

表 1 生根阶段蔗糖、CO₂ 浓度和光强对草莓组培苗生长的影响Table 1 Effects of sucrose supply and CO₂ concentration and light intensity during in vitro rooting on morphological characteristics of strawberry plantlets

处 理 Treatment	光照强度 PPFD ($\mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$)	蔗糖 Sucrose (%)	CO ₂ ($\mu\text{L} \cdot \text{L}^{-1}$)	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、CO₂ 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 CO₂ 的处理 3 最高, 有蔗糖供应同时增施 CO₂ 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^[10], 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。

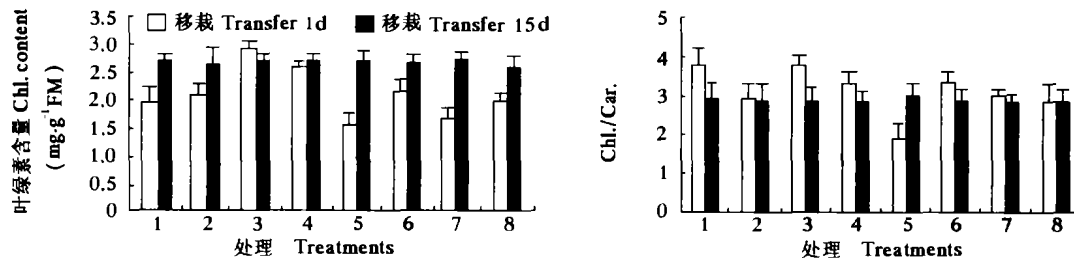


图 1 生根阶段蔗糖、CO₂ 浓度和光强处理对草莓组培苗叶绿素含量和类胡萝卜素含量的影响
处理见表 1。

Fig. 1 Effects of sucrose supply and CO₂ 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、CO₂ 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 ΦPSII 和净光合速率均略高于低光下相应的处理。添加蔗糖对 ΦPSII 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 CO₂ 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 F_v/F_m 和 q_p 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 CO₂ 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。

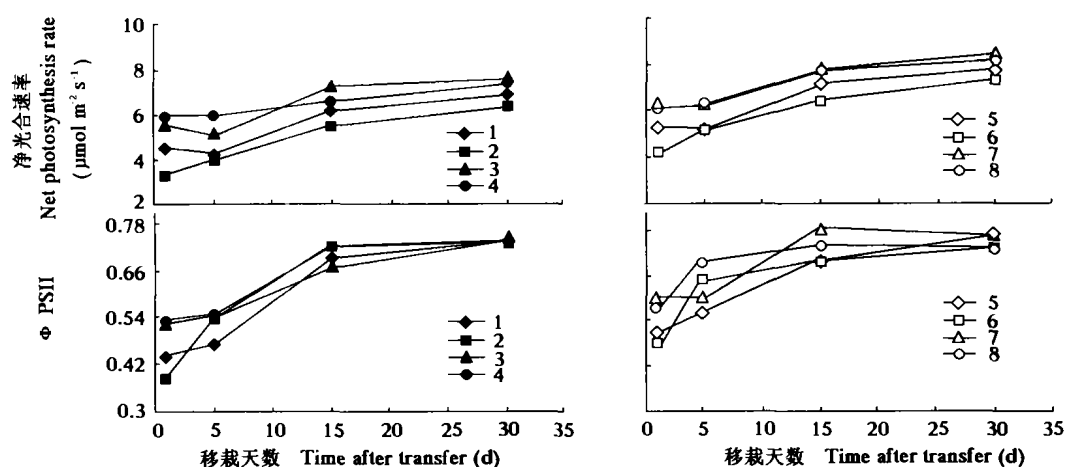


图2 生根阶段蔗糖、CO₂浓度和光强处理对草莓组培苗移栽过程中光合速率和ΦPSII的影响

Fig. 2 Effects of sucrose supply and CO₂ 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

Zhou Yaohong, Zhu Zhujun, and Qian Qiongqiu

(Department of Horticulture, Zhejiang University, Hangzhou 310029, China)

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 ($700 \pm 20 \mu\text{L} \cdot \text{L}^{-1}$) CO₂ 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 CO₂ 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 CO₂. 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 CO₂ and PPFD may be helpful to the growth of plantlets.

Key words: Strawberry; Micropropagation; Microenvironment; Photoautotrophy; Photomixotrophy