

# 草莓组培生根微环境对幼苗移栽后生理特性的影响

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**摘要:** 研究了草莓组培苗生根阶段微环境对其移栽驯化过程中生长和生理的影响。未生根的草莓苗在3%蔗糖或无糖培养基中诱导生根, 同时分别给予( $60 \pm 10$ )和( $150 \pm 10$ ) $\mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ 两种光照及( $350 \pm 20$ )和( $700 \pm 20$ ) $\mu\text{L} \cdot \text{L}^{-1}$ 两种 $\text{CO}_2$ 浓度, 培养20 d后移至温室驯化。结果表明, 3%蔗糖有利于植株生物量的形成, 提高光照和 $\text{CO}_2$ 浓度, 进一步促进其生长。较高光照降低了叶绿素含量, 而类胡萝卜素的相对含量有所提高。蔗糖的提供在未增加 $\text{CO}_2$ 的条件下对移栽植株的光合有轻微负影响。各处理移栽苗均未表现出明显的光抑制,  $\Phi_{\text{PSII}}$ 呈上升趋势。移栽后各处理间的差异随驯化时间延长而减小。

**关键词:** 草莓; 组织培养; 微环境; 光合自养; 光合异养

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## 1 目的、材料与方法

有研究表明, 改变组培微环境使其更接近自养条件, 有利于移栽的试管苗加速驯化<sup>[1]</sup>。也有研究指出移栽时是否有积极的光合并不是首要的, 而试管苗在培养阶段积累的营养是否能维持移栽初期的消耗才是关键<sup>[2]</sup>。本试验以脱毒快繁的草莓组培苗为材料, 通过改变组培微环境中光照强度和 $\text{CO}_2$ 浓度, 并结合培养基中蔗糖的添加与否, 研究其对驯化移栽过程中植株生长和光合生理的影响。

试验于2002年4~6月在浙江大学园艺系进行, 试验重复2次。未生根的草莓组培苗(株高 $1.1 \text{ cm} \pm 0.1 \text{ cm}$ , 3~4片叶, ‘丰香’品种)分别转接到添加3%蔗糖和无蔗糖的MS生根培养基上, 并设置光照强度( $60 \pm 10$ )、( $150 \pm 10$ ) $\mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ 和 $\text{CO}_2$ 浓度( $350 \pm 20$ )、( $700 \pm 20$ ) $\mu\text{L} \cdot \text{L}^{-1}$ , 共8个处理。培养容器采用带滤纸的透气膜封口, 光照由生物镝灯调节高度控制,  $\text{CO}_2$ 浓度由置于玻璃培养箱<sup>[3]</sup>中的碳酸缓冲液( $2 \text{ mol} \cdot \text{L}^{-1}$ )提供<sup>[4]</sup>。生根时温度为( $25 \pm 2$ )/( $18 \pm 2$ )℃, 光照14 h, 环境相对湿度80%。生根培养20 d后各处理分别取大小一致的苗50株, 移栽到消毒过的栽培基质中, 于温室内驯化。于移栽当时和移后30 d随机取样5株测定生长形态指标。驯化过程中光合、荧光参数及色素含量测定时选取各处理叶龄相当的叶片进行。光合速率用氧电极(Clark电极)法<sup>[5]</sup>测定。叶绿素荧光参数(最大光化学效率 $F_v/F_m$ , PSII电子传递量子效率 $\Phi_{\text{PSII}}$ 和光化学猝灭系数 $q_p$ )由FMS2型荧光仪(英国Hansatech公司)测定<sup>[6]</sup>。色素含量采用丙酮-乙醇混合液法<sup>[7]</sup>测定。测定重复4次。

## 2 结果与分析

### 2.1 生根阶段蔗糖、 $\text{CO}_2$ 浓度和光强对草莓组培苗移栽后生长的影响

在不同的组培环境中生根培养20 d后移栽, 各处理移栽成活率均可达95%以上。如表1所示, 移栽当时处理8和7的植株生长较好。3%蔗糖处理, 植株干物质含量高, 根系生长也较发达。而 $\text{CO}_2$ 对株高的影响尤为明显。增加光照同时提高 $\text{CO}_2$ 浓度对生长势有显著的促进效应。移栽30 d后, 植株生长势上的差异有所减小。 $\text{CO}_2$ 处理的植株生长优于有蔗糖供应的处理, 反应出改进组培微环境(不加糖)提高了组培苗光合自养能力, 促进移栽后生长。

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表 1 生根阶段蔗糖、CO<sub>2</sub>浓度和光强对草莓组培苗生长的影响

Table 1 Effects of sucrose supply and CO<sub>2</sub> concentration and light intensity during in vitro rooting  
on morphological characteristics of strawberry plantlets

处 理 Treatment	光照强度 PPED (μmol·m <sup>-2</sup> ·s <sup>-1</sup> )	蔗糖 Sucrose (%)	CO <sub>2</sub> (μL·L <sup>-1</sup> )	鲜样质量 Fresh mass (g)		干物质含量 Dry matter percentage (%)		根 长 Root length (cm)		株 高 Height (cm)		叶 数 Number of leaves	
				0 d	30 d	0 d	30 d	0 d	30 d	0 d	30 d	0 d	30 d
1	60 ± 10	0	350 ± 20	0.15 d	0.66 d	7.60 d	13.91 c	1.6 b	8.8 b	2.1 e	4.75 c	4.0 c	6.1 c
2	60 ± 10	3	350 ± 20	0.20 cd	0.85 cd	10.62 ab	15.62 bc	2.8 a	9.7 b	2.3 de	7.1 b	5.3 abc	6.3 c
3	60 ± 10	0	700 ± 20	0.16 cd	1.26 b	7.74 cd	17.15 abc	2.4 ab	10.9 ab	2.6 de	8.7 ab	5.0 bc	6.5 bc
4	60 ± 10	3	700 ± 20	0.36 b	1.30 ab	10.76 a	18.25 ab	3.1 a	11.1 ab	3.1 bc	8.8 ab	7.0 a	7.1 abc
5	150 ± 10	0	350 ± 20	0.28 c	1.29 ab	7.34 d	18.13 ab	2.9 a	10.5 ab	2.5 de	8.6 ab	5.7 abc	7.3 abc
6	150 ± 10	3	350 ± 20	0.34 b	1.23 bc	10.45 ab	17.89 ab	2.9 a	9.80 b	2.8 cd	9.02 ab	6.3 ab	7.9 ab
7	150 ± 10	0	700 ± 20	0.37 b	1.35 a	9.18 bc	19.24 a	2.5 ab	12.8 a	3.7 ab	9.25 a	6.5 ab	8.2 a
8	150 ± 10	3	700 ± 20	0.53 a	1.54 a	11.39 a	19.92 a	2.8 a	11.3 ab	4.2 a	9.25 a	6.6 ab	8.3 a

注: 根据 LSD 法分析, 表中数字后的字母表示差异显著性 ( $P = 0.05$ ), 含相同字母表示处理间无显著差异。

Note: According to LSD test, in the same column the treatment followed by different letter means significant difference at 0.05 level.

## 2.2 生根阶段蔗糖、CO<sub>2</sub>浓度和光强对草莓组培苗移栽后叶片色素含量的影响

如图 1 所示, 低光下培养的植株叶绿素含量较高, 并以增施 CO<sub>2</sub> 的处理 3 最高, 有蔗糖供应同时增施 CO<sub>2</sub> 的次之。移栽 15 d 后除处理 3 外, 其他处理叶绿素含量增加, 各处理间无差异。叶片中叶绿素与类胡萝卜素的比值在移栽时以高光下培养的略低, 即类胡萝卜素的相对含量较高, 特别是处理 5 的植株。类胡萝卜素对光氧化的破坏可起到保护功能<sup>[10]</sup>, 相对含量的提高在一定程度反映出光合机构对不同光环境的适应调节。移栽 15 d 后, 各处理间无显著差异。

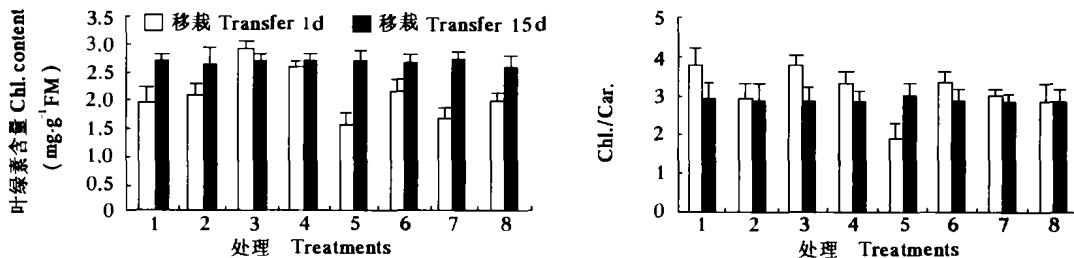


图 1 生根阶段蔗糖、CO<sub>2</sub>浓度和光强处理对草莓组培苗叶绿素含量和类胡萝卜素含量的影响  
处理见表 1。

Fig. 1 Effects of sucrose supply and CO<sub>2</sub> concentration and light intensity during in vitro rooting  
on the contents of chlorophylls and carotenoids of strawberry plantlets

The treatments in this figure are the same as in table 1.

## 2.3 生根阶段蔗糖、CO<sub>2</sub>浓度和光强对草莓组培苗移栽过程中光合速率及叶绿素荧光参数的影响

图 2 表明, 草莓苗在移栽时即具有较高的光合能力, 高光处理的植株  $\Phi_{PSII}$  和净光合速率均略高于低光下相应的处理。添加蔗糖对  $\Phi_{PSII}$  和光合速率呈轻微的负影响。无糖培养的植株其光合在移栽后出现轻微的下降, 而蔗糖处理未出现。说明蔗糖在组培时虽然对光合有一定的负面影响, 但在移栽后却可降低组培苗对环境的敏感性。适宜的蔗糖供应可能保证了植株多种保护和修复机制的运作。同样光照条件下, 增加 CO<sub>2</sub> 可有效提高光合电子传递的量子效率, 增加净光合速率。移栽初期, 植株光合速率的提高与光合电子传递之间并不表现正相关, 这可能关系到气孔因素的影响。移栽驯化后期各处理间差异不明显。生根阶段不同处理对移栽驯化过程中 Fv/Fm 和 q<sub>p</sub> 的影响不显著, 各处理之间无显著差异, 这可能与植株在生根培养阶段已发展了较好的光合机构, 且在移栽后未遭遇强光有关。

我们认为, 适当提高光照和 CO<sub>2</sub> 浓度可促进组培苗生长, 缩短生根培养时间及驯化过程。虽然组培微环境适宜时蔗糖并非必要, 但考虑到能耗因素, 添加少量蔗糖仍是促进组培苗生长的方法之一。

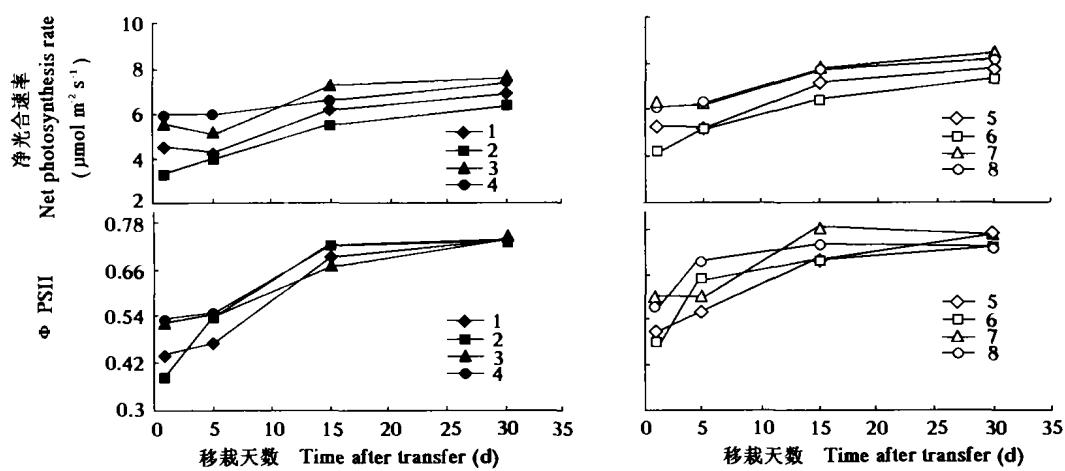
图2 生根阶段蔗糖、CO<sub>2</sub>浓度和光强处理对草莓组培苗移栽过程中光合速率和ΦPSII的影响

Fig. 2 Effects of sucrose supply and CO<sub>2</sub> concentration and light intensity during in vitro rooting on net photosynthesis rate and ΦPSII during ex vitro acclimatization

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## Effects of in Vitro Microenvironment on Physiological Characteristics during Ex Vitro Acclimatization of Strawberry Plantlets

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**Abstract:** The influence of in vitro microenvironment during rooting stage on the growth and physiology of strawberry (*Fragaria ananassa* Duch ‘Fenxiang’) plantlets during ex vitro acclimatization was studied. Nodal cuttings were cultured on solid Murashige-Skoog medium with 3% sucrose or without sucrose, and in low ( $60 \pm 10 \mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ ) or high ( $150 \pm 10 \mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ ) photosynthetic photon flux densities, and normal ( $350 \pm 20 \mu\text{L} \cdot \text{L}^{-1}$ ) or elevated ( $700 \pm 20 \mu\text{L} \cdot \text{L}^{-1}$ ) CO<sub>2</sub> concentration. After 20 days of rooting culture, plantlets were transferred to the greenhouse for a month period of acclimatization. The results indicate that 3% sucrose is beneficial to biomass formation of plantlets, higher PPFD and elevated CO<sub>2</sub> concentration were both of benefit to the growth of plantlets. But higher PPFD reduced the chlorophyll content, and a slight negative effect on photosynthesis could be found in the culture conditions of 3% sucrose without elevated CO<sub>2</sub>. During the acclimatization, photoinhibition was not obvious, and ΦPSII was increased. The distinctive effects of the different in vitro culture conditions on growth, pigments and photosynthetic parameters were decreased during greenhouse acclimatization. Therefore, we could conclude that proper sucrose concentration may promote the biomass formation and weaken the sensibility to the environment variable, and properly elevated CO<sub>2</sub> and PPFD may be helpful to the growth of plantlets.

**Key words:** Strawberry; Micropagation; Microenvironment; Photoautotrophy; Photomixotrophy