, 在温室内随机排列。

生物量的测定: NaCl处理后第 10天, 分别收集地上部和地下部, 称其鲜质量, 之后放入烘箱 105 杀酶 15 min, 再在 75 下烘至恒重, 称其干质量。多胺的提取按 Song等 (2002) 的方法进行。用 Shimadzu LC-10AT型高效液相色谱仪进行多胺含量的测定。数据用 SAS软件进行方差分析, 并对平均数用邓肯氏新复极差法进行多重比较。

## 2 结果分析与讨论

### 2.1 NaCl胁迫对番茄嫁接苗和自根苗生物量的影响

由表 1可知, NaCl胁迫对番茄嫁接苗和自根苗的生长均产生显著的抑制作用。但嫁接苗地上部鲜质量和干质量分别是自根苗的 1.45和 1.64倍, 地下部鲜质量和干质量分别是自根苗的 1.59和 1.84倍, 说明嫁接苗在 NaCl胁迫下生长受抑制的程度较小, 对盐胁迫的适应性强于自根苗。另外, NaCl胁迫后, 嫁接苗根系的丙二醛含量 (数据未给出) 也显著低于自根苗, 进一步证实嫁接苗的耐盐性强于自根苗。

表 1 NaCl胁迫下番茄嫁接苗和自根苗生物量的比较

Table 1 Comparison of biomass production between grafted and own-rooted tomato seedlings under NaCl stress

处理 Treatment	鲜质量 Fresh mass (g)		干质量 Dry mass (g)		根冠比 Root/Shoot ratio
	地上部 Shoot	地下部 Root	地上部 Shoot	地下部 Root	
自根苗对照 Own-rooted control	100.33 ± 6.09b	34.14 ± 3.68b	9.47 ± 0.77b	1.99 ± 0.13c	0.21 ± 0.02c
自根苗 + NaCl Own-rooted + NaCl	60.51 ± 5.61d	22.05 ± 2.37c	6.08 ± 0.82c	1.47 ± 0.06d	0.24 ± 0.01b
嫁接苗对照 Grafted control	133.29 ± 6.42a	48.03 ± 2.05a	13.27 ± 1.21a	3.06 ± 0.18a	0.23 ± 0.02bc
嫁接苗 + NaCl Grafted + NaCl	87.67 ± 4.56c	36.25 ± 3.51b	9.67 ± 0.56b	2.70 ± 0.09b	0.28 ± 0.02a

注: 同列数值不同字母表示差异达 5%显著水平。下同。

Note: Different letters within the same column indicate significant difference at 5% level. The same below.

### 2.2 NaCl胁迫对番茄嫁接苗和自根苗根系游离态多胺含量的影响

由表 2可知, 在游离态腐胺含量方面, NaCl胁迫前, 嫁接苗含量显著低于自根苗; NaCl胁迫后, 自根苗含量下降, 而嫁接苗上升。自根苗与自根苗相比, 从胁迫第 2天起胁迫处理显著低于对照; 嫁接苗与嫁接苗相比, 从第 2天起胁迫处理显著高于对照; 胁迫处理中嫁接苗与自根苗相比, 处理前期 (0、2 d), 嫁接苗显著低于自根苗, 从第 4天起嫁接苗显著高于自根苗。在游离态亚精胺含量方面, 未经 NaCl胁迫时, 嫁接苗显著低于自根苗; NaCl胁迫后, 嫁接苗和自根苗含量均显著下降, 但嫁接苗下降的幅度小于自根苗, 两者均从胁迫第 2天起显著低于对照; 胁迫处理中嫁接苗与自根苗相比, 均是嫁接苗显著低于自根苗。在游离态精胺含量方面, NaCl胁迫前, 嫁接苗与自根苗差异不显著; NaCl胁迫后, 自根苗含量在处理 6 d内上升, 第 8天开始缓慢下降, 而嫁接苗则保持上升。两者均

从胁迫第 2 天起显著高于对照; 胁迫处理中嫁接苗与自根苗相比, 胁迫前期 (0、2、4 d), 两者差异不显著, 胁迫后期 (6、8、10 d), 嫁接苗显著高于自根苗。

表 2 NaCl胁迫下番茄嫁接苗和自根苗根系游离态多胺含量的比较

Table 2 Comparison of free polyamine contents in roots between grafted and own-rooted tomato

seedlings under NaCl stress		(nmol · g <sup>-1</sup> FM)		
天数 Days (d)	处理 Treatment	腐胺 Putrescine	亚精胺 Spermidine	精胺 Spermine
0	自根苗对照 Own-rooted control	279.42 ± 2.93a	288.22 ± 1.88a	50.54 ± 2.11a
	自根苗 + NaCl Own-rooted + NaCl	281.41 ± 4.45a	273.98 ± 7.35a	52.48 ± 2.37a
	嫁接苗对照 Grafted control	244.71 ± 9.46b	215.28 ± 4.44b	51.93 ± 1.09a
	嫁接苗 + NaCl Grafted + NaCl	250.52 ± 9.77b	220.03 ± 3.75b	53.98 ± 1.77a
2	自根苗对照 Own-rooted control	287.71 ± 4.51a	297.20 ± 7.13a	45.48 ± 1.66b
	自根苗 + NaCl Own-rooted + NaCl	273.95 ± 3.87b	259.98 ± 3.17b	58.71 ± 2.28a
	嫁接苗对照 Grafted control	237.05 ± 3.44d	224.15 ± 5.03c	50.13 ± 1.76b
	嫁接苗 + NaCl Grafted + NaCl	255.08 ± 6.08c	210.93 ± 3.80d	57.85 ± 1.56a
4	自根苗对照 Own-rooted control	281.34 ± 6.39a	297.15 ± 5.84a	52.27 ± 1.55b
	自根苗 + NaCl Own-rooted + NaCl	253.56 ± 3.21b	242.11 ± 6.22b	66.03 ± 1.46a
	嫁接苗对照 Grafted control	239.95 ± 7.55b	232.00 ± 4.32b	56.28 ± 2.64b
	嫁接苗 + NaCl Grafted + NaCl	269.00 ± 3.36a	195.92 ± 7.00c	68.32 ± 1.49a
6	自根苗对照 Own-rooted control	292.62 ± 3.08a	289.84 ± 4.58a	43.28 ± 1.50c
	自根苗 + NaCl Own-rooted + NaCl	237.72 ± 3.81c	220.86 ± 4.54b	75.59 ± 1.96b
	嫁接苗对照 Grafted control	251.75 ± 5.84b	216.82 ± 5.68b	47.33 ± 1.79c
	嫁接苗 + NaCl Grafted + NaCl	286.47 ± 1.86a	177.59 ± 2.35c	79.49 ± 1.92a
8	自根苗对照 Own-rooted control	289.58 ± 2.56a	290.66 ± 3.41a	46.44 ± 1.15c
	自根苗 + NaCl Own-rooted + NaCl	222.81 ± 5.38c	200.35 ± 6.50c	70.93 ± 2.35b
	嫁接苗对照 Grafted control	247.37 ± 5.75b	220.45 ± 7.73b	51.78 ± 1.15c
	嫁接苗 + NaCl Grafted + NaCl	296.51 ± 3.99a	164.29 ± 5.36d	87.49 ± 2.90a
10	自根苗对照 Own-rooted control	277.26 ± 4.83b	282.46 ± 7.76a	50.05 ± 1.53c
	自根苗 + NaCl Own-rooted + NaCl	209.05 ± 3.17d	186.19 ± 5.93c	60.59 ± 1.58b
	嫁接苗对照 Grafted control	242.31 ± 9.02c	222.37 ± 5.67b	48.47 ± 0.92c
	嫁接苗 + NaCl Grafted + NaCl	310.30 ± 7.70a	148.55 ± 6.52d	95.82 ± 3.07a

注: 统计分析是在同一天数内分别进行的。下同。

Note: Statistic analyses were carried out in the same day respectively. The same below.

### 2.3 NaCl胁迫对番茄嫁接苗和自根苗根系结合态和束缚态多胺含量的影响

如表 3 所示, NaCl胁迫后, 结合态多胺的变化趋势与游离态多胺的变化趋势一致, 只是在亚精胺含量方面, 未经 NaCl胁迫时, 嫁接苗游离态亚精胺含量显著低于自根苗, 而两者结合态亚精胺含量差异不显著。NaCl胁迫后, 束缚态腐胺和亚精胺的变化趋势与游离态腐胺和亚精胺的变化趋势一致。在束缚态精胺含量方面, NaCl胁迫前, 嫁接苗显著高于自根苗; NaCl胁迫后, 自根苗含量基本不变, 而嫁接苗缓慢上升, 嫁接苗与嫁接苗相比, 从第 6 天起胁迫处理显著高于对照, 胁迫处理中嫁接苗与自根苗相比, 均是嫁接苗显著高于自根苗。

多胺是一类具有强烈生理活性的低分子量脂肪族含氮碱, 参与植物体对逆境的响应。有研究表明, 游离态腐胺和精胺在植物耐盐性方面发挥重要作用 (Katiyar & Dubey, 1990)。本试验中 (表 2), NaCl胁迫期间, 番茄自根苗根系的游离态腐胺含量下降, 游离态精胺含量在胁迫前期 (0~4 d) 上升, 后期 (6~10 d) 下降; 而嫁接苗两者含量持续上升, 并且其生物量积累显著高于自根苗, 表明嫁接苗受到的伤害较小, 游离态腐胺和精胺含量的上升有利于番茄耐盐性的提高。生理 pH 条件下, 游离态多胺能与细胞中的阴离子如 DNA、膜磷脂以及细胞壁等组分通过共价键以及非共价结合, 对 DNA 的复制、转录以及生物膜功能稳定性的维持起重要作用 (Liu et al, 2004)。盐胁迫后, 游离态多胺向结合态和束缚态多胺的转化对植物耐盐性的提高具有十分重要的作用。本研究结果表明, NaCl胁迫后, 嫁接苗根系结合态、束缚态腐胺和精胺含量上升 (表 3), 表明游离态腐胺和精胺向结

合态、束缚态的转化增强。其生物量积累显著高于自根苗,表明游离态腐胺和精胺向结合态、束缚态的转化有利于提高番茄的耐盐性。

综上所述,盐胁迫后,番茄嫁接苗生物量积累显著高于自根苗,其根系3种形态的腐胺、精胺含量持续上升,表明腐胺和精胺在番茄嫁接苗根系耐盐性方面发挥重要作用。

表3 NaCl胁迫下番茄嫁接苗和自根苗根系结合态和束缚态多胺含量的比较

Table 3 Comparison of conjugated and bound polyamine contents in roots between grafted and own-rooted tomato seedlings under NaCl stress (nmol · g<sup>-1</sup> FM)

天数 Days (d)	处理 Treatment	结合态 Conjugated form			束缚态 Bound form		
		腐胺 Putrescine form	亚精胺 Spermidine	精胺 Spermine	腐胺 Putrescine	亚精胺 Spermidine	精胺 Spermine
0	自根苗对照 Own-rooted control	313.30 ±5.33a	209.70 ±7.05a	45.57 ±2.21a	803.22 ±12.93a	197.20 ±7.31b	71.45 ±4.96b
	自根苗 +NaCl Own-rooted +NaCl	308.23 ±7.45a	208.89 ±5.43a	50.70 ±1.96a	795.23 ±12.45a	193.23 ±6.78b	69.67 ±4.97b
	嫁接苗对照 Grafted control	264.33 ±7.90b	204.60 ±5.35a	46.70 ±0.48a	713.98 ±8.86b	237.13 ±5.77a	86.53 ±3.12a
	嫁接苗 +NaCl Grafted +NaCl	250.04 ±4.69b	210.85 ±8.62a	52.49 ±1.38a	716.29 ±9.10b	230.51 ±9.99a	86.39 ±4.62a
2	自根苗对照 Own-rooted control	297.28 ±7.41a	213.14 ±5.97a	55.76 ±1.65b	795.79 ±12.38a	188.71 ±8.29b	67.58 ±2.96b
	自根苗 +NaCl Own-rooted +NaCl	289.69 ±5.96a	191.42 ±5.69b	57.86 ±1.71ab	786.22 ±8.87a	185.66 ±9.47b	71.75 ±3.80b
	嫁接苗对照 Grafted control	254.80 ±5.88b	206.38 ±6.69a	53.77 ±2.00b	709.73 ±10.93b	225.12 ±5.80a	93.22 ±4.58a
	嫁接苗 +NaCl Grafted +NaCl	263.43 ±6.80b	196.38 ±5.75b	60.15 ±1.97a	723.08 ±10.20b	223.31 ±5.69a	87.62 ±3.64a
4	自根苗对照 Own-rooted control	308.23 ±9.94a	207.17 ±4.62a	52.02 ±1.66b	810.01 ±13.07a	205.51 ±8.76b	70.61 ±3.80b
	自根苗 +NaCl Own-rooted +NaCl	267.80 ±5.17b	169.60 ±3.81c	57.03 ±1.77a	773.90 ±6.86b	173.36 ±9.28c	74.72 ±3.32b
	嫁接苗对照 Grafted control	250.27 ±8.60c	210.61 ±4.16a	49.33 ±1.27b	723.08 ±7.57c	239.33 ±5.24a	88.01 ±5.12a
	嫁接苗 +NaCl Grafted +NaCl	281.07 ±8.89b	178.24 ±5.54b	72.21 ±1.55a	733.48 ±9.69c	213.37 ±8.70b	90.41 ±5.48a
6	自根苗对照 Own-rooted control	319.06 ±5.56a	218.13 ±5.04a	46.77 ±2.07c	792.06 ±12.78a	207.37 ±6.79b	66.37 ±4.94c
	自根苗 +NaCl Own-rooted +NaCl	253.42 ±6.43d	143.68 ±4.02c	76.67 ±1.89b	754.45 ±8.11b	164.73 ±3.36c	71.75 ±3.80c
	嫁接苗对照 Grafted control	272.91 ±5.20c	214.52 ±5.75a	52.03 ±1.63c	710.63 ±12.71c	244.85 ±5.16a	91.89 ±3.78b
	嫁接苗 +NaCl Grafted +NaCl	291.95 ±7.12b	161.30 ±4.75b	88.01 ±3.01a	746.75 ±8.83b	203.34 ±6.56b	98.68 ±4.82a
8	自根苗对照 Own-rooted control	307.96 ±8.67a	221.36 ±5.83a	54.36 ±2.11c	809.49 ±17.12a	202.89 ±5.80b	63.82 ±3.89c
	自根苗 +NaCl Own-rooted +NaCl	234.87 ±5.75c	118.98 ±3.85c	70.33 ±1.64b	733.23 ±12.38c	150.25 ±8.22d	73.76 ±2.79c
	嫁接苗对照 Grafted control	269.11 ±9.82b	212.42 ±5.24a	56.31 ±2.57c	705.94 ±13.37d	222.73 ±9.05a	95.31 ±5.23b
	嫁接苗 +NaCl Grafted +NaCl	305.58 ±4.82a	141.66 ±4.22b	100.42 ±2.94a	754.58 ±8.35b	187.25 ±7.83c	104.88 ±1.43a
10	自根苗对照 Own-rooted control	315.44 ±4.61a	223.10 ±5.97a	50.69 ±2.51c	806.18 ±9.13a	199.85 ±9.13b	77.69 ±4.34c
	自根苗 +NaCl Own-rooted +NaCl	216.74 ±3.58c	99.54 ±2.96c	70.93 ±1.69b	706.81 ±14.35c	132.14 ±7.81d	83.94 ±4.60bc
	嫁接苗对照 Grafted control	259.57 ±6.08b	220.83 ±6.98a	54.44 ±2.83c	716.83 ±14.25c	242.31 ±5.93a	82.94 ±2.04b
	嫁接苗 +NaCl Grafted +NaCl	323.59 ±5.86a	116.77 ±3.69b	108.59 ±3.59a	770.30 ±3.86b	174.91 ±5.29c	114.20 ±2.88a

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