Vegetative Growth and Fruit Yield of Three Types of Micropropagated 'Redwing' Red Raspberry Nursery Stock

Chad Finn¹,
Michele Warmund², and
Chris Starbuck²

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Summary. The vegetative growth and fruit yield of three types of micropropagated 'Redwing' red raspberry (*Rubus idaeus* L. var. *idaeus*) nursery stock were compared. The three types of nursery material included: 1) stage IV (S-IV) actively growing plants; 2) dormant-stage IV (DS-IV) plants; and 3) nursery-matured (NM) S-IV plants, grown for 8 to 12 weeks in the field before harvest for cold storage. On 1 Apr. 1991, primocane-fruiting 'Redwing' plants of each type were planted 0.6 m apart in ridged, drip-irrigated, and straw-mulched rows spaced 3 m apart in six, three-plant replications. In the establishment year, a small, but commercially viable, crop was harvested from 16 Aug. 1991 to 28 Oct. 1991. The S-IV and NM plants produced greater yields than DS-IV plants in the establishment year. However, by the end of the second year, the S-IV plants had the greatest fruit yield, followed by NM, with the DS-IV plants continuing to have the lowest yield. Fruit size of the S-IV plants was largest in both years. While there were differences in dry weight during the planting year, by the experiment's conclusion, the

dry weights were similar among all nursery types. When planting 'Redwing', the less-expensive, easier-to-handle, and higher-yielding S-IV plants would be recommended over the other nursery types.

Micropropagated red raspberry plants provide nurseries and growers with several advantages when compared to those propagated by layering (Handley, 1989; Trinka and Pritts, 1992). Nurseries favor micropropagation because large numbers of disease-free plants can be produced rapidly as new cultivars are released or to adjust to trends in sales. Mature plants derived from micropropagated (tissue-culture) material are often more vigorous and productive than traditionally propagated plants when field-planted (Grout et al., 1986; Handley, 1989; Swartz et al., 1981). The disadvantages of micropropagated plants are their cost and the special handling they require during establishment (Neal et al., 1990; Trinka and Pritts, 1992). Plants are shipped while they are still small, require immediate irrigation, and are not tolerant of herbicides during their initial establishment.

At present, three types of micropropagated plants are available from nurseries. Stage-IV (S-IV) plants are actively growing (Read and Debergh, 1991) and, in the case of raspberry, the plants are 10 to 15 cm tall. Dormant-stage IV (DS-IV) plants are S-IV plants (10 to 15 cm tall) that have been stored in a cooler until shipment to a grower; they do not have any leaves when they are shipped. Nursery-matured (NM) plants are S-IV plants that have been grown for 8 to 12 weeks in the field and are cold-stored before shipment; these also arrive dormant. NM plants have one to two canes that are 30 to 40 cm tall and have no leaves. NM plants generally have a substantial root system with vegetative buds that produce new primocanes. S-IV plants and DS-IV plants are typically sold at a similar price, while NM plants are 10% to 15% more expensive (P. Otten, North Star Gardens, personal communication).

Privé and Sullivan (1991) compared the relative growth rates of two types of micropropagated planting stock of 'Heritage', 'Ruby', and 'Redwing'. S-IV and cold-treated plantlets

(similar to DS-IV plants) were grown outdoors in containers for 10 weeks. Although the types of stock and cultivars had different relative growth rates during the first 6 weeks, with the cold-treated plantlets having the greatest dry weight, rates were similar 10 weeks after planting.

The following experiment was conducted at the Horticulture Research Center at New Franklin, Mo., to compare the growth and fruit yield of S-IV, DS-IV, and NM micropropagated 'Redwing' red raspberry plants in the field for two growing seasons.

Materials and methods

One-meter-wide strips, 3 m apart, were cultivated and a 15- to 18-cm-tall mounded ridge was formed in each strip. Primocane-fruiting 'Redwing' plants of each of three types of nursery stock were planted in a randomized complete-block design with six, three-plant replications on 1 Apr. 1991. The three types of nursery stock, obtained from the same commercial nursery, included: 1) S-IV plants that were green, actively growing and 10 to 15 m tall with a root mass that filled a 4.5 × 4.5 × 5-cm container; 2) DS-IV plants that were similar to S-IV plants in size (plants had been stored at 2°C at the nursery and were leafless and dormant); and 3) NM plants that had a single, dormant, 30-cm tall-cane and were shipped bare-root.

Plants were set 0.6 m apart within the row with 3 m between rows. In-line drip-irrigation tubing with 0.3-m emitter spacings and 1.9-liters·h⁻¹ capacity was placed in the row immediately after planting. The plants were irrigated with 2.5 cm/week during vegetative growth and 5 cm/week during fruiting when rainfall was insufficient. In 1991, the summer months were warm and dry, followed by a wet September and October. In 1992, the summer was cool and rainfall was near normal. A 10- to 15-cm-thick straw mulch was applied after planting over the top of the irrigation tubing and around the plants, across the entire ridge. The straw mulch was reapplied over the entire ridge prior to primocane emergence in 1992. Plants were hand-weeded through each season.

Some of the plants had a small florican crop in 1991 and the harvest from the primocanes occurred between 16 Aug. and 28 Oct. In 1992, harvest began 19 July and continued until 18

¹Research Geneticist, Northwest Center for Small Fruit Research, Horticultural Crops Research Laboratory, USDA/ARS, Corvallis, OR 97330.

²Associate Professor, Department of Horticulture, University of Missouri, Columbia, MO 65211.

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Oct. Harvest was terminated each year when severe low temperatures and frost made the crop unsalable. Early in the season under warm conditions, fruit was picked every 3 days. Later, as the weather cooled, fruit was harvested every 5 to 7 days. In 1991, total fruit weight and number were recorded. In 1992, total fruit weight and the weight of a randomly selected sample of 25 berries were measured for each three-plant plot.

On 12 Nov. 1991, the above-ground portion of each plant was harvested and cane number, individual cane diameter (at the soil surface), and total length (length of main cane plus length of all lateral shoots) were recorded for each plot. Harvesting the above-ground portions of the plant in November instead of late in the winter may have lowered total yield slightly in 1992. However, the early removal of plant material was done to ensure collection of foliage. The above-ground portion of plants in each plot was oven-dried, and dry weights measured. Due to the large number of canes and limited drying-oven facilities, plant material harvested on 21 Oct. 1992 was sampled from a 0.25-m² area within each plot (Trinka and Pritts, 1992). Cane diameters, length of the tallest cane, and dry-weight measurements were recorded from canes harvested from this area. Data were subjected to analysis of variance and means were separated by LSD at $P \leq 0.05$.

An unidentified looper (*Lepidoptera*) severely reduced yield in one replication in 1991 and 1992. This looper consumed floral parts, thereby preventing fruiting, so only five replications were included in the analysis of fruit yield. The damage caused by this looper did not affect growth (ANOVA showed no significant effect due to replication; data not shown); therefore, six replications were included in the analysis of growth.

Results and discussion

Fruit yield. In 1991, S-IV and NM plants produced greater yields than DS-IV plants (Table 1). In 1992 and in the combined analysis, S-IV plants had the greatest yields, followed by the NM plants; the DS-IV plants had the lowest yield. S-IV plants had heavier fruit than the DS-IV and NM plants in each year and in the combined-years analysis (Table 1). In the overall analysis, the plants in 1992, not surprisingly, had significantly greater yield than the younger, smaller plants in 1991. Fruit weight did not differ between the two years.

In the establishment year, the average first harvest date was earliest for the NM plants (23 Aug. 1991), followed 4 days later by the S-IV plants and another 6 days later by the DS-IV plants. The week with the greatest harvest was 19 Oct. for all three types of plants (Fig. 1). In 1992, all three nursery types had their first harvest on 29 July 1992 (Fig. 2). The production

was highest between 8 Aug. and 5 Sept., after which it began to decline.

Growers who are establishing a new planting often hope that sale of fruit in the establishment year will largely cover their planting costs. While the plants in this study produced a small, but commercially viable, crop in 1991, the bulk of this fruit was produced in October (Fig. 1). In 1991, the early spring and warm weather advanced the harvest of most fruit crops in Missouri by 1 to 2 weeks. This, combined with a lack of early frosts, gave the plants a much longer period than normal to ripen a crop. In a typical year, or in different regions of the country, production late in the season might not be commercially viable.

Plant growth. In 1991, the NM plants produced canes of greater length and diameter than DS-IV plants (Table 2). The DS-IV plants produced more canes than the other two types of nursery plants and had a larger above-

Fig. 1. Total fruit production per week for stage-IV (S-IV), dormant stage-IV (DS-IV), and nursery-matured (NM) nursery stock of 'Redwing' red raspberry in 1991.

Table 1. Total fruit weight and average fruit size in 1991, 1992, and combined analysis for 1991–1992 for three-plant plots of stage-IV, dormant stage-IV, and nursery-matured 'Redwing' red raspberry plants.

Nursery type	1991		1992		Combined years	
	Average fruit size (g)	Total fruit wt (g)	Average fruit size (g)	Total fruit wt (g)	Average fruit size (g)	Average total fruit wt (g)
Stage-IV (S-IV)	1.7 a ^z	1200 a	1.8 a	4839 a	1.8 a	3020 a
Dormant stage-IV (DS-IV)	1.4 b	264 b	1.6 b	1648 c	1.5 b	956 c
Nursery-matured (NM)	1.4 b	960 a	1.5 b	3179 b	1.4 b	2070 b
LSD (0.05)	0.2	602	0.2	1061	0.2	863

^zNumbers in a column followed by the same letter are not significantly different by LSD at $P \leq 0.05$.

Table 2. Average total cane length, diameter, number, and dry weight per plant for the three types of nursery stock of 'Redwing' red raspberry in 1991.

Nursery type	Total cane length (cm)	Cane diam (mm)	No. canes	Dry wt (g)
Stage-IV (S-IV)	230 ab ^z	10.0 ab	3 b	431 ab
Dormant-stage IV (DS-IV)	162 b	8.8 b	7 a	547 a
Nursery-matured (NM)	290 a	11.7 a	3 b	396 b
LSD (0.05)	97	1.8	3.8	142

^zNumbers in a column followed by the same letter are not significantly different by LSD at $P \leq 0.05$.

Fig. 2. Total fruit production per week for stage-IV (S-IV), dormant stage-IV (DS-IV), and nursery-matured (NM) nursery stock of 'Redwing' red raspberry in 1992.

ground dry weight than the NM plants. The fact that the DS-IV plants produced more canes and less fruit than the other types was due to their shorter cane length and a later season, which was terminated by frost. Privé and Sullivan's (1991) observation that cold-stored 'Redwing' plantlets had a lower root dry weight than stage-IV plants may explain partially the slower development of the DS-IV plants. In 1992, all three types formed a solid hedgerow and above-ground dry weight, average cane diameter, tallest cane length, and cane number of the different nursery types were similar (data not shown).

Privé and Sullivan (1991) could not recommend one container-grown nursery type over another based on growth rate after 10 weeks of observation. However, the nursery types used

in our study showed vegetative and reproductive differences during the first year. In the second year, and in the combined analysis, there were differences in fruit production, but not in growth among the nursery stocks. The physiological basis for the superior performance of the S-IV plants is unknown and requires further study. Finally, in addition to having the greatest fruit yield during the 2 years of this study, the S-IV 'Redwing' plants cost less and are easier to handle (plugs that can be set easily with a transplanter) than NM plants, which suggests that S-IV plants are a better option than NM or DS-IV plants for red raspberry growers.

NM plants are reportedly more tolerant of herbicides than S-IV plants (P. Otten, personal communication)

and, due to their larger root mass, may be more tolerant of inadequate or delayed irrigation. Trinka and Pritts (1992) examined the effects of various weed control practices, rowcover use, and nitrogen fertilizer placement on the establishment of micropropagated red raspberry plants. They found that weed control practices had a strong effect on S-IV plant performance; simazine or napropamide herbicides reduced cane length and cane weight when compared to non-hand-weeded, straw-mulched plots. Thus, to maximize yield during the first 2 years of establishment of 'Redwing', S-IV nursery stock should be planted, grown with supplemental irrigation, and weeds controlled with mulches that preclude the need for herbicides or cultivation that may inhibit growth.

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