Influence of Light Intensity on Optimum Fertilization Rate in Five Species of Tropical Ornamental Plants

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ADDITIONAL INDEX WORDS. *Pilea serpyllacea*, *Dracaena reflexa*, *Caryota mitis*, *Dypsis lutescens*, *Veitchia mcdanielsii*

SUMMARY. Five species of tropical ornamental plants—artillery fern (*Pilea serpyllacea*), pleomele (*Dracaena reflexa*), fishtail palm (*Caryota mitis*), areca palm (*Dypsis lutescens*), and sunshine palm (*Veitchia mcdanielsii*)—were grown in containers under full sun, 55% shade, or 73% shade. They were fertilized every 6 months with Osmocote Plus 15–9–12 (15N–4P–10K) at rates of 3, 6, 12, 18, 24, 30, and 36 g/pot (0.1, 0.2, 0.4, 0.6, 0.8, 1.1, and 1.3 oz/pot). For pleomele and the three palm species, optimum shoot dry weights and color ratings were similar among the three light intensities tested. However, artillery fern grown in full sun required fertilizer rates at least 50% higher for optimum shoot dry weight and color than under 55% or 73% shade. Light intensity × fertilizer rate interactions were highly significant for pilea and fishtail palm color and dry weight and sunshine palm and pleomele color.

Ornamental plants used for landscaping in tropical and subtropical areas are often the same species that, when acclimatized under shade, are used in interiorscapes. Plants destined to be used in tropical or subtropical landscapes are typically produced under full sun conditions, whereas those intended for interiorscape use are grown under shade. However, large trees or palms to be used in the interior environment are often grown in full sun for several years, and are subsequently acclimatized under shade for up to 1 year prior to interiorscape installation (Conover and Poole, 1990). This full sun phase of interiorscape plant production not only reduces production costs, but also enhances growth rate, stem caliper, compactness, and basal branching (Braswell et al., 1982; Conover and Poole, 1977; Donselman and Broschat, 1982).

Since plants grown in full sun are often lighter in color than similarly fertilized shade-grown plants, plant nutritional requirements are believed to be higher under full sun than under lower production light levels (Joiner et al., 1981). Fertilizer recommendations for tropical foliage plants have been based on production light intensities used for each crop (Conover and Poole, 1990). However, there is little published data on optimal fertilization rates for tropical plants grown under different light intensities (Conover and Poole, 1974, 1975). Conover and Poole (1990) suggest that fertilizer rates for plants grown under full sun be increased by 50% or more over those recommended for 50% shade and that those grown at even lower light intensities should be given about 25% less fertilizer than those growing under 50% shade. The purpose of this study was to determine the relationship between production light intensity and fertilization rate for several species of tropical ornamental plants that are used both as tropical landscape plants and as tropical interiorscape plants.

Materials and methods

Five species of tropical ornamental plants that can be used as interiorscape plants or outdoor landscape plants in tropical or subtropical climates were grown under full sun [maximum photosynthetic photon flux (PPF_{max}) = 2000 $\mu mol \cdot m^{-2} \cdot s^{-1}$], 55% shade ($PPF_{max}$ = 900 $\mu mol \cdot m^{-2} \cdot s^{-1}$) or 73% shade ($PPF_{max}$ = 540 $\mu mol \cdot m^{-2} \cdot s^{-1}$) in Fort Lauderdale, Fla. Liners of artillery fern, pleomele, areca palm, sunshine palm, and fishtail palm growing in 450-mL (1-pt) containers were potted up into 2.4-L (1-gal) plastic containers using a 5 pine bark : 4 Florida sedge peat : 1 sand (by volume) substrate on 31 Mar 1999. This substrate was amended with dolomitic limestone at 7.1 $kg \cdot m^{-3}$ (12 lb/yard^3) and Micromax (Scotts Co., Marysville, Ohio) at 890 $kg \cdot m^{-3}$ (1.5 lb/yard^3). The sunshine palms were grown only under full sun and 73% shade levels.

Pots were surface fertilized with Osmocote Plus 15–9–12 (15N–4P–10K) (8 to 9 month formulation) (Scotts Co., Marysville, Ohio) every 6 months at rates of 3, 6, 12, 18, 24, 30, and 36 g/pot. The sunshine and areca

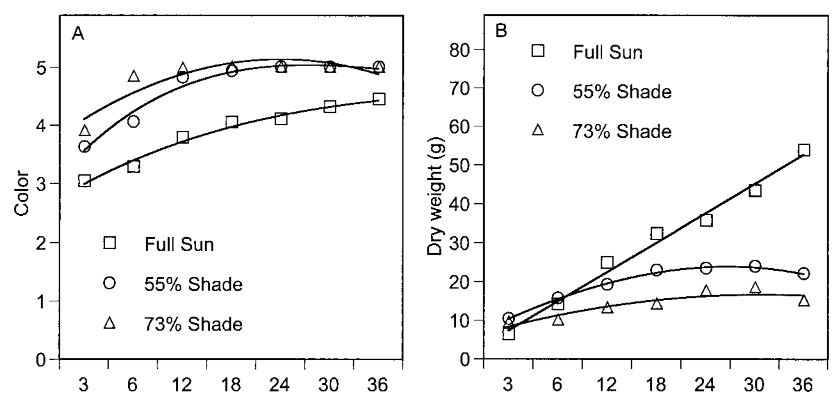

Fig. 1. Shoot dry weight and color rating (1 to 5 scale with 5 = darkest green, 3 = light green, 1 = completely yellow) responses in artillery fern grown under full sun, or 55% or 73% shade and fertilized with varying rates of Osmocote Plus 15–9–12 (15N–4P–10K). Regression equations for plant color ratings are full sun y = $0.0017x^3 - 0.049x^2 + 0.54x + 2.50$, R^2 = 0.983, $P < 0.0001$; 55% shade y = $0.0.0069x^3 - 0.16x^2 + 1.09x + 2.62$, R^2 = 0.968, $P < 0.0001$; 73% shade y = $-0.065x^2 + 0.65x + 3.52$, R^2 = 0.824, $P < 0.0001$. Regression equations for shoot dry weights are full sun y = $7.57x - 0.27$, R^2 = 0.990, $P < 0.0001$; 55% shade y = $-0.023x^3 - 0.42x^2 + 6.56x + 4.19$, R^2 = 0.996, $P < 0.0001$; 73% shade y = $-0.31x^2 + 3.86x + 4.80$, R^2 = 0.841, $P < 0.0001$; 28.35 g = 1.0 oz.

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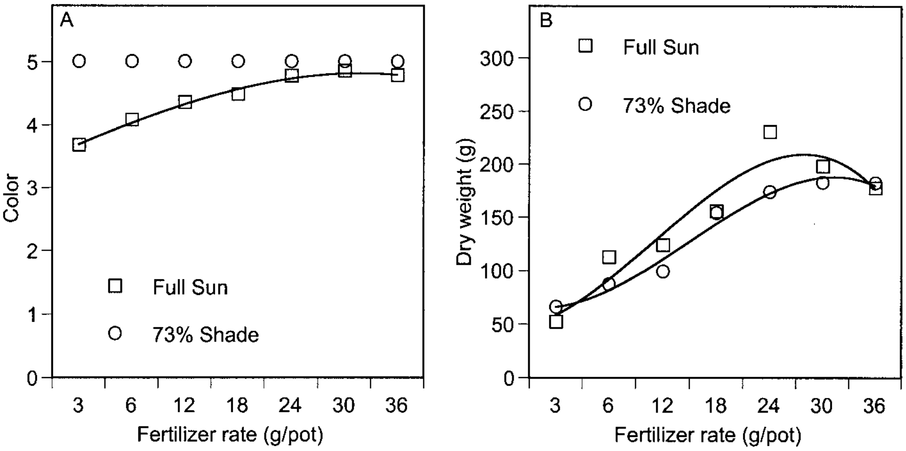

Fig. 2. Shoot dry weight and color rating (1 to 5 scale with 5 = darkest green, 3 = light green, 1 = completely yellow) responses in sunshine palm grown under full sun or 73% shade and fertilized with varying rates of Osmocote Plus 15–9–12 (15N–4P–10K). Regression equations for plant color ratings are full sun $y = -0.0025x^3 - 0.006x^2 + 0.38x + 3.32$, $R^2 = 0.989$, $P < 0.0001$; 73% shade (nonsignificant). Regression equations for shoot dry weight are full sun $y = -1.86x^3 + 15.9x^2 - 1.63x + 46.1$, $R^2 = 0.916$, $P < 0.0001$; 73% shade $y = -1.51x^3 + 15.8x^2 - 21.4x + 73.2$, $R^2 = 0.980$, $P < 0.0001$; 28.35 g = 1.0 oz.

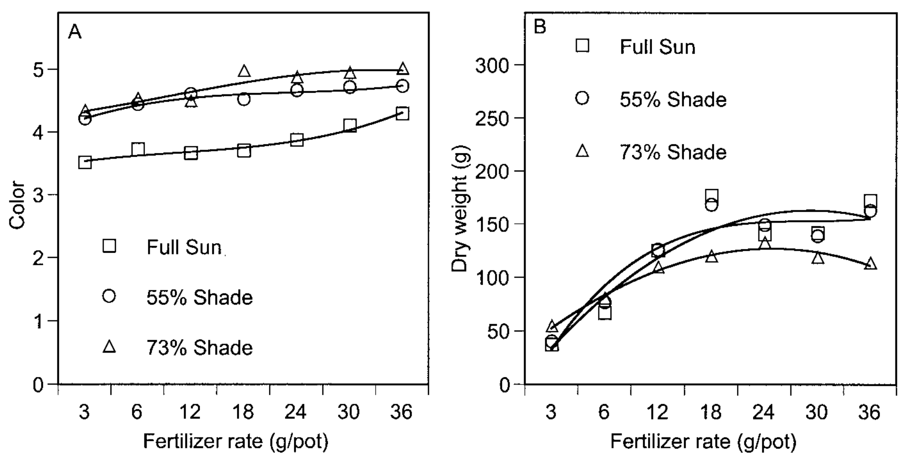

Fig. 3. Shoot dry weight and color rating (1 to 5 scale with 5 = darkest green, 3 = light green, 1 = completely yellow) responses in areca palm grown under full sun or 55% or 73% shade and fertilized with varying rates of Osmocote Plus 15–9–12 (15N–4P–10K). Regression equations for plant color ratings are full sun $y = 0.0053x^3 - 0.044x^2 + 0.18x + 3.39$, $R^2 = 0.960$, $P < 0.0001$; 55% shade $y = 0.0053x^3 - 0.077x^2 + 0.4x + 3.88$, $R^2 = 0.938$, $P < 0.0001$; 73% shade $y = -0.0033x^3 + 0.026x^2 + 0.093x + 4.21$, $R^2 = 0.863$, $P < 0.0001$. Regression equations for shoot dry weight are full sun $y = -5.44x^2 + 63.8x - 2.45$, $R^2 = 0.853$, $P < 0.0001$; 55% shade $y = 1.03x^3 - 18.1x^2 + 107.0x - 5.73$, $R^2 = 0.920$, $P < 0.0001$; 73% shade $y = -0.058x^3 - 3.66x^2 + 42.3x + 13.7$, $R^2 = 0.981$, $P < 0.0001$; 28.35 g = 1.0 oz.

palms were transplanted a second time into 6.2-L (2-gal) containers on 6 Sept. 1999 and the fishtail palms were similarly potted up on 18 Apr. 2000. Fertilization rates for 6.2-L containers were twice those used for 2.4-L containers. Ten replicate pots per species, light level, and fertilizer combination were arranged in a split plot design with complete randomization of fertilizer treatments within each light level and species plot. Pots received about 2 cm (0.75 inch) of water daily from overhead irrigation plus natural rainfall. The experiment was terminated on 7 June 1999 for artillery ferns, 27 Mar. 2000 for pleomele, 4 Apr. 2000 for areca palms, 13 Apr. 2000 for sunshine palms, and 20 Oct. 2000 for fishtail palms. At that time plants were subjectively scored for foliage color on a scale of 1 to 5, with 5 = darkest green for the species, 3 = light green, and 1 = completely yellow. Plants were then harvested by cutting the shoots off at the substrate surface level and drying them in an oven at 66.3 °C (145 °F) until constant weight was achieved. Data were analyzed using regression analysis (PROC GLM; SAS Systems, Cary, N.C.) within each light level to determine the fertilization rate for each light level at which plant quality was highest.

Results and discussion

For artillery ferns growing in full sun, both plant color and dry weight continued to increase with increasing fertilization rate to the maximum rate applied in this experiment (Figs. 1A and B). Plants grown under shade had highest plant color ratings and dry weights at rates of about 18 to 24 g/pot for both shade levels, with higher fertilizer rates resulting in a slight decrease in plant color and dry weight. Light intensity × fertilization rate interactions were highly significant ($P < 0.0001$) for both plant color ratings and shoot dry weight. Thus artillery ferns growing in full sun required fertilization rates at least 50% greater than those growing under 55% or 73% shade for similar plant quality. Within the range of fertilizer rates tested, plant color was always lighter for full-sun-grown plants than for shade-grown plants ($P < 0.0001$). However, plant dry weight was greater in full sun than in shade-grown plants, presumably due to greater carbohydrate production under higher light intensities (Conover and Poole, 1981). Conover and Poole (1977) found a similar plant color response for heartleaf philodendron (*Philodendron oxycardium*) to varying fertilization levels under 40%, 60%, or 80% shade.

Sunshine palms did not respond in terms of plant color to increasing fertilization rates when grown under 73% shade (Fig. 2A), but increasing fertilization rate to 30 g/pot improved plant color when grown in full sun. Plant color for sun-grown plants approached that of shade-grown plants only at fertilizer rates of 24 g/pot or higher. Plant dry weight increased with increasing fertilization rate under both light intensities, reaching maximum size at a rate of 24 g/pot under full sun and 30 g/pot under 73% shade (Fig. 2B). The light intensity × fertilization rate interaction was highly significant ($P < 0.0001$) for plant color ratings, but was nonsignificant for shoot dry weights. Unlike artillery ferns, sun-

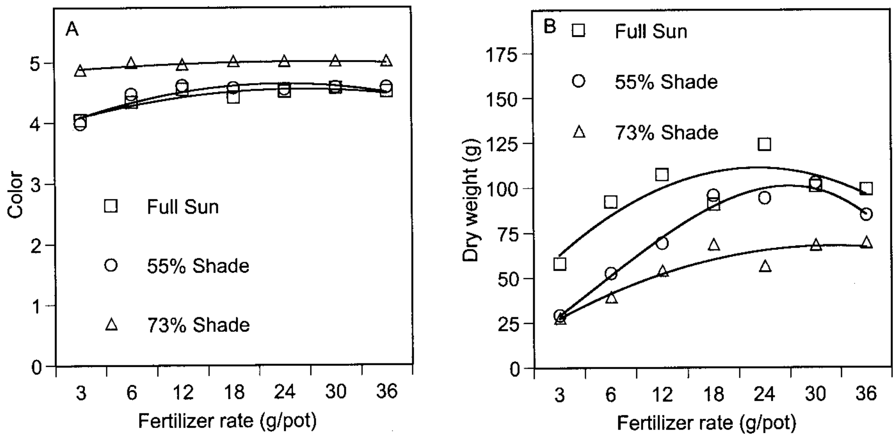

Fig. 4. Shoot dry weight and color rating (1 to 5 scale with 5 = darkest green, 3 = light green, 1 = completely yellow) responses in pleomele grown under full sun or 55% or 73% shade and fertilized with varying rates of Osmocote Plus 15–9–12 (15N–4P–10K). Regression equations for plant color ratings are full sun $y = -0.025x^2 + 0.27x + 3.85$, $R^2 = 0.836$, $P < 0.0001$; 55% shade $y = 0.0035x^2 + 0.35x + 3.76$, $R^2 = 0.805$, $P < 0.0001$; 73% shade $y = -0.0066x^2 + 0.071x + 4.82$, $R^2 = 0.796$, $P < 0.0001$. Regression equations for shoot dry weight are full sun $y = -3.24x^2 + 31.56x + 34.29$, $R^2 = 0.724$, $P < 0.0001$; 55% shade $y = 00.54x^3 + 2.90x^2 + 17.14x + 9.38$, $R^2 = 0.979$, $P < 0.0001$; 73% shade $y = -1.43x^2 + 18.09x + 10.60$, $R^2 = 0.897$, $P < 0.0001$; 28.35 g = 1.0 oz.

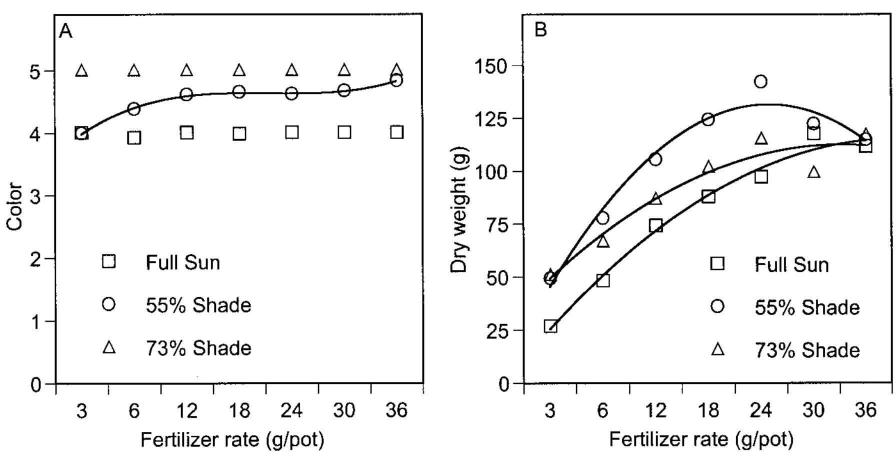

Fig. 5. Shoot dry weight and color rating (1 to 5 scale with 5 = darkest green, 3 = light green, 1 = completely yellow) responses in fishtail palm grown under full sun or 55% or 73% shade and fertilized with varying rates of Osmocote Plus 15–9–12 (15N–4P–10K). Regression equations for plant color ratings are full sun (nonsignificant); 55% shade $y = 0.051x^3 - 0.021x^2 + 0.93x + 3.24$, $R^2 = 0.997$, $P < 0.0001$; 73% shade (nonsigificant). Regression equations for shoot dry weight are $y = -0.0021x^2 + 31.1x - 3.9$, $R^2 = 0.985$, $P < 0.0001$; 55% shade $y = 4.99x^2 + 51.4x - 0.097$, $R^2 = 0.968$, $P < 0.0001$; 73% shade $y = -2.06x^2 + 26.9x + 2.45$, $R^2 = 0.928$, $P < 0.0001$; 28.35 g = 1.0 oz.

shine palm dry weights were similar for sun-grown and shade-grown palms. This suggests that this species may not be able to use the higher light intensities during this early (juvenile) stage of its life cycle. Thus, optimum sunshine palm quality was achieved at a rate of about 24 g/pot for plants growing in either full sun or 73% shade.

Plant color increased very slowly in response to increasing fertilization levels in shade-grown areca palms (Fig. 3A), but increased more rapidly in full sun-grown palms as fertilizer rate was increased from 24 to 30 g/pot. Although optimum plant color was obtained at a fertilizer rate of about 18 g/pot for 73% shade and 24 g/pot for 55% shade, optimum plant color for full-sun-grown areca palms may require rates of above 36 g/pot, the highest rate tested.

Areca palm dry weight was greatest at a rate of about 24 g/pot for palms growing under 73% shade (Fig. 3B). Optimum fertilization rate for palms growing under full sun or 55% shade cannot be determined with certainty due to variability in the data between 18 and 36 g/pot. In general, plant dry weight responded similarly for plants grown under full sun or shade, but plants grown under 73% shade ultimately had lower dry weights than those grown under full sun or 55% shade ($P = 0.03$). Light intensity × fertilization rate interactions were nonsignificant for both plant color ratings and shoot dry weights.

When grown under 73% shade, pleomele showed little plant color response to increasing fertilizer levels (Fig. 4A). For plants growing under full sun or 55% shade, optimum color was obtained at a rate of about 18 g/pot, but pleomele color was never as dark for full sun or 55% shade-grown plants as it was for 73% shade plants ($P < 0.0001$). Pleomele dry weight increased with increasing fertilizer rate up to 18 g/pot for 73% shade, about 28 to 30 g/pot for 55% shade, and 24 g/pot under full sun (Fig. 4B). In general, pleomele dry weight was greatest for full-sun-grown plants and least for those grown under 73% shade ($P < 0.0001$). The light intensity × fertilization rate interaction for plant color ratings was significant ($P = 0.035$), whereas the interaction for shoot dry weights was nonsignificant. Conover and Poole (1975) found that red-edged dracaena (*Dracaena marginata*) grown under full sun required higher levels of fertilizer to achieve the same plant color as those grown under 40% or 80% shade.

Plant color for fishtail palms grown under full sun or 73% shade did not respond to increasing fertilizer levels (Fig. 5A). For reasons not understood, plant color appeared to improve slightly with increasing fertilizer rate for palms growing under 55% shade. Fishtail palm dry weight increased with increasing fertilizer rate to a maximum at 24 g/pot for palms growing under 55 or 73% shade (Fig. 5B). Maximum dry weight under full sun was obtained at a rate of 30 g/pot. Light intensity × fertilization rate interactions were highly significant ($P < 0.0001$) for both plant color ratings and shoot dry weights.

This study demonstrates that different tropical plant species respond differently to increasing fertilization rates under varying light intensities. Artillery fern was unique among the species tested in that plants growing in full sun required much higher fertilizer rates than those growing under shade.

Since artillery fern was the only dicot tested, it is not known if its growth response to fertilization is characteristic of dicots in general, or atypical among plants in general. For pleomele and the three palm species, optimum fertilization rates with respect to plant dry weight differed little among the various light levels. With the exception of sunshine and areca palms growing in full sun, plant color responses among these monocots were similar among the three light levels studied.

These data showed that for pleomele and the three palm species tested, similar fertilizer rates can be used for full sun and shade production. For artillery fern, much higher rates are required to achieve optimum plant quality under full sun. Further studies on other dicot species would be helpful in determining if all dicots respond to fertilization in the same manner as artillery fern.

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Seasonal Fluctuations of Leaf and Root Weight and Ginsenoside Contents of 2-, 3-, and 4-year-old American Ginseng Plants

Thomas S.C. Li and Doug Wardle

Additional index words. *Panax quinquefolium*

Summary. The effect of harvest period on fresh and dry leaf and root weights and ginsenoside contents of 2-, 3-, and 4-year-old american ginseng (*Panax quinquefolium*) plants was investigated. Ginseng plants harvested once every 4 weeks from the end of June through September had the highest and lowest fresh and dry leaf weights in June and September, respectively. The trend was reversed in roots, except for 3-year-old roots that exhibited maximum weight at the end of August. Total ginsenoside contents in leaves of 3- and 4-year-old plants increased with the growing season until the end of August, but in 2-year-old plants it increased until the end of September. Total ginsenoside contents in roots peaked at the end of June for 3- and 4-year-old plants.

American ginseng is a perennial aromatic herb, native to eastern North America (Lewis and Zenger, 1982). Ginseng has been used in Asia for thousands of years as an energy booster and general tonic. Trade in american ginseng between Canada and China began in the early 1700s when it was discovered that the roots possessed properties similar to those of the asian ginseng (*Panax ginseng*) from China (Li, 1995). The popularity of american ginseng around the world has led to extensive cultivation in Canada, China, the United States, and recently in Australia and New Zealand.

The chemical constituents of american ginseng, triterpene saponins known as ginsenosides, Rx (x = b, c, d, e, f, g, etc.), are believed to contribute to its pharmacological effects (Lewis, 1988; Li and Wang, 1998). Every part of the ginseng plant, root, stem, leaf, flower and berry, contains ginsenosides (Li et al., 1996; Ma, 1995). Traditionally, roots are the only parts of the ginseng plant utilized as a health remedy in Asia and North America, even though valuable ginsenosides are present in other parts of the plant, especially in the leaves (Li and Mazza, 1999). Ginsenoside extraction from leaves is beginning to attract attention from the nutraceutical industry.

Farmers have traditionally harvested and processed the roots of 4-year-old plants between September and November without consideration of the effects of harvest date on ginsenoside content and yield, two of the most important parameters directly affecting market values. Obtaining the best quality and highest yield by establishing the plant age and period to harvest ginseng is important. The objectives of this study were to determine harvest period (June until September) within each plant age (2-, 3-, and 4-year-old) on fresh and dry weights, and ginsenoside contents of american ginseng.

Materials and methods

Ten 2-, 3-, and 4-year-old american ginseng plants were collected from three separate ginseng research plots [1/4 acre (0.10 ha) each] at Pacific Agri-Food Research Center, Summerland, B.C., at the end of each month from June until September, the end of growing season, which represent 1 to 4 months of plant growth. One row of each plot [3 × 30 ft (0.9 × 9.1 m)] was divided into ten sections (3 × 3 ft) and one plant each was randomly sampled. The fresh weights of leaves, without stem, and root of each plant were recorded immediately after washing and drying with paper towels. All the samples were temporarily stored in a freezer at –4 °F (–20 °C). In October, all samples were freeze-dried at –85 °F (–65 °C) and

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