

Improvement of Runner Plant Production by Increasing Photosynthetic Photon Flux during Strawberry Transplant Propagation in a Closed Transplant Production System

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Abstract. The formation and elongation of runners, growth of runner plants, and transplant propagation rates of ‘Maehyang’ strawberry were investigated at various photosynthetic photon flux (PPF) levels. Strawberry plants having 3.1 ± 0.4 leaves and 7.0 ± 1.1 mm of crown diameter were used as propagules and were cultured for 35 days in 9 transplant production modules using fluorescent lamps as artificial lighting sources. Applied PPF levels were 137.4 ± 2.1 , 217.0 ± 1.0 , and $274.7 \pm 8.4 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ as measured on the surfaces of empty shelves. The numbers of runners and runner plants per propagule were the greatest at $280 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ PPF. The runner plant propagation rate was 0.27 plant/day/propagule at $280 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, which was significantly greater than that of conventional propagation methods. Results indicate that high PPF levels promotes the formation of runners and runner plants of strawberry and that the rapid propagation method with high PPF levels can be feasible for production of vigorous transplants in a closed transplant production system.

Additional key words: *Fragaria* × *ananassa*, mother plant, propagation rate, propagule, vegetative propagation

Introduction

The development of new strawberry cultivars involves significant time investment. Recently in Korea, several promising strawberry cultivars such as ‘Maehyang’, ‘Seolhyang’, and ‘Sugyeong’ were bred and distributed. They are cultivars that are adapted for a semi-forcing or a forcing culture and have been favored by growers because of their high fruit quality (Kim et al., 2004).

Commercial strawberry transplants are vegetatively propagated because plants produced from seeds are not true type (Bish et al., 2000). Vegetative propagation using runner plants is the principle method of producing strawberry transplants (Hartmann et al., 1997) and the propagation rate of this propagation method is relatively low. Usually it takes more than five years for the newly-bred strawberry cultivars to be distributed to growers after implementation of multiple steps of vegetative propagation and distribution program. Therefore, the more effective propagation method for newly-established cultivars must be developed.

Use of a closed transplant production system (Chun and

Kozai, 2001) may reduce transplant production time and improve the quality and yield of the final product by optimizing environmental conditions. Production efficiency of transplant may also be improved by using transplant production systems (Dressen and Langhans, 1991, 1992). Kubota and Kozai (2001) reported that precise control of plant growth and multiplication is an advantage offered by vegetative propagation under artificial lighting.

Only a few studies have focused on the rapid multiplication of strawberry transplants. Among multiple environmental parameters that may affect strawberry transplant propagation, the effects of temperature and day length on growth and runner formation were already well investigated from previous studies (Darrow, 1936; Kurokura et al., 2005; Nicoll and Galletta, 1987; Yanagi and Oda, 1993). But the effect of light intensity on the propagation of strawberry transplants has not been studied yet, since the vegetative propagation has been practiced in an open field or greenhouses where the light intensity is mainly determined by solar radiation.

Light is one of critical limiting factors affecting plant growth and reproduction. Kinet et al. (1985) reported that

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photosynthetic production increased under high light intensities, and therefore, levels of carbohydrates available for growth and development also increased. Manipulating lighting conditions has enhanced the growth and development of various vegetable transplants (McCall, 1992; Morgan, 1971; Tremblay and Gosselin, 1998). Supplementary lighting has been used as a cultivation technology to enhance the relative growth rates of celery, tomato, peppers, broccoli, and lettuce transplants grown in greenhouses (Boivin et al., 1987; Bruggink, 1987; Fierro et al., 1994; Knight and Mitchell., 1983; Masson et al., 1991; Morgan, 1971; Mortensen and Moe, 1983). This study concentrated on the effect of PPF, since very few studies have investigated the relationship between PPF and strawberry transplant production. The objective of this study was to investigate the effect of PPF on formation and development of runner plants and propagation rate of strawberry transplants in a closed transplant production system.

Materials and Methods

Plant materials

Transplants of 'Maehyang' strawberry with 3.1 ± 0.4 leaves and 7.0 ± 1.1 mm of crown diameter were transplanted into plastic pots (ϕ 110 mm) filled with a mixture of soil and fertilizers (90:10, v/v, Plant world, Nongwoobio, Korea). Ten transplants were placed in each transplant production module and three replications of three treatments were arranged with a completely randomized design.



Fig. 1. Nine multi-purpose transplant production modules with fluorescent lamps as artificial lighting sources used in the present study. The modules were placed in a closed system.

Physical environments during transplant propagation

Nine multi-purpose transplant production modules [1100 mm \times 1100 mm \times 775 mm (L \times W \times H, outside), 1000 mm \times 1000 mm \times 640 mm (inside), and 625 L (volume)] equipped with ten 32-watt cool white fluorescent lamps (TLD32W830RS, Philips Electronics, The Netherlands) were constructed and placed in a closed system in which the air temperature was set at 20°C (Fig. 1). Air temperature inside the modules was maintained at 25/20°C during photo-/dark-periods. The photoperiod was 16 hr/day and three different PPF levels, 137.4 ± 2.1 , 217.0 ± 1.0 , and 274.7 ± 8.4 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, were achieved by changing the number and allocation of fluorescent lamps. The PPF was measured using a portable light meter (LI-250, Li-Cor, Lincoln, NE, USA). Transplants were irrigated with a nutrient solution composed of 19 N, 6 P, 19 K, and 2 Ca $\text{me}\cdot\text{L}^{-1}$ water-soluble fertilizers (Megasol, Netafim Ltd., Tel Aviv, Israel) for 20 minutes everyday using an automatic irrigation system consisting of a pump (HP-30, Hankookmedo Co., Seoul, Korea), a digital timer (TM-2, ZDF Electronic, Seoul, Korea), and valves.

Measurements

Both number and length of runners were measured everyday during transplant propagation. The number of runner plants per propagule was measured everyday until the runner plants were stuck into a soil medium in plug trays after confirmation of rooting. After 20 days, they were separated from the mother plant by severing and subsequently grown under the same conditions. Number of unfolded leaves, leaf length, crown diameter, and fresh and dry weights of runner plants were measured 35 days after transplanting, and runner plant production rate was calculated based on number of runner plants produced during the transplant propagation.

Statistical analysis

The ANOVA was performed using SAS (Version 9.1, SAS Institute Inc., Cary, NC, USA). Mean separation was analyzed using Duncan's multiple range test ($P \leq 0.05$) for growth parameters of runner plants.

Results and Discussion

Formation and elongation of runners

Number of runners per propagule increased as PPF increased and was the greatest at $280 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, indicating that increased PPF significantly promoted runner formation (Fig. 2). At 140, 210, and $280 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ PPF, number of primary runners formed after 35 days were 5.62 ± 0.19 , 6.40 ± 0.27 , and 6.62 ± 0.32 per propagule, and those of secondary and tertiary runners formed after 35 days were

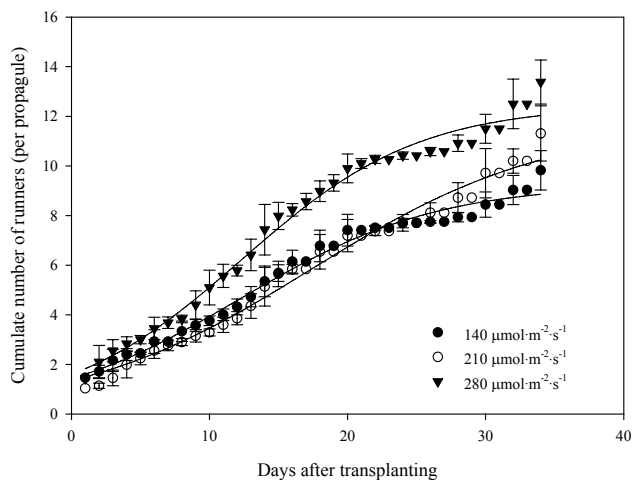


Fig. 2. Time course of number of runners per propagule formed at 140, 210, and 280 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ PPF. Vertical bars show standard errors (n=30).

5.08 \pm 2.02, 6.25 \pm 2.21, and 8.97 \pm 1.65 per propagule, respectively (data not shown). The differences in number of primary runners among the three treatments were smaller than those of the secondary and tertiary runners. Number of runners formed for 35 days at 280 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ was 15.6 per propagule, which is significantly greater than the previously reported results (de Oliveira et al., 2007; Kim et al., 1999) that the average number of runners for several strawberry cultivars cultivated for one month using a conventional method was 1 to 2 per plant. June-bearing strawberry can produce up to 10-15 runner chains per plant per year (Hancock, 1999), depending on the variety and cultural conditions, with 3 to 5 runner plants per runner, giving the opportunity to generate 40-50 runner plants per each mother plant in a single season. The runner production increased with increasing light intensity (Smeets, 1955) and that effect of increasing light intensity on runner production was quantitative (Dennis et al., 1970).

Length of primary runners at 140, 210, and 280 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ PPF were 372.22 \pm 16.20, 354.31 \pm 13.42, and 312.78 \pm 11.16 mm, respectively (Fig. 3). The average runner length between propagules and secondary and tertiary runner plants also decreased as the PPF increased, resulting in the smallest runner elongation rate in the treatment of the highest PPF level. Cain (1994) determined that runner length decreased in favorable environment because that was partially dependent on the direction of runner growth, which implicates that 280 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ was favorable as compared to lower PPF levels in the present study.

Propagation of runner plants

Number of runner plants per propagule increased as the PPF increased and was the greatest at 280 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ PPF,

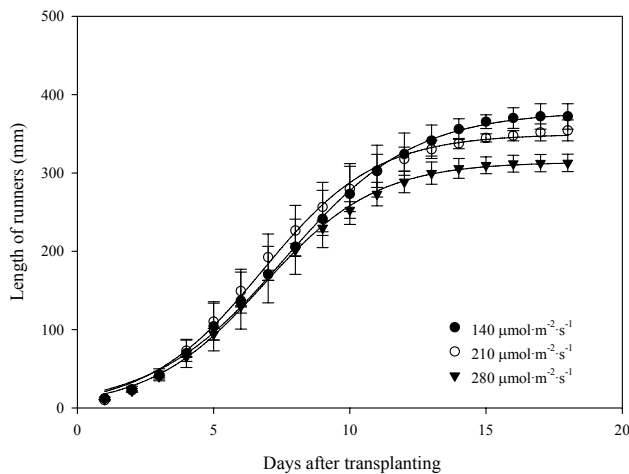


Fig. 3. Time course of length of the primary runners at 140, 210, and 280 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ PPF. Vertical bars show standard errors (n=30).

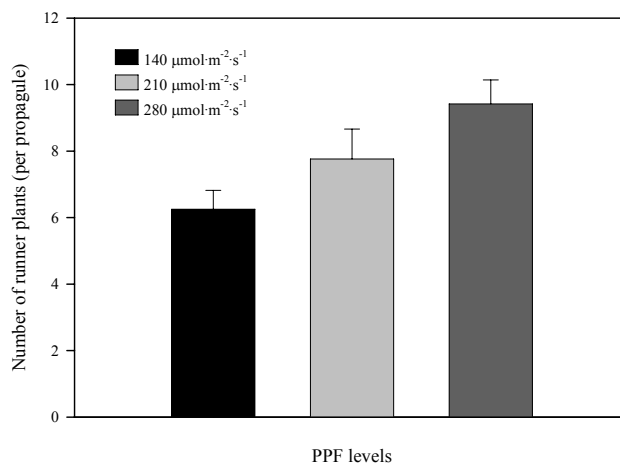


Fig. 4. Number of runner plants per propagule as affected by PPF level during a 35 days transplant production period. Vertical bars show standard errors (n=30).

indicating that increased PPF significantly promoted runner plant production (Fig. 4). Number of runner plants formed for 35 days at 140, 210, and 280 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ was 6.25 \pm 0.57, 7.76 \pm 0.90, and 9.42 \pm 0.72 per propagule, respectively, which was much greater than the previously reported results (de Oliveira et al., 2007; Kim et al., 1999). Before runner plants develop roots and leaves, they rely highly on the propagule for nutrients and water that are transported via the runners, even though the runner plants also produces their own assimilates (Blanke and Cooke, 2000). Under higher PPF conditions, net assimilates of propagule might be improved and the amount of essential nutrients transported from the propagules to runner plants would be increased, which might result in the better shoot and root formation of runner plants as shown in the present study. The propagation rate of runner plants during 35 days at 280 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ PPF was 0.27 plant/day/propagule (Fig. 5), 1.5- and 1.2-fold

greater than those at 140 and 210 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, respectively, a value which was much greater than 0.18 plant/day/propagule, the propagation rate calculated from the average number of runners propagated for 122 days using a conventional method (Kim et al., 1999).

Growth parameters of each runner plant were not significantly different among the three treatments (Table 1). The runner plants propagated had large enough crown diameters, shoot/root fresh and dry weights, and leaf number to be used as propagules for further propagation cycles in a closed transplant production system. Also, the uniformity in size of runner plants harvested during a 35 days propagation cycle was thought to be much greater than that in a 120 days or longer production cycle of a conventional method. Takeda and Hokanson (2003) reported that runner plants with a widely range of size (0.9-9.8 g in fresh weight) were obtained in a conventional propagation system. Since the use of non-uniform runner plants as propagules would result in the much greater irregularity in the next propagation cycles, many of them should be discarded because of the unacceptable size.

Results of the present study indicate that high PPF levels enhance photosynthesis of propagules and runner plants, and promote the formation of runners and runner plants of strawberry. They also implicate that a rapid propagation method

with high PPF levels can be achieved for production of vigorous transplants in a closed transplant production system.

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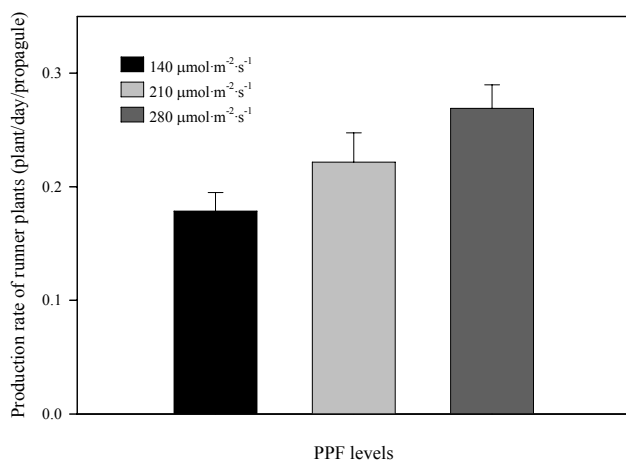


Fig. 5. Propagation rates of runner plants per propagule as affected by PPF level during a 35 days transplant production period. Vertical bars show standard errors (n=30).

Table 1. Growth of runner plants as affected by PPF level during a 35 days transplant production period.

PPF ($\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$)	Crown diameter (mm)	Maximum leaf length (mm)	No. of leaves (per plant)	Fresh wt. (g/plant)		Dry wt. (g/plant)	
				Shoot	Root	Shoot	Root
140	5.56 a ²	42.01 a	2.54 a	1.98 b	0.41 a	0.47 a	0.07 a
210	6.01 a	47.28 a	2.02 b	1.57 b	1.21 a	0.51 a	0.09 a
280	5.90 a	42.75 a	2.16 b	2.16 a	0.58 a	0.52 a	0.12 a

²Mean separation within columns by Duncan's multiple range test at 5% level.

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폐쇄형 육묘 시스템에서 딸기의 러너플랜트 생산 증진에 적합한 광합성유효광량자속

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초 록. 국내 육성 품종인 '매향' 딸기의 육묘 기간 중 광합성유효광량자속의 환경 조절을 통하여 러너 및 러너플랜트의 발생과 생산 효율을 증대시키고자 하였다. 딸기 육묘에 이용된 증식체의 엽수와 관부 직경은 각각 3.1±0.4와 7.0±1.1mm였다. 광합성유효광량자속을 각각 140, 210 및 280μmol·m⁻²·s⁻¹로 설정한 9기의 인공광 이용형 육묘 모듈에서 35일 동안 육묘하였다. 러너플랜트 생산 효율은 증식체당 일일 0.27주로 처리구 중 유의하게 가장 높았으며 관행의 딸기 육묘 방식의 러너플랜트 생산 효율과 비교하여도 크게 증진되었음을 확인하였다. 폐쇄형 육묘 시스템을 활용하여 육묘 기간 중의 PPF를 280μmol·m⁻²·s⁻¹로 조절하면 국내 육성 품종인 '매향'의 러너 발생 및 러너플랜트 생산을 증진시킬 수 있음이 확인되었다. 따라서 최근 국내에서 육성된 신품종 딸기의 급속 보급을 위한 증식체계 구축에 본 연구 기술이 활용되면 육성된 품종의 조급 보급이 가능할 것으로 판단된다.

추가 주요어 : *Fragaria* × *ananassa*, 모주, 증식틀, 증식체, 영양번식