African Journal of Biotechnology Vol. 8 (8), pp. 1497-1501, 20 April, 2009
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2009 Academic Journals

Full Length Research Paper

Efficacy of highland production of strawberry transplants

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Accepted 16 March, 2009

This study was conducted to evaluate the effect of propagation environment (high and low elevation) on runner productivity and quality of 'Maehyang' and 'Red Pearl' strawberry cultivars. Two propagation methods (bare root plants and plug plants) were used for both environments. Regardless of cultivar or propagation method, runners produced at high-elevation had significantly greater crown diameter, and root and whole plant dry weights, and carbohydrate accumulation tended to be greater in runners from the highland. The high elevation site was more effective for producing high quality strawberry runners than the low-elevation site.

Key words: Strawberry, bare root plant, carbohydrates, high-elevation nursery, low elevation nursery, plant quality, plug plants.

INTRODUCTION

Strawberry (Fragaria x ananassa Duch.) is a high-value crop grown worldwide. Strawberry plants are clonally propagated by means of runner (daughter) plants and are generally transplanted as either bare root plants or plugs. Cultivation follows one of two general models: annual plasticulture or a perennial system of matted rows. The development of improved cultivars and production systems have resulted in significant increases in fruit production and a longer fruit harvest season in many parts of world, including Europe, U.S. and Asia. Several studies have shown that runner quality is a major factor affecting both productivity and fruit quality (Larson and Shaw, 1995; Durner et al., 2002; Cobos, 2006; Hicklenton and Reekie, 2002). However, in many emerging strawberry production areas, strawberry plant propagation technologies are poorly developed and runner plants are often of low quality with relatively low carbohydrate content, root and crown infections with serious fungal plant pathogens such as Phytophthora, Verticillium and Colletotrichum, and poor performance after transplanting (Bringhurst et al., 1960; Lopez et al., 2002). In regard to fresh-dug strawberry plants, there is increased interest in plant propagation in high elevation (HE) areas as growers recognize that HE runner plants typically have larger roots and crowns and fewer diseases. Compared to plants propagated in low-elevation (LE) areas, physiological conditioning due to exposure to cooler temperatures in HE nursery sites often results in increased plant health, as well as greater fruit size and yield (Durner et al., 2002; Larson, 1994) due to greater plant carbohydrate levels. However, relatively little research has been conducted to assess the differences in plant physiology between HE and LE-propagated plant material.

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MATERIALS AND METHODS

Propagation of runner plants was conducted at both LE and HE sites in Kangwon-do Province in the Republic of South Korea. The LE nursery site was located at the University Agricultural Research Farm of the Department of Plant Science, Kangnung National University in the city of Kangnung (10 m above sea level, lat. 37.45° N.). The HE nursery site was located on a private farm near the National Institute of Highland Agriculture (780 m above sea level, lat. 37.5° N.). Both locations are characterized by a temperate humid climate with cold winters. During the experimental period, monthly average temperatures ranged from -0.6 to 30.1ºC and from -10.5 to 25.4ºC at LE and HE sites respectively, while monthly precipitation ranged from 1.5 to 503 mm and from 8.4 to 453 mm at

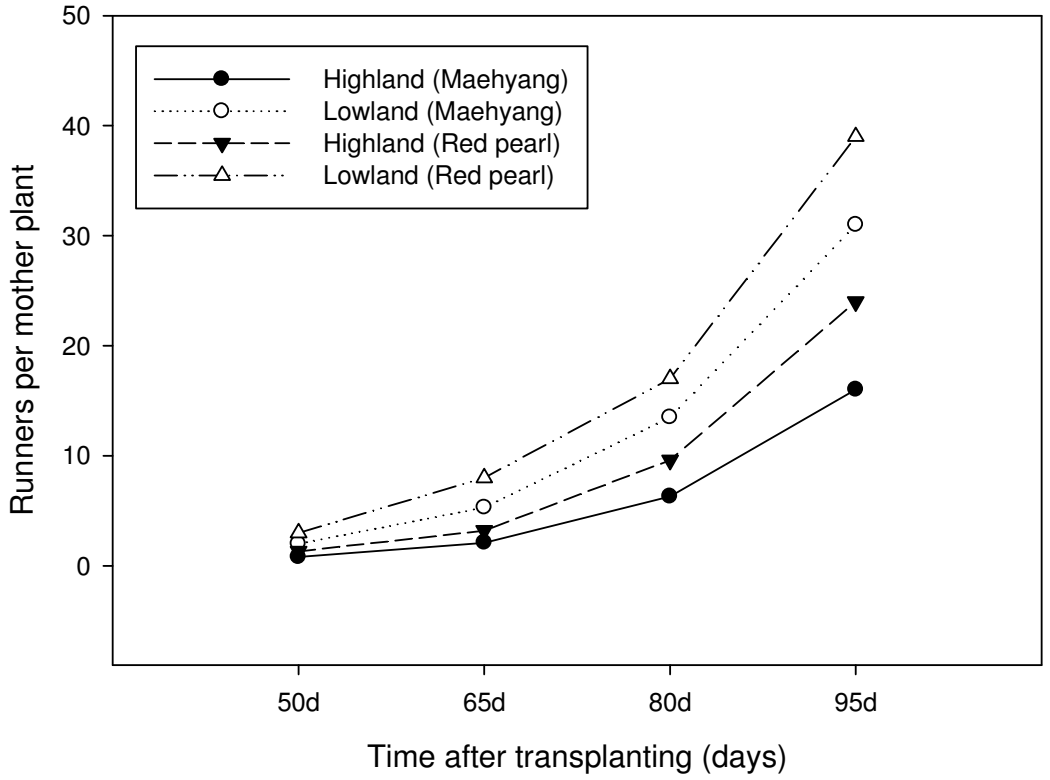

Figure 1. Number of runners per mother plant with bare root propagation system under lowland and highland conditions.

LE and HE sites, respectively. Heavy precipitation occurred in September. Soils in both sites were characterized by sandy soils with a pH of 6.8.

Cold-stored plants of cultivars 'Maehyang' and 'Red Pearl' were planted at both LE and HE sites on April 25 for generation of bare-root transplants. Mother plants were established at 20 cm spacing in the center of raised beds (1.8 m width, 20 cm high) in large, walk-in polyethylene tunnels using randomized complete block design with four replications. At both sites, trickle irrigation systems supplied water as necessary, and flower buds were removed throughout the experimental period. All other management inputs were similar for both sites.

Mother plants of 'Maehyang' and 'Red Pearl', identical to those used in the bare-root propagation trial, were established at both experimental sites in containers (100 × 25 ×35 cm), with 3 plants per container. Containers were placed on shelves 1 m above ground in green house. Containerized plugs (58 x 29 cm, 32 cells), filled with commercially available potting media (BioBest, Seminis Korea) were placed on shelves adjacent to the containers to allow runners to root and form plugs. Plug cell dimensions were 5 × 3 × 10 cm. Water was supplied by hand as necessary and flower buds were removed upon emergence. Management inputs were similar for both sites.

The number of runners, crown diameter, crown dry weight, root dry weight and whole plant dry weight were determined for each cultivar at each propagation site. On September 10, 100 intact runners of each cultivar and propagation method were randomly harvested from both sites. From each set of 100 plants, ten plants were randomly selected and five plants were carefully washed and subjected to sugar content. Aerial parts of the plant were removed to the height of the shoot apex, and a 6 mm-long pith cylinder (about 4 mm diameter) was collected from the core of the crown tissue. Sugar content determination was conducted using an HPLC as described by Lieten (1997). Data were analyzed using GLM (General Linear Model) of SAS program with Duncan's Multiple Range Test (P ≤0.05).

RESULTS AND DISCUSSION

Regardless of cultivar or propagation method, LE mother plants produced more runners than HE mother plants at all four measurement intervals (Figure 1). Sixty-five days after planting 'Red Pearl' mother plants produced 6 and 9 runners at HE and LE nursery sites, respectively. Ninety-five days after planting, 'Maehyang' mother plants produced 16 and 31 runners at high- and low-elevation sites, respectively, while mother plants of ´Red Pearl' produced 25 and 39 runners plant at HE and LE sites, respectively. Previous studies demonstrated that, compared to HE sites with cooler temperatures, warmer temperatures at LE sites resulted in greater numbers of runner plants (Lopez et al., 2002), but reduced runner plant quality (Anderson and Guttridge, 1975). Similar results were reported by Leiten (1997).

The yield components of crown diameter, crown dry weight, root dry weight and whole plant dry weight were greater for plants propagated at high elevation compared to low elevation (Table 2). Strawberry crown diameter is an important determinant of rapid plant establishment,

Table 1. Mean monthly temperature and precipitation for lowland and highland area during experiments.

Contents			Month											Total
			Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
lowland	Temp. (℃)	Highest	7.2	10.3	11.5	16.6	23.1	25.6	25.5	30.1	23.9	20.2	13.5	8.6	18.01
		Mean	2.8	5.5	7.0	12.2	18.3	21.5	22.7	26.4	20.8	15.6	9.1	4.4	13.86
		Lowest	-0.6	1.5	2.9	7.8	13.8	17.2	20.5	23.2	18.3	12.0	5.2	1.1	10.24
	Precip. (mm)		17.0	19.1	96.0	44.5	111.5	44.4	311.2	158.9	503.3	73.6	60.6	1.5	1,441.6
highland	Temp. (℃)	Highest	0.5	4.0	5.9	12.1	18.1	21.5	21.7	25.4	19.5	14.4	7.3	1.0	12.62
		Mean	-5.2	-1.9	0.8	6.5	12.3	16.1	18.3	21.5	16.1	9.1	1.5	-3.6	7.63
		Lowest	-10.5	-7.8	-3.8	1.3	6.9	10.4	16.0	18.3	13.3	4.4	-4.1	-7.9	3.04
	Precip. (mm)		23.4	21.6	107.6	51.7	114.5	66.0	266.2	242.2	452.8	22.6	24.1	8.4	1,401.1

Korean Meteorology Institute, Korea 2007.

Table 2. Parameters of runner quality for two cultivars propagated using two methods at lowland and highland.

Cultivar	Treatment	Crown diameter (mm)	Crown dry weight (g)	Root dry weight (g)	Whole plant dry weight (g)
Maehyang	HB	12.68 a Y	4.74 a	0.94 ab	5.68 a
	LB	9.53 bc	2.5 b	0.36 c	2.86 b
	HP	11.14 ab	2.76 b	1.16 a	3.92 b
	LP	9.01 c	2.06 b	0.76 b	2.82 b
Red Pearl	HB	12.47 a	3.7 a	1.44 a	5.14 a
	LB	9.31 b	2.02 b	0.28 c	2.30 b
	HP	9.08 b	1.60 b	0.86 b	2.46 b
	LP	8.52 b	1.60 b	0.82 b	2.42 b

HB, LB, HP and LP represent highland bare root, lowland bare root, highland plugs and lowland plugs, respectively. Y Means separation within column by Duncan's multiple range tests at p = 0.05.

early vegetative growth and fruit yield, as well as high total yield (Bish et al., 1997). Mean crown diameter of bare-root plants of 'Maehyang' was 9.53 and 12.68 mm for plants propagated at LE and HE sites, respectively (Table 1); similar results were observed for plug plants, and the same general trends were observed for 'Red Pearl'. Similarly, compared to propagation at LE, propagation at HE resulted in significant increases in dry mass for both cultivars (Table 1).

The carbohydrate content of strawberry crown tissues affects vegetative growth, flower initiation, fruit size and runner storage life, and plants produced at high-elevation

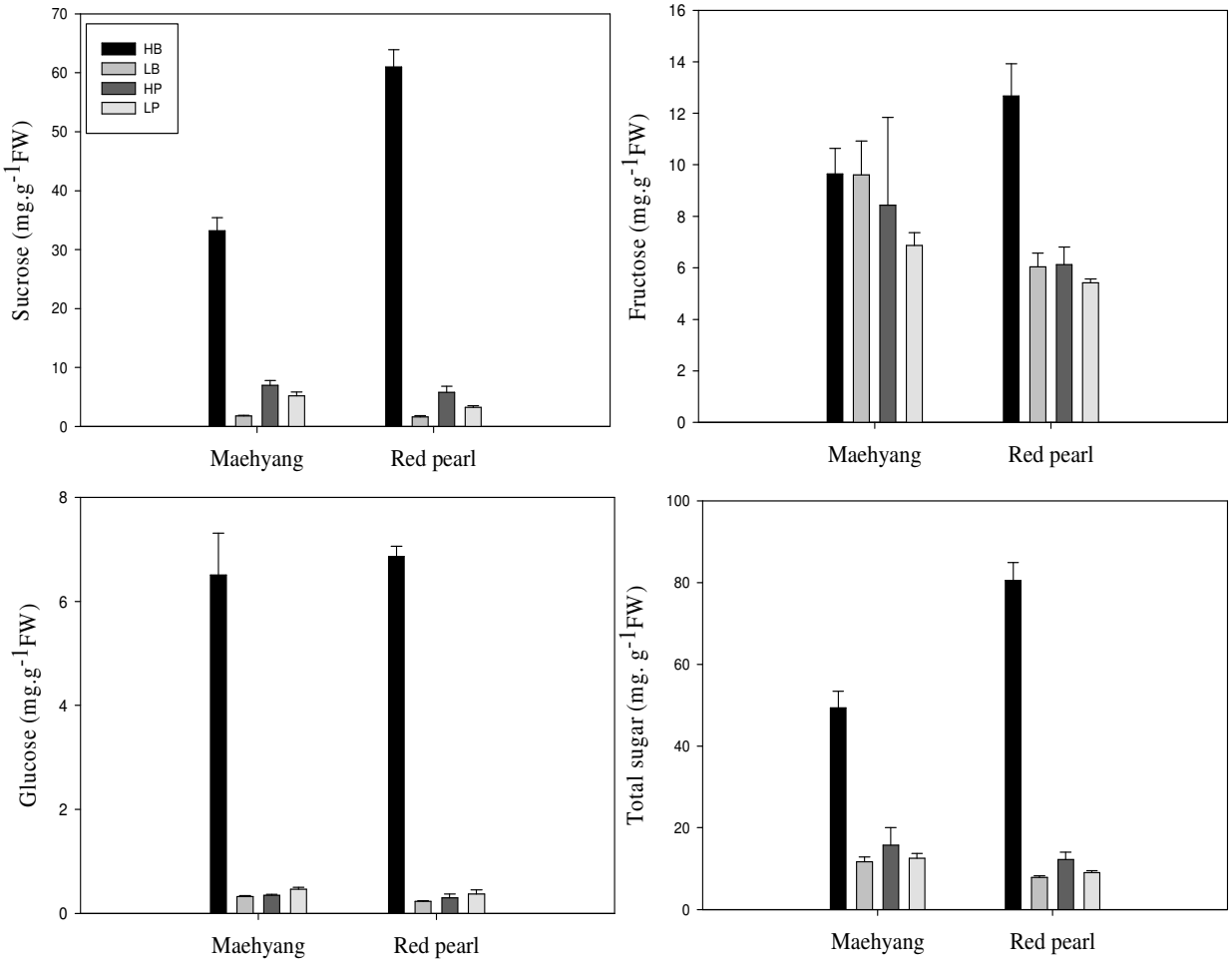

Figure 2. Sucrose, fructose, glucose and total sugar content of crown tissue of runners from lowland and highland. HB, LB, HP and LP represent highland bare-root, lowland bare-root, highland plugs and lowland plugs, respectively

consistently had greater carbohydrate contents than plants propagated at low-elevation (Bringhurst et al., 1960; Larson, 1994). In the current study, and compared to LE, propagation at HE resulted in significant increases in carbohydrates as determined by sucrose, fructose and glucose contents (Figure 2). For bare-root plants of 'Maehyang' and 'Red Pearl' cultivars propagated at HE, crown tissue sucrose content contains 35 and 65 mg.g-1 FW, respectively, compared with 3 mg.g-1 FW for these cultivars propagated at LE (Figure 2). However, there was relatively little difference in sucrose content between plug plants propagated at HE and LE (Figure 2), probably as a result of reduced growth and development due to limited rooting volume of the plug cells (Table 1).

At the time of runner harvest from the nurseries, total sugars in crown tissues of bare-root plants of 'Maehyang' were 15 and 46 mg.g-1FW for LE and HE plants, respectively, while those of ´Red Pearl' were 10 and 80 mg.g-1FW at LE and HE, respectively. These results suggest that lower temperatures at the HE site resulted in reduced plant respiration rates compared to LE plants, thereby maintaining greater carbohydrate content (Lieten, 1996, 1997; Lopez et al., 2002; Glass and Kadir, 2005).

In the course of the experiment we observed reduced disease incidence of *Colletotrichum acutatum*, *Phytophthora cactorum*, and *Verticillium dahlia* at HE compared to LE propagation sites.

The results of this study demonstrate that the HE environment resulted in decreased plant production compared to LE propagation, but that plants produced at HE had increased plant quality and reduced disease incidence as a result of cooler temperatures and lower respiration rates (Elad et al., 2004; Su and Gubler, 2000), resulting in increased plant vigor after transplanting (data not shown). The results of this study suggest that plant propagation at HE sites can result in increased plant quality and reduced incidence of major plant pathogens compared to propagation at LE sites. Additional studies should be conducted to assess the effects of propagation environment on yield performance and fruit quality.

ACKNOWLEDEMENTS

The authors thank Liz Ponce (Lassen Canyon Nursery, U.S.A) for supporting Korean student internship program and experimental material. This research was partially supported by funds of ARPC, Korea and Lassen Canyon Nursery, U.S.A.

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