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

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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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dry weights were recorded. Freeze dried tissue was ground in a Wiley mill to pass through a 1-mm screen and stored in plastic bags at –31 °F (–35 °C) until analyzed. Seven major ginsenosides—Rb_1, Rb_2, Rc, Rd, Re, Rf, and Rg_1—were extracted using reverse-phase high-performance liquid chromatography (HPLC) (Li et al., 1996). Each ginsenoside was quantified using standard curves prepared by injecting measured volumes of standard solutions of authentic ginsenosides (Carl Roth GMBH, Karlsruhe, Germany). Data collected from each parameter investigated in each of three plant age groups with four different harvest periods were statistically analyzed separately using the SAS GLM (1990) procedure and Duncan's new multiple range test.

Results and discussion

Seasonal variation of leaf and root fresh and dry weights and ginsenoside contents in 2-, 3-, and 4-year-old ginseng plants were observed. Harvest period affected fresh and dry weights of both leaves and roots. Fresh and dry weights of leaves of 2-, 3-, and 4-year-old plants were highest at the end of June and lowest at the end of September (Table 1). This trend coincided with vegetative growth flushes during the early growing season. In contrast, the fresh and dry root weights of 2-, 3-, and 4-year-old plants increased steadily during the growing season until the end of September except for those of 3-year-old plants, in which fresh and dry weights were highest at the end of August (Table 1). Results from this experiment were in partial agreement with the report of Xu and Xu (1994), where seasonal changes in leaf weight of the asian ginseng was highest at the end of June and again at the beginning of August. Similar results were reported by Soldati and Tanaka (1984), who suggested that the best harvest period for roots of 5-year-old asian ginseng plants was at the end of summer. Court et al. (1996) reported that root weight increased with the age in american ginseng. Similar results were observed in this study; root fresh weight increased from an average of 0.19 oz (5.3 g) in 2-year-old to 0.74 oz (20.9 g) in 4-year-old plants.

Harvest period affected individual and total ginsenoside contents in leaves (Table 2). In 2-year-old plants, the levels of ginsenoside Rg_1 and total ginsenoside increased with the harvest period.

Similar trend was observed for ginsenosides Rb_1, Rb_2, Rc, Rd, Re, and Rf, although differences were not significant In leaves of 3- and 4-year-old plants, all the individual and total ginsenoside, except Rc in 3-year-old leaves, showed a trend of reaching the highest level at the end of August. This seasonal variation or remobilization of ginsenosides from leaves to root is a complicated physiological process within ginseng plant which is related to developmental and environmental changes.

Harvest period had less effect on ginsenoside content in roots than in leaves (Table 3). Harvest periods affected the Rb_1 and Re contents in the root of 2-year-old plants, total ginsenosides in 3-year-old, and Rf, Rb_1, Rb_2 Rd, and total ginsenoside contents in 4-year-old plants. Although there were no significant differences, the trend of the contents of Rb_1, Rc, Rd and total ginsenoside of roots in 3-year-old plant was at the highest level at the end of June and started to decrease in July.

Similar trend was observed in the root of 4-year-old plants, ginsenoside Rb_1, Rb_2, Rc, and Rd and total ginsenoside was statistically at the highest level at the end of June. Similar to the ginsenoside contents, this pattern of seasonal fluctuation has been observed in other crops. Conway et al. (1999) reported that in chinese tallow (*Sapium sebiferum*) roots, total nonstructural carbohydrate concentrations in the roots were highest during leaf fall and lowest during leaf development. In sweet cherry (*Prunus avium*), Schwalb and Feucht (1999) reported that concentrations of phenolic substances in the leaves reached maximum levels during mid-July and then started to decrease, coinciding with the decline in shoot growth.

To the best of our knowledge no similar study has been published showing the relationship between harvest period during the growing season and total ginsenoside contents in leaves and roots of ginseng of different plant ages. Reynolds (1998) reported that a delay in ginseng harvest date from August to November, resulted in a decrease in ginsenoside contents, and he concluded that early harvesting improved quality. Liu (1988) reported that total ginsenoside content increased with the age in the Asian ginseng roots from 1.15% (1-year-old) to 4.85% (6-year-old). Court et al. (1996) investigated the influence of root age on the ginsenosides of american ginseng and found that ginseng harvested after only

Table 1. Effects of harvest period on fresh and dry weights (oz) of american ginseng.

	Plant age (years)					
Harvest	2		3		4	
period	Fresh wt	Dry wt	Fresh wt	Dry wt	Fresh wt	Dry wt
Leaves						
30 June	0.09[z] a[y]	0.02 a	0.46 a	0.09 a	0.61 a	0.12 a
28 July	0.07 ab	0.02 a	0.44 ab	0.09 a	0.45 b	0.09 ab
31 Aug.	0.06 ab	0.02 a	0.34 ab	0.09 a	0.38 b	0.08 ab
28 Sept.	0.05 b	0.01 b	0.29 b	0.06 b	0.34 b	0.07 b
Roots						
30 June	0.14 b	0.05 b	0.51 b	0.17 b	0.46 b	0.20 b
28 July	0.16 b	0.02 b	0.59 b	0.22 ab	0.55 ab	0.20 b
31 Aug.	0.20 ab	0.08 ab	0.86 a	0.30 a	0.63 ab	0.24 b
28 Sept.	0.25 a	0.08 a	0.81 a	0.27 a	0.93 a	0.31 a

[z]1.00 oz = 28.35 g.
[y]Means in each column followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's new multiple range test.

Table 2. Effects of harvest period on ginsenoside contents of american ginseng leaves.

Harvest period	Ginsenoside content (% dry wt) Rg1	Re	Rf	Rb1	Rc	Rb2	Rd	Total
2-year-old plants								
30 June	0.16 b[z]	1.11 a	0.03 a	0.07 a	0.07 a	0.23 a	0.24 a	1.91 b
28 July	0.15 b	0.97 a	0.02 a	0.08 a	0.08 a	0.23 a	0.20 a	1.74 b
31 Aug.	0.17 b	1.34 a	0.01 a	0.11 a	0.07 a	0.21 a	0.35 a	2.26 ab
28 Sept.	0.39 a	1.44 a	0.04 a	0.12 a	0.11 a	0.30 a	0.53 a	2.93 a
3-year-old plants								
30 June	0.12 b	0.90 b	0.06 a	0.20 a	0.08 a	0.19 a	0.30 b	1.85 b
28 July	0.16 b	1.03 b	0.02 a	0.04 a	0.05 a	0.23 a	0.62 ab	2.14 b
31 Aug.	0.32 a	1.90 a	0.09 a	0.12 a	0.11 a	0.41 a	0.80 a	3.76 a
28 Sept.	0.17 b	1.22 ab	0.06 a	0.05 a	0.13 a	0.40 a	0.61 ab	2.64 b
4-year-old plants								
30 June	0.07 b	1.04 b	0.07 a	0.05 bc	0.05 b	0.18 c	0.30 b	1.76 c
28 July	0.16 b	1.33 ab	0.01 a	0.04 c	0.10 ab	0.27 bc	0.71 a	2.62 b
31 Aug.	0.23 a	1.74 a	0.04 a	0.11 a	0.15 a	0.46 a	0.79 a	3.53 a
28 Sept.	0.15 b	1.17 b	0.01 a	0.10 ab	0.10 ab	0.36 ab	0.75 a	2.64 b

[z]Means in each column within each plant age followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's new multiple range test.

Table 3. Effects of harvest period on ginsenoside contents of american ginseng roots.

Harvest period	Ginsenoside content (% dry wt) Rg1	Re	Rf	Rb1	Rc	Rb2	Rd	Total
2-year-old plants								
30 June	0.16 a[z]	0.46 b	0.03 a	0.51 ab	0.09 a	0.03 a	0.13 a	1.42 a
28 July	0.13 a	0.72 a	0.01 a	0.44 b	0.03 a	0.10 a	0.15 a	1.58 a
31 Aug.	0.07 a	0.73 a	0.06 a	0.69 a	0.09 a	0.02 a	0.08 a	1.74 a
28 Sept.	0.08 a	0.76 a	0.02 a	0.50 ab	0.08 a	0.01 a	0.15 a	1.61 a
3-year-old plants								
30 June	0.13 a	0.97 a	0.01 a	1.28 a	0.18 a	0.02 a	0.27 a	2.86 a
28 July	0.14 a	0.96 a	0.01 a	1.00 a	0.14 a	0.02 a	0.20 a	2.47 ab
31 Aug.	0.08 a	0.90 a	0.02 a	0.73 a	0.13 a	0.02 a	0.21 a	2.09 b
28 Sept.	0.11 a	1.06 a	0.05 a	0.90 a	0.12 a	0.02 a	0.14 a	2.40 ab
4-year-old plants								
30 June	0.07 a	0.96 a	0.01 b	2.28 a	0.25 a	0.04 a	0.39 a	4.00 a
28 July	0.17 a	1.06 a	0.02 ab	1.25 b	0.16 a	0.02 b	0.23 b	2.91 b
31 Aug.	0.19 a	0.94 a	0.01 b	0.81 b	0.15 a	0.02 b	0.20 b	2.32 b
28 Sept.	0.06 a	0.82 a	0.04 a	1.01 b	0.14 a	0.02 b	0.15 b	2.24 b

[z]Means in each column with each plant age followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's new multiple range test.

3 years of cultivation contained lower amounts of ginsenosides than ginseng harvested after 4 years.

Conclusions

This study outlined the seasonal fluctuation in leaf and root fresh and dry weights and ginsenoside contents within each plant age. Fresh and dry leaf weights were the greatest in June and the lowest in September. The trend was reversed in roots, except for roots of 3-year-old plants which reached the highest level at the end of August. Total ginsenoside contents in leaves of 3- and 4-year-old plants, increased with the advance of the growing season until the end of August, and in roots, highest at the end of June. World ginseng production, especially american ginseng, is increasing steadily in recent years and may have saturated the market. Besides the color, texture, and shape, ginsenoside contents are being used as a marker by manufacturers to decide the quality of the ginseng roots. To meet this demand, farmers are trying to produce top quality product and information provided in this report can be used as a useful reference.

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Using Paclobutrazol to Control Height of Poinsettia 'Freedom'

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ADDITIONAL INDEX WORDS. bract area, plant growth retardant, stem elongation, *Euphorbia pulcherrima*

SUMMARY. Late-season height control of poinsettia (*Euphorbia pulcherrima*) is difficult since most chemical growth retardants adversely reduce bract size when applied after first bract color. Paclobutrazol (Bonzi) controls stem elongation late in poinsettia crop development but can excessively reduce bract size if improperly applied. Two experiments were conducted to quantify how paclobutrazol application influenced height and bract area of 'Freedom' poinsettia. In the first experiment, paclobutrazol was applied at 1 mg·L^{-1} (ppm) in 118-mL (4.0-fl oz) volumes per pot [(a.i.) 0.12 mg/pot (28,350 mg = 1.0 oz)] as a drench to a new group of plants weekly from the initiation of short days until 1 week before anthesis. Maximum reduction in height and bract area was obtained when paclobutrazol was applied immediately after short days, and the response to paclobutrazol decreased as application time was increasingly delayed toward anthesis. In the second experiment, paclobutrazol was applied weekly after first bract color as either a drench or subapplication at various concentrations. Plant height and bract area were reduced by 23% when 2 mg·L^{-1} [(a.i.) 0.24 mg/pot) paclobutrazol was applied through subapplication at first color. The effects of paclobutrazol on height and bract area reduction decreased as application time was progressively delayed. Concentrations lower than 1 mg·L^{-1} had no significant effect on height or bract area reduction, regardless of application time or method. Generally, the reduction in height and bract area was larger when paclobutrazol was applied through subapplication. The combined results from both experiments indicate that paclobutrazol drench applications after flower initiation concomitantly reduce plant height (internode extension) and bract area. Therefore, drench applications should be delayed as long as possible to limit reduction in bract size.

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Height control is difficult for poinsettia producers. Commercial growers must produce plants that meet the market height specifications; otherwise, plants will have a lower value, be more expensive to ship, or be totally unsaleable. Without some method of height control, poinsettias generally grow too tall in a greenhouse. Factors that contribute to tall plants include genetics, high plant density, positive DIF (difference between day and night temperatures), and excessive vegetative growth before the start of short-day flower initiation (Fisher and Heins, 1997). Traditionally, growth-retardant chemicals are applied intermittently for height control from planting until the poinsettia shows first bract color. Although growth retardant chemicals applied after first color effectively reduce stem elongation, they also reduce bract size and may delay bract development (Hartley, 1992). The reduction in bract size can be substantial. Plants with small bracts are less attractive, and if bracts are excessively small, plants may not be saleable.

'Freedom' was introduced to the poinsettia market in the early 1990s and accounts for about 55% of the red poinsettias grown in North America (Barrett and Wieland, 1997). This cultivar tends to elongate slowly when plant density and leaf area index (LAI) are low but elongates rapidly when the crop forms a solid leaf canopy and LAI is high. Under typical crop culture, the crop forms a solid canopy in late October and early November after first color. Poinsettia shoots can then elongate rapidly to quickly exceed final height specifications (Faust and Klein, 1998).

The rapid elongation in late October and early November is commonly called late stretch. The term is appropriate because the elongation occurs late in crop development when stem