J. Amer. Soc. Hort. Sci. 123(1):26–29. 1998.

Patterns of Saskatoon (*Amelanchier alnifolia* Nutt.) Fruit and Seed Growth

Roisin McGarry, Jocelyn A. Ozga,[1] and Dennis M. Reinecke
Department of Agricultural, Food, and Nutritional Science, University of Alberta, Edmonton, Alberta, Canada T6G 2P5

Additional index words. service berry, June berry, fruit growth, seed growth

Abstract. **Saskatoon fruit are an emerging horticultural crop across the Canadian prairies. As fruit size varies greatly among cultivars, knowledge of fruit growth patterns and factors that affect fruit size can be used to establish breeding trials and develop orchard management strategies that could enhance the production of this crop. In this study, we 1) determined fruit and seed growth patterns among large-, medium-, and small-fruited cultivars of saskatoon using growing degree days to standardize time to crop development and 2) assessed the role of seed number on fruit size. Fruit growth patterns of four cultivars (Thiessen, Northline, Regent, and Smoky) were determined from weekly measurements of fresh and dry fruit mass during two consecutive seasons. These growth patterns exhibited three phases. The largest fruit at maturity were from 'Thiessen', followed by 'Northline', 'Smoky', and 'Regent', in descending order. Pedicel cross-sectional areas 1 week before maturity correlated linearly with increasing fresh and dry fruit mass and seed number per fruit. At maturity, seed number per fruit correlated linearly with fresh and dry fruit mass. 'Thiessen' contained significantly more seeds per fruit (4.6) than 'Northline' (3.7), 'Smoky' (3.2), and 'Regent' (3.2). The results of this research suggest potential areas for orchard management improvement and future research directions for saskatoon crop improvement.**

The hardy saskatoon shrub has considerable potential for cultivation across western Canada, particularly with its natural adaptation to the harsh prairie climate. With the rapid increase in popularity of this native fruit, growing numbers of saskatoon orchards are being developed across the Canadian prairies to meet consumer demand (St. Pierre, 1992). Knowledge of fruit growth patterns among cultivars and factors that affect them can be particularly insightful for many horticultural procedures, such as selecting superior genotypes, establishing breeding programs, and implementing orchard management strategies (Westwood, 1993). However, no thorough studies comparing fruit growth among cultivated varieties of saskatoon have been reported.

The saskatoon fruit is a pentalocular pome with the potential to produce 10 seeds, although this is rarely achieved. St. Pierre and Steeves (1990) observed that fruit from natural stands contained one to five seeds, with 80% containing only one to three seeds. Since fruit size is related to seed number in many species (Dennis, 1984), the number of seeds per fruit may be a significant factor contributing to the fruit size variation observed among saskatoon cultivars. The objectives of this study were to compare patterns of fruit and seed growth among large-, medium-, and small-fruited saskatoon cultivars and examine the role of seed number on final fruit size.

Materials and Methods

Field growth studies were conducted during two seasons (1994 and 1995) at the Alberta Crop Diversification Centre North in Edmonton, Alberta, Canada. Three shrubs of 'Thiessen' and two shrubs of 'Northline', 'Smoky', and 'Regent' were selected arbitrarily among a block of 6-year-old saskatoon shrubs. Two flowers or fruit were harvested from each of 10 arbitrarily selected inflorescences or infructescences per shrub. Flowers were collected at 50% to 70% full bloom (13 May 1994 and 23 May 1995) and fruit were collected weekly thereafter until the fully mature ripe fruit stage (fruit color purple-black; 15 July 1994 and 18 July 1995). From fruit set (17 June 1994 and 13 June 1995) to maturity, an additional 10 fruit were similarly harvested for seed analysis.

Flowers and fruit were trimmed to include a 2-mm pedicel length, and fresh flower and fruit mass, measured at nine sampling dates each year (13 May to 15 July 1994; 23 May to 18 July 1995), was determined gravimetrically. After drying for 1 week at 60 °C, dry flower and fruit mass, measured on the same dates, was determined gravimetrically. Pedicel diameters were measured using calipers at the pedicel–fruit abscission zone 1 week before harvest maturity and converted to cross-sectional areas using the equation for a circle. Seed analysis required dissection of seeds from fruit, scoring of seed number, and determination of fresh mass per seed. Plump seeds containing fully formed cotyledons and embryo axes were scored as fully developed seeds; only fully developed seeds were counted in this study.

Patterns of fruit development among cultivars were compared using growing degree days (GDDs) to standardize time to crop development, enabling the trends observed in this study to be corrected for varying seasonal conditions. Sampling dates in each year were expressed as heat units (HUs) using the following equation:

$$HU = [(T_{max} + T_{min})/2] - T_{base}$$

where T_{max} = daily maximum temperature (°C), T_{min} = daily minimum temperature (°C), and T_{base} = estimated base temperature of 4.4 °C. Negative HUs were assigned a value of zero. Cumulative HUs (from 1 Apr.) were expressed as GGDs as follows:

$$GDD = \sum_1^n HU$$

where n = days.

The experiment was conducted and analyzed as a split-plot design, with shrubs within cultivars as the whole plot and the yearly measurements of each shrub as the split plot. The general

Received for publication 27 Dec. 1996. Accepted for publication 18 Aug. 1997. Funding from the Alberta Agriculture Research Institute to J.A.Ozga is gratefully acknowledged. We thank Lloyd Hausher for providing the saskatoon orchard used in this study, Simone Dalpe for maintenance of the orchard, Robert Hardin for assistance in statistical design and analysis, and Frank Dennis, Jr., for his editorial assistance. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.
[1]To whom reprint requests should be addressed.

linear model (GLM) procedure of SAS 6.10 (SAS Institute Inc., Cary, N.C.) was used for statistical computation.

Results

The seasonal growth patterns in fruit fresh and dry mass were similar for all cultivars in both years ($P > 0.10$); therefore, the data were averaged over years. In general, 'Thiessen' produced the largest fruit with advancing growing degree days, followed by 'Northline', 'Smoky', and 'Regent', in descending order (Fig. 1 A and B). Seed fresh mass increased linearly up to 670 GDDs in all cultivars studied (Fig. 1C; $P < 0.05$). The most rapid rate of increase in seed fresh mass (440 to 670 GDDs) was observed in 'Northline' (25.5 µg/GDD, $R^2 = 0.98$), followed by 'Smoky' (14.6 µg/GDD, $R^2 = 0.95$), 'Thiessen' (15.4 µg/GDD, $R^2 = 0.99$), and 'Regent' (10.0 µg/GDD, $R^2 = 0.94$). In general, fresh fruit mass increased in three stages (Fig. 1A). Stage I of fruit development (50% to 70% full bloom at 144 to 300 GDDs) is characterized by an initial rate of growth of 0.36 mg/GDD, which increases to 0.83 mg/GDD between 225 to 300 GDDs. In Stage II (300 to 590 GDDs), the growth rate slows to 0.49 mg/GDD. At this time, rapid seed development was occurring (Fig. 1C). Stage III, the final phase of fruit growth, was characterized by exponential growth

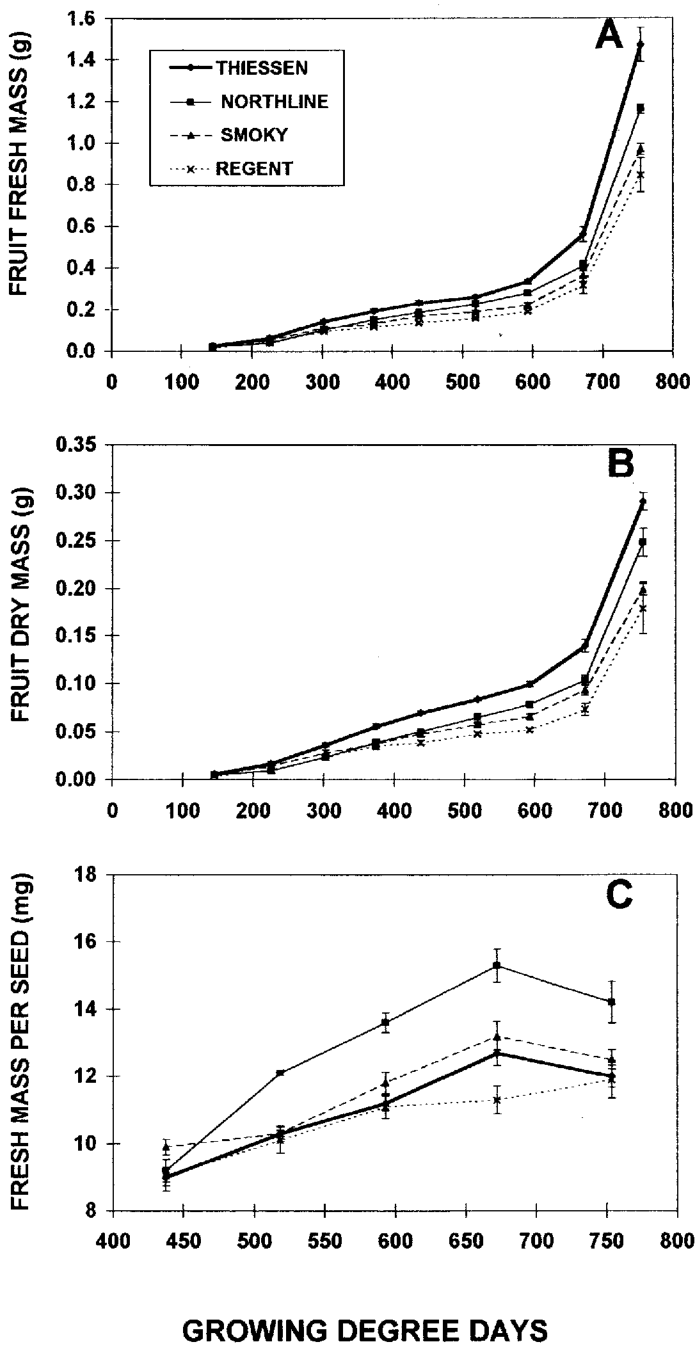

Fig. 1. Fruit and seed growth patterns in 'Thiessen', 'Northline', 'Smoky', and 'Regent' saskatoon (main effect of year was not significant, the averages of 1994 and 1995 are reported): (**A**) fruit fresh mass; (**B**) fruit dry mass; and (**C**) fresh mass per seed. Data for 144 growing degree days were obtained from flowers at 50% to 70% full bloom, the remaining data were obtained from developing fruit (A and B). Data are means ± SE (n = 6 for 'Theissen' and n = 4 for all other cultivars; A–C).

Table 1. Pedicel cross-sectional areas of four saskatoon cultivars measured 1 week before harvest maturity.

Cultivar	Pedicel cross-sectional area (mm^2)
Thiessen	0.81 a[z]
Northline	0.60 b
Smoky	0.55 b
Regent	0.54 b

[z]Mean separation among cultivars for pedicel cross-sectional areas by LSD, $P < 0.01$.

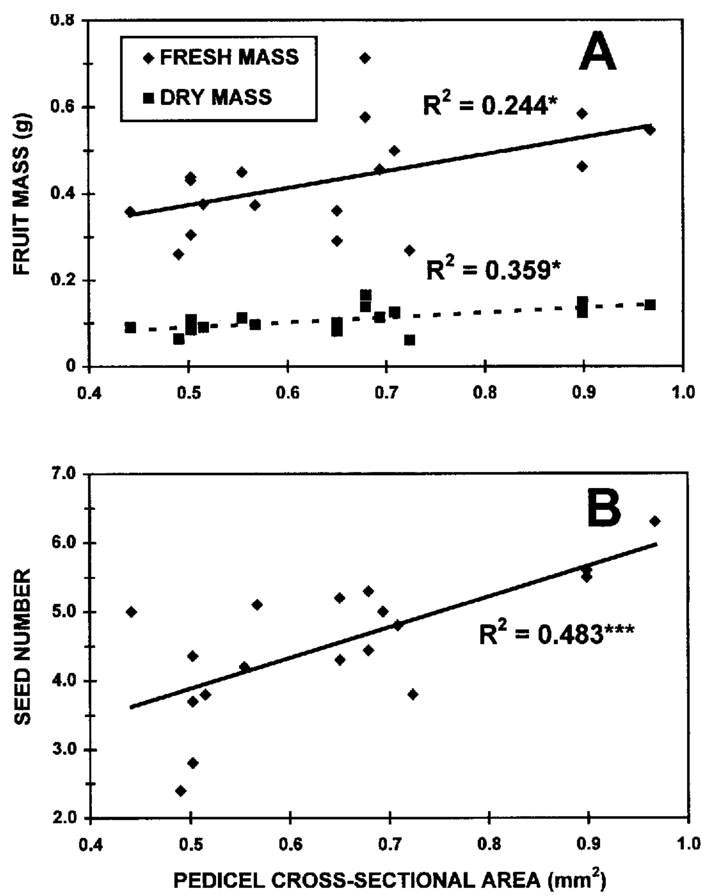

Fig. 2. The relationships between pedicel cross-sectional area and (**A**) fruit fresh mass ($y = 0.388x + 0.180$) and fruit dry mass ($y = 0.113x + 0.0339$) and (**B**) seed number ($y = 4.44x + 1.66$) in saskatoon fruit measured 1 week before harvest maturity (pooled data from all cultivars from 1994 and 1995). *,***Significant at $P < 0.05$ or 0.001, respectively.

Table 2. The number of seeds per fruit, total seed fresh mass per fruit, and fresh mass per seed among saskatoon cultivars measured at harvest maturity.

Cultivar	Seeds/fruit (no.)	Total seed fresh mass/ fruit (mg)	Fresh mass/ seed (mg)
Thiessen	4.57 a[z]	54.6 a	11.9 b
Northline	3.65 b	51.5 a	14.2 a
Smoky	3.20 b	40.1 b	12.5 b
Regent	3.18 b	37.7 b	11.9 b

[z]Mean separation among cultivars by LSD, $P < 0.01$.

from 590 GDDs to harvest maturity (fruit fresh mass increased 1.98 mg/GDD between 590 to 670 GDDs, and 8.55 mg/GDD between 670 to 750 GDDs).

'Thiessen' fruit had significantly larger pedicels (measured 1 week before harvest maturity) than those from 'Northline', 'Smoky', and 'Regent' fruit (Table 1). In general, pedicel cross-sectional area increased linearly with increasing fruit fresh and dry mass (Fig. 2A) and number of fully developed seeds per fruit (Fig. 2B).

At harvest maturity (15 July 1994 and 18 July 1995), 'Thiessen' fruit were the largest, followed by 'Northline', 'Smoky', and 'Regent', in descending order (Fig. 3). 'Thiessen' had significantly more seeds per fruit than the other cultivars, while 'Northline' exhibited the greatest fresh mass per seed (Table 2). The fresh mass of seeds per fruit was significantly greater in 'Thiessen' and 'Northline' than in 'Regent' and 'Smoky' (Table 2). At maturity, seed number and seed fresh mass per fruit increased linearly with fruit fresh and dry mass (Fig. 4 A and B).

Discussion

The general pattern of saskatoon fruit growth, based on fruit fresh mass, was characterized by three phases. In the first phase, growth is initially slow and then increases (Stage I; 50% to 70% full bloom to 300 GDDs). The rate of fruit growth is relatively constant during the second phase (Stage II; 300 to 590 GDDs) followed by a single period of exponential growth in the third phase (Stage III; 590 GDDs to harvest maturity, 750 GDDs). If fruit remain on the shrub past harvest maturity, fruit growth slows and eventually ceases (Rogiers and Knowles, 1997). Pome fruit, such as apples and pears, typically exhibit sigmoid growth curves with a single period of exponential fruit growth (Westwood, 1993). In contrast, berries and drupes typically exhibit double sigmoid growth curves, where a phase of minimal fruit development separates two periods of exponential fruit growth (Coombe, 1976; Monselise, 1986).

Knowledge of the patterns of saskatoon fruit growth can be used to optimize orchard management strategies. Chemical management of disease and pests can be scheduled before the exponential phase of fruit growth (Stage III) to avoid applications close to harvest. Orchard irrigation can be scheduled at the onset of Stage III to maximize fruit size before harvest. Furthermore, because saskatoon fruit attain harvest maturity during the period of very rapid fruit growth, minimizing bruising during mechanical harvesting and immediate precooling of fruit to reduce quickly fruit respiration rate is advisable to avoid deterioration in fruit quality.

Fruit growth is correlated with the number of developed seeds per fruit in *Vaccinium corymbosum* L. (Brewer and Dobson, 1969; Eaton, 1967; Gorchov, 1985), tomato (*Lycopersicon esculentum* Mill.) (Dempsey and Boynton, 1965), and *Amelanchier arborea* (Gorchov, 1985). Mature saskatoon pedicel and fruit size increased linearly with the number of developed seeds (Figs. 2B and 4A), suggesting that saskatoon seeds influence growth of the surrounding fruit tissues. Seed number distinguished 'Thiessen' (4.6 seeds/fruit), the cultivar producing the largest fruit, from the remaining cultivars (3.3 seeds/fruit). 'Thiessen' fruit also had larger pedicels compared to the other cultivars studied. Immature seeds contain high concentrations of hormones (Coombe, 1976);

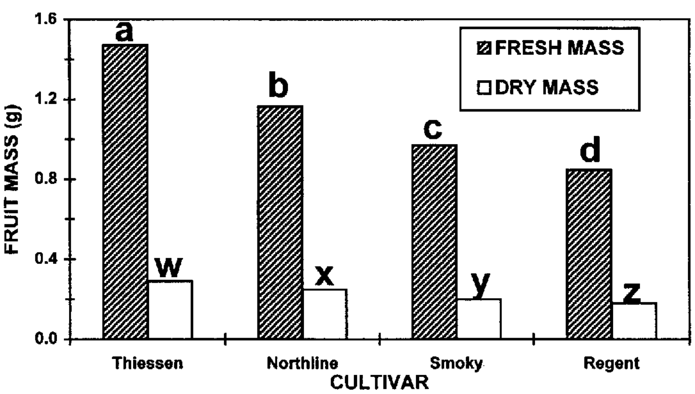

Fig. 3. Fruit fresh and dry mass of four saskatoon cultivars at harvest maturity. Mean separation between cultivars for fresh mass (abcd) and dry mass (wxyz) by LSD, $P < 0.05$.

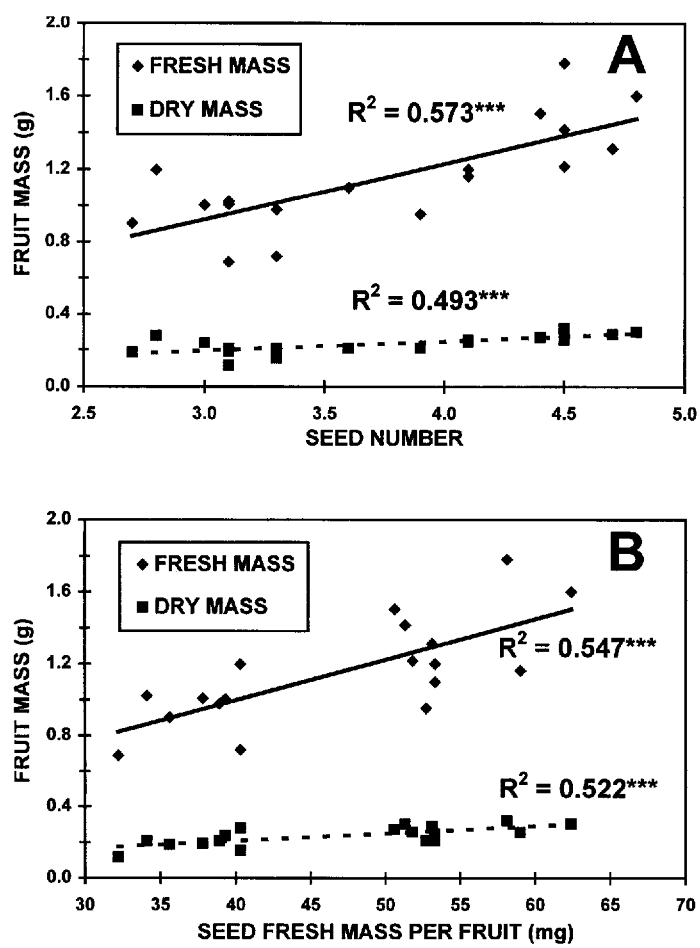

Fig. 4. (**A**) The relationship between seed number per fruit and fruit fresh mass ($y = 0.307x + 0.0022$) and fruit dry mass ($y = 0.0541x + 0.0332$) and (**B**) the relationship between seed fresh mass per fruit and fruit fresh mass ($y = 0.0226x + 0.0934$) and fruit dry mass ($y = 0.0042x + 0.0394$) in saskatoon fruit at harvest maturity (pooled data from all cultivars from 1994 and 1995). ***Significant at $P < 0.001$.

thus, saskatoon seeds may release hormones that stimulate vascularization within the pedicel. This, in turn, may increase the delivery of photosynthates to the developing fruit. Alternatively, fruit with more developing seeds may be greater sinks for photosynthate and hormones from vegetative tissues. The cultivar producing the second largest fruit, 'Northline', had the largest fresh mass per seed compared to the other cultivars. Seed fresh mass per fruit differentiated the larger from the smaller fruited cultivars (Thiessen and Northline vs. Smoky and Regent). Pedicel cross-sectional area was linearly correlated with fruit mass (Fig. 2A); however, low coefficients of determination indicated that only a small fraction of variation was attributable to the linear relationship. Therefore, pedicel cross-sectional area would likely not be a good predictor of fruit size.

The results of this research indicate that fruit size in saskatoon is related to seed number per fruit and the total seed fresh mass per fruit. Furthermore, these data suggest that seed number is more critical than seed size in determining the largest fruit size in the cultivars studied. However, the higher seed number associated with larger fruit size is undesirable in many value-added saskatoon products; hence, future efforts to improve this fruit crop need to address the relationship between fruit size and seed content. As genotype is often the dominant factor affecting fruit size (Brown, 1975; Galletta, 1975), breeding for large fruit with fewer seeds (exhibited in some blueberry clones; Moore et al., 1972) and/or using plant growth regulators to reduce seed number without significantly diminishing fruit size (McGarry, 1996; Naylar, 1984; Pharis and King, 1985) are two promising areas for future research efforts for saskatoon crop improvement.

Literature Cited

Brewer, J.W. and R.C. Dobson. 1969. Seed count and berry size in relation to pollinator level and harvest date for the highbush blueberry, *Vaccinium corymbosum*. J. Econ. Entomol. 62:1353–1356.

Brown, A.G. 1975. Apples, p. 3–37. In: J. Janick and J.N. Moore (eds.). Advances in fruit breeding. Purdue Univ. Press, W. Lafayette, Ind.

Coombe, B.G. 1976. The development of fleshy fruits. Annu. Rev. Plant Physiol. 27:207–228.

Dempsey, W.H. and J.E. Boynton. 1965. Effect of seed number on tomato fruit size and maturity. Proc. Amer. Soc. Hort. Sci. 86:575–581.

Dennis, Jr., F.G. 1984. Fruit development, p. 265–289. In: M.B. Tesar (ed.). Physiological basis of crop growth and development. Amer. Soc. Agron.–Crop Sci. Soc. Amer., Madison, Wis.

Eaton, G.W. 1967. The relationship between seed number and berry mass in open-pollinated highbush blueberries. HortScience 2:14–15.

Galletta, G.J. 1975. Blueberries and cranberries, p. 154–196. In: J. Janick and J.N. Moore (eds.). Advances in fruit breeding. Purdue Univ. Press, W. Lafayette, Ind.

Gorchov, D.L. 1985. Fruit ripening asynchrony is related to variable seed number in *Amelanchier* and *Vaccinium*. Amer. J. Bot. 72:1939–1943.

McGarry, R.C. 1996. The role of plant hormones in saskatoon fruit development. MS thesis. Univ. of Alberta, Edmonton, Alberta.

Monselise, S.P. 1986. CRC handbook of fruit set and development. CRC Press Inc., Boca Raton, Fla.

Moore, J.N., B.D. Reynolds, and G.B. Brown. 1972. Effects of seed number, size, and development on fruit size of cultivated blueberries. HortScience 7:268–269.

Naylar, A.W. 1984. Functions of hormones at the organ level of organization, p. 172–218. In: T.K. Scott (ed.). Hormonal regulation of development II. Encyclopedia of plant physiology, ns, vol. 10. Springer-Verlag, New York.

Pharis, R.P. and R.W. King. 1985. Gibberellins and reproductive development in seed plants. Annu. Rev. Plant Physiol. 36:517–568.

Rogiers, S.Y. and N.R. Knowles. 1997. Physical and chemical changes during growth, maturation and ripening of saskatoon (*Amelanchier alnifolia* Nutt.) fruit. Can. J. Bot. 75:1215–1225.

St. Pierre, R.G. 1992. The development of native fruit species as horticultural crops in Saskatchewan. HortScience 27:866, 947.

St. Pierre, R.G. and T. A. Steeves. 1990. Observations on shoot morphology, anthesis, flower number, and seed production in the saskatoon, *Amelanchier alnifolia* (Rosaceae). Can. Field-Naturalist 104:379–386.

Westwood, M.N. 1993. Temperate-zone pomology. Timber Press, Oregon.