Growing Saskatoons

A Manual For Orchardists

Richard G. St-Pierre, Ph.D.

An Introduction To Growing Saskatoons

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"On the great Plains there is a shrub bearing a very sweet berry of a dark blue color, much sought after, great quantities are dried by the Natives; in this state, these berries are as sweet as the best currants, and as much as possible mixed to make Pemmecan; the wood of this shrub, or willow, is hard, weighty and flexible, but not elastic, and wherever it can be procured always forms the Arrow of the Indian, the native name is Mis-sars-cut; to which mee-nar is added for the berry; we call it by the native name, but the french who murder every foreign word call the Berry, Poires, and Pim-me-carn; Peemittegar. I have dwelt on the above, as it [is] the staple food of all persons, and affords the most nourishment in the least space and weight ..."

David Thompson's Narrative 1784-1812; entry from June 22, 1810

The saskatoon has long been a treasured wild fruit and a prairie tradition, being an abundant, staple fruit for prairie peoples for centuries. Although often compared to the blueberry in terms of its size, texture and flavour, the saskatoon is dissimilar to the blueberry and is much more closely related to the apple, mountain ash and hawthorn (members of the Rose family). The edible, sweet fruit have a distinctive flavour with subtle almond overtones. The fruit is not actually a berry but in essence, a tiny apple.

The horticultural potential of the saskatoon has long been recognized. In his various references to the saskatoon, the explorer David Thompson suggested that this fruit ought to be cultivated in Canada and England. The saskatoon was first cultivated in the Peace River area of northern Alberta by W. D. Albright in 1918. The first professor of horticulture at the University of Saskatchewan, C.F. Patterson, wrote about cultivating the saskatoon in 1936.

The saskatoon is a hardy and tolerant fruit species. It is resistant to low temperatures and drought, and grows in a wide range of soil types. It has the capacity to be productive for many years. In addition to its value as a fruit, the saskatoon also has value as an ornamental. Masses of showy flowers appear in the spring, and at least one cultivar produces brilliant fall foliage. Other uses include range restoration, plantings for birds and other wildlife, windbreaks, and low maintenance, or native plant landscaping.

The saskatoon has not been domesticated, that is, has not undergone breeding and selection for cultivated environments. However, a number of selections having superior characteristics have been chosen from the wild, and it is this material which is being propagated and cultivated. This native fruit species is gaining importance as a commercial fruit crop on the prairies. Relatively small orchards or plantations of such fruit species can produce high yields and profits. Interest in cultivating the saskatoon has grown, in part, because of inconsistent wild crops and the loss of many wild plants. As well, the short, dry growing season and harsh winters typical of the prairie climate are not conducive to the commercial production of typical domesticated fruit crops such as the apple, or peach.

The cultivation of native fruit species, including the saskatoon, could significantly contribute to the diversification and health of the prairie agricultural economy by enhancing alternative agricultural production, by promoting the development of mixed farming operations, by providing a more substantive base for a processing industry, and by enhancing our connections with native prairie ecosystems through the use of native plant species.

Cultivating native fruit species like the saskatoon as fruit crops will help relieve the pressures of large-scale harvesting from wild populations. A renewed interest in our native fruit species may be critical to their long-term preservation. The initial clearing and landbreaking for prairie agriculture, urban expansion, cattle grazing, lack of prairie fire, the use of herbicides, deforestation, and the clearing of marginal land for agricultural purposes have contributed to the loss of genetic diversity in many native fruit species, including the saskatoon. Fortunately, many farms on the prairies harbor varieties of native fruit species that have been selected from local wild germplasm. Prairie rural gardens represent an excellent way of maintaining grassroots interest in the preservation of genetic diversity and patches of natural ecosystems.

Getting Started - Advice For Novice Saskatoon Orchardists

It has become apparent over the years that some initial advice for the novice orchardist or the potential grower of saskatoons would be useful. One might summarize this advice as follows: start small, do your homework, get your hands dirty, make mistakes, learn, and enjoy the process.

Potential growers of saskatoons and especially novice orchardists must obtain as much information as possible before they begin. The management of any fruit orchard is a complex and demanding job and those not familiar with the activities required to manage an orchard effectively are well-advised to learn as much as they can. This manual is a good starting point.

It is important for potential growers of saskatoons, and novice orchardists to start small and gain the experience necessary to manage a larger operation. A two hectare orchard demands a considerable amount of management which may overwhelm the beginner with no prior experience. Also, mistakes, or wrong approaches to management can be very costly, especially if a grower's initial investment was large.

Even if a grower has a considerable amount of experience, it's important to note that a 15 hectare orchard is a large orchard that will require a large investment of time, labour and money to manage economically. Prior to establishing orchards larger than 0.5 hectares in size, potential growers are advised to have a sound business plan developed. This plan should include specific details of the operations required for orchard management and marketing of the fruit.

History, Use & Economic Importance Of The Saskatoon

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Historically, the saskatoon was important to many North American Indian peoples, and later, European explorers and settlers.

The saskatoon was a popular and widely used plant among many North American Indian tribes. Both flowers and fruit were important in native ceremonies. Holding a fruit up to the sun and then burying it in the ground was a thanksgiving to the earth for its abundance of gifts. Saskatoon blossoms symbolized spring in the tobacco-planting ceremony of the Blackfoot. The Sun Dance was held in July when the fruit were ripe. Klamath Indian legends relate that the first people were created from saskatoon bushes.

The fruit were a staple food. The saskatoon, along with the chokecherry and buffaloberry, were often the only kind of fruit available in any quantity. Because of their importance, most tribes distinguished different kinds of saskatoons on the basis of fruit color, taste, seediness and size, in addition to blooming time, ripening time, bush form, and habitat. The Okanagan Indians distinguished eight different kinds of saskatoon, varying in their suitability for eating fresh or drying. Many tribes held ceremonies and feasts to celebrate the beginning of the saskatoon harvest.

The fruit were eaten fresh and prepared in a variety of ways. Fruit were steamed and mashed, made into cakes, and then dried to a brick-like consistency. Pieces were chipped off as needed and added to soups, stews, or boiled to reconstitute them. Pemmican was a mixture of dried lean meat (bison, moose or deer), which was ground or pounded, mixed with an equal amount of melted fat, mixed with saskatoons, and moulded into cakes. Pemmican would keep for months if stored in a cool, dry place and was a winter staple of the Plains Indian tribes. Young shredded shoots, mashed dried fruit, and dry leaves were used to make a tea. The fruit were also used by the Thompson and Interior Salish tribes to produce a dye. Dried saskatoons were a common item of trade.

Several parts of the shrub were used medicinally. Concoctions of the inner bark and roots were used to treat diarrhea, dysentery, painful menstruation, and bleeding during pregnancy. A warm decoction of the stems and twigs, or bark, was used by the women of the Thompson Indians to treat pain and bleeding after giving birth to a child. A root tea was believed to prevent miscarriage. The fruit were also used, along with spruce tips, blue currants, and snowberry leaves and stems, as part of a concoction for gonorrhoea. Some tribes boiled the inner bark of the saskatoon to produce a remedy for snowblindness; one drop of the strained fluid was placed in the affected eye three times daily. Fruit concoctions were also used for sore eyes and stomach problems.

The wood has a straight grain, and is hard and strong. It was used for arrows and other tools, basket-frames and cross-pieces for canoes.

Fruit of the saskatoon and related *Amelanchier* species also were popular with European explorers and settlers. It is recorded that the fruit of the saskatoon were used by the members of the Lewis and Clark Expedition, who refer to a bread of serviceberries and ground lamb's quarters. Pemmican was adopted by fur-traders and voyageurs. The saskatoon was often the only fruit available to early prairie settlers and was an important food source for victims of drought and depression in the 1930's. The green fruit were crushed and used to treat diarrhea. Juice from the ripe fruit was used as a laxative, and to treat stomachache. European settlers used wood of various *Amelanchier* species to make umbrella handles and fish poles.

The City of Saskatoon apparently derived its name in 1882 or 1883 (the date is contentious) from the fruit which grew abundantly along the banks of the South Saskatchewan River, being named by temperance leader John Lake. After being brought a handful of red fruit which appeared similar to red currants, and which he was told were called saskatoons (the anglicized version of the Cree name), Lake is said to have exclaimed ‘Arise Saskatoon, Queen of the North’ (the truth of this story is uncertain). This was in August of 1882 or 1883, well past the usual period when saskatoon fruit normally ripen. The usual color of ripe fruit is purple to blue-black, never red. It’s quite possible that these fruit were actually chokecherries!

The first recorded *Amelanchier* cultivar was Success, which was introduced in 1878, and grown in Illinois. Success apparently originated in Pennsylvania from seed of *A. canadensis*. In Canada, the domestication of the saskatoon was initiated by W.D. Albright at Agriculture Canada's Beaverlodge Research Station in Alberta in 1918, when a hedgerow of wild saskatoons was established. The first selections of saskatoons were made from this hedgerow in 1928 by W.T. Macoun. About this time, John Wallace, a nurseryman in the region, was also selecting saskatoons from the wild near Barrhead, Alberta. Collaboration between Wallace and Albright resulted in an exchange of plant material. The cultivars Smoky and Pembina were not formally released until 1952, but it was clear by 1932 that the selections on which these cultivars were based were superior.

The first commercial saskatoon orchards were established in the early 1970's and a second wave was established in the late 1980's and early 1990's. The primary variety initially used was Smoky because only this variety was available in adequate quantities. With the advent of appropriate techniques for micropropagation, large quantities of many cultivars have become available. Most saskatoon orchards are now primarily comprised of a mixture of the cultivars Smoky, Pembina, Northline, Thiessen, Martin, and Honeywood, and secondarily, with some of the other cultivars that are available.

Accurate estimates of the total acreage of saskatoons planted to date are difficult to obtain. As of the publication date of this factsheet, it is estimated that there are approximately 500 to 800 hectares of saskatoons established in Alberta, Manitoba, and Saskatchewan, with about half producing fruit. There are approximately 250 to 300 growers of saskatoons and about 50% of the orchards are U-Pick operations. Orchard sizes range from 0.5 - 16 or more hectares. Two or more hectares is probably the minimum size for an economically viable commercial saskatoon orchard. Currently, demand for fruit exceeds supply. The saskatoon industry is in its infancy. It has been predicted that over 4,000 hectares of saskatoons will eventually be planted on the prairies.

Saskatoon Botany

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Table 1. Saskatoon Botany At A Glance	
Characteristic	**Details**
Plant Family	Rose
Latin Name	*Amelanchier alnifolia*
Related Species	Apple, pear, hawthorn, mountain ash
Native Geographic Range	Continental interior of North America
Plant Form	Small to large shrub; small tree
Hardiness	-50 to -60°C
Chilling Requirements	A minimum of 2100 hours at 0 to 4°C to obtain consistent breaking of dormancy
Toxins	Prunasin (cyanogenic glycoside); restricted to new wood, buds, leaves, green fruit
Lifespan	Estimated at 30 to 50 years
Precocity & Maturity	Age at first bearing is 2 to 3 years; mature yields occur at 6 to 8 years of age
Flowering	Flower buds form on 1 year old wood the season prior to bloom; flowering occurs in early- May to early-June over a period of 3 to 20 days; each cluster contains from 1 to 20 flowers
Alternate Bearing	Significant in the cultivars Smoky and Honeywood, and to a lesser extent in the cultivars Northline and Thiessen
Pollination	Self-fruitful; supplementary pollination increases fruit set marginally and fruit seediness markedly; the number of seeds/fruit varies from 1 to 10 with an average of 3
Fruit Loss	A period of well-defined fruit loss follows petal drop; this is caused by disease, insect damage, and late-spring frosts
Days To Ripening	45 to 60 days from bloom
Average Yields/Plant	3.1 to 4.4 kg/plant over a 10 year period; marketable yields are about 90% of total yields
Marketable Crop Yields	An average of 6,000 to 8,600 kg/ha (5,400 to 7,700 lbs/acre) over a 10 year period; maximum marketable yields have attained 31,850 kg/ha (28,430 lbs/acre), as extrapolated from well-managed trial sites; average planting densities are 2,170 plants/ha (880 plants/acre).

Basic Botany Of The Saskatoon

The saskatoon is a perennial, woody, fruit-bearing shrub belonging to the rose family, and native to the interior of the North American continent.

The genus *Amelanchier*, to which the saskatoon belongs, is comprised of about two dozen species of shrubs and small trees distributed in North America, Europe, northern Africa and eastern Asia. The generic name *Amelanchier* has been derived from the French Provencal name, 'amelanche', for the European species, *Amelanchier ovalis*. The word amelanche simply refers to the fruit of *Amelanchier*. Amelanche is a derivation of the Gauloise word for small apple (note - Gauloise was the language of the Celtic peoples who inhabited Gaul, the geographic region that predated modern France, and whose language predates that of old French). The word ‘amelanchier’ first appears in writing in the year 1549, and ‘amelanche’ appears in 1721.

The North American species of *Amelanchier* are variously called by the common names serviceberry, saskatoon, sarviceberry, sarvis, maycherry, Juneberry, Junebush, shadblow, shadbush, shadberry, shadblossom, shadwood, sugar pear, Indian pear, grape-pear, lancewood, boxwood, Canadian medlar, bilberry, snowy mespilus and poirier or petites poires. The French Canadians referred to *Amelanchier* fruit as 'poires' because of the pear-shaped fruit of some species. The English translation, pear, was used by British and American traders. The common name 'serviceberry' may derive from the similarity of the fruit to the service or sarvis, a forgotten English fruit (possibly *Sorbus torminalis*), or from the fact that serviceberry branches were once collected and forced to bloom for mid-winter church services. Shadbush is associated with eastern species that bloom when the shad (a fish) begin to return to their spring spawning grounds.

As botanically classified, the genus *Amelanchier* is a member of the apple subfamily (Pomoideae), within the Rose family (Rosaceae). The species of *Amelanchier* are closely related and often difficult to distinguish. Much of the confusion is due to the extreme variability in foliage characteristics within any given species; leaf shape and size can differ significantly, depending on the stage of development of the plant and the habitat in which the plant grows. The most useful distinguishing characters are associated with the form and structure of the flowers and fruit. The genus *Amelanchier* is different from other members of the apple subfamily on the basis of these same characteristics. Hybrids between the different *Amelanchier* species are common, adding to the difficulty of accurate identification.

The fruit of *A. alnifolia* and *A. canadensis* in particular, are widely used in North America. Many species of *Amelanchier* are used as landscape plants because of their very early flowering.

Amelanchier alnifolia, the saskatoon, is a western North American species, ranging from Alaska, the Yukon and Northwest Territories (close to the Arctic Circle), and south to California, Arizona, and New Mexico. In the east, its range overlaps that of *A. canadensis* near the western borders of Ontario, Minnesota and Iowa, and in the west and southwest, its range overlaps that of *A. florida* and *A. cusickii* (both of which are considered as subspecies of *A. alnifolia* by some botanists).

The saskatoon is commonly found in open woods, coulees and bluffs, on hillsides, and along gulleys and stream banks, on dry, rocky soils in full sunlight to moist, deep, fertile soils, from near sea level to subalpine altitudes. Moisture appears to be the limiting factor in determining habitat. The saskatoon only occurs in habitats receiving a minimum of 340 mm of annual precipitation.

The saskatoon was first described botanically by Thomas Nuttall in 1818 as *Aronia alnifolia.* Its range was given as from Fort Mandan (North Dakota) to the Northern Andes (Rocky Mountains). The species was also referred to as *Pyrus alnifolia* by Sprengel in 1825 and subsequently as *Amelanchier alnifolia* by Nuttall again, in 1834. The specific name *alnifolia* means 'with leaves like the alder'. In western North America, the saskatoon is also referred to as the western serviceberry, mountain Juneberry, western shadbush, and Rocky Mountain blueberry.

The word saskatoon apparently was an anglicized version of the Cree name for the fruit which was Mis-sask-qua-too-mina or Mis-sask-a-too-mina (plural Sask-a-too-mina). However, it's also possible that the name was derived from the Cree name for the place where stems of saskatoon bushes were collected for arrow shafts; this name was Mane-me-sas-kwa-tan (note that the latter half of this word is 'saskwatan').

The saskatoon is an extremely variable species. In habit, it may range from a low and spreading to erect and slender shrub or small tree. Its height varies from 0.3 to over 6m. It often has multiple stems and may form large thickets. Vegetative propagation is through rhizomes. Its root system is a combination of vertical tap roots and lateral roots. The bark is smooth, gray on the older branches and reddish-brown on the new growth. The leaves are alternate, simple, and roughly oval; the leaf tips are usually rounded and the edges are finely to coarsely toothed. The leaves are half to fully expanded at flowering time and in general are extraordinarily variable in shape.

In the wild, the saskatoon is considered a species adapted to areas that, in the past, were often exposed to fire. Fire, as well as mowing and grazing, stimulate vegetative growth. Saskatoon seedlings require bare mineral soil to become established; humus and full shade, which promotes higher humidity, predispose seedlings to disease.

The saskatoon is capable of tolerating wide ranges of soil pH and texture and is also very cold-hardy. The flower buds have been found to have the potential for extreme resistance to low temperature injury (-50 to -60°C) at maximum hardiness. However, the saskatoon is still susceptible to damage from late-spring frosts in particular.

One experimental study has reported that chilling requirements for the saskatoon are 400 to 600 hours at 0 to 7°C for the cultivars Smoky and Pembina. However, in practice, a minimum of 2,100 hours (3 months) at 0 to 4ºC appear to be necessary for budbreak and subsequent growth to be normal.

The saskatoon is generally grazed by white-tailed and mule deer, elk, moose, bighorn sheep and mountain goat, primarily as winter forage in December through March. Its fruit are consumed by many species of birds and mammals including robins, magpies, grosbeaks, waxwings, coyotes, bears and rodents. Saskatoon seeds are dispersed in the droppings of these animals.

Generally, foliage and green shoots of the saskatoon are palatable to grazing animals. However, it has been observed that the twigs of one variety (var. *cusickii*, or *A. cusickii*) of saskatoon often have an unpleasant odor and bitter taste. This variety of saskatoon has been implicated as a poisonous plant because it contains a cyanide-containing sugar called prunasin. The shrub's vegetative parts are potentially hazardous to ruminant browsers such as cattle, sheep or deer, but the fruit are essentially innocuous. Chewing, and the presence of enzymes found in the stomachs of these animals, release the cyanide. Prunasin content is very high in new wood and decreases in the buds, leaves, old wood, green fruit and ripe fruit in that order; overall levels decline after flowering. While browsing on leaves, buds and twigs may be dangerous for grazing animals, a human would have to rapidly ingest 2 kg of ripe fruit (assuming a 50 kg body weight) to generate a dangerous dose of hydrogen cyanide.

Horticulturally, the saskatoon is grown in gardens, orchards, and shelterbelts, generally on its own roots, but sometimes grafted onto *Cotoneaster* rootstock. Eventually the individually planted stems produce suckers, thus creating a solid hedgerow. The extent of suckering is associated with cultivar, type and extent of pruning, depth of cultivation, and growing conditions.

Understanding Flower And Fruit Production In The Saskatoon

Flower and fruit production in the saskatoon, as in any fruit species, is a complex process influenced by a wide range of environmental and physiological factors. Understanding the processes of flower and fruit initiation and development allows the grower to better define the saskatoon's cultural requirements and thus maximize health and yield through the use of efficient and economic management practices.

Flower and fruit production in the saskatoon can be considered in terms of two primary developmental processes that occur over two successive growing seasons. The first is the initiation of flower buds during the summer and fall of the first season. The second is the actual flowering process, and then fruit set and fruit growth, all of which occur during spring and summer of the second season. These processes can be further defined in terms of flower structure, flower bud initiation and development, flowering, pollination and fruit set, fruit growth and fruit loss. These aspects are not separate and distinct from one another, but are interrelated and continuous.

Obviously many factors can affect flower and fruit production. Factors that have direct effects generally cause injury and include insect and disease organisms, frost, wind and hail. Factors that have indirect effects influence physiological processes within the plant, and include the availability of water, nutrients and other growth regulating substances.

Flower Structure And Flowering Habit

The saskatoon flower is typical of other flowers of members of the Rose family, and apple subfamily, such as the apple, mountain ash, and hawthorn. Figure 1 is a drawing of a typical saskatoon flower. The flowers are somewhat bowl-shaped and have 5 white (sometimes pink) petals. Collectively, the petals are referred to as the corolla. The petals are inserted into a part of the flower called the hypanthium. At the top of the hypanthium, between each of the petals, are green sepals. Collectively, the sepals are called the calyx. It is the sepals, along with some scales, that protectively cover the unopened flower bud. On top of the hypanthium, and within the sepals and petals, are five stigmas (surfaces receptive to pollen) on stalks called styles. Also, there are 20 anthers (pollen producing structures). The ovary is contained within the hypanthium, and it is this part of the flower that eventually becomes the fruit. Undeveloped seeds, or ovules, are contained within the ovary. The flowers of the saskatoon are characteristic of insect-pollinated flowers.

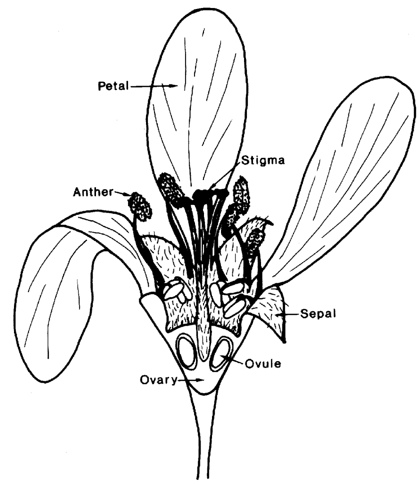


Figure 1: A typical saskatoon flower cut lengthwise; 5 times actual size (Drawing by R. St-Pierre).

Flowers of the saskatoon are borne in clusters which occur on wood at least 1 year old. Typically, twigs and branches of the saskatoon can be described as either long shoots or short shoots; short shoots do not grow to any appreciable length. Flower clusters are usually, but not necessarily associated with short shoots (Figure 2).

Timing Of Developmental Events

An overview of the timing of developmental events is illustrated in the color graphic - General Pattern Of Growth & Development Of A Woody Fruit Plant.

The production of a saskatoon fruit crop is dependent upon developmental events that occur over two growing seasons. The saskatoon typically flowers anywhere

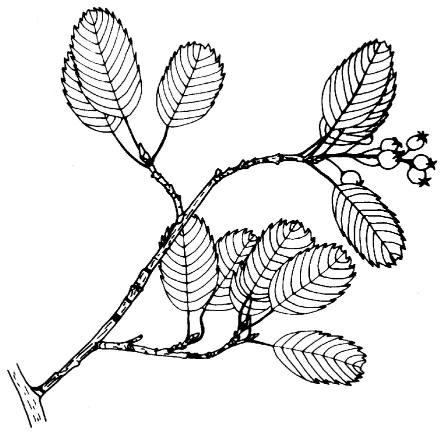


Figure 2: A typical saskatoon branch. This branch is composed of a single long shoot and 3 short shoots; the terminal short shoot has a fruit cluster. The drawing is 1/4 actual size and is modified from St-Pierre and Steeves (1990).

from early-May to early-June, but these flowers were initiated during the summer and early-fall of the previous growing season.

The expansion of new shoots begins in late-April or early-May and continues until the end of May, or early-June; sometimes shoots continue to grow into mid-summer. Growth in shrub height averages about 23-25 cm per year.

Each year, many previously vegetative shoots are converted to reproductive shoots that bear flower buds. In those shoots that will produce flower buds, the transition to the flowering state occurs during the last week of June or the first week of July. This transition takes about two weeks; at the end of this time (about mid-July), the basic pattern of the flower cluster has developed. Subsequently, the flowers themselves begin to develop. This process can continue until the end of October, but remains incomplete. Development ceases until early to mid-April but it is not until early-May that a fully functional flower has formed.

Flowering then occurs in early to late-May, and fruit ripening usually occurs anywhere from early to late-July.

Flower Bud Initiation

Flower bud initiation is the process whereby embryonic flowers begin to form. In other woody fruit species such as the apple, flowers are initiated just after shoot growth ceases and when leaves are mature. All flower parts are formed by the time of winter dormancy. The extent and quality of flower development are influenced by the presence of developing fruit, drought, low light intensity, low temperatures, the availability of adequate nitrogen and carbohydrates, adequate leaf area, and pests and diseases. The timing and intensity of flower bud initiation can be altered by fertilizers and pruning.

The presence of developing fruit is an important factor affecting flower bud initiation in the apple. Fruit with developing seeds inhibit flower bud formation. Seedless fruit do not inhibit flower bud formation. Developing seeds release a growth regulating substance called gibberellin which is associated with this inhibition. The problem of alternate bearing, that is, heavy crop years interspersed with light or no crop years as a result of a biennial flowering pattern, is associated with this inhibition; in apple trees, this problem has led to the use of procedures to decrease the number of fruit per tree in order to produce more consistent fruit crops.

The initiation of flower buds in the saskatoon occurs during the period of late-June to mid-July with embryonic flower development following. Little information is available concerning which factors influence this process in the saskatoon. There is some tendency for shoots that produce fruit to not produce as many flowers for the following season, compared to shoots that do not produce fruit. If fruit are removed from developing fruit clusters, the bud on the same shoot that produces the next year's flowers will produce more flowers. If leaves are removed, fewer flowers are produced.

There is some indication from growers that a heavy fruit crop one year reduces the amount of bloom the following year, but this situation has not been well-defined.

Timing And Variability Of Flowering

The timing of flowering in the spring is a naturally variable process that is associated with weather conditions during the previous fall and in the spring during the weeks prior to flowering. This timing can vary or be altered depending upon orchard exposure, spring temperatures, rainfall, fall applications of ethephon (a growth regulating substance that slows flower bud development), or possibly the use of overhead irrigation applied in the spring.

The saskatoon can begin flowering anywhere from early to late-May. The length of the period of flowering is also variable, ranging from 10 to 20 days in wild populations. This period is somewhat shorter in an orchard setting where only one cultivar is grown. The length of this period appears to be dependent upon temperature, wind and rainfall. Dry, windy conditions can significantly shorten the period of flowering. Cool spring temperatures will delay or slow flowering.

Early flowering predisposes the saskatoon to damage from late-spring frosts; such damage can be devastating to the production of a fruit crop. The selection of later-flowering cultivars, or the development of cultural practices that would delay flowering, would help alleviate this problem.

The number of flowers per cluster is also quite variable, ranging from 1 to 15 flowers, and sometimes more. The most important factors that influence the number of flowers per cluster in the saskatoon have not been determined.

Pollination And Fruit Set

Variation in fruit yield can be associated with the degree of effective pollination. Pollination is the process by which pollen is transferred from the anthers (the pollen producing organs) to a stigma (the pollen receptive tissue); this process may involve two or more flowers, or only one flower; in the latter case, successful pollination and subsequent fertilization depends on whether a particular crop species is self-fruitful or not. The transfer of pollen usually requires a vector, or carrier, such as the wind or a honeybee.

Multiseeded fruits, such as the strawberry, raspberry, currant, blueberry and cranberry, require adequate pollination, fertilization, and seed development for large, regularly shaped fruit; fruit size is proportional to the number of seeds per fruit.

In most fruits, pollination is required for fruit set and seed development, and fruit growth is dependent upon seed development. Fruit set is defined as the burst of growth of the ovary following successful pollination and is accompanied by petal wilting and loss. Pollination and fruit set are therefore influenced by a wide variety of factors. These include the temperature range before, during and after bloom, humidity, pollen source, amount of pollen, the presence and degree of activity of the required pollen carrier, leaf area, light intensity (or amount of shading), supplies of carbohydrates, nitrogen and other nutrients, amount of rainfall and wind, and the longevity and sterility of embryonic seeds. For example, with respect to the effects of temperature, long, cold winters and cold spring temperatures can reduce the amount of viable pollen, and high spring temperatures can sterilize pollen; both can result in less effective or no pollination and possible fruit loss.

Little information is available concerning pollination and fruit set in the saskatoon. Horticulturalists have long recognized that the saskatoon is self-fruitful. Some observations have indicated that pollen can be shed within the flower prior to the petals opening, but the extent and consistency of this phenomenon is not known. Wind may also play a role in pollen transfer, primarily within single flowers or clusters, because the pollen is sticky and forms clumps. Insects do not appear to be strictly necessary as pollen carriers; some beekeepers maintain that the domesticated honeybee is not very interested in the saskatoon. However, numerous wild bees, wasps and flies are present within flowers at flowering time and they may be important for pollination in the saskatoon (Figure 1.4).

Variability of characteristics for seedlings from controlled crosses and for open-pollinated seedlings is similar, suggesting that cross-pollination is common.

Greenhouse experiments done at the University of Saskatchewan suggest that supplementary pollination of the saskatoon may increase fruit set, but at the expense of producing somewhat seedier fruit. Interestingly, 20% of flowers in which pollination was completely prevented set fruit. The fact that no pollination is necessary in some cases suggests the possibility that further manipulation using growth regulating substances could result in the production of relatively seedless fruit.

Fruit Growth And Loss

Under optimal conditions, woody fruit species produce excess flowers and set too many fruits. Generally, fruit species, like the apple, cannot simultaneously support all fruit to a commercially desirable size and quality, produce an adequate number of flower buds for the following year, support root growth, and accumulate adequate nutrient reserves to withstand winter. In apples, a natural process of fruit thinning, resulting in the loss or drop of immature fruit, is a normal occurrence. To some extent, this process adjusts fruit number so as to maintain adequate tree health and consistent yields. The process is affected by many factors including extent of pollination, light intensity, excessively high or low temperatures during flowering, availability of carbohydrates and other nutrients, availability of sufficient water, and insect pests and diseases. However, despite the natural occurrence of this process, the degree of thinning is often insufficient and the result is alternate or biennial bearing (where heavy crop years are followed by light crop years). For commercial apple production, artificial thinning is often necessary, not to increase fruit size, but to allow flower bud initiation and thus the prevention of alternate bearing.

The saskatoon appears to produce an excess of flowers. In the saskatoon, a significant loss of fruit occurs sometime during the period of mid-May to mid-June. The loss occurs early in the period of fruit development; only small, immature fruit are lost (Figures 1.5 & 1.6). In wild populations of saskatoons, the extent of this loss is considerable, ranging from 55 to 98% of the potential crop. In orchards, the loss is considerably less, but still occurs. Generally, much of this early loss is a result of damage by frost, or insects, such as the saskatoon sawfly and various caterpillars (leaf rollers and bud moths).

However, up to 50% of early fruit loss in the saskatoon can be undamaged. The reasons for this loss are not known. In apples, developing fruit compete for nutrients and the losers abort and drop off the tree. There is limited evidence for such a phenomenon in the saskatoon. A study made at the University of Saskatchewan indicates that thinning flower clusters does not appear to affect the loss. Removing leaves (thus removing a source of sugars), or nearby short shoots (thus also removing a source of sugars, but also reducing competition if other fruit are present), increases the number of fruit lost, to a small extent. These experiments suggest that the availability of sugars does have some influence on continued fruit development.

The production of ripe fruit in the saskatoon takes 45-60 days from the time of flowering.

Yield

Vigorous growth during the first two years is essential for early flowering because the plants must attain a certain minimum size before they have the capacity to flower. Under normal circumstances, saskatoons begin to bear fruit when 2 to 3 years old. Saskatoons produce significant fruit yields at 7 to 8 years of age; maximum yield may not occur until the plants reach 12-15 years of age. A reasonable expectation is 2 to 4 kg of fruit per mature bush; some mature Thiessen bushes have produced about 16 kg. If properly cared for, orchards should be productive for 30 to 50 or more years. Growers routinely report yields of 3,000 to 5,000 kgs/hectare, although in some years, no production can occur. Some growers have recorded yields over 13,500 kg/hectare, but such high yields are dependent on weather, management techniques, and cultivar.

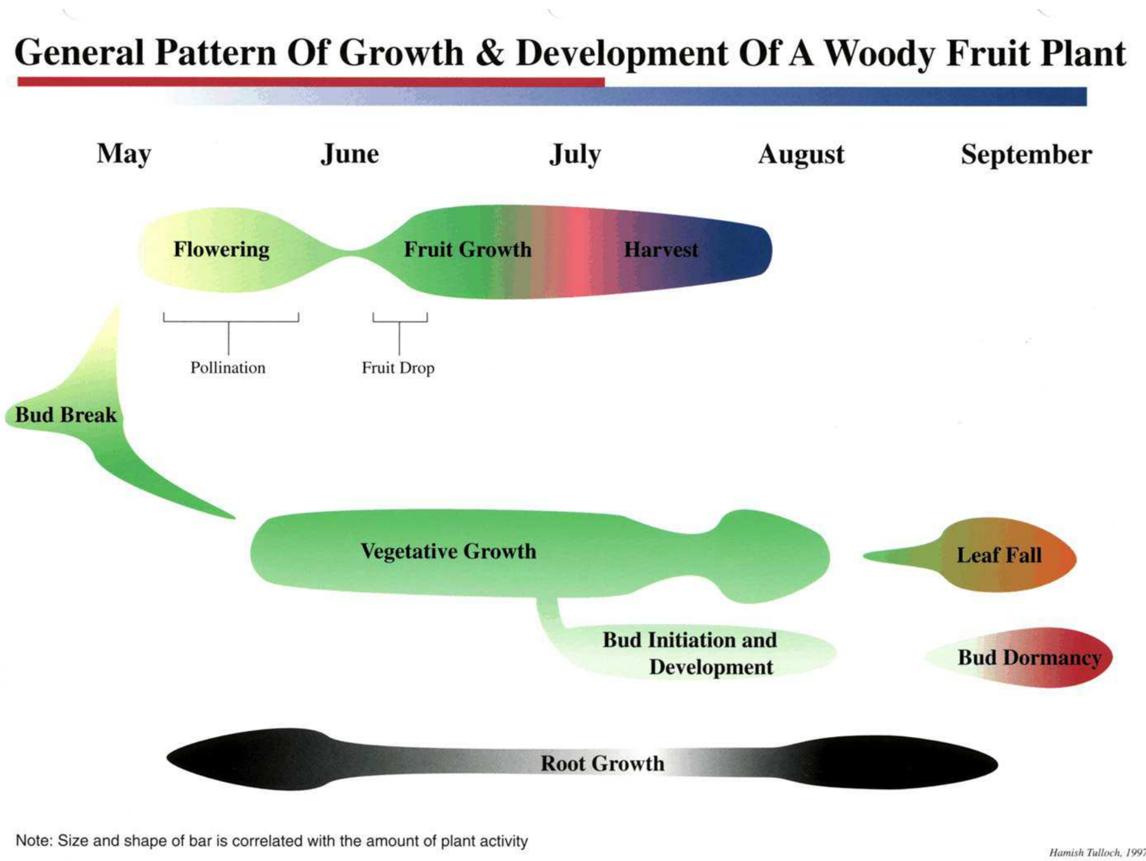


Plate 1. Saskatoon Botany

Figure 1.1: Green-tip stage of bud development; 1/2 actual size.

Figure 1.2: Beginning white-tip stage of bud development; actual size.

Figure 1.3: Advanced white-tip stage of bud development; 1 1/4 times actual size.

Figure 1.4: Saskatoon flowers and wild insect visitor.

Figure 1.5: Stages of fruit development; arrows indicate stages that commonly abscise (Photo by A.R. Olson).

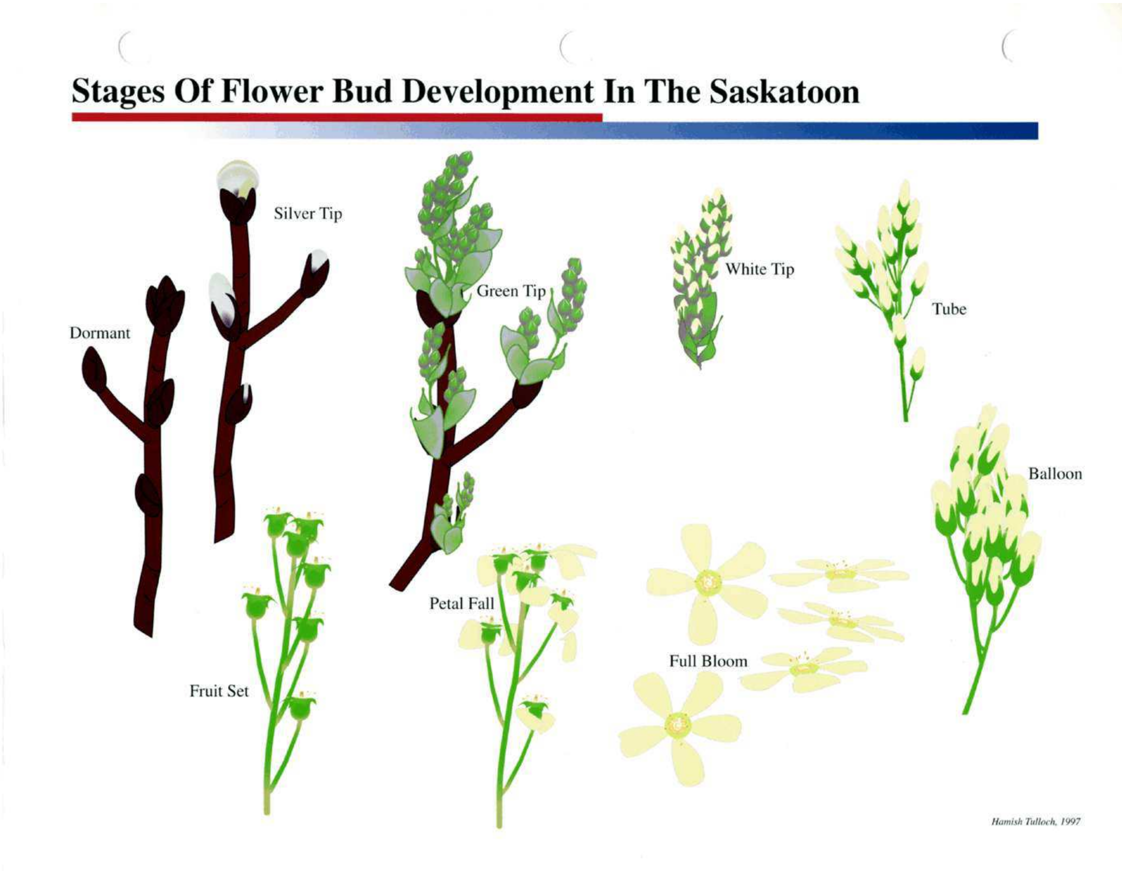
Figure 1.6: Abscising immature fruit (indicated by arrows); actual size.

Stages Of Flower Bud Development In The Saskatoon

A knowledge of flower bud development in the saskatoon will help the grower to monitor for the incidence of insect pests and diseases, and to appropriately time the application of pesticides and other control procedures. Eight different stages of development are defined in Table 2. These stages are illustrated in Figures 1.1 to 1.3 and the color graphic - Stages Of Flower Bud Development In The Saskatoon.

Table 2. Stages Of Flower Bud Development In The Saskatoon

Stage	Description
Dormant	- buds are tightly enclosed by brown bud scales
Silver Tip	- stage immediately following dormancy where the brown bud scales have split open, and are falling off; the bud beneath appears silver because of the presence of many hairs
Green Bud or Green Tip	- the flower bud cluster is visible; the flower buds are very small and tightly packed together; the entire cluster appears green in color
White Tip	- the flower bud cluster has expanded so that the individual buds are no longer tightly pressed against each other; the white petals of the individual flowers are visible as a small cone
Tube	- the petals of the individual clusters have elongated to form a tube or cylinder
Balloon	- a very brief stage immediately prior to full-bloom when the tube of petals has loosened and the petals are beginning to separate
Full-bloom	- the petals have fully expanded and the anthers (pollen-bearing structures) and pistil (pollen-receptive structure) are visible; the flower is receptive to pollination and fertilization at this stage
Post-bloom	- the petals fall off of the flower and the ovary begins to swell, indicating fruit set


Stages Of Flower Bud Development In The Saskatoon
Silver Tip
Dormant
Green Tip
White Tip
Tube
Balloon
Petal Fall
Fruit Set
Full Bloom
Hamish Tulloch, 1997

Propagation Of Saskatoons

Richard G. St-Pierre, Ph.D. (December 2005)

Introduction

Saskatoons may be propagated through the use of seed, suckers (rhizome sprouts), root cuttings, softwood cuttings, grafting, hardwood cuttings, cuttings from etiolated shoots, crown division, and through micropropagation. However, some methods are not economical because of the difficulty in obtaining adequate amounts of material to start with, and because of significant problems associated with an insufficient development of root mass and subsequent poor survivability.

The easiest, most successful methods of propagating saskatoons include the germination of seed, the use of etiolated shoots for cuttings, transplanting suckers, and micropropagation. Ease of propagation is important because it is associated with the production of higher quality planting stock.

Vegetative propagation is asexual propagation. Vegetatively propagated plants come from plant parts other than seed; these parts may include cuttings from shoots or roots, suckers, pieces of leaves, or buds. Plants derived from these parts have a single parent only and therefore are genetically identical to the parent plant. In such plants, fruit production occurs at an earlier age than in those plants propagated by germinating seed. Vegetative propagation is the method of choice for most fruit species. Micropropagated plants are not necessarily superior or inferior to plants originating from other methods of propagation. Micropropagation is possibly the best method currently available for mass propagating large quantities of saskatoons, but the technique has only been in use since 1987. To date, micropropagated saskatoons have established and grown well.

Propagation by germinating seed is sexual propagation. Seeds usually contain a mixture of genetic material from two parents, consequently, seedlings are not identical to their parents. Desirable characteristics may be lost, and plants grown from seed may take longer to produce fruit. Fruit plants propagated by germinating seed are used primarily for growing rootstocks onto which selected cultivars will be grafted.

However, the saskatoon is a relatively unique fruit crop in that it is self-fruitful, that is, two, genetically distinct parents and cross-pollination are not required for the production of fruit and seed. The consequence of this is that saskatoon seedlings are very similar to, and perhaps indistinguishable from the parent plant. For this reason, there is no substantial disadvantage to propagating saskatoons by seed, provided that only seed produced by the parental clone is used (first generation, or F1, seed).

Regardless of the method of propagation, it should be noted that the quality and vigour of planting stock can vary substantially, depending upon the source. When purchasing new saskatoon plants, a potential grower first must consider the quality of the planting stock, the quantity required, the quantity available from the propagator, and the price. The method of propagation is of secondary concern. Saskatoon plants produced by any method of propagation appear to perform equally well, more or less, in an orchard setting. A certain small amount of genetic variability will be present within orchards established using seedlings.

The following table provides a summary of the advantages and disadvantages of the various methods of propagating the saskatoon.

A Comparison Of Methods Of Propagating The Saskatoon

Source of Material	Advantages/Disadvantages
Seed	- only first generation seed produced by parental clone should be used; seedlings very similar to, or perhaps indistinguishable from the parent plant; some roguing of dissimilar plants may be necessary once maturity is reached
Suckers	- simple technique; available material may be limited; suckers have poor root mass & may be susceptible to transplant shock
Typical shoot cuttings	- difficult to root; uneconomical
Etiolated shoot cuttings from crown of plant	- inexpensive; genetically uniform plants produced; excellent root mass; simple, successful technique
Micropropagation	- genetically uniform plants produced; quick production of large numbers of plants; complex technique; initial high capital cost for propagator
Grafting (budding)	- technique requires skill; rootstock suckers require consistent pruning; effects of rootstock uncertain; the technique is useful for topworking new cultivars

Propagating Saskatoons By Seed

The saskatoon is a relatively unique fruit crop in that it is self-fruitful, that is, two, genetically distinct parents and cross-pollination are not required for the production of fruit and seed. The consequence of this is that saskatoon seedlings are very similar to, or perhaps indistinguishable from the parent plant. For this reason, there is no substantial disadvantage to propagating saskatoons by seed, provided that only seed produced by the original parent clone is used (first generation, or F1, seed).

Reports differ with respect to the amount of dissimilarity in seedlings compared to the parental material. Propagators report a range of 70 to 99% similarity to the parental stock, with the seedling plants being of equal quality, more or less, to the parental stock. Because a certain amount of cross-pollination is possible, it is important to only use F1, or first generation, seed. Seed of subsequent generations will be more dissimilar to the parental stock.

For the potential grower of saskatoons, the purchase of seedlings may be a cost-effective way to establish an orchard.
However, a certain small amount of genetic variability will be present within the orchard.

It must be noted that plant variability associated with seedlings may be useful in the search for new cultivars, especially where resistance to insect pests or diseases is expressed. Other advantages of using seed include lower initial cost and the production of disease-free material.

However, for those predisposed to the do-it-yourself approach and who wish to germinate seed, a number of factors must be considered. Seed may germinate erratically, depending on where it was collected and how it was stored. Germinated seedlings may go dormant very quickly, and inducing them to grow to a size where they can be transplanted successfully will require appropriate cultural techniques in a greenhouse and then a nursery environment. Seedlings will require an additional year of growth before the production of a fruit crop is possible, and some roguing of mature plants that are significantly different may be necessary. Under these circumstances, it is suggested that such an approach only be used where a minimal start-up cost is essential, and where potential genetic variability is not considered detrimental (in shelterbelts, for example).

Collection Of Naturally-germinated Seedlings

In some years, it is possible to find numerous naturally-germinated seedlings under mature plants in an orchard. Such seedlings appear to be more common where the soil surface is bare. These seedlings may be transplanted to a suitable nursery environment.

Seed Collection And Storage

Fruit should be collected when fully ripe so that the seed can easily be extracted from the flesh of the fruit; this facilitates cleaning and allows for higher germination rates.

Wild seed is best collected from parental stock material that has vigorous growth and good form, high yield, freedom from insect pests and disease (especially viruses and bacterial infections), and good quality fruit.

Seed are best extracted from fresh, ripe fruit; alternatively, fruit can be frozen. Extract seed from mature fruit, wash thoroughly, sterilize, and surface dry. Seed may be sterilized in hot water (40 to 50ºC) for 5 to 30 minutes. Subsequently, immediately cool the seed in water. Seeds also may be sterilized using 1 part household bleach to 9 parts water, or treated with a fungicide such as captan.

Seed should be stored in sealed containers at temperatures of 1 to 7ºC. Extracted and cleaned seed should not be stored in the open, or in a warm, dry atmosphere, otherwise the seed will go into a deeper dormancy, with resulting decreased rates of germination.

If seed is purchased, it is important to ask about the seed generation and age, where it was collected, and how it was stored.

Prior to planting or stratification, dry seeds should be soaked in water for several hours to enhance germination.

Basic Concepts Of Seed Germination

Proper sanitation is essential to maximize germination success; all tools, pots and media must be sterile. Media may be sterilized by placing in an oven at 80ºC for 2 hours.

Plant seeds remain dormant because of the presence of chemical inhibitors and/or physical mechanisms which prevent germination in the fall. Otherwise, germination in the fall would make seedlings susceptible to cold temperatures; mechanisms for dormancy also allow time for dispersal. In nature, germination inhibitors are naturally overcome by soil microorganisms, rain, cool temperatures, digestive enzymes of animals that may have consumed the seed, or various combinations of these factors.

Consequently, in order to successfully germinate seed, such factors need to be mimicked through the use of ‘preconditioning treatments’ that overcome the mechanisms that inhibit germination. For example, soaking seed in water may help remove chemical inhibitors by mimicking the action of rainfall, although the use of aeration and running water is best.

Saskatoon seeds have embryo dormancy and a relatively impermeable seed coat. This combination of mechanisms requires that cold stratification be used to overcome dormancy. Germination rates for saskatoon seed vary from 7 to 67%, are apparently genetically controlled, and vary with the location the seed is collected from.

Stratifying And Germinating Seed

Recipes for germinating saskatoon seed vary. Studies done at the University of Saskatchewan indicate that, contrary to what is often stated, scarification using a concentrated acid such as sulfuric is not necessary for saskatoon seed to absorb water.

The simplest germination procedure is to sow seed in slightly moist, sandy nursery beds in late-fall. A 1 m by 2.5 m bed can easily hold 1,000 seedlings. The seeds should be broadcast in flats or pots of sterile medium and covered to a depth 2 to 3 times the seed diameter. Germination will occur the following spring. Protection from birds and mice is necessary, so the bed must be covered with a wire screen. Once the seedlings start crowding each other, individual seedlings may be transplanted to a suitable container. Growing seedlings require frequent watering; the soil should be kept moist but not saturated. Overwatering leads to soil saturation, forcing oxygen out of the soil. This stresses roots, encourages damping off fungi, and can kill the seedling. Seedlings must be protected from hot, dry winds and strong winds so as to reduce water consumption and stress. However, some airflow is important to reduce humidity and to increase plant sturdiness.

The storage of seed under moist, cool conditions is called stratification. Stratification is a common treatment used to help seeds overcome dormancy.

The simplest method of stratification is to mix seed with sterile, moist coarse sand, or vermiculite, (3 to 5 parts medium:1 part seed) and then to place this mixture in a plastic bag or container. The container must be kept in the refrigerator at a temperature of 1 to 7ºC for several weeks to 3 or 4 months. The medium should not dry out, but also should not be wet. The emergence of a root from the seed indicates that dormancy has been satisfied and that seeds are ready to plant. However, the root of the newly germinated must not be allowed to get too long, otherwise the germinated seeds will be more difficult to remove and successfully transplant.

The following stratification and germination procedure should provide consistent results:

1) The seed is extracted from the fruit using a blender with dull blades at low speed; the seed will not be damaged, but will have to be sieved from the pulp; the seed must not be allowed to dry out. Fungal problems can be minimized if the seed is surface-sterilized in a solution of household bleach (1 part bleach to 9 parts water) for 5 minutes.

2) The seed is then soaked in water for 24 hours to ensure the maximum absorption of water by the seed. Aerated (using an aquarium pump) or running water is best.

3) Next, the seed is placed in clean, coarse sand (size 20; #3 chicken grit may also be used) that is moist, not wet; the mixture should consist of about 4 parts of sand to 1 part of seed; the seed and sand are then placed into a perforated plastic bag which is then sealed (perforated vegetable storage bags are available in supermarkets).

4) The bag is placed in a fridge or other location that is kept at 4ºC, but no higher; the temperature must not increase at any time; every week, the sand and seed mixture should be stirred for aeration and examined to make certain that the sand is still moist and that fungal problems are not occurring.

5) The bag must be left under these conditions, usually for 4 or 5 months. The seeds often begin germinating under these conditions after about 3 months.

6) The germinated seeds are carefully removed from the bag and planted in a sand:peat moss mixture (50:50), or vermiculite:peat moss mixture (40:60), in a tray, or Spencer-Lamaire Rootrainers. Upon completion of stratification, the seeds may be placed in controlled environment of 16 hours daylight at 25ºC and 8 hours of darkness at 10ºC to complete germination.

7) Further growth and development will be favoured by a warm, well-lit environment; a dilute (concentration is dependent on brand of fertilizer), soluble 10-52-10 or 20-20-20 fertilizer may be applied continuously with every watering. Maximum growth may be obtained using bright full- spectrum fluorescent light (a mixture of cool and warm white) where bright, but indirect sunlight is not available, a constant 25 to 27ºC temperature, 70 to 90% relative humidity, and two 30 minute periods of darkness every 24 hours; a moderate amount of air movement is necessary to provide adequate ventilation and to produce stronger stems. The use of carbon dioxide supplementation in greenhouses so equipped may be advantageous in promoting vigorous growth.

8) Before transplanting outdoors, acclimatization is necessary; this involves restricting water, switching to natural lighting and reducing the temperature.

Propagating Saskatoons By Shoot Cuttings

Cuttings are pieces of stems, branches, or roots that are capable of growing new roots (adventitious roots). Shoots that are producing flowers or fruit should not be used for cuttings.
Cuttings from younger plants are usually easier to root. Cuttings should not be taken during times of stress (drought, very hot temperatures, cold temperatures). All cuttings should have at least 3 nodes. The best cuttings are basal (from around the trunk or stem), or lateral (horizontal or close to). Rapidly growing vertical shoots with long internodes (watersprouts) do not make good cuttings (these produce plants with fewer branches). Cuttings should be taken just below a leaf node or bud. All cuttings should be planted (stuck) so that at least two leaf nodes are below the surface of the soil. Cuttings need to be protected from hot sun and wind by using shade, mulch and windbreaks.

Softwood Cuttings

Softwood cuttings are derived from the green, new growth of the current season. Cuttings of new growth, 10 to 15 cm in length are taken, usually in early to mid-June. The terminal portions are not used unless some maturation has occurred. The leaves from the lower third of the cutting are removed, and the cutting is dipped into rooting hormone of appropriate strength. The cuttings are then stuck (inserted) into a rooting medium (1:1 perlite, or vermiculite:peat or sand). The rooting medium should be well-drained and sterile. The use of intermittent mist will minimize water loss from the cuttings until rooting occurs. The frequency of misting must be adjusted to prevent the leaves from drying out following rooting. The cuttings may be hardened-off by reducing the frequency of misting, or by placing them in pots in a shady location for several weeks.

Propagation Using Etiolated Shoots

Etiolated shoots are shoots that have grown in very weak or no light. They have yellow or white foliage and appear rather sickly. Cuttings of etiolated shoots have the ability to root easily. The following procedure (an application of the propagation method termed mound layering) is relatively simple and will lead to rooting percentages and transplant survival in excess of 90%.

During the early spring, before budbreak, a shrub (a minimum of 3 years old) is cut back to ground level to form a stool bed (Figure 2.1). The stool bed is then covered with a black polyethylene (6 mil) tunnel or tent supported by wire hoops (Figure 2.2). Lengths of black plastic pipe (5 cm diameter) may be used to ventilate the tunnels.

When forced shoots are long enough for cuttings (12 to 18 cm), usually in 4 to 6 weeks, they are regreened by slitting the tunnel on the north side so as to avoid direct sunlight which will scorch the etiolated shoots (Figures 2.3 & 2.4).

After 6 days of regreening, 12 to 18 cm cuttings are taken and their bases dipped in a 3,000 to 10,000 ppm (parts per million) solution of rooting hormone (IBA). Liquid Stim-Root 10,000 (Westgro Horticultural Supplies) works well.

The cuttings are then stuck in #4 Sunshine Mix (Fisons), Premier Promix ‘HP’, or a 50:25:25, by volume, peat:vermiculite:perlite mixture, in RootTrainers (Spencer-LeMaire Industries; these direct root growth downwards). The rooting containers are put outdoors in a mist bed under a clear polyethylene tunnel (or mesh shading cloth), located on 7 to 10 cm of coarse gravel (Figure 2.5 & the color graphic - Basic Components Of A Mist Bed).

Humidity levels under the mist bed’s tunnel should be kept high by using automatic misting units (L10 or L12 brass mist nozzles controlled by a timer and solenoid valves; microsprinklers may also be used). Mist frequency and duration for the first 4 weeks is 20 seconds every 5 minutes, day and night. The following 3 weeks, this is reduced to 20 seconds every 7.5 minutes; subsequently, this is further reduced to every 10 minutes during the daytime only. It will take approximately 4 to 6 weeks for the cuttings to root (Figure 2.6).

Adequate ventilation is required. Temperatures under the tunnel should not exceed 40ºC.

A dilute (the concentration depends on the brand available) 10-52-10 or 20-20-20 fertilizer solution may be used for misting. Weekly applications of a sanitizer (45 ml Rocal or Skyclean) also should be made.

The cuttings can be left to harden-off, then mulched with peat moss and wood chips in mid- to late-October. Enclosure with a wire mesh is necessary to prevent rodent damage.

The cuttings also may be transplanted to the field in late-August when the roots show through the bottom of the container. Transplants should be kept moderately well-irrigated until late-summer; weeds should be controlled, but deep cultivation close to the plants must be avoided.

Propagating Saskatoons By Suckers

Offshoots or suckers are shoots that arise from rhizomes (which are underground stems). Propagation using suckers is a form of dividing the plant. Suckers older than 1 year of age must be carefully inspected for the presence of *Cytospora* canker. If *Cytospora* canker is present elsewhere in the orchard, suckers should not be used for propagation because of the possibility of spreading this disease. Suckers are usually removed with the aid of a pruning knife and/or shovel and can be used as rootstocks for grafting, or as new plants to be grown on their own roots. When removing suckers, it is essential to obtain as large a root mass as possible, and the root mass should not be allowed to dry out prior to transplanting. Suckers are best removed in early-spring or late-fall when the plants are dormant. Succulent suckers should be allowed to air dry for several days before planting to reduce problems associated with rotting.

Propagating Saskatoons By Root Cuttings

Root cuttings, 1 to 1.5 cm diameter, and 5 to 10 cm long, should be taken in the fall or early-spring. If root pieces are cut in the fall, they should be stored for two months at 4°C. The root cuttings are then placed in polyethylene bags filled with moist peat moss and stored in the dark for 3 weeks at 21°C. This treatment promotes shoot growth in 2 to 4 weeks. The root cuttings can then be planted in nursery rows, stem end up, and 0.5 cm below the soil surface. Frequent, light irrigation, and shading, will encourage shoot growth.

Micropropagation Of The Saskatoon

Micropropagation is a term that has the same meaning as the terms tissue culture and *in vitro* culture. Micropropagation requires some specialized equipment, precise environmental control, and scrupulous technique, but in the long run, should not produce more expensive plants. The technique uses small plant parts, including pieces of leaves and stems, or entire buds, which are cultured under sterile conditions on artificial growing media, ultimately producing thousands of new

Plate 2. Propagation Using Etiolated Shoots

Figure 2.1: Stool bed created from a mature bush.

Figure 2.2: Black polyethylene tunnels over stool beds (Photo by R. Sawatzky).

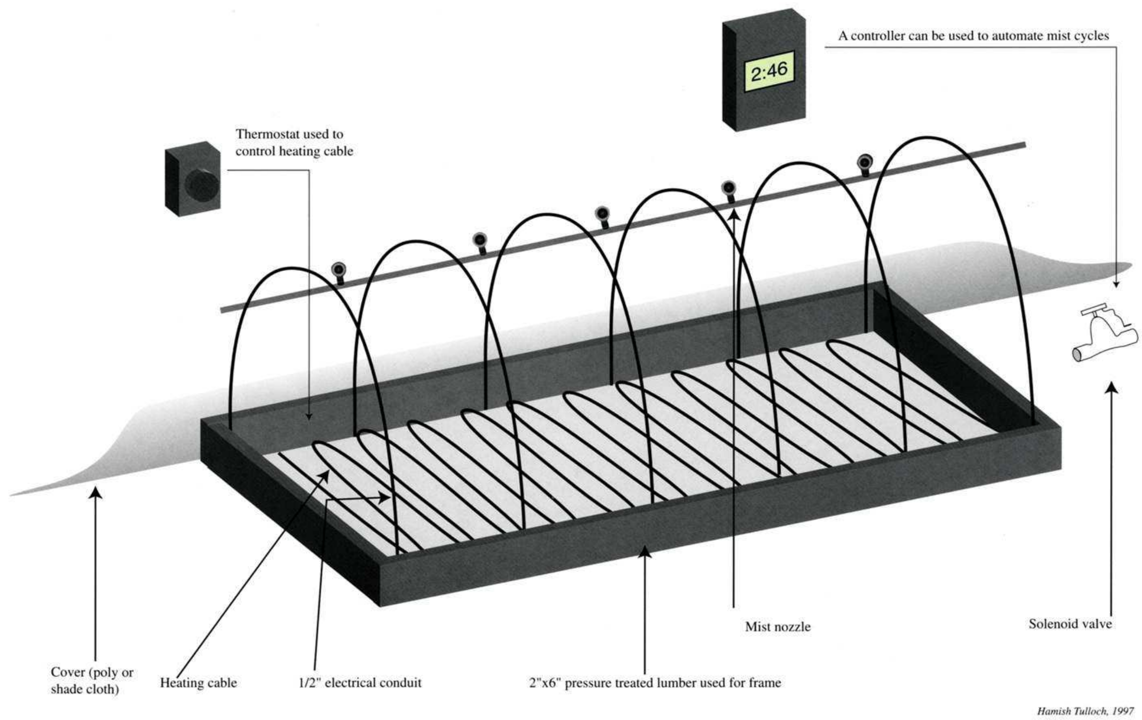
Figure 2.3: Regreening etiolated shoots (Photo by R. Sawatzky).

Figure 2.4: Etiolated shoots prior to cutting (Photo by R. Sawatzky).

Figure 2.5: A typical covered mist bed.

Figure 2.6: Rooted saskatoon cuttings ready for transplanting (Photo by R. Sawatzky).

Basic Components Of A Mistbed



plants. The technique allows for the tremendous multiplication of what may be very limited parental material. Micropropagated plants are not necessarily superior to plants originating from other methods of propagation, but it should be noted that the quality and vigour of micropropagated plantlets can vary substantially, depending upon the source.

Micropropagation is possibly the best method currently available for mass propagating large quantities of saskatoons, but the technique has only been in use since 1987. To date, micropropagated saskatoons have established and grown well.

For those interested in learning more about the micropropagation of saskatoons, the following references should be consulted:

Chu, C. and K.W. Mudge. 1996. Using a rockwool plug system *in vitro* on *Amelanchier*, *Cercis*, *Kalmia*, cherry and apple. HortScience 31(4):566 (Abstract 009).

Pruski, K., M. Mohyuddin and G. Grainger. 1991. Saskatoon (*Amelanchier alnifolia* Nutt.). pp. 164-179 in Y.P.S. Bajaj (ed.). Biotechnology In Agriculture And Forestry. Vol. 16. Trees III. Springer-Verlag, Berlin.

Pruski, K., J. Nowak and G. Grainger. 1990. Micropropagation of four cultivars of saskatoon berry (*Amelanchier alnifolia* Nutt.). Plant Cell, Tissue and Organ Culture 21:103-109.

Propagating Saskatoons By Budding

Budding, a type of grafting, involves the process of joining parts of two plants in a manner such that they will unite and grow as a single unit. Budded plants consist of two parts, the scion and the rootstock, or understock. The scion is the part that develops into new branches, leaves and fruit; the rootstock is the part into which the scion is inserted and which comprises the root system and lower stem. Budding involves the use of a scion with only a single bud attached to a piece of bark.

In general, rootstocks for fruit plants may be derived from seed, rooted cuttings, suckers, or layers. They are selected for control of size, cold hardiness, disease resistance, nematode resistance and so on. Seedling rootstocks are used primarily. The main disadvantage of using seedlings is the lack of genetic uniformity, but the use of seedlings is easier and less expensive than the use of clonal rootstocks.

In the past, budding was the easiest and most economical method of propagating saskatoons. Budding would still be a useful method of propagation on a small scale because the rootstock will confer resistance to the woolly elm aphid, and topworking a number of different cultivars on a single stem may be of interest to some.

The best rootstock to use for saskatoons is *Cotoneaster acutifolia*. This rootstock is hardy, readily available, entirely compatible, and transplants easily. Rootstocks of mountain ash, apple, hawthorn have also been used, but not very successfully because of a certain degree of incompatibility.

Budding may be accomplished anytime that stocks and scionwood are available; in deciduous shrubs, this is usually about a month or so before a new period of growth.

Basic Guidelines For Budding

1) Both rootstock and scion should be alive, vigorous, and healthy.

2) The best scionwood/budwood has healthy vegetative buds, and no flower buds (vegetative buds are narrower and more pointed). The buds should be dormant (bud break and leafing out immediately following grafting will require too much water and the scion will die). Budwood is selected from the previous season's growth or the base of current season's growth after it has matured.

3) The best rootstock is young; vigorous seedlings are better than rooted cuttings or layered plants.

4) Cleanliness is important; debris and dirt must be removed before making cuts.

5) Quick and efficient work is best. Scions or budwood must be kept cool and in the shade. Once the buds are collected, they may be placed in plastic bags with moist paper towels if necessary, and stored in a

refrigerator at 5 to 7°C.

6) Cutting tools must be sharp and clean to allow for controlled, clean cuts, and to prevent the crushing of plant tissues and infection. Tools must be disinfected with bleach, alcohol, vinegar or soap.

7) The correct orientation and position of the scion pieces must be maintained. Buds must always point upwards, otherwise the graft will fail. Buds are usually inserted 10 to 15 cm above the soil on the north side of the rootstock for protection against exposure to the sun.

8) Contact of cambial tissues between the scion and the rootstock must be ensured. Matching is easy if the rootstock and scion are of similar size. If they are of different sizes, the inner edge of the bark must be matched.

9) Scions may be secured to the rootstock using rubber bands, teflon tape, string, plastic, leather strips, or plant fibers. These must be removed when the graft union has healed, otherwise growth will be restricted.

10) The graft must be protected from hot, dry, or very wet conditions. The best time to graft is in the mornings or evenings, otherwise exposed surfaces will dry out and tissues may be killed. Heated beeswax, melted paraffin wax, plastic, moist cloth, or local tree resins may be used to cover the graft union to prevent desiccation.

11) Budded or grafted material should be inspected 10 to 14 days following the grafting procedure. If the bud is still green, then the graft is likely successful; if the bud is brown and shrivelled, the operation has failed. A successful bud will have begun to grow in 25 to 30 days. At this time, the bud wrap can be untied. Shoots from the rootstock will have to be consistently pruned out during the lifetime of the grafted plant.

Methods Of Budding

Shield Budding

Shield budding (T-bud, or its variation, the inverted T-bud), is the most commonly used method of budding. This method of budding is illustrated in the color graphic - Shield Budding. This method only can be used when the bark is slipping from the wood. A 3 to 4 cm long vertical cut is made through the bark of the rootstock. A 1 to 2 cm horizontal cut is made across the upper (for the T-bud method) or lower (inverted T-bud method) end of the vertical cut; the knife blade must be angled away from the vertical cut so as to open the bark. Both cuts should be just through the bark to the wood. The shield is cut starting 1 cm below the bud and completed 1 cm above the bud; the scion wood should be held with the bud pointing towards you and the cut made parallel to the axis of the scionwood and only just into the wood. The bud shield is then inserted under the bark flaps of the rootstock so that is completely enclosed. The bud is then wrapped in an upward spiral, starting just below the base of the wound on the rootstock, and finishing above the wound.

Chip Budding

Chip budding is used when the bark is not slipping from the wood, or when the bark is too thick. This method of budding is illustrated in the color graphic - Chip Budding. The lower branches and leaves are removed from the rootstock. A horizontal cut is made at a 45^o angle at a suitable location on the rootstock. This is followed by a shallow, vertical, downward cut, 2.5 to 4 cm long, starting above the first cut. A shield is cut from the scionwood to match the wound on the rootstock. The bud is removed so that it is near the center of the shield; the cut must be as parallel to the scionwood as possible and just into the wood; the base of the shield is squared with a slanted cut and the bud is set in place on the rootstock with the cambial layers aligned on at least 1 side. The bud is then wrapped in an upward spiral, starting just below the base of the wound on the rootstock, and finishing above the wound.

Care Of Newly-Propagated Saskatoons

Once plant material has been propagated, an environment favourable to vigorous growth and hardening-off is necessary before the new plants can be transplanted to the field.

Containers

Containers should be small enough so that they can be easily moved, but large and deep enough for adequate root growth. Vertical ridges on the inner surfaces of the containers prevent roots from growing in a spiral pattern and prevents plants from becoming rootbound (the condition where root growth becomes excessive for the restricted space, water and nutrients in the container; under such conditions, roots become unhealthy and may even wilt; rootbound plants will not anchor themselves properly upon transplanting). Containers must also have holes for adequate drainage.

Soil Mixtures

Planting mixtures must be able to hold moisture, but also provide for good drainage.

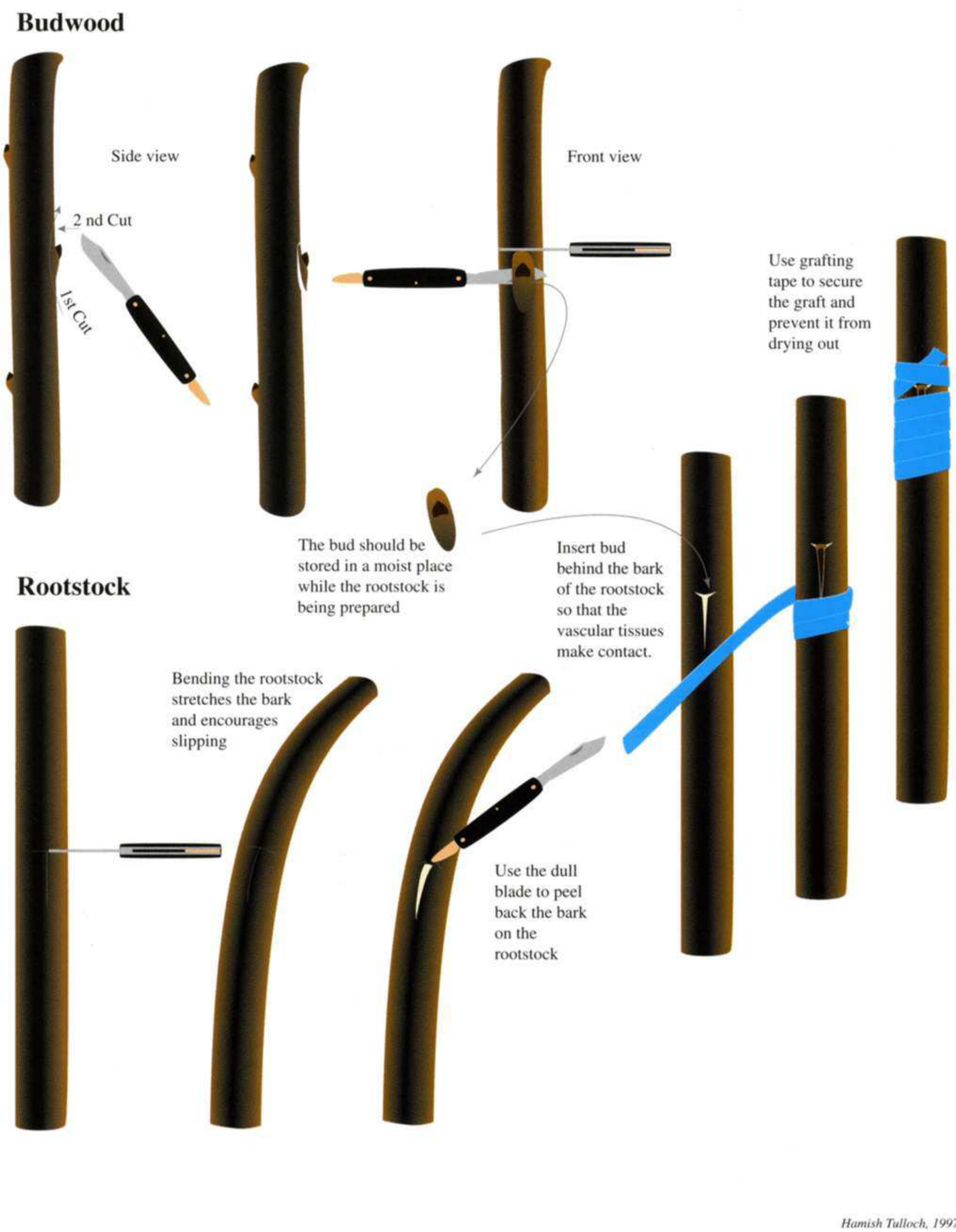
Soil Sterilization

Heating moistened soil to 71^{o}C for about 30 minutes kills most soil-borne disease organisms. However, note that sterilization also kills beneficial soil microorganisms and therefore should only be used where necessary. Sterilization may be accomplished in various ways. A simple method is to place moist soil into a covered metal pot or closed plastic bag and left to heat up in the sun for several days. More sophisticated soil sterilizers also are available.

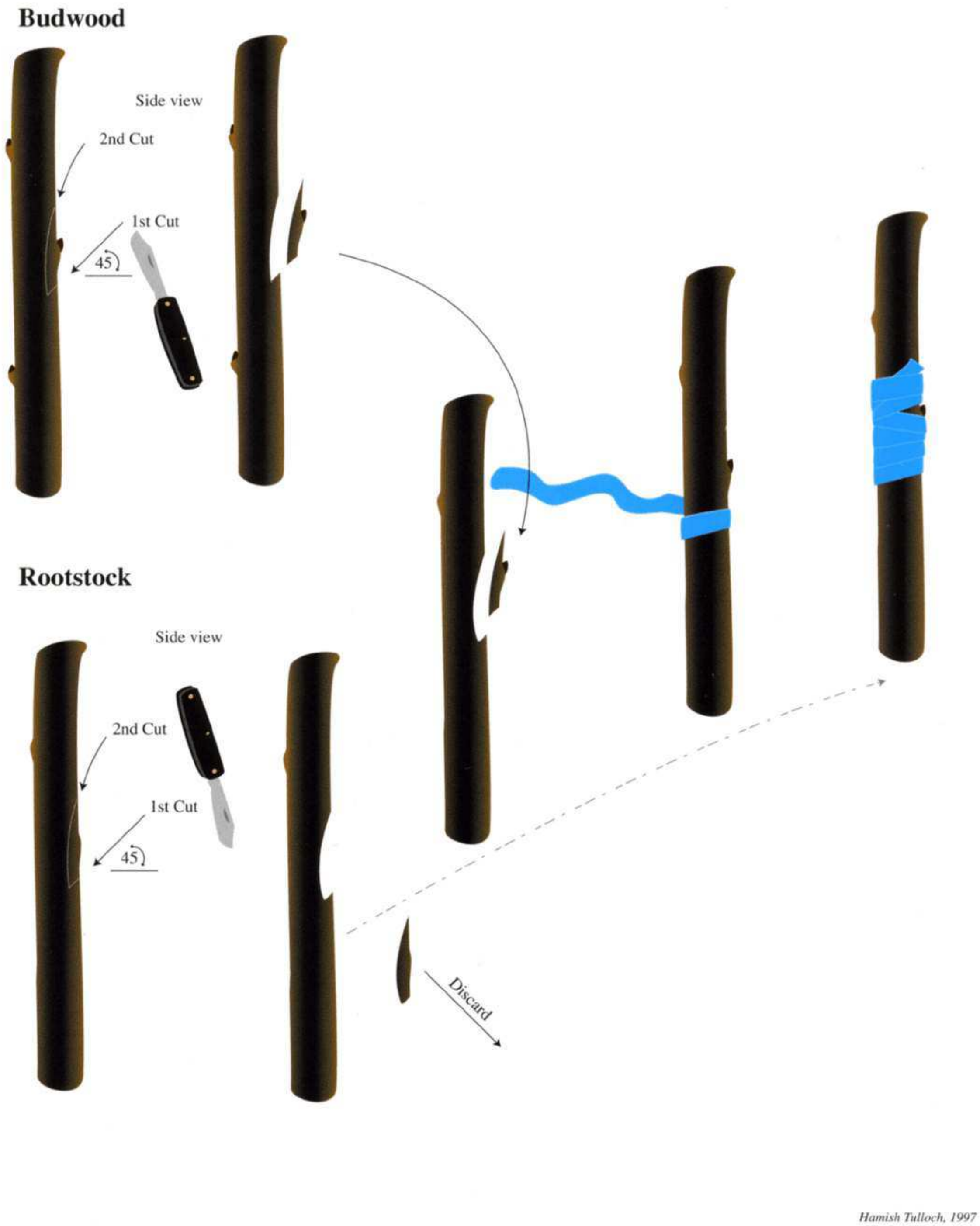
Shading

A lack of shade, or excess shade results in poor plant growth. Shading is required for hardening-off. Very young seedlings require a 50% reduction of incident light for most purposes; a 40%

Shield Budding



Chip Budding



reduction is sufficient for hardening purposes. The following regime for hardening-off is useful: 30% reduction at 45 days prior to transplanting, 15% reduction at 20 days prior to transplanting, and 0% reduction at 5 days priorn to transplanting. It is essential to maintain the evenness of shade. Shade materials can be plastic or fabric netting (shade cloth), or wooden slats (lathing).

Maximizing Growth In A Greenhouse

Growth and development will be favoured by a warm, well-lit environment; a dilute (the concentration depends on the brand used), soluble 10-52-10 or 20-20-20 fertilizer may be applied with each watering. Maximum growth may be obtained using bright full-spectrum fluorescent light (a mixture of cool and warm white), where bright, but indirect sunlight is not available, a constant 25 to 27^{o}C temperature, 70 to 90% relative humidity, and two 30 minute periods of darkness every 24 hours. The plant canopy must not be closer than 20 cm to the light. A moderate amount of air movement is necessary to provide adequate ventilation and to produce stronger stems. The use of carbon dioxide supplementation in greenhouses so equipped may be advantageous in promoting vigorous growth.

Hardening-Off

Before transplanting newly propagated material, hardening-off, or acclimatization to field conditions is necessary; this involves restricting water, switching to natural lighting and reducing the temperature.

Transplants must be hardened-off so that they can better withstand the move from the sheltered greenhouse or nursery environment to harsher field conditions, which may be warmer, colder, and drier. Hardening-off is a process of tempering whereby plants are gradually exposed to more sun and heat and/or lower temperatures, to wind, and to moisture stress. Hardening-off is a process of controlled stress which reduces the rate of transpiration and photosynthesis, causes plant tissue to become more dense (therefore containing less water), and encourages food storage in plant tissues because growth is slowed. The initial stages may involve some wilting, but plants should recuperate at night (as long as the central stem and growing tips remain green and firm, the plants are not being harmed). Hardened-off plants are better able to cope with subsequent droughts and are more productive under dry conditions.

Hardening-off should be initiated 2 weeks prior to transplanting. Hardening-off should not be overly excessive, otherwise plant growth will be affected for the rest of the growing season.

Selecting & Propagating New Varieties Of Saskatoons

It’s a simple matter for a grower to select and propagate their own new variety of saskatoon, which may have some superior characteristics, and which may eventually become a new cultivar. Special training is not required, simply the ability to observe and compare.

When picking fruit from native stands of saskatoons, it's not unusual to notice that one particular shrub appears superior to the others around it. Fruit flavour, size, or shrub yield might be outstanding. A particular shrub may be known to you to bear consistent yields from year to year in contrast to others. The shrub may appear less diseased, or of a different stature. Such observations are the basis of new plant varieties and are invaluable in terms of new crop development. They are a way in which any grower can make a valuable contribution to a developing industry and the conservation of native fruit germplasm.

Some characterisitics to look for when selecting a new saskatoon variety include unusual fruit size, yield, health and vigour of the shrub, hardiness, fruit flavour, and apparent resistance to insect pests or diseases. Only one of these superior characterisitics need be present to make your find a valuable one.

The simplest methods to propagate a potential new variety include seed collection and germination, removal and rooting of suckers, and softwood cuttings. Ensure that the proper procedure for the method of propagation is followed. Such methods ensure the preservation of the parent plant, and the success of propagation. Uprooting and removal of the original plant is not recommended because it is unlikely that the plant will survive.

Saskatoon Cultivars

Richard G. St-Pierre, Ph.D. (December 2005)

Introduction

Saskatoon cultivars have been selected on the basis of superior fruit size, taste, yield, flowering time, and color of flowers, fruit, and fall foliage. Cultivar differences such as fruit diameter and weight, acidity, sugar content, and bush yield may vary appreciably. For example, the cultivar Thiessen produces fruit considerably more acidic than fruit of the cultivar Smoky.

Currently, there are approximately 26 named cultivars of saskatoon. These include Altaglow, Bluff, Buffalo, Elizabeth, Forestburg, Honeywood, JB30, Killarney, Lee #3, Martin, Moonlake, Nelson, Northline, Paleface, Parkhill, Pearson II, Pembina, Regent, Smoky, Sturgeon, Success, and Thiessen. The cultivars, Parkhill, Regent and Success appear to be hybrids between *Amelanchier alnifolia* and *A. stolonifera*, as indicated by a recent study using genetic fingerprinting. Other cultivars of the saskatoon, and other *Amelanchier* species, are available from certain nurseries, especially in the United States. These include Beaverlodge, Gypsy, Idaho Giant, and Timm. However, these cultivars are either not widely available, or no longer available, and little or no information about their characteristics is available.

Initially, most commercial saskatoon orchards were based on the cultivar Smoky. This was because only Smoky had been available in any quantity, and it was one of the first varieties to be released. The cultivars Honeywood, Martin, Northline, Pembina and Thiessen now have been commonly planted. These cultivars are considered to be some of the best cultivars. Other cultivars and new selections have not been planted to any great extent, partly because of the lack of comparative data on cultivar performance and potential.

At present, it is not possible to make any valid recommendations about cultivar performance at different locations, where soil type and various climatic factors differ, because properly designed cultivar comparisons are still in progress. Saskatoon cultivar evaluation trials have been established in Alberta, Saskatchewan and Manitoba, but it will be two to three more years before useful data starts to become available.

The table on the following page provides a comparison of the more popular saskatoon cultivars.

A Comparison Of Some Popular Saskatoon Cultivars					
Cultivar	**Smoky**	**Pembina**	**Northline**	**Thiessen**	**Honeywood**
Shrub Form	upright to spreading	upright to spreading	upright	sprawling to open, erect	upright
Mature Spread of Crown	6 m	5 m	6 m	6 m	4 m
Height	4.5 m	5 m	4 m	5 m	5 m
Flowering Time	average	average	average	early	late
Yield	very productive	productive	very productive	very productive	productive, especially at an early age
Fruit Size	14 mm	14 mm	16 mm	17 mm	16 mm
Fruit Flavour	mild, sweet	full, tangy	full, sweet	tangy, juicy	full, tangy

*Note: these characteristics may vary considerably, depending on location and year.

Selection Of Planting Stock For Orchards

Characteristics Of Quality Plants

Ideally, high-quality planting stock:

a) is true-to-variety, that is, its characteristics are identical to the named parent plant.

b) is healthy, vigorous, not too old, 15 - 60 cm in height.

c) has leaves with a vibrant, green color, and stem tissues that are not soft.

d) has a well-developed, fibrous, moist, root mass that is straight (not twisted, or wound).

e) has uniformly spreading branches, if branched.

f) has no signs of physical damage, or of insect pests or diseases.

g) has graft unions that are properly healed, if grafted.

Seedling, Cutting, Or Micro-propagated Stock?

Saskatoon plants may be derived from several different sources including seedlings (from germinated seeds), suckers, rooted cuttings, and micropropagated plantlets. The easiest, most successful methods of propagating saskatoons include the germination of seed, the use of etiolated shoots for cuttings, transplanting suckers, and micropropagation. Ease of propagation is important because it is associated with the production of higher quality planting stock.

Vegetative propagation is asexual propagation. Vegetatively propagated plants come from plant parts other than seed; these parts may include cuttings from shoots or roots, suckers, pieces of leaves, or buds. Plants derived from these parts have a single parent only and therefore are genetically identical to the parent plant. In such plants, fruit production occurs at an earlier age than in those plants propagated by germinating seed. Vegetative propagation is the method of choice for most fruit species. Micropropagated plants are not necessarily superior or inferior to plants originating from other methods of propagation. Micropropagation is possibly the best method currently available for mass propagating large quantities of saskatoons, but the technique has only been in use since 1987. To date, micropropagated saskatoons have established and grown well.

The saskatoon is a relatively unique fruit crop in that it is self-fruitful, that is, two, genetically distinct parents and cross-pollination are not required for the production of fruit and seed. The consequence of this is that saskatoon seedlings are very similar to, or perhaps indistinguishable from the parent plant. For this reason, there is no substantial disadvantage to propagating saskatoons by seed, provided that only seed produced by the original parent clone is used (first generation, or F1, seed).

Reports differ with respect to the amount of dissimilarity in seedlings compared to the parental material. Propagators report a range of 70 to 99% similarity to the parental stock, with the seedling plants being of equal quality, more or less, to the parental stock. Because a certain amount of cross-pollination is possible, it is important to only use F1, or first generation, seed. Seed of subsequent generations will be more dissimilar to the parental stock.

For the potential grower of saskatoons, the purchase of seedlings may be a cost-effective way to establish an orchard. However, a small amount of genetic variability will be present within the orchard.

It must be noted that plant variability associated with seedlings may be useful in the search for new cultivars, especially where resistance to insect pests or diseases is expressed. Other advantages of using seed include lower initial cost and the production of disease-free material.

However, for those predisposed to the do-it-yourself approach and who wish to germinate seed, a number of factors must be considered. Seed may germinate erratically, depending on where it was collected and how it was stored. Germinated seedlings may go dormant very quickly, and inducing them to grow to a size where they can be transplanted successfully will require appropriate cultural techniques in a greenhouse and then a nursery environment. Seedlings will require an additional year of growth before the production of a fruit crop is possible, and some roguing of mature plants that are significantly different may be necessary. Under these circumstances, it is suggested that such an approach only be used where a minimal start-up cost is essential, and where potential genetic variability is not considered detrimental (in shelterbelts, for example).

Regardless of the method of propagation, it should be noted that the quality and vigour of planting stock can vary substantially, depending upon the source. When purchasing new saskatoon plants, a potential grower first must consider the quality of the planting stock, the quantity required, the quantity available from the propagator, and the price. The method of propagation is of secondary concern. To date, saskatoon plants produced by any method of propagation appear to perform equally well, more or less, in an orchard setting.

What Cultivars Should A Grower Purchase?

The productive life of a saskatoon orchard is thought to be 30 to 50 years. However, because of the ongoing development of superior, newer cultivars, it is to be expected that cultivars could become obsolete before their productive life ends.

It is important to note that recommendations for specific cultivars of most native fruit species are only tentative. Valid scientific cultivar evaluation trials are still in progress. Because cultivar recommendations are not possible at the present time, more than one cultivar, and probably a minimum of three, should be planted when establishing an orchard. An orchard comprised of several cultivars may have the following long-term advantages: a) better consistency of overall orchard yield; b) harvesting can be spread over a larger period of time because different cultivars ripen at slightly different times; c) greater overall resistance to insect pests and diseases; and d) greater adaptability for future processing possibilities.

Sources Of Planting Stock

It is wise not to purchase inexpensive plants from unknown sources. Before purchasing plant material, it is important to investigate several sources before making any decisions. The cost and availability of plant material may vary considerably. The cost of purchasing high-quality planting stock may be greater, but the investment usually provides better returns in the long run.

When purchasing seed or plants, several factors must be considered. It would be useful to be able to verify that the plant material being purchased is in fact the cultivar that it is labelled as. Unfortunately, there is no easy way to verify the identification of saskatoon cultivars at present.

If the plants were grown from seed,

first generation (F1) seed should have been used. Similarly, only F1 seed should be purchased if one is starting plants from seed. It is suggested that written certification of F1 status be obtained at the time of purchase of seed or seedlings.

Plants grafted onto *Cotoneaster* rootstocks may be quite useful in avoiding loss from the woolly elm aphid. Unfortunately, such plants are more expensive, and are not as widely available. The graft union must be planted below the soil surface in order for the saskatoon to develop its own roots. Annual pruning to remove developing shoots of rootstock material will be necessary, thus requiring extra hand labor.

Characteristics Of Saskatoon Cultivars

Most *Amelanchier* cultivars grown for fruit production belong to the species *A. alnifolia*. Similar quality fruit from selections of closely-related and naturally-hybridizing species usually are treated as saskatoons. Most saskatoon cultivars appear to be self-fertile. The cultivar descriptions in this factsheet are based on limited published data, unpublished research data, and comments by originators or their successors; scientifically acceptable, comparative data are only now becoming available. The Department of Horticulture Science, University of Saskatchewan, is the International Registration Authority for the genus *Amelanchier*.

These descriptions have been modified from the publication: St-Pierre, R.G. 1997. Saskatoon. pp. 666-668 in The Brooks and Olmo Register Of Fruit & Nut Varieties. Third Edition. ASHS Press. Alexandria, Virginia.

Altaglow. Originated in Red Deer River valley, Alberta (51ºN), and selected by A. Griffin prior to 1923; wild plant transplanted to Alberta Horticultural Research Station, Brooks. Initial selection and distribution for testing, 1928. Tested at Agriculture Canada Research Station, Beaverlodge (BRS), Alberta as Brooks White. Selected as an ornamental by J.A. Wallace, BRS, 1946. Introduced by P.D. Hargrave, Brooks, Alberta, in 1964. Fruit up to 16 mm diameter, nearly spherical, white, easily bruised (Figure 3.2); typically 5-9 per cluster, clusters tight, even ripening, very uneven in size; flavor bland but sweet. Apparently self-sterile. Shrub to 7 m high; tall and erect habit, 3 m spread at maturity; moderate to good suckering close to crown, crown expanding indefinitely; crown long-lived, 40 + years. Apparently susceptible to woolly elm aphid. Introduced as an ornamental for its habit in large landscapes, for the oddity of its white fruit, but mainly for its splendid fall foliage colors.

Bluff. Originated near Buffalo Lake, Sexsmith, Alberta (55ºN) and selected by P. Student; wild clump discovered on his farm in 1946. Selected in 1975 by J.G.N. Davidson and K.T. (Student) Davidson; introduced in 1990. Fruit up to 13 mm diameter, nearly spherical, blue-black with light bloom; typically 7-13 cluster, cluster tight, even size, and exceptionally even ripening; good, well-balanced flavor, moderately tangy; holds its flavor when cooked better than other cultivars; seeds relatively few and small. Shrub to 5 m high (Figure 3.4); initially upright, tends to retain tall, erect habit, 2.5 m spread at maturity unless pruned; moderate to good and close suckering near crown; crown long-lived, 50 + years. May have some resistance to leaf diseases. Currently being evaluated in a comprehensive cultivar trial.

Buffalo. Originated near Buffalo Lake, Sexsmith, Alberta (55ºN) and selected by A. Student; wild clump discovered on his farm in 1925. Selected in 1980 from suckers transplanted in 1975 by J.G.N. Davidson and K.T. (Student) Davidson; introduced in 1990. Fruit up to 14 mm diameter, obovate to nearly spherical, blue-black with slight bloom; typically 7-13 per cluster, cluster fairly loose, fairly even ripening; excellent flavor with very good balance between tanginess and sweetness, best fresh but also cooks, cans and jams well. Shrub to 4 m high; initially upright, to spreading at maturity, 5 m spread; moderate suckering near crown, crown expands similarly to Pembina; crown long-lived, 70 + years. Currently being evaluated in a comprehensive cultivar trial.

Elizabeth. Originated near Langham, Saskatchewan (52ºN) and selected by J. Blushke; propagated from wild plant discovered by E. Blushke (date unknown). Commercially introduced in 1991 under the name Pasture. Fruit up to 15 mm diameter, fairly even-ripening, sweet, full flavor. Shrub to 4 m high; upright to spreading; moderate suckering; consistent bearer. Currently being evaluated in a comprehensive cultivar trial.

Forestburg. Originated near Forestburg, Alberta (52º30'N); wild plant discovered by A. Nixon on his farm. Transplanted to Agriculture Canada Research Station, Beaverlodge (BRS), Alberta, in 1948; tested as B.E.F. 0003. Selected by J.A. Wallace, BRS; introduced in 1963. Fruit up to 16 mm diameter, nearly spherical, blue-black with bloom; typically 7-11 cluster, clusters very tight, fairly even ripening, later than Smoky; flavor mild, quite sweet, juicy; pH 4.2. Shrub to 4 m high; initially upright to arching-spreading, 5 m spread at maturity; moderate to light suckering near crown, crown expands slowly; crown long-lived, 40 + years. Heavy producer of large fruits. Currently being evaluated in a comprehensive cultivar trial.

Honeywood. Originated near Parkside, Saskatchewan (53ºN) and selected by A.J. Porter. Seedling selection from wild plant discovered by A.J. Porter *circa* 1955 near his Honeywood Nursery; introduced by him in 1973. Flowers 4-8 days later than other cultivars, and ripens somewhat later also. Fruit up to 16 mm diameter, basically flattened to spherical, blue-black with little bloom; typically 9-15 per cluster, cluster fairly tight, fairly even ripening; excellent full and tangy flavor; pH 3.7-3.9; seeds relatively large. Shrub to 5 m high; initially upright to arching-spreading, 4 m spread at maturity; sparse suckering near crown, crown expands relatively slowly like Pembina. May have some resistance to powdery mildew. Very productive and precociously fruitful. Currently being evaluated in a comprehensive cultivar trial.

JB30. Originated near Langham, Saskatchewan (52ºN) and selected by J. Blushke; propagated from wild plant discovered by J. Blushke (date unknown). Commercially introduced in 1991 under the name Quaker. Fruit up to 15 mm diameter, ripening over an extended period; good, rounded flavor. Shrub to 3.5 m high; upright to spreading; productive. Currently being evaluated in a comprehensive cultivar trial.

Killarney. Originated near Killarney, Manitoba (49°N) and selected by A. Eigler (date unknown); propagated from a wild plant; introduced by him in 1994(?). Good-sized fruit, pleasing taste. Shrub to 4 m high. Very productive, consistent bearer.

Lee #3. Originated near Barrhead, Alberta (54°N) and selected by L. Lee in 1989; cross between Pembina and Northline(?); introduced by K. Pruski, Alberta Agriculture, Crop Diversification Centre - North, Edmonton, Alberta, in 1994. Fruit up to 16 mm diameter, intense flavor and bouquet; few-seeded. Shrub to 3 m high, compact, spreads slowly.

Martin. Originated in Langham, Saskatchewan (52°N) and selected by D. Martin (D. Martin Nursery); introduced by D. Martin in 1990. Seedling selection from Thiessen for large fruit size and apparent, more uniform ripening, otherwise similar to Thiessen. May have partial resistance to the woolly elm aphid. Currently being evaluated in a comprehensive cultivar trial.

Moonlake. Originated near Saskatoon, Saskatchewan (52°N) and selected by G. Krahn (Lakeshore Tree Farms); wild plant discovered by Moon Lake; introduced by G. Krahn in 1974. Fruit up to 16 mm diameter, obovate to nearly spherical, blue-black with light bloom; typically 6-10 per cluster, cluster open; flavor relatively mild, sweet, good; pH 3.9. Shrub to 3 m high; initially upright to arching-spreading, 3 m spread at maturity; suckering moderate. Productivity moderate, somewhat sporadic. May have some resistance to powdery mildew. Currently being evaluated in a comprehensive cultivar trial.

Nelson. Originated near Bradwell, Saskatchewan (52°N); wild plant discovered by S.H. Nelson in 1974; introduced by R. St-Pierre, University of Saskatchewan, Saskatoon in 1992. Flowers 3-7 days later than other cultivars. Fruit up to 13 mm diameter, nearly spherical, blue-black with little bloom, few seeds; typically 6-12 fruit per cluster, cluster compact, ripening somewhat uneven; good tangy flavor. Shrub, compact, to 1.5 m high; suckering moderate. Possibly some resistance to saskatoon-juniper rust (*Gymnosporangium spp.*). Currently being evaluated in a comprehensive cultivar trial.

Northline. Originated near Beaverlodge, Alberta (55°N) and selected by J.A. Wallace (Beaverlodge Nursery) in 1958; introduced by him in 1965. Fruit up to 16 mm diameter, obovate to nearly spherical, blue-black with bloom, very firm; typically 7-13 per cluster, fairly even ripening; excellent full flavor, similar in quality to Pembina, fairly sweet; pH 3.8-3.9; resistant to cracking. Shrub to 4 m high (Figure 3.3); initially upright to arching-spreading, 6 m spread at maturity; suckering quite freely near crown, crown expands indefinitely; crown long-lived, 50 + years. Possible susceptibility to woolly elm aphid. Very productive, exceeds Smoky at some locations. Occupies an increasing proportion of commercial hectarage in Canada, the third largest in 1993. Currently being evaluated in a comprehensive cultivar trial.

Paleface. Introduced by W. Oaks, Miami, Manitoba (49ºN) (year unknown). Large, white, mild-flavoured fruit, easily bruised. Shrub pyramidal to 2 m high; productive; suckers uncommon.

Parkhill. Originated in Michigan; wild plant selection; introduced by Parkhill Nursery, Bismarck, North Dakota in 1974. Species uncertain; recent genetic fingerprinting studies suggest a hybrid of *A. stolonifera* with *A. alnifolia*. Fruit up to 13 mm diameter, obovate to nearly spherical, blue-black with bloom; typically 7-11 per cluster, cluster fairly open, fairly even ripening; flavor mild and relatively bland; pH 4.1. Shrub to 1.5 m high; initially upright to spreading, 2.5 m spread at maturity; low to moderate suckering, crown expands slowly. Susceptible to powdery mildew. Possible partial resistance to *Entomosporium* leaf and berry spot. Currently being evaluated in a comprehensive cultivar trial.

Pearson II. Originated in Bowden, Alberta (52ºN) and selected by L. Pearson; introduced by him in 1990. Open-pollinated seedling of Smoky. Fruit up to 10 mm diameter; flavor similar to Smoky. Shrub to 3 m high, consistently high production. Possible susceptibility to *Entomosporium* leaf and berry spot. Currently being evaluated in a comprehensive cultivar trial.

Pembina. Originated near Barrhead, Alberta (54ºN) and selected by J.A. Wallace, Agriculture Canada, Beaverlodge, Alberta; wild plant discovered in Pembina River valley *circa* 1928; tested as Barrhead No. 1 and as B.E.F. 3501; re-selected 1950; introduced in 1952. Fruit up to 14 mm diameter, obovate to nearly spherical, blue-black with bloom; typically 9-13 per cluster, fairly even ripening; excellent, full, tangy flavor, fairly sweet; pH 4.1; fruit susceptible to cracking from excessive moisture. Shrub to 5 m high; initially upright to upright-spreading, 5 m spread at maturity; moderate to sparse suckering near crown, crown expands more slowly than Smoky; crown long-lived, 70 + years. Possible susceptibility to *Entomosporium* leaf and berry spot and woolly elm aphid. Nearly as productive as Smoky. The full-flavor standard against which other cultivars are judged. Currently being evaluated in a comprehensive cultivar trial.

Regent. Originated near Regent, North Dakota (46ºN); introduced in 1977 by J. Candrian, Farmer Seed and Nursery Co., Faribault, Minnesota. Open-pollinated seedling; species uncertain; recent genetic fingerprinting studies suggest a hybrid of *A. stolonifera* with *A. alnifolia*. Fruit up to 13 mm diameter, ovoid to nearly spherical, blue-black with bloom; typically 7-11 per cluster, cluster loose and open; flavor somewhat plum-like, mild, sweet and somewhat bland; pH 4.1-4.5; relatively few and small seeds. Shrub to 2 m high; initially upright, 2 m spread at maturity; suckering low to moderate. Precociously fruitful. Possible resistance to *Entomosporium* leaf and berry spot and saskatoon-juniper rust (*Gymnosporangium spp.*). It is also used as an ornamental, having attractive fall foliage colours. Currently being evaluated in a comprehensive cultivar trial.

Smoky. Originated near Beaverlodge, Alberta (55ºN), and selected by W.D. Albright; wild plant discovered on the Beaverlodge Research Station (in the Smoky River drainage basin), transplanted in 1918; tested as Selection no. 9 (1928), and B.E.F. 3502 (1935), re-selected 1950; introduced in 1952 by J.A. Wallace, Agriculture Canada, Beaverlodge, Alberta. Fruit up to 14 mm diameter, spherical, blue-black with bloom; typically 7-11 per cluster, relatively uneven ripening; good, mild flavor, sweetest cultivar with highest sugar/acid ratio so far; pH 4.1-4.5; relatively large and many seeds. Shrub to 4.5 m high; initially upright to arching-spreading, 6 m spread at maturity; freely suckering near crown, crown expands indefinitely; crown long-lived, 70 + years. Possible partial resistance to woolly elm aphid. Possible susceptibility to *Entomosporium* leaf and berry spot and *Cytospora* canker. Most productive commercial cultivar so far, yielding up to 6,000 kg/ha. The cultivar that enabled commercial production to start in the prairies; in 1990 it occupied about 85% of the hectarage in Canada. Currently being evaluated in a comprehensive cultivar trial.

Sturgeon. Originated on the east shore of Sturgeon Lake near Valleyview, Alberta (55ºN); introduced by J.A. Wallace, Beaverlodge, Alberta, in 1971. Flavorful, large fruit in large clusters. Shrub upright to 3 m height; productive.

Success. Originated in Pennsylvania mountains (*circa* 41ºN). Selection made before 1868 from seedlings of wild plants. Acquired 1873 by H.E. Van Deman, Kansas, and introduced by him in 1878. Van Deman sold more than 10,000 plants by 1888. Species uncertain; recent genetic fingerprinting studies suggest a hybrid of *A. stolonifera* with *A. alnifolia*. Fruit up to 14 mm diameter, obovate to nearly spherical, blue-black with bloom; typically 7-11 per cluster, cluster loose, ripens slowly, fruit held firmly; flavor good but mild, somewhat apple-like, quite sweet; pH 4.0; seeds relatively large. Shrub to 2 m high; initially upright to upright-spreading, 2 m spread at maturity; moderate suckering near crown. Possible resistance to *Entomosporium* leaf and berry spot, and partial resistance to woolly elm aphid. Susceptible to powdery mildew. In one study it made the best fruit leather of 9 cultivars. Also attractive as an ornamental, having glossy, green foliage, turning an attractive red in the fall. By far the oldest surviving cultivar. Currently being evaluated in a comprehensive cultivar trial.

Thiessen. Originated west of Hepburn, Saskatchewan (52ºN) near the North Saskatchewan River; wild plant discovered in 1906 by Maria Loewen and transplanted to her parent's farm near Debenham. Years later, removed to their farm near Langham, Saskatchewan. Obtained from this farm and introduced by G. Krahn (Lakeshore Tree Farms, Saskatoon, Saskatchewan) in 1976. Flowers a few days earlier than other cultivars. Fruit up to 17 mm diameter, nearly spherical, blue-black with slight bloom (Figure 3.1); typically 6-12 per cluster, cluster fairly loose, uneven ripening; excellent flavor, fresh and juicy. Shrub to 5 m high; initially upright, but tends to sprawl from an early age, eventually becoming a large bush, up to

6 m spread at maturity; moderate to good suckering near crown, crown expands indefinitely; crown long-lived, 70 + years. Some resistance to powdery mildew. Possible susceptibility to *Cytospora* canker and 2,4-D damage. It is much favored for U-pick orchards. It had the second largest commercial hectarage in Canada in 1993. Winner of the Canadian Society for Horticultural Science Outstanding Cultivar Award in 1994. Currently being evaluated in a comprehensive cultivar trial.

Saskatoon Cultivar Trials & New Cultivar Development

Development And Improvement Of Saskatoon Cultivars

The saskatoon has not been domesticated, that is, it has not undergone breeding and selection for cultivated environments. However, a number of selections having superior characteristics have been chosen from the wild, and it is this material which is being propagated and cultivated. Cultivated, or so-called tame saskatoons are still essentially wild saskatoons. Saskatoon cultivars have been selected on the basis of superior fruit size, taste, yield, flowering time, and color of flowers, fruit, and fall foliage. Cultivar differences such as fruit diameter and weight, acidity, sugar content, and bush yield may vary appreciably.

Initially, most commercial saskatoon orchards were based on the cultivar Smoky. This was because only Smoky had been available in any quantity, and it was one of the first varieties to be released. The cultivars Honeywood, Martin, Northline, Pembina and Thiessen now have been commonly planted. These cultivars are considered to be some of the better cultivars. Other cultivars and new selections have not been planted to any great extent, partly because of the lack of comparative data on cultivar performance and potential. At present, it is not possible to make any valid recommendations about cultivar performance at different locations, where soil type and various climatic factors differ, because properly designed cultivar comparisons are still in progress.

Although superior cultivars of saskatoons exist, these existing cultivars could be improved in a variety of ways. Cultivars with increased yields, increased tolerance or resistance to insect pests or diseases, increased ease of picking, and improved fruit quality and storability would considerably enhance the commercial production of saskatoons.

Saskatoon Cultivar Trials

Comprehensive saskatoon cultivar trials are in progress in Saskatchewan at five locations. The objective of these trials is to evaluate named saskatoon cultivars and additional new selections at a number of sites in the province of Saskatchewan. New, different saskatoon cultivars can only be developed if promising unnamed selections are tested against known cultivars to evaluate their potential. The scientific evaluation and comparison of saskatoon cultivars growing together at different sites has not previously been done. Data collected from this study will allow recommendations about expected cultivar performance to be made to growers, will further the development of promising new cultivars, and will allow comparisons to be made of fruit processing potential.

Cultivar Trial Design

The saskatoon cultivar evaluation trial involves 5 sites within the province of Saskatchewan. These include 4 grower locations: a) Hudson Bay (Connie Espenant); b) Makwa (Oscar Berube); d) Saskatoon (Dan Byblow); and e)Yorkton (Martin Neuhofer). The saskatoon cultivar evaluation trial is also established at the University of Saskatchewan. These sites differ in terms of soil texture, fertility, pH, organic matter content, and local climate. Seventeen cultivars have been planted including Buffalo, Bluff, Forestburg, Honeywood, Martin, Nelson, Northline, Quaker, PAR90TRS, Parkhill, Pasture, Pearson II, Pembina, Regent, Smoky, Success, and Thiessen.

Data collection at all sites, and for all cultivars includes, where possible, post-transplant survival, mean number of suckers/plant, growth, length of the period of juvenility, bush form, flowering date, uniformity of ripening, degree of alternate bearing, degree of suckering, susceptibility to insect pests and diseases, yield/plant, number of fruit per cluster and fruit size. Fruit quality is being measured in terms of color, soluble solids content, % moisture, titratable acidity, pH, and anthocyanin content.

Cultivar Trial Results To Date

The saskatoon cultivar evaluation trial in Saskatchewan is now in its fifth year. Differences among cultivars, and site effects on cultivar performance are becoming evident. Overall, no single cultivar appears to be outstanding. Cultivar performance appears to be dependent on location. Substantial site differences are appearing for some of the characteristics measured. These differences reflect overall site effects on all plants of all saskatoon cultivars. Site effects are associated with differences in soil type, amount of rainfall and irrigation, heat units available for growth, and co-operator care and attention. For example, the Makwa site is not irrigated and suffered from extensive deer browsing prior to fruit ripening in 1996. Site also significantly affects all of the fruit quality variables measured as did cultivar. The next few years of data collection should provide important, practical information about these saskatoon cultivars and enable recommendations about performance to be made.

Plate 3. Saskatoon Cultivars

Figure 3.1: Fruit of the cultivar Thiessen.

Figure 3.2: Fruit of the cultivar Altaglow.

Figure 3.3: Four-year-old shrub of the cultivar Northline.

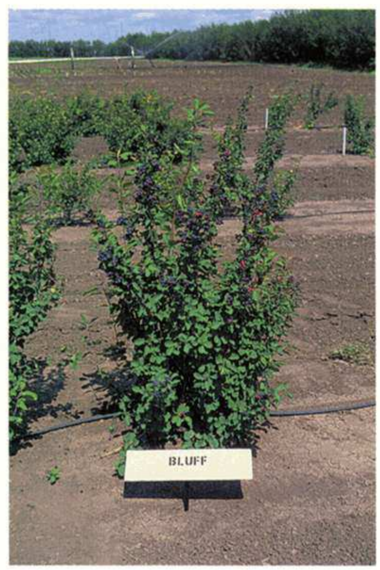


Figure 3.4: Four-year-old shrub of the cultivar Bluff (Photo by H. Tulloch).

Orchard Establishment

Richard G. St-Pierre, Ph.D. (December 2005)

Selecting A Site For Your Saskatoon Orchard

It is imperative to select a good site from the start. The use of a marginal site may lead to an orchard or plantation that is not economically viable because of increased costs associated with poor plant survival and replanting, decreased plant vigour and yields, greater susceptibility to weather, insect, disease, and nutritional problems, increased inputs, and loss of time and money. It is much easier to change location than to attempt to solve the limitations of a poor site. Remember that fruit plants are perennial and that initial mistakes can have long term consequences. Figures 4.1 to 4.6 illustrate some typical saskatoon orchards in Saskatchewan, and some typical problems.

The Prairie Climate

High quality fruit crops can be grown on the prairies provided that good management practices are followed.

The primary climatic limitations include a lack of rainfall, temperature extremes, strong winds, a short frost-free growing season (approximately from May 24 through September 7; this is about 100 days, depending on location), and sunshine in the winter, which can result in sunscald. Winter injury may be associated with extreme low temperatures, freeze-thaw cycles, dehydration, and improper hardening-off in the fall, depending on fall weather conditions. Cold temperatures, rain, and wind may reduce pollinator activity in the spring.

Despite these limitations, economically viable, commercial production of some fruit crops is possible. The Prairies have climatic advantages which include large amounts of sunshine necessary for the coloring and ripening of fruit, lower humidity levels which reduce the incidence of fungal infestation, and generally fewer insect pests.

Growers should make note of minimum and maximum temperatures, rainfall distribution and amount, and the prevailing direction and extent of wind for their chosen orchard location.

Topography

If possible, orchard sites should have a slight slope (1 to 3%) so as to provide for the drainage of water and cold air. Low-lying areas which form frost pockets and are prone to flooding and standing water must

Plate 4. Saskatoon Orchards

Figure 4.1: A typical two-year-old saskatoon orchard.

Figure 4.2: Typical saskatoon orchard with caragana shelterbelt.

Figure 4.3: Intercropping saskatoons with strawberries.

Figure 4.4: Giant sunflowers used as a windbreak.

Figure 4.5: Saskatoon orchard with standing water (Photo by H. Tulloch).

Figure 4.6: Saskatoon orchard on saline soil (Photo by H. Tulloch).

be avoided. There should be a break in any shelterbelt at the low end of the orchard to allow for proper air flow.

North, northeast, and east-facing slopes suffer fewer freeze-thaw cycles in the spring, stay cooler, and are moister; this helps delay the onset of growth, delays flowering, and results in less sunscald. South and southwest-facing slopes warm up earlier in the season, promoting earlier flowering, thus making the potential fruit crop vulnerable to late-spring frosts. Such slopes are also more vulnerable to sunscald in the winter.

Drainage

Most fruit crops require well-drained soils. If water stands around roots after rains, or if the water table is near the soil surface, problems with root rot will result. Drainage ditches may be required.

Soil

The saskatoon will grow in all types of soil, provided that the soil is well-drained. Clay soils may hold excessive water and lack drainage. Sandy soils don't hold adequate amounts of water and require additional fertility. The best soil is a fertile, deep (at least 1 m above the water table), sandy loam or loam with 2 to 3% organic matter. Sandy loam and loam soils provide the best balance of drainage and retention of moisture. Heavy clay soils lacking in humus should be avoided, as should shallow soils and sites where the water table is high or erratic.

The saskatoon appears to be tolerant of a wide range of soil pH (5.0 to 8.0), although some observations suggest that low pH's may retard plant development. A pH range of 6 to 7 is best for maximizing the availability of plant nutrients.

Representative soil samples should be taken and analyzed for mineral nutrient content, pH, and organic matter. Past recommendations for fruit orchards on prairie soils generally indicated that minimum soil nutrient levels at 0 to15 cm depth be maintained at 28 to 56 kg N, 56 to 112 kg P, and 336 to 672 kg K per hectare. At a depth of 15 to 30 cm, minimum levels should be 39 to 84 kg N, 90 to 180 kg P, and 560 to 1120 kg K per hectare. Fertile loam soils may not require additional fertilizer. Ideally, soil salinity levels should be less than 1 mS/cm.

Note that many marginal soils can be improved considerably given some time and appropriate management techniques.

Availability Of Water

A source of water is required for irrigation, mixing pesticides, and washing of fruit prior to marketing.

For irrigation purposes, surface water is generally of better quality than well water, which can have a high salt content (the measure of salinity, or EC, should be less than 1 mS/cm). Ideally, the water supply should be situated relatively near the orchard, preferably at the same elevation or higher. Moving water upslope is more difficult and costly. The supply should be sufficient to meet annual irrigation requirements.

Shelter

Protection from strong, drying winds is essential. Shelterbelts should be established to provide protection from the prevailing north and northwest winds in winter, and south and southwest winds in summer. Shelterbelts also help to trap snow and increase soil moisture reserves.

Cropping History

Previous practices may have left problems that could negatively affect fruit production. Such problems include residual levels of herbicide, compacted soil, high levels of salinity, disease and insect pest reservoirs, and weeds.

If it is suspected that herbicide residues are present in the soil, growing cucumbers during the period of site preparation will provide a fairly sensitive indication of the presence of herbicides.

Storage Facilities, Transport, Nearness To Markets

Fruits are highly perishable and will often spoil within a day or two of picking. Harvested fruit either must be sent to market as soon as possible, especially if refrigeration is uneconomical, or frozen or otherwise processed as quickly as possible. Spoilage can very quickly decrease a grower’s profits.

Method Of Marketing

Growers must have a marketing plan in place prior to orchard establishment. The method of marketing dictates the method of harvest, orchard location, plant spacing and overall orchard design. Fruit destined to be processed or for the fresh frozen markets may be machine harvested. Fruit destined to be sold at the farmgate, or orchards designated to be U-pick or Pre-picked are more restricted in terms of possible locations (should be close to urban centres), must be accessible via a good all weather road, and should be simple to find.

Initial Preparation Of The Orchard Site

Prior to ordering and planting trees, an orchard plan should be drawn on paper to show tree locations, irrigation system, roads or paths, and a packing or storage shed. Proper layout allows for uniform plant growth, facilitates orchard operations (cultivation, intercropping, irrigation, spraying, harvesting, and so on), and avoids wastage of space.

It is strongly suggested that at least a full year be used for site preparation.

The site should be levelled and soil and water analyses done. Fine-textured soils such as silts and clays should be deep plowed, disced, and then subsequently rotovated; rotovation by itself only works the top 15-20 cm of soil, and may leave a hard layer beneath which can restrict water drainage and root growth. Where a hard layer restricts drainage, a deep chisel or subsoiler may be required. On coarse or shallow soils, surface tillage may be acceptable. Ploughing in the fall allows frost to penetrate deeper into the soil, helping to break up large clods of soil. The following spring, the soil will be much easier to work.

Any amendments required should be made during this time and are best made during the fall. Heavy, clay soils with a pH greater than 7 may be amended with the addition of sulfur and peat in order to decrease the pH, otherwise iron chlorosis could be a chronic problem; acid fertilizers (21-0-0, or 16-20-0) may also be of benefit. Soil amendments using superior or hypnum peat may substantially improve growth (for any unit area of row length, add approximately 1/3 by volume peat). Well-composted manure may also be worked into the rows.

Prior to transplanting, the use of a non-residual herbicide such as glyphosate, will eliminate perennial weed infestations. Two years may be necessary for adequate control of perennial weeds. A green manure crop could be grown for 2 years prior to orchard establishment. It is important to eliminate all perennial weeds because young saskatoon plants do not compete well. Treflan may be used as a pre-plant treatment from 3 weeks to immediately prior to transplanting.

The entire orchard site could be sown with a grass cover such as sheep's fescue. Prior to transplanting, an application of Banvel and 2,4-D at recommended rates will destroy most broadleafed weeds. Subsequently, the fescue can be killed in 60 cm wide strips on 6 m centres using glyphosate plus a surfactant. The entire orchard site would then be mowed, and mulch lain on the 60 cm wide strips of killed fescue, prior to transplanting.

Design & Establishment Of Orchard Shelterbelts

Wind Damage

Protection from the prevailing winds is important. Strong or persistent winds can cause substantial water loss from soil evaporation, increased leaf transpiration, reduced photosynthetic activity, and desiccation of the plant, especially during the winter. Cold winds decrease the heat available for plant growth. Wind can cause physical or mechanical damage through abrasion and tearing, which may result in the breakage of branches, tearing of leaves, loss of shoots, buds, flowers and fruit, and damage to the fruit surface. Such damage acts as a natural form of pruning and results in reduced bush size and an atypical form. Additionally, leafing out and flowering can be negatively affected on the windward side of bushes; both can be delayed and the amount of bloom can be reduced. Wind can interfere with insect movement, therefore causing a lack of pollination. Exposure to wind may also reduce fruit size, and can cause the fruit to adhere more tightly to the pedicel (fruit stalk), therefore making the fruit more difficult to harvest. Wind can also cause soil erosion, unpleasant working conditions, and make chemical application inefficient and hazardous because of spray drift.

A shelterbelt, or windbreak, is

considered necessary for optimal growth and production of saskatoons. Windbreaks reduce surface wind speed, increase the air temperature within the orchard during the day, reduce soil moisture loss and evapotranspiration, help trap snow and maintain the snow cover (thus helping to increase potential soil moisture reserves), and decrease soil erosion. Windbreaks allow for better pollination and may serve to partially screen the orchard from airborne fungal spores. Windbreaks improve growth and yield, enhance early maturity, and result in better quality fruit.

Guidelines For The Establishment Of Shelterbelts

Protection from the wind can take the form of planted windbreaks, or the installation of a synthetic wind fence; a synthetic wind fence must be at least 3 m in height to have any significant effect. The exception is when fruit plants are small. During the first 2 or 3 years of orchard establishment, intercropping with barley, rye or a similar crop will provide acceptable wind protection.

Shelterbelts should be situated on the north, west and south sides of the orchard so as to reduce the effects of the prevailing winds in both summer and winter. Shelterbelts should extend 10-15 m beyond the area to be protected. The porosity and height of the shelterbelt determine the protective effect. A shelterbelt will provide protection upwind for a distance 2 to 5 times its height, and downwind for a distance up to 30 times its height. A 3 m high shelterbelt will reduce wind velocity for up to 15m upwind and 90 m downwind; a 9 m high shelterbelt reduces wind speed for 45 m upwind and 270 m downwind. Synthetic windbreaks should have a porosity of about 40 to 60%. Planted shelterbelts provide the best wind protection.

Shelterbelts should be planted 1 to 2 years earlier than fruit trees and there should be a distance of 10 to 15 meters from the shelterbelt to the first orchard row. Shelterbelt rows should be spaced at a distance 10 times that of the shelterbelt’s height. Trees that are not too dense (about 50% permeable) are desirable for air circulation. Weeds must be controlled. Shelterbelts are best fertilized and irrigated in early years to increase their rate of growth. Natural shelterbelts can be single, double, or even multirowed, and can be utilized for fruit, firewood, or thatching material, depending on the species used. The distance between shelterbelt plants depends on the plant species rate of growth and soil fertility; the position of plants in double or multiple rows should be alternated.

Corn or sunflowers are useful for initial short-term protection. Fast growing deciduous trees such as caragana, lilac, laurel willow, sharp-leaf willow, and Siberian elm are good choices for shelterbelts. However, evergreens such as spruce or pine will provide the best long-term protection.

Row Orientation And Plant Spacing For Saskatoon Orchards

Plant primarily with air drainage in mind. North-south rows will maximize the penetration of light into the plant canopy, whereas east-west rows will maximize air flow. Rows should begin about 10 to 15 m from the shelterbelt.

Between-row spacing must be adequate to allow passage of equipment for tillage, pest control and harvesting of the mature crop. In general, rows should be at least 1 to 2 m wider than the equipment available. Between-row spacings for U-Pick operations can be as narrow as 3.5 to 4 m. Over-the-row, self-propelled harvesters require a minimum 5 m spacing, while pull-type harvesters require about a 6 m spacing between rows.

Within-row spacing is limited primarily by the provision of sufficient space for growth, and airflow through the plant canopy, and secondarily by soil fertility and the availability of moisture. A suitable distance between fruit plants is required for proper development and maximum yield. A decreased within-row spacing will require increased management as crop develops. It is suggested that spacing between plants be 1 to 1.5 m, although some growers have been planting using a spacing of 30 to 60 cm between plants. A between-plant spacing of 1 m and a between-row spacing of 4.5 m requires about 2,400 plants per hectare; the exact number of plants varies with the dimensions of the area planted.

To estimate the number of plants per hectare, multiply the between-row spacing (in meters) by the between-plant spacing (in meters); divide 10,000 by this number. To estimate the number of plants per acre, repeat the above calculation using yards as the unit of measure, and divide 4047 by this number.

Wider between-row and within-row spacings provide for better orchard ventilation and therefore help reduce the risk of disease problems. Smaller within-row spacings increase early yields and returns, but will require pruning earlier. For the period 3 to 6 years following orchard establishment, a within-row spacing of 0.5 m yields over twice as much fruit as a within row spacing of 1 m.

If a U-pick operation is to be established, 90 - 120 m long rows are the maximum suggested length.

Transplanting Saskatoons

Survival, establishment, growth, and early yield of young saskatoon plants vary with site quality, local climate, site preparation, transplant quality, method of transplanting, post-transplanting care, and site maintenance. The following information is derived from published scientific literature on woody plant and small fruit crop management, in addition to the limited published material available for the saskatoon.

Plant Material

Healthy plants 20 to 60 cm tall should be used. The plants should be straight from rootstock to tip, free of damage, with the branches intact, and preferably still dormant. A well-developed root mass is essential. The roots should be fibrous, and not dry. Plants having tightly-wound roots should not be purchased. Such plants will never develop a wide-spreading root system, will grow slowly, and may eventually decline in vigour and die. It is important to keep plants cool and moist (but not wet) upon purchase. Root and plant dehydration can restrict normal growth and activity for several seasons. Roots may be covered with damp sawdust or peat, or placed in polyethylene bags, and must not be allowed to dry out. Plants should be protected from excessive sun, wind, and/or frost before planting.

Hardening-off Transplants

Although it is best to obtain dormant plant material, most propagators supply non-dormant plants. Consequently, before transplanting newly-propagated plant material, hardening-off, or acclimatization to field conditions is necessary. Transplants must be hardened-off so that they can better withstand the move from the sheltered greenhouse or nursery environment to harsher field conditions, which may be warmer, colder, and/or drier. Hardening-off is a process of tempering whereby plants are gradually exposed to more sun and heat, and/or lower temperatures, to wind, and to moisture stress. This process of controlled stress reduces the rate of transpiration and photosynthesis, causes plant tissue to become more dense (therefore containing less water), and encourages food storage in plant tissues because growth is slowed. The initial stages may involve some wilting, but plants should recuperate at night (as long as the central stem and growing tips remain green and firm, the plants are not being harmed). Hardened-off plants are better able to cope with subsequent droughts and are more productive under dry conditions. Hardening-off should be initiated 2 weeks prior to transplanting. Hardening-off should not be overly excessive, otherwise plant growth will be affected for the rest of the growing season.

Timing Of Transplanting

A study currently underway at the University of Saskatchewan indicates that early-season planting dates result in increased transplant survival compared with planting dates later in the season. There is a greater risk of poor transplant survival if planting occurs after the end of June. The survival data indicate that July and August plantings should be avoided. Fall planting appears to have variable results. In general, it’s important to avoid transplanting just before or during a time of environmental stress, such as during hot, dry periods, or when there is a substantial risk of frost.

Planting in the spring while the plants are still dormant will decrease the danger of plants drying out because the soil is cool and moist; slow evaporation of water from the soil, and slow growth will allow for good initial establishment. Early planting also helps to increase root growth. In fruit crops such as apples, new roots form when soil temperatures reach 7ºC; existing roots will grow at even lower temperatures. The most active periods of root growth are in early-spring and late-summer. Consequently, transplanting may be done when soil temperatures reach 5ºC. The use of dormant plants allows for a full cycle of plant growth, and therefore maximal root and shoot growth, which is not the case if non-dormant plants are used.

Fall transplanting will allow some root growth will occur. At this time of the year water loss from the plant is minimal, and dormancy is naturally imposed by winter. There is generally a lower risk of moisture stress at this time of the year, and the roots will grow at a significant rate until the soil temperature drops below 5ºC. However, an excessively wet or dry fall, followed by a cold winter may result in a large percentage of loss. Excessively wet fall weather inhibits the development of adequate winter hardiness and may lead to root damage because of the depletion of soil oxygen. Excessively dry fall weather causes damage from plant desiccation.

Placement Of Plants In The Soil

Plants may be placed into furrows, trenches or holes in the soil using a variety of equipment. Planting holes must be large enough to easily accommodate the root mass. The use of an auger or similar implement can glaze the walls of a hole, thus inhibiting water drainage, root penetration, and the transfer of water. Trenches in heavy clay soil may be susceptible to poor water drainage. Plant roots should be disturbed as little as possible and should not be allowed to dry out. When transplanting, plants should be set a little deeper (5 to 7 cm) than they were in the propagation container. If planted too shallowly, frost heaving will push the plants out of the ground. Subsequently, once the rooting medium becomes exposed, the plants will dry out very quickly. The soil can then be firmed around the roots to remove pockets of air. However, growers must be careful not to transplant too deeply. Research on deep-planted maple and oak seedlings has indicated a decrease in survival and caliper growth (increase in stem diameter) and an increase in susceptibility to winter injury, compared to seedlings that were planted with the root collar at the soil surface. Deep-planting may also lead to girdling (strangulation) of the stem by roots. Girdling roots and soil compaction around stems decreases annual growth in caliper, and consequently decreases the flow of water, nutrients and growth regulators within the plant, leading to a decrease in vigour.

Fertilization should not be necessary at the time of transplanting, provided that soil nutrient levels have been adjusted appropriately prior to transplanting. It is widely held that a starter fertilizer high in phosphorus should be added to the soil prior to placing the plant, in the belief that this will stimulate root growth and promote rapid transplant establishment. However, studies have indicated that applications of high P fertilizers do not promote either root or shoot growth in woody plants except where substantial deficiencies exist. Additionally, concentrated fertilizer can burn roots and cause plant death. Excessive soil fertility may actually reduce root development and over-fertilization may cause a spurt of growth that the roots can't support. The addition of compost or well-composted manure may help to increase growth because the increase in organic matter content will improve soil aeration and moisture-holding capacity. Following placement, the plants need to be watered well, and consistently, but not overwatered. Mulching will help reduce moisture loss. Remember that transplants require protection from wind and grazing animals.

Application Of Mulches

The orchard site must be well-prepared by pre-working the soil to a depth of 15 to 20 cm, prior to transplanting. Mulches can be applied immediately following transplanting. Black plastic (2 to 3 mil, UV resistant) or fabric mulches are preferred. Such mulches effectively control weeds, retain soil moisture, and warm the soil earlier in the growing season, thus enhancing growth. Organic mulches tend to keep the soil too cool in the spring, thus having a negative impact on growth, and are labour-intensive to manage. Black plastic or fabric mulches can be applied in conjunction with a trickle irrigation system and fertilization is then done via the irrigation system (fertigation). Plastic and fabric mulches must be applied mechanically; there is a variety of equipment available, some of which will integrate the procedures of transplanting, laying trickle and mulch. The transplants are placed in the ground first, and then pulled through a cross- or X-shaped slit in the plastic or fabric immediately after the mulch is laid.

Pruning Newly-Transplanted Saskatoons

Past practice has dictated that pruning at planting time will improve a transplant's chances of survival and enhance subsequent growth. It is usually thought that such a practice will reduce the transplant's requirements for water because of the reduction in actual and potential leaf area. However, the practice is labor-intensive and actually may have long-term negative effects on plant vigour and growth. Prior to transplanting, plants usually have a smaller root mass than shoot mass, that is, their root to shoot ratio is low. Additionally, the process of transplanting can destroy up to 90% of the effective root mass. Heavy pruning at planting time was thought to increase the root to shoot ratio. However, scientific research published in the last decade suggests that this is not what happens. Studies with apple, pear, peach, linden, and birch, where pruned transplants have been compared to unpruned transplants, have indicated that a minimalist approach to pruning newly-transplanted plants is the best. These studies all have indicated that topping or severe pruning at transplanting is not beneficial to survival, establishment and subsequent growth, and in fact may have substantial negative effects on subsequent root and shoot growth. The additional moisture stress resulting from leaving the shoot intact (that is, not-pruning) is more than compensated for by the additional availability of carbohydrates stored in the shoot, and the capacity to produce carbohydrates by the leaves, both of which are important to root and shoot growth. Additionally, severe pruning of young fruit trees delays the onset of bearing because of delayed growth and consequent lengthening of the period of juvenility.

For the first three years following orchard establishment, pruning should be primarily associated with the maintenance of plant health and the encouragement of vigour and growth. During this period, pruning primarily involves the removal of weak, diseased, damaged and dead shoots. Low, spreading branches should be removed and the centers of shrubs thinned to keep them open and thus allow good air circulation.

Irrigation of Newly-Transplanted Saskatoons

New transplants should be monitored closely and irrigated every 1 to 2 days with small volumes of water, so as to ensure that the root plug does not dry out. It is very important to maintain even soil moisture levels. The root plug of young saskatoon transplants dehydrates at a similar rate to the soil near the top of the root plug, even if soil near the base of the plug is adequately moist. To prevent root damage from dehydration in newly-transplanted saskatoons, the moisture level of the soil near the top of the root plug must be monitored in order to determine if irrigation is necessary.

A Final Word

Although the above may not be the final word on transplanting saskatoons, growers should be aware that some alternative methods of transplanting are being heavily promoted in the absence of well-founded, scientifically-based information and studies. Growers are advised to question the validity of these alternative methods because of the potential for negative effects on orchard establishment and/or increased costs. In determining the merit of any approach, growers should consider the horticultural basis of the method, labour requirements, and the feasibility of the approach relative to increased profitability.

Groundcover Management

Richard G. St-Pierre, Ph.D. (January 2006)

Using Mulches In Saskatoon Orchards

Types Of Mulches

A mulch is any artificial modification of soil surface using organic or inorganic materials. A wide variety of such materials may be used for mulching. These include dried grass, sawdust (spruce or poplar in particular), chopped plant refuse (wood chips, bark, straw), flax shives, waste hay, manures, gravel, polyethylene sheets, and fabric sheets. The most useful materials absorb little moisture, do not pack down or shed water, and allow rainfall to move rapidly downwards.

Effects Of Mulches On The Soil Environment

Conservation Of Soil Moisture

Mulches will help retain soil moisture because they are a barrier to evaporation. Thin layers of organic mulch reduce soil moisture loss by 10%, while thick layers of organic mulch, or plastics, reduce soil moisture loss by 50%. Soil moisture loss is also reduced by the inhibition of weed growth.

Modification Of Soil Temperatures

Mulches will reduce the extreme fluctuations between daytime and nighttime soil temperatures. Mulches may either increase or decrease average soil temperatures, relative to bare soil. Black plastic mulches increase soil temperatures by 2 to 4ºC, and clear plastic mulches increase soil temperatures by 6 to 10ºC. On the other hand, white or reflective mulches decrease soil temperatures by 4 to 6ºC, and organic mulches usually reduce soil temperatures by 2 to 3ºC. Organic mulches also act as insulation, preventing the soil from warming up as quickly as bare soil in the spring, thus delaying root growth, but at the same time slowing developmental events such as flowering.

Weed Control

The use of mulches will help suppress weeds, between plants within the row. Most mulches reduce weed germination and growth, therefore directly controlling weeds. Mulches also help indirectly in weed control by allowing for an increased efficiency of irrigation water and use of fertilizer.

Soil Composition And Structure

Mulches will help to prevent soil erosion, will decrease nutrient leaching, will prevent soil crusting and will enhance soil aeration. Organic mulches add organic matter to the soil, but may up soil nitrogen and therefore can negatively affect plant growth.

Crop Responses To Mulches

Mulching may result in more vigorous plant growth (including root growth), earlier canopy formation, earlier heavy yields, improved stem caliper, the development of uniformly distributed, wide-angled branches, the promotion of shallower, more fibrous root systems, and the promotion of suckering.

The use of mulches may also result in increased yields because of more favourable soil moisture levels and temperature, improved crop quality because of more uniform crop development, larger fruit because of less moisture stress, and earlier maturity because of an increased rate of crop development.

Disadvantages Of Mulches

The main disadvantages of mulches include the initial expense of the materials, and the costs of application, removal and disposal. Mechanical application of plastic mulches is usually necessary, as is the ability to fertigate (apply fertilizer through the irrigation system).

Organic mulches can be difficult to obtain in large quantities and their application is laborious. Organic mulches create a damper, cooler soil environment and therefore result in reduced plant growth. The use of organic mulches on heavier soils appears to be correlated with heavier infestations of the woolly elm aphid. The introduction of weed seeds is another possible side effect of the use of organic mulches.

Which Type Of Mulch Is Best?

Black plastic mulches appear to be the best compromise in terms of cost, ease of management, effects on soil environment and crop response. Black plastic mulches on average increase soil temperatures while reducing weed growth. In comparison to organic mulches, black plastic mulches result in greater fruit plant growth and earlier fruiting. Woven plastic mulches are permeable and stronger than a simple plastic mulch, but are substantially more expensive. UV-stabilized, polypropylene or polyethylene mulches are recommended. These mulches have a lifespan of 5 to 10 years and come in 460 m long rolls, 1.25 m wide.

Application Of Mulches

Organic mulches should be from 10 to 30 cm in depth. A maximum of 30 cm of mulch should be applied (greater thicknesses may not be economical). However, wood chip mulches greater than a depth of 10 cm may reduce root development. Organic mulches should be kept 20-30 cm from the plant stems to discourage mice. The width of the mulch should be at least 60 cm on both sides of the plants. Organic mulches are probably best removed in fall to prevent rodent problems during the winter.

The orchard site must be well-prepared prior to the application of plastic mulch. Black plastic mulches must be applied in conjunction with a trickle irrigation system and fertilization must be done via the irrigation system (fertigation). Plastic mulch must be applied mechanically. Commercial mulch applicators cost between $1,500 and $2,000. Planting sites must be well prepared by pre-working the soil to a depth of 15 to 20 cm prior to planting. The transplants are placed in the ground first and then pulled through an X-shaped slit in the plastic immediately after the mulch is laid. A 15 cm wire staple will need to be placed near the plant to ensure that the plastic stays in place. Plastic mulches either may have to be removed, or slit open lengthwise after the first 3 or 4 years to allow for suckering.

Alternative Mulches

The use of sand, gravel and pebble mulches may seem peculiar, but in fact, such mulches are well-suited to perennial crops such as fruit trees. In the process of cooling during the night, moisture evaporating from the soil condenses on the lower surfaces of the mulch, instead of being lost to the air. Such mulches also allow the re-radiation of the soil's heat at night, increasing the air temperature around the plants, thus providing some frost protection. However, some experimentation is advised if using sand, gravel or pebble mulches. On some soils, the mixture of these mulches with the soil and water may result in the production of a concrete-like surface.

Another variation of mulching is the use of vertical mulches. These provide water a pathway to the root zone and reduce the area of soil surface that is wet. Narrow trenches (15 cm wide, 30 cm deep) running the length of the orchard rows can be filled with stalks of millet, corn, sunflower, Jerusalem artichoke, or amaranth. The air spaces created by these stalks conduct water quickly down to the root zone where it is less likely to evaporate than when it is spread on the soil surface and infiltrates slowly. Vertical mulches are suitable for use only on a small scale such as in conjunction with a shelterbelt.

Grass Covers For Saskatoon Orchards

A permanent grass cover may be planted in the alleys of an orchard as an alternative to cultivation and may help reduce the use of herbicides. Grass covers are aesthically pleasing, prevent disruption of the root systems of the fruit plants, reduce soil compaction, and generally help reduce orchard maintenance. A grass cover will increase the absorption of rainfall and at the sametime minimize runoff, thus may be important for the control of erosion from wind and water. Grass covers create cooler soil temperatures thus decreasing soil moisture loss. A grass cover will help control some weeds, and enables mechanical harvesting even in wet conditions. Grass covers also may help increase winter hardiness because they will compete with the fruit crop for moisture in early to late-fall.

Grass covers will have to be mowed and may require some irrigation, otherwise they may compete to some extent with the fruit crop, especially on light, sandy soils. Grass covers may also allow increased damage from rodents, especially if they are not mowed sufficiently.

Suitable grasses must not be invasive (weedy, like quack grass), must produce only one seed crop per year, must be hardy and resistant to snow mold, and should form a resilient turf capable of withstanding the use of a mechanical harvester during wet weather. Bunch grasses have a number of desirable characteristics. They are short, relatively drought-tolerant, shade-tolerant, slow-growing, and require little maintenance (2 mowings per season).

Recent trials by the PFRA's Tree Nursery at Indian Head, SK, have evaluated a number of bunch grasses for use as grass covers in orchards. These grasses included Sheep's Fescue (cv Nakiska), Hard Fescue (cv Aurora), Alpine Bluegrass, and Parkland Mix.

Sheep's Fescue is a densely-tufted, low-growing, shade and drought-tolerant, and hardy grass attaining a mature height of 30 to 45 cm if left unmowed. The approximate price is $7 to $8.00 per kilogram. Hard Fescue is a low-growing, shade and drought-tolerant grass with fine leaves. The approximate price for seed of this grass is $5 to $6.00 per kilogram. Alpine Bluegrass is a low, dense grass with high resistance to traffic. It grows well in shade and full sun and is somewhat drought-tolerant, but is hard to establish and expensive (approximately $16 to $17.00 per kilogram of seed). Parkland Mix is comprised of the following mixture of grasses: Sheep's Fescue (20%), Hard Fescue (25%), Alpine Bluegrass (20%) and Canada Bluegrass (30%). This mixture costs approximately $9 to $10.00 per kilogram of seed.

In the trials that the PFRA made, Sheep's Fescue was rated as the best grass cover for orchards. Sheep’s Fescue formed a dense, short groundcover that required little if any mowing or irrigation.

Grass covers may be established in fall or early-spring. Row alleys should be tilled and rotovated, and the grass seed broadcast using a Gandy applicator at a rate of 45 kg per hectare. The alleys may then be lightly harrowed. The depth of seeding is important because buried seeds will not germinate. Grass seed should not be spread closer than 45 to 60 cm to the fruit plants. Once the cover is established, additional seeding may be required to fill in any barespots. Grass covers should be kept mowed at a height of 5 to 10 cm. It is not necessary to establish a grass cover until fruit production begins, if intercropping is desired. However, the cover should be well-established prior to mechanical harvesting.

An alternative method to establishing a grass cover is to sow the entire orchard site with a suitable grass prior to transplanting. Once established, an application of Banvel and 2,4-D at recommended rates will destroy most broadleafed weeds. Subsequently, the grass can be killed in 60 cm wide strips on 6 m centres using glyphosate plus a surfactant. The entire orchard site would then be mowed, and mulch lain on the 60 cm wide strips of killed fescue, prior to transplanting.

Green Manures & Other Cover Crops For Saskatoon Orchards

Most orchards will benefit from some form of cover crop. Cover crops are grown in the alleys between the rows of fruit plants. They may be used prior to orchard establishment to improve soil organic matter levels and to reduce weed populations. They may be established at the same time as the orchard to provide more immediate cash returns. Cover crops may also be established following orchard establishment in order to aid longterm orchard management. A wide variety of cover crops may be planted, including permanent sod covers, green manure cover crops, or alternative food or forage crops. Cover crops are especially advantageous when compost and manures are not available. They are important in areas where orchard soils are susceptible to erosion, where drainage of water is poor, where soil nutrient levels or organic matter content are low, where weeds are a persistent problem, or where moisture conservation is important.

An ideal cover crop will reduce weed levels, improve soil nutrient status and organic matter content, be simple and inexpensive to establish. The primary advantages of using green manures include: a) the maintenance of soil organic matter content; b) the prevention of erosion; c) the suppression of weeds; d) the addition of nitrogen to the soil; e) the reduction of soil temperature and temperature fluctuations; f) an improvement of the physical structure of the soil; g) an increase in water infiltration and a decrease of soil crusting; h) a possible increase in populations of beneficial insects such as predatory mites; i) the enhancement of nutrient retention by a reduction of leaching; and j) the reduction of soil compaction, dust and mud.

Cover crops are especially important on lighter soils. If planted in late-July, cover crops will absorb water & nutrients therefore slowing fruit plant growth. They provide for the protection of fruit plant roots over the winter, and trap snow. If used for site preparation, a cover crop will add organic matter to the orchard site.

However, some cover crops may increase irrigation requirements, require more intensive labour for weed control, may harbour diseases or pest insects, or provide increased cover for rodents. Consquently, the choice of cover crop is important.

Guidelines For Using Green Manures

Cover crops should be planted in mid- to late-July, however, adequate moisture must be available for the germination of the seed. A 45 to 60 cm bare space should be left between the cover crop and the row of fruit plants. The seed should be applied with a drill, or broadcast, and then the orchard alleyways harrowed or dragged to just cover the exposed seed. Some examples of typical seeding rates for white and crimson clover are 22 to 33 kg/ha and for perennial ryegrass, fescues, and bent grasses, 44 to 66 kg/ha.

Leguminous cover crops include pea, mungbean, lentil, fenugreek, various clovers and vetches, birdsfoot trefoil and alfalfa. Fall rye, oats, barley, winter wheat, or a combination of crops may also be used. Fall rye appears to release substances that inhibit weed germination and growth. Other possible cover crops include creeping red fescue, red top, canola, and marigolds.

Cover crops must be incorporated into the soil before the seed matures. Surface, or shallow incorporation will provide an acceptable release of nitrogen with the added benefit of surface trash that will help reduce erosion. Otherwise, the crops may be ploughed and disced; one or more passes with the discer may be required.

Intercropping With Alternative Food Crops

Because perennial fruit crops take a few years to produce their first crops, fruit growers will not receive any immediate returns. Intercrops can be grown between the rows of fruit plants. Intercrops might include certain grains, vegetable (tomato, peppers), or spice (coriander) crops, but may also include quick-growing and early-bearing fruit crops such as strawberry. It is important that intercrops not deplete the soil too much. Intercrops that grow very tall or spread rapidly should not be used (squashes, for example). The timing of fertilization and irrigation should coincide as much as possible with those of the primary fruit crop.

Weed Management In Saskatoon Orchards

Richard G. St-Pierre, Ph.D. (January 2006)

Negative Effects Of Weeds

Weeds are a problem because they compete with fruit plants for water and mineral nutrients, they can make movement on foot or by machines difficult, they can harbour insects, mites and diseases, they retain moisture after rainfall (thereby increasing humidity levels within the orchard, which encourages the growth of fungal diseases), they may increase the risk of frost damage by reducing soil heat absorption during day and re-radiation at night, and they make the orchard appear neglected and reflect on the competence of the grower.

Positive Effects Of Weeds

Weeds can be of some benefit to the grower in that they can act as a mulch, can provide some control of soil erosion, and can be used as a green manure.

Weed Control Prior To Orchard Establishment

It is essential to destroy perennial weeds such as quackgrass and Canada thistle prior to orchard establishment, otherwise subsequent control will be very difficult. Actively growing weeds may be treated with Roundup and the site then cultivated once the weeds have been killed.

Timing Of Weed Control

Knowing weed life cycles and how they reproduce is essential for controlling them. Weeds must be removed before they set seed or spread vegetatively.

Methods Of Weed Control

There are a variety of methods that can be used for weed control, including mechanical methods (heavy mulching, handweeding, mowing, cultivation, burning, use of steam or hot water), chemical methods (herbicides), and biological methods (grazing animals such as geese, cover crops).

The most difficult weeds to control are low-growing perennials. Consistent tilling or mowing is necessary to prevent seed production and to deplete the root reserves of such weeds.

Mechanical Weed Control

Periodic, shallow cultivation in combination with some hand hoeing and/or mowing can be used to control weeds. Deep cultivation and cultivation too close to the plants is not suggested because roots can be damaged and extensive suckering may be promoted. Cultivation for weed control is especially important during the early years of orchard growth, but because newly-planted fruit plants can be easily damaged, extra care is required. Shallow cultivation is the best method for controlling weed growth in row alleyways.

Cultivation makes more water available to fruit plants by killing weeds. Cultivation maintains soil aeration, stimulates the activity of soil organisms, and may destroy some insect pests by exposing pupae to hot sun, or cold temperatures. In wet years, it is best not to cultivate later than mid- to late-summer; subsequent weed growth will help slow fruit plant growth and provide for better winter hardening. However, weeds must not be allowed to grow too large, nor must they be allowed to set seed, otherwise cultivation may be ineffective. Shallow cultivation (5 to 8 cm deep) will not cause damage to the shallow roots of the fruit plants.

Annual weeds must be mowed when their flowers first appear. Mowing is less effective for perennial weed control. Frequent, repeated mowings may be required for 1 to 3 years.

Chemical Weed Control

Five herbicides are registered for use in saskatoon orchards: glyphosate (Roundup); trifluralin (Bonanza 400, Rival 500EC, Treflan EC,); sethoxydim (Poast Ultra); dichlobenil (Casoron 4G); and linuron (Afolan F, Linuron 480, Lorox DF). One herbicide, trifluralin/metribuzin mix (Treflan EC/Sencor 95 DF), is registered for use for saskatoons grown in shelterbelts. A grower may use only legally registered herbicides at the recommended rates on saskatoons.

Herbicide Guidelines

Richard G. St-Pierre, Ph.D. (January 2006)

Overview Of Herbicides Registered For Use In Saskatoon Orchards		
Herbicide	**Registered Use**	**Timing**
Glyphosate (Round Up)	Non-selective control of annual and perennial weeds	Used prior to planting, or as a directed spray away from crop plants, or as a spot application to individual weeds
Sethoxydim (Poast Ultra)	Annual and perennial grasses	Varies with stage of weed development; should not be applied within 30 days of harvest
Dichlobenil (Casoron 4G)	Germinating broadleaf weeds, grasses and shallow-rooted perennials	Applied to established orchards in late-fall (more than 9 months before harvest)
Linuron (Afolan F; Linuron 480; Lorox DF)	Germinating broadleaf weeds	Pre-emergent; applied in early-spring or late-fall to established plantings
Trifluralin (Bonanza 400; Rival; Treflan EC)	Germinating broadleaf weeds and grasses	Pre-plant; applied three weeks to immediately before transplanting in the spring
Trifluralin/Metribuzin (Treflan EC + Sencor Solupak 75 DF)	Broad spectrum - broadleaf weeds and grasses	Pre-plant; applied as a tank mix from three weeks to immediately before transplanting in the spring to saskatoons in shelterbelts

Caution - The following information is solely meant as a guide. Application of all pesticides must be in accordance with the instructions on the product label as prescribed under the Pest Control Products Act. Always refer to label.

Guidelines To The Use Of Casoron

Manufacturer - United Agri Products.

Trade Names - Casoron 4G.

Formulation - Granular herbicide containing 4% dichlobenil.

Weeds Controlled - Germinating broadleaf weeds, grasses, and shallow-rooted perennials. Weeds controlled include annual bluegrass, bindweed, Canada thistle, chickweed, couchgrass, crabgrass, dandelion, foxtail, groundsel, horsetail, knotweed, kochia, lamb's quarters, mustard, pigweed, purslane, shepherd's purse, smartweed, stinkweed, and wild buckwheat.

Timing Of Application - Casoron 4G is registered for saskatoon orchards established for 1 or more years. Apply before freeze-up in late-fall. Application must not be made within 9 months of harvest.

Application Rate & Guidelines - Casoron 4G in granular form is broadcast before freeze-up in late-fall at a rate of 110-175 kg per hectare. Casoron 4G should not be applied within 9 months of harvest. Apply with a granular applicator or spreader.

Points To Note - Dichlobenil is readily absorbed by leaves and roots. The mode of action of dichlobenil is to inhibit germination by disrupting growing points and root tips. Dichlobenil is volatile and must be applied during periods when air temperatures will not exceed 10ºC. Dichlobenil must not be applied to light, sandy soil. This herbicide is relatively expensive but effective and may provide 2 to 3 years of control.

Calculating Amount Of Herbicide Required - Recommended rates are volume or weight per hectare, that is, the entire orchard area. Most herbicides are applied in bands alongside the rows. Consequently, the area where herbicide is to be applied must be calculated as follows:

1) Multiply width of application band (including both sides of row) by row length (both measured in metres), then multiply this by the number or rows.

2) Divide this result by 10,000 (which is the number of sq m per ha).

3) The result is the total application area in hectares.

4) Multiply this figure by the application rate to obtain the total amount of Casoron required.

Guidelines To The Use Of Glyphosate

Manufacturer - Monsanto.

Trade Names - Roundup.

Formulation - Glyphosate, 356 g acid equivalent/L present as an isopropylamine salt.

Registered Use - Control of annual and perennial weeds. Weeds controlled include alfalfa, barnyard grass, blue grass, brome grass, Canada thistle, cattail crabgrass, cotton top, curled dock, dandelion, downy brome, fall panicum, field bindweed, foxtail (giant, green & - yellow), foxtail barley, hemp dogbane, hoary cress, knotweed (Japanese), milkweed (common), persian darnel, Pennsylvania smartweed, prickly lettuce, poison ivy, purple loosestrife, quackgrass, ragweed, redroot pigweed, Russian thistle, shepherd's purse, smooth pigweed, sowthistle (annual & perennial), stinkweed, toad flax, velvet leaf, volunteer barley, volunteer canola, volunteer corn, volunteer flax, volunteer wheat, wild mustard, wild oats, wild tomato, wormwood and yellow nutsedge.

Timing Of Application - Varies depending on weed type and stage of weed development. It is recommended that a preplant application of glyphosate be used to control annual weeds.

Application Rate & Guidelines - Application of glyphosate is restricted to directed sprays; avoid contact with green shoots and leaves of crop plant. Rates vary with target weed. Users must refer to label for specific rates.

Points To Note - Open wounds and fresh pruning cuts facilitate absorption of glyphosate. Extreme care should be taken to avoid contact of spray with such regions. The Roundup label makes no specific reference to the use of this product in saskatoon orchards, however according to Monsanto, glyphosate may be used with a saskatoon orchard when applied as a directed spray away form saskatoon plants. Other glyphosate products are available, however the manufacturers of these products should be contacted prior to use.

Guidelines To The Use Of Linuron

Manufacturers - AgrEvo Canada Inc. (Afolan F); Dupont Canada Inc. (Lorox DF); United Agri Products (Linuron 480).

Trade Names - Trade names for linuron include Afolan F, Linuron 480, and Lorox DF.

Formulation - Afolan F - 480 g/L linuron as a liquid; Linuron 480 - 480 g/L linuron as a liquid; Lorox DF - 50% linuron as a dry flowable solid.

Weeds Controlled - Germinating broadleaf weeds: annual sowthistle, barnyard grass (suppresses), chickweed, crabgrass, green foxtail (suppresses), knotweed, lamb's quarters, purslane, ragweed, redroot pigweed, shepherd's purse, smartweed, stinkweed, and wild buckwheat.

Timing Of Application - Linuron is applied as a pre-emergent herbicide in early-spring or late-fall when saskatoons are dormant. It should be applied only to established plantings at least 1 year old. Linuron should not be applied more than once per season, nor within 50 days of harvest.

Application Rate & Guidelines - Afolan F: 4.2 to 6.3 L/ha in 200 to 400 L water/ha; Linuron 480: 4.2 to 6.3 L/ha in 225 to 326 L water/ha; use lower rate for coarse-textured soil with less than 2% organic matter; Lorox DF - 4 to 6 kg/ha in 225 to 325 L water/ha; use lower rate for coarse-textured soil with less than 2% organic matter. Apply as a directed, basal spray to uniformly cover the soil surface and emerged weeds without contacting the crop foliage. Apply before weeds reach 10 cm in height. Rainfall or sprinkler irrigation is necessary within 10 days of application to incorporate linuron into the germination zone of the soil. Once linuron has been applied, the soil should not be cultivated because this will disrupt the action of the herbicide.

Points To Note - Linuron is absorbed by plant roots and foliage; it acts to disrupt photosynthesis. This herbicide can slightly burn and discolor lower leaves if contacted by the herbicide, but linuron does not appear to affect the plant in any other way. Weed control is best when temperatures are moderate, soil moisture is adequate, and relative humidity is high. Established perennials are not controlled.

Guidelines To The Use Of Sethoxydim

Manufacturer - BASF.

Trade Names - Poast Ultra.

Formulation - 450 g/L sethoxydim.

Weeds Controlled - Annual and perennial grasses including barnyard grass, crabgrass, fall panicum, foxtail (green and yellow), persian darnel, proso millet, volunteer corn, volunteer barley, volunteer wheat, witchgrass, wild oats.

Timing Of Application - Most annual grasses are controlled if Poast Ultra is applied between the 1 and 6 leaf stages. Poast Ultra is most effective on quackgrass when applied between the 1 and 3 leaf stages.

Application Rate & Guidelines - Rates per hectare range from 4.7 - 1.1 litres of concentrate in 100 - 200 litres of water. Users should add Merge® adjuvant at the rate of 1% of the water volume. Poast Ultra may be applied around non-bearing saskatoons at any time but must not be applied within 30 days of harvest in fruit-producing shrubs.

Points To Note - Risk of damage to crop plants is minimal since saskatoons are tolerant of this herbicide. For best coverage, use an 80º to 110º flat fan nozzle, angled forward at 45º. According to the Poast Ultra label, quackgrass growth can be suppressed by applying 0.47 L/ha of concentrate at the 2 - 5 leaf stage and controlled using 1.1 L/ha concentrate at the 1 - 3 leaf stage.

Guidelines To The Use Of Trifluralin

Manufacturers - AgrEvo - Rival 500 EC; Dow AgroSciences Canada Inc. - Treflan EC; United Agri Products - Bonanza 400.

Trade Names - Bonanza 400, Rival, Rival 500 EC, Treflan EC.

Formulation - Bonanza 400 - 400 g/L trifluralin as an emulsifiable concentrate; Rival 500 EC - 500 g/L trifluralin as an emulsifiable concentrate; Treflan EC - 480 g/L trifluralin as an emulsifiable concentrate.

Weeds Controlled - Germinating broadleaf weeds and grasses: barnyard grass, carpetweed, chickweed, crabgrass, green foxtail, knotweed, lamb's quarters, pigweed, purslane, wild oats, yellow foxtail.

Timing Of Application - Trifluralin products can be applied from three weeks to immediately before transplanting in the spring.

Application Rate & Guidelines - Application rates vary with soil texture and organic matter content. Bonanza 400: 2 L/ha for light soils, 2.75 L/ha for medium to heavy soils; Treflan EC and Rival 500 EC: rates vary from 1.7 (light soils) to 2.3 L/ha (medium to heavy soils) for soils with 2 to 6% organic matter, and 2.3 L/ha for soils with 6 to 15% organic matter content. A water volume of 100 L/ha is required. The higher application rates are used on heavier soils.

Points To Note - For effective weed control, trifluralin must be incorporated into the zone where weed seeds germinate (the upper layer of soil). The mode of action of trifluralin is to inhibit seedling development following germination. Trifluralin products must be incorporated into the soil in two directions to a depth of 10 cm. The soil must not be crusted, lumpy or wet. Trifluralin is somewhat volatile and subject to decomposition by sunlight. Members of the mustard family are resistant to trifluralin.

Guidelines To The Use Of Trifluralin/Metribuzin Tank Mix

Manufacturers - Dow AgroSciences Canada Inc. - Treflan EC; Bayer - Sencor Solupak 75 DF.

Trade Names - Treflan EC; Sencor Solupak 75 DF.

Formulation - Treflan EC - 480 g/L trifluralin; Sencor 75 DF - 75% metribuzin (water-dispersible granular herbicide).

Weeds Controlled - Broad spectrum; barnyard grass, carpetweed, chickweed, cow cockle, crabgrass, green foxtail, green smartweed, hemp nettle, knotweed, lady's thumb, lamb's quarters, Persian darnel, pigweed, purslane, Russian thistle, shepherd's purse, stinkweed, wild buckwheat, wild mustard, wild oats, witch grass.

Timing Of Application - Pre-plant. Treflan EC/Sencor 95 DF Tank Mix can be applied from three weeks to immediately before transplanting in the spring.

Application Rate & Guidelines - Mix 5.2 L of Treflan EC and 400 g Sencor 95 DF in 100 - 225 litres of water/ha. Incorporation is the same as for trifluralin products, except this mix should be incorporated to a depth of 7 cm.

Points To Note - It is important to follow the correct sequence when mixing Sencor with Treflan (refer to pesticide label). This mix is not for use on soils with less than 5% organic matter.

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knowledge of the biology and culture of the saskatoon may not be applicable to all locations every year. Additionally, the information that is available often changes over time. Little scientific research has been done on many aspects of the culture and management of saskatoons. Consequently, this publication can only serve as a guide. All actions taken which are based on the information presented in this publication are solely the responsibilities of the readers or users, and the author is not liable for any direct, indirect, incidental, or consequential damages in connection with or arising from the furnishing, performance, or use of this material. Comments on information contained in this publication are welcomed.

Diagnosing Herbicide Damage In Saskatoon Orchards

Richard G. St-Pierre, Ph.D. (January 2006)

Introduction

Drift from the application of herbicides to fields near to the orchard, excessive rates and non-uniform applications, and mistaken applications of herbicides can have substantial negative effects on saskatoon orchards.

The general symptoms of herbicide injury include feathering and cupping of leaves, distorted or abnormal growth, reduced growth, delayed development, yellowing of leaves, loss of flowers or leaves, and dieback of branches and stems.

The severity of herbicide damage is associated with the specific chemical that the plants have been exposed to, the concentration of the herbicide, the amount of drift, and the duration of exposure. The effects of herbicide damage may be temporary and the plants often recover, although this may take one or two years.

Herbicide damage can be difficult to diagnose. Symptoms similar to herbicide damage may result from weather-related disorders, insect pests, diseases, nutritional problems, or damage from other air pollutants.

Glyphosate (Round-Up) Damage

Symptoms

Small leaves, slightly cupped upwards, short internodes; primarily associated with suckers.

Causes

Drift from use of glyphosate in proximity to fruit plants can be absorbed through the slick or porous bark of young stems. Apples, pears and stone fruits are very sensitive to bark absorption. Usually, the plants appear to be able to outgrow this damage and return to a healthy condition in 2 to 4 years.

Glyphosate is normally neutralized by negatively-charged clay particles in the soil. Overly sandy soils with very little organic matter may not sufficiently neutralize glyphosate, with the result that roots may absorb the herbicide. Thick mulches may contain functioning roots and therefore do not necessarily provide protection from exposure.

Control

Avoid the application of glyphosate

in locations near to the orchard on windy days. The use of devices to control drift from sprayers is advisable. All equipment used to apply herbicides must be thoroughly cleaned and flushed after every operation. Water sources that may be contaminated by herbicides must not be used for mixing any pesticide.

2,4-D & Phenoxy Herbicide Damage

Symptoms

Leaves with pronounced, feathery extensions; ends of leaves flattened (Figures 1, 2, 3, and 4). Leaves may have a leathery appearance, with the veins appearing prominent.

Causes

Drift from use of 2,4-D and related phenoxy herbicides in proximity to fruit plants is absorbed through developing leaves and buds. Saskatoon plants appear to be able to outgrow this damage and return to a healthy condition in 2 to 4 years.

Control

Avoid the application of 2,4-D or related herbicides in locations near to the orchard. Herbicides must not be applied on windy days. The use of devices to control drift from sprayers is advisable. Control of such damage may be difficult because drift appears to be able to travel considerable distances. All equipment used to apply herbicides must be thoroughly cleaned and flushed after every operation. Water sources that may be contaminated by herbicides must not be used for mixing any pesticide.

Figure 1. Symptoms of 2,4-D and phenoxy herbicide damage on saskatoon leaves.

Figure 2. Symptoms of 2,4-D and phenoxy herbicide damage on saskatoon leaves.

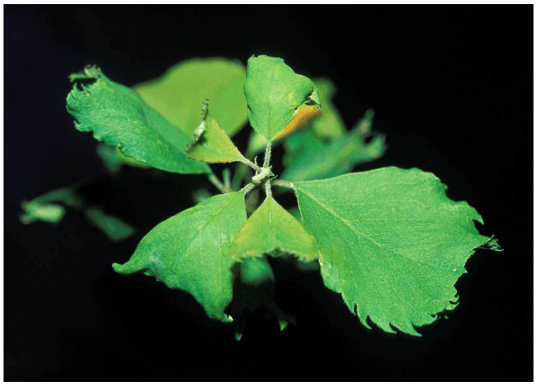

Figure 3. Symptoms of 2,4-D and phenoxy herbicide damage on saskatoon leaves.

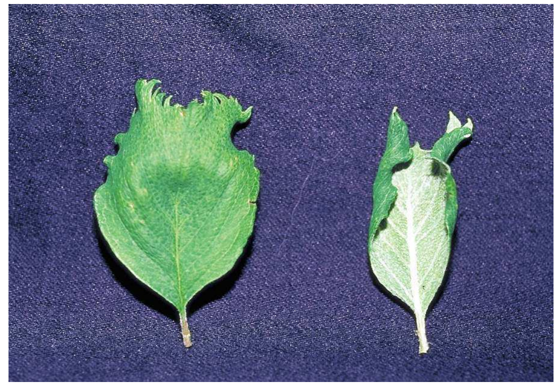

Figure 4. Symptoms of 2,4-D and phenoxy herbicide damage on saskatoon leaves.

Fertilizing Saskatoon Orchards

Richard G. St-Pierre, Ph.D. (December 2005)

General Aspects Of Fertilization

Nutrient Availability In Soils

The availability of soil nutrients to plants is variable because of the complex interactions among a number of factors including soil structure and texture, soil parent material, organic matter content, pH, and drainage. For example, sandy soils low in organic matter content and in regions of high rainfall are usually deficient in nitrogen; the availability of iron decreases in alkaline, calcareous soils; and acidic, sandy, light soils are low in potassium.

The most favourable soil pH is between 6 and 7 where all nutrients are easily absorbed by plant roots. At soil pH levels below 6, phosphorus, potassium, sulphur, calcium and magnesium deficiencies can appear. Lime or dolomite amendments are usually required. At soil pH levels above 7.5, iron, manganese, boron, copper or zinc deficiencies might appear. Sulphur amendments may be required.

Ion-holding capacity is the ability of the soil to store and to supply nutrients. Clay soils have a high ion-holding capacity, and sandy soils have a low ion-holding capacity. Ion-holding capacity is difficult to change, but can be managed.

Soil salinity is determined by local soil characteristics and the amount of rainfall versus evaporation. Saskatchewan soils are generally low in salinity but local effects are possible. Fruit crops have a low tolerance of saline soils. Excessive application of fertilizers and over-irrigation may increase soil salinity.

Soil organic matter is comprised of residues from decayed plants. Soil organic matter increases aeration, moisture and nutrient holding capacity and helps to reduce erosion. Soil organic matter content declines in heavily managed soils and must be replaced with manure or cover crops.

Saskatchewan soils may be considered low in nitrogen and phosphorus relative to the needs of fruit crops. Potassium and sulphur deficiencies may occur in certain areas and on certain soil types. Our soils also have occasional problems with excessive or insufficient calcium or iron.

Past recommendations for fruit orchards on prairie soils generally indicated that minimum soil nutrient levels at 0 to15 cm depth be maintained at 28 to 56 kg N, 56 to 112 kg P, and 336 to 672 kg K per hectare. At a depth of 15 to 30 cm, minimum levels should be 39 to 84 kg N, 90 to 180 kg P, and 560 to 1120 kg K per hectare. Fertile loam soils may not require additional fertilizer.

Amount & Placement Of Fertilizers

Fertilizer should be placed in the root zone for efficient use. Low rates of fertilizers applied often ensure even distribution within the root zone and prevent root damage due to excess salt concentrations. Potassium and phosphorus should be drilled deeply or plowed in so as to be available in the root zone where moisture can be maintained. These nutrients move little from where they are placed. More fertilizer is required for closer rows and plant spacing. Irrigation or rain can result in the leaching of soluble nutrients, especially nitrogen, into deeper areas of soil. Extra nitrogen may be necessary under these circumstances. More fertilizer, especially phosphorus, must be supplied than the crop will utilize. Most soils fix significant quantities of phosphorus which then becomes unavailable to the plant.

Because the crop removes relatively few nutrients from the soil, it is likely that little fertilizer will be required during the first 3 to 4 years when the orchard is becoming established, provided that the minimum recommended soil nutrient levels exist.

Timing Of Fertilizer Applications

Fertilizers often are best applied as split applications early in the growing season. Fertilizers may be applied late in the fall or early in the spring before bud-break, and subsequently following petal fall.

Micronutrients

Micronutrients are not necessary unless a nutrient deficiency is diagnosed. Micronutrient deficiencies are uncommon on prairie soils. Deficiencies often first appear on sandy sites. Copper deficiency problems also may occur on black soils, gray-black transition soils, and organic soils.

Organic Soil Amendments

Organically-derived materials are an important means of soil improvement and maintenance of crop productivity. The practices of tillage and irrigation, harvesting, and high temperatures decrease the quantity of soil organic matter because these factors increase the rate at which decomposition proceeds. Organic matter from local sources is a high quality, low-cost resource for the maintenance of soil fertility.

The presence of soil organic matter may provide a large number of benefits including: a) an increase in the available carbon resulting in increased biological activity of beneficial soil organisms (eg.decomposers); b) an increase in soil water-holding capacity (water-holding capacity increases by about 2.5 cm of water for each percentage increase in organic matter content; c) the suppression of pathogenic organisms; d) the provision of a nutrient reservoir (the decomposition of soil organic matter releases nitrogen, phosphorus and sulphur in particular, retains nutrients in available form for plants by improving the cation exchange capacity; e) the increase in availability of micronutrients (iron, manganese, zinc, copper); f) an increase in soil aggregation, thus improving soil structure; g) an increase in soil porosity, therefore improving water retention, infiltration rate, and soil aeration; and h) a moderation of changes in pH when acid or alkaline substances are added to the soil.

A wide variety of organic amendments include animal manure, compost, and green manures, leguminous cover crops, bacterial inoculants, blood, fish or feather meals, rock phosphate, mined granite, greensand, basalt, feldspar, langbenite and potassium sulphate, kelp and seaweed extracts and powders, dolomite, gypsum, keiserite, langbenite, limestone, oyster, clam, lobster and crab shells. The availability of such materials will, of course, be dependent on where the orchard is located.

Animal manures must be fully composted. Raw manure can cause substantial root burning and may also cause unwanted late-season growth. Pig and poultry manures are high in phosphorus content and may provide a positive growth response, but are hazardous if not well composted. The use of sheep, horse or cow manures may require an additional source of phosphorus.

Nutrient Utilization & Fertilization Practices

Plant growth and development requires 15 nutrient elements. Carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, magnesium, sulphur, and calcium are referred to as the macronutrients. Boron, molybdenum, iron, manganese, copper, and zinc are referred to as micronutrients.

Of all the essential mineral nutrients, nitrogen (N), phosphorus (P), and potassium (K) are the ones used in quantities that may require replacement. Nitrogen is the most common nutrient requirement, but it has been observed that excessive levels of nitrogen occur more frequently in fruit orchards than deficient levels.

Magnesium, manganese and boron are only rarely required. Iron, although present, may not be available to plants on alkaline, or excessively wet soils. Members of the rose family are particularly susceptible to a lack of iron, which is indicated by a yellowing of the foliage (termed iron chlorosis).

Generally speaking, the nutrient requirements of fruit crops change with geographic location, as climate and soil type change.

Adequate levels of nitrogen increase shoot growth, blossom formation, and reduce alternate bearing. Excessive nitrogen levels may delay bloom, decrease hardiness and increase susceptibility to a variety of diseases. Deficiencies of nitrogen are more common on sandy soils, but also may occur on heavy, wet soils.

The storage of nitrogen in the plant at the end of the season is somewhat dependent on late-summer and early-fall temperatures. Warmer temperatures, and late, light frosts allow the plant to reabsorb nitrogen from the leaves before they fall. Early, hard frosts cause leaves to senesce and fall quickly, and therefore the plant isn't able to reabsorb the nitrogen in the leaves.

In fruits such as the apple, phosphorus fertilization improves the growth of seedlings and increases yields at a younger age. Apple seedlings may be fertilized with a soluble fertilizer high in phosphorus (11-55-0 or 10-52-10). Such a fertilizer promotes better root growth, stiffer, thicker stems, thicker leaves, and some branching. New plantings of apples may benefit from an application of water soluble 12-48-8 or 10-52-10.

Generally speaking, nutrient requirements for fruit crops increase as the plant ages and becomes more productive. Fertilization practices for fruit crops vary considerably, but some examples are useful. Recommendations by the Ontario Ministry of Agriculture and Food for apples are 30 to 40 g nitrogen per tree for each year of age, and 50 g of potassium per tree for each 2.5 cm of trunk diameter, annually. Fertilizer recommendations for currants and gooseberries are 5 to 20 g per bush of nitrogen, depending on plantation age and soil type. For highbush blueberries, it is suggested that 14 to 48 g nitrogen be applied per bush per year, again depending on plantation age and soil type. Recommendations for other mineral nutrients are dependent on soil and leaf tissue analyses.

Foliar Fertilization

Foliar fertilization refers to the application of fertilizer sprays to plant leaves. Although foliar sprays appear to have the potential for more efficient fertilization, they are generally not considered to be a replacement or alternative to soil and root health and function, but rather a supplement. As a general rule, the uptake of nutrients in the soil by roots must be maximized in order to obtain the most benefit from foliar sprays.

Foliar sprays may provide for a temporary, rapid response by the plant. Their most effective usage in commercial fruit crops is to alleviate iron chlorosis, to supply boron for increased fruit set, and to supply calcium and phosphorus to alleviate various physiological disorders of the fruit.

Foliar sprays of nitrogen, usually in the form of urea, are not considered adequate to maintain tree vigor unless sufficient nitrogen reserves are available in the soil. Nitrogen sprays applied in late-summer may increase flower bud production and fruit set, but the studies that have been done conflict in their results.

Where iron chlorosis is a problem, a spray of chelated iron may be used 4 weeks following bloom, and 3 weeks later. However, such sprays are considered a temporary measure only. A better method is to make a soil application of Fe-EDDHA chelate, but also to amend the soil pH appropriately with applications of sulphur.

Foliar sprays can be toxic if the concentrations applied are too high. Additionally, fall-applied nitrogen may delay leaf fall and reduce shoot winter hardiness.

Determining Fertilizer Requirements

The determination of the specific nutrient requirements of a fruit crop is complex and inaccurate to a certain extent because of variable responses by the fruit crop. Plant growth and yield is associated with the concentration of mineral nutrients available, but especially the ratio among these nutrients.

Soil tests estimate nutrient availability, pH and salinity. Leaf tests reflect the nutritional status of the plant. What a plant can obtain from the soil is more important than the concentrations of nutrients found in the soil.

Fertilizer requirements are best determined through annual monitoring of soil and leaf tissue analyses for several years, in relationship to records of shoot growth, yield, fruit quality, pest problems and weather.

In general, reduced growth and yield, and visible nutrient deficiency symptoms may be indicative of additional nutrient requirements, or of a nutrient imbalance. Crop foliage should be regularly examined for symptoms of nutrient deficiency or excess.

It is important for growers to monitor new shoot growth, leaf color and luxuriance, and fruit production and size. Unfertilized saskatoon orchards may begin to show a lack of nitrogen after about 3 years of growth, depending on soil type and adequacy of initial site preparation. Pale leaf color and reduced shoot growth are indicators of nitrogen deficiency.

Collecting Samples For Soil Analysis

Soil analysis will indicate the nutrient status of the soil, that is, the potential of the soil to supply nutrients to the plant. Soil samples are analysed for texture, organic matter content, nutrients (N, P, K, S), pH, and salinity. Soil test results will vary from season to season because of varying crop yields and precipitation. Higher yields remove larger quantities of available nutrients. Available nitrogen in particular can change considerably from year to year. On the other hand, potassium and phosphorus levels may not change substantially for several years.

When To Sample

Soil tests should be taken in the fall before soil freeze-up, but prior to any fertilizer application. It is usually safe to sample soil after the beginning of October when soil surface temperature is less than 7^oC, and soil microbial activity has declined. The nutritional status of the soil at this time of year will reflect the crop's demand over the previous few months. This time of sampling will also provide the grower with the time to adequately determine the orchard’s nutrient requirements.

Where To Sample

Soil samples should be collected under bushes in the area that is wetted by the irrigation system. Samples should be collected near to the same plants sampled for leaf tissue analyses. Locations sampled should be marked for future reference.

The samples should be uniform and representative of the orchard. Areas which are visibly different (hill tops, depressions, saline spots, old manure piles or corrals, areas where soil color or crop response differ) should be sampled separately, or avoided if they are not characteristic of the orchard location. At least 15 to 20 samples are required to provide a good mixed sample representative of the orchard. Care must be taken to avoid contamination of the samples with fertilizer, manure, salt, water or dirt.

How To Sample

Clean tools and containers (preferably plastic pails) must be used. Metal pails should not be used if samples are to be tested for micronutrients. Samples can be collected using shovels, trowels or soil sampling probes. A soil sampling probe is best for taking samples to the 45 cm depth and is a worthwhile investment.

Samples should be uniform throughout the sampling depth. If a shovel is used to collect the samples, the samples will be wedge-shaped and therefore must be trimmed to form an even core. The leaf litter must be removed. A small sample is dug to a depth of 15 cm. If salinity is a suspected problem, samples must be collected at 0 to 15 cm, 15 to 30 cm, and 30 to 45 cm. Samples from different soil depths must not be mixed. Samples from 10 to 25 different locations in the orchard should be collected and mixed thoroughly in a pail to provide a good composite sample.

The mixed samples should then be spread on clean paper and air dried, but not heated. The use of a fan, and mixing every few hours will speed up the drying.

Once the sample is dried, it may be sent by mail or bus to the nearest soil testing laboratory. It is important to ensure that the soil testing lab does not group samples from different depths, and that the analysis indicate the specific concentrations of the various mineral nutrients. It would be best not to request specific recommendations for fertilization of a saskatoon orchard because current recommendations are not based on adequate information of the response of saskatoons to fertilization.

Foliar (Leaf Tissue) Analysis

Foliar analysis, or leaf tissue testing, provides an index of a plant's nutritional status. Foliar analysis is the most accurate method of determining which nutrient or nutrients are limiting to the fruit crop, provided that optimum nutrient concentrations are known, and provided that normal, deficient and excessive concentrations have been established. Foliar analysis also is used to diagnose nutrient disorders and to prescribe remedial action.

Nutrient levels within leaves vary substantially from plant to plant, season to season, and with growth stage, part of plant sampled, disease and insect damage, weather conditions, and availability of nutrients in the soil. Optimum soil moisture conditions and well-developed root systems are conducive to high nutrient uptake by the plant. Low moisture levels, cool temperatures, poor soil aeration, or a small root mass are usually reflected by a low nutrient uptake.

Consequently, the timing of sampling and the leaf material sampled are very important. The sampling procedure must be followed carefully for the samples to provide valid results.

How To Sample

Remove leaf samples with a sharp, clean knife (rust-free). The petiole (leaf stem) must remain attached to the leaf. Remove soil particles and other debris with a clean, dry cloth or soft brush. It is preferable not to wash samples. If necessary, wash for less than 1 minute with a mild solution of dish detergent in water, blot the excess water from the leaf sample with a paper towel, and subsequently air dry.

Do not place in an air-tight or damp container. Samples should be placed in paper bags, and kept cool but not frozen. They should be shipped to the testing laboratory as soon as possible.

Plants To Sample

Each sample should be comprised of 50 leaves collected from 5 plants of the same variety, the same age group, and the same vigour. Collect 2 samples for every 2 hectares of orchard. Collect leaves for the 2 samples from plants that are at right angles from one another. Where a problem in the orchard seems to exist, collect samples from 5 to 10 affected plants and 5 to 10 unaffected plants.

Plants that are stressed because of heat or lack of moisture should not be sampled. Plants that have been recently sprayed with foliar fertilizers or pesticides must not be sampled. The use of such sprays in the orchard must be noted.

Tag or mark plants sampled for future reference and testing.

Leaf Material To Sample

Collect the youngest, fully-expanded leaves from the middle third of current year's growth that is growing upward and outward at a 30 to 60 degree angle. Collect 10 leaves per plant; each leaf should be collected from a different shoot, with shoots being randomly selected from all sides of the plant. A sample of 50 leaves will therefore be collected from 5 plants. Dead or damaged leaves should not be collected.

When To Sample

Collect samples in mid-July through August because this is the period when leaf nutrient concentrations are most stable. Better background data will be collected if samples are collected at 2 to 3 week intervals from budbreak to leaf fall. The number of days following bloom should be noted for future reference. Samples should be collected in the morning, but not immediately following a rain.

Nutrient Analyses

The testing lab should analyze for nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), magnesium (Mg), boron (B), iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu).

Typical Leaf Nutrient Concentrations For Saskatoons

Information on leaf nutrient concentrations is necessary to provide standards for the annual comparison and interpretation of leaf tissue (foliar) analyses for any fruit crop. No extensive research has yet been done to develop comprehensive standards of foliar nutrient concentrations for saskatoons, nor is there information available that correlates leaf nutrient concentrations with fertilizer requirements. However, data collected by the Native Fruit Development Program at the University of Saskatchewan has provided values of leaf nutrient concentrations that likely are typical for saskatoon orchards. The table in this factsheet contains averages and ranges of leaf nutrient concentrations derived from data based on a total of 36 leaf samples collected yearly between the last week in July and mid-August, over three years, from 14 different locations in Saskatchewan, Manitoba and Alberta. Samples consisted of a composite of 50 leaves (10 leaves from from each of 5 trees) collected from the mid-portion of the current season's shoot growth. Not all locations were sampled each year.

Leaf nutrient concentrations vary throughout the season for a number of the nutrients. For growers to make valid comparisons of their own leaf tissue analyses to the values presented in the table, leaf samples of saskatoons must be collected during the last week in July through mid-August using the correct sampling procedure as described in the factsheet "Foliar (Leaf Tissue) Analysis For Saskatoon Orchards".

Leaf nutrient concentrations can vary from site to site and from year to year. Site differences can occur due to variations in soil conditions such as levels of fertility, moisture, and pH. Yearly variations can occur due to differences in rainfall. These variations have not been well-documented for saskatoons. However, it has been noted that saskatoon orchards on lighter-textured soils may be susceptible to deficiencies in some micronutrients. Some of the leaf nutrient concentration data collected suggest that the lowest copper and zinc levels were correlated with low soil concentrations of these nutrients.

Large yearly variations in leaf nitrogen concentrations occur according to changes in crop load. This is a common occurrence in apple trees and appears to also occur in saskatoons to some extent. Leaf nitrogen levels during years of heavy fruiting, or 'on' years, tend to be higher than during lighter cropping, or 'off' years. The values presented in the table represent the average of two 'on' years and one 'off' year. Therefore, a grower might expect nutrient values to be slightly lower during 'off' years than the averages presented in the table.

Other leaf nutrients such as phosphorus, potassium, calcium and magnesium also may vary according to crop load, although generally not as dramatically as nitrogen. The maximum value shown here for manganese in saskatoon leaves is somewhat higher than the limit for most fruit crops but still acceptable. However, foliar manganese concentrations 2-3 times higher than this have been reported for saskatoons without noticeable signs of toxicity.

Typical leaf nutrient concentrations commonly differ slightly among cultivars of apples and other tree fruits, however, this has not yet been studied in saskatoons.

The values provided can be used as a general guideline, however more extensive research is required to determine the optimum ranges of leaf nutrient concentrations and critical values of nutrient deficiency and toxicity for saskatoons.

Suggested Fertilization Practices For Saskatoons

Fertilization is an inexact science for fruit crops such as the saskatoon whose nutrient requirements are unknown. It is certain however, that fruit production utilizes soil nutrients and that these must eventually be replaced.

Proper use of fertilizers is important to reducing costs, to growing healthy plants, and to minimizing the ecological impact of fertilizers on water bodies. An excess of fertilizer can result in problems as serious as a deficiency, and is an unnecessary expense.

Although a wide variety of fertilization practices have been suggested for saskatoons in the past, it isn't known how effective or generally applicable these practices are. Scientific studies of mineral nutrient utilization by saskatoons have not been made. In light of the lack of knowledge regarding specific fertilization practices for saskatoons, how should a grower look after the nutritional requirements of their saskatoon crop? There is no simple solution. The following is considered a reasonable approach to creating a solid information base on which a grower can make fertilization management decisions.

If adequate attention has been paid to site preparation in regards to site selection, soil fertility, and organic matter content, there should be a sufficient supply of nutrients to sustain the orchard for the first few years.

It is likely best to ensure that the orchard's soil meets the minimum fertility requirements recommended for orchards on prairie soils, prior to planting. Past recommendations for fruit orchards on prairie soils generally indicated that minimum soil nutrient levels at 0 to15 cm depth be maintained at 28 to 56 kg N, 56 to 112 kg P, and 336 to 672 kg K per hectare. At a depth of 15 to 30 cm, minimum levels should be 39 to 84 kg N, 90 to 180 kg P, and 560 to 1120 kg K per hectare. Fertile loam soils may not require additional fertilizer. Ideally, soil salinity levels should be less than 1 mS/cm.

On coarse-textured, infertile soils, a solution of 10-52-10, 11-55-0 or 20-20-20 may be required for better establishment and initial growth. Caution should be used when fertilizing young plants.

The nutrient status of the orchard's soil and plant leaf tissue, appropriately sampled, must be annually monitored. Consistent, clear, yearly records of shoot growth, yield, fruit quality, pest problems, and weather should be kept.

Fertilizer should be applied based primarily on changes in soil and leaf tissue nutrient status, and secondarily, on changes in crop performance, relative to the minimum soil fertility requirements. Soil testing laboratories will suggest appropriate formulations and amounts of fertilizer to make up for nutrient loss. It is generally considered that fertilization should replace what nutrients are lost from the harvest of a fruit crop. Fertilizer will have to be applied if visible nutrient deficiency symptoms appear.

If required, fertilizers should be applied as a split application in May (prior to bud break) and in early-June (shortly following petal fall).

It is best not to fertilize on a prophylactic basis without there being a defined need for fertilizer. Over-fertilization with nitrogen in particular may decrease plant resistance to diseases and insect pests, reduce the ability of the plants to harden-off properly for winter, and promotes vegetative growth at the expense of flower bud production. It is best not to fertilize after harvest prior to leaf fall because high levels of soil fertility delay the development of winter hardiness.

Typical Leaf Nutrient Concentrations For Saskatoon Leaves Collected From Late-July Through Mid-August

Nutrient	Average Concentration	Typical Range Of Concentrations
Nitrogen (%)*	2.48	2.05 - 2.90
Phosphorus (%)*	0.18	0.13 - 0.28
Potassium (%)*	1.16	0.75 - 1.73
Sulphur (%)*	0.15	0.12 - 0.22
Calcium (%)*	1.54	1.03 - 2.30
Magnesium (%)*	0.52	0.30 - 0.92
Iron (ppm)*	105	47 - 172
Boron (ppm)*	28	16 - 44
Zinc (ppm)*	17	10 - 34
Copper (ppm)*	7	4 - 12
Manganese (ppm)*	130	43 - 289

[a] Samples consisted of a composite of 50 leaves (10 leaves from from each of 5 trees) collected from the mid-portion of the current season's shoot growth. Averages and ranges were derived from data based on a total of 36 leaf samples collected yearly between the last week in July and mid-August, over three years, from 14 different locations in Saskatchewan, Manitoba and Alberta.

* % = % dry weight
ppm = parts per million

educational resource for individuals who are interested in growing saskatoons, in orchards, shelterbelts, or gardens. Every effort has been made to ensure the accuracy and effectiveness of the information in this publication. However, the author makes no guarantee, express or implied, as to the information and procedures contained herein. The information cannot be guaranteed because knowledge of the biology and culture of the saskatoon may not be applicable to all locations every year. Additionally, the information that is available often changes over time. Little scientific research has been done on many aspects of the culture and management of saskatoons. Consequently, this publication can only serve as a guide. All actions taken which are based on the information presented in this publication are solely the responsibilities of the readers or users, and the author is not liable for any direct, indirect, incidental, or consequential damages in connection with or arising from the furnishing, performance, or use of this material. Comments on information contained in this publication are welcomed.

Diagnosing Nutritional & Soil-related Disorders

Richard G. St-Pierre, Ph.D. (January 2006)

Diagnosing Nutritional & Soil-related Disorders

Saskatchewan soils may be considered low in nitrogen and phosphorus relative to the needs of fruit crops. Deficiencies of nitrogen are more common on sandy soils, but also may occur on heavy, wet soils. Acidic, sandy, light soils may be low in potassium. Our soils also have occasional problems with excessive or insufficient calcium or iron. Iron, although present, may not be available to plants on alkaline, or excessively wet soils. Members of the rose family are particularly susceptible to a lack of iron, which is indicated by a yellowing of the foliage (termed iron chlorosis). Magnesium, manganese and boron are only rarely required. Micronutrient deficiencies are uncommon also. If they occur, such deficiencies often first appear on sandy sites.

The most favourable soil pH is between 6 and 7 where all nutrients are easily absorbed by plant roots. At soil pH levels below 6, phosphorus, potassium, sulfur, calcium and magnesium deficiencies can appear. Lime or dolomite amendments are usually required. At soil pH levels above 7.5, iron, manganese, boron, copper or zinc deficiencies might appear. Sulfur amendments may be required.

It is important for growers to monitor new shoot growth, leaf color and luxuriance, and fruit production and size. Unfertilized saskatoon orchards may begin to show a lack of nitrogen after about 3 years of growth, depending on soil type and adequacy of initial site preparation. Pale leaf color and reduced shoot growth are indicators of nitrogen deficiency.

Symptoms associated with mineral nutrient deficiencies or toxicities are often similar to those produced by disease, insect pests, mechanical injury or climatic conditions. For example, root injury and phosphorus deficiency may cause similar symptoms.

Nutrient deficiencies or toxicities produce symptoms having an even pattern on the plant, either on the oldest plant parts, or the youngest, and on all plants. Insect and disease damage tends to be spotty within and among plants.

Nitrogen, phosphorus, potassium and magnesium deficiencies always first appear on the oldest leaves. Calcium, sulfur, boron, copper and zinc deficiencies start on the youngest, or terminal portions of plants.

Iron, manganese and molybdenum symptoms vary in location, depending on crop species, but often occur first on terminal parts.

Symptoms of toxicity can sometimes appear similar to symptoms of deficiency. The specific symptoms of deficiency or toxicity can vary with crop species. A laboratory analysis of the soil and/or plant tissue is required to confirm a suspected nutritional disorder.

Symptoms characteristic of excess soluble salts in the soil or irrigation water include delayed germination, poor germination, erratic growth of seedlings, lesions of the stem at soil line, seedlings have fallen over, marginal leaf scorch, yellowing of leaves, root discoloration, root dieback, and low survival of transplants.

Iron Chlorosis

Symptoms

The symptoms of iron chlorosis include yellow leaves with prominent, but narrow, green veins. These symptoms are especially noticeable on young leaves, on suckers and on other new succulent growth (Figures 1, 2 & 3). Younger leaves may be entirely bleached. Leaf margins may be necrotic. If serious, iron chlorosis can cause dieback and even death of the entire plant.

Cause

On occasion, the saskatoon can suffer iron chlorosis (also referred to as lime-induced chlorosis). An overly alkaline soil (also referred to as high lime, or more commonly, high pH soils), poor soil aeration or drainage, or irrigation water containing excessive quantities of calcium can make iron unavailable to the plants. This affects the development of chlorophyll causing the characteristic symptoms. The condition must be corrected otherwise it will affect the vigour of the plant.

Control

In general, iron chlorosis is a very difficult problem to solve. Additionally, it may take some time for the effects of any control measures to become noticeable.

It is important to treat the cause of the problem, that is, reduced availability of micronutrients as a result of high soil pH and/or excess calcium, as opposed to the symptoms of leaf chlorosis. Foliar sprays of iron chelate are only of temporary help.

The orchard soil may be acidified using acidic peat or sulfur. Several applications of peat or elemental sulfur (300 to 500 gm/sq m, or 60 to 100 lbs/1000 sq ft) over two or more years may be necessary to correct the problem. Unfortunately, such applications may work only on sandy soils, or where organic matter content is high.

However, decreasing the pH of the orchard's soil will not necessarily solve the problem. Increased soil aeration and the addition of an iron chelate directly to the soil may be required.

Deep cultivation (greater than 12 inches in depth) close to the plants, every 2 years, may be required to adequately aerate the soil. Soil aeration may be further accomplished in the long run by the addition of more organic matter to the orchard soil. This would require cropping the row alleys with a green manure (oats or vetches for example) for several years.

The addition of 70 to 140 g/plant of Sequestren 138 Fe (or some other form of Fe EDDHA) at 7 to 14 day intervals during May and June will add iron chelate to the soil.

Iron chlorosis also may result from combined deficiencies of iron and manganese or zinc.

If iron deficiencies are accompanied by zinc deficiencies, the addition of a 0.1 to 0.3% zinc salt to the orchard soil may be required.

Symptoms of iron deficiency are very similar to symptoms of manganese deficiency, except that the green zone surrounding the leaf veins is wider, and the interveinal areas of the leaf may be necrotic. Consequently, what is diagnosed as an iron deficiency may be a manganese deficiency, or possibly, a moderate deficiency of both nutrients. If the addition of iron, and/or zinc does not reduce the symptoms, a manganese deficiency should be suspected.

Figure 1. Saskatoon suckers exhibiting symptoms of iron chlorosis.

Figure 2. Saskatoon leaves exhibiting symptoms of iron chlorosis.

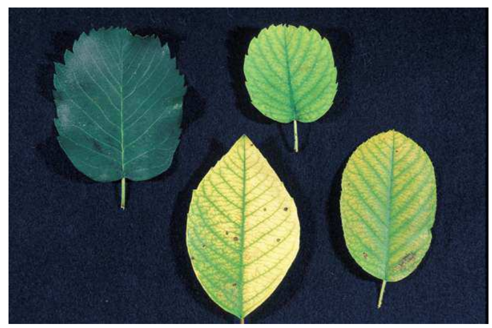

Figure 3. Saskatoon leaves exhibiting different degrees of symptoms of iron chlorosis.

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Irrigating Saskatoon Orchards

Richard G. St-Pierre, Ph.D. (December 2005)

An Introduction To Orchard Water Management

The primary goal of orchard water management is to provide adequate supplies of water to fruit plants with a reasonable investment of time, money and other resources, without creating salinity or waterlogging problems, and without jeopardizing the quality or quantity of the water source. The efficient use of water means using the smallest amount of water to produce the largest harvest in ways that do not cause these problems. Orchard water management includes irrigation, weed control, and drought-avoidance strategies.

Irrigation generally is required for commercial fruit production in Saskatchewan. The Province receives an average of 25-35 cm of water annually, about half of which is considered available to the crop. The water requirements of fruit crops usually are in excess of the water available from precipitation. Soil water reserves are also important to consider. Soil water reserves are based on precipitation received the previous fall, amount of snowfall, amount of snow trapped, and temperatures in late-winter and early-spring during snow melt.

Plant growth, yield and fruit quality are sensitive to water stress. Irrigation is used to increase the total amount of available water, or to adjust the distribution of water to better fit crop requirements. Properly irrigated orchards are less susceptible to cold damage (moist soil stores more heat during the day for release at night). However, weed growth may be stimulated in dry periods by irrigation.

The successful establishment of fruit crops will very largely depend on the supply of water to the young plants during their first two dry seasons. Adequate moisture is essential during the critical stages of leaf expansion, bloom, fruit set and fruit enlargement. When available soil water is reduced, young plants with limited root systems show reduced growth more quickly than do older plants having deeper more extensive root systems. A large, bearing surface and greater yields are the cumulative result of the previous 2 to 5 years of shoot growth and leaf production. Frequent irrigation and shallow or no cultivation encourage roots to grow near the soil surface which is usually more mineral rich. There is a consequent increase in fruit size but too frequent irrigation can decrease flavour and longterm keeping quality.

Most native fruit species, like the saskatoon, will survive under normal moisture conditions without supplemental irrigation, provided that weeds are not allowed to grow. However, irrigation will improve plantation establishment and rapid growth, appears essential for production at an earlier age, and may be required to maximize fruit yield, depending on natural rainfall. The critical periods for shoot growth, fruit growth and bud development for the following year occur from about mid-May through late-July.

Problems With Over-Irrigation Or Excessive Soil Moisture

Excess water can result in root damage from poor soil aeration and may prevent the uptake of mineral nutrients and water; young plants are especially susceptible to root rot. Proper irrigation is essential for nutrient utilization; excessive irrigation will leach nutrients below root systems and may contribute to pollution of ground water sources. Over-irrigating may increase the incidence of disease, and also may delay the development of winter hardiness, thus increasing the probability of winter damage. Excessive water may reduce yield and contributes to insipid fruit flavour and fruit cracking. Over-irrigation may also leach herbicides below the zone of germinating weed seeds. Ultimately, over-irrigation wastes a grower’s time and money.

Strategies To Conserve Water & Minimize Moisture Stress

The four primary ways by which water is lost from an orchard, and which may contribute to moisture stress, include runoff, deep percolation below the root zone, evaporation, and excess transpiration. Reducing unnecessary losses will help conserve water and reduce the potential for moisture stress, and make more efficient use of available water.

Strategies to prevent water loss include: a) minimizing runoff; b) maximizing the infiltration of rain or irrigation water into the soil by improving soil structure; c) minimizing the loss of water below the root zone by not overwatering; d) increasing the soils's water-holding ability with organic matter; e) minimizing evaporation and excess transpiration by mulching, close spacing of plants, shading, and windbreaks; f) planting native drought-resistant grasses to maximize water absorption and minimize runoff (these also act as passive, dormant mulches during periods of heat and drought); g) pruning consistently and properly (unchecked, excessive growth uses available soil moisture; h) minimizing loss of irrigation water from storage in reservoirs, tanks or other containers by covering or shading the surface to reduce evaporation; i) minimizing the loss of water during distribution by reducing the number of leaks or low spots, and the amount of time the water is exposed to evaporation and to infiltration before reaching the orchard; and j) improving and maintaining water quality by minimizing salts, toxic substances and organisms that cause plant and human diseases.

Planning An Irrigation System For A Saskatoon Orchard - First Steps

Planning an irrigation system is one of the most important steps in establishing a successful saskatoon orchard. Inadequate water supply, or poor water quality, could mean that a grower’s plans for an orchard are not feasible or in excess of the available water supply. The following information is intended to help growers determine the feasibility of an irrigation project.

An Overview Of Irrigation Requirements And Strategies

It is important to accurately determine the water requirements of the mature orchard prior to planting in order to ensure that the irrigation system can provide enough water during critical periods when rainfall is inadequate. Water consumption in a mature saskatoon orchard is approximately 1acre-foot per season (equivalent to 12 inches of rainfall, or 275,000 gallons of water). The range of water consumption for a mature saskatoon orchard is estimated to vary from less than 225,000 to over 400,000 gallons/ acre/season, depending on amount of rainfall, daily temperatures, soil type, and length of growing season. Growers frequently underestimate the water requirements of their orchard, or assume rainfall will provide all that is required. As a result, reduced transplant survival, slow orchard establishment, and reduced growth and yields often occur. Years with lower than average precipitation could leave growers who don't realistically anticipate their irrigation needs caught without water during critical times such as during fruit development or during the period of flower bud initiation, which is essential to the next season's fruit crop. Water stress during other parts of the season can also lead to diseases such as *Cytospora* canker. Many growers feel that 3 to 5 heavy irrigations per season are adequate for a healthy crop. This strategy would only be effective if consistent and sufficient rainfall occured between irrigations. Trickle irrigation systems in particular are designed to provide a small volume of water on a frequent schedule in order to meet the water requirements of the crop. As a rule, in order to achieve the most favourable conditions for plant growth and yield in a fruit crop, plants should not be subjected to prolonged or severe water stress. However, under certain circumstances it may be beneficial to provide some water stress during specific periods to improve fruit flavour, increase sugar content, or to reduce plant growth.

Steps Required To Develop An Irrigation System

The first step in undertaking an irrigation project is to contact Sask Water. Any irrigation project larger than 2.5 acres requires at least some involvement with Sask Water. During the initial consultation, the grower will be provided with some general information on the irrigation development process, irrigation system options, and available water source(s). Assuming that the project is large enough to require further Sask Water involvement, a Request for Technical Assistance application form will be sent to the grower. For an irrigation project to be feasible, the recharge rate of the water source must exceed the water demands of the crop. With overhead sprinkler irrigation, additional water may be needed to flush the site every second season in order to prevent salt build-up in the soil.

The PFRA should also be contacted

when planning a dugout. Financial assistance may be available to help with construction costs, and the local PFRA office should be able to assist with grant applications. The PFRA will consult with Sask Water on projects that involve dugout construction for irrigation purposes. Considering the water use of saskatoons, it is unlikely that an average-sized dugout could be relied upon to irrigate more than 3 acres of mature bushes. Unless the water recharge rate of the dugout is roughly equivalent to the water used, then a dugout cannot be sustained over the long term.

To qualify for technical assistance from Sask Water, there must be a minimum of 12 acre inches of available water from the potential water source 7 out of every 10 years, and the irrigated area must be at least 2.5 acres. The initial cost for technical assistance is approximately $275.00, which includes the application fee, a water quality test, a preliminary water supply study, a soil assessment, and a site inspection by a representative from Sask Water. During the site inspection, the results of the water supply study and the soil assessment will be discussed with the client. A water sample to be analyzed for quality will be collected during the initial site visit. The quality of the water sample will help determine the suitability of the water source for irrigation purposes. Irrigation system options, including system components and pumping requirements, an overview of irrigation system design, and a preliminary cost estimate, also will be provided during the on-site consultation. Detailed irrigation design plans are included with this initial cost, and will be provided if the client decides to proceed with the project.

Orchards larger than 10 acres in size require an Irrigation Certificate from Sask Water. To obtain an Irrigation Certificate, extensive soil salinity testing is conducted across the site at two soil depths with specialized equipment. As well, numerous soil samples are collected and analyzed for soil texture, electrical conductivity, sodium adsorption ratio, pH, and the concentration of major ions. The data are collated, and detailed elevation and salinity maps are created. These maps are used to classify the site in terms of suitability for irrigation and are used to determine whether an Irrigation Certificate will be granted. The cost of this testing is approximately $1,400.00.

Once all the requirements for the project are met, then a permit for Approval to Construct Works will be provided by the Water Resource Office and construction of the project can begin. Subsequently, to obtain an Approval to Operate permit, the system should meet the minimum engineering design specifications outlined in the preliminary plan.

More information on the irrigation development process can be obtained from Sask Water, Irrigation & Agricultural Serivices Division, 410 Saskatchewan Avenue West, Box 1000, Outlook, SK, S0L 2N0; Phone (306) 867-5500; Fax (306) 867-9868.

Water Salinity Guidelines For Saskatoon Orchards

A knowledge of water quality is important to proper water management. Water quality tests should include measures of electrical conductivity (EC), pH, iron, sulfides, and total dissolved solids (TDS). Surface water should be rated in terms of colour and particulate matter in suspension. Water quality is associated with organic and inorganic materials suspended or dissolved in the water, and the presence of algae and/or bacteria.

Two-thirds of the groundwater in Saskatchewan has sodium or salinity levels greater than recommended for use. Adequate testing of water quality is essential prior to any commitment to irrigation.

Measuring Water Salinity

The symptoms of excessive salinity may first be noticed on young plants where growth and survival may be substantially reduced. Symptoms on older plants include drying or `burning' of leaves beginning at the leaf tips and moving along edges. The leaves also may abscise prematurely. Salt injury may be reduced by irrigating more frequently, and by irrigating when conditions are least conducive to evaporation (in the early morning, for example).

The amount of salt leaving the root zone through drainage should equal the amount brought in through irrigation and rainfall. To prevent salt buildup, it is important that there be enough extra water applied at regular intervals to wash out the salt, and adequate drainage to carry water away from the root zone. With an increase in soil salinity, plant roots extract water less easily from the soil solution. This situation is more critical under hot and dry conditions. A high soil salinity can also result in toxic concentrations of ions because they can accumulate in leaves. This is especially true of chloride ions.

Levels of salinity are usually expressed in terms of the ability of water to conduct electricity (electrical conductivity; EC). The better water conducts electricity, the saltier it is, and the more that crop production will be reduced. Conductivity is measured by special instruments in units of millimhos/centimeter (mmhos/cm), or deciSiemens/meter (dS/m); 1 dS/m = 1 mmhos/cm (equivalent to 640 ppm salt).

Salt content can also be expressed in terms of milligrams of dissolved solids per liter of water (simply measured by completely evaporating a liter of water in a container protected from dust); the result is a measure of total dissolved solids (TDS) in milligrams per liter of water, and expressed as parts per million (ppm). A TDS of 0 - 500 ppm is acceptable for all crops. Water with a TDS of greater than 500 ppm may present a clogging hazard, especially if drip irrigation is used. Water with a TDS of 800-1000 ppm can cause salt burn symptoms if overhead sprinkler irrigation is applied infrequently for long periods. Water sources with a TDS of greater than 800 ppm should be considered unsuitable for irrigation.

Irrigation Requirements Of Saskatoons

When irrigating a saskatoon orchard, a grower may ask a number of questions. Why irrigate at all? How frequently should irrigation be applied? How much water is ideal? The goal of using irrigation should be to achieve a balance among total yield, fruit quality, and year-to-year reliability of the crop. Irrigating properly will help maximize an orchard's profit over the long term.

Factors Affecting Water Use

The water requirements of saskatoons vary with plant age, row spacing, soil type, soil texture, and climatic conditions such as temperature, daylength, relative humidity, and wind. The type of irrigation system used also will have an impact on how water is applied to an orchard. The scheduling of irrigation in an orchard irrigated by overhead sprinklers is different than with a trickle irrigation system. These differences are inherent in the system's design since the water application rate for each system is quite different. Trickle irrigation systems are designed to frequently provide small volumes of water to a limited amount of soil. Sprinkler systems deposit water to the entire area occupied by the crop on a more intermittent schedule, where the soil is allowed to dry out more between each irrigation cycle.

Soil texture has an impact on water-holding capacity and availability of water. Water drains quickly from sandy (course) textured soils, which is good for aeration, but the water-holding capacity is low and water stress can occur rapidly. Course soils require more frequent irrigation scheduling than other soil textures. Heavy clay (fine) textured soils have a high water-holding capacity but also have greater amounts of hygroscopic water. These characteristics make it difficult to maintain a balance between waterlogging and too dry a soil. Clay soils should never be allowed to dry out since large cracks can form in the soil structure and these can damage crop plant root systems. Loam (medium) textured soils drain reasonably quickly, have a high water-holding capacity, and a large amount of available water, making it relatively easy to manage the soil water balance.

Rooting depth is also a major factor in determining the need for irrigation. A restricted rooting depth increases the need for irrigation.

The wet zone created underneath a trickle emitter is relatively small when compared to the entire soil surface that is wetted by sprinkler irrigation systems. For trickle-irrigated crops, it is more effective to have the majority of the root system in the volume of soil wetted by the trickle emitters. Plants grown on well-drained, sandy soils may have feeder roots extending 2 m or more into the soil. However, these roots won't help the plant when the soil becomes very dry, if most of the root system is outside of the soil volume wetted by the trickle emitters.

Orchards consume and lose water daily. This consumption and loss consists of water used by the fruit plants (transpiration), and water evaporated from the soil surface (evaporation). During hot, dry summer days in Saskatchewan, peak evapotransporation rates vary between 5.6 and 7.1 mm (0.22 - 0.28 inches) per day.

To keep pace with this loss, a trickle irrigation system should be designed to provide approximately 40 - 70 litres per minute per hectare (5 - 7 US gallons per minute per acre), otherwise there will not be enough hours in the day to keep up with water use during periods of peak demand.

Growers often comment that they start their trickle irrigation when the fruit crop starts to develop but the system can't seem to keep up with water demands. This is because the system was not designed to apply water on an intermittent schedule. Typical trickle irrigation scheduling requires that irrigation be applied to maintain soil moisture around 75% of field capacity. If the soil is allowed to dry out much beyond this point, and crop water use increases, then it may be impossible for a trickle system to meet the water demands of the orchard.

One study looking at water use in saskatoon orchards found that saskatoon plants growing in an orchard environment use significant amounts of water from the row alleys outside the wet zone of the trickle irrigation system. The same study also showed that under certain conditions it may be difficult for the irrigation system to keep up with the water demands of the plants. Once soil reserves are low and summer heat intensifies, it's often impossible to replace the water needed to maintain a good moisture reserve. For this reason it was recommended that irrigation begin before inter-row areas dry out. These observation and conclusions are not surprising considering the design parameters of trickle irrigation systems.

In order to achieve optimal conditions for growth and yield in a fruit crop, plants should not be subjected to prolonged or severe water stress. It may be beneficial to create a slight water stress during specific periods to increase fruit sugar content, thereby improving fruit flavour, or to reduce plant growth.

Young plants are particularly vulnerable due to their small and shallow root systems. Water stress can severely affect root growth and survival in young plants. Attempting very long irrigation periods with a trickle irrigation system on an intermittent schedule will increase the risk of waterlogged soil conditions and could cause significant root damage.

Rainfall, high relative humidity, low air temperature, and light winds all reduce the amount of irrigation required. Although trickle irrigation systems are intended to operate more frequently than other types of irrigation, it is possible to provide too much water to the crop, especially in fine textured soils. Excessive moisture, especially early in the season, may cause waterlogged conditions and limit soil aeration, thus preventing normal root growth. Water-logged soil, especially early in the season, can kill fruit plants. Excessive moisture will encourage root-rot organisms, and excessive moisture in any soil, but particularly in sandy soils, will leach out nutrients.

Irrigation Guidelines For Saskatoon Orchards

Research has shown that a mature saskatoon orchard will use approximately 250 - 350 mm (10 - 14 inches) of water per season, depending on environmental conditions.

Newly-established saskatoon bushes require only small volumes of water, but should never be allowed to dry out. During the first year, plants generally require about 1 - 2 litres (0.25 - 0.50 US gallons) of water per plant per day during warm dry weather. Water use in the orchard will increase yearly in proportion to plant size. In the absence of rainfall, 16 - 24 litres (4 - 6 US gallons) of water per plant per day will be required in a mature orchard. Trickle irrigation systems are designed to provide small volumes of water on a frequent schedule, typically every 1 to 3 days in the absence of adequate rainfall. These amounts may be met by rainfall but it is important to monitor soil moisture so that plants are not stressed.

Electronic soil moisture senors and tensiometers provide the most accurate guide to water requirements in a trickle-irrigated orchard. It is best to maintain soil moisture levels between 20 and 30 centibars in medium- textured soils, and between 40 and 50 centibars in fine-textured soils. Soil moisture levels in sandy (course) textured soil should be maintained in the 15 - 20 centibar range. In course soils, tensiometers capable of measuring low water tension must be used. Electronic soil moisture sensors such as Watermark™ sensors are not accurate in the soil moisture range needed for course soils.

The use of soil moisture sensors or tensionmeters will allow growers to adjust more easily to differing soil types and amounts of rainfall.

Growers may reduce irrigation during August and September to slow plant growth and to allow proper hardening-off. To accomplish this, it is not necessary to induce significant water stress. When temperatures cool off in September, water use will decline dramatically. However, it is still important to continue irrigating as needed until and following leaf-fall to prevent dehydration over the winter, and perhaps to increase resistance to *Cytospora* canker.

Drip Irrigation - An Overview

Richard G. St-Pierre, Ph.D. (January 2006)
with Illustrations by Hamish Tulloch © 1997

Introduction

Drip irrigation is commonly used to water fruit crops in Saskatchewan and worldwide. The purpose of this guide is to provide an overview of current drip irrigation technology and a basic understanding of system design. In order to determine specific system requirements, a qualified irrigation system designer should be consulted. Note that currently, there are no guidelines relating native fruit production to irrigation rates and timing. Additionally, any reference made to manufacturers is for illustrative purposes only and is not meant as an endorsement.

Drip irrigation is a very efficient method of applying water to an orchard site. Drip systems apply controlled volumes of water directly to the orchard rows, which conserves water (especially in young plantings) and discourages weed growth between rows. Drip irrigation does not interfere with orchard operations such as pruning, harvesting, and spraying, and drip systems are easily automated. However, drip systems do not wet the crop canopy and therefore cannot provide frost protection nor retard blooming time.

Research in other fruit crops has shown that drip-irrigated orchards grow and yield as well as orchards watered by other methods of irrigation. Drip-irrigated orchards require more frequent watering than orchards using other types of irrigation, but soil moisture levels can be kept at near optimal levels.

The initial cost of a drip irrigation system ranges from $1,800 to $3,000 per hectare (not including the cost of equipment used to supply water to the site, or chemical injection equipment). A good quality drip system will last for many years if properly maintained.

It is a good idea to include the irrigation system in the initial planning stages of an orchard project. System components can then be matched to site characteristics. However, a drip system may be installed in virtually any established orchard site.

System Components

A basic drip irrigation system consists of a filter, pressure regulator, and a distribution network (mainline, submain/manifold lines and lateral lines), connected to a pressurized water supply (Figure 1). Collectively, the water supply, pump, filter and pressure regulator are

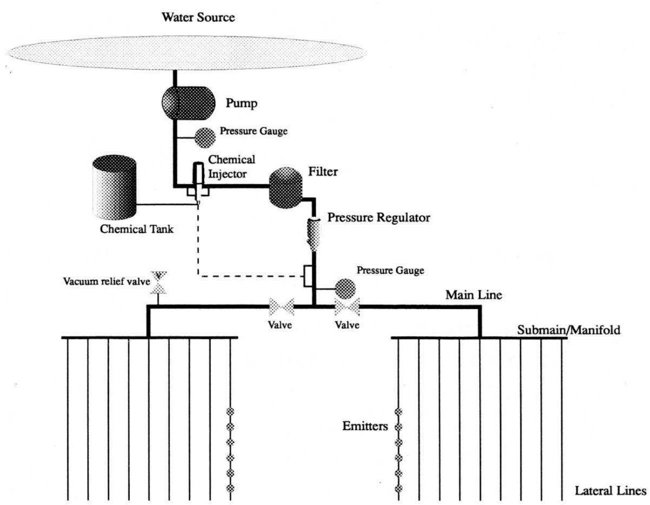


Figure 1. Components of a typical drip irrigation system (H. Tulloch1997)

called the system head. A chemical injector and water pressure gauge(s) may also be incorporated into the system head. Some systems may have more than one chemical injector and chemical injection points may vary. A back-flow prevention device is essential if chemicals are injected into the system. Vacuum relief valves should be installed at all high points in the system to avoid drawback of soil into the emitters when the system is shut off.

Filters

A filter is needed to prevent plugging of the irrigation system and is essential to maintain accurate control over emitter output. Filter requirements are dependent on system size, the type of emitters used, system flow rate and the characteristics of the irrigation water.

Particulate matter can be filtered from the water supply using screen filters. Mesh screen and grooved discs are two common types that are available. Mesh screens may be fabricated from either stainless steel or nylon. Steel screens are stronger but are considered to be more prone to debris buildup and corrosion than nylon screens. Stacks of grooved plastic discs are used in grooved disc filter elements. Disc filters are strong and are better for removing organic material such as algae but may require more frequent back-flushing than screens. Typical filter screens used in drip systems range in pore size from 100-200 mesh. The pore size of the filter is a function of emitter orifice size and system flow requirements. A supplier of drip-irrigation components will be able to determine filter specifications for specific situations.

Centrifugal separators can also be used to remove suspended particles from irrigation water. Unlike screen filters, centrifugal separators remove suspended material from water on the basis of particle density rather than particle size. Only particles that are denser than water can be removed using centrifugal separators. This makes these filters unsuitable for the removal of biological contaminants such as bacteria.

Media filters remove unwanted material from the water supply by forcing water to pass through layered beds of media having varying pore sizes. Inert materials must be used in the media bed. Silica sand and inert gravel are commonly found in media filters.

Activated carbon may also be layered in the media bed, although this is not common in irrigation filters. Media filters are most effective at removing biological material such as bacteria and algae. These filters are much more expensive than screen filters but are usually essential with an open water supply.

Filters should be cleaned and inspected on a regular basis for signs of wear or damage. Holes in the filter screen can result in plugged emitters. Filters should be back-flushed regularly to keep them clean. Some filters are available with self-flushing mechanisms. These may be electronically or hydraulically activated. All hydraulic and some electronic automatic filters back-flush when the pressure differential between the inlet and outlet sides of the filter exceeds a certain level. Other electronic filters back-flush on a timed flushing cycle. Flushing timers are usually used with media filters and centrifugal separators.

Pressure Regulator

The pressure regulator reduces and stabilizes the water pressure to the operating range of the emitters. This is important so that emitter flow rates can be controlled and the volume of water applied to the crop can be predicted.

The Distribution Network

The main line, submains and lateral lines make up the distribution network which carries water to the crop. The size of the main and submain lines vary depending on the slope of the site, size of the irrigation system, the flow rate and number of emitters being operated.

The lateral lines carry water along the orchard rows and deposit water to the crop via emitters. Common types of lateral lines include porous tubing, drip tape and hard wall lateral lines. Porous tubing is relatively expensive and is not commonly used in large scale drip systems. Drip tape is more commonly used to irrigate annual crops but thick-walled drip tape is suitable in some orchard situations. One-half inch (inside diameter) polyethylene tubing is commonly used for hard wall lateral lines. This tubing is very durable and is recommended for long term use.

Head pressure decreases along the length of the lateral lines. This limits the maximum length of the lateral line to the point where there is less than a 10% change in emitter flow rate from the beginning of the lateral line to the end. The actual length of lateral line allowable is determined in the system design process and depends on the inside diameter of the lateral line, system pressure, emitter number and flow rate, and type of emitters used.

Emitter Technology

The purpose of emitters is to accurately regulate the flow of water and to deposit a small volume of water over a long period of time. There is a wide selection of emitters on the market. The required flow rate is dependent on many factors including the type of crop, soil texture, length of lateral line, and water analysis. Emitter spacing depends on crop spacing, soil texture and flow rate of the emitters. Additional devices (flaps, moving parts, elastic baffles) are sometimes incorporated into emitter designs to help regulate flow characteristics.

Hard wall lines are used in combination with some kind of emitter installed either in the line (in-line emitter), or through the wall of the line (on-line emitter). In-line emitters must be installed by the manufacturer and so emitter spacing options are limited. The main benefit of in-line emitters is that they are less likely to leak. On-line emitters can installed on site at any spacing required. One of the challenges of on-line emitter design is to integrate features into an emitter that is not bulky or prone to damage. In-line emitters can be larger and more elaborate than on-line emitters without actually protruding from the line.

There are many approaches used to regulate emitter flow rates. The main concern with emitter design is to maintain accurate flow rate and at the same time be resistant to plugging. Long path emitters force water to travel a long distance to control water flow. Microtube (laminar flow) and spiral path emitters are two examples of long path emitters. Turbulent flow and tortuous path emitters force water to travel a twisted path through the emitter passageways to restrict water flow. In constrast to reducing the orifice size this approach helps to reduce the risk of emitter blockages.

Variations in the slope of an orchard site and long lateral lines can cause significant pressure differentials within irrigation lines. Some emitters are known as pressure-compensating. These emitters maintain a constant water flow even when there are variations in water pressure within the irrigation system (Figure 2). Pressure-compensating emitters can be operated at higher pressure and still maintain a specific flow rate. Lateral lines using pressure-compensating emitters can be longer than lateral lines using regular emitters.

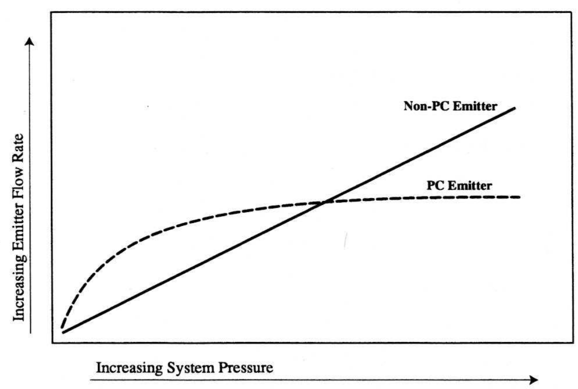


Figure 2. A comparison of the effect of increasing pressure on the flow rate of pressure-compensating (PC) and non-pressure-compensating (non-PC) emitters (H. Tulloch 1997)

Vortex emitters are not as sensitive to pressure changes as many emitter designs, and are less expensive than pressure-compensating emitters. In these emitters, incoming water spins around inside a vortex chamber creating requirements are higher than with turbulent flow emitters.

Drip tape is a form of lateral line where emitters are integrated into the wall of the line. Two common types of drip tape used are bi-wall tubing and turbulent flow emitter tapes. Several manufacturers produce this material. Bi-wall tubing and turbulent flow tapes differ mainly in the methods used to reduce water flow rates from the emitter holes (Figures 3 & 4). There are many variations of these basic drip tape designs. This basic bi-wall design is not used anymore. Modern bi-wall tapes generally integrate turbulent flow technology into the design.

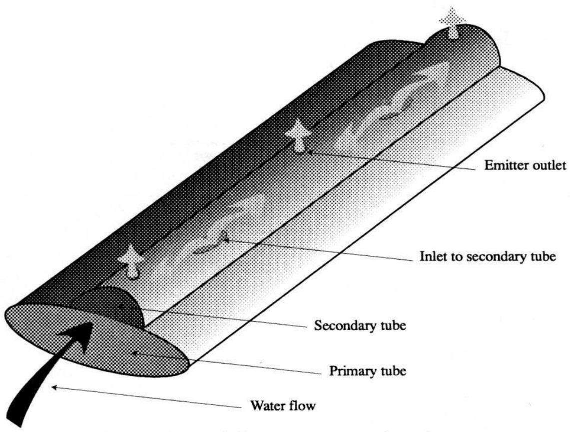


Figure 3. Bi-wall lateral lines use two chambers to regulate water flow. Flow volume is restricted in the secondary tube and water pressure is stabilized. The inner orifices distribute water to a fixed number of emitter holes. This provides uniform flow from the outlet holes at all points in the lateral line (H. Tulloch 1997).

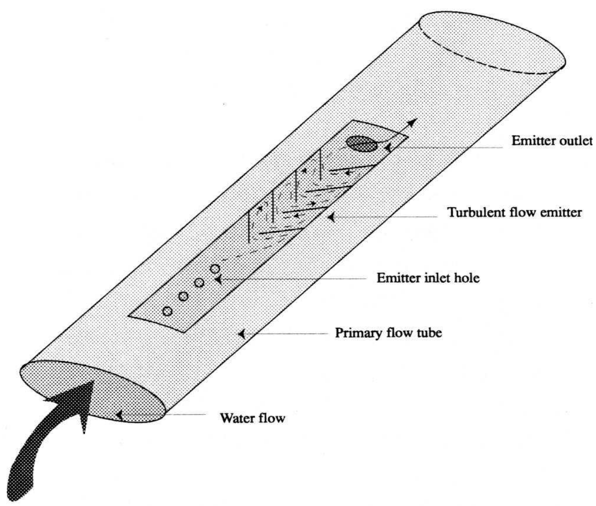


Figure 4. Cutaway view of turbulent flow drip irrigation tape. Water enters the emitter through a series of inlet holes and is forced to travel a twisted path to the emitter outlet. The flow rate in this type of emitter is regulated by flow path and not by orifice size. This reduces the chance of particles being caught in small passageways (H. Tulloch 1997).

a low pressure zone in the center where the water outlet is located. The pressure at the outlet remains fairly stable over a wide range of input pressures. Filtration

Burial Of Drip Lines

Lateral lines placed on the soil surface are exposed to large and sometimes rapid temperature fluctuations, sunlight, and field equipment. All of these factors have the potential to damage irrigation lines and to increase maintenance and repair costs. Day/night temperature changes cause the expansion and contraction of lateral lines which produces a snake-like movement of the lines and emitters away from their target areas. Burying lateral lines provides stable temperatures, avoids UV degradation from sunlight and places the lines out of reach of tractor tires and shallow tillage equipment.

The plugging of emitters from root penetration and inability to be seen are common concerns with buried lines.

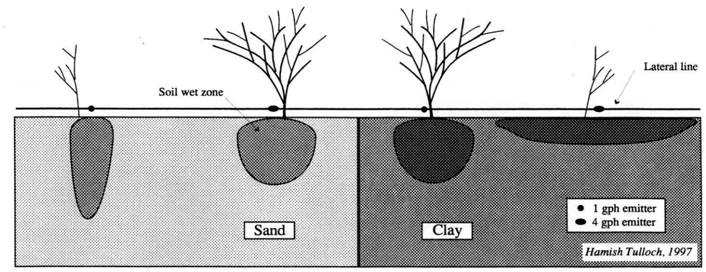


Figure 5.Soil texture and emitter flow rate influences water movement in the soil.

Frequently operating the system leaves a water-saturated zone around the emitter opening which is impermeable to roots and should prevent this type of plugging. Flushing with acid or herbicides is another method used to prevent this problem. Buried drip tapes should be operated during, or immediately after heavy rains to prevent permanent flattening of the line. Problems with buried lines are more difficult to detect and repair, but should occur less frequently assuming suitable materials are used.

Effects Of Soil Characteristics On System Design

Soil characteristics should be considered when designing a drip irrigation system. Soil texture influences water movement in the soil and water quality requirements. In sandy soils, water movement tends to be vertical whereas water movement in clay soil is relatively horizontal. It is possible to modify these wetting patterns by varying emitter discharge rates (Figure 5). Increasing water discharge increases the horizontal movement of water through the soil. In practice, low discharge emitters used in clay soil will promote deeper water movement. Applying irrigation water in short, pulsed applications is another method used to avoid ponding on the soil surface and to promote deeper water permeation.

Drip irrigation can be used to control salinity problems in some soils. Salts are carried at the perimeter of the water front which significantly reduces the salt load within the wetted zone. This allows for normal plant growth in this desalinized region of the soil. The high frequency watering schedules required with drip-irrigation further help to maintain soil salt concentration at levels which will not affect plant growth.

Effects Of Water Quality On System Design

The location of the water source, the volume of the water supply, and water quality must be considered when planning any irrigation system. The location of the water supply has a direct impact on the energy required to move water to the orchard site and on pump requirements. Vertical movement of water requires much more energy than horizontal movement and therefore has a greater impact on pumping costs.

The water source must be able to supply enough water to meet crop demands. For the purpose of estimating water supply requirements, the

Saskatchewan Water Corporation estimates crop water use as 74 cm of precipitation per hectare per season. The actual amount of water used will vary depending on the crop, crop age and the season.

Water quality is determined by the amount and type of dissolved salt. Salt concentration of water is measured as total dissolved solids (TDS) or by electrical conductivity (EC). Runoff water is generally low in dissolved salts and is suitable for irrigation purposes. For details on digging a dugout and using runoff water for irrigation purposes, contact your local PFRA or Saskatchewan Water Corporation office. Ground-water is sometimes used for irrigation but it is more difficult to obtain government approval for such use. The salt level, and in particular, the sodium concentration of well water is often too high for irrigation use. Sodium salts tend to breakdown soil structure and often cause crusting problems. The sodium adsorption ratio (SAR) measures the proportion of sodium relative to magnesium and calcium. Carbonates and bicarbonates can effect calcium and magnesium levels of the water. A more accurate measure of the sodium hazard is the adjusted sodium adsorption ratio (adj.RNa) which takes the carbonate and bicarbonate effects into account. The effect of sodium in irrigation water varies, depending on soil texture (Table 1). Excessive calcium, sulfur and iron levels in well water can cause plugging of emitters. Some ground water supplies cannot be used for irrigation because of toxic levels of micronutrients such as boron.

Assuming that the quality of the well water is adequate, a temporary permit for irrigation use may be granted but water levels in the aquifer must be monitored to show that other users are not affected by the irrigation project. If the well density in an area is high, temporary permits for irrigation use of well water are usually not granted. The additional monitoring costs and the risk of shut down generally prohibit the use of well water for large scale irrigation projects.

Research has shown that more saline water can be used when drip-irrigating crops than by using other methods. Since the water is not applied to leaf surfaces, leaf burn will not occur. High frequency watering minimizes salt accumulation between waterings. Salts are also continually being washed to the perimeter of the emitter's moisture zone. Brackish water has been used successfully with some crops but this practice is not recommended.

Maximum Sodium Salt Levels For Irrigation Water For Various Soil Types

Soil Texture	Maximum Sodium Adsorption Ratio (SAR)
Silty clay	8
Clay	8
Heavy clay	8
Sandy clay loam	10
Silty clay loam	10
Clay loam	10

Silt	10
Sandy clay	10
Loam	12
Silty loam	12
Sand	16
Loamy sand	16
Sandy loam	16

*Adapted from: Understanding Your Soil Water Report. Saskatchewan Water Corporation, 1989.

Chemical Injection

Chemical injection equipment can be used to inject chemical solutions such as fertilizers, pesticides and cleaning solutions into the irrigation system. A back-flow prevention device must be installed upstream from the injection point to prevent contamination of the water supply. Chemical solutions can be injected into an irrigation system using a chemical pump or with some type of pressure differential delivery system. Ideally, a drip system should have two chemical injection points, one before and one after the filter. This may require more than one injector, depending on the type of chemical injection system used. The pre-filter injection point should only be used if the chemical solution presents a risk of clogging. The post-filter injection point is important so that very corrosive materials can bypass the system head.

Chemical Pumps

Chemical pumps may be powered by an external power source or by the system's water pressure (hydraulic pumps). Chemical pumps are very precise, once calibrated, and easy to control but are expensive. With the exception of hydraulic pumps, all chemical pumps inject solutions into the irrigation system under pressure. These injectors are known as positive injection pumps. Gas or diesel engines, electric motors, and tractor PTO units are potential sources of pump power. Electric pumps can be connected to automatic controllers but electricity is not always available.

Piston pumps and diaphragm pumps are usually used to inject chemical solutions. It is important to make sure that pump materials are compatible with chemical solutions. Pumps with fewer metal components, such as diaphragm pumps are better suited for use with corrosive materials. Other parts in the irrigation system must also be considered in terms of susceptibility to corrosion. Injection rates can be adjusted by varying chemical solution concentration or by modifying pump flow. Pump flow can be regulated by changing drive pulleys, modifying piston stroke, or by varying pumping speed (variable speed motors). System flow rates must be known in order to calibrate positive injection pumps.

Hydraulic injection pumps are very useful if an external power source is not available. Hydraulic pumps use system pressure to drive the chemical mixing and delivery mechanism. Piston, diaphragm, or impeller designs are common variations of hydraulic pumps. These pumps can provide very accurate proportioning of the chemical solutions even if input pressure fluctuates. Some hydraulic injectors are designed to proportion chemical solutions at variable rates. This eliminates the need to adjust solution concentration or to modify the pump every time a different chemical or a new dosage is applied.

The most common type of pressure differential chemical delivery system is the venturi injector. Venturi injectors are very simple (Figure 6), reasonably priced, and are accurate as long as system pressure and solution viscosity remain constant for the duration of the injection period.

Venturi injectors are safer then positive injection pumps since the chemical solution is drawn into the system by vacuum rather then forced under pressure. This reduces the risk of chemical leakage which could result in injury, crop damage, or environmental contamination.

Fertigation

Drip irrigation produces a localized wetting pattern in the soil which limits root development and the area that the plant has for nutrient uptake. To ensure that applied nutrients are readily available to the plants, most sources recommend that fertilizers be applied through the irrigation system (fertigation). One of the advantages of drip irrigation is the ability to accurately place and time fertilizer applications. Unfortunately the response of native fruit species to fertilization is not very well understood. Only moderate amounts of fertilizer should be applied initially until accurate recommendations are available.

Fertilizer solutions can be injected using chemical injection equipment but care must be taken to avoid blockages from precipitates and microbial growth. It is important that the irrigation system be fully charged before injection begins, otherwise the dosage from each emitter will vary. Flush the system for one hour after fertigating to avoid the build-up of bacteria and algae and to discourage root penetration into the emitters. Fertilizer solutions are salt solutions and solid salts may form (salting out) if crystallization temperatures are reached. Salting out can occur in the solution holding tank if there is a significant drop in temperature from the mixing temperature, or inside the irrigation system if the water supply is very cold.

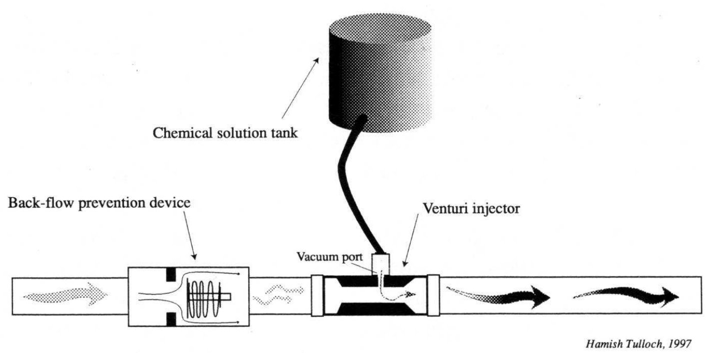


Figure 6. Venturi injector for a drip irrigation system.

Phosphorus

Most of the phosphorus in the soil is unavailable to plants and is tightly bound to soil particles. It is most practical to apply phosphorus (preferably using deep placement equipment) to the orchard site before planting. Since phosphorus is bound to soil particles, a long term reservoir can be established before the site is planted. Over-fertilization can lead to problems with salinity and inhibited uptake of certain nutrients, such as zinc.

If phosphorus deficiencies occur once an orchard is established, it is not practical to apply phosphorus to the soil surface and often it is difficult to side band fertilizers in an orchard. Phosphorus can be successfully applied through drip lines if certain precautions are taken. Studies have demonstrated significant phosphorus movement through the soil profile from drip fertigation relative to other methods of irrigation-applied phosphorus. The concentration of phosphorus in the wetted zone saturates the sites in the soil where phosphorus is bound and allows for greater movement of phosphorus outside of this zone.

Phosphorus can react with calcium and magnesium in the water supply to form an insoluble precipitate which can plug emitters. To avoid this problem, it is necessary to acidify the phosphorus stock solution or to inject an acid solution immediately following the injection of phosphorus. Sulfuric acid and hydrochloric acid are usually used for this.

Triple super phosphate (0-45-0) should not used in phosphorus solutions because calcium phosphate readily precipitates from this solution. Ammonium phosphates such as ammonium phosphate sulfate (16-20-0), monoammonium phosphate (11-48-0), and diammonium phosphate (16-46-0) can be applied safely in solution through the drip system. Phosphoric acid solutions are also used for phosphorus injection.

Since phosphorus does not leach from the soil, it will not need to be applied very often. Phosphorus levels should be tested in the spring and a single adjustment can be made at this time.

Nitrogen

There are a variety of fertilizer sources that can be used to apply nitrogen through drip irrigation lines. Once in the soil, nitrogen is usually taken up by plants in the form of nitrate ions (NO^{3-}) or less frequently, ammonium ions (NH^{4+}). All forms of nitrogen fertilizer are eventually converted to the nitrate form. Nitrate is mobile in the soil, whereas ammonium ions bind to the surface of soil particles. Most ammonium salts, except ammonium phosphate, are readily dissolved in water and should not cause plugging. However, it is not as easy to control the placement of solutions having a high concentration of the ammonium form of nitrogen. Dry urea is very soluble in water and is also completely mobile in the soil. With a urea-based nitrogen solution, placement is simply a matter of controlling water placement. Urea is often mixed with ammonium nitrate in commercial liquid fertilizer blends. Some nitrogen fertilizers, such as aqua and anhydrous ammonia, can increase water pH and may cause calcium and magnesium precipitates to form.

Nitrogen in solution is pushed to the perimeter of the wet zone in the soil out of reach of most of a plant's root system. Therefore, it is most efficient to make several nitrogen applications throughout the growing season. It is not advisable to make any fertilizer applications late in the season, because this can delay the winter hardening processes.

Potassium

In general, Saskatchewan soils already contain high levels of potassium and therefore will not need to be supplemented in most cases. If a deficiency does occur, potassium chloride, potassium sulfate and potassium nitrate dissolve readily in water and should not increase the risks of clogging.

Preventing Blockages

Clogging will eventually occur in any drip irrigation system. Clogging may be caused by debris, chemical sedimentation, or by the build-up of bacteria, algae and even insects.

Debris such as clay and silt may accumulate inside filters or form aggregates in the irrigation lines and emitters which may prevent or restrict the water flow. This type of blockage can be avoided with regular flushing of the irrigation lines and backflushing of the filter. The amount of debris naturally found in the water supply should be considered when determining filtration needs. Initial reductions in drip irrigation flow rates are usually the result of debris blockages which often lead to other types of blockages. It is important to routinely monitor the water flow through the irrigation system and to correct problems as they occur.

Emitters can also be clogged by salt deposits left behind as water evaporates from emitters. This type of blockage may need to be cleaned out manually but can often be cleared by injecting acid into the irrigation line. To clear salt blockages, the pH of the water needs to be lowered to between 1 and 2. Sulfuric or hydrochloric acid can be used to lower the pH.

Insects can inhabit emitters and plug them; these need to be removed manually. Bacteria and algae blockages can be cleared with a biocide such as chlorine gas or a hypochlorite solution. The chlorine concentration of the irrigation water should be 1 mg of free chloride (Cl^2) per liter of water which should be applied for 30 minutes. Calcium and sodium hypochlorite (laundry bleach) solutions are recommended since they are effective and relatively safe. Chlorine gas is also used to clear biological blockages but it is much more difficult to handle safely.

Chlorination can cause manganese and iron to precipitate out of irrigation water. Therefore chlorine must be injected before the filters, and time must be provided for the precipitates to fall out of solution. The filter system must be able to adequately screen these precipitates. Where the risk of precipitate formation is high, it may be necessary to reroute the chlorinated water to delay passage through the filter. Chlorination rates must be adjusted to compensate for the effect of dissolved solids on the free chloride concentration. For heavy algal infestations, first flush the system with the lateral lines open, then close them to clear the emitters. Chlorine is corrosive to irrigation system components and should be flushed from the system after treatment. Some fruit species ,such as black currants, are very sensitive to chlorine and supplemental flushing with untreated water is recommended to avoid toxicity problems. Other biocides are available but many are extremely toxic and should be avoided. Acids and hypochlorites need to be stored carefully so that they don't contact each other. Accidental mixing of these chemicals results in the release of large amounts of chlorine gas and heat, which may result in a fire.

Pruning & Orchard Renewal

Richard G. St-Pierre, Ph.D. (January 2006)

The Basics Of Pruning & Orchard Renewal

Pruning is defined as the art and science of cutting away a portion of a plant to improve its shape, to influence its growth, flowering and fruitfulness, to improve the quality of the entire plant, or various parts, and to repair injury. The primary purpose of pruning fruit plants is to establish a balance between vegetative growth and fruit bearing growth. A certain minimum leaf area has to be maintained for fruit production. Pruning is also done to allow the penetration of light and air into the plant canopy for the improvement of fruit quality, and to aid in harvest and pest control.

Pruning branches or shoots controls function within the plant. Training is a more comprehensive form of pruning and includes the steps required to produce a particular shape. Training controls plant form, including the direction of growth. Training includes pruning, and perhaps also the use of a trellis.

Plant Responses To Pruning

There is a tendency for plants to balance shoot and root growth if they are not pruned. Pruning removes leaves (photosynthetic tissue), wood (food storage tissue), growing points (buds), and flower buds, while leaving the root system intact, unless root pruning is specifically undertaken.

Positive Responses

a) Dormant pruning of deciduous fruit plants can be invigorating by removing flower buds, thus reducing demand on the plant's stored food. The surplus food is utilized for new vegetative growth.

b) Moderate dormant pruning of deciduous fruit plants can increase yield. Fruit- producing growth, that is, one-year-old shoots and spurs, are stimulated to grow.

c) Thinning decreases self-shading, thereby increasing yields and improving fruit quality; fruiting wood should be in less than 50% shade.

Negative Responses

a) Heavy annual pruning of young fruit trees delays the onset of bearing.

b) Severe pruning at the beginning of a growth flush will weaken the plant and reduce total growth, especially when plants are young. This is because energy for new growth comes from stored food which is not replaced until new growth is complete.

Neutral Responses

a) Pruning results in a reduction of total vegetative growth, thus dwarfing the plant, despite localized vigorous growth following pruning.

b) Pruning smaller shoots and branches results in localized effects by forcing the growth of one or two new shoots from buds just below the pruning cut.

c) Removing shoot terminals in fruits with strong apical dominance (such as apples) causes lateral branching.

d) Natural heading-back by winter tipkill and browsing animals, and heading-back by pruning, tends to suppress suckering because the plant responds to the site of injury by branching. Sucker production may be stimulated within the row if annual cultivation is practiced along row edges.

Practical Reasons For Pruning

Pruning can be used by the grower to accomplish the following: a) to decrease leaf surface area, therefore reducing water loss and concentrating resources during times of stress such as grafting and transplanting; b) to improve fruit size and quality by increasing the exposure of fruit to light, by reducing the number of bearing sites, and by increasing the spacing of the remaining fruit; c) to reduce disease and insect pest problems (pruning improves air circulation, light penetration, decreases relative humidity, and increases UV light penetration, both of which reduce infection); d) to increase flower bud initiation (increased light penetration increases flower bud initiation); e) to remove damaged branches; f) to produce new growth (larger fruit on newer growth); and g) to reduce labor costs (savings of time because picking and subsequent pruning is easier).

Timing Of Pruning

Pruning should be initiated when plants are still young. Early-spring pruning (late-March to early-May), prior to budbreak, is suggested. Pruning at this time will also help to stimulate vegetative growth. Active shoot growth following pruning at this time will encourage healing and will better prevent diseases from infecting the tissues.

Late-fall and early-winter pruning may leave shoots susceptible to winter damage, although this is usually only a problem if there is an extreme drop in temperature within two weeks following pruning. Under such circumstances, younger plants are more susceptible to such damage.

Summer pruning is not recommended because removal of the leaf surface limits normal growth and development, fresh cuts can enhance the spread of various diseases such as fireblight and canker, and pruning at this time may induce the formation of new shoots that will not have time to harden properly for winter. Summer pruning slows growth and can have a dwarfing effect because of the removal of leaves that produce carbohydrates.

Pruning Equipment Required

A number of tools are available that will enable a grower to prune properly. A pruning knife is used for light trimming such as the pruning of shoots and roots on transplanting. Secateurs are used for the thinning of diseased shoots, the removal of suckers, and the removal of branches up to 1.25 cm in diameter. Loppers are used for pruning branches up to about 4 cm in diameter. A pruning saw is necessary for cutting out large branches, and for root pruning.

Pruning tools must be kept clean and sharp. Properly made, clean pruning cuts and overall vigor and health of the plant are the most important factors in the healing of wounds.

Large orchards will require the purchase of pneumatic or hydraulic pruners which will help the grower save time and reduce the possible development of repetitive stress disorders from manual pruning.

Types Of Pruning Cuts

The two basic types of pruning cuts are the heading-back cut, and the removal or thinning cut. Heading-back cuts are made anywhere on a branch or twig between two leaf nodes. Such cuts are designed to stimulate dormant buds below the cut to break dormancy and to develop new branches. Removal or thinning cuts involve the removal of an entire twig, branch or stem at its origin (point of branching). These cuts are designed for the removal of excessive growth without stimulating bud break and subsequent growth. Such cuts allow for enhanced flowering and fruit set, and improved fruit quality on inside branches.

Making Pruning Cuts

The primary consideration is to not damage the plant, thus disturbing growth and leaving a wound vulnerable to infection. The branch collar evident in older branches should not be cut off because the collar tissue forms a rapidly growing, disease-resistant callus over the pruning cut. On young plants, the collar may not be evident, however, do not cut flush to the main stem or main branch. Large branches require 3 cuts. The first cut is underneath (this prevents the tearing of bark). The second cut is on top, removing most of branch except for a stub. The third is to remove the stub. For small branches, or ends, make the cut at a slight angle with the high point just above a desirable bud (this will promote the growth of the bud. All cuts should be made cleanly, leaving a smooth surface and without tearing the bark. For the best healing, cuts should not be covered or treated. Exposure to air promotes healing. Hot, dry conditions may require some shading of large cuts.

The disinfection of tools is important to help control the spread of disease, but is not 100% effective. If disease is not present, then disinfection is probably not necessary, however, in such instances, growers must be able to distinguish diseased plant tissue from healthy plant tissue. When pruning diseased growth, tools should be disinfected with Lysol (1 part Lysol to 19 parts water), or household bleach (1 part bleach to 9 parts water) after every cut of diseased tissue. Lysol is less corrosive to pruning tools. It is preferable to spray disinfectant on pruning tools after every cut, however, in practice, this isn’t very workable. Dipping tools in disinfectant will eventually dilute the disinfectant and make it ineffective. Consequently, the disinfectant solution must be replaced often. Disinfection of tools is practical only when moving from diseased plants to healthy plants if a considerable amount of pruning is necessary. Pruned material should be removed and burned.

Orchard Renovation

Orchards may need to be renovated once they reach a mature, bearing age. Orchard renovation involves the removal of 5 to 10% of the orchard/plantation each year in order to provide for space to replace plants and to plant new cultivars. This practice would make it easier to recover from disease problems and to adapt to changes in the market. Once initiated, this becomes a constant process which must be planned for because the new plantings will not begin to bear acceptable yields for the following 4 to 6 years.

Pruning Transplants

It is usually thought that pruning at planting time improves a transplant's chances of survival or growth because the reduction in actual and potential leaf area will reduce the transplant's requirements for water. This practice certainly does reduce water requirements and therefore may be useful under drought conditions. However, the practice is labor-intensive and may have long-term negative effects on plant vigour. Studies with apple, birch and linden, where pruned transplants have been compared to unpruned transplants, have indicated that shoot pruning at the time of transplanting substantially reduces root growth and subsequent shoot growth. Studies with pears have found no advantages or disadvantages with this practice.

Pruning Saskatoons

Regular, careful pruning is important to maintain plant health and to improve yield and fruit quality. Properly pruned saskatoon orchards can produce for more than 30 years. If pruning is neglected, orchard lifespan may be less than 12 years.

Saskatoons may be pruned using the practices of typical renewal pruning of deciduous shrubs. The steps involved in pruning saskatoons are simple and straightforward. The objective is to create plants with an open centre and vigorous shoots. Pruning should be carried out so as to create a balance between older, but less productive growth and newer, more productive growth.

Proper pruning removes unproductive or damaged wood and encourages strong, healthy growth.Thinning or removal of stems is used to rejuvenate and promote new growth of strong stems; such thinning begins after 3 to 4 years of bearing fruit. The removal of older, less productive stems, allowing the production of new plant growth should be encouraged because the largest fruit are usually produced on 2 to 4 year old shoots. Removal pruning should be a yearly job. Substantial pruning does not become necessary until the orchard is about 6 to 10 years old.

For the first three years following

orchard establishment, pruning is primarily associated with the maintenance of plant health and the encouragement of vigour. During this period, pruning primarily involves the removal of weak, diseased, damaged and dead shoots. Low, spreading branches should be removed and the centers of shrubs thinned to keep them open and thus allow good air circulation.

Yearly pruning should be carried out in late-March to early-May, prior to budbreak. The reasons for pruning in the spring while the plant is still dormant are to remove any wood which was killed or damaged over the winter and to do this before the plant puts any energy into new growth which may have to be removed. There are three basic pruning steps which should be carried out each spring: 1) Remove dead, damaged or diseased stems; 2) Cut back weak or spindly growth; 3) Remove stems greater than 2.5cm in diameter at ground level.

Once the shrubs reach 3 to 6 years of age, depending on the vigour of growth and stem production, renewal thinning may begin. This involves the removal of 1/4 to 1/3 of the older stems back to the crown each year. Thus, flowering wood is present every year, and each shrub is completely renewed on a 3 to 4 year cycle. Certainly any stems greater than 2 to 2 ½ m in height need to be pruned out to facilitate harvest.

If the orchard is machine-harvested, damaged stems will have to be pruned out following harvest to avoid infection by canker.

Regular pruning is important to contain canker, blackleaf and fireblight (always remember to disinfect pruning tools after pruning diseased plant material, and before pruning healthy plant material, and also to burn pruned material).

Pruning for disease control may be carried out anytime between late-winter and late-fall. Pruning for control of canker and blackleaf may be easiest in autumn after leaf-fall because, at this time, it is easy to see the split bark symptomatic of canker, and the infected leaves symptomatic of blackleaf that remain attached to the stems.

Once the saskatoon orchard reaches mature bearing age (6 to 7 years), a program of orchard renewal or renovation could be considered. This involves the complete removal of all plants in 5 to 10% of the rows every 4 to 5 years in order to provide space to replace plants and to plant new cultivars. This practice would make it easier to recover from disease problems and to adapt to changes in the market. Once initiated, this becomes a constant process which must be planned for because the new plantings will not begin to bear acceptable yields for the following 4 to 6 years.

Disclaimer: This publication was designed to be an educational resource for individuals who are interested in growing saskatoons, in orchards, shelterbelts, or gardens. Every effort has been made to ensure the accuracy and effectiveness of the information in this publication. However, the author makes no guarantee, express or implied, as to the information and procedures contained herein. The information cannot be guaranteed because knowledge of the biology and culture of the saskatoon may not be applicable to all locations every year. Additionally, the information that is available often changes over time. Little scientific research has been done on many aspects of the culture and management of saskatoons. Consequently, this publication can only serve as a guide. All actions taken which are based on the information presented in this publication are solely the responsibilities of the readers or users, and the author is not liable for any direct, indirect, incidental, or consequential damages in connection with or arising from the furnishing, performance, or use of this material. Comments on information contained in this publication are welcomed.

Diagnosing Disease Problems In Saskatoon Orchards

Richard G. St-Pierre, Ph.D. (January 2006)

Introduction

Fungal diseases are the most important barriers to successful saskatoon production. A variety of diseases are known to affect the saskatoon. These include *Entomosporium* leaf and berry spot, saskatoon-juniper rust, *Cytospora* canker, blackleaf, brown fruit rot, powdery mildew, and fireblight. No virus diseases or mycoplasmas have been reported for the saskatoon.

It is important to carefully monitor for diseases and to take preventive measures. Disease problems are more prevalent in years of greater than normal precipitation. Disease control in the saskatoon involves the use of fungicides in addition to pruning and other cultural practices. Three fungicides are registered for use on the saskatoon: 1) triforine (Funginex 190EC); 2) myclobutanil (Nova 40W); and 3) sulphur (Kumulus DF).

Regular inspections and pruning are required to effectively control diseased shoots. The disinfection of tools is important to help control the spread of disease, but is not 100% effective. If disease is not present, then disinfection is probably not necessary, however, in such instances, growers must be able to distinguish diseased plant tissue from healthy plant tissue. When pruning diseased growth, tools should be disinfected with Lysol (1 part Lysol to 19 parts water), or household bleach (1 part bleach to 9 parts water) after every cut of diseased tissue. Lysol is less corrosive to pruning tools. It is preferable to spray disinfectant on pruning tools after every cut, however, in practice, this isn't very workable. Dipping tools in disinfectant will eventually dilute the disinfectant and make it ineffective. Consequently, the disinfectant solution must be replaced often. Disinfection of tools is practical only when moving from diseased plants to healthy plants if a considerable amount of pruning is necessary. Pruned material should be removed and burned.

Pruning any diseased parts prior to harvest is essential if mechanical harvesting. Harvesters can actively spread disease and these machines may need to be disinfected. Pruning damaged stems and branches following harvest is also important to prevent the development of disease.

Cultural Practices To Help Reduce Disease Problems

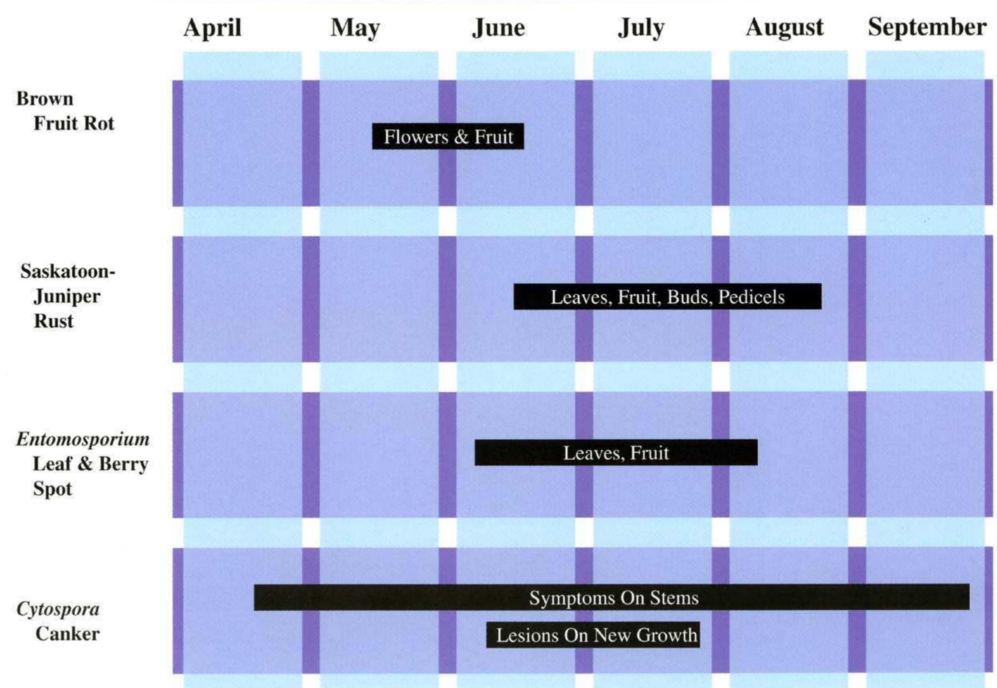
1) Ensure that transplants are disease-free.
2) Avoid planting in wet, poorly-drained soils, or in frost pockets.
3) Avoid planting near diseased plants.
4) Disinfect pruning tools between plants.
5) Prune to remove diseased material in dry

weather during June and early-July.
6) Avoid late-summer and fall cultivation, irrigation, and fertilization.
7) Protect against rodent damage.

The following table and graphic are aids to identifying common disease problems of saskatoons.

Primary Symptoms	Possible Causes
Hard, yellow patches on leaves or fruit; often with spiky, brown outgrowths	Saskatoon-Juniper rust
Swelling & distortion of smaller branches, especially at branch & leaf nodes	Saskatoon-Juniper rust
Leaves with small, angular, brown spots; often followed by leaf yellowing & loss in mid-season	*Entomosporium* leaf & fruit spot
Semi-ripe & ripe fruit with watery grey lesions	*Entomosporium* leaf & fruit spot
Prematurely brown flower petals	Brown fruit rot
Discolored fruit with gray or light brown tufts	Brown fruit rot
Shrunken, hard, brown or black fruit often from previous year	Brown fruit rot
Leaf edges rolled downwards; bottom surfaces covered in grey to black felt	Blackleaf
Drying & shrivelling of buds & leaves in late-spring	*Cytospora* canker
Bark wrinkled with vertical splits or folds	*Cytospora* canker
Sunken areas of cracked or broken bark	*Cytospora* canker
Leaf surfaces coated with a white powder	Powdery mildew
Wilting of new shoots in a characteristic crook-shaped manner; sudden wilting and browning of blossoms	Fireblight

Seasonal Occurrence Of Common Diseases Of The Saskatoon



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Common Disease Problems In Saskatoon Orchards

Richard G. St-Pierre, Ph.D. (January 2006)

Entomosporium Leaf & Berry Spot

Symptoms

Symptoms on the leaves are small, angular brown spots. If these spots have expanded and coalesced, they may also have a yellow halo. The leaves eventually turn entirely yellow. Lesions on the leaf petiole result in defoliation. Infected fruit have watery, greyish lesions. Fruit infections are characterized by disfiguration, discoloration, cracking and shrivelling. The stalks of the fruit and fruit cluster may also become infected, causing fruit loss. Figures 6.2 to 6.5 illustrate the various symptoms of *Entomosporium* leaf and berry spot.

Life Cycle

The causal organism is the fungus *Entomosporium mespili* (other latin names include *Fabraea maculata* and *Diplocarpon maculatum*). Other common names for this disease include common or angular leaf and berry spot, or leaf blight. This fungus can also infect hawthorn, mountain ash, apple, pear and possibly cotoneaster. However, it is likely that the strains that infect these plants are different from those that infect the saskatoon.

This is the most serious disease of saskatoons and has been the primary barrier to fruit crop production. It appears to be present every year, but normally only as leaf spots on succulent, new shoots at the base of the shrub. In years of greater than normal amounts of precipitation and warm temperatures, all foliage and fruit can be infected. The marketability of even lightly-infected fruit is downgraded. The fruit are considered unusable by processors if greater than 6% of the surface area of the fruit is blemished.

Relative humidity and warm temperatures are the primary determinants of the incidence of this disease. Orchards located on drier, more exposed sites are less susceptible. Increased plant and row density appear to result in an increase in the severity of this disease. This fungus can cause severe defoliation of seedlings growing in heavy to full shade; this results in seedling death. The fungus flourishes from early-May through mid-July if the season is moist. It overwinters on fallen leaves and twigs (Figure 6.1).

Control

Preventive measures include thinning seedlings in dense nursery beds, watering at the soil surface, thinning shrubs adequately, and controlling weeds. It was once thought that removing the leaf litter was an important control measure but observations in Alberta have indicated that this measure is not effective in reducing the incidence of the disease.

The fungicides Topas 250E, Kumulus DF and Funginex 190EC have been registered for use against this disease.

Plate 6. *Entomosporium* Leaf & Berry Spot

Figure 6.1: Spore-producing structures of *Entomosporium* leaf and berry spot on fallen leaf from litter; actual size.

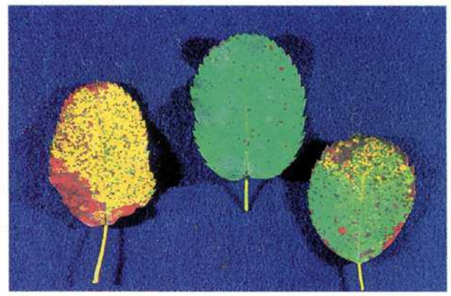


Figure 6.2: Varying densities of *Entomosporium* leaf and berry spot lesions on saskatoon leaves; 3/4 actual size.

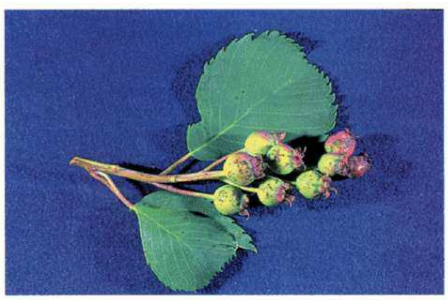


Figure 6.3: Lesions of *Entomosporium* leaf and berry spot on green fruit; 3/4 actual size.

Figure 6.4: Lesions of *Entomosporium* leaf and berry spot on ripening fruit; 1 1/4 times actual size.

Figure 6.5: Lesions of *Entomosporium* leaf and berry spot on ripe fruit (indicated by arrow); 1 1/4 times actual size.

Saskatoon-Juniper Rust

Symptoms

Early symptoms include yellowish spots and swellings on leaves and fruit. Mature symptoms include firm, yellow, spiky outgrowths from leaves and fruit. Another species of this rust infects twigs and branches, causing swelling and distortion. This damage may allow subsequent infection by the canker fungi. Infected fruit are unmarketable. Figures 7.1 to 7.5 illustrate the symptoms of saskatoon-juniper rust.

Life Cycle

The life cycle of saskatoon-juniper rust is illustrated in the color graphic - The Life Cycle Of Saskatoon-Juniper Rust. The causal organisms are the rust fungi, *Gymnosporangium nelsonii* and other species. The fungus first appears as globular, woody galls on juniper. Jelly-like, brown horns grow out of these galls following a rain. The horns discharge spores that can infect the saskatoon. The most common species of *Gymnosporangium* fungi infect saskatoon leaves and fruit, and can cause extensive damage. The infected sites on the saskatoon also produce spores which re-infect the juniper.

Control

If possible, orchard sites should not be established near wild stands of juniper. Spores from rust galls on native junipers substantially further than 1 to 2 km from saskatoon orchards may still reach and infect plants. Removal of all native junipers to a distance of 1 km is impractical and ineffective. A variety of factors influence the susceptibility of the saskatoon to infection by rust; heavily-infected junipers do not necessarily mean that nearby saskatoons will be infected. If the number of nearby junipers is small, it may be possible to prune out the woody rust galls that occur on the juniper. Funginex 190 EC is registered for use on saskatoons for control of saskatoon-juniper rust. The use of Nova 40W to control powdery mildew, or Topas 250E to control *Entomosporium* leaf and berry spot, may provide some control of saskatoon-juniper rust coincidentally.

Plate 7. Saskatoon-Juniper Rust

Figure 7.1: Lesions of saskatoon-juniper rust on saskatoon leaves; 1/2 actual size (Photo by L. Harris).

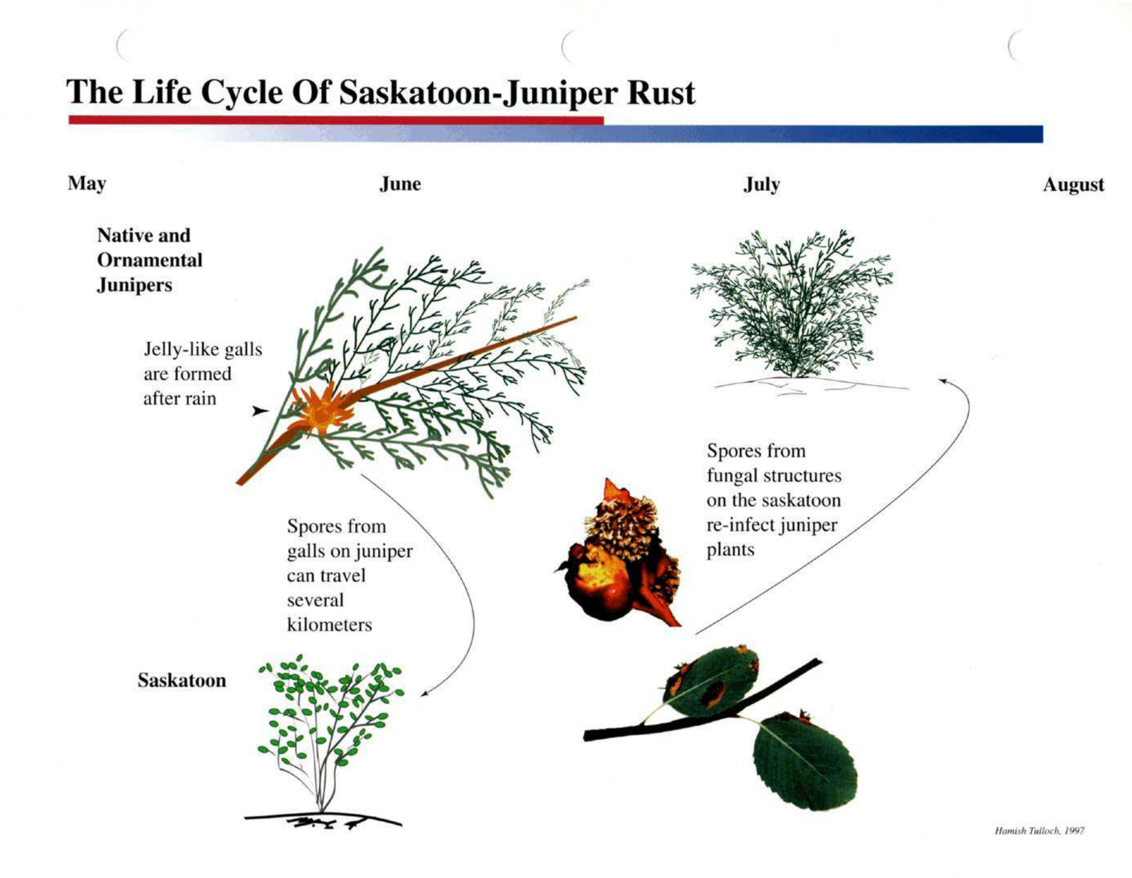
Figure 7.2: Characteristic structures of saskatoon-juniper rust on the undersides of saskatoon leaves; 2/3 actual size (Photo by T. Kabaluk).

Figure 7.3: Developing symptoms of saskatoon-juniper rust on saskatoon fruit; actual size.

Figure 7.4: Mature saskatoon-juniper rust on saskatoon fruit; actual size.

Figure 7.5: Saskatoon-juniper rust at base of fruit cluster; actual size.

Figure 7.6: Spore-producing structure of saskatoon-juniper rust on juniper, the rust's alternate host; 1/3 actual size.


The Life Cycle Of Saskatoon-Juniper Rust
May
June
July
August
Native and Ornamental Junipers
Jelly-like galls are formed after rain
Spores from galls on juniper can travel several kilometers
Saskatoon
Spores from fungal structures on the saskatoon re-infect juniper plants
Hamish Tulloch, 1997

Brown Fruit Rot (Mummyberry)

Symptoms

The symptoms of brown rot include flowers turning brown prematurely, discolored fruit surfaces, brown spots on fruit surfaces, and gray to light brown tufts on the rotted surface. Fruit eventually shrink and mummify (Figures 8.1 & 8.2). Those infected fruit that do not drop immediately become mummified, and are the source for re-infection the next season. The mummified fruit may or may not drop off in the fall.

Life Cycle

The causal organism is the fungus *Monilinia amelanchieris*. Spores are released from mummified fruit, fallen fruit and leaves at budbreak. Infection occurs during flowering. This fungus infects flowers, young fruit, and sometimes leaves. Infected fruit may drop within three weeks following infection. Humid weather during flowering favors a higher incidence of infection. Insect damage to flowers and fruit also can increase the incidence of this disease.

Control

Prevention includes picking and burning of all mummified fruit, removing fallen fruit, and leaves. Excessive fertilization with nitrogen appears to favour infection by this disease. The use of Funginex 190 EC to control *Entomosporium* leaf and berry spot may help control brown fruit rot coincidentally.

Plate 8. Brown Fruit Rot & *Cytospora* Canker

Figure 8.1: Brown fruit rot; 1 1/2 times actual size (Photo by J. Davidson).

Figure 8.2: Brown fruit rot; 1 1/4 times actual size (Photo by J. Davidson).

Figure 8.3: Cracked and split bark characteristic of *Cytospora* canker.

Figure 8.4: Current season's growth newly infected with *Cytospora* canker (lesion is indicated by the circle).

Cytospora Canker (Dieback)

Symptoms

General symptoms include drying and shrivelling of buds and leaves in the spring, leaves developing fall coloration earlier than normal (referred to as flagging), and bark appearing wrinkled, or having vertical splits and folds (Figure 8.3). Cut surfaces of shoots may be stained black when infected. Some confusion with the symptoms of winter injury or woolly elm aphid infestation is possible.

Specific symptoms vary with age of wood and location on plant. Symptoms on younger growth, especially 1 year old wood, include sunken, discolored or darker areas, which may appear watersoaked; the bark may be wrinkled (Figure 8.4). There is an abrupt transition from dead bark to live bark. Symptoms on older growth include sunken areas where the bark is cracked and broken longitudinally; the outer bark is folded back, revealing rusty-colored inner bark; these symptoms are termed exfoliation. Grey-black, pinhead-sized bumps or pustules may be present on dead branches or stems, or on stems where the disease is well-advanced.

Life Cycle

The primary causal organism is the fungal species *Cytospora leucostoma* (*Leucostoma persoonii* is a synonym). Similar cankers and diebacks may be found in apples, cotoneaster, mountain ash, poplar, willow, and green ash, although these apparently are genetically distinct strains of *Cytospora*. Less commonly, some cankers and diebacks may be caused by *Stereum* species (silverleaf), *Nectria cinnabarina* (coral spot), and *Poria* species. The presence of pinhead-sized, orange bumps may indicate infection by coral spot.

The occurrence and severity of canker and dieback are strongly affected by location, weather, and management practices. Canker and dieback are usually seen in older or neglected orchards, but in recent years has been found in newly-established orchards. Exposure to drought, cold, frost, and wind, mechanical injury from harvesting equipment, pruning wounds, rodent damage, poor soil drainage, high levels of salts in the soil, and inadequate levels of nitrogen, potassium or calcium in the soil may predispose the plant to infection by *Cytospora*. Late-summer pruning and late-fall injury may especially predispose the plant to infection because of inadequate wound healing. Canker appears to severely affect young plants, or newly-established orchards, if on exposed, poorly managed sites.

Canker fungi infect buds and shoots through cracks caused by injury and frost. The fungi grow down to the root crown, causing the stem to dieback as they move downwards. The canker fungi sequester calcium which is used to create oxalic acid, a chemical which will kill plant tissue. Plants appear to be able to limit the spread of the disease if only twigs or branches are infected, but not if the main stems or crown are infected. These fungi will infect the entire plant and others unless pruned out; the consequence will be the eventual death of the plant. This disease can be a serious threat to orchards.

Control

Immediate pruning is required to remove all dead and dying shoots. Infected branches or stems must be pruned 25 to 30 cm below the last visible symptoms of infection. Symptoms on older stems may be easier to spot after leaf-fall or before bud break, and therefore pruning can easily be done. If the crown is infected, the entire plant must be removed. All pruned material or rogued plants must be burned.

As preventive measures, plants should be allowed to harden-off properly after harvest. Root suckers greater than one year old should be carefully inspected for canker and perhaps not be transplanted if canker is present elsewhere in the orchard. Orchard location and protection is important. Orchards should not be planted in locations having poor soil or air drainage, must be sheltered from the wind, and groundcover management to trap snow appears helpful. Susceptibility to infection may be associated with low moisture levels within the bark, suggesting that a late-fall watering may be important to prevent dessication of the plant. *Cytospora* cankers of aspen generally grow more quickly when soil nitrogen levels are deficient. Although it's not known if *Cytospora* behaves similarly in saskatoons, growers should ensure that minimum recommended levels of soil nitrogen are present in their orchard.

Complete elimination of this disease likely is not possible.

Powdery Mildew

Symptoms

This disease is common on lower leaves and the leaves of suckers. The primary symptoms include the appearance of a fine powdery white growth on one or both leaf surfaces (Figure 9.1). Infected new leaves may appear distorted, which results in discoloration and the death of the leaves. New shoots can also be infected and these appear stunted.

Life Cycle

The causal organism is the fungus *Podosphaera clandestina*. The fungus can infect both leaves and fruit. This fungus apparently can exacerbate the effects of blackleaf. The fungus is a substantial problem in wetter climates. The saskatoon cultivars Parkhill, Success and Forestburg appear to be more susceptible to infection. Honeywood, Moonlake, Thiessen and Regent appear to be less susceptible.

Control

The fungicide Nova 40W has been registered for use against powdery mildew. Where incidence of the disease is low, infected shoots may be pruned out. Avoid the use of susceptible cultivars.

Plate 9. Powdery Mildew, Fireblight & Blackleaf

Figure 9.1: Powdery mildew on saskatoon leaves and fruit.

Figure 9.2: 'Shepherd's crook' characteristic of fireblight; 1/4 actual size.

Figure 9.3: Blackleaf; note symptomatic downward rolling of leaf edges; 2/3 actual size (Photo by J. Davidson).

Figure 9.4: Blackleaf; note heavy black growth on undersides of leaves; 2/3 actual size (Photo by L. Harris).

Fireblight

Symptoms

Symptoms appear in May through June. Symptoms include the wilting of new shoots in a characteristic crook-shaped manner (Figure 9.2), sudden wilting and browning of blossoms, scorching of foliage, and oozing from cracks in the bark. Infected, young fruit may appear watery or oily, later becoming brown or black.

Life Cycle

The causal organism is *Erwinia amylovora*. Fireblight infects more than 140 species of fruit and ornamental plants, especially those belonging to the Rose family. Saskatoons are less likely to be infected than other fruits such as the apple. Infection occurs during flowering, and is primarily transmitted by bees that are pollinating the flowers, but may also be transmitted by wind, splashing raindrops, other insects, and pruning tools. Succulent, new growth is very susceptible to infection. The symptoms of infection appear in the month subsequent to flowering. Fireblight is most common in years with prolonged, wet spring weather.

Control

It is necessary to prune the infected shoots 25 to 45 cm below the diseased areas as soon as they are observed.

There are no chemicals registered for use against fireblight on the saskatoon. Streptomycin and various copper compounds are registered for use in apples, pears, mountain ash, hawthorn and other ornamentals.

Blackleaf (Witches' Broom)

Symptoms

The edges of initially infected leaves roll downwards (Figure 9.3) and the underside of the leaves become covered in a grey, felt-like fungal growth. This felt-like growth eventually turns black and the leaves die (Figure 9.4). Infected leaves normally remain on the branches. The fungus also penetrates shoot tips and stimulates many new shoots to develop, thereby causing the characteristic witches' broom. Fruit on infected branches dries up or ripens prematurely.

Life Cycle

The causal organism is the fungus *Apiosporina collinsii*. This disease is non-lethal but debilitating where stem density is high. The disease appears to be especially prevalent in orchards located on exposed sites. Only new wood can be infected; previous years' wood is impervious. The fungus infects new wood below the infected leaves. The fungus overwinters on infected leaves and leaf debris, twigs and branches. Infective spores are released from this material the following spring. Suckers are very susceptible to this fungus. The fungus also can invade the root crown of young plants turning the entire plant into a witches' broom.

Control

All infected seedlings and transplants must be removed and destroyed; on established plants, all infected branches must be pruned 10 to 20 cm below the infected site.

The presence of a protective shelterbelt around the orchard, and adequate snow cover in the winter is considered important to minimizing the incidence of this disease.

Damping-off

Symptoms

Seedlings affected by post-emergent damping-off wilt upon emergence and have rotting stems, especially near the surface of the medium. This disease kills germinating seeds and very young seedlings with less than 2 true leaves.

Life Cycle

The causal organisms include fungal species of the genera *Pythium*, *Rhizoctonia*, *Fusarium* and *Ceratobasidium*.
Pre-emergent damping-off affects the sprouting seed and is favored by cold, wet germinating media, and where seedlings are crowded. The fungi survive in soils with high organic matter.

Control

Prevention involves the use of sterilized soils, other potting media, and containers, when germinating seed and growing seedlings. A 5 minute surface sterilization of the seed, using household bleach (1 part bleach to 9 parts water), prior to placing the seed in the germination medium, can help.

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available often changes over time. Little scientific research has been done on many aspects of the culture and management of saskatoons. Consequently, this publication can only serve as a guide. All actions taken which are based on the information presented in this publication are solely the responsibilities of the readers or users, and the author is not liable for any direct, indirect, incidental, or consequential damages in connection with or arising from the furnishing, performance, or use of this material. Comments on information contained in this publication are welcomed.

Fungicide Guidelines For Saskatoon Orchards

Richard G. St-Pierre, Ph.D. (February 2011)

Overview Of Fungicides Registered For Use In Saskatoon Orchards		
Fungicide	**Registered Use**	**Timing**
Pristine WG	Entomosporium leaf & berry spot, saskatoon-juniper rust	Apply a maximum 4 times per season; prior to disease development, and subsequently at intervals of 7 to 14 days; there is no pre-harvest interval.
Switch 62.5 WG	Entomosporium leaf & berry spot	Apply 2 to 3 times per season; at early bloom, 7 to 10 days later, and a third if disease pressure warrants, but no later than 1 day before harvest.
Topas 250E	Entomosporium leaf & berry spot	Apply 3 times per season; at white tip, petal drop, and green fruit stages, no later than 38 days before harvest.
Kumulus DF	Entomosporium leaf & berry spot	Apply first at flower bud break and subsequently at 10-14 day intervals.
Nova 40W	Powdery mildew	Apply first at flowering and subsequently at 14 day intervals; do not apply more than 3 times per season or within 14 days of harvest.
Funginex 190EC	Entomosporium leaf & berry spot, saskatoon-juniper rust	Apply one application per season, only between flower bud break and white tip stage; efficacy limited because of this restriction.
***Important Note: Fungicide use should be based on information derived from scouting of orchards for the presence of disease, disease history, and previous fungicide use. Reliance on a single fungicide will increase the probability of resistance developing, with the consequence that future disease control will become increasingly difficult. If possible, rotate use of one fungicide with others registered for the same disease during the growing season.**		

Caution - This information is solely meant as a guide. Application of all pesticides must be in accordance with instructions on the product label as prescribed under the Pest Control Products Act. Always refer to the label.

1. Guidelines To The Use Of Pristine WG

1.1. Manufacturer – BASF Canada, Inc.

1.2. Trade Names - Pristine WG Fungicide.

1.3. Formulation - Broad spectrum fungicide; water dispersible granule; boscalid 25.2% and pyraclostrobin 12.8%.

1.4. Registered Use - Suppression of Entomosporium leaf and berry spot and saskatoon-juniper rust.

1.5. Timing Of Application - Apply a maximum of 4 times per season; prior to disease development, and subsequently at 7 to 14 days later, using shorter intervals and/or higher rates if disease pressure is high. There is no pre-harvest interval. Avoid application if heavy rain is forecast.

1.6. Application Rate & Guidelines – 1.6 kg/ha; apply in sufficient water to ensure thorough coverage.

1.7. Restrictions – Pristine WG has no pre-harvest interval; no more than 4 applications should be made per year; if crop is hand-harvested, there is a 29 day restricted-entry interval between fungicide application and harvest. Pristine WG should not be used in areas treated with this product during the previous growing season.

1.8. Points To Note – Pristine WG is toxic to aquatic organisms, non-target terrestrial plants and small wild animals. Buffer zones are required between the crop and sensitive terrestrial and freshwater habitats. Runoff from treated areas to aquatic habitats must be avoided. Refer to the label.

2. Guidelines To The Use Of Switch 62.5 WG

2.1. Manufacturer - Syngenta Crop Protection Canada, Inc.

2.2. Trade Names - Switch 62.5 WG Fungicide.

2.3. Formulation - Broad spectrum fungicide; water dispersible granule; cyprodinil 37.5% (systemic action) and fludioxonil 25% (contact action).

2.4. Registered Use - Suppression of Entomosporium leaf and berry spot.

2.5. Timing Of Application - Apply 2 to 3 times per season; at early bloom, 7 to 10 days later, and a third if disease pressure warrants, but no later than 1 day before harvest.

2.6. Application Rate & Guidelines - 775 to 975 g in a minimum of 200 L of water/ha; apply in sufficient water to ensure thorough coverage.

2.7. Restrictions - Switch 62.5 WG cannot be applied within 1 day of harvest; no more than 3 applications should be made per year; hand-harvesting, pruning or thinning should not be done for

10 days following application.

2.8. Points To Note - Switch 62.5 WG is highly toxic to aquatic organisms. This fungicide should not be applied if heavy rains are imminent and should not be applied if spray will drift onto adjacent lakes, ponds, sloughs, rivers, creeks, marshes or wetlands. Appropriate buffer zones are required.

3. Guidelines To The Use Of Topas 250E

3.1. Manufacturer - Engage Marketing Ltd.

3.2. Trade Names - Topas 250E.

3.3. Formulation - Systemic fungicide; emulsifiable concentrate; 250 g/L propiconazole.

3.4. Registered Use - Control of Entomosporium leaf and berry spot, and saskatoon-juniper rust (Gymnosporangium species).

3.5. Timing Of Application - Apply at white tip, petal drop and green fruit stages; the last application must be made no later than 38 days before harvest.

3.6. Application Rate & Guidelines - 500ml/ha in a minimum of 200 litres of water, applying to runoff. If rainfall occurs within one hour of application, reapplication is necessary. High humidity and low temperatures (10 to 20^{o}C) allow for better deposition of spray droplets.

3.7. Restrictions - Topas 250 E cannot be applied within 38 days of harvest.

3.8. Points To Note - Topas 250E is also registered to control monolinia blight (mummyberry) in lowbush blueberries. It is a broad spectrum systemic fungicide that should be applied as a preventative control, although it has both preventative and curative activity. The length of control is from 3 to 4 weeks.

4. Guidelines To The Use Of Kumulus DF

4.1. Manufacturer - BASF Canada Inc.

4.2. Trade Names - Kumulus DF.

4.3. Formulation - Water-dispersible granular fungicide; 80% sulphur.

4.4. Registered Use - Control of Entomosporium leaf and berry spot.

4.5. Timing Of Application - Apply first at flower bud break and at 10 to 14 day intervals while risk of disease persists.

4.6. Application Rate & Guidelines - 6.5 kg/ha in 1000 L water/ha.

4.7. Restrictions - Kumulus DF should not be applied: a) later than 1 day before harvest; b) if temperature is greater than 27^{o}C and humidity is high; c) under intense sunshine; d) if rain or frost are expected; or e) during flowering.

4.8. Points To Note - Applications made after the onset of disease symptoms are less effective. Application rates and restrictions must be carefully followed otherwise symptoms of toxicity may appear. These include a bronze discoloration of the leaves and possible defoliation of the plant. Such toxic effects do not appear to have long-term effects on the plants. Kumulus DF is also an acaricide (miticide).

5. Guidelines To The Use Of Nova 40W

5.1. Manufacturer - Rohm and Haas Canada Inc.

5.2. Trade Names - Nova 40W.

5.3. Formulation - Water-soluble fungicide; 40% myclobutanil.

5.4. Registered Use - Control of powdery mildew.

5.5. Timing Of Application - Apply at flowering and subsequently twice at 2 week intervals.

5.6. Application Rate & Guidelines - 113 g per 100 L water per ha. Ensure thorough wetting of plants.

5.7. Restrictions - Nova 40W can be applied a maximum of 3 times during the growing season and cannot be applied within 14 days of harvest.

6. Guidelines To The Use Of Funginex 190EC

6.1. Manufacturer - Cyanamid.

6.2. Trade Names - Funginex 190 EC.

6.3. Formulation - Systemic fungicide; emulsifiable concentrate; 19% triforine.

6.4. Registered Use - Control of Entomosporium leaf and berry spot, saskatoon-juniper rust.

6.5. Timing Of Application - Only a single application can be made during the period of flower bud break to the white tip stage.

6.6. Application Rate & Guidelines - 3 L/ha where row spacing is twice the height of the plants; use 1000 L of water per ha (sufficient water to ensure thorough wetting of plants).

6.7. Restrictions - Funginex 190 EC cannot be applied within 60 days of harvest.

6.8. Points To Note - Saskatoon leaves are only partially expanded during the period when Funginex 190 EC can be applied. Consequently, uptake of this systemic fungicide may be limited. This is why efficacy may be poor when disease pressure is high. Funginex 190 EC is registered for control of mummyberry (brown fruit rot) in blueberry, cranberry, peach, cherry, plum and prune, for control of powdery mildew in roses, non-bearing apples, and other ornamentals, and for control of black spot in roses and other ornamentals.

Diagnosing Sulphur Toxicity In Saskatoon Orchards

Richard G. St-Pierre, Ph.D. (January 2006)

Symptoms

The leaves may have patchy, bronze discolorations (Figure 1); defoliation also may occur (Figures 2 and 3).

Figure 1. Patchy, bronze discoloration resulting from sulphur toxicity.

Causes

Use of excessive application rates of Kumulus DF may cause symptoms of toxicity may appear. These include bronze discolorations of the leaves and possible defoliation of the shrub. Such toxic effects do not appear to have long-term effects on the plants.

Control

Application rates and restrictions must be carefully followed when applying Kumulus DF.

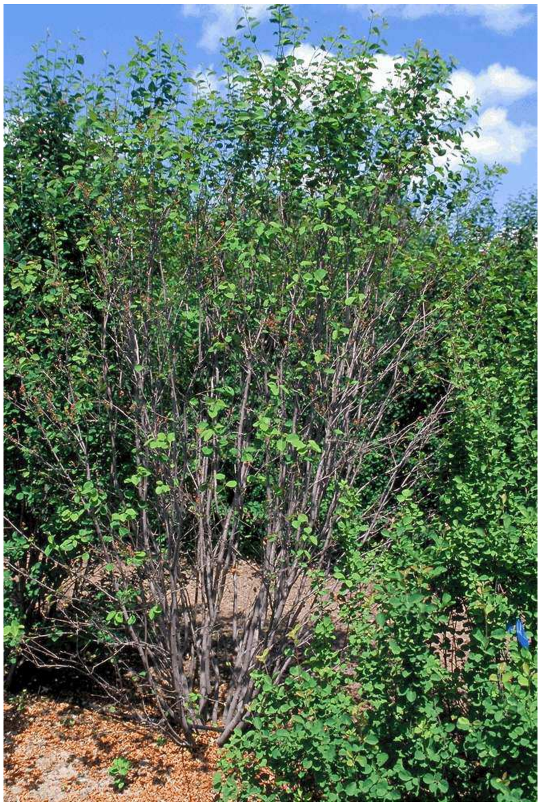


Figure 2. Defoliation resulting from sulphur toxicity.

Figure 3. Defoliation resulting from sulphur toxicity.

Diagnosing Insect & Mite Pests Of Saskatoons

Richard G. St-Pierre, Ph.D. (January 2006)

Introduction

A large variety of insects, and a species of mite feed on the saskatoon. All parts of the plant are attacked, including leaf and flower buds, flowers, immature fruit, ripe fruit, leaves, new shoots, older branches and stems and roots. The extent of damage that these insects cause is variable and dependent upon year and orchard location. However, only a few species appear to be of major significance to the grower. These few insect pests can be very destructive and have a major impact on fruit crop production. Inconsistent fruit crops are often caused by insect damage, but such damage may be difficult to detect. Some insect pests of saskatoons are small, attack the plant early in the season before flowering, and complete their life cycle before harvest.

The timing of insect feeding has a great effect on the extent of damage caused. Insect damage prior to bloom, and during flowering and fruit set, decreases potential crop yield through flower bud, flower and fruit loss; insect damage during fruit development can cause the loss of young, green fruit. At later stages of fruit development, damaged fruit are not lost, but marketable yield is reduced. The effects of leaf feeding insects are less clear. Most leaf feeding insects cause little damage. However, some can defoliate branches or even the entire plant. Unlike many other shrubs and trees, saskatoons that have suffered from defoliation will not produce new leaves that same season. If damage to the total leaf area of a shrub is great enough, some fruit loss could occur because sugar production would be substantially reduced. Flower bud production (which occurs in July and August) could also be reduced. Additionally, leaf feeding could affect the storage of sugars within the plant and this could have longer-term effects on plant survival and growth, depending upon the severity of the damage.

General Principles Of Insect & Mite Pest Control

Only a small number of the organisms that may be found in a fruit orchard or plantation are pests. Many organisms are beneficial and include decomposers of organic matter, pollinators, predators and parasites, organisms that provide shelter or food for natural enemies of pests, and so on. Other organisms are incidental and have little or no impact on crop production. Additionally, many pest species can be tolerated because there are so few, or they cause little damage.

The first steps in designing any pest management program are to understand which pests cause crop damage, to determine what conditions are necessary for damage to occur, and to properly diagnose the problem. The development of an integrated pest management program includes regular inspection of plants for pests or damage, use of crop management practices that prevent pest invasions, buildups or damage, and techniques for control that are applied at appropriate times.

The primary purpose of a pest management program is not to eliminate pests, but to allow the harvest of a food product in an acceptable quantity and quality (eg. fruit crops can often tolerate some leaf damage). Pest management strategies must be continually tested, evaluated and redesigned if necessary.

In general, growers must: a) be able to recognize the symptoms of insect damage; b) positively identify the presence of a pest insect; c) monitor plants regularly and in a representative manner to assess the presence of insect damage or pests; d) determine if the damage or abundance of insect pests is sufficient to require control; and e) be familiar with the general life cycles of the major insect pests.

How To Monitor For Insect Pests

Systematic checking for pests and damage symptoms should be carried out weekly as a minimum. The presence of insect pests is often associated with a particular developmental stage of the plant. Useful equipment includes a hand-lens (having a magnification of 7 to 10X), small jars or plastic bags for samples, 70% rubbing alcohol, and an insect sweep net.

The following methods may be of some help to growers in monitoring for some of the insect pests of saskatoons.

1) Sweep representative bushes or sections of the orchard with an insect sweep net. Place the insects collected in a jar of 70% rubbing alcohol.

2) Gently tap flower clusters into a jar containing white tissue and examine for thrips, or other insects.

3) Hang small (10 by 25 cm) heavy cards painted white and coated with STP engine additive in arbitrary locations throughout the orchard. These cards will attract and capture the saskatoon sawfly.

4) Collect plant parts from representative bushes or sections of the orchard. Using a magnifying glass, examine this material carefully. The undersides of leaves may contain fine webbing and mites. New shoots, leaf and flower buds, flowers, and immature fruit may contain feeding holes of various sizes.

5) Cut off the bottoms of large, plastic containers to a depth of about 5 cm. Paint the insides yellow. Yellow ice cream buckets may also be used. Fill these containers with 2 to 3 cm of water, and a drop or two of dish detergent, and place these in representative locations within the orchard. These traps will attract and capture the woolly elm aphid.

6) Redbanded leafroller pheromone traps used in apple orchards may be useful for leafrollers in saskatoon orchards. This pheromone is primarily used for monitoring, but also for some trapping.

7) All insects captured may be preserved in jars of 70% rubbing alcohol for storage or transportation.

Pest Identification

Misidentification of pests accounts for many control failures. Do not hesitate to seek help from an advisor. Be familiar with pest life cycles and be able to recognize characteristic types of damage.

Damage Tolerance Levels

Integrated pest management involves the fundamental concept that a certain amount of pest damage, or number of pests, can be tolerated. Unfortunately, it is often very difficult to determine the point at which some action must be taken to control the pests so as to prevent unacceptable damage. Guidelines for applying control measures have not been developed for insect pests of saskatoons. A crop's ability to tolerate pest damage depends on the stage of crop development, part of plant attacked, weather, and pest distribution. Control measures may not be necessary if the incidence of the pest organism is low.

Useful Management Practices

It is important to maintain strong, vigorous plants, to keep the orchard clean by disposing of fallen fruit and leaves, to burn pruned stems and branches, and to encourage the presence of insect-eating for control of insect pests.

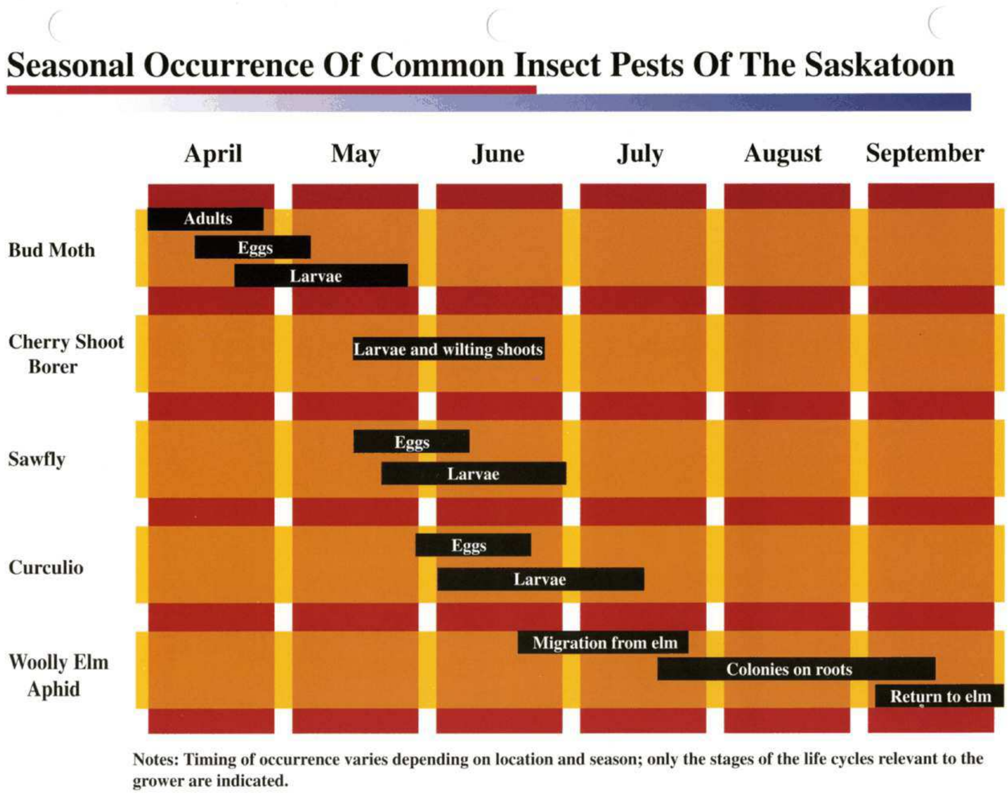
Vigorously growing crops can often tolerate more pest damage (even though they may be more attractive to pests) than a less vigorous one. Dry, dusty conditions are conducive to the buildup of mite populations. Excessive levels of nitrogen may promote aphid problems.

Most pest organisms come from sources within the orchard itself, or adjacent areas. They survive on alternate hosts, crop debris, or as dormant forms (eggs, pupae) in the soil. Some are accidentally brought in on contaminated transplants, soil or equipment. Sanitation practices are required to remove or minimize these sources. Check transplants for aphids.

If available, use cultivars, or rootstocks, that are resistant to important insect pests and diseases where possible. Intercropping and companion planting of nectar- and pollen-producing flowering plants (especially of the family Umbelliferae) grown within or near the orchard can attract, support and increase the activities of beneficial insects, especially tiny parasitic wasps, syrphid flies, other predatory insects and mites. Most biological control can occur naturally without assistance. This is usually noticed when a broad spectrum pesticide is applied for control of a particular pest, and a new pest (secondary pest outbreak) becomes a serious problem; the pesticide kills off beneficial insects as well as pest insects.

The following table and graphic are aids to identifying common insect pest and mite problems of saskatoons.

Primary Symptoms	Possible Causes
Flower buds with small holes; oozing droplets may be present; may contain a tiny caterpillar	Saskatoon bud moth
Young leaves & flowers tied together with white threads or webbing	Saskatoon bud moth
Green fruit extensively damaged, hollow; may contain a larval insect	Saskatoon sawfly
Substantial yellowing & loss of green, unripe fruit	Saskatoon bud moth; saskatoon sawfly; lygus bug
Lack of vigour in young plants; early flagging (change of color) of leaves in late-July or early-August	Woolly elm aphid
White, woolly masses on plant's roots immediately under soil surface	Woolly elm aphid
Partial leafing-out, followed by plant death early in season	Woolly elm aphid
Green fruit, shoot tips with distinctive dark punctures	Apple curculio
Presence of white larval insect within center of ripe fruit	Apple curculio
Sudden wilting & death of new green shoots & flower or fruit cluster	Cherry shoot borer
Leaves & green fruit clusters tied & rolled together with webbing; may contain a caterpillar	Leaf rollers
Large, yellow or brown patches on leaves; presence of green, black, or orange sluglike insects	Pear slug
Stippled or mottled, yellowing leaves; presence of many, lacy-winged insects on undersides of leaves	Lace bugs
Leaves with a stippled appearance; yellowing of leaves; presence of very fine webbing on the undersides of leaves	Spider mites


Seasonal Occurrence Of Common Insect Pests Of The Saskatoon
April
May
June
July
August
September
Bud Moth
Adults
Eggs
Larvae
Cherry Shoot Borer
Larvae and wilting shoots
Sawfly
Eggs
Larvae
Curculio
Eggs
Larvae
Woolly Elm Aphid
Migration from elm
Colonies on roots
Return to elm
Notes: Timing of occurrence varies depending on location and season; only the stages of the life cycles relevant to the grower are indicated.

Insect & Mite Pests Of Saskatoon Orchards - Part I

Richard G. St-Pierre, Ph.D. (January 2006)

Saskatoon Bud Moth

Symptoms

Flower buds with tiny holes about 1 mm in diameter. Oozing droplets may be present on these buds. Yellowish flower buds that fall off when touched. The folded leaves may contain tiny larvae and some webbing within.

Life Cycle

The saskatoon bud moth, (*Epinotia bicordana*; *Olethreutidae*), is a moth that is greyish-black, and tinged brown in color (Figure 10.1 & 10.2). The saskatoon bud moth lays its eggs during the first two weeks of April at the base of buds and in crevices in the bark of twigs (Figure 10.3). During late-April and early-May, the newly hatched larvae bore into the base of the bud and feed on the interior parts of the flower buds (Figure 10.4). They can destroy entire buds. Mature larvae can be found within leaf material (Figure 10.5) or flower petals that have been tied together (Figure 10.6). The larvae are yellow to light-green in color. Larval development is more or less complete by the time of petal drop.

The cotoneaster webworm (*Cremona cotoneaster*; *Pyralidae*), and the striped bud moth (*Filantima telphusa* - species uncertain) are similar insects that may be present at the same time as the saskatoon bud moth. The cotoneaster webworm is a small, greenish-black larva that feeds into the ends of developing buds, but also skeletonizes young leaves and new growth. The striped bud moth appears very similar to the saskatoon bud moth, although the larvae have reddish-brown stripes that run the length of their bodies.

Control

The insecticide Decis has been registered for use against the saskatoon bud moth. The first application of Decis made when the buds are at the green tip stage will control the saskatoon bud moth.

Plate 10. Saskatoon Bud Moth

Figure 10.1: Adult saskatoon bud moth; 6 times actual size (Photo by L. Harris).

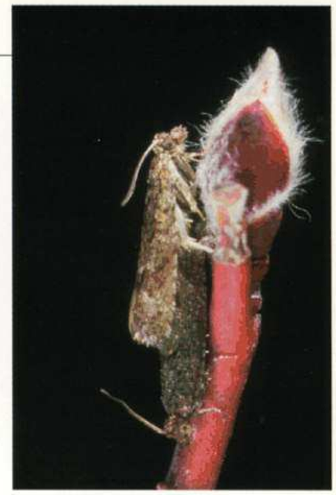


Figure 10.2: Adult saskatoon bud moths mating; 6 times actual size (Photo by L. Harris).

Figure 10.3: Egg of saskatoon bud moth at base of bud (indicated by arrow); 6 times actual size (Photo by L. Harris).

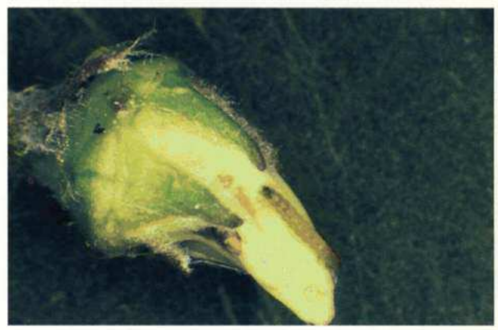


Figure 10.4: Larva of saskatoon bud moth feeding on flower bud; 6 times actual size.

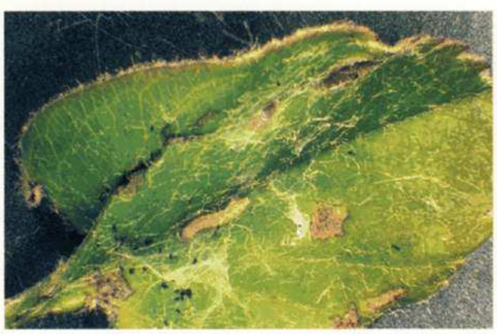


Figure 10.5: Larva of saskatoon bud moth within folded saskatoon leaf; 3 times actual size.

Figure 10.6: Mature bud moth larva in saskatoon flower; 8 times actual size (Photo by L. Harris).

Woolly Elm Aphid

Symptoms

Aboveground: Sparse or reduced establishment of saskatoon plants during the 3 years following transplanting. Saskatoon plants may fail to leaf out in the spring, some branches appear dead, or plants have an obvious lack of vigor (Figure 11.1). Flagging of leaves (development of early-fall coloration) in late-July and early-August, and early defoliation, is correlated with aphid infestation.

Belowground: Bluish-white, waxy or woolly masses may be found on roots 2 to 10 cm below the soil surface in late-July through October (Figure 11.3). A proliferation of tiny white or yellow shoots may also be noticed (Figure 11.2). Dead plants are easily pulled from the soil. Very little root mass remains and few if any secondary roots are present. The remaining roots appear as empty cylinders or sleeves with many distorted swellings.

Life Cycle

The only insects known to feed on the roots of the saskatoon are the woolly elm aphid (*Eriosoma americanum; Aphididae)*, and its close relative, the woolly apple aphid (*Eriosoma lanigerum*). The woolly elm aphid has the potential to cause substantial transplant loss. Young plants less than four years old are the most severely affected. The aphids are blue-black in color and their posterior ends are covered with a white waxy material (Figure 11.4).

The aphids have a complex life cycle which include the elm as an alternate host. This life cycle is illustrated in the color graphic - The Life Cycle Of The Woolly Elm Aphid.

Elm: When the leaves of the American elm begin to unfold in early-May, aphid nymphs emerge from the eggs. This first generation of aphids are wingless females which feed on the underside of elm leaves and give birth to many live young. The fluids injected by the feeding aphids cause the leaves to curl. Distorted and curled elm leaves may contain over 1,000 aphids per leaf, although 200 aphids per leaf is the average number. In mid-June to mid-July, a generation of winged, grey-colored aphids is produced. These aphids migrate to the saskatoon. The duration of the migratory activity is quite long, and begins 35 to 40 days following full-bloom in the saskatoon, about 2 weeks following the bloom of the purple lilac. The beginning of this migration is closely correlated with the blooming of yarrow (*Achillea millefolium*), northern bedstraw (*Galium boreale*), and especially the wild roses (*Rosa* species). Migration may continue throughout the month of July.

Saskatoon: Within an hour of landing on the saskatoon, the winged aphids give birth to 12 to 15 wingless, yellow-orange nymphs on the undersides of the leaves. These nymphs then begin to move down to the saskatoon's roots. Once these aphids reach the roots, their numbers increase quickly. By mid-August, over 200 new aphids may have been associated with a single winged aphid.

Aphid colonies may be found on saskatoon roots from early-July through

October, although it may be difficult to detect the young colonies in July.

By early-September, a new generation of winged, dark-green to black female aphids is produced. This generation migrates back to the American elm, the migration continuing until late-October, depending on the weather. These aphids then give birth to a sexual generation of aphids which mate. The females are essentially a single large egg. They hide in tiny cracks in the bark of the elm, die, and the eggs overwinter in this way.

The woolly elm aphid does not overwinter on the roots of the saskatoon but must return to the elm. The aphid requires the American Elm to complete its life cycle; it cannot do so on the Siberian or Japanese elm.

All cultivars of the saskatoon appear susceptible to woolly elm aphid infestation. Younger, more succulent roots and suckers are more susceptible to infestation. The most susceptible saskatoon plants appear to be those in their second or third growing season, and those growing in unsheltered locations, or in non-irrigated orchards.

Some evidence indicates that this aphid prefers sites with more moisture and moderated temperatures, such as would be found on heavier soils with organic mulches.

Unless grower's carefully monitor for the aphid, their presence and subsequent damage may not be noticed until the spring following infestation. At this point, it may be too late to salvage the plants.

Control

Orthene has been registered for use as a soil injection.

Alternative methods of control that have been investigated include the use of yellow mulches, diatomaceous earth, and predacious nematodes. Yellow plastic mulch sprayed with horticultural oil may act as an attractant and trap. The use of diatomaceous earth around each saskatoon plant (10 g per plant, half incorporated into the soil) may reduce the levels of aphid infestation to some extent, but mainly appears to drive the aphids deeper into the soil. Entomopathogenic nematodes may be purchased and these will attack the woolly elm aphid. A late application of these nematodes may be useful, but results are preliminary and further studies need to be done.

Dormant oils and Tanglefoot are ineffective. Tanglefoot, which is applied to the base of the plant stems as a physical barrier, weakens the stems, which may cause the plant to topple over.

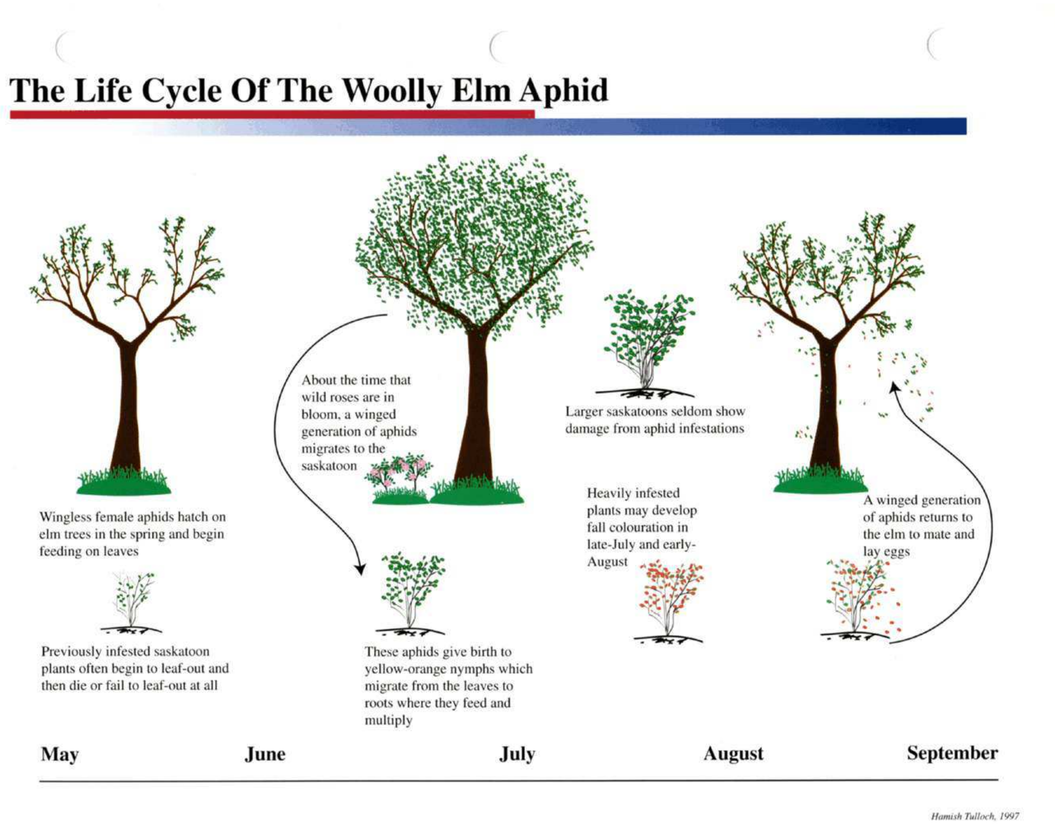
Plate 11. Woolly Elm Aphid

Figure 11.1: Stunted growth characteristic of root aphid-infested saskatoon; 1/4 actual size.

Figure 11.2: Saskatoon plant killed by woolly elm aphid infestation; note substantial shoot proliferation from crown and destroyed root system; 1/8 actual size.

Figure 11.3: Woolly elm aphid infestation on crown of plant; 1/2 actual size.

Figure 11.4: Woolly elm aphids on saskatoon root; 7 times actual size (Photo by L. Harris).


The Life Cycle Of The Woolly Elm Aphid
Wingless female aphids hatch on elm trees in the spring and begin feeding on leaves
Previously infested saskatoon plants often begin to leaf-out and then die or fail to leaf-out at all
About the time that wild roses are in bloom, a winged generation of aphids migrates to the saskatoon
These aphids give birth to yellow-orange nymphs which migrate from the leaves to roots where they feed and multiply
Larger saskatoons seldom show damage from aphid infestations
Heavily infested plants may develop fall colouration in late-July and early-August
A winged generation of aphids returns to the elm to mate and lay eggs
May
June
July
August
September
Hamish Tulloch, 1997

Saskatoon Sawfly

Symptoms

Small (2 mm diameter) holes may be found at the top of small, green fruit; larger holes may be observed on the sides of larger, green fruit. Such fruit may contain a 4 to 7 mm long, white, or light-brown larva. Towards the end of June, some fruit may appear as black, empty shells.

Life Cycle

The saskatoon sawfly (*Hoplocampa montanicola* and three other *Hoplocampa* species; *Tenthredinidae*) is a type of plant feeding, non- stinging wasp. Its host plants include both the saskatoon and chokecherry.

Adult sawflies are about 6 mm long, and are yellow with brown markings (Figure 12.1). The adults appear in May each year, 3 to 9 days, on average, prior to the period of maximum flowering in the saskatoon. They feed within the flower nectaries of the saskatoon and may also feed on pollen. Mating occurs at this time.

Eggs of the sawfly are laid in the nectaries of the blossoms of the saskatoon, the position being marked externally by a dark scar about 1-2 mm long on the calyx of the flower (Figure 12.2). Normally, only one egg is laid within any single flower. It is common to find 1 or 2 eggs per flower cluster, although up to 9 eggs have been found. Eggs are present during the periods of flowering and petal drop in the saskatoon and hatch from about 4 to 11 days on average after petal drop in the saskatoon.

Young larvae begin feeding at the top of the developing fruit. They often feed on more than one fruit. On average, each larva damages about 2 fruit per cluster. Attacked young fruit usually drop off the plant, but older fruit attacked later often remain attached, even though they consist only of an empty shell (Figure 12.3).

Mature larva are about 6 mm long and have a yellow-brown head. The last fruit that is eaten is completely hollowed out (Figure 12.4).

Larval development requires about 45 days and is complete by the end of June; subsequently the larvae drop out of the fruit. A study made at the University of Saskatchewan found that the larval drop was particularly noticeable when branches of saskatoons were covered with bags after petal drop; many larvae were found in the bags from mid- to late-June. These larvae overwinter in the soil and pupation (a stage of transformation to the adult form) occurs in the spring.

Larval feeding can cause large numbers of immature fruit to drop from a saskatoon bush; one study done at the University of Saskatchewan found that, in some years, more than 90% of the potential fruit crop could be lost because of larval feeding.

Control

The insecticide Decis has been registered for use against the saskatoon sawfly. The second and third applications of Decis will control the saskatoon sawfly.

Plate 12. Saskatoon Sawfly

Figure 12.1: Adult sawfly on saskatoon flower; 6 times actual size (Photo by L. Harris).

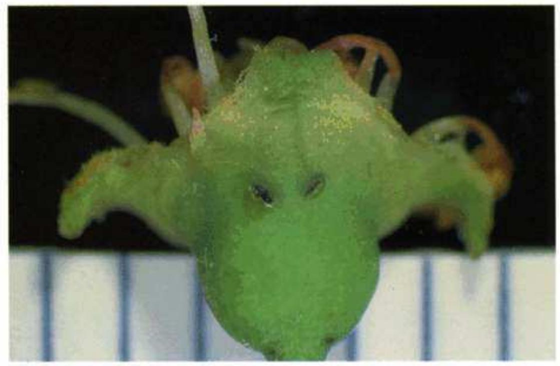


Figure 12.2: Scars made by a sawfly while depositing eggs on the exterior surface of a developing saskatoon fruit; 12 times actual size.

Figure 12.3: Immature fruit damaged by sawfly; 9 times actual size.

Figure 12.4: A mature sawfly larva within a saskatoon fruit; 11 times actual size.

Apple Curculio

Symptoms

Dark puncture wounds, less than 1 mm in diameter, may be observed on green fruit and tender shoot tips. Fat, curled larvae with brown heads, or whitish to transparent pupae, may be found within the centers of ripe fruit.

Life Cycle

The apple curculio (*Anthonomus quadrigibbus*; *Curculionidae*; previously *Tachypterellus quadrigibbus*), belongs to the beetle family of insects and is a type of weevil. The apple curculio is native to North America and is widely distributed. Its host plants include the apple, hawthorn, pear, and saskatoon.

Adult curculios emerge in the spring during the time that the saskatoon is in flower. Adults are about 5 mm long and reddish-brown in color (Figure 13.1). They have a characteristic long curved snout. Adult curculios can be found during the periods of flowering and petal drop in the saskatoon. They feed on immature fruit and shoot tips producing characteristic puncture marks (Figure 13.2). The feeding punctures are relatively large in diameter (about 0.5 mm), often 2-3 mm deep and may be found on any part of a fruit (except the top). Fruit with several feeding punctures develop to an irregular shape and often are hard.

Egg laying does not occur until near the end of the period of fruit drop in the saskatoon, on average, 28 to 33 days after the period of peak flowering in the saskatoon. Egg laying by the apple curculio is restricted to punctures at the base of the young fruit close to where the fruit's stem is attached; the punctures are sealed with excrement. Only 1 egg is laid per fruit.

Early larval development in the saskatoon is restricted to 1 developing seed within the fruit (Figure 13.3). By the time larval development is complete, all seeds will be eaten (Figure 13.4). Feeding is restricted to the developing seeds and is not associated with the fleshy part of the fruit. The fruit are beginning to ripen at this time and do not drop off. Larval development and pupation (a stage of transformation to an adult form) occur in fruit that stay on the plant. Larval development requires less than 31 days. Pupation occurs within the ripe fruit and requires less than 7 days. Adults emerge by mid-July.

The ripe fruit do not appear to be fed upon by the new generation of apple curculios. The new generation of curculio adults enters the leaf litter very soon after their emergence from ripe fruit and overwinter in this stage; adults are not found after the period of fruit ripening. Only one generation occurs each year. Damage to saskatoon fruit by the apple curculio can be extensive. Adult feeding does not appear to cause fruit loss but causes fruit to be of poor quality. Fruit with larvae inside them also are not desirable. One study done at the University of Saskatchewan found that in some years, 80 to 99% of mature fruit could be damaged.

Control

The insecticide Decis has been

registered for use against the apple curculio on the saskatoon.

The third application of Decis will help control the apple curculio.

Plate 13. Apple Curculio

Figure 13.1: Adult apple curculio on developing saskatoon fruit; 5 times actual size (Photo by L. Harris).

Figure 13.2: Feeding punctures made by the apple curculio on a saskatoon fruit; 10 times actual size.

Figure 13.3: Immature apple curculio larva within a saskatoon fruit; 10 times actual size.

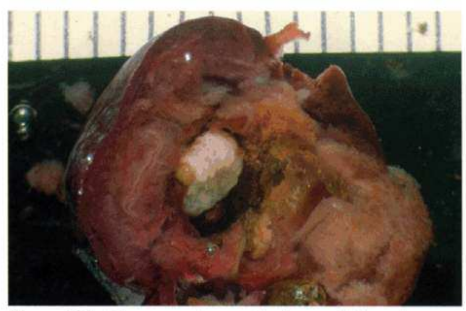


Figure 13.4: Mature apple curculio larva within a ripe saskatoon fruit; 5 times actual size.

Insect & Mite Pests Of Saskatoon Orchards - Part II

Richard G. St-Pierre, Ph.D. (January 2006)

Cherry Shoot Borer

Symptoms

New, green shoots wither and die in late-May and early-June. The presence of small holes may be noted at the base of these shoots. Small, light-green larvae may be found within the stems of these shoots.

Life Cycle

The cherry shoot borer (*Argyresthia oreasella*; *Argyresthiidae*) is a moth species whose larvae damage shoot tips. The adults are small, silver-white moths that have dark gold markings. Adult moths are present from June through late-July and into mid-August. Young larvae tunnel into the tips of tender green shoots and cause a typical wilting, and subsequent death, of the shoot (Figures 14.1 & 14.2). Some observations have indicated that in certain localities, 50% of the flower clusters can be affected. Mature larvae are about 7 mm in length. It is likely the egg that overwinters on buds of the saskatoon. The cherry shoot borer may also be found on the chokecherry and hawthorn.

Control

Prune out dying shoots as soon as they are observed.

McDaniel Spider Mite

Symptoms

Leaves with a stippled appearance; yellowing of leaves; presence of very fine webbing and excessive, fine hairiness on the undersides of leaves (Figure 14.3); heavily damaged leaves may drop off the plant.

Life Cycle

McDaniel spider mite (*Tetranychus mcdanieli*) is not actually an insect but a close relative of the spiders. These mites overwinter as adult females beneath bark or among fallen leaves. Depending on their age and food source, female mites range in color from yellow-green to almost black. Overwintered female mites move up saskatoon stems in the spring and begin feeding on leaf and flower buds, and subsequently on leaves. They lay about 50 spherical, translucent eggs. The eggs become opaque immediately prior to hatching. Immature mites molt 3 times before reaching the mature, adult stage. Mites have numerous generations each season and serious infestations can develop very quickly. The McDaniel spider mite can produce 8 to 15 generations per season, depending on the temperatures. Mean generation time at 18ºC is 30 days, while at 27ºC, it is only 18 days. Hot, dry sunny conditions create ideal conditions for mite infestation. Possible effects of mite damage include some fruit drop, smaller fruit, and decreased flower bud production. Effects are dependent on the timing and severity of mite damage.

Control

Start scouting for mites early in the season. Predatory mites (*Amblyseius* or *Typhlodromus* species) may be introduced into the orchard once levels of infestation are such that 25% of the leaves show presence of McDaniel's spider mite.

Hawthorn Lace Bug

Symptoms

Stippled or mottled, yellowing leaves; presence of many, lacy-winged insects and also many, small dark cone-like structures on the undersides of leaves (Figure 14.4).

Life Cycle

The hawthorn lace bug (*Corythucha cydoniae; Tingidae*) may occur in very large numbers on saskatoons. These insects feed on the undersides of leaves, piercing them with their mouthparts and sucking out the juices. The egg cases of these insects are clearly visible as small, black cones. The hawthorn lace bug produces two generations per year.

Control

No specific recommendations. Damage by these insects is not considered to be of economic concern.

Plate 14. Cherry Shoot Borer, McDaniel Spider Mite & Hawthorn Lace Bug

Figure 14.1: Wilting and death of a flower cluster caused by cherry shoot borer damage; 1 1/4 times actual size (Photo by L. Harris).

Figure 14.2: Cherry shoot borer larva (indicated by arrow) and feeding damage to the central axis of a flower cluster; 5 times actual size (Photo by L. Harris).

Figure 14.3: Infestation of McDaniel spider mite on the underside of saskatoon leaves; actual size.

Figure 14.4: Hawthorn lace bugs on the underside of a saskatoon leaf; 1 1/4 times actual size.

Pear Slug

Symptoms

Mottled leaves with variously colored patches; heavily skeletonized leaves; presence of black, green, or orange slug-like larvae approximately 1 cm long (Figures 15.1 & 15.2).

Life Cycle

The pear slug (*Caliroa cerasi; Tenthredinidae*) is actually the larva of a leaf-feeding sawfly. These larvae are green-black in color and sluglike in their early stages. Their bodies are enlarged at one end and narrow towards the other. The last larval stage of the pear slug is green-orange and 12 mm long. The larvae can cause considerable damage, primarily before fruit harvest, to the leaves. The pear slug overwinters as a pupa in the soil. Adults emerge in early-summer. Adults are shiny black, and about the size of a housefly. They lay their eggs in slits on the undersides of leaves.

Control

No insecticides registered. Generally, not much of a problem.

Similar Insects

Green slug sawfly (*Fallocampus albostigmus; Tenthredinidae*); occurs on foliage about harvest time.

Flower & Leaf Gall Insects

Symptoms

Vary with leaves or flowers. Leaves - various shaped, purple-colored abnormal growths, up to 5 mm in length or diameter, occurring on either side of the leaf; these growths may or may not be hairy (Figures 15.3 & 15.4). Flowers - petals remain unopened; bases of flowers are swollen and reddish in color (Figure 15.5). Buds - terminal buds prematurely break dormancy and the small, folded leaves become swollen; these contain a number of aphid-like insects (Figure 15.6).

Life Cycles

Gall insects cause sporadic, minimal, primarily cosmetic damage. Leaf galls are caused primarily by various midges (*Cecidomyiidae*) or mites (*Eriophyiidae*). The midge larvae, or mites, are very small and live and feed inside the galls. Flower galls are caused by a midge (*Cecidomyiidae*) which lays its eggs within the flower bud. Feeding by the larvae causes the nectaries of the flower to swell. The bud galls are formed by an unidentified, aphid-like insect.

Control

Control is not necessary.

Plate 15. Pear Slug & Various Galls

Figure 15.1: Extensive leaf damage by the pear slug; 1/2 times actual size.

Figure 15.2: Pear slug on saskatoon leaf; 1 1/2 times actual size.

Figure 15.3: Leaf galls caused by a cynipid wasp; 1 1/4 times actual size.

Figure 15.4: Cecidomyiid midge galls on saskatoon leaves; 1 1/4 times actual size.

Figure 15.5: Midge galls of saskatoon flowers; 1 1/4 times actual size.

Figure 15.6: A leaf bud gall caused by an aphid-like insect; 1 1/4 times actual size.

Lygus Bugs

Symptoms

Yellow, aborting flower buds. Droplets of brownish liquid may exude from newly pierced buds.

Life Cycle

Several species of lygus bugs feed on the saskatoon; they include the alfalfa plant bug (*Adelphocoris lineolatus*) and the tarnished plant bug (*Lygus lineolaris*). Lygus bugs feed on a wide variety of crops including strawberry, raspberry, cabbage, bean, cucumber, alfalfa, various grasses, and broadleaf weeds such as dandelion and chickweed.

Lygus bugs are sucking insects that pierce flower buds, blossoms, and developing fruits when feeding; such damage can cause fruit deformation, or the loss of these parts. The tarnished plant bug is about 6 mm long, brown or yellow, or sometimes green in color, with dark markings. Adults overwinter in the leaf litter, or under debris, and become active in early spring. Egg laying occurs when temperatures exceed 20ºC for 10 to 31 days, with 5 eggs being laid per day. The eggs are laid into stems, leaf petioles, the midribs of leaves, buds and flowers. In 7 to 10 days, the eggs hatch into nymphs that resemble the adults. Nymphs may be present as early as mid-May. There are 2 to 3 generations annually.

Control

Lygus bug damage is usually considered tolerable. Control of lygus bugs generally requires the removal of weeds, especially leguminous plants. Alfalfa should not be planted close to a saskatoon orchard because it may be a significant source of lygus bugs. The insecticide Decis has been registered for use against lygus bugs on the saskatoon.

Leaf-rolling Caterpillars

Symptoms

Leaves rolled and bound together with webbing; rolled leaves may include flower or immature fruit clusters; substantial feeding damage to leaves, flower and immature fruit clusters; presence of caterpillars inside the rolled leaves.

Life Cycle

A number of related, leaf rolling caterpillars may be found feeding on the saskatoon. These caterpillars include the fruit tree leaf rollers (*Archips argyrospilus* and *Argyrotaenia quadrifasciana*; *Tortricidae*), and the oblique-banded leafroller (*Choristoneura rosaceana; Tortricidae*). Their host plants include the saskatoon, hawthorn, pear and cherry.

These caterpillars bind and roll leaves together to form a shelter as they feed. In the saskatoon, these rolled leaves often include the flower or immature fruit clusters. These caterpillars can defoliate small shrubs and destroy large numbers of flowers and developing fruit. Their life history is not well known. Adult moths emerge from hibernation about the time of budbreak, and deposit egg masses on the undersides of branches. The moths are about about 10 mm long and are variously brown with white markings. Eggs probably hatch about the time the saskatoon flowers. The larvae are pale green caterpillars up to about 15 mm long. The larvae complete their development by late-June. It is possible that a second generation occurs.

Control

Although not registered for use specifically against these caterpillars, applications of Decis made for control of the saskatoon bud moth, saskatoon sawfly, and apple curculio will probably control leafrollers as well.

Other Leaf-feeding Caterpillars

Symptoms

The most obvious symptoms include large, silken or webbed nests or tents containing numerous, variously colored caterpillars; substantial defoliation of branches or entire shrubs.

Life Cycles

A large variety of caterpillars feed on leaves of the saskatoon, primarily from early-spring until late-June. These include:

Prairie tent caterpillar (*Malacosoma californicum lutescens*; *Lasiocampidae*); these are fuzzy, blue caterpillars up to 5 cm long which spin webbed tents in the crotches of branches.

Forest tent caterpillar (*Malacosoma disstria*; *Lasiocampidae*)

Green fruitworm (*Lithophane anennata*; *Lasiocampidae*). The green fruitworm is a smooth, light-green caterpillar which feeds on leaves and fruit in mid-summer, but rarely causes extensive damage.

Spring cankerworm (*Paleacrita vernata*; *Geometridae*)

Fall cankerworm (*Alsophila pometaria*; *Geometridae*)

Control

Prune out and burn heavily-infested branches.

Insect Pests Of Minor Importance

The following insects have been reported as being found on the saskatoon but are not considered of economic importance. Specific control measures are not necessary.

Stem-boring Insects

Roundheaded apple borer (*Saperda candida*; *Cerambycidae*). The roundheaded apple borer is a brown, cylindrical beetle with long antennae and 2 white stripes running the length of its body. The underside of its body is also white. Adults are present in June and July, during which time they mate, and deposit eggs at the base of saskatoon stems. The larvae feed beneath the outer bark of the stem, on the inner bark and sapwood for 2 to 3 years, making large tunnels. This feeding may girdle the stems and cause dieback.

Metallic wood borer (*Agrilus crataegi*; Buprestidae)

Weevils

Hawthorn weevil (*Pseudanthonomus crataegi*; *Curculionidae*), and also *Anthonomus corvulus* (*Curculionidae*). The larvae of these weevils tunnel along new shoots, killing flower clusters in a manner similar to that of the cherry shoot borer.

Other Insects

Western flower thrips (*Frankliniella tritici)*, a seed-feeding wasp (*Habrocytus* species; *Chalcididae*), and bark beetles (*Scolytidae*) have also been found on the saskatoon but do not appear to be of economic importance.

Insecticide Guidelines For Saskatoon Orchards

Richard G. St-Pierre, Ph.D. (February 2011)

Overview Of Insecticides Registered For Use In Saskatoon Orchards		
Insecticide	**Registered Use**	**Timing**
Admire 240 Flowable	Woolly elm aphid	Apply when aphid migration from elm to Saskatoon is 75-100% complete (early to mid-July)
Bartlett Superior ‘70' Oil	Saskatoon bud moth, fruit tree leafrollers	Apply once per season in the spring at bud break
Orthene	Woolly elm aphid in newly-established, non-bearing saskatoon orchards, less than 4 years of age	Apply once per year in mid-July or early-August
Decis 5.0EC	Apple curculio, hawthorn weevil, lygus bug, saskatoon bud moth, saskatoon sawfly, tarnished plant bug	Apply 3 times per season: once at green tip, once at early flowering, once after petal drop but not within 21 days of harvest

Caution - This information is solely meant as a guide. Application of all pesticides must be in accordance with instructions on the product label as prescribed under the Pest Control Products Act. Always refer to the label.

1. Guidelines To The Use Of Admire 240 Flowable Systemic Insecticide

1.1. Manufacturer – Bayer CropScience Inc.

1.2. Trade Names – Admire 240 Flowable Systemic Insecticide

1.3. Formulation – Imidacloprid 240 g/L

1.4. Registered Use – Suppression of woolly elm aphid on saskatoon

1.5. Timing Of Application - Apply once per season when aphid migration from elm to Saskatoon is 75-100% complete (early to mid-July).

1.6. Application Rate & Guidelines – Apply at a rate of 0.125 mL per plant as a soil surface spray in a band covering the width of the root crown in 200L of water per hectare. The application of Admire 240 should be followed by 5-10mm of irrigation within 24 hours to move the active ingredient to the root zone.

1.7. Restrictions – Applications should not be made within 14 days of harvest. Only one application per year is approved. Admire 240 should not be applied pre-bloom or during bloom, or when bees are actively foraging.

1.8. Points To Note – The use of Admire 240 should be based on monitoring of the orchard for adult root aphids and previous history of the orchard. Admire 240 should not be applied to waterlogged or saturated soils because the active ingredient will not penetrate to the root zone.

2. Guidelines To The Use Of Bartlett Superior ‘70' Oil

2.1. Manufacturer - N.M. Bartlett Inc., 4509 Bartlett Rd., Beamsville, ON, L0R 1B1; 1 800 263 1287; www.bartlett.ca.

2.2. Trade Names - Bartlett Superior ‘70' Oil.

2.3. Formulation - 98.5% Superior ‘70' Oil.

2.4. Registered Use - Control of saskatoon bud moth and fruit tree leafrollers.

2.5. Timing Of Application - Apply once per season in the spring at bud break; Refer to Plate 1 and the Stages of Flower Bud Development color graphic in Section III: Botany of this manual for further information on timing.

2.6. Application Rate & Guidelines - Apply at the rate of 20 L product in 1000 L water per hectare. All plant surfaces are to be thoroughly coated. Applicators should wear a long-sleeved shirt, long pants, chemical-resistant gloves, eye protection, and a mask fitted to exclude spray mist. Superior ‘70' Oil is an Eye Irritant.

2.7. Restrictions - Applications should not be made during freezing weather, or if frost is expected before the plants dry. Only one application per year is approved.

2.8. Points To Note - Horticultural spray oils such Bartlett’s Superior 70 Oil are highly-refined petroleum oils. If applied when plant buds are dormant, or shortly thereafter, such oils are effective against exposed eggs and soft-bodied immature and adult pests (including most species of mites and some species of young caterpillars and various sucking insects; they are also effective on eggs of mites, aphids, and some moths). Their mode of action is not clear but may include smothering of insect or eggs; they may also disrupt cell membranes. Modern horticultural oils are easy to use in the field, and are inexpensive and safe to handle. If properly used, they have low toxicity to most plants. They are relatively harmless to humans, other mammals and birds. Additionally, they dissipate quickly after spraying, leaving little or no residue on crops. Because of this reduced residual activity, they usually are less harmful to beneficial insects and predatory mites. Target pests develop little or no resistance to oils. The use of Bartlett's Superior 70 Oil as a replacement for at least the first application of Decis will help reduce the probability of insect pests developing resistance to Decis. Bartlett's Superior '70' Oil is well suited for use in Integrated Pest Management (IPM) programs, and can be used by organic growers.

3. Guidelines To The Use Of Orthene

3.1. Manufacturer - United Agri Products.

3.2. Trade Names - Orthene.

3.3. Formulation - Soluble powder; 75% acephate.

3.4. Registered Use - Control of woolly elm aphid in newly-established, non-bearing saskatoons, less than 4 years of age.

3.5. Timing Of Application - Apply once per year in mid-July or early-August.

3.6. Application Rate & Guidelines - Mix 1.7 gm / 2 L water (3.4 kg/ha with a planting density of 2,000 plants/ha). Apply 2 L per plant. Inject with a probe 15 cm from the stem of the plant to a depth of 12 cm at 3 to 5 locations around the plant. Inject into moist soil, otherwise a 2 L volume of insecticide may be insufficient to wet the volume of soil required for aphid control.

3.7. Restrictions - Use only on non-bearing saskatoons less than 4 years of age.

3.8. Points To Note - The efficacy of orthene tends to be greater if the application is made in early to mid-July. However, orthene is not registered for application at this time of the season. Orthene is available in 1.5 kg bags; this is sufficient for approximately 880 plants at a cost of $0.10 per plant. Plans for a do-it-yourself single-point soil injector can be obtained from the PFRA Shelterbelt Center, Indian Head, SK.

4. Guidelines To The Use Of Decis 5.0 EC

4.1. Manufacturer - AgrEvo Canada Inc.

4.2. Trade Names - Decis 5.0 EC.

4.3. Formulation - 50 gm/L deltamethrin (synthetic pyrethroid); emulsifiable concentrate.

4.4. Registered Use - Control of apple curculio, hawthorn weevil, lygus bug, saskatoon bud moth, saskatoon sawfly, tarnished plant bug.

4.5. Timing Of Application - Apply 3 times per season; once at the green tip stage of flower bud development, once during early flowering (25 - 50% bloom), and once after petal drop, remembering to observe the preharvest interval of 21 days. Refer to Plate 1 and the Stages of Flower Bud Development color graphic in Section III: Botany of this manual for further information on timing.

4.6. Application Rate & Guidelines - Use 2 ml/4.5 L water for every 100 sq m of orchard row face (including both sides of the row alley, or both sides of a single row of plants; to calculate the total amount of Decis required, refer to section 4.9 of this factsheet). Ensure that the foliage is thoroughly sprayed, including the undersides of the leaves.

4.7. Restrictions - Do not apply within 21 days of harvest. Do not apply when temperature is greater than 25^{o}C; application in early-morning or early-evening is best.

4.8. Points To Note - Extensive use of Decis may contribute to increasing problems with the McDaniel spider mite. Decis controls insects through contact and/or ingestion. Decis works best under cool conditions. The first application will control the saskatoon bud moth, lygus and tarnished plant bug. The second application will control the saskatoon sawfly. The third application will ensure control of the saskatoon sawfly, hawthorn weevil and apple curculio.

4.9. Calculating Amount Of Pesticide Required - 1) Multiply row length in m by row height in m
2) Multiply this figure by 2, then divide this last figure by 100
3) The result is the number of 100 square meter sections that must be sprayed
4) Multiply this figure by 2 ml to obtain the total amount of Decis required, and by 4.5 L to obtain the total amount of water required.
5) Calibrate sprayer and tractor speed to uniformly deposit spray volume over entire orchard area.

Disclaimer: This publication was designed to be an educational resource for individuals who are interested in growing saskatoons, in orchards, shelterbelts, or gardens. Every effort has been made to ensure the accuracy and effectiveness of the information in this publication. However, the author makes no guarantee, express or implied, as to the information and procedures contained herein. The information cannot be guaranteed because knowledge of the biology and culture of the saskatoon may not be applicable to all locations every year. Additionally, the information that is available often changes over time. Little scientific research has been done on many aspects of the culture and management of saskatoons. Consequently, this publication can only serve as a guide. All actions taken which are based on the information presented in this publication are solely the responsibilities of the readers or users, and the author is not liable for any direct, indirect, incidental, or consequential damages in connection with or arising from the furnishing, performance, or use of this material. Comments on information contained in this publication are welcomed.

Weather-Related Disorders

Richard G. St-Pierre, Ph.D. (January 2006)

An Overview Of Weather-related Disorders Of Saskatoon Orchards	
Primary Symptoms	**Possible Cause**
Death of entire plant	Cold injury, drought
Death of new wood, leaf buds, flower buds	Cold injury, drought
Light browning, then yellowing and loss of flower buds, flowers, young leaves	Frost damage
Leaves with hard, brown edges, often torn	Wind damage
Light brown or grey scabs on fruit	Wind damage
Discoloured, bubbled bark, or splitting bark	Sunscald
Ripe fruit with large cracks in the skin	Excessive rain, or irrigation during ripening

Frost Damage

Symptoms

Symptoms of spring frost damage include light browning of flowers and leaves, which may drop off. Flowers and newly-set fruit are especially susceptible to frost damage. Such damage may be restricted to the internal parts of these parts and may not be noticeable except under magnification (Figures 16.1 & 16.2). A substantial loss of flowers and newly-set fruit may result from frost damage.

Symptoms of fall frost damage may include splits in the bark of stems and branches, some of which may be partially healed as indicated by smooth, inward-rolling tissue.

Cause

Killing frosts are defined as -2.2ºC or lower; at this point, most actively growing plant tissues are killed.

Frost cracks are prime sites for the entry of decay-causing fungi and *Cytospora* canker.

Control

Overhead irrigation may be used when temperatures approach freezing. Water releases heat as it freezes on the plant, thereby slightly elevating the temperature of the plant parts above those of the surrounding air. Overhead irrigation can provide protection to about -4 to -6ºC.

Wind Damage

Symptoms

Torn, ragged leaves; leaves with a leathery texture; leaves may have holes of various shapes and sizes, or missing pieces along the leaf margins; leaf margins may be brittle and brown; fruit may have light brown or grey scabs; fruit may be deformed below the scabs; reduced growth and yields.

It may be difficult to distinguish abrasion from symptoms associated with drought, herbicide drift, or some diseases.

Cause

Wind may have both direct and indirect effects on fruit plants; the type and extent of wind damage dependent on wind speed.

Direct effects include abrasion, tearing and desiccation of leaves. Leaves and new shoots are susceptible to wind damage. Fruit can also be affected, grey or light brown scabs forming (fruit russett or dry scab) (Figure 16.3). Desiccation is associated with leaf moisture loss. Plants are also exposed to evaporative cooling.

Indirect effects include reduced yields and fruit quality, increased winter damage, interference with pollination, suppression of growth, and increased soil moisture loss because of increased evaporation from the soil.

Control

Provide adequate windbreaks, and ample irrigation or groundcover management.

Cold Injury

Symptoms

Symptoms may include death of an entire plant, or death of more susceptible plant parts such as new wood, leaf buds and flower buds; death of entire plants or parts of plants results in buds not breaking dormancy. Gently scraping a bit of bark off of a branch will indicate if the underlying cambial tissue is still living (moist and green colored), or dead (dry and grey-brown). Less severe symptoms include delayed bud-break, reduced growth, small leaves, fewer leaves than normal, or a variable pattern of flowering within plants, or within the orchard. These symptoms may not become noticeable until mid-June.

Cause

Cold injury is associated with prolonged extreme cold temperatures, or sudden extreme drops in temperature following a warm spell. Prolonged, extreme cold can affect roots and root crowns, especially if there is little or no insulating snow cover. Sudden, extreme drops in temperature will more likely affect buds and shoots because the soil insulates roots against such rapid changes in temperature. Increasing susceptibility to such temperature changes is as follows: older shoots, most recent shoots, leaf buds, flower buds.

Cold injury is, in part, associated with the development of winter hardiness and dormancy. The development of winter hardiness (a process called hardening-off) and dormancy allow a woody plant to survive our winters. The requirement for a period of dormancy is often referred to as a chilling requirement. If this chilling requirement is not met, abnormal growth and development, or no growth, may result. Dormancy requires, and follows hardening-off, which is a physiological process initiated by decreasing daily temperatures and shorter days. Inadequate hardening-off predisposes a plant to cold injury.

Symptoms of both cold injury and desiccation are similar and often associated. Warm, dry winds can be followed by sudden drops in temperature. Cold injury can allow the subsequent entry of dieback and decay fungi such as *Cytospora* canker.

Control

Prune injured and dead branches to help prevent infection by disease-causing organisms.

The development of adequate winter hardiness requires low levels of soil moisture and fertility in late-summer and fall. The use of excess nitrogen must be avoided throughout the growing season. Irrigation should be reduced in August and September; allowing weeds, grass or cover crops to grow during August will help reduce soil moisture levels. Fertilization after harvest is not suggested. Low-lying sites with a high water table also may delay hardening-off, and increase the susceptibility of the orchard to frost damage because of poor air drainage.

Desiccation

Symptoms

Symptoms of both cold injury and desiccation are similar and often associated. Symptoms may include death of an entire plant, or death of more susceptible plant parts such as new wood, leaf buds and flower buds; death of entire plants or parts of plants results in no bud-break. Less severe symptoms include delayed bud break, reduced growth, or a variable pattern of flowering within plants, or within the orchard.

Cause

Desiccation is caused by relatively warm dry winds that have effects when the ground, and consequently a plant's roots, are still frozen; the aboveground parts of the plant lose water to the warm, dry winds, but this water cannot be replaced because the roots are frozen.

Control

Irrigation after leaf-fall, but prior to soil freeze up is important if soils are dry, because this will help reduce desiccation in winter and early-spring. Windbreaks are important for reducing the drying effects of strong, persistent winds.

Sunscald

Symptoms

Bark on stems or branches appears discolored and perhaps bubbled. Sunken areas with cracked or split bark may be present.

Cause

Sunscald, which is a bark injury, can occur in both summer and winter. Bark exposed to the hot summer sun can discolor and bubble, subsequently forming cankers. On cold, sunny days during the winter, bark that is exposed to the sun and reflection from the snow may become warmer than the air, allowing some sap movement to occur, and then cool rapidly after sunset; splitting and subsequent canker development can occur. Such injury allows access by disease organisms.

Control

Prevention of these problems is associated with proper site selection and management practices.

A slight NE slope to the orchard will help prevent sunscald; a spray of white exterior latex paint can also be used to reflect sunlight and help reduce the extreme temperature fluctuations. This may also help delay flowering in the spring.

Fruit Cracking

Symptoms

Large cracks in the skin of ripe saskatoon fruit (Figure 16.4).

Cause

Fruit cracking is associated with high soil water levels and high humidity. Ripening fruit can only lose excess water by transpiration through the skin; conditions that reduce the fruits' ability to transpire, including high humidity and minimal air movement within the plant's canopy, are likely to increase the incidence of fruit cracking following rain. Cultivars may also vary in their susceptibility to fruit cracking. The saskatoon cultivar Pembina may be more susceptible to fruit cracking than other cultivars.

Control

Depending on soil moisture levels, irrigation should be reduced or not applied once fruit begin to ripen. Plants must be adequately thinned to maintain an open canopy in order to maximize the circulation of air and exposure to sunlight.

Plate 16. Weather-related Disorders

Figure 16.1: Typical frost-damaged flower bud; internal browning indicates tissue damage; 17 times actual size.

Figure 16.2: Saskatoon flower damaged by frost; internal browning and browning of a flower petal indicates tissue damage; 12 times actual size.

Figure 16.3: Russetting of saskatoon fruit.

Figure 16.4: Cracking of saskatoon fruit from excessive uptake of water.

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Animal-Related Problems

Richard G. St-Pierre, Ph.D. (January 2006)

Birds

Symptoms

Large numbers of birds in the orchard; fruit with large, ragged holes (Figure 17.1); bird droppings containing many seeds.

Cause

Birds such as robins, finches, and sparrows, feeding on semi-ripe and ripe fruit.

Control

Bird feeding on semi-ripe and ripe fruit can cause a substantial loss of marketable fruit. Unfortunately, bird control is difficult and it is illegal to shoot songbirds which are protected under the Migratory Bird Act. A combination of methods will provide the best solution to this problem.

One approach to this problem is to grow more plants and absorb the losses in yield.

The use of netting (plastic impregnated paper, nylon, cotton, or polyethylene) has been shown to be both effective and economically feasible in blueberry orchards (Figure 17.2). The netting can be either installed as a tent, or as a floating cover, not long before the fruit begin to ripen. Floating covers will have to be removed immediately before harvest.

There is some indication that birds feed on fruit, not only for food, but also for water. Consequently, providing a source of water for the birds may partially solve this problem.

Table sugar (sucrose), applied when the fruit are beginning to ripen at a rate of 1 kg/L of water has been used as a repellent. It's thought that either the stickiness of the sugar coating on the fruit, or the indigestibility of the coating (birds can't digest sucrose) is the basis of the repellent action. However, the use of a sugar spray would require that the fruit be washed and the sugary coating could increase potential disease problems.

A variety of bird scare devices are available. These work in a variety of ways.

Visual scare devices include a number of variations on reflective tapes, kites and balloons with large 'eyes' that mimic the eyes of predators such as hawks and owls. The balloon-type devices are suspended on flexible poles (bamboo, poplar, willow, fiberglas), at a density of 5 to 10 per hectare. They are installed as the fruit begin to ripen, and removed immediately following harvest so that the birds do not become accustomed to them. Individual balloons also are moved every 7-10 days for the same reason. These balloons appear to be effective in apple orchards. Reflective mylar tapes, or flash tapes, are usually silver or red in color, reflect light brightly, and produce a fluttering sound. These tapes vary from 1.25 to 5 cm in width and are used in various lengths tied to fence posts, or whatever is convenient. Three tapes should be used for each row of saskatoons, one above the row, and one on each side of the row.

A variety of electronic devices are available that produce sounds which irritate, distract, or frighten fruit-feeding birds. Some of these devices will be intolerable to both the grower and their neighbours because the sounds created are so loud. Some of these devices create high-frequency sounds that cannot be heard by people. Unfortunately, birds often adapt to these devices and subsequently ignore the noise.

Another method that some growers believe is effective is to attract natural predators such as hawks, owls, magpies and ravens to the orchard. Such birds may be attracted to the orchard by hanging raw meat or a carcass from a tree. One grower apparently has used dogfood as a bait to attract magpies. The use of artificial hawk nests and roosts may entice hawks to nest in the vicinity of the orchard. The presence of natural predators helps to reduce feeding by other birds.

Electric fence technology also has been adapted for bird control. Pairs of electrical wires may be installed above the orchard rows in such a way that pruning and harvesting operations are not interfered with. When birds land on the wires, they receive a shock and fly away. This shock apparently acts as an effective deterrent.

Suppliers of bird control devices are listed in the Sources section of this manual.

Rodents & Rabbits

Symptoms

Chewing damage to bark near base of stems, main roots, feeder roots; loss of plants for unknown reasons; trails, burrows, runways beneath mulch; ground spongy around plants; 2.5 cm diameter holes in ground around or between plants; damage is especially severe during the winter months when other food sources are scarce

Cause

Rabbits may eat young shoots; rabbits, mice and voles can girdle stems (strip away bark completely around the circumference of the stem). Stems that are completely girdled will die.

Control

A good method of control is to manage weeds, grass and mulch effectively. Organic mulches should be kept 60 cm from the base of the crop plants and should be removed in late-August. Row alleyways should be kept mowed or regularly cultivated depending on the type of groundcover. Mulches, long grass, matted grass and weeds provide rodents with protection from predators such as hawks, owls, coyotes, cats and dogs.

Rodents can be effectively controlled during the winter by packing the snow in the orchard alleyways with a snowmobile. The packed snow makes it much more difficult for mice in particular to freely move about under the snow.

Fencing with 1 m high chicken wire (4 cm mesh size), and persistent trapping & shooting, will help in controlling rabbits.

Hawks, owls and other raptors (predatory birds) can be attracted by artificial nests and perches placed on poles 7 to 10 m tall; perches or nest platforms must be 60 cm wide. Chickens apparently can be trained to feed on mice by providing them with mice caught in traps and then left to run free in the orchard.

The use of commercially available repellents may be necessary. Such repellents incorporate the fungicide thiram which has a bitter taste. A homemade mixture of 1 part (by weight) thiram (75% wettable powder) with ten parts water-emulsifiable black asphalt can be made. The repellant must be applied to dry stems after leaf fall on a warm day.

A spray of white latex paint to the base of stems may act as a feeding deterrent because of its chalky texture. White latex paint is 44% water and contains the pigments titanium dioxide and zinc oxide, both of which are non-toxic (and used in medicinal preparations).

Bait stations containing a rodenticide (most commonly grain treated with zinc phosphate) can be distributed, 1 every 20 m^2, after leaf fall. The bait can be placed under boards, in old tires, in plastic pipe (10 cm diameter, 30 to 45 cm long), or in empty oil cans having a hole large enough for the rodent to enter.

Deer

Symptoms

Feeding on terminal buds and the ends of branches, especially during winter.

Cause

Deer may feed on twigs and larger branches.

Control

It's important to determine if the cost of the damage is less than the cost of protection. The methods of providing protection from deer are not foolproof and may be expensive.

If deer become a serious problem, the only adequate protection is a tall, sturdy fence of woven wire. Woven wire fencing must be at least 2.4 m in height with no crawl spaces underneath.

Some growers have experimented with a simple, baited, electric fencing. The fence consists of single strand polywire or tape strung 0.75 to 1 m above ground level. Every 3 m, a 5 by 15 cm aluminum foil flag is taped or stapled to the polywire; the underside is coated with peanut butter. A standard livestock fence line is used to energize the fence. The baited aluminum foil flags attract the deer who are then shocked on the nose by the electric wire. This system is said to work well in conditioning deer to avoid the fence.

Dogs left to roam in the orchard may be helpful, provided that they can be kept in the orchard. Odor and taste repellants, including human hair, mothballs, bloodmeal, and the commercial products Hinder, Ro-pel, Skoot and others, may not be reliable. Some of these, especially strongly-scented soap bars hung every 3 m, have been considered helpful by some growers.

Plate 17. Bird Damage

Figure 17.1: Fruit damaged by bird feeding (Photo by A. Delidais).

Figure 17.2: Highbush blueberry orchard covered with netting for protection against birds (Photo by M. Bantle).

Harvesting Saskatoons

Richard G. St-Pierre, Ph.D. (January 2006)

The proper timing of harvest and appropriate handling of fruit during and after harvest are critical for the maintenance of fruit quality. Any damage to the fruit will increase the rate of deterioration and therefore shelf life.

Timing Of Harvest

The correct timing of fruit harvest is important to maximizing marketable yield and fruit quality. Normal harvest dates for saskatoons vary from early- to late-July. Harvesting of fruit can begin when fruit are at the reddish-purple stage, but it is preferable to wait until about two-thirds of the fruit are fully ripe. Fruit at an early stage of maturity are high in pectin and have greater acidity, and are suitable for processing. Fully mature fruit have higher sugar contents and are better for wine making. Depending on the degree of uneveness of ripening, up to three pickings may be required. The duration of the harvestable period ranges from about five days (under hot, dry conditions) to 15 days (under cool, humid conditions). Fruit quality quickly declines once the fruit are fully ripe. It is better to harvest too soon rather than too late. Green fruit are easier to cull than are fruit that are too ripe.

Saskatoon fruit often do not ripen evenly; this is partly dependent on cultivar and weather, but may also be associated with a variable number of seeds per fruit. Dry weather may increase uneven ripening, but regular irrigation does not appear to completely solve this problem. Too much water may lead to insipid fruit flavour and fruit cracking. Research done at the University of Alberta has indicated that ethephon (at a concentration of 250 to 1,000 ppm), applied six days prior to harvest (when most fruit were still red), significantly enhanced uniform ripening. However, this effect was dependent on the cultivar tested. At present, ethephon is not registered for use on saskatoons.

Picking And Handling Fruit

Fruit should be harvested at their optimum stage of ripeness. Over-ripe fruit should not be picked as they are less firm, more susceptible to decay and have a shorter shelf life. Although saskatoon fruit continue to ripen after picking, harvesting the fruit before they are fully ripe will result in significant reductions in marketable yield. This is because the largest gains in fruit weight of saskatoons occur during the later stages of fruit ripening. Fruit must be handled minimally and gently to avoid injury or crushing. The depth of saskatoons in containers should not exceed 10-15 cm. Containers should have holes or slots on the sides and bottom to permit air movement through the fruit to facilitate cooling.

If fruit are hand-picked, care should be taken to ensure that no twigs or other debris gets into the pail. Pressure from fingers and thumbs can bruise fruit and sharp fingernails can cause damage. Fruit also should not be dropped (a 30 cm fall can be quite damaging). Any poor quality or immature fruit should be culled in the field during the picking process. Clean picking will prevent or minimize the need to clean out debris and sort through fruit after harvest. If practical, hand-pick directly into the containers that the fruit will be marketed in, in order to minimize handling. Machine-harvested fruit will contain immature fruit, twigs and other debris, which must be removed with a blower.

Completing the harvest of fruit early in the morning, or late in the evening, when the air temperature is no greater than 18 to 20ºC, substantially reduces problems resulting from field heat. At this time, outdoor and fruit temperatures are cooler, and less time and energy will be required for subsequent cooling of the fruit. After the fruit are harvested, they should be kept in the shade or covered with reflective tarpaulins to avoid warming in the sun. Fruit left in full sun can increase in temperature from 2 - 8ºC per hour. Reflective tarpaulins have been found to keep fruit temperature lower, and also maintain a higher humidity around the fruit, reducing moisture loss. The fruit should also be protected from the sun and wind during transportation. Refrigerated transport, or some type of portable cooling unit are preferable for transporting fruit.

Fruit should not be harvested if there has been a heavy dew, or immediately after a rain. The fruit should be dry when harvested, otherwise conditions conducive to the development of disease may substantially reduce potential shelf life.

Methods Of Harvest

During the first two to three years of production, yields may be low. It is not economical to use commercial harvesters under these circumstances and therefore U-Pick, or contract hand picking should be considered. Hand-harvesting requires only a low capital cost for equipment and results in less damage to the fruit. Some of the most successful growers hire pickers annually.

Reconditioned, hand-held vibrators (manufactured by BEI) are powered by batteries carried on a cart, cause little, if any damage to saskatoon plants, are sturdy and require little maintenance. Up to four vibrators can be run from the battery cart and a catching frame is used to collect the harvested fruit. A single, hand-held vibrator will enable a grower to harvest 200 to 400 kg of fruit per day, depending on how heavy the yields are.

Mechanical harvesters are often too expensive for growers to afford if their orchards are small. Some budget analyses indicate that an orchard must be greater than 8 ha in size in order for machine harvesting to be economically feasible. Harvesting machines are faster and require less labour, but are harder on the fruit, work better if the crop ripens uniformly and may be better suited to fruit destined for processing.

Mechanical harvesting can be accomplished using pull-type or self-propelled harvesters made by companies such as Joonas, Korvan, Littau or BEI (Figures 5.1 to 5.3). The cost of new machines is high (up to $120,000 or more), but used, pull-type harvesters can be found for less than $10,000. These machines usually need to be modified with the addition of a shrub splitter for more efficient harvest. The Joonas 1500 has been modified specifically for saskatoons. It has been made somewhat larger, more robust, and has greater power and storage capacity. This harvester comes with a removable V-splitter and an optional V-picking head. The V-picking head is preferable because 50% less fruit are lost, more being effectively transferred to the conveyor in the machine which collects the harvested fruit.

Effective machine-harvesting of saskatoons requires that row width at ground level be no more than 50 cm and shrub height no more than two to three m.

Regardless of the method of harvest, a certain percentage of the fruit will be lost. When machine-harvesting, approximately 15% of the fruit will be lost; hand-harvesting results in about a 5% loss of fruit. Additional losses of fruit may occur from culling during cleaning.

The BEI Model H Harvester - An Inexpensive Harvester For Small Or Young Orchards

The BEI Model H harvester, manufactured by BEI Inc. South Haven, Michigan, is a portable, battery-powered, small fruit harvester originally designed for the highbush blueberry industry. The harvesting system (Figures 1 and 2) includes a cart which contains two automotive batteries and a battery charger, two handheld shakers and two catch frames. Production of these harvesters began during the mid 1960's and ended in the mid 1970's. All harvesters currently sold are reconditioned. The cost for the entire harvesting system is approximately US$1600.00.

Figure 1. BEI Model H harvester.

Overview Of Harvester Design

The BEI Model H harvester is powered by two 12 volt automotive batteries. The batteries, two 28 foot cables, a 5 amp battery charger and shakers can be moved throughout the orchard on the cart. Recharging times require 6 to 12 hours using a 110 volt (AC) outlet, depending on the initial charge and condition of the batteries.

The handheld shakers each weigh approximately 0.75 kg and are pistol-shaped. At the end of each shaker are four aluminum fingers. A button switch activates the fingers which vibrate at a frequency of 5100 hertz. The shakers can be raked over or simply pressed against fruit-bearing branches. Fruit are harvested into 115 x 165 cm catch frames. Each frame is covered with plastic fabric with a hole and flap at the back of the frame, used to drain fruit into other containers. The front of each frame is contoured to allow better access underneath the bushes. Hard rubber wheels mounted on the front corners of the catch frame permit the frame to be manoeuvred underneath the bushes and throughout the orchard.

Figure 2. Operating the BEI Model H harvester.

Observations On Use

The BEI Model H harvester effectively removed fruit from saskatoon bushes, but harvesting rate was found to be dependent on the density of fruit on the bush. Trials done at the University of Saskatchewan in 1997 indicated that kilograms of fruit harvested per hour per operator varied from 37.9 for the cultivar Honeywood, to 68.9 for Smoky, to 72.7 for Pembina. These rates included the time required to move the catch frames along the row. Saskatoon yields in 1997 were above average and rates of fruit removal may have been exceptional. Results will likely vary with yield, cultivar, growth habit, pruning practices, and plant size. Sparse yields will significantly reduce harvesting speed. Plants of the cultivars Smoky and Pembina tested were an ideal height, ranging from 1.5 to 2.5 m. The cultivar Smoky was particularly easy to harvest since its fruit-laden branches hung over the catch frames. Honeywood bushes were too tall (approximately 3.6 meters) to easily harvest the fruit from the higher branches.

The BEI Model H harvester was also used to harvest fruit from the Native Fruit Development Program's saskatoon cultivar trials during the 1997 and 1998 seasons. All the cultivars could be harvested by this method but not with equal ease. Large-fruited cultivars such as Thiessen were easiest to harvest. Cultivars with smaller fruit and less rigid branches such as Regent were more difficult to harvest but not impossible.

The BEI Model H harvester is a logical choice for small or young orchards. Harvesting was much faster than hand-picking and fruit were of superior quality. Very few over-ripe or unripe fruit were harvested and a single carefully-timed harvest could be used to remove most of the fruit. During hand-picking, fruit that are difficult to remove are often squashed, which increases the amount of moisture around the fruit and the risk of fruit spoilage. The natural appearance of the saskatoon fruit was preserved when harvested using the BEI Model H harvester since the delicate bloom was not removed. Since the fruit are picked more quickly, time in the field prior to cooling can be reduced, thus accelerating the removal of field heat and improving storage life.

Some operators found the shakers too heavy and/or the vibration in their hands and wrists unbearable. Switching operators between bushes and limiting total harvesting time to about 3 hours helped avoid operator fatigue. An increased amount of debris such as twigs, leaves and insects, was harvested along with the fruit as compared with hand-picked fruit. This debris was easily removed using a commercial fruit cleaning machine.

Plate 5. Harvest & Post-Harvest Handling

Figure 5.1: Korvan self-propelled harvester (Photo by M. Bantle).

Figure 5.2: BEI pull-type harvester (Photo by M. Bantle).

Figure 5.3: Joonas harvester (Photo by M. Bantle).

Figure 5.4: Sorting saskatoon fruit (Photo by J. Davidson).

Figure 5.5: Freezing saskatoon fruit (Photo by J. Davidson).

Figure 5.6: Fresh saskatoons packaged for shipping (Photo by J. Davidson).

Postharvest Handling & Storage Of Saskatoons

Richard G. St-Pierre, Ph.D. (January 2006)

Factors Affecting The Shelf Life Of Fruit

Fruit quality, that is, flavour, color, texture and size, generally improve as the crop approaches maturity. Unfortunately, ripening increases the sensitivity of the fruit to damage and decay from handling. Fruit begin to deteriorate as soon as they are harvested. Fruit are comprised of living cells and continue to respire after harvest. Respiration involves the uptake of oxygen from the atmosphere and the release of carbon dioxide, moisture and heat. Moisture loss causes fruit to dehydrate and the heat produced causes loss of quality, in particular flavour. Freshly-harvested fruit are prone to injury and attack by micro-organisms, and high temperatures during harvesting increase the susceptibility of fruit to fungal infection. Therefore, effective temperature management is crucial for maintaining post-harvest quality and prolonging shelf life of saskatoons.

In general, the following factors have been found to decrease the shelf life of fruit: a) excessive use of nitrogen fertilizer; b) an excess of water; c) fruit damage resulting in cracks and abrasion allowing access by disease-causing organisms; d) fruit picked prior to optimal maturity; and e) long delays between harvesting and storage.

Fruit quality may be maintained by appropriately timing harvest, minimizing bruising and handling, harvesting early in the day to minimize heat load, cooling the fruit as quickly as possible, and transporting the harvested crop to market as quickly as possible.

Rapid Field-cooling Of Harvested Fruit

Freshly harvested fruit should be placed in clean, shallow trays that are rigid and reusable. The trays should have openings that permit heat to escape and allow cool air to enter. To prevent crushing and permit cold penetration, the depth of fruit in the containers should not exceed 15 cm. The trays should be routinely cleansed to prevent the accumulation of microorganisms and other unwanted residue.

The trays with the harvested fruit should be kept in the shade or covered with reflective tarpaulins to avoid warming in the sun. Fruit left in full sun can increase in temperature from 2 - 8ºC per hour. Reflective tarpaulins have been found to keep fruit temperature lower, and also maintain a higher humidity around the fruit, reducing moisture loss.

Rapid cooling of fresh fruit after harvest is essential to maintain quality and lengthen shelf life. Pre-cooling of the fruit prior to storage is required to remove the field heat and reduce the heat of respiration as quickly as possible. Cooling should commence as soon as possible and should be completed within 6 hours after harvest in order to maintain fruit quality. Fruit sugars, acidity, and other flavour components, as well as moisture will be lost through fruit respiration if cooling is delayed. It is estimated that for every hour delay in cooling, shelf life is reduced by one day.

Cooling of fruit does not occur at a constant rate. The initial cooling rate is quite rapid as there is a large difference between the temperature of the air in the cooler and that of the fruit. However, the cooling rate decreases substantially as the fruit temperature approaches the air temperature. For example, if 5 hours are required to remove 50% of the field heat, then 10 hours of cooling are required to remove 75%, 15 hours to remove 87.5%, and 25 hours to remove 97% of the field heat.

Decay organisms thrive on warm fruit, decreasing their shelf life. Gray mold (*Botrytis cinerea*) is the most common fungal organism causing postharvest fruit decay in small fruits including saskatoons. Although this fungus continues to grow even at 0ºC, its development is significantly reduced at this temperature. Saskatoon fruit should be cooled and stored as close as possible to 0ºC.

In general, room cooling (that is, placing fruit in a storage cooler) is not an efficient means of quickly cooling large quantities of fruit even with evaporator fans set on high. In addition, the high air circulation and heavy load on the cooling unit required to remove field heat from newly-harvested fruit can dehydrate previously cooled fruit stored in the cooler. A standard room cooler is intended only to maintain the temperature of precooled fruit using a low air circulation rate. Depending on the quantity of fruit and the refrigeration capacity of the cooler, fruit from the field often take up to 24 hours or longer to reach 0ºC in a room cooler. Room cooling is generally used for produce such as potatoes or citrus fruit with low respiration rates and a relatively long shelf life.

A number of more effective methods are available to rapidly cool fruit including ice cooling, hydrocooling, and forced-air cooling. Cooling with ice usually involves spreading crushed ice over the containers of fruit using a ratio of 1 part ice to 3 - 4 parts fruit by weight. Sealed cold packs can remedy the situation, but excess condensation may be a concern. Cold packs have the benefit of being reusable. An ideal product is a reusable ice substitute such as that manufactured by Cryopak Corporation. This is a versatile product purchased in rolls which can be cut to size. The coolant in the Cryopak ice substitute is food grade material, thus eliminating any concerns with accidental leakage. In hydrocooling, fruit are showered or immersed in chilled water. These two ‘wet’ methods of cooling can be quite effective, but unless the fruit are to be frozen or processed, the excess moisture left on the fruit can contribute to the growth and spread of disease. Chlorination of hydrocooled water, while controlling the spread of microorganisms, can create worker safety and disposal problems, depending on the chlorination compound and concentration used. Although hydrocooling is very rapid, it does not lend itself well for use by producers with small operations, or for containerized fruit that are cooled after packaging.

Forced-air cooling is commonly used and recommended for small fruit crops. Forced-air cooling is considered the most efficient and effective means to cool small fruits. In forced-air cooling, cold air is forced through containers of fruit in order to remove field heat as rapidly as possible. Forced-air systems can be set up in a number of ways but all involve creating a pressure gradient across the two sides of a stack of produce. This is usually accomplished by using a fan to draw cold air through stacked containers within a cooler. Forced-air systems can utilize either horizontal or vertical air flow. Horizontal flow has the disadvantage that a large portion of the air can bypass the fruit through the head space above the fruit in the containers. In vertical flow, all the air must pass through the entire mass of fruit making this method more efficient.

In a common horizontal system, two rows of pallets of fruit are lined up starting from one wall of the cooling room. A space of 0.6 - 1 m is left between the two rows and a fan is centered on this gap placed at the end opposite the wall. The top of this space is covered with a tarp or plywood to create an enclosed tunnel. The fan will then pull air from the outside through the containers of fruit. If fewer stacks are available, one row of pallets can be arranged starting against the wall and 0.6 - 1 m out from a corner of the room; the tunnel can then be created between the stacks and the wall.

Cool air contact with all of the fruit during cooling is critical, otherwise fruit in the interior of the containers will not be properly cooled, and will continue to respire and lose quality. For forced-air cooling to be effective, fruit containers must have openings on at least 15% of their surface to permit air to pass through. The holes in the containers should not be blocked by boxes or pallets (if vertical air flow is used). To achieve the best results, the containers of fruit must be stacked and arranged to allow air to come in contact with the fruit and not bypass around. The end of the stacks must be set tightly against the wall and the pallets against each other to minimize air gaps. Closing off outside cracks between the pallets with foam rubber increases the cooling efficiency and decreases the cooling time. This system should be set up to cool fruit quickly, ideally within two hours. Cooling time will depend on the fruit temperature, the amount of fruit to be cooled at one time, fan size, and the refrigeration capacity of the cooler. If cooling is not rapid enough, a larger fan may be required. Forced-air cooling can be up to 10 times faster than room cooling.

Ideally, forced-air cooling should take place in one cooler and cold storage in another. A high refrigeration capacity is required for a forced-air system to handle the large amount of field heat to be removed. For example, 100 times more refrigeration capacity is required to cool pears in 24 hours than to keep them in cold storage for this time. Cooling rooms with large evaporators need to run less often which makes it easier to maintain a high humidity in the room. Humid air minimizes fruit moisture loss and has a greater capacity for removing heat than dry air. Cooling rooms that are used for storage require a smaller refrigeration capacity as they only need to maintain the temperature of the precooled product.

Growers with small orchards and only one walk-in cooler may be able to improvise. The forced-air system can be set up at one end of the cooler and storage at another. However, the refrigeration capacity of the cooler must be sufficient to remove the field heat, otherwise the room temperature will warm, lengthen the cooling time and cause condensation to form on already cooled fruit. The forced-air system should be set up under the evaporator coils and the already cooled fruit stored at the opposite end of the cooler. This allows the cold air from the evaporators to contact the cold produce first (as the air flows over the tunnel of fruit to be cooled), otherwise the cold air would first contact the hot produce, warm up, and then would come in contact with the cold produce, causing undesirable condensation. Stored fruit should be arranged in such a way to allow for good air flow within the cooler.

A simple form of a forced-air system can be adopted by producers with small operations, who do not have the fruit volume for the typical set up. Recently-picked containers of fruit can be set into a cardboard box which is opened at both ends. A household fan is then placed at one end of the box pointing outward to draw air through the containers of fruit. Alternatively, the top and sides of a row of stacked trays of fruit can be wrapped in plastic leaving the narrower ends open. A fan can be positioned at the narrow end of the row to draw air through the stack of fruit.

The absence of water in forced-air cooling avoids the spread and growth of mold and bacteria which can be a problem when using ice or hydrocooling. However, the disadvantage of forced-air cooling is that it can cause dehydration of the fruit. If the forced-air cooling unit is within a cooler that is also used for storage, the high air flow through the cooler can result in excessive moisture loss from previously cooled fruit unless they are covered with plastic. The fruit will constantly lose water to any atmosphere that is drier than the interior of the fruit. To minimize water loss from the fruit during forced-air cooling, the humidity should be maintained at 90-95% within the cooler. Some growers have found that wetting the walls and floors of the cooler is effective in maintaining a high humidity. A cool mist humidifier or some other form of humidification may need to be installed. Once the fruit are cool, containers or flats can be wrapped in plastic to reduce moisture loss from the fruit during storage and to prevent condensation forming on the fruit when removed to warmer temperatures.

Cooled fruit should be kept cold through all subsequent processes including transportation and storage. If the fruit are brought into a warm environment after cooling, condensation will form on the fruit, unless the containers are covered with plastic. Thus it is important to avoid warming of packaged fruit until the fruit reach the retail counter. Because it is difficult to avoid warming and cooling of the fruit during the transportation and marketing process, some blueberry growers only cool their fruit to 5°C so that condensation will more likely be prevented; however this will also shorten the shelf life. The plastic wrap covering the fruit can be removed after the fruit have warmed on the retail counter; any condensation will have formed on the plastic wrap rather than the produce.

Refrigerated transport is intended only to maintain the temperature of the cooled fruit and is not designed to remove field heat from the fruit. Transport trailers should be cooled prior to loading the fruit. Containers or pallets of fruit should be arranged in the trailer away from the side walls, allowing for good air circulation around the stacks of containers. The time of loading and unloading of the fruit, as well as time in transit, should be kept to a minimum.

All postharvest handling and cooling systems must be appropriate in size, cost and performance to suit the grower. The systems should also be adaptable for future expansion to support increasing production. Each step in the process, from harvesting, to cooling, and to storage, should be designed to work together. For example, the capacity of the handling and cooling systems must match the capacity of the harvester. Proper handling, cooling, storage and transport of the fruit all contribute to ensuring that a good quality product reaches the consumer.

Cleaning & Sorting Fruit

Cleaning fruit is a slow, messy job, and the primary bottleneck to getting the harvested fruit to market. The maintenance of consistent fruit quality is important.

The cleaning and sorting line should be as cold as is practical. Cooling costs will be reduced if fruit go through the cleaning and sorting process prior to rapid cooling. However, this should only be done if the fruit can make it from the field, through the sorting and grading process, into containers, and rapidly cooled within 3 - 4 hours of harvest. Fruit can benefit from rapid and immediate cooling even if some rewarming occurs during subsequent handling.

The process of cleaning is far slower than harvesting. Two to three cleaning tables will be required to keep up with a mechanical harvester. If fruit are hand-picked, the pickers can be trained to pick only those fruit that appear to be marketable. Machine-harvested fruit need to be cleaned of leaves and twigs. Regardless of the method of harvest, the fruit will need to be examined on some form of conveyor system in order to cull green and red fruit, leaves, fruit stalks, diseased or damaged fruit, and overripe or mushy fruit (refer to Figure 5.4, Plate 5 in factsheet 14.1 on harvesting saskatoons).

Machines used for cleaning and sorting should be made of stainless steel, should have a variable speed fan, an adjustable air flow, a white conveyor belt, and troughs for culled fruit.

An airdraft berry cleaner equipped with a sorting table (Figures 1 & 2) can be purchased from Hometown Machines (Sundre, AB) at a cost of approximately $9,000. With three persons on both sides of the sorting table (3.7 m (12 ft) long, 1.8 m (6 ft) high, and 0.8 m (30 in) wide), 20 kg of fruit can be sorted in less than 30 minutes. A similar cleaner equipped with a 3.1 m (10 ft) sorting table can be obtained from BEI

(South Haven, MI) at a cost of approximately US$9,000.

Figure 1. Top view of an airdraft berry cleaner.

Figure 2. Sorting table.

Washing Fruit

Unless the fruit are to be frozen or immediately processed, washing of fresh fruit is not advisable, as any excess moisture remaining on the fruit can contribute to the spread and development of disease. Consumers are accustomed to washing fresh produce prior to eating.

Fruit intended for frozen storage or processing needs to be washed prior to freezing. The reason is that most secondary processors do not wash fruit prior to processing. Therefore, it is important that primary processing should include a washing step. However, for small operations, washing fruit does not appear practical. The water used for washing must be potable (i.e. free of toxic chemicals and not contaminated with micro-organisms).

Washing removes dirt and chemical residues from fruit surfaces. After washing, the excess moisture on fruit surfaces needs to be removed prior to freezing. Drying is therefore necessary; drying avoids clumping of fruit during freezing.

A washing/drying unit can be purchased from BEI at a cost of approximately US$9000. This unit is 3.1 m (10 ft) long, 1.5 m (5 ft) high, and 0.8 m (30 in) wide (Figure 3). Machines used for washing and drying should be made of stainless steel, should have a variable speed motor, a stainless steel mesh conveyor belt and troughs to remove culled fruit during final inspection. A longer conveyor belt allows for more effective drying.

It is important to remember to routinely clean harvesting equipment, coolers and processing facilities. This is necessary to avoid contaminating clean fruit and to ensure optimum quality of stored fruit. Growers must also be aware that care must be taken to ensure good sanitary practices when handling fruit. Good sanitary conditions must also be provided in the work place. Some potential ways in which fruit can become contaminated by people is by touching other body surfaces (such as skin, hair, nose, mouth), coughing, sneezing, using toilet facilities, or any other activity in which hands become soiled.

Figure 3. Primary processing line showing airdraft cleaner and washing/drying unit.

If the fruit are bagged, the bags should not be tied shut with a twist tie because these can get mixed in with the fruit. It is better to tie the actual bag, or use brightly-colored string. Figures 5.5 and 5.6 (refer to Plate 5 in factsheet 14.1 on harvesting saskatoons) illustrate two methods of packaging and marketing fresh saskatoons, including freezing and fresh-packaging the fruit.

Optimal fruit quality (i.e. flavour, colour, texture and nutritive value), fruit size and fruit weight are important characteristics for marketing fresh fruit. These quality characteristics can be attained by harvesting fruit at full maturity (purple fruit) and by proper handling of fruit after harvest. Good temperature management during harvesting and at post-harvest is critical for maintaining quality and prolonging shelf life, and can be achieved by harvesting in the cool hours of the day (early in the morning or late in the evening), promptly cooling fruit to remove field heat, promptly cleaning fruit to remove diseased and damaged fruit, and holding fruit at or near the optimum storage temperature during transportation and primary processing.

Storage Of Fresh Fruit

Fresh saskatoons in marketable condition can be stored for a minimum period of two weeks using modified atmosphere packaging (MAP). Modified atmosphere packaging is a storage method that involves wrapping fruit with plastic. The plastic packaging modifies the atmosphere around the fruit by decreasing oxygen levels from 21% (atmospheric level) to 1 to 2%, and increasing carbon dioxide levels from 0.03% (atmospheric level) to well above 5%. By altering the atmospheric composition around the fruit, respiration and other chemical processes associated with fruit deterioration are substantially slowed down. Modified atmosphere packaging also creates high humidity around the fruit, thus preventing dehydration, and decreases the activities of decay organisms. The consequence is that fruit quality is maintained and shelf life extended. It is important to note that modified atmosphere packaging is only effective if fruit are stored at low temperatures. For saskatoon fruit, the optimum storage temperature is 0˚C.

Fruit destined for retail markets can be stored in half-pint plastic containers (typically used for packaging strawberries and blueberries) which are placed in cardboard boxes. The cardboard boxes must be wrapped in plastic and heat-sealed. This is necessary to effectively modify the atmosphere around the fruit in order to maintain a high relative humidity (85-90%), and to slow the growth of micro-organisms.

Modified atmosphere packaging can be obtained from Unisource Canada, Saskatoon or Regina, SK (code 039029), or from Winpak Ltd.,Winnipeg, MB, as roll stock (PAE 2060 L) or as a stock pouch (VAK 3 L).

Modified atmosphere packaging allows a minimum storage period of two weeks. This is sufficient time to transport fruit from the processing centre to retail markets. Several market avenues currently exist for fresh fruit but the major limitation is a consistent fruit supply. It is important to remember to transport fruit in a cool environment. This is necessary precaution to continue maintaining fruit quality and prolonging shelf life.

Pallet loads of fruit, stacked in two or three Fish 'N Farm trays, can be stored for at least one week by wrapping the pallet with plastic and heat-sealing. Fruit can then be stored at 0˚C. No more than three trays should be stacked on a pallet. More trays allows the accumulation of excess moisture in the lower trays, which could increase the susceptibility of the fruit to disease.

Frozen Storage

For optimum freezing quality, fruit must be frozen as quickly as possible. A blast freezer or a cryogenic freezer (to produce individually quick frozen, or IQF, fruit) can be used. Although a cryogenic freezer is faster at freezing fruit than a blast freezer, the costs of operating are much higher.

For blast freezing, the fruit are placed in Fish 'N farm trays and frozen. These trays are effective for freezing because the slots at the sides and bottom allow for rapid air movement which hasten the freezing process. Trays can be stacked to create freezer space. After freezing is completed (usually within 2 to 3 hours depending on the freezer temperature), the trays containing the fruit are wrapped with plastic. Wrapping minimizes freezer damage and maintains frozen fruit quality. The frozen fruit should be stored at -20˚C to -40˚C. Lower temperatures are more effective for prolonged storage. For cryogenic freezing, after the freezing operation is completed, the fruit are wrapped with plastic and stored at -20˚C to -40˚C. As a general rule, temperature fluctuations in the freezer should be minimized to ensure good fruit colour, texture and flavour. Household deep-freezers should not be used. These freezers are not equipped for freezing large quantities of fruit, are characterized by large temperature fluctuations, and decrease fruit quality.

Research conducted at the University of Manitoba has shown that saskatoon fruit can be frozen within 1 hour to -10˚C using an on-farm blast freezer. The temperature of the freezer was -30˚C ; the temperature of the incoming fruit was 5˚C. The prototype freezer consisted of a compressor, and an evaporator with a fan enclosed in an insulated chamber (2.4 m (8 ft) wide x 2.4 m (8 ft) long and 3.1m (10 ft) high). During the operation of this freezer, air circulating from fans draws heat away from stacked trays of fruit. The capacity of the blast freezer was 600 kg and the trays used were Fish 'N Farm trays.

Further Reading

Mitchell, F.G. 1992. Cooling Horticultural Commodities. I. The Need for Cooling. pp. 53-56 in Kader, A.A. (ed.). Postharvest Technology of Horticultural Crops. University of California, Division of Agriculture and Natural Resources. Publication 3311.

Mitchell, F.G. 1992. Cooling Horticultural Commodities. II. Cooling Methods. pp. 56-63 in Kader, A.A. (ed.). Postharvest Technology of Horticultural Crops. University of California, Division of Agriculture and Natural Resources. Publication 3311.

Rogiers, S.Y. and N. R. Knowles. 2000. Efficacy of low O_2 and high CO_2 atmospheres in maintaining the postharvest quality of saskatoon fruit (*Amelanchier alnifolia* Nutt.). Canadian Journal of Plant Science, Volume 80, Pages 623-630.

Quality & Nutritive Value Of Saskatoon Fruit

Richard G. St-Pierre, Ph.D. (January 2006)

Introduction

Orchard management techniques and cultivar selection can have a substantial effect on fruit quality. Once fruit is harvested, quality rarely improves, therefore storage and delivery systems must be able to maintain the quality of the fruit until it reaches the consumer. Fruit which deteriorates or falls below acceptable quality before it can be sold, decreases profits.

Fruit quality characteristics are evaluated to determine which cultivars are the best for specific purposes, better orchard management practices, harvest techniques, the effect of storage and/or the feasibility of processing.

How Is Fruit Quality Determined?

Fruit quality is defined in terms of chemical, physical and sensory characteristics. Microbiological analysis is not routine in the testing and grading of fresh fruit, although it is expected that the fruit would be free from visible growth of molds or bacterial rot. Physical analyses include size, texture, viscosity, colour and fruit firmness before and after storage. Chemical analyses include dry matter content, sugar content, acidity levels, moisture content, benzaldehyde content (this chemical is responsible for the almond flavour found in cooked saskatoon fruit). Sensory characteristics include sight (colour, size, shape, cosmetic appearance), smell (aroma of the fruit), touch (texture), taste (flavourful, sweet, sour, salty or bitter), or sound (the crispness of an apple).

Fresh Weight

Fresh weight refers to the weight in grams of a single fruit or the weight of a stated measure of fruit (eg. weight per 250 mls of fruit). Fruit seediness is correlated with fruit weight; larger fruit generally have more seeds.

Soluble Solids Or Dissolved Solids Content

Soluble solids are the sugar content of the fruit. Soluble solids content is often reported as °Brix. A reading of 12 °Brix would indicate a sugar content of the fruit of 12%.

Dry Matter Or Moisture Content

Dry matter content is a measure of the quantity of total solids in the fruit. Dry matter content is determined by removing all the moisture from the fruit and then weighing the solids which remain. It is generally reported as a percentage. A dry matter reading of 13.5% indicates that in 100 grams of fresh fruit, there were 13.5

grams of solids and 86.5 grams of moisture. Some analysts will report the moisture content, which would be 86.5%; either method of reporting is acceptable.

Colour

A very common colour analysis method utilised by the food industry is done with the Hunterlab Colorimeter. It is a detector which reports the degree of lightness or darkness and redness or blueness of a fruit sample and gives these characteristics a numerical value.

Anthocyanin Content

Anthocyanins are the chemical components of fruit responsible for the red and blue colours. Cyandin-3-galactoside is the major anthocyanin in saskatoon fruit.

pH

pH is a measure of acidity and the pH scale is calibrated from 1 to 14. Measurements below 7 indicate an acid solution and measurements above 7 indicate that the solution is alkaline or basic, while a reading of 7 indicates neutrality. The pH of foods is used as an indicator of bacterial spoilage. Foods closer to neutrality are generally more susceptible to microbial spoilage. Fruits are on the acid side of the scale and therefore slightly more resistant to bacterial spoilage.

Titratable Acidity

Titratable acidity is a measure of the quantity of organic acids within the fruit and can be reported on a gram or percentage basis. It can be a useful measurement for determining if fruit are under or over-ripe.

Firmness

The amount of force required to compress or shear a sample of fruit can often be an indicator of fruit quality. Fruits which are too firm or too soft can be over- or under-ripe. This test can be useful when assessing various storage regimes.

Preliminary Evaluation Of Fruit Quality Of Saskatoon Cultivars

Saskatoon fruit collected from 16 cultivars from five sites in Saskatchewan were evaluated for fruit quality after the 1995 crop year. Although these results are preliminary, the results of this work follow.

Soluble Solids Content

At irrigated sites, the fruit collected had a range of soluble solids content of 9.1 to 16.9 ^{o}Brix. At an unirrigated site, soluble solids content was 16.8 to 22.9 ^{o}Brix. Soluble solids can be manipulated by the quantity of water applied through irrigation to the crop.

Moisture Content

The fruit from irrigated sites had moisture contents ranging from 76.9 to 84.1%; fruit from the unirrigated site were lower in moisture and ranged from 71.2 to 77.4%. Fruit from the unirrigated site were smaller, sweeter and contained less moisture. Such fruit may be very good for processing into jam and jelly, but might not be as acceptable to a U-Pick customer.

Anthocyanin Content

The anthocyanin content of the fruit was analyzed to determine if differences could be detected amongst cultivars. During the 1995 growing season, only 5 cultivars produced fruit in sufficient quantities to be analyzed for anthocyanin content. The analyses indicated that there were cultivar differences. The cultivar Martin had a higher anthocyanin content than did the cultivars Regent, Parkhill, or Honeywood.

pH

The results of the pH analyses indicate that the cultivars analyzed had a wide range of pH's which could have an effect on processing quality. Fruit with a low pH, Martin (3.69) and Thiessen (3.72), had greater anthocyanin contents than did Honeywood (pH 4.02) and Regent (pH 4.03). Fruit with a low pH have a more intense color.

Hunterlab Colour Analysis

A weak juice extract and the whole fruit of each cultivar were analyzed for colour using this instrument. It was noted that those cultivars with higher pH's produced juice extracts which were less purple in colour and in extreme cases turned an apricot - brown colour when heated. There was very little difference among cultivars in the purple colour of ripe saskatoon fruit which had been frozen, thawed and tested.

How Are Fruit Quality Analyses Utilized?

Fruit quality analyses are used to to determine if the fruit are ready to harvest, if the fruit are of acceptable quality for processing, to improve current cultivars, and to allow fruit breeders to assess potential new cultivars.

As saskatoon fruit mature, the fruit changes from a green to red to a deep-purple colour. Once this has occurred, it is assumed that the fruit have completed ripening. Over-ripe fruit will also be this deep-purple colour. Harvesting fruit when they have reached the just-ripe phase may allow for longer storage and transit times than if fruit are allowed to over-ripen.

In blueberry crops, a maximum ratio of soluble solids to titratable acidity of 18 is considered desirable for fruit that are to be transported to market. As blueberries become over-ripe, the amount of titratable acidity begins to decrease. This decrease in the titratable acidity causes the sugar to acid ratio to rise above 18 and therefore the fruit are less desirable to buyers.

Processors of fruit products may have specifications which the fruit must meet to be considered acceptable for processing. Processors may require certain cultivars known to have characteristics which are desirable for their products, they may require the fruit to be chilled immediately after harvest and shipped in this manner to prevent the continued respiration of the fruit, or their demands may be as simple as wanting a shipment of saskatoon fruit with an average sugar content of

16°Brix. These processors may use one or several of the above tests to determine if they are receiving the fruit required for their method of processing.

Improvements in cultural practices can lead to improved fruit quality, therefore fruit quality analyses are useful for comparing results of orchard management techniques. Once the quality characteristics of the currently available saskatoon cultivars have been adequately defined, it will be much simpler to assess new selections to determine if they are superior in any way.

Nutritive Value Of Saskatoon Fruit

The following table provides an overview of the nutritive value of saskatoon fruit in terms of the typical characteristics of water content, sugars, fat, protein, fiber, mineral constituents, and caloric content.

Characteristic	Value	Comments
Water	75 to 80%	
Sugar	11 to 19%	Primary sugars are fructose & glucose
Protein	1.9 to 9.7%	
Fat	0.8 to 4.2%	
Fiber	3.8 to 19%	
Iron	55 to 79 ppm	12 to 22% of RDA; higher than blueberries or strawberries
Potassium	244 to 300 mg/100 g fruit	10% of RDA; higher than blueberries, strawberries or oranges
Magnesium	400 mg/100g fruit	100% of RDA; higher than blueberries or strawberries
Calcium	88 mg/100 g fruit	11% of RDA; higher than red meats, most vegetables & cereals
Sodium	0.6 to 1 mg/100 g fruit	low
Manganese	1.4 mg/100 g fruit	34% of RDA
Carotene	0.59 mg/100 g fruit	20% of RDA
Seed to Pulp Ratio	7.6 g/100 g fruit	
Calories	55 to 75 kcal/100 g fruit	

RDA = required daily allowance; ppm = parts per million

Saskatoons As Nutraceuticals And Functional Foods

Nutraceuticals are products, obtained from foods, which offer health benefits including the treatment and prevention of chronic diseases. These products are sold in powders, pills and other medicinal forms. Functional foods are foods, in natural or processed form, which are consumed as part of a diet, but which contain substances that promote health, physical capacity and the mental health of an individual.

Fruits and vegetables contain natural chemicals which may help to reduce the incidence of chronic diseases. For saskatoons, these natural chemicals include some that are called phenols. Phenols protect plants from oxidation damage, that is, they are antioxidants, and in the human body they carry out the same function. The phenol group includes a subgroup called anthocyanins. Anthocyanins are responsible for the purple colour of saskatoon fruit and have antioxidant properties. Antioxidants may help prevent heart disease, stroke, cancer, cataracts, Alzheimer's disease, arthritis and other chronic illnessess associated with aging. Because saskatoon fruit contain an abundance of anthocyanins, they represent opportunities for the development of new health-promoting products, namely nutraceuticals and functional foods.

Saskatoon fruit are comparable to bilberries and blueberries in terms of total antioxidant activity but with respect to anthocyanin content, bilberries contain 2-3 times as much anthocyanins as saskatoons and blueberries. Bilberries are currently the standard for comparing anthocyanins among other small fruit. The anthocyanin content of saskatoons and blueberries is close. Processing saskatoons into syrups, jams, pie-fillings, toppings and juice concentrates may increase antioxidant activity and anthocyanin content because these value-added products contain concentrated fruit extracts.

Saskatoon fruit also have potential to become natural food colourants. Anthocyanin pigments are being considered as replacements for banned artificial dyes in foods; anthocyanins dissolve easily in water and they have an attractive colour. Because of the abundance of anthocyanins in saskatoons, the fruit can be incorporated into processed foods.

Further Reading

Mazza, G. 2000. Potential Health Benefits of Saskatoon Berries. Prairie Fruit Journal Volume 7, Issue 1, Pages 3-4.

Disclaimer: This publication was designed to be an educational resource for individuals who are interested in growing saskatoons, in orchards, shelterbelts, or gardens. Every effort has been made to ensure the accuracy and effectiveness of the information in this publication. However, the author makes no guarantee, express or implied, as to the information and procedures contained herein. The information cannot be guaranteed because knowledge of the biology and culture of the saskatoon may not be applicable to all locations every year. Additionally, the information that is available often changes over time. Little scientific research has been done on many aspects of the culture and management of saskatoons. Consequently, this publication can only serve as a guide. All actions taken which are based on the information presented in this publication are solely the responsibilities of the readers or users, and the author is not liable for any direct, indirect, incidental, or consequential damages in connection with or arising from the furnishing, performance, or use of this material. Comments on information contained in this publication are welcomed.

Factors Affecting Fruit Yield & Quality

Richard G. St-Pierre, Ph.D. (January 2006)

Factors Affecting Fruit Yield In Saskatoons

The production of fruit yield is an astonishingly complex process dependent on a wide variety of factors and processes. Fruit yield depends on such things as number of plants in the orchard, plant maturity, plant structure, number of flower clusters/plant, number of flowers/cluster, and fruit size. Processes that affect fruit yields include pruning, irrigation, fertilization, and pollination. Environmental factors that affect fruit yields include the occurrence of frost, amount of sunshine, length of the growing season, amount of heat available during the growing season, insect pests and diseases. Two critical periods during the growing season include the time surrounding flowering when cool and freezing temperatures can have significant negative effects on effective pollination and fruit set, and during July and August when the flower buds for the following year begin to form.

Actual yield is a result of interaction among weather, soil, insect pest and disease problems, and orchard management. Specific insect and disease problems of fruit obviously directly reduce yield and are simple to observe. Harvest losses due to overripe fruit, bird damage, harvester efficiency, and culls from cleaning may substantially reduce marketable yield.

Other causes of yield reduction are not as simple or direct in their effects. Yield is correlated with the amount of light intercepted by the plant. This is associated with orchard planting design, pruning, training, and leaf damage. Shading of stems in the center of a shrub may decrease potential yield by 25%. A north-south row orientation and adequate thinning of stems will help maximize light interception. Control of leaf-feeding insects is important because the activity of these pests reduce the capacity of the plant to harvest light. Water stress reduces the photosynthetic activity of the plant. Under conditions of water stress, the leaf stomata (pores) close, and the amount of carbon dioxide that is converted to sugars (plant food) may be substantially reduced. Consequently, it is important to monitor soil moisture levels and irrigate adequately when necessary. Growers have little control over factors such as the amount of sunshine, length of the growing season, or the amount of heat available during the growing season.

The primary causes of poor fruit crops in saskatoons include: a) saskatoon bud moth (causes flower loss); b) *Entomosporium* leaf and berry spot (makes fruit unmarketable); c) wind and heavy rain during flowering (decreases effective pollination resulting in loss of potential fruit); d) frost (causes flower and fruit damage and loss); e) saskatoon sawfly (causes fruit loss); e) brown fruit rot (causes fruit loss); f) saskatoon-juniper rust (makes fruit unmarketable); and g) damage from bird feeding (reduces marketable yield).

How Growers Can Maximize Fruit Yield In Saskatoon Orchards

Stressed, unhealthy plants of low vigour produce little or no fruit yield; the maintenance of plant health and reasonable vigour is very important to the production of consistent and economically acceptable fruit yields.

Windbreaks should be used wherever possible to prevent water stress, reduce shoot breakage and leaf tattering, and to reduce bruising of fruit.

When pruning, adequate thinning of stems, plus maintaining a vertical orientation of stems, will maximize leaf exposure to the sun, thus maximizing photosynthetic efficiency of the leaves; thick, or overly dense canopies limit the penetration of light which results in poor flower bud formation on interior branches.

Insects and diseases that cause defoliation must be controlled because the loss of leaves may decrease flower bud formation.

The excessive application of nitrogenous fertilizers increases shoot growth and vigour, but decreases the formation of flower buds.

Growers should ensure that leaf chlorosis does not occur in their orchard by monitoring and, if necessary, correcting soil pH and poor drainage.

The excessive application of water also increases shoot growth and vigour, which again inhibits flower bud formation.

Intermittent overhead sprinkling may be used during very hot days to decrease the negative effects of high temperatures, low humidities and to reduce plant stress; grassing down alleys between rows will also help prevent the soil from absorbing too much heat.

Overhead irrigation may be used to prevent frost damage.

Plant Vigor - A Question Of Balance

Adequate plant vigor is important for the maintenance of fruit plant health, and for consistent, adequate fruit yields. Vigor is defined in terms of adequate yearly shoot growth, shrub size, leaf color, and yield. Initial vigor is important for effective plant establishment and fruit production at an earlier age.

Poor plant growth may be associated with an excessively low or high soil pH, moisture stress, poor soil structure, low soil nitrogen levels, insufficient available phosphorus, cold or heat stress, poor quality planting stock, insect or disease damage, damage from pesticide drift, inadequate hardening prior to transplanting, root damage, very heavy yields, lack of pruning, or inadequate weed control.

The primary symptoms of poor plant growth include shrubs that appear smaller than normal, short internodes between the leaves, small leaves, and/or poorly developed root systems with few, fine feeder roots. Vegetative growth may be consistently low from year to year, and the plants in question may never be as productive as healthy ones.

Plant vigor is enhanced by rich soils, high soil nitrogen levels, use of mulches, effective weed control, heavy pruning, ample irrigation, and low yields.

High vigor is not necessarily the best for fruit plants. Excessive vigor can contribute to poor fruit flavour and a longer period of non or light bearing. Excessive vigor creates the necessity for more pruning, and may increase the risks of some disease problems and physiological disorders.

Pollination & Fruit Set In Saskatoons

Variation in fruit yield can be associated with the degree of effective pollination. Pollination is the process by which pollen is transferred from the anthers (the pollen producing organs in the flower) to a stigma (the pollen receptive organs in the flower); this process may involve two or more flowers, or only one flower. In the latter case, successful pollination and subsequent fertilization depends on whether a particular crop species is self-fruitful or not. The transfer of pollen usually requires a vector, or carrier, such as the wind or a honeybee.

In most fruits, pollination is required for fruit set and seed development, and fruit growth is dependent upon seed development. Fruit set is defined as the burst of growth of the ovary following successful pollination and is accompanied by petal wilting and loss (petal drop). Multiseeded fruits, such as the strawberry, raspberry, currant, blueberry and cranberry, require adequate pollination, fertilization, and seed development for large, regularly shaped fruit; fruit size is proportional to the number of seeds per fruit.

Pollination and fruit set are influenced by a wide variety of factors. These include the temperature range before, during and after bloom, humidity, pollen source, amount of pollen, the presence and degree of activity of the required pollen carrier, leaf area, light intensity (or amount of shading), supplies of carbohydrates, nitrogen and other nutrients, amount of rainfall and wind, and the longevity and sterility of embryonic seeds. For example, long, cold winters and cold spring temperatures can reduce the amount of viable pollen, and high spring temperatures can sterilize pollen; both can result in less effective or no pollination and possible fruit loss.

Little information is available concerning pollination and fruit set in the saskatoon. Horticulturalists have long recognized that the saskatoon is self-fruitful. Some observations have indicated that pollen can be shed within the flower prior to the petals opening, but the extent and consistency of this phenomenon is not known. Wind may also play a role in pollen transfer, primarily within single flowers or clusters, because the pollen is sticky and forms clumps. Insects do not appear to be strictly necessary as pollen carriers; some beekeepers maintain that the domesticated honeybee is not very interested in the saskatoon. However, numerous wild bees, wasps and flies are present within flowers at flowering time and they may be important for pollination in the saskatoon.

Variability of characteristics for seedlings from controlled crosses and for open-pollinated seedlings is similar, suggesting that cross-pollination is common. Cross-pollination creates seeds that vary in their similarity to the parent plant. Reports differ with respect to the amount of dissimilarity in seedlings compared to the parental material. Propagators report a range of 70 to 95% similarity to the parental stock, with the seedling plants being more or less of equal quality to the parental stock. Because a certain amount of cross-pollination is possible, it is important to only use F1, or first generation, seed. Seed of subsequent generations will be more dissimilar to the parental stock.

Studies done at the University of Saskatchewan suggest that supplementary pollination of the saskatoon may increase fruit set, but at the expense of producing somewhat seedier fruit. Interestingly, 20% of flowers in which pollination was completely prevented set fruit. The fact that no pollination is necessary in some cases suggests the possibility that further manipulation using growth regulating substances could result in the production of relatively seedless fruit.

Irregular Bearing In Saskatoons

Irregular, alternate or cyclic fruit crop production (also called alternate or bienniel bearing) is characteristic of many fruit crops, such as the apple, pear and hazelnut. This phenomenon often consists of a heavy flower and fruit crop one year (the 'on' year), followed by a light one the next year (the 'off' year), although a regular bienniel pattern (one year on, one year off in terms of fruit crop load) does not necessarily exist. It is not unusual for many fruit crop and forest tree species to produce fruit or seed in an irregular, alternate or cyclic manner. However, what this means to the fruit grower is that fruit crop production is inconsistent from year to year, with the consequence of a reduction in yield in the long run.

Irregular bearing appears to be characteristic of saskatoons. The 1995 crop on the prairies was excellent, but flower production appeared considerably lower in the spring of 1996. It is said that over a 10 year period, a grower of saskatoons can expect 2 excellent years, 6 average years, and 2 off years.

Causes Of Irregular Bearing

Irregular bearing is a complex phenomenon. Irregular bearing can be expressed over a large geographic area involving many orchards, on individual plants within individual orchards, and even within individual branches of a single plant.

To some extent, irregular bearing has a genetic basis. In apples, some cultivars such as Golden Delicious, are characterized by irregular bearing, while other cultivars such as Rome Beauty or Jonathon, bear much more regularly. In general, increasing alternation of bearing occurs as the age of the plant increases.

Two sets of situations may bring about irregular bearing: a) an off year caused by a lack of flowers, poor fruit set, or excessive fruit loss; and b) an on year with excessive fruit set, little fruit loss, and too large a fruit crop. The triggers for these circumstances are varied, but appear to be a combination of environmental and physiological factors. Perpetuation of the cycle is of a physiological nature.

It's important to note that, in woody, perennial fruit crops like the apple and saskatoon, flower bud production for the following season begins while the current season's fruit are growing and ripening. The presence of fruit with seeds inhibits flower initiation. The reason for this inhibition is somewhat controversial but appears to be associated with the presence of chemical growth regulators called gibberellins, which are produced by seeds, and the depletion of the tree's carbohydrate supply below that required for flower bud production. The presence of few fruit, or seedless fruit has little effect on flower bud production, therefore many more flower buds are initiated.

Flower loss, poor fruit set, or excessive fruit loss (and subsequently, high numbers of flower buds initiated), may occur for the following reasons:

Frost destroys flower blossoms. The consequence is a smaller fruit crop, and much greater flower bud production with a heavy fruit crop the following season. This heavy crop in turn inhibits flower bud production, and therefore an off season follows.

Cool weather may reduce fruit set by decreasing pollinator activity, or by slowing or stopping pollen tube growth, once pollen is transferred. Low air humidity may decrease the germination of pollen once it has been transferred. Low fruit set results in a smaller fruit crop.

Drought directly reduces fruit set and therefore yield with a potential increase in flower bud production later in the season if conditions are favourable. However, drought later in the season may also directly reduce flower bud production.

The capacity for self-pollination (which is not characteristic of most fruit species, but is for the saskatoon) may actually contribute to excessive pollination in years where cross-pollination associated with increased pollinator activity also is greater. Subsequent excessive fruit set and/or excessive seed production per fruit result in a heavy crop load, or seedier fruit, both of which inhibit flower bud production and therefore result in a poor fruit crop the following year.

Excessive leaf damage and loss from insect feeding or disease can alter the plant's carbohydrate supply thus reducing flower bud initiation, although this may not directly affect the current season's level of fruit production.

The reverse of the above circumstances, seasons characterized by little flower loss, high fruit set, and little fruit loss, mean that low numbers of flower buds will be initiated. The following year, an excessive fruit crop substantially reduces the carbohydrate supply within the plant, which causes root starvation and loss, and consequent mineral deficiencies and imbalance among growth regulators. All of these processes are directly or indirectly related to an inhibition of flower bud initiation, a subsequent off year, and so the cycle continues.

Management Practices Used To Regulate Yields In Other Fruit Crops

Reducing excessive crops in on years, or increasing bloom or fruit set in off years, are two potential means of evening out irregular bearing.

In apples, flower and especially fruit thinning in on or heavy crop years are considered satisfactory ways of evening out crop production, although the use of regularly-bearing cultivars has also helped. A variety of chemicals, including ethephon and carbaryl (Sevin), are registered for fruit thinning in apples. Reducing the crop load by thinning helps regulate the initiation of flower buds.

Excessive irrigation actually may intensify alternate bearing in apples because it stimulates vegetative growth and trunk expansion at the expense of flower development.

Mineral requirements for fruit production are high. In apples, approximately one-third of the nitrogen absorbed per tree per year is used in fruit growth. In years of heavy fruiting, nitrogen reserves may become depleted. Nitrogen deficiencies limit both leaf growth and flower bud production, as well as fruit set. Flower bud production in apples is stimulated by nitrogen fertilization, thereby reducing alternate bearing, and summer applications of nitrogen fertilizers increases fruit set in some cultivars.

However, the relationship between nitrogen fertilization and increased flower bud initiation or fruit set is not a simple one. The carbohydrate to nitrogen ratio appears to be more important. As a result, a balanced approach to crop management is considered a better way of evening out fruit yields.

Managing Irregular Bearing In Saskatoons

At present, it's difficult to say how widespread irregular bearing is in saskatoons, or what the causes are. The following management practices may help even out crop production.

When pruning, yearly thinning of older stems (greater than 2.5 cm in diameter) will help maximize leaf exposure to the sun, thus maximizing photosynthetic efficiency of the leaves. Thick, or overly dense canopies limit the penetration of light which results in poor flower bud formation on interior branches. Additionally, younger stems appear to produce more consistently.

The excessive application of nitrogenous fertilizers which increase shoot growth and vigour, but decrease flower bud initiation, should be avoided. The excessive application of water, which also increases shoot growth and vigour, and again inhibits flower bud formation, should also be avoided. Insects and diseases that affect leaves and cause defoliation must be controlled because the loss of leaves may decrease the formation of flower buds.

Many environmental factors including cool temperatures during bloom, frost, insect pests and diseases are difficult to predict and control, and our knowledge of the timing and amounts of irrigation and fertilization for saskatoons is limited. Consequently the problem of irregular bearing may be ongoing until we become more knowledgable at managing saskatoons as a crop.

Improving Fruit Quality In Saskatoon Orchards

Producing quality fruit requires appropriate plant management. A number of factors influence fruit quality, but plant vigor and light conditions are particularly critical.

Vigor is defined as the amount of shoot growth. Plants of high vigor produce large fruit but the fruit is invariably poorly colored, soft and prone to storage disorders and short storage life. Fruit from plants of low vigor will be small but well-colored and firm, will seldom suffer from storage disorders and will have a longer storage life. A number of factors influence vigor but nitrogen has the most influence. The application of nitrogen should be based on leaf tissue analysis and visual observations. If trees are too vigorous, applications of nitrogen should be reduced or eliminated until the need for it is shown. If trees are too weak, the application of nitrogen should be increased. In addition to reducing or eliminating nitrogen, vigor can often be reduced by reducing irrigation, and/or allowing weeds and a cover crop to grow.

The management of nutrition and irrigation will help control plant size, but will not prevent self-shading; the challenge then is to find the optimum density of stems.

The interception of light and penetration of light to the interior of the plant are both important. Fruit quality is proportional to the amount of sunshine present during the period of ripening, and to the degree that light is able to penetrate the plant canopy. High light levels are required for optimum fruit size, color and sugar content. Consequently, shading within the plant canopy, and shading by other plants must be minimized. Shading can be minimized by controlling vigor, removing shading and upright branches, and adequate thinning of stems.

Fruit cracking is associated with high soil water levels and high humidity. Ripening fruit can only lose excess water by transpiration through the skin; conditions that reduce the fruits' ability to transpire, including high humidity and minimal air movement within the plant's canopy, are likely to increase the incidence of fruit cracking following rain. Cultivars also vary in their susceptibility to fruit cracking.

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Improving Insect Pest & Disease Management Practices In Saskatoon Orchards

Richard G. St-Pierre, Ph.D. (January 2006)

Insect pest and disease damage can cause extensive crop losses in saskatoon orchards. For example, in most growing seasons there are numerous examples of serious yield losses due to *Entomosporium* leaf and berry spot where some growers have given up on their harvest entirely. To a large extent, crop losses caused by insect pest and disease damage can be controlled with timely pesticide applications and by following appropriate management practices. The following information is meant to help growers improve the effectiveness of their applications of insecticides and fungicides.

Pruning to Enhance Disease Control

Growers with saskatoon plants of differing sizes often observe that overgrown areas of their orchard are more seriously affected by disease problems than areas where the plants are not as dense. Other growers have commented that row ends show less disease than row centers and that very sheltered locations have greater disease problems. These examples illustrate the impact of poor airflow through the plant canopy on the initiation and development of disease in an orchard. Recent research suggests that *Entomosporium* leaf and berry spot requires a minimum of 12 hours of continuous leaf wetness for spore germination to occur on saskatoon leaves. Increased airflow through an orchard reduces the risk of disease initiation by reducing the time leaves remain wet following a rain. Seasonal pruning is essential to maintain uniform yields and to keep disease problems in check. Pruning conducted while bushes are dormant will have an impact on air flow and disease development during the growing season. Reducing the number of stems by thinning out older wood (greater than 2.5 cm in diameter) will increase airflow through the orchard and reduce the severity of fungal diseases.

Monitoring for Insect Pest and Disease Problems

It is important for growers to know which insect pests and diseases are likely to be problems in their saskatoon orchards, and to be able to identify these pests and diseases accurately. Regular monitoring and accurate problem identification provide the information necessary to choose the most appropriate management strategy. Monitoring requires surveys for the presence of insect pests and diseases, natural enemies of pest species, developmental stage and health of the crop, soil moisture and weather, at weekly or more frequent intervals throughout the growing season. Records of the results of these monitoring activities will help a grower forecast outbreaks of insect pests and diseases and schedule management practices. Monitoring techniques are beyond the scope of this factsheet because they are often specific to the species of insect pest or disease. However, it's important to note that growers may need to learn some specialized information and techniques to adequately monitor for some saskatoon insect pests and diseases. For further information on specific insect pests and diseases of saskatoons, refer to the Insect and Disease sections of **Growing Saskatoons - A Manual For Orchardists**.

Gathering Diagnostic Data

The key to diagnosing crop problems is careful observation. Diagnosis can be a complex task which requires experience, skill, knowledge and science.

The first step in diagnosis is the initial recognition of the problem because of certain symptoms. A symptom is any noticeable abnormal plant condition. Non-specific symptoms, such as yellow leaves, are common. It is very easy to misinterpret symptoms. Accurate diagnosis takes time and is best done in a structured manner so as to avoid hasty conclusions and misinterpretation.

1) Look for a pattern of damage on individual plants, or on all plants in an area. Are the symptoms consistent, different, uniform, or scattered? It's important to try to determine the distribution of the problem with respect to water drainage, soil, shade, or exposure to wind.

2) What is the frequency or intensity of the problem? Do there appear to be different stages of development of the problem? How long have the symptoms been present in the orchard? What is the history of the site (previous crops, chemical application, standing water, and so on).

3) Are there any signs of disease organisms, insect feeding damage, eggs, webbing, adult or larval insects, fungal organisms, or other causal factors (chemical residues, odors, and so on)?

4) Is there any evidence of recovery by the damaged plant?

5) Are root zones shared by the affected plants?

6) Inspect the interior, crown and roots of plants. Cut open stems, crowns, flowers, fruits and roots. Are there any hidden, internal symptoms (for example, rotten or discolored tissue)? Learn what a healthy root looks like by digging up healthy roots and carefully washing them.

7) What is the condition of the soil (wet, dry, compacted, odoriferous)?

8) Remember that many symptoms are non-specific and that a great variety of causes may be manifested by the same symptom(s).

Additional useful information includes the following: 1) cultivar/variety, age, propagation method, site preparation, dates and rates of fertilizer and pesticide applications, dates of transplanting and pruning, omissions or additions to usual/conventional management program; 2) water quality, frequency, rate and timing of irrigation; 3) soil pH, texture, drainage, homogeneity, aeration, temperature, salinity; planting depth; construction near site; 4) environmental conditions and recent history (temperatures, amount and distribution of rainfall, light intensity, air quality, wind); 5) rate of symptom development; coincidence with any treatment or environmental event; 6) recent unusual human, animal, insect or mite activity around or on the plant with symptoms.

Diagnosing Specific Problems With Saskatoons

Saskatoons are susceptible to a variety of problems. They are prone to a number of disorders caused by weather-related factors. They are also susceptible to many of the insect pests and diseases that are common to other related fruits in the Rose family. Diseases and certain insects appear to be the primary factors that limit total yield and fruit quality.

The following table indicates some of the more common problems growers may encounter in their saskatoon orchards.

Common Problems Of Saskatoons

Problem	Symptoms
Entomosporium leaf & berry spot	Leaves with small, angular, brown spots; often followed by leaf yellowing & loss in mid-season
Saskatoon-Juniper rust	Hard, yellow patches on leaves or fruit; often with spiky, brown outgrowths
Cytospora Canker	Drying & shrivelling of buds & leaves in late-spring; sunken areas of cracked or broken bark
Woolly elm root aphid	Lack of vigour in young plants; early flagging (change of color) of leaves in late-July or early-August; white, woolly masses on plant's roots immediately under soil surface; partial leafing-out, followed by plant death early in season
Saskatoon bud moth	Flower buds with small holes; oozing droplets may be present; may contain a tiny caterpillar; young leaves & flowers tied together with white threads or webbing

Spider mites	Leaves with a stippled appearance; yellowing of leaves; presence of very fine webbing on the undersides of leaves
Winterkill	Loss of young plants on exposed sites; death of new wood, leaf buds and flower buds; delayed bud-break, reduced growth, small leaves, fewer leaves than normal, variable pattern of flowering within plants, or within the orchard; symptoms may not become noticeable until mid-June
2,4-D damage	Leaves with pronounced, feathery extensions; ends of leaves flattened; leaves may have a leathery appearance, with veins appearing prominent
Bird Feeding Damage	Large numbers of birds in the orchard; fruit with large, ragged holes; bird droppings containing many seeds

Flower Bud Development and the Timing of Management Practices

A knowledge of flower bud development in the saskatoon will help a grower to monitor for the incidence of insect pests and diseases, and to appropriately time the application of pesticides and other control procedures. The developmental stages of saskatoon buds are similar to those of the apple or pear. However, the structure of the inflorescence of the saskatoon is different from that of the apple and pear, and the period of bud development in the saskatoon is much shorter. Additionally, there may be substantial variability in bud development both within a plant and within an orchard, depending on plant material, growing season, and microclimate surrounding any one plant. This variability alone makes it difficult to easily characterize the larger number of stages used for the apple and pear. The developmental stages chosen for the saskatoon reflect easily-defined stages that growers can recognize. Eight different stages of development are defined in the following table.

Stage	Description
Dormant	- buds are tightly enclosed by brown bud scales
Silver Tip	- stage immediately following dormancy where the brown bud scales have split open, and are falling off; the bud beneath appears silver because of the presence of many hairs
Green Bud or Green Tip	- the flower bud cluster is visible; the flower buds are very small and tightly packed together; the entire cluster appears green in color

Stage	Description
White Tip	- the flower bud cluster has expanded so that the individual buds are no longer tightly pressed against each other; the white petals of the individual flowers are visible as a small cone
Tube	- the petals of the individual clusters have elongated to form a tube or cylinder
Balloon	- a very brief stage immediately prior to full-bloom when the tube of petals has loosened and the petals are beginning to separate
Full-bloom	- the petals have fully expanded and the anthers (pollen-bearing structures) and pistil (pollen-receptive structure) are visible; the flower is receptive to pollination and fertilization at this stage
Post-bloom	- the petals fall off of the flower and the ovary begins to swell, indicating fruit set

Safe Pesticide Use

The word pesticide is a broad term that includes herbicides, insecticides, fungicides, repellants, wood preservatives, and bactericides. Pesticides are important pest management tools and are often required to maintain an economically viable commercial orchard. Pesticides vary dramatically in toxicity, spectrum of pests controlled, hazard to health and environment, and mode of action. Pesticides include synthetically produced chemicals (carbaryl, benomyl, glyphosate), naturally occurring substances derived from plant or animal sources (rotenone, pheromones), naturally occurring rock sources (sulfur, copper sulfate), and microbial agents (*Bacillus thuringiensis*). Substances derived from plant and animal sources (organic pesticides) tend to break down more rapidly than synthetic substances (less persistent), however these may be difficult to use effectively. Some pesticides are very toxic. A pesticide that is appropriate for managing a specific pest problem must be chosen. The label must be carefully read. Careless pesticide applications endanger human and environmental health, and are less likely to control the target pest properly.

It is important for grower's to recognize that the supply of healthy fruit is associated with pesticide use, residues and food safety. Pesticides must be registered with Agriculture Canada in order to be legally used on a commercial fruit crop. The process of registration is associated with the determination of efficacy and safety. Knowledge of the application rate and timing of use (preharvest interval) are important to keeping residues at safe limits. If a fruit crop is tested, and pesticide residues higher than the legal limit are found, the fruit crop may be confiscated and destroyed, and the grower given a fine or jail term. The illegal use of pesticides is not worth the risk to individual growers, nor the industry in general.

Some Guidelines To Using Pesticides In Saskatoon Orchards

1) The problem must be identified correctly and it must be determined that a pesticide is the most appropriate solution to the problem.

2) The pesticide label must be referred to for the proper rate and timing of application.

3) In general, pesticides stored for more than 2 years should not be used.

4) Pesticides must not be mixed unless the compatability of the chemicals is known.

5) Pesticides must be applied only when weather conditions are appropriate. Rain may wash pesticides off the plants; hot, dry weather can cause a pesticide to become toxic to the plant; wind causes substantial drift of pesticides.

6) Complete and accurate records of pesticide use should be kept.

7) Application equipment must be appropriate for the job and must be cleaned properly.

8) A sufficient spray volume to thoroughly cover the target area is essential for proper control of the problem.

9) The pH of the grower's water supply may be important when mixing pesticides; some insecticides degrade in alkaline (high pH) water.

10) Additives recommended by the pesticide label (pH adjusters, surfactants) must be mixed with the pesticide and water to maintain the effectiveness of the chemical.

11) Appropriate application equipment should be used. Small droplets provide better spray coverage than large droplets and reduce the volume of the spray required.

12) Growers should be familiar with the toxicity of the chemical they are using and protect themselves properly during both mixing and application.

Pesticide Application Equipment

Growers who experience poor control of insect or disease problems should examine their pesticide application equipment. Uniform leaf coverage is essential to reliably protect a saskatoon crop, particularly from fungal diseases. Growers who use modified ground application equipment, with flat-fan nozzles, and pressures less than 60 PSI, likely will experience incomplete coverage and poor pest control. The nozzles and pressure used in conventional field equipment do not produce enough dispersion of the spray droplets to provide uniform coverage of an orchard crop's canopy. The use of commercial airblast spray equipment is recommended for spraying insecticides and fungicides in saskatoon orchards. Orchard and vineyard sprayers operate at relatively high pressure, generally between 100 and 300 PSI. These sprayers generate a spray mist that is carried into the plant canopy via a fan. The forced airstream provided by the fan also results in more complete coverage of top and bottom leaf surfaces.

Effects of Water Quality and pH on Pesticide Activity

It is important to consider water quality prior to mixing pesticides. If water is obtained from an open source such as a dugout, suspended organic material in the water may interfere with active ingredients in the pesticide or cause a malfunction of the pesticide application equipment. If possible, filter the water before mixing with pesticide concentrates. The pH of the water supply should be tested prior to mixing with any pesticide. This can be done at a local soil or water testing lab, or on site with a pH meter or pH-testing paper (Litmus paper). The impact of water pH on pesticide activity varies with the product used. The deactivating effects associated with inappropriate pH levels are greater the longer a mixed pesticide product is allowed to sit, so it is important to use mixed pesticides immediately. In the case of some pesticides, the effectiveness of a mixed product may be cut in half in less than one hour if the pH of the water is too high or too low. As a general rule, most pesticides are stable in the pH range of 6 to 7. There are no known problems associated with the pesticide products currently registered for use on saskatoons, however, if the pH of the water source is above 8.5, the likelihood of having a problem is significantly increased. In this case the grower should consider using a buffering agent in the water to neutralize the water and stabilize its pH.

Applying Insecticides and Fungicides

Adequate monitoring for insect pest and disease problems, along with proper application rates and timing of chemical sprays, are important factors in efficient and effective control. At present, one insecticide (Decis 5.0 EC) and four fungicides (Topas 250 E, Kumulus DF, Funginex 190 EC and Nova 40W) are registered for aboveground use in commercial saskatoon orchards. Note that more than one fungicide may be used each season. The use of several fungicides reduces the risk of incomplete control that can occur when the scheduled application timing does not coincide with actual disease development or due to the development of chemical resistance in the fungal pathogen. There are no registered tank mixes for any combination of insecticide and fungicides available to saskatoon growers and this practice is not recommended. For further information regarding the registered uses of these pesticides, refer to the Insect and Disease sections of **Growing Saskatoons - A Manual For Orchardists**.

A General Operations Guide For Saskatoon Orchards

Richard G. St-Pierre, Ph.D. (January 2006)

Timing		**Operation**						
Month(s)	**Bud or Crop Developmental Stage**	**Pruning***	**Irrigation***	**Weed Control***	**Fertilization***	**Insect Pest & Disease Monitoring***	**Insecticide/ Fungicide Application***	**Harvest***
September - April	**Dormant** (buds tightly enclosed by brown bud scales)	- stem thinning; removal of excess suckers; pruning for disease control	- monitor soil moisture levels; irrigate if necessary (when soil moisture tension reaches 20-40 cbars); irrigate prior to soil freeze-up if orchard is dry &/or exposed	- Casoron applied before soil freeze-up in fall; or linuron applied to dormant plants	- soil test in September or October if not done in spring	- monitor buds for insect eggs, stems & branches for canker		
April/May	**Silver Tip** (stage immediately following dormancy where the brown bud scales have split open, & are falling off; bud beneath appears silver because of presence of many hairs)	- stem thinning; removal of excess suckers; pruning for disease control	- monitor soil moisture levels; irrigate if necessary (20 - 40 cbars soil moisture tension)	- linuron applied to dormant plants, if not applied in fall	- soil test may be done	- monitor buds for bud moth larvae	- first application of Kumulus at bud-break; subsequently at 10 - 14 day intervals -application of Bartlett Superior ‘70' Oil	
May	**Green Bud or Green Tip** (flower bud cluster is visible; flower buds are very small & tightly packed together; entire cluster appears green in color)	- pruning for disease control	- monitor soil moisture levels; irrigate if necessary (20 - 40 cbars soil moisture tension)	- cultivation; mowing; spot applications of RoundUp if necessary	- first fertilizer application, either surface-broadcast or via drip system (if necessary) - fertigation may be continuous through May & June	- monitor flower clusters for bud moth larvae, other caterpillars, lygus bugs	- first application of Decis (no later than this bud stage) - application of Kumulus as required	

	White Tip (flower bud cluster has expanded so that individual buds are no longer tightly pressed against each other; white petals of individual flowers are visible as a small cone)			- cultivation; mowing; spot applications of RoundUp if necessary		- monitor flower clusters for bud moth larvae, other caterpillars, lygus bugs; leaves for spider mites	- application of Funginex (no later than this stage) - first application of Topas	
	Tube/Balloon (petals of individual buds have elongated to form a tube or cylinder; subsequently, tube of petals loosens & petals begin to separate)			- cultivation; mowing; spot applications of RoundUp if necessary		- monitor flower clusters for bud moth larvae, other caterpillars, lygus bugs, sawflies; leaves for spider mites, & lace bugs	- second application of Decis (no later than balloon stage) - first application of Nova	
	Full Bloom (petals have fully expanded)			- cultivation; mowing; spot applications of RoundUp if necessary		- monitor flower clusters for bud moth larvae, other caterpillars, lygus bugs, sawflies, brown fruit rot; leaves for spider mites, lace bugs & powdery mildew	- no applications of any fungicide or insecticide	
May/June	**Petal Drop/Fruit Set** (petals fall off of flower & ovary begins to swell, indicating fruit set)	- pruning for disease control	- monitor soil moisture levels; irrigate if necessary (20 - 40 cbars soil moisture tension)	- cultivation; mowing; spot applications of RoundUp if necessary		- monitor flower & fruit clusters for caterpillars, sawflies, apple curculio, brown fruit rot; leaves for spider mites, lace bugs & powdery mildew	- second application of Topas	

June	**Green Fruit**	- pruning for disease control	- monitor soil moisture levels; irrigate if necessary (20 - 40 cbars soil moisture tension)	- cultivation; mowing; spot applications of RoundUp if necessary	- second surface-broadcast fertilizer application - fertigation may be continuous through June - monitor new shoots & leaves for iron chlorosis & other possible nutrient deficiencies	- monitor fruit clusters for caterpillars, sawflies, apple curculio, brown fruit rot; leaves for spider mites, lace bugs, Entomosporium leaf & berry spot, saskatoon-juniper rust, powdery mildew; shoots for fireblight	- third application of Topas (38 day PHI) - third application of Decis (21 day PHI) - second & third applications of Nova (14 day PHI) - application of Kumulus as required	
July	**Mature Fruit**	- pruning for disease control	- monitor soil moisture levels; irrigate if necessary (20 - 40 cbars soil moisture tension)	- cultivation; mowing; spot applications of RoundUp if necessary		- monitor fruit clusters for caterpillars, sawflies, apple curculio, brown fruit rot; leaves for spider mites, Entomosporium leaf & berry spot, saskatoon-juniper rust, powdery mildew; surface roots for woolly elm aphid	- application of Kumulus as required	- begin harvest when half to two-thirds of branches or plants are fully ripe; two to three harvests may be best if ripening is very uneven
July - September	**Post-Harvest**	- pruning for disease control; stem-thinning & removal of excess suckers; in late-fall	- monitor soil moisture levels; irrigate if necessary (20 - 40 cbars soil moisture tension); irrigate prior to soil freeze-up if orchard is dry and/or exposed	- cultivation; mowing; spot applications of RoundUp if necessary	- leaf tissue analysis following harvest, but no later than mid-August - soil test in September or October if not done in spring	- monitor surface roots for woolly elm aphid (mid-July to late-August); stems & branches for canker in September/ October	- application of orthene to non-bearing plants (mid-July to early-August)	

*Notes:

Bud or Crop Developmental Stages - note that there is variability in these stages from branch to branch within plants, from plant to plant, from location to location, and from year to year. Consistent warm temperatures speed up the developmental stages, whereas consistent cool temperatures slow development down. The developmental stages are easier to distinguish where temperatures have been consistently cool.

Pruning - preferably late-March to early-May, prior to budbreak: 1) remove dead, damaged or diseased stems; 2) cut back weak or spindly growth; 3) remove stems greater than 2.5cm in diameter at ground level; 4) remove excess suckers; if orchard is machine-harvested, prune out damaged stems following harvest to avoid infection by canker; pruning for disease control may be carried out anytime between late-winter & late-fall; pruning for control of canker & blackleaf may be easiest in autumn after leaf-fall because, at this time, it is easy to see the split bark symptomatic of canker, & the infected leaves symptomatic of blackleaf that remain attached to the stems.

Irrigation - soil moisture levels should be monitored continuously from the time the soil thaws until close to soil freeze-up; some form of soil moisture meter is very useful & strongly suggested; irrigation may be carried out when soil moisture tension in the root zone is between 20 & 40 cbars; soils that are dryer (soil moisture tension greater than 40 cbars) will inhibit growth & may severely stress plants; irrigation may be necessary after leaf-drop in the fall, but prior to freeze-up in order to reduce dessication over the winter & to reduce the development of canker; for newly-established plants, monitor moisture status of root plug carefully & frequently; irrigation of newly-established plants should be frequent so as not to allow the root plug to dry out.

Weed Control: a) Linuron - applied as a pre-emergent herbicide in early-spring or late-fall when saskatoons are dormant; apply only to established plantings at least 1 year old; do not apply more than once per season, nor within 50 days of harvest; b) Casoron - apply only to established plantings at least 1 year old; apply before freeze-up in late-fall; application must not be made within 9 months of harvest (Do Not apply both Casoron & linuron in same growing season); c) RoundUp - spot application as necessary; a wick applicator is best; open wounds & fresh pruning cuts facilitate absorption of glyphosate; extreme care should be taken to avoid contact of spray with such regions.

Fertilization - if soil & leaf tissue analyses indicate that fertilizer is necessary, fertilizer should be applied in at least 2 split applications (one pre-bloom, one post-bloom) if surface-broadcast; if soluble fertilizers are applied through a trickle irrigation system, then fertilizer applications will have to be made on a more continuous basis; a maximum of 40 lbs/acre of nitrogen per season should be sufficient; very sandy soils and/or large amounts of rainfall may lead to greater requirements for N; surface-broadcast phosphorus will be quickly immobilized in the soil before it reaches the root zone; if required, phosphorus should be applied prior to planting, & then subsequently a soluble form may be injected or applied via the drip system; it is important not to apply excessive amounts of nitrogen because this will produce excessive vegetative growth at the expense of flower bud production; excessive amounts of potassium could negatively affect fruit production & quality.

Leaf Tissue Analyses - leaves should be collected after harvest, between late-July & mid-August.

Soil Analyses - composite samples taken in fall or spring.

Monitoring for Disease & Insect Problems - buds, flower & fruit clusters, leaves, stems & branches should be examined weekly from the time of bud break for signs of insect pests or disease; a magnifying glass is very useful; clusters may be tapped gently on a white sheet of paper to shake out insect pests & the buds; flowers or fruit may also be pulled off of the cluster to make examination easier.

Applications of Insecticides/Fungicides: PHI = pre-harvest interval when the specific pesticide **may not** be applied; no tank mixes may be used; refer to pesticide labels to ensure that proper rates are used; rates that are too low may reduce efficacy of the pesticide; rates that are too high may be toxic to the crop, and/or may create toxic residue levels; shorter pre-harvest intervals also may create toxic residue levels. For control of Entomosporium leaf and berry spot, use either Kumulus or Topas; however, if Topas is used, an application of Kumulus prior to harvest may be necessary.

Harvest - begin when branches or plants are half to two-thirds fully ripe; this depends on plant source (seedling or clonal), cultivar, season & method of harvest; two to three harvests may be more economical if ripening is very uneven.

November 2001 Edition

Designing A Production Budget For A Saskatoon Orchard

Richard G. St-Pierre, Ph.D. (January 2006)

Introduction

Potential growers of saskatoons must give serious consideration to the high costs of orchard establishment, and the minimum 4 to 5 year delay in obtaining any return on their initial investment. Budget projections are necessary to summarize the costs of an orchard operation and to estimate returns. Budget projections are based on an estimation of projected incomes, capital investments and operating expenses.

The gathering of data is the most important step in a developing a budget projection. Unfortunately, accurate estimates of yield and production costs are often lacking for saskatoon orchards, making it difficult to develop an accurate budget projection. Consequently, a number of assumptions must be made. Budget projections for saskatoon orchards are sensitive to yields obtained, method of harvest, loss of potential yield and marketable yield, and method of marketing. As a result, the amount and timing of return on investment can vary substantially.

Potential growers can consult the following publications which contain budget projections for saskatoon orchards, but these projections should be used as guidelines only.

1) Economics of saskatoon berry production. Farm Facts Bulletin, Saskatchewan Agriculture and Food, and Saskatchewan Rural Development. Regina, SK, 1990.

2) Commercial Saskatoon Berry Industry. Ag-Ventures Agriculture Business Profile. Alberta Agriculture, Food and Rural Development. Agdex 238/830-1. June 1996.

3) A Consensus of costs and returns for a 10 acre saskatoon berry production enterprise in the Peace River Region of Alberta. G. Monner and G. N. Chaudhary. Alberta Agriculture, Food and Rural Development, Economic Services Division, Production Economics Branch. Publication #288. October 1996.

Potential growers must develop budget projections for their own operations based on their experience, anticipated yields, production costs and market prices, and must be able to adjust these projections on an ongoing basis. The use of spreadsheet software on a microcomputer is an appropriate and powerful tool that can be used to investigate various production scenarios and assumptions.

The objective of this factsheet is to provide an overview of what factors a grower must consider in developing a production budget for a saskatoon orchard.

Factors To Consider When Designing A Production Budget

Budget projections are comprised of three main categories: a) projected income based on technical data concerning the orchard; b) capital investment; and c) operating expenses.

Projected Income

The technical data required include the area of the orchard, the total number of plants per hectare, expected yield per hectare, anticipated price per kilogram of fruit, and type of operation (U-pick, machine-harvested, owner cleans and bags fruit, or not).

Accurate figures for expected yields and anticipated prices are critical to accurately estimate returns, however, both figures may vary substantially from year to year. Current data indicates that average yields for mature plants (6 to 7 years old) are approximately 3,300 to 4,500 kg per hectare. The potential maximum yield appears to be 13,500 kg per hectare. Yields may or may not remain constant from year to year. Current prices for saskatoon fruit vary from less than $3.30/kg (U-pick) to $6.60/kg (pre-picked). Processors pay from $3.30/kg to $4.40/kg fruit. These prices are approximate only.

Capital Investments

Capital investments include everything necessary to establish and operate an orchard. Capital investments include refrigerated storage and other buildings, machinery (truck, tractor, transplanter, cultivator, harrow, mower, pesticide sprayers, harvester, fruit sorter and cleaner), other equipment (for pruning, harvesting, maintenance, safety), irrigation system and dugout, land preparation, fencing, and mulches. It's obvious that capital investments may vary considerably depending on the type of orchard operation to be run, and what the grower already has in their possession. Data concerning capital investments include the purchase price, useful life, depreciation, and interest on loans for purchase.

Used machinery is a fraction of the cost of new and usually will be suitable, although some modifications may be necessary.

The initial cost of a drip irrigation system ranges from $1,800 to $3,000 per hectare (not including the cost of equipment used to supply water to the site, or chemical injection equipment). A good quality drip irrigation system will last for many years if properly maintained.

In areas not located near a river or lake, dugouts may be needed to supply water for irrigation. Government subsidies may be available for the construction of a dugout.

Depreciation is the reduction in the market value of a machine due to wear, obsolescence, and age. This cost is a tax deduction, and can be used to decrease net farm income, thus reducing taxes paid. As well, depreciation can be used as an indication of replacement cost. Each year a machine depreciates, the amount of depreciation should be put into the bank for purchasing a replacement for the machine.

Land preparation may or may not be a major expense. Costs of preparation may include cultivation and spraying, as well as rock picking and land leveling.

Operating Expenses

Operating expenses consist of fixed costs and variable costs. Fixed costs include the cost of plants, property taxes, and possibly land rental. Variable costs include labour, inputs, fruit losses, overhead, marketing, and unexpected expenses.

Saskatoon orchards require over 2,000 plants per hectare; the exact number varies with the dimensions of the orchard, and distance between the rows. The cost of saskatoon plants varies from less than $1.50 to $5.00 each. It is reasonable to expect a 10% loss of plants during the first two years of orchard establishment and these plants will need to be replaced. Consequently, a grower's investment in plants can be substantial.

All land has a property tax attached to it. The amount varies with the assessment of the land and the MIL rate. In some cases, the cost of land rental may need to be taken into consideration.

Labor is one of the greatest expenses in fruit production. Planting, pruning, spraying, weed control, irrigation, collection of samples for soil and leaf tissue analyses, harvesting, sorting and cleaning, marketing and maintenance are all included in labor. Estimates of the hourly costs of labour and of the total number of hours required vary. Some studies suggest that 350 to over 600 hours per hectare per year are required. If the farm is a corporation, management or supervisory salaries may have to be paid. As well, some growers may wish to draw a salary before waiting until the end of the production year.

Orchard inputs include herbicides, fungicides, insecticides, water, fertilizer, equipment operation and maintenance, containers, packaging, and transportation.

Fruit losses will occur during harvest, sorting and cleaning. Handpicking usually results in about a 5% loss of fruit. Machine harvesting may result in a 15% loss of fruit.

Overhead costs include electricity, heating and water. These costs will vary with the size of buildings and machinery, and the extent to which they are used.

Marketing costs vary depending on the type of advertising. For example, newspaper ads are less expensive than TV ads. Transportation costs also may be incurred. Telephone calls and faxes are a part of marketing often overlooked. Calls to potential buyers can become quite costly.

Some unexpected expenses will occur throughout the production year. Extra labor, equipment rental and repairs may be needed.

Disclaimer: This publication was designed to be an educational resource for individuals who are interested in growing saskatoons, in orchards, shelterbelts, or gardens. Every effort has been made to ensure the accuracy and effectiveness of the information in this publication. However, the author makes no guarantee, express or implied, as to the information and procedures contained herein. The information cannot be guaranteed because knowledge of the biology and culture of the saskatoon may not be applicable to all locations every year. Additionally, the information that is available often changes over time. Little scientific research has been done on many aspects of the culture and management of saskatoons. Consequently, this publication can only serve as a guide. All actions taken which are based on the information presented in this publication are solely the responsibilities of the readers or users, and the author is not liable for any direct, indirect, incidental, or consequential damages in connection with or arising from the furnishing, performance, or use of this material. Comments on information contained in this publication are welcomed.

Marketing Your Fruit Crop

Richard G. St-Pierre, Ph.D. (January 2006)

Getting Started

It is wise for growers to start small, gain experience, and develop a market. A marketing plan must be in place before a fruit crop is produced. It is better to sell a small crop then to be stuck with a large, unharvested crop. A marketing plan requires an assessment of the potential fruit market, and the selection of a method of marketing.

Market Assessment

It is important for growers to have a knowledge of their crop (including total and marketable yields, variability in yields, date of maturity, quality, storability, causes of loss), a knowledge of the fruit market (including total demand and seasonal distribution, competition, potential buyers, price stability and controlling factors, assessment of additional supply on current prices), and a knowledge of the economics of production (including the cost of production, cost of transport, storage and handling, cost of marketing, cost of financing, risk, returns on investment of time, effort and capital).

Some important components of market assessment include:

1) The identification of prospective buyers and probable sales areas. The development of a buyer's list is suggested because it is beneficial when it comes time to market the fruit. This buyer's list should include restaurants, wholesalers, farmers' markets, bakeries, and small retail stores. Growers should contact all buyers on the list prior to the fruit being ready for market, and to determine the quantity and quality of fruit each buyer requires. This approach requires the grower to have a good idea of the quality and quantity of the fruit that will be available after harvest.

2) The evaluation of prices. Marketing fruit requires the grower to study price trends throughout the year and in other locations. Pricing of fruit may be difficult due to the fluctuations that occur in the fruit industry.

3) The determination of the costs of production. The grower must have a good understanding of what their costs are to produce the fruit.

4) The design of a budget. Budgets are important to determine cash flow analysis. A cash flow analysis is important when dealing with debt financing because it indicates if financial obligations (loan payments, sales of fruit, replacement costs, maintenance costs, labor costs and so on) can be met at the required times.

Method Of Marketing

Once market assessment is complete, an effective method of marketing must be chosen and implemented. Small fruit industries primarily use some form of direct marketing. Direct marketing is where the grower produces, harvests and sells fruit to the final consumer. Direct marketing may be advantageous because:

a) The grower has control of the fruit throughout the entire operation. All business aspects are handled by the grower, who dictates when and where the fruit will be sold.

b) The grower may receive a better price. The grower can evaluate all the potential markets in which fruit can be sold, increasing the probability that the highest possible return will be obtained. For example, if the price available from bakeries is higher than selling the fruit directly to the consumer, the fruit grower has the option to sell the majority of fruit to bakeries.

c) Direct marketing may be the easiest and most economic means to market the fruit, or may be the only means to market the fruit.

d) The small size of the operation may determine if the grower has to direct market or not (most wholesalers need a specific quantity before they will market fruit).

The two disadvantages of direct marketing are that it is very time consuming, and growers typically do not have large enough operations to affect market prices, so must accept the prices offered.

Marketing Options

U-Pick or Pick-your-own

U-pick marketing may be ideal

for smaller operations because it is a method of marketing suited to entry-level growers. It is one of the most economical methods to market fresh fruit to consumers. The benefit of a U-pick marketing strategy is that the grower has control of the fruit from the initial stages until it reaches the consumer. The grower saves the cost of harvesting the fruit, and equipment and storage costs are minimal. The grower sets the prices and quantities of the fruit and provides a recreational opportunity for the consumer. However, growers must provide weigh scales, containers and restrooms, must advertise, must deal with the public, must train the public on how to pick without causing damage, and must purchase additional insurance to cover the added liability.

The following factors must be considered before establishing a U-pick operation: a) there must be enough people in the area to maintain a U-pick operation (in Canada, studies have indicated that 10,000 people are required to maintain one hectare of a U-pick operation; the average distance a consumer will travel is 30 to 50 km); b) pricing must be competitive (prices that are charged at other U-pick sites should be known at all times; if an operation stays competitive with prices other factors will determine the success of the site); c) cleanliness, friendliness and service can provide an edge over the competition; d) the location of the operation is significant (the location should have direct access from the highway so that customers can enter with ease); e) signs are needed so that customers do not have problems in locating the site and to reduce the chances of getting lost; f) it is important to advertise so people know about the operation (the use of newspaper, television and radio are the most conventional forms, but such items as billboards and roadside signs are effective as well); g) the easier it is to pick the fruit, the happier the customer will be (if the customer has to struggle to pick fruit because of overhanging branches or insufficient room between trees, he/she will be dissatisfied and find somewhere else to go).

Farmers' Markets

Farmers' markets also work well for small operations. Growers rent stall space in the market, which provides the public with readily available, fresh produce, and allows price and quality comparisons. Fruit may generally be sold for a good price, and advertising is handled by the organizers. Because farmers' markets are located in large centers, travel costs for the consumer are less, and consumers can purchase all their fresh fruit and vegetable items in one place. However, farmers' markets are characterized by limited sales volumes, the grower will have transportation and handling requirements and costs, and will face competition from other growers.

Farm Gate Sales, or Roadside Stands

Farm gate sales may be very successful for small operations where the grower does not have the time, resources or desire to use other methods of marketing. The grower is able to harvest to meet the daily demand, there are minimal equipment or storage requirements, no middlemen are involved, and growers set their own price and quality standards. However, farm gate sales are labor intensive, the grower must be people-oriented, and must be located near a sufficiently-sized population or tourist attraction with good road access.

Specialty Stores

Many stores may purchase fresh and processed fruit products. Gift shops in hotels and airports are high traffic, popular tourist areas where specialty products are demanded and premium prices may be recieved.

Bakeries and Restaurants

Bakeries often use fresh fruit for their products. They will purchase small quantities of fruit to mix into muffins and other pastries. It may be beneficial to contact and discuss the potential of selling into local bakeries in a given area. Often restaurants will purchase and pay premium prices for fruit and specialty items such as syrups. However, there may be increased storage and transportation costs for the grower because bakeries and restaurants usually purchase in small quantities only.

Packers/Brokers

The advantages of selling to a fruit packer/broker are that the packer/broker handles the storage, washing, grading, packaging, and shipping of the fruit. This method of marketing is efficient and likely will allow a large sales volume. However, the grower must expect to receive a lower price for their fruit, and must meet the packer/broker's requirements for quality, supply and price. The availability of such markets may be limited also.

Processors

Processors may purchase fruit, or growers may process fruit themselves. Processing adds value to the fruit, but growers may not receive very high prices if they sell to processors. Processors may require an assured supply of fruit.

Wholesalers

Growers may be able to sell washed, graded and packaged fruit to wholesalers who then supply major retailers. Such markets are efficient because of the possibility of a large sales volume to a single buyer. The grower gets the added value from the packaging. However, wholesalers usually require large volumes of fruit, the grower must absorb the costs of handling, storage, and packaging of the fruit, and the grower must guarantee availability, quality and price. Consequently, the wholesale market may not be suitable for small fruit operations because it may not be possible for the grower to satisfy the contract requirements of quantity and quality of fruit required. Growers having larger operations may have the supply of fruit and the resources to undertake this type of marketing.

Sources Of Plants, Equipment & Supplies

Richard G. St-Pierre, Ph.D. (January 2006)

Please note that the following sources are incomplete, may not be accurate, and are not an endorsement. Many of these sources have not been updated since 1999.

Beneficial Organisms

Applied Bio-Nomics Ltd., 11074 West Saanich Road, Sidney, B.C., V8L S0S; Tel: (604) 656-2123 (Insectary), (604) 940-0290 (BC), (416) 793-7000 (ON); Fax: (604) 656-3844.

Better Yield Insects, R.R.3 , Belle River, ON, NOR 1A0; Tel: (519) 727-6108; Fax: (519) 727-5989.

Bio-Logicals, 60 Taggart Court, #1, Guelph, ON, NIH 6H8; Tel: (5l9) 763-8653; Fax: (519) 763-9103.

Canadian lnsectaries, 5 Alderwood Road , Winnipeg, MB, R2J 2K7; Tel: (204) 257-3775; Fax: (204) 256-2206.

Coast Agri Ltd., 464 Riverside Road South, R.R. #2, Abbotsford, B.C., V2S 4N2; Tel: (604) 853-4836; Fax: (604) 853-8419.

Koppert Canada Ltd., 3 Pullman Court , Scarborough, ON, M1X IE4; Tel: (416) 291-0040/(800) 567-4195; Fax: (416) 219-0902.

Manbico Biological, Box 17, GRP 242, RR2, Winnipeg, MB, R3C 2E6; Tel: (204) 697-0863/ (800) 665-2494; Fax: (204) 697-0887.

Natural Insect Control, R.R. #2 , Stevensville, ON, L0S lS0; Tel: (905) 382-2904; Fax: (905) 382-4418.

Nature's Alternative Insectary Ltd. , Box 19, Dawson Road, 1636 East Island Highway , Nanoose Bay, B.C., V0R 2S0; Tel: (604) 468-7912/(604) 468-7911; Fax: (604) 468-7912.

Richters, 357 Highway 47, Goodwood, ON, L0C 1A0; Tel: (905) 640-6677; Fax: (905) 640-6641.

Westgro Sales Inc., 7333 Progress Way, Delta, B.C., V4G 1E7; Tel: (604) 940-0290; Fax: (604) 940-0258.

Bird Control Devices

Allsopp Helikites Ltd., South End Farm, Damerham, Fordingbridge, Hampshire, SP6 3HW, England; Tel: 01144 1725 518750; Fax: 01144 1725 518786; Website: http://www.allsopphelikites.com; Vigilante helikites.

Bird-X, Inc., 730 West Lake St., Chicago, IL 60661, USA; Tel: (312) 648-2191; Irri-tape, Ultrasonic devices.

Gerry Van Ryk, 105-2279 McCallum Road, Abbotsford, BC, V2S 6J1; Tel: (604) 853-5706; electronic devices.

Insulbird Electric Fence, c/o John and Laura Gund, Walnut Grove Farm, 48 Cartland Rd., Lee, NH 03824, USA; Tel: (603) 659-2044; Fax: (603) 659-4130.

Joonas Agritech, 3046 McMillian Road, Abbotsford, BC, V2S 6A8; Tel: (604) 852-5016; Fax: (604) 859-3916; various electronic devices.

Joe Kovar Co., P.O. Box 37, Anoka, MN 55303, USA; Tel: 1-800-947-1246; Predator Eyes.

K-5 Market Enterprises, c/o Tony Kustiak, Box 806, Shellbrook, SK, S0J 2E0; Tel: (306) 747-2829; Fax: (306) 747-2727.

McFayden Seed Co., 30 - 9th St., Suite 200, Brandon, MB, R7A 6N4; BirdScare balloons.

Modern Agri-Products, 322 Main St., Lynden, WA 98264, USA; Tel: (206) 354-8884; Fax: (206) 354-8885; Birdscare Octopus; Birdscare Flash Tape.

Pest Management Supply, Inc., P.O. Box 938, Amherst, MA 01004, USA; Scare-Eye balloons.

Sutton Agricultural Enterprises Inc., 538 Brunker Ave., #7, Salinas, CA, 93901, USA.

Transonic Sound Technology, 105 - 2279 McCallum Road, Abbotsford, BC, V2S 6J1; Tel: (604) 853-5706; Fax: (604) 853-5706.

Vesey's Seeds Ltd., P.O. Box 9000, Charlottetown, PEI, C1A 8K6; ScareAway bird line.

Disease, Insect & Weed Identification Services

Alberta

Ken Fry, Alberta Resource Council, P.O. Bag 4000, Vegreville, AB, T9C 1T4; Tel: (403) 632-8224

Rudy Esau, Weed Specialist, Crop Diversification Centre South, SS4 Brooks, AB, T1R 1E6; Tel: (403) 362-1300

Ron Howard, Disease Specialist, Crop Diversification Centre South, SS4 Brooks, AB, T1R 1E6; Tel: (403) 362-1300

HortInfo Services, P.O. Box 38088, 1086 Capilano Postal Outlet, Edmonton, AB, T6A 3Y6; Tel: (403) 944-1845

Brooks Diagnostic Limited, P.O. Box 1701, Brooks, AB, T1R 1C5; Tel: (403) 632-5555

Manitoba

Rhonda Kurtz, Crop Diagnostic Centre, Manitoba Agriculture, Agricultural Services Complex, 545 University Crescent, Winnipeg, MB, R3T 5S6; Tel: (204) 945-3083

Saskatchewan

Doug Billet, Weed Specialist, Saskatchewan Agriculture and Food, 125-3085 Albert Street, Regina, SK, S4S 0B1; Tel: (306) 787-8081

Lloyd Harris, Insect Specialist, Saskatchewan Agriculture and Food, 125-3085 Albert Street, Regina, SK, S4S 0B1; Tel: (306) 787-4669

Michael Celetti, Disease Specialist, Saskatchewan Agriculture and Food, 125-3085 Albert Street, Regina, SK, S4S 0B1; Tel: (306) 787-4671

Crop Protection Laboratory, 3211 Albert Street, Regina, SK, S4S 5W6; Tel: (306) 787-8130.

Drip Irrigation Supplies & Equipment

Alberta

Automatic Drip Irrigation Ltd., Box 237, Monarch, AB, T0L 1M0; Tel or Fax: (403) 553-2027.

First Choice Irrigation Inc., 4130-37A St. Edmonton, AB, T6L 5R6; Tel: (403) 464-0011.

Green Thumb Irrigation Ltd., 7016A-82nd Ave., Edmonton, AB; Tel: (403) 469-1222; Fax: (403) 469-9797.

South Alta Drip System, Box 1689, Fort Macleod, AB, T0L 0Z0; Tel: (403) 553-4520; Fax: (403) 553-2082.

British Columbia

C.P.I. Equipment Ltd., 22652 Fraser Hwy., Langley, BC, V3A 4P6; Tel: (604) 530-0264.

E.D.S. Pumps and Plumbing Ltd., 23184 Fraser Hwy., Langley, BC, V3A 4P6; Tel: (604) 534-1115; Fax: (604) 534-5522.

Southern Drip Irrigaton Ltd., 44130 Yale Road West, Sardis, BC, V2R 1A9; Tel: (604) 762-0041; Fax (604) 762-9515.

Valley Waterworks & Irrigation Ltd., 5-368 Industrial Drive Ave., Kelowna, BC, V1Y 7E8; Tel: (604) 763-9107.

Ontario

Aquamaster Irrigation Products, 1 Guardsman Road, Thornhill, ON, L3T 6L2; Tel: (416) 881-4794; Fax: (416) 881-7922.

Van den Bussche Irrigation, P.O. Box 304, Delhi, ON, N4B 2X1; Tel: (519) 582-2380; Fax: (519) 582-1514.

Saskatchewan

C & F Installations Ltd., 2622B Faithful Ave., Saskatoon, SK, S7K 5W3; Tel: (306) 931-8755.

Central Irrigation Co. Ltd., 3310 Idylwyld Dr. N., Saskatoon, SK, S0L 2N0; Tel: (306) 975-1999.

Eljay Irrigation, 15-844 51st St. E.,

Saskatoon, SK, S7K 5C7; Tel: (306) 931-2440; Fax: (306) 931-4955.

John's Nursery and Garden Center, Box 24, Henriburg, SK, S0J 1C0; Tel: (306) 764-8139; Fax: (306) 764-8153.

Smart Irrigation Distributors Ltd., 144 Cardinal Crescent, Saskatoon, SK, S7L 6H6; Tel: (306) 653-5444; Fax: (306) 664-1934.

The Lawn Ranger Inc., 107 Rodenbush Dr., Regina, SK, S4R 7X8; Tel & Fax: (306) 721-9960.

Valley West Irrigation, Box 670, Outlook, SK, S0L 2N0; Tel: (306) 867-9252.

Water Boy Supplies Ltd., 1265 Scarth St., Regina, SK, S4R 2E6; Tel: (306) 757-6242; Fax: (306) 347-7992.

Fruit Cleaning & Sorting Equipment

Alberta

Berry Fields Equipment (Earl Langenecker), Box 1, Site 10, RR 2, Grande Prairie, AB, T8V 2Z9; Tel: (403) 538-1034; conveyers, blowers, destemmers, sizers, inspection tables, conveyors.

Bill Campbell, Box 3979, Leduc, AB, T9E 6M8; Tel/Fax: (403) 986-0658; handheld picker, table top fruit cleaner.

Dani Products Ltd., R.R. #3, Site 4, Box 32, Red Deer, AB, T4N 5E3; Tel: (403) 343-6222; Fax: (403) 347-3988.

United States

Lakewood Manufacturing Inc., 11441 East Lakewood Boulevard, Holland, MI 49424 USA; Tel: (616) 392-6926; Fax: (616) 392-8977.

Michigan Orchard Supply, 07078 - 73 ½ Street, South Haven, MI 49090 USA; Tel: (616) 637-1111; Fax: (616) 637-7419.

Denmark

A/S Skals Maskinfabrik, Hovedgaden 56, DK - 8832 Skals, Denmark; Tel: 45 86 69 4311; Fax: 45 86 69 4999.

Fruit Growers Associations

Alberta

Alberta Market Gardeners Association, Box 2488, Pincher Creek, AB, T0K 1W0; Tel: (403) 627-4589; Fax: (403) 627-4589 or c/o A.S.C.R.C., SS4, Brooks, AB, T1R 1E6; Tel: (403)362-1300.

Fruit Growers Society of Alberta, c/o Myrna Hammer, RR 1, Site 2, Box 8, Olds, AB, T4H 1P2; Tel: (403) 556-3837; Fax: (403) 556-3878.

British Columbia

British Columbia Fruit Growers Association, 1473 Water Street, Kelowna, BC, V1Y 1J6; Tel: (604) 762-5226.

Manitoba

Prairie Fruit Growers Association, c/o Lise Marion, Secretary-Treasurer, 20 Northumbria Bay, Winnipeg, MB, R2J 1Y4; Tel: (204) 254-3903.

Saskatchewan

Saskatchewan Fruit Growers Association, c/o Charon Blakley, Secretary-Treasurer, P.O. Box 622, 1117 Francis Ave., Rocanville, SK, S0A 3L0; Tel: (306) 645-4447; Fax: (306) 645-4447.

Fruit Industry Specialists/Consultants

Fruit Production Specialists

Alberta

Lloyd Hausher, Fruit Specialist, Crops Diversification Center South, SS4, Brooks, AB, T1R 1E6; Tel: (403) 362-1300.

Betty Vladicka, Horticulture Development Officer, Crop Diversification Centre - North, RR 6, 17507 Fort Road, Edmonton, AB, T5B 4K3; Tel: (403) 422-1789.

Manitoba

Janice Deremiens, Fruit Specialist, Manitoba Agriculture, P.O. Box 1149, Carman, AB, R0G 0J0; Tel: (204) 745-2040.

Saskatchewan

Clarence Peters, Fruit Specialist, Saskatchewan Agriculture and Food, 125-3085 Albert Street, Regina, SK, S4S 0B1; Tel: (306) 787-4666.

Richard St-Pierre, Research Scientist & Director, Native Fruit Development Program, Department of Horticulture Science, University of Saskatchewan, 51 Campus Drive, Saskatoon, SK, S7N 5A8; Tel: (306) 966-5867; Fax (306) 966-8106.

Irrigation Consultants

Alberta

Dennis Roll, Irrigation Specialist, Irrigation and Resource Management Division, Agriculture Center, Bag 1, Airdrie, AB, T4B 2C1; Tel: (403) 948-8540.

Alberta Environment, Water Rights Branch, Oxbridge Place, 9820 - 106th Street, Edmonton, AB, T5K 2J6; Tel: (403) 427-6168.

Saskatchewan

Bill King, Irrigation Specialist, Saskatchewan Water Corporation, Box 1000, Outlook, SK, S0L 2N0; Tel: (306) 867-5526.

Shelterbelt Information

Manitoba

P.F.R.A., P.O. Box 1000B, R.R. #, Brandon, MB, R7A 5Y3; Tel: (204) 726-7584.

P.F.R.A., 100 Federal Building, 317 Main Street North, Dauphin, MB, R7N 1C5; Tel: (204) 638-6108.

P.F.R.A., 200 - 101 Route 100, Morden, MB, R6M 1Y5; Tel: (204) 822-4078.

Saskatchewan

P.F.R.A. Tree Nursery, P.O. Box 940 Indian Head, SK, S0G 2K0; Tel: (306) 695-2284.

Soils Specialists

Alberta

Colin McKenzie, Soils Specialist, Crops Diversification Center South, SS4, Brooks, AB, T1R 1E6; Tel: (403) 362-1300.

Saskatchewan

Brandon Green, Soils Specialist, Sustainable Production Branch, Saskatchewan Agriculture and Food, 125 - 3085 Albert Street, Regina, SK, S4S 0B1; Tel: (306) 787-0556.

Processing Consultants

Alberta

Dr. Zenig Hawrysh, Department of Foods and Nutrition, University of Alberta, Edmonton, AB, T6G 2P5; Tel: (403) 492-3830.

Susan Lutz, Food Processing Development Centre, 6309 - 45th Street, Leduc, AB, T9E 7C9; Tel: (403) 986-4793, Fax: (403) 986-5138.

Janet Panford, Processing Specialist, Crops Diversification Center South, SS4, Brooks, AB, T1R 1E6; Tel: (403) 362-1300.

Saskatchewan

Saskatchewan Food Talk, Applied Microbiology and Food Science, University of Saskatchewan, 51 Campus Drive, Saskatoon, SK, S7N 5A8; Tel: (306) 966-5029.

Marketing and Economic Consultants

Saskatchewan

Barbara Cox-Lloyd, Marketing Specialist, Saskatchewan Agriculture and Food, 329 - 3085 Albert Street, Regina, SK, S4S 0B1; Tel: (306) 787-5966.

Lyle Stavness, Farm Management Specialist, Saskatchewan Agriculture and Food, 231 - 3085 Albert Street, Regina, SK, S4S 0B1; Tel: (306) 787-5039.

Alvin Ulrich, Economic Consultant, 707 Eastlake Avenue, Saskatoon, SK, S7N 1A2; Tel: (306) 668-0130; Fax: (306) 668-0131.

Fruit Harvesters

Alberta

Northern Horticulture Equipment, Dave and Monica Turta, Box 752, Calmar, AB, T0C 0V0; Tel: (403) 987-3217; Fax: (403) 987-4364.

British Columbia

Joonas Agritech, Kerry Doyle, 3046 McMillan Road, Abbotsford, BC, V2S 6A8; Tel: (604) 852-5016.

United States

Blueberry Equipment Incorporated, 1375 Kalamazoo Street, South Haven, MI 49090, USA; Tel: (616) 637-8541; Fax: (616) 637-4233.

JVD Equipment, Jeff DeVries, 13530 Tyler Street, Holland, MI 49424, USA; Tel: (818) 399-6267.

Korvan Industries Inc., 270 Birch Bark Lynden Road, Lynden, WA 98264, USA; Tel: (206) 354-1500; Fax: (206) 354-1300.

Littau Harvester, 893 Wilco Road, Stayten, OR 97383, USA; Tel: (503) 769-5953; Fax: (503) 769-4562.

Peco Berry Harvesting Equipment, 95 Moorhouse Avenue, Christchurch, New Zealand; Tel: 64-03-65632.

General Horticultural Supplies

Alberta

Westgro Horticultural Supplies Inc., 1557 Hastings Crescent S.E., Calgary, AB, T2G 4C8; Tel: 1-800-661-2991; Fax: (403) 243-7470; fertilizers, pruners, safety equipment, soil mixes, root trainers, greenhouse equipment, pesticides.

The Professional Gardener Company Ltd., 915 - 23 Avenue S.E., Calgary, AB, T2G 1P1; Tel: (403)263-4200; Fax: (403) 237-0029; fertilizers, pruners, safety equipment, soil mixes, root trainers, greenhouse equipment, pesticides.

Saskatchewan

Early's Farm and Garden Center, 2615 Lorne Avenue, Saskatoon, SK, S7J 0S5; Tel: (306) 931-1982; Fax: (306) 931-7110; fertilizers, pruners, safety equipment, soil mixes, root trainers, greenhouse equipment, pesticides.

Grass Seed

Alberta

Prairie Seeds, 1805 8th St., Nisku, AB, T9E 7S8; Tel: (403) 955-7345.

Saskatchewan

Early's Farm and Garden Center, 2615 Lorne Avenue, Saskatoon, SK, S7J 0S5;

Tel: (306) 931-1982; Fax: (306) 931-7110.

Mulches & Mulch Applicators

Alberta

Innovative Plastics Marketing (1992) Ltd., 11535 - 160th Street, Edmonton, AB, T5M 3V8; Tel: (403) 454-8162; impermeable plastic.

Canadian Forestry Equipment Ltd., 17309 - 107th Avenue, Edmonton, AB, T5S 1E5; Tel: 1-800-661-7959; Fax: (403) 484-6783; plastic squares.

British Columbia

Arbortec Industries, Site 33, Comp 21, R.R. 1, Penticton, BC, V2A 6J6; Tel: 1-800-561-9888; Fax: (204)857-2827; plastic squares.

Manitoba

Jeffries Nursery, Portage La Praire, MB; Tel: (204) 857-5288; Fax: (204)857-2877; impermeable plastic.

Quebec

Casccades Multi-Pro Inc., 1 Place Bille-Marie, Bureau 3615, Montreal, PQ, H3B 3P2; Tel: (514) 393-2611; Cellu-Fib.

Plasti-Tech, 478 Rue Notre-Dame, St. Remi, PQ, J0L 2L0; Tel: (514) 454-3961; Fax: (514) 454-6638.

Saskatchewan

K-5 Market Enterprises, c/o Tony Kustiak, Box 806, Shellbrook, SK, S0J 2E0; Tel: (306) 747-2829; Fax: (306) 747-2727; mulch layer, assorted mulches.

United States

Buckeye Tractor Company, P.O. Box 123, Columbus, OH 45830, USA; Tel: (419) 659-2162; Fax: (419) 659-2082.

Dewitt Products, 2916 Tulane Drive, Fort Collins, CO 80525, USA; Tel: (303) 225-1912; Fax: (303) 225-0167; permeable woven plastic.

Holland Transplanter Company, 510 East 16th Street, P.O. Box 1527, Holland, MI 49422-1527, USA; Tel: (616) 392-3579; Fax: (616) 392-7996.

PolyWest, 4883 Ronson Ct, Suite R, San Diego, CA 92111, USA; Tel: (619) 279-6393; yellow plastic mulch.

Packing & Shipping Supplies

British Columbia

Unisource Canada Inc., 1425 Derwent Way, Annacis Island, P.O. Box 2500, New Westminster, BC, V3L 5A9; Tel: 1-800-242-3691; Fax: (604) 520-7400.

Ontario

PCA Canada Inc., 3471 McNicoll Avenue,

Scarborough, ON, M1V 4B8; Tel: 1-800-387-3282; Fax: (416) 321-5435.

Prairie Provinces

Shippers Supply Inc., outlets in Calgary, Edmonton, Regina, Saskatoon, and Winnipeg; Tel: 1-800-661-5639; shipping supplies and material handling products.

Pesticide Analysis Laboratories

Alberta

AGAT Laboratories, 8740- 51 Avenue, Edmonton, AB, T6E 5E8; Tel: (403) 469-0106; 3801 - 21 Street, N.E., Calgary, AB, T2E 6T5; Tel: (403) 291-2428.

A & L Mid West Lab (Canada) Ltd., 2443 - 42 Avenue N.E., Calgary, AB, T2E 8A3; Tel: (403) 250-3317.

Chemex Labs AB Inc., 2021 - 41 Avenue, Calgary, AB, T3E 6P2; Tel: (403) 291-3077; Chemex Labs AB Inc., 9331 - 48 Street, Edmonton, T6B 2R4; Tel: (403) 465-9877.

Core Laboratories, Western Atlas Canada Ltd,, 1540 - 25 Avenue, N.E., Calgary, AB, T2E 7R2; Tel: (403) 250-4000.

ETL Enviro-Test Laboratories, 9936 - 67 Ave, Edmonton, AB, T6E 0P5; Tel: (403) 434-9509.

HBT Agra Limited, 4810 - 93 Street, Edmonton, AB, T6E 5M4; Tel: (403) 436-2152.

Norwest Labs, 9938 - 67 Avenue, Edmonton, AB, T6E 0P5; Tel: (403) 438-5522.

Plains Innovative Lab Services, 4244 - 91A Street, Edmonton, AB, T6E 5V2; Tel: (403) 463-5468.

Saskatchewan

SRC Analytical, 101 Research Drive, Saskatoon, SK, S7N 3R2; Tel: (306) 933-6932.

Plains Innovative Laboratory Services, A Division of Enviro-Test Laboratories, 124 Veterinary Road, Saskatoon, SK, S7N 5E3; Tel: 1-800-667-7645 (send samples to their lab in Edmonton).

Manitoba

Manitoba Technology Center, A Division of Enviro-Test Laboratories, 745 Logan Avenue, Winnipeg, MB, R3E 3C5; Tel: (204) 945-3705; Fax: (403) 945-0763.

Pesticides

Fungicides

Custom Ag Services, P.O. Box 9393, Saskatoon, SK, S7K 7E9; Tel: (306) 249-2200; Fax: (306) 249-0150; Kumulus.

United Agri Products, 820 - 26th Street NE, Calgary, AB, T2A 2M4; Tel: (403) 273-4355; Nova 40W.

United Agri Products, 2911D Cleveland Avenue, Saskatoon, SK, S7K 8A9; Tel: (306) 244-3558; Nova 40W.

Van Waters and Rogers Ltd., 99 Lowson Crescent, Winnipeg, MB, R3P 0T3; Tel: (204) 489-0102; Nova 40W.

Van Waters and Rogers Ltd., 1 - 2642 Miller Avenue, Saskatoon, SK, S7K 5V2; Tel: (306) 932-5252; Funginex 190 EC and Nova 40 W.

Westgro Horticultural Supplies Inc., 1557 Hastings Crescent SE., Calgary, AB, T2G 4C8; Tel: 1-800-661-2991; Fax: (403) 243-7470; Funginex 190 EC.

Herbicides

Bayer, Inc., 202 Auld Cres., Saskatoon, SK, S7H 4W9; Tel: (306) 955-2755; Sencor Solupak 75 DF.
Custom Ag Services, P.O. Box 9393, Saskatoon, SK, S7K 7E9; Tel: (306) 249-2200; Fax: (306) 249-0150; Afolan F.

Dow Elanco Canada, Inc., 241 - 111 Research Dr., Saskatoon, SK, S7N 3R2; Tel: 1-800-667-3852; Treflan EC.

Early's Farm and Garden Center, 2615 Lorne Avenue, Saskatoon, SK, S7J 0S5; Tel: (306) 931-1982; Fax: (306) 931-7110; Casoron.

K-5 Market Enterprises, c/o Tony Kustiak, Box 806, Shellbrook, SK, S0J 2E0; Tel: (306) 747-2829; Fax: (306) 747-2727; Casoron.

The Professional Gardener Company Ltd. 915 - 23 Avenue SE., Calgary, AB, T2G 1P1; Tel (403) 263-4200; Fax: (403) 237-0029; Casoron and Lorox.

United Agri Products, 820 - 26th Street NE, Calgary, AB, T2A 2M4; Tel: (403) 273-4355; Casoron.

United Agri Products, 2911D Cleveland Avenue, Saskatoon, SK, S7K 8A9; Tel: (306) 244-3558; Casoron.

Van Waters and Rogers Ltd., 1 - 2642 Miller Avenue, Saskatoon, SK, S7K 5V2: Tel: (306) 932-5252; Lorox DF.

Van Waters and Rogers Ltd., 99 Lowson Crescent, Winnipeg, MB, R3P 0T3; Tel: (204) 489-0102; Lorox DF.

Insecticides

Custom Ag Services, P.O. Box 9393, Saskatoon, SK, S7K 7E9; Tel: (306) 249-2200; Fax: (306) 249-0150; Decis.

Early's Farm and Garden Center, 2615 Lorne Avenue, Saskatoon, SK, S7J 0S5; Tel: 1-800-667-1159; (306) 931-1982; Fax: (306) 931-7110; Decis and Orthene 75% SP.

Even-Spray, Bay 2 - 851 Lagimodiere Blvd., Winnipeg, MB, R2J 3K4; Tel: 1-800-665-3836; Orthene 75% SP.

The Professional Gardener Company Ltd. 915 - 23 Avenue SE., Calgary, AB, T2G 1P1; Tel (403) 263-4200; Fax: (403) 237-0029; Orthene 75% SP.

United Agri Products, 820 - 26th Street NE, Calgary, AB, T2A 2M4; Tel: (403) 273-4355; Orthene 75% SP.

United Agri Products, 2911D Cleveland Avenue, Saskatoon, SK, S7K 8A9; Tel: (306) 244-3558; Orthene 75% SP.

Westgro Horticultural Supplies Inc., 1557 Hastings Crescent SE., Calgary, AB, T2G 4C8; Tel: 1-800-661-2991; Fax: (403) 243-7470; Decis 5.0 EC and Orthene 75% SP.

Plant & Seed Suppliers

Alberta

Alberta Nurseries & Seed Ltd., Box 20, Bowden, AB, T0M 0K0; Tel: (403) 224-3544.

Coaldale Nurseries Ltd., Box 1267, Coaldale, AB, T1M 1N1; Tel: (403) 345-4633.

D'n A Gardens, Box 544, Elnora, AB, T0M 0Y0; Tel: (403) 773-2489; Fax: (403) 773-3784.

Eagle Lake Nurseries, Box 2340, Strathmore, AB, T1P 1K3; Tel: (403) 934-3622.

The Hillson Nursery, Box 39, Rochester, AB, T0G 1Z0; Tel: (403) 698-3956; Fax: (403) 698-2333.

Johnson V L Tree Farms, Box 45, Caroline, AB, T0M 0M0; Tel: (403) 722-2412.

Laidlaw Nursery, Box 316, Tofield, AB, T0B 4J0; Tel: (403) 662-2778.

Pearson's Berry Farm Ltd. (L. Pearson), RR #1, Bowden, AB, T0M 0K0; Tel: (403) 224-3011; Fax: (403) 224-2096.

The Saskatoon Farm (P. Hamer), RR #1, Dewinton, AB, T0L 0X0; Tel: 1-800-463-2113/(403) 938-6245.

Spruce Lane Farm, Box 278, Irricana, AB, T0M 1B0; Tel: (403) 274-1875.

SunTropicals (Division of Oasis Gardens Ltd.), 237 Main Street, Balzac, AB, T0M 0E0; Tel: (403) 226-0220.

British Columbia

Agri-Forest Technologies Ltd., 4290 Wallace Hill Road, Kelowna, BC, V1Y 7R2; Tel: (604) 764-2224.

Kato's Nursery Ltd., 29435 Downes Road, RR #3, Matsqui, BC; Tel: (604) 856-2470/857-0036; Fax: (604) 856-9307.

Manitoba

Aubin Nurseries Ltd., Box 1089, Carman, MB, R0G 0J0; Tel: (204) 745-6703; Fax: (204) 745-6838.

Boughen Nurseries, Box 12, Valley River, MB, R0L 2G0; Tel: (204) 638-7618.

Foothills Greenhouse, Box 700, Winkler, MB, R6W 4A8; Tel: (204) 325-8132.

Jeffries Nurseries Ltd., Box 402, Portage La

Prairie, MB, R1N 3B7; Tel: (204) 857-5288; Fax: (204) 857-2877.

Patmore Nursery Sales, 1307 18th Street N, Brandon, MB, R7C 1A6; Tel: (204) 728-1321.

Vanstone Nursery, Box 670, Portage La Prairie, MB, R1N 3C2; Tel: (204) 857-8435.

Saskatchewan

Jarvis Blushke, Box 612, Langham, SK, S0K 2LO; Tel: (306) 245-4351.

Honeywood Lilies and Nursery, Box 63, Parkside, SK, S0J 2A0; Tel: (306) 747-3296.

J. Boughens Wholesale Nursery, Box 1679, Nipawin, SK, S0E 1E0; Tel: (306) 862-5313.

John's Nursery and Market Garden, Ltd., Box 24, Henribourg, SK, S0J 1C0; Tel: (306) 764-8139.

Parenteau's Saskatoon Berry Chocolates, Inc. (R. Parenteau), Box 618, Langham, SK, S0K 2L0; Tel: (306) 283-4960; Fax: (306) 283-4961.

Prairie Plant Systems Inc., 108 - 106 Research Drive, Saskatoon, SK, S7N 3R3; Tel: (306) 975-1207.

Select Seedling Nursery (Vic & Lee Krahn), Box 1A, RR3, Saskatoon, SK, S7K 3J6; Tel: (306) 978-1940; Fax: (306) 384-1747; E-mail: Krahn.select@sk.sympatico.ca.

Zosel Tree Farm, Box 179, Pleasantdale, SK. S0K 3H0; Tel: (306) 874-5729; Fax: (306) 874-5749.

Propagation Supplies & Equipment

Alberta

The Professional Gardener Co. Ltd., 915- 23 Avenue SE , Calgary, AB, T2G 1P1; Tel: (403) 263-4200; Fax: (403) 237-0029; greenhouse coverings, greenhouse structures, media, root trainers, pots, trays, fertilizer, rooting hormone, heating cables, thermostats.

Spencer-Lemaire Industries Ltd., 11413- 120 Street, Edmonton, AB, T5G 2Y3; Tel: 1-800-668-8530; Fax: (403) 452-0920; Email: spencer_lemaire@worldmail.net; root trainers.

Westgro Horticultural Supplies Inc., 1557 Hastings Crescent SE, Calgary, AB, T2G 4C8; Tel: (403) 287-3988; Fax: (403) 243-7470; greenhouse coverings, media, root trainers, pots trays, fertilizer, rooting hormone, heating cables, thermostats, mist bed equipment.

British Columbia

Coast Agri, 464 Riverside Road South, Abbotsford, BC, V2S 4N2; Tel: (604) 853-4836; Fax: (604) 853-8419; fertilizer.

Galaxy Agri-Products International Inc., 44775 Yale Road W., Sardis, BC, V2R 1A4; Tel: (604) 795-7588; Fax: (604) 795-5757; greenhouse structures, greenhouse coverings.

Gro-Tech Greenhouse Systems Inc., 26045-2nd Avenue, RR1, Aldergrove, BC, V4W 1L8; Tel: (604) 856-8323; Fax: (604) 856-2166; greenhouse structures, greenhouse coverings.

JVK Western Distribution Center, Unit #6, 1080 Cliveden Avenue, Delta, BC, V3M 6G6; Tel: (604) 526-5851; Fax: (604) 526-2312; greenhouse coverings, media, pots, heating cables, trays, inserts, rooting hormone, fertilizers.

Westgro Sales Inc., 7333 Progress Way, Delta, BC, V4G 1E7; Tel: (604) 940-0290; Fax: (604) 940-0258; greenhouse coverings, media, fertilizers, root trainers, trays, pots, rooting hormone, heating cables, thermostats.

Ontario

AMA Plastics Ltd., 1367 Oxford Avenue, Kingsville, ON, N9Y 2S8; Tel: (519) 322-1397; Fax: (519) 322-1358; nursery containers, root trainers, trays, inserts.

Saskatchewan

Early's Farm and Garden Center, 2615 Lorne Avenue, Saskatoon, SK.; Tel: (306) 931-1982); greenhouse coverings, media, root trainers, pots, trays, fertilizer, rooting hormones, heating cables.

Pruning Equipment

Alberta

The Professional Gardener Co. Ltd., 915- 23 Avenue SE , Calgary, AB, T2G 1P1; Tel: (403) 263-4200; Fax: (403) 237-0029; range of pruners.

Westgro Horticultural Supplies Inc., 1557 Hastings Crescent SE, Calgary, AB, T2G 4C8; Tel: (403) 287-3988; Fax: (403) 243-7470; range of pruners from small hand-held pruners to large loppers.

British Columbia

Holland Imports Inc., 2306 Madison Avenue, Burnaby, BC, V5C 4Y9; Tel: (604) 299-5741; Fax: (604) 299-5741; range of pruning equipment.

Kato's Nursery Ltd., 29435 Downes Road, Abbotsford, BC, V4X 1S3; Tel: (604) 856-2470, 857-0036; Fax: (604) 856-9307; E-mail: katos@bcnta.nwave.com; range of pruners from hand-held pruners to loppers and pruing saws.

Westgro Sales Inc., 7333 Progress Way, Delta, BC, V4G 1E7; Tel: (604) 940-0290; Fax: (604) 940-0258; range of pruners from hand-held pruners to large loppers.

Ontario

Sandvik Canada Inc., 6835 Century Avenue, Mississauga, ON, L5N 2L2; Tel: (514) 954-0172; Fax: (514) 735-1046; range of pruners from hand-held pruners to loppers and pruing saws.

Timm Enterprises Ltd., PO Box 157, Oakville, ON, L6J 4Z5; Tel: (905) 878-4244; range of pruning equipment including hand-held and pneumatic pruners.

Saskatchewan

Early's Farm and Garden Center, 2615 Lorne Avenue, Saskatoon, SK; Tel: (306) 931-1982; range of pruners from small hand- held pruners to loppers.

Refrigeration Equipment

Alberta

Western Refrigeration (carries a complete range of walk-in coolers and freezers).

British Columbia

Cryopak Corporation, Suite 1120 - 625 Howe Street, Vancouver, BC, V6C 2T6; Tel: (604) 685-5143; Fax: (604) 685-9170.

Manitoba

Coldstream Products Corporation, 1001 Regent Avenue West, Winnipeg, MB, R2C 4M2; Tel: (204) 669-1201; Fax: (204) 222-0655; range of walk-in cooler and freezer designs are available from dealers across western Canada.

Saskatchewan

Western Food Equipment Ltd., 3047-B Miller Avenue , Saskatoon, SK, S7K 6G5; Tel: (306) 933-2255; Fax: (306) 933-3191; supplier of walk-in coolers and freezers from a number of brand names.

Western Refrigeration Ltd., Box 8114 , Saskatoon, SK; Tel: (306) 956-3090; carries a complete range of walk-in coolers and freezers.

Safety Equipment

Alberta

The Professional Gardener Co. Ltd., 915- 23 Avenue SE , Calgary AB, T2G 1P1; Tel: (403) 263-4200; Fax: (403)237-0029; respirators, masks, gloves, disposable coveralls, helmets.

The St. George Company Ltd., PO Box 10, Foremost, AB, T0K 0X0; Tel: (403) 867-2226; Fax: (403) 867-2226; helmets, filters, gloves, disposable coveralls.

Westgro Horticultural Supplies Inc., 1557 Hastings Crescent SE, Calgary, AB, T2G 4C8; Tel: (403) 287-3988; Fax: (403) 243-7470; respirators, masks, gloves, disposable coveralls, helmets.

British Columbia

Westgro Sales Inc., 7333 Progress Way, Delta, BC, V4G 1E7; Tel: (604) 940-0290; Fax: (604) 940-0258; respirators, masks, gloves, disposable coveralls, helmets.

Saskatchewan

Safety Supply Canada, 518- 51st Street East, Saskatoon, SK, S7K 7L1; Tel: (306) 933-3341; Fax: (306) 934-0979; respirators, gloves, goggles, disposable coveralls.

Mid-North Safety, 215 - 103rd St. E., Saskatoon, SK, S7N 1X8; Tel: (306) 374-3635; Fax (306) 373-5611; respirators, gloves, goggles, disposable coveralls.

Soil & Water Testing Laboratories

Alberta

AGAT Laboratories, 3801 - 21 Avenue, N.E., Calgary, AB, T2E 6T5; Tel: (403) 291-2428; Fax: (403) 299-2022; 8740-51st Avenue, Edmonton, AB, T6E 5E8; Tel: (403) 469-0106; Fax: (403) 468-2887; soil analysis, water analysis, plant tissue testing, fertilizer recommendations.

Chemex Labs, 2021 - 41 Avenue, N.E., Calgary, AB, T2E 6P2; Tel: (403) 291-3077; Fax: (403) 291-9468; 9331 - 48 Street, Edmonton, AB, T6B 2R4; Tel: (403) 465-9877; Fax: (403) 466-3332.

A & L Midwest Laboratories (Canada) Ltd, 2443 - 42 Avenue, N.E., Calgary, AB, T2E 8A3; Tel: (403) 250-3317; Fax: (403) 250-5249.

Lakeside Research, Box 800, Brooks, AB, T1R 1B7; Tel: (403) 362-3326; Fax: (403) 362-8231.

Plains Innovative Laboratory Services, Enviro-Test Laboratories, 9936 - 67 Avenue, Edmonton, AB, T6E 0P5; Tel: (403) 434-9509; Fax: (403) 437-2311.

Norwest Soil Research Ltd., 9938 - 67 Avenue, Edmonton, AB, T6E 0P5; Tel: (403) 438-5522; Fax: (403) 438-0396; 3131 - 1 Avenue, South, Lethbridge, AB, T1J 4Hl; Tel: (403) 329-9266; Fax: (403) 327-8527.

Sandberg Laboratories Ltd., 3510 - 6 Avenue, North, Lethbridge, AB, T1J 5S3; Tel: (403) 328-1133; Fax: (403) 320-1033.

Manitoba

Manitoba Technology Center, A Division of Enviro-Test Laboratories, 745 Logan Avenue, Winnipeg, MB, R3E 3C5; Tel: (204) 945-3705; Fax: (403) 945-0763; soil analysis, plant tissue testing, fertilizer recommendations.

Saskatchewan

Plains Innovative Laboratory Services, A Division of Enviro-Test Laboratories, 124 Veterinary Road, Saskatoon, SK, S7N 5E3; Tel: 1-800-667-7645; fertilizer recommendations, plant tissue testing, soil analysis and water testing.

Spray Equipment

Alberta

The Professional Gardener Co. Ltd., 915- 23 Avenue SE, Calgary, AB, T2G 1P1; Tel: (403) 263-4200; Fax: (403)237-0029;

sprayers ranging in size from 12 to 15 liters.

Westgro Horticultural Supplies Inc., 1557 Hastings Crescent SE, Calgary, AB, T2G 4C8; Tel: (403) 287-3988; Fax: (403) 243-7470; sprayers ranging in size from 4.5 to 20 liters.

British Columbia

Hazmasters Environmental Controls Inc., 3131 Underhill Avenue, Burnaby, BC, V5A 3C8; Tel: (604) 420-0025; Fax: (604) 420-5282.

Joonas Agritech, 3046 McMillian Road, Abbotsford, BC, V2S 6A8; Tel: (604) 852-5016; Fax: (604) 859-3916.

Westgro Sales Inc., 7333 Progress Way, Delta, B.C., V4G 1E7; Tel: (604) 940-0290; Fax: (604) 940-0258; sprayers ranging in size from 4.5 to 20 liters.

Saskatchewan

Central Supply Ltd., 2326 Northridge Drive North, Saskatoon, SK, S7L 1B9; Tel: (306) 934-1546; Fax: (306) 242-4239; 25 gallon pull sprayers.

Early's Farm and Garden Center, 2615 Lorne Avenue, Saskatoon, SK; Tel: (306) 931-1982; Fax: (306) 931-7110; range of sprayers from 2 liters to 15 liters.

Enviromist Sprayers, 33-1st Avenue North, Swift Current, SK, S9H 2A9; Tel: (306) 778-2171; low volume covered sprayers.

Spray-Tech Systems Ltd., Box 290, Vonda, SK, S0K 4N0; Tel: (306) 258-2175; Fax: (306) 258-2176; range of spray equipment available and will custom build sprayers to desired specifications.

Scientific & Technical Literature Consulted

Richard G. St-Pierre, Ph.D. (January 2006)

Acharya, S.N., C.B. Chu and R. Hermesh. 1989. Effects of population, environment and their interaction on saskatoon berry (*Amelanchier alnifolia* Nutt.) seed germination. Canadian Journal of Plant Science 69:277-284.

Abod, S.A. and A.D. Webster. 1990. Shoot and root pruning effects on the growth and water relations of young *Malus*, *Tilia* and *Betula* transplants. Journal of Horticultural Science 65(4): 451-459.

Anonymous. Undated. Mulches for tree planting. PFRA Shelterbelt Centre. Indian Head, SK.

Anonymous. Undated. Planting trees for wildlife. PFRA Shelterbelt Centre. Indian Head, SK.

Anonymous. 1927. Narratives of Saskatoon 1882 - 1912. Committee of the Historical Association of Saskatoon. University of Saskatchewan, Bookstore, Saskatoon, SK.

Anonymous. 1976. *Amelanchier alnifolia* (Nuttall) Nuttall. Davidsonia 7(1):5-12.

Anonymous. 1981. Applying Nutrients And Other Chemicals to Trickle-Irrigated Crops. University of California, Division of Agricultural Sciences. Bulletin 1893.

Anonymous. 1988. Alberta Saskatoon Industry Survey 1987. Alberta Special Crops and Horticultural Research Center Pamphlet 88-13. Brooks, AB.

Anonymous. 1989. Shelterbelt Species. PFRA Shelterbelt Centre. Indian Head, SK.

Anonymous. 1990. Economics of saskatoon berry production. Farm Facts Bulletin produced by Saskatchewan Agriculture and Food, and Saskatchewan Rural Development. Regina, SK.

Anonymous. 1990. Low Volume Irrigation System Maintenance Manual. Rain Bird International Inc. Glendora, California.

Anonymous. 1991. Planning Farm Shelterbelts. PFRA Shelterbelt Centre. Indian Head, SK.

Anonymous. Wade Rain. 1991. Landscape Manual For Drip And Micro-Irrigation. Tualitin, Oregon.

Anonymous. 1992. Berry Production Guide For Commercial Growers. Ministry of Agriculture, Fisheries and Food. Province of British Columbia. Victoria, British Columbia.

Anonymous. 1992. Introduction To T-tape Drip Irrigation. San Diego, California.

Anonymous. 1993. Natural compounds

inhibit decay fungi. Northland Berry News 12/93.

Anonymous. 1993. Protecting Orchards From Deer. Province of British Columbia, Ministries of Environment, Lands and Parks, and Agriculture, Fisheries and Food. Victoria, B.C.

Anonymous. 1993. Roberts Irrigation Products Inc. Ro-Drip Strip Tubing Manual. San Carcos, California.

Anonymous. 1993. Tree Fruit Home Nurseries. A Grower's Manual. Okanagan Valley Tree Fruit Authority. Penticton, B.C.

Anonymous. 1996. Commercial Saskatoon Berry Industry. Ag-Ventures Agriculture Business Profile. Alberta Agriculture, Food and Rural Development. Agdex 238/830-1. June 1996.

Anonymous 1996. Guide To Fruit Crop Protection For Commercial Growers. Prairie Fruit Growers Association, Winnipeg, MB.

Anonymous. 1997. Plastic mulches for saskatoon berry orchards. PFRA Shelterbelt Centre, Indian Head, SK.

Austin, D.D. and A.B. Hash. 1988. Minimizing browsing damage by deer. Landscape planning for wildlife. Utah Science 49(3):66-70.

Barkley, S.J. 1992. Protecting garden plants from winter rodent feeding. Crop Protection Newsletter. Alberta Special Crops and Horticultural Research Center, Brooks, Alberta. October:3-4.

Bethune, T.D., D.M. Lehmkuhl and T.A. Steeves. 1979. An insect pest of saskatoons. Blue Jay 37:130-137.

Bishop, B.H. and S.H. Nelson. 1980. Propagation and transplanting of saskatoon (*Amelanchier alnifolia* Nutt.) softwood cuttings. Canadian Journal of Plant Science 60:883-890.

Brazell, M. 1992. Growing Trees On The Great Plains. Fulcrum Publishing, Golden, Colorado.

Brinkman, K.A. 1974. *Amelanchier* Med. Serviceberry. pp. 212-215 in C.S. Schopmeyer (ed.). Seeds Of Woody Plants In The United States. Agriculture Handbook Number 450. Forest Service, U.S. Department of Agriculture, Washington, D.C.

Brooke, B.M., McDiarmid, R.E., and W. Majak. 1988. The cyanide potential in two varieties of *Amelanchier alnifolia*. Canadian Journal of Plant Science 68:543-547.

Brown, A. 1970. Old Man's Garden. Gray's Publishing Ltd., Sydney, British Columbia.

Buckell, E.R. 1930. The apple curculio as a pear pest in British Columbia. Canadian Entomologist 62(3):47-49.

Caswell, K.L., N.J. Tyler and C. Stushnoff. 1986. Cold hardening of *in vitro* apple and saskatoon shoot cultures. HortScience 21(5):1207- 1209.

Cessna, A.J. 1988. The determination of the herbicide linuron in saskatoon berries using HPLC with column switching. Journal of

Liquid Chromatography 11(3):725-735.

Chandler, C.K. 1990. Comparison of pruned and unpruned pear seedlings for survival and growth. HortScience 25(1):123.

Chaney, D.E., L.E. Drinkwater and G.S. Pettygrove. 1992. Organic Soil Amendments And Fertilizers. University of California, Division of Agriculture and Natural Resources, Oakland, California. Publication 21505.

Chu, C. and K.W. Mudge. 1996. Using a rockwool plug system *in vitro* on *Amelanchier*, *Cercis*, *Kalmia*, cherry and apple. HortScience 31(4):566 (Abstract 009).

Cinq-Mars, L. 1971. Le genre *Amelanchier* au Quebec. Naturaliste Canadian 98:329-346.

Clark, G. and A. Toogood. 1992. The Complete Book Of Plant Propagation. Ward Lock Limited, London.

Cleveland, D.A. and D. Soleri. 1991. Food From Dryland Gardens. Center For People, Food And Environment, Tucson.

Cline, R.A. 1981. Trickle irrigation for fruit crops. Ontario Ministry of Agriculture and Food. Factsheet 81-070.

Cline, R.A. and B. McNeill. 1990. Leaf analyses for fruit crop nutrition. Ontario Ministry of Agriculture and Food. Factsheet 90-105.

Crandall, C.S. 1905. The curculio and the apple. Illinois Agricultural Experiment Station Bulletin 98:467-560.

Cruise, J.E. 1964. Studies of natural hybrids in *Amelanchier*. Canadian Journal of Botany 42:651-663.

Currah, R., A. Smreciu, and M. Van Dyk. 1983. Prairie Wildflowers. Friends of the Devonian Botanic Garden. University of Alberta, Edmonton, Alberta.

Dale, R. 1995. Permanent sod culture for raspberries and blueberries. Northland Berry News. September:25-26.

Darrow, G.M. 1975. Minor temperate fruits. pp. 289-284 in J. Janick and J.N. Moore (eds.). Advances In Fruit Breeding. Purdue University Press, West Lafayette, Indiana.

Daskberg, A. and Bresler, E. 1985. Drip Irrigation Manual. International Irrigation Information Center, Bet Dagan, Israel.

Davidson, C.G. and G. Mazza. 1991. Variability of fruit quality and plant height in populations of saskatoon berries (*Amelanchier alnifolia* Nutt.). Fruit Varieties Journal 45(3):162-165.

Davidson, C.G., R.J. Enns, and M. Reimer. 1991. Tree Fruit Production For The Prairie Provinces. Communications Branch. Agriculture Canada, Ottawa, Ontario. Publication 1866/E.

Davidson, J.G.N. 1985. The principal diseases of saskatoons. The Fruit Grower 2(1):8- 12.

Davidson, J.G.N. 1986. Principle insect pests of saskatoons. The Fruit Grower

2(2):29-32.

Davidson, J.G.N. 1986. Non-infectious diseases. The Fruit Grower 2(3):10-13.

Davidson, J.G.N. 1986. Pruning, Part I. The Fruit Grower 2(4):6-7.

Davidson, J.G.N. 1987. Smoky and Pembina saskatoons: the real story. Agriculture Canada, Northern Research Group, NRG News 87-07.

Davidson, J.G.N. 1990. *Entomosporium* leaf and berry spot of saskatoons in Alberta 1990. Agriculture Canada, Northern Research Group, NRG News: NRG 91-04, Beaverlodge, AB.

Davidson, J.G.N. 1991. Diebacks and cankers can destroy your saskatoon orchard. Agriculture Canada, Northern Research Group, NRG Bulletin: NRG 88-05b, Beaverlodge, AB.

Davidson, J.G.N. 1991. Principle insect pests of saskatoons. Agriculture Canada, Northern Research Group, NRG Bulletin: NRG 90-04b, Beaverlodge, AB.

Davidson, J.G.N. 1992. Principal diseases of saskatoons in the prairies. Part I. The Fruit Grower 8(1):6-11.

Davidson, J.G.N. 1992. Principal diseases of saskatoons in the prairies. Part II. The Fruit Grower 8(2):9-11.

Davidson, J.G.N., P. Bains, Z. Pesic-Van Esbroeck, and D. Kaminski. 1991. Epidemic of *Entomosporium* berry and leaf spot of saskatoons throughout Alberta in 1990. Canadian Plant Disease Survey 71(1):123-125.

Davidson, J.G.N. and R.G. St-Pierre. 1994. Saskatoons. In J.N. Cummins (ed.). Register of new fruit and nut varieties. Brooks and Olmo. List 36. HortScience 29(9):959-960.

Davidson, R.H. and W.F. Lyon. 1979. Insect Pests of Farm, Garden, And Orchard. Seventh edition. John Wiley and Sons, New York.

Dirr, M.A. 1975. Manual Of Woody Landscape Plants. Their Identification, Ornamental Characteristics, Culture, Propagation And Uses. Stipes Publishing Co., Champaign, Illinois.

Dirr, M.A. and C.W. Heuser, Jr. 1987. The Reference Manual Of Woody Plant Propagation: From Seed To Tissue Culture. Varsity Press, Inc., Athens, Georgia.

Drouin, J.A. and D.S. Kusch. 1978. Chemical control of a seed-boring sawfly and a midge damaging chokecherry in Alberta. Environment Canada. Forestry Service. Bimonthly Research Notes 34(6):37.

Drouin, J.A. and D.S. Kusch. 1980. Pesticide field trials on shade and shelterbelt trees in Alberta, 1979. Environment Canada. Forestry Service. Information Report NOR-X-227:7-8.

East, M.A. 1952. The Saskatoon Story 1882 - 1952. General Printing and Bookbinding Ltd., Saskatoon, SK.

Facciola, S. 1990. Cornucopia. A Source

Book Of Edible Plants. Kampong Publications, Vista, California.

Faust, M. 1989. Physiology Of Temperate Zone Fruit Trees. John Wiley & Sons, New York.

Felt, E.P. 1965. Plant Galls And Gall Makers. Hafner Press, N.Y.

Fereres, E. (ed.). 1992. Drip Irrigation Management. Co-operative Extension. University of California. Division of Agriculture and Natural Resources. Leaflet 21259.

Fernald, M.L. 1950. Gray's Manual Of Botany. Eighth edition. American Book Co., N.Y.

Flint, M.L. 1990. Pests Of The Garden And Small Farm. Division of Agriculture and Natural Resources. University of California, Oakland, California. Publication 3332.

Friesen, L.J. and C. Stushnoff. 1985. Spring frost injury relative to phenophase bud development in saskatoon berry. HortScience 20(4): 744-746.

Friesen, L.J. and C. Stushnoff. 1989. Vegetative maturity of *Amelanchier alnifolia* Nutt. compared to red- osier dogwood and Rescue crabapple. Canadian Journal of Plant Science 69:955-960.

Fry, A.W. Rain Bird International Drip Systems Design Manual. Rain Bird International Inc. Glendora, California.

Fulton, B.B. 1928. The apple curculio and its control by hogs. Journal of Agricultural Research 36(2):249-281.

Fung, M.Y.P. 1984. Vegetative propagation of native shrubs in the Fort McMurray area, Alberta, Canada. Plant Propagator 30(4):7-9.

Galletta, G.J. and D.G. Himelrick (eds.). 1990. Small Fruit Crop Management. Prentice Hall, Englewood Cliffs, New Jersey.

Glover, R. (ed.). 1962. David Thompson’s Narrative 1784 - 1812. The Champlain Society, Toronto, ON.

Graham, T.O. 1977. A possible new commercial fruit crop. Paper presented at the Annual Meeting of the Canadian Society for Horticultural Science, University of Guelph, Guelph, Ontario; 15 August, 1977.

Grant, C. 1989. A wipeout year for saskatoons. The Fruit Grower 5(2):33.

Green, R.C. and G. Mazza. 1986. Relationships between anthocyanins, total phenolics, carbohydrates, acidity and colour of saskatoon berries. Journal of the Canadian Institute of Food Science and Technology 19(3):107-113.

Hall-Beyer, B. and J. Richard. 1989. Ecological Fruit Production In The North. Jean Richard. Trois Rivieres, Quebec.

Hammer, O.H. 1932. Studies on control of the apple curculio in the Champlain Valley. Journal of Economic Entomology 25:569-575.

Hammer, O.H. 1933. Further studies on the control of the apple curculio in the

Champlain Valley. Journal of Economic Entomology 28:420-424.

Hargrave, P.D. 1937. Seed germination of the saskatoon and pincherry. Scientific Agriculture 17:736-739.

Harris, L. 1993. Insects on saskatoons. The Fruit Grower 9(1):12-17.

Harris, R.E. 1961. The vegetative propagation of *Amelanchier alnifolia*. Canadian Journal of Plant Science 41(10):728- 731.

Harris, R.E. 1970. The genus *Amelanchier*. Journal of the Royal Horticultural Society 95:116-118.

Harris, R.E. 1973. The Saskatoon. Agriculture Canada Publication 1246.

Harris, R.E. 1976. Saskatoons (*Amelanchier alnifolia*). Summary report. Proceedings of the Western Canadian Society for Horticulture 32:50-59.

Harris, R.E. 1984. Rapid propagation of saskatoon plants *in vitro*. Project 82-0017. Farming For The Future Research Program. Alberta Agriculture, Edmonton, Alberta.

Harris, R.E. 1984. Rooting of *in vitro* produced shoots of saskatoon (*Amelanchier alnifolia*). Project 83- 0054. Farming For The Future Research Program. Alberta Agriculture, Edmonton, Alberta.

Harris, R.E. 1990. From the Archives. The effect of irrigation, mulching and type of plant on the early production of saskatoons. The Fruit Grower 6(3):24-27.

Hartmann, H.T., W.J. Flocker, and A.M. Kofranek. 1981. Plant Science. Prentice-Hall, Inc., Englewood Cliffs, New Jersey, U.S.A.

Hartmann, H.T., D.E. Kester and F.T. Davies, Jr. 1990. Plant Propagation. Principles And Practices. Prentice Hall. Englewood Cliffs, New Jersey.

Hilton, R.J. 1982. Registration of *Amelanchier* cultivar names. Fruit Varieties Journal 36(4):108-110.

Hilton, R.J. 1985. *Amelanchier* - A shade tree? Gardenland (October):9.

Hilton, R.J., A.S. Jaswal, B.J.E. Teskey and B. Barabas. 1965. Rest period studies on seeds of *Amelanchier*, *Prunus*, and *Sorbus*. Canadian Journal of Plant Science 45:79-85.

Hiratsuka, Y. 1987. Forest Tree Diseases Of The Prairie Provinces. Canadian Forestry Service. Northern Forestry Centre. Information Report NOR-X-286.

Hoag, D.G. 1965. Trees And Shrubs For The Northern Plains. North Dakota Institute For Regional Studies, Fargo, North Dakota.

Horst, R.K. 1979. Westcott's Plant Disease Handbook. Fourth edition. Van Nostrand Reinhold Company, New York.

Hosie, R. 1979. The Native Trees Of Canada. Eighth edition. Fitzhenry and Whiteside Ltd., Don Mills, Ontario.

Howard, R.J. 1990. Fireblight disease demands control. The Fruit Grower 6(3):12-13.

Howard, R.J. 1991. Saskatoon dieback and canker research update. The Fruit Grower 7(1):6-8.

Howard, R.J., P.S. Bains, E.R. Moskaluk, and Z. Pesic-Van Esbroeck. 1992. Evaluation of eleven saskatoon cultivars for resistance to powdery mildew. Canadian Plant Disease Survey 72(1):90-93.

Imbs, P. 1973. Tresor De La Langue Francaise. Tome Deuxieme. Editions Du Centre National De La Recherche Scientifique. Paris.

Ives, W.G.H. and H.R. Wong. 1988. Tree And Shrub Insects Of The Prairie Provinces. Canadian Forestry Service. Northern Forestry Centre. Information Report NOR-X-292.

Jackson, D. 1986. Temperate And Subtropical Fruit Production. Butterworths Horticultural Books. Wellington, New Zealand.

Jesperson, G. 1992. Apple replant problem. Crop Protection Factsheet. Pest Control Note 92-02. B.C. Ministry of Agriculture, Fisheries and Food. Kelowna, B.C.

Johnson, W.T. and H.H. Lyon. 1988. Insects That Feed On Trees And Shrubs. Comstock Publishing Associates, Ithaca, New York.

Jones, G.N. 1946. American species of *Amelanchier*. Illinois Biological Monographs 20(2):1-128.

Joyce, D. 1992. The Complete Guide To Pruning And Training Plants. Simon and Schuster, New York.

Junttila, O., C. Stushnoff and L.V. Gusta. 1983. Dehardening in flower buds of saskatoon- berry, *Amelanchier alnifolia*, in relation to temperature, moisture content, and spring bud development. Canadian Journal of Botany 61(1):164-170.

Kabaluk, J.T. and R.G. St. Pierre. 1992. A technique for screening seedlings of the saskatoon for resistance to the rust *Gymnosporangium nelsonii*. Canadian Journal of Plant Science 72:627-630.

Kalt, Willy and Jane E. MacDonald. (1996). Chemical Composition of Lowbush Blueberry Cultivars. Journal of the American Society for Horticultural Science 121(1)142-146.

Kaurin, A., C. Stushnoff, and O. Junttila. 1984. Cold acclimation and dormancy of *Amelanchier alnifolia*. Journal of the American Society for Horticultural Science 109(2):160-163.

Kerr, D. and S. Hanson. 1982. Saskatoon: The First Half-Century. NeWest. Saskatoon, SK.

Kienholz, J. 1995. Project - saskatoon cooling. The Fruit Grower 2(2):8-9.

Kourik, R. 1992. Drip Irrigation For Every Landscape And All Climates. Metamorphic Press, Santa Rosa, California.

Krahn, G. 1978. Cotoneaster as understock for *Amelanchier*. Pomona 12(2):95-96.

LaRue, J.H. and R.S. Johnson. 1989. Peaches, Plums, And Nectarines. Growing And Handling For Fresh Market. Co-operative Extension, Division of Agriculture and Natural Resources, University of California, Oakland, California. Publication 3331.

Laughlin, K.M., R.C. Smith and R.G. Askew. 1988. Juneberry for commercial and home use on the northern Great Plains. North Dakota State University, Fargo, North Dakota.

List, G.M. 1932. A cherry pest in Colorado. Bulletin of the Colorado Agricultural Experiment Station 385. 106 pp.

Looman, J. and K.F. Best. 1979. Budd's Flora Of The Canadian Prairie Provinces. Agriculture Canada Publication 1662.

Lorenz, O.A. and D.N. Maynard. 1988. Knott's Handbook For Vegetable Growers. John Wiley & Sons, New York.

Love, A. 1975. IOPB Chromosome number reports XLVIII. Taxon 24(2/3):367-372.

Majak, W., R.J. Bose, and D.A. Quinton. 1978. Prunasin, the cyanogenic glycoside in *Amelanchier alnifolia*. Phytochemistry 17:803.

Majak, W., R.E. McDiarmid and J.W. Hall. 1981. The cyanide potential of saskatoon serviceberry (*Amelanchier alnifolia*) and chokecherry (*Prunus virginiana*). Canadian Journal of Animal Science 61:681-686.

Majak, W., B. Pink, J. Hall, and J.S. McKenzie. 1982. A rapid method for determining cyanide potential in saskatoon (*Amelanchier alnifolia*). Canadian Journal of Plant Science 62:439-443.

Majak, W., D.A. Quinton and K. Broersma. 1980. Cyanogenic glycoside levels in saskatoon serviceberry. Journal of Range Management 33(3):197-199.

Majak, W., T. Udenberg, L.J. Clark and A. McLean. 1980. Toxicity of saskatoon serviceberry to cattle. Canadian Veterinary Journal 21:74-76.

Martin, L.C. 1992. The Folklore Of Trees And Shrubs. The Globe Pequot Press, Chester, Connecticut.

Mazza, G. 1979. Development and consumer evaluation of a native fruit product. Journal of the Canadian Institute of Food Science and Technology 12(4):166-169.

Mazza, G. 1982. Chemical composition of saskatoon berries (*Amelanchier alnifolia* Nutt.). Journal of Food Science 47:1730-1731.

Mazza, G. 1986. Anthocyanins and other phenolic compounds of saskatoon berries (*Amelanchier alnifolia* Nutt.). Journal of Food Science 51(5):1280-1284.

Mazza, G. and M.W. Hodgins. 1985. Benzaldehyde, a major aroma component of saskatoon berries. HortScience 20(4):742-744.

McConkey, M. 1979. What's a saskatoon? The pioneering and popularizing of a native fruit. North American Pomona 12(1):2-10.

McGarry, R., J.A. Ozga, and D.M. Reinecke. 1996. Fruit development in saskatoon (*Amelanchier alnifolia* Nutt.).

Abstract. HortScience 31(4):682.

McKay, S.M. 1973. A biosystematic study of the genus *Amelanchier* in Ontario. M.Sc. Thesis, Department of Botany, University of Toronto, Toronto, Ontario.

McKenzie, R.H. and D.J. Heaney. 1992. Micronutrients - are they really necessary? The Fruit Grower 7(3):17-18.

Merrill, C.S. 1986. Boosting saskatoon growth. The Fruit Grower 2(3):24-25.

Miller, W.S. and C. Stushnoff. 1971. A description of *Amelanchier* species in regard to cultivar development. Fruit Varieties and Horticultural Digest 25(1):3-10.

Monner, G. and G. N. Chaudhary. 1996. A Consensus of costs and returns for a 10 acre saskatoon berry production entreprise in the Peace River Region of Alberta. Alberta Agriculture, Food and Rural Development, Economic Services Division, Production Economics Branch. Publication #288. October 1996.

Moss, E.H. 1959. Flora Of Alberta. University of Toronto Press, Toronto.

Munson, R.H. and R.G. Nicholson. 1994. A germination protocol for small seed lots. Journal of Environmental Horticulture 12(4):223-226.

Nakayama, F. and Bucks, D.A. 1986. Trickle Irrigation For Crop Production. Design, Operation and Management. Elsevier Science Publishers, Amsterdam, The Netherlands.

Neill, G.B., D.A. Reynard, D.A. McPherson, and J.L. Harris. 1994. Woolly elm aphid investigations. PFRA Shelterbelt Centre Supplementary Report 94-1, Indian Head, SK.

Neill, G.B., D.A. Reynard, D.A. McPherson, and J.L. Harris. 1994. Woolly elm aphid investigations 1995. PFRA Shelterbelt Centre Supplementary Report 95-3, Indian Head, SK.

Nelson, S.H. 1987. Effects of stock plant etiolation on the rooting of saskatoon berry (*Amelanchier alnifolia* Nutt.) cuttings. Canadian Journal of Plant Science 67:299-303.

Nelson, S.H. and B.H. Bishop. 1980. Rootstock studies on saskatoons (*Amelanchier alnifolia* Nutt.). Canadian Journal of Plant Science 60:879-882.

Nelson, S.H. and J.R. Sawatzky. 1987. Etiolation of stock plants as an aid in the rooting of saskatoonberry (*Amelanchier alnifolia* Nutt.) cuttings. Landscape Trades (December):21, 24.

Nelson, S.H. and C. Stushnoff. 1987. Pruning. Division of Extension and Community Relations, University of Saskatchewan, Saskatoon, SK. Publication 553.

Nielsen, E.L. 1939. A taxonomic study of the genus *Amelanchier* in Minnesota. American Midland Naturalist 22:160-206.

Nielsen, G.H., E.J. Hogue, and P. Parchomchuk. 1990. Flowering of apple trees in the second year is increased by first-year P fertilization. HortScience 25(10):1247-1250.

Oberhofer, H. 1990. Pruning the slender spindle. B.C. Ministry of Agriculture and Fisheries. Victoria, B.C.

Olson, A.R. and T.A. Steeves. 1982. Structural changes in the developing fruit wall of *Amelanchier alnifolia*. Canadian Journal of Botany 60(10):1880-1887.

Olson, A.R. and T.A. Steeves. 1983. Frost damage in flowers and immature fruits of *Amelanchier alnifolia* Nutt. (Maloideae). Canadian Journal of Plant Science 63:461-466.

Olson, A.R. 1984. Structural aspects of pollination in *Amelanchier alnifolia* (Maloideae). Canadian Journal of Botany 62:858-864.

Panford, J. 1995. Evaluation of the saskatoon cooling project. The Fruit Grower 2(2):9-10.

Parmelee, J.A. 1971. The genus *Gymnosporangium* in western Canada. Canadian Journal of Botany 49:903-928.

Patch, E.M. 1915. Woolly aphid of elm and juneberry. Bulletin 241. Maine Agricultural Experiment Station, Orono, Maine.

Patterson, C.F. 1936. Hardy Fruits With Special Reference To Their Culture In Western Canada. Published by the author, Saskatoon, Saskatchewan.

Petch, C.E. 1928. The apple curculio and its control in Quebec. Canada Department of Agriculture, Entomology Branch Circular 36.

Pirone, P. 1978. Diseases And Pests Of Ornamental Plants. John Wiley and Sons, New York.

Pluim, R.A., R.J. Howard, J.P. Tewari and N.R. Knowles. 1990. Survey for dieback and canker disease of saskatoon caused by *Cytospora sp.* Canadian Plant Disease Survey 70:1.

Porter, W. 1994. A baited electric fence for controlling deer damage to orchards. Newsletter of the Fruit Growers' Society of Alberta 1(1):11.

Powell, C.C. and R. Rossetti. 1992. The Healthy Indoor Plant. Rosewell Publishing, Inc., Columbus, Ohio.

Pruski, K., M. Mohyuddin and G. Grainger. 1991. Saskatoon (*Amelanchier alnifolia* Nutt.). pp. 164-179 in Y.P.S. Bajaj (ed.). Biotechnology In Agriculture And Forestry. Vol. 16. Trees III. Springer-Verlag, Berlin.

Pruski, K., J. Nowak and G. Grainger. 1990. Micropropagation of four cultivars of saskatoon berry (*Amelanchier alnifolia* Nutt.). Plant Cell, Tissue and Organ Culture 21:103-109.

Quinton, D.A. 1985. Saskatoon serviceberry toxic to deer. Journal of Wildlife Management 49(2):362-364.

Reuther, W., J.A. Beutel, A.W. Marsh, J.L. Meyer, F.K. Aljibury, R.S. Ayers, H. Schulbach. 1981. Irrigating Deciduous Orchards. Leaflet 21212. Division of

Agricultural Sciences, University of California, Riverside, California.

Riley, C.V. 1871. The apple curculio. Third Annual Report on the noxious, beneficial and other insects of the state of Missouri:29-35.

Ritcher, P.O. 1936a. Larger apple curculio in Wisconsin. Journal of Economic Entomology 29(4):697-701.

Ritcher, P.O. 1936b. Host relationships of the larger apple curculio, *Tachypterellus quadrigibbus* Magnus List. Journal of the Kansas Entomological Society 9(3):94-99.

Robert, P. 1985. Le Grand Robert De La Langue Francaise. Deuxieme Edition. Tome I. Le Robert, Paris.

Robertson, K.R. 1974. The genera of Rosaceae in the southeastern U.S.A. Journal of the Arnold Arboretum 55(4):611-662.

Roll, D. 1989. Trickle irrigation for the saskatoon orchard. The Fruit Grower 5(2):8-18.

Rombough, L. 1995. A challenge to fruit exploring. Pomona 26(1):20,21.

Ross, H.H. 1943. The North American sawflies of the genus *Hoplocampa* (Hymenoptera: Tenthredinidae). Transactions of the American Entomological Society 69:61-92.

Ryugo, K. 1988. Fruit Culture: Its Science And Art. John Wiley & Sons, New York.

Sanders, M. 1994. Steps To Success In Replanting. Okanagan Valley Tree Fruit Authority, British Columbia Ministry of Agriculture, Fisheries and Food, Kelowna, B.C.

Sawatzky, R. 1991. Improved rooting efficiency of shy-rooting species using etiolated juvenile cuttings. Department of Horticulture Science, University of Saskatchewan, Saskatoon, SK.

Schofield, J.J. 1989. Discovering Wild Plants. Alaska Northwest Books, Anchorage, Alaska.

Schroeder, B. and S. Faye. 1996. Mulches as an alternative weed control method in saskatoon berry orchards. PFRA Shelterbelt Centre Supplementary Report 96-1. Indian Head, SK.

Scoggan, H.J. 1978. The Flora Of Canada. National Museums of Canada. Ottawa, Ontario.

Sharma, M.P. 1986. Recognizing Herbicide Action And Injury. Alberta Environmental Centre, Vegreville, AB.

Shepersky, K. 1984. Landscape Drip Irrigation Design Manual. Rain Bird Sales Inc. Turf Division. Glendora, California.

Shewfelt, Robert L. And Stanley E. Prussia (1993). Postharvest Handling: A Systems Approach Academic Press Inc. San Diego, CA.

Snyder, L.C. 1980. Trees And Shrubs For Northern Gardens. University of Minnesota Press, Minneapolis, Minnesota.

Solutions 2000+ Management Consultants and the Trimension Training and Consulting Group. 1994. Specialty Berry Market Assessment Study. Prepared for the Saskatchewan Indian Agriculture Program Inc. and the Agriculture Development Fund, Saskatchewan Department of Agriculture and Food, Regina, SK.

Stebbins, R.L. and K.L. Wilder. 1993. Leaf analysis of nutrient disorders in tree fruits and small fruits. Publication FS118. Oregon State University Extension Service. Corvallis, Oregon.

Steel, M. 1986. Using Saskatchewan Fruits. Publication No. 548. Division of Extension and Community Relations, University of Saskatchewan.

Steeves, T.A., D.M. Lehmkuhl, and T.D. Bethune. 1979. Damage to saskatoons, *Amelanchier alnifolia*, by the apple curculio, *Tachypterellus quadrigibbus* (Coleoptera: Curculionidae).Canadian Entomologist 111:641- 648.

Steeves, M.W. and T.A. Steeves. 1990. Inflorescence development in *Amelanchier alnifolia*. Canadian Journal of Botany 68(8):1680-1688.

Steeves, T.A., M.W. Steeves, and A.R. Olson. 1991. Flower development in *Amelanchier alnifolia* (Maloideae). Canadian Journal of Botany 69(4):844-857.

Stephens, H.A. 1973. Woody Plants Of The North Central Plains. The University Press of Kansas. Lawrence, Kansas.

St-Pierre, R.G. 1986. Immature fruit loss in *Amelanchier alnifolia* Nuttall (Rosaceae). Ph.D. Thesis. Department of Biology, University of Saskatchewan, Saskatoon, Saskatchewan.

St- Pierre, R.G. 1989. Magnitude, timing, and causes of immature fruit loss in *Amelanchier alnifolia* (Rosaceae). Canadian Journal of Botany 67:728-731.

St-Pierre, R.G. 1995. Notes on Factors Affecting Fruit Yield. The Prairie Fruit Journal 2(4):4, 14.

St-Pierre, R.G. 1997. Saskatoon. pp. 666-668 in The Brooks and Olmo Register Of Fruit & Nut Varieties. Third Edition. ASHS Press. Alexandria, Virginia.

St-Pierre, R.G. and D.M. Lehmkuhl. 1990. Phenology of *Hoplocampa montanicola* Rohwer (Tenthredinidae) and *Anthonomus quadrigibbus* Say (Curculionidae) on their host plant *Amelanchier alnifolia* Nutt. (Rosaceae) in Saskatchewan. Canadian Entomologist 122:901-906.

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). The Canadian Field-Naturalist 104:379-386.

St. Pierre, R.G. and D.A. Kaminski. 1993. Triforine, metiram and sulphur for control of saskatoon-juniper rust, brown rot, and *Entomosporium* leaf and berry spot, 1992 & 1993. Pest Management Research Report - 1993. Agriculture Canada, Research Branch, Ottawa, Ontario.

Stout, D.G. 1983. Evaluation of freezing injury and freeze-thaw injury to membranes of saskatoon serviceberry twigs by measuring HCN release. Physiologia Plantarum 57:573-578.

Stubbendeick, J., S.L. Hatch and K.J. Kjar. 1982. North American Range Plants. University of Nebraska Press. Lincoln, Nebraska.

Swietlik, D. and M. Faust. 1984. Foliar nutrition of fruit crops. Horticultural Reviews 6:287-355.

Tan, C.S. and R.E.C. Layne. 1990. Irrigation scheduling for fruit crops. Ontario Ministry of Agriculture and Food. Factsheet 90-069.

Tucker, D.P.H. 1983. Citrus Irrigation Management. Circular 444. Florida Co-operative Extension Service, University of Florida, Gainesville, Florida.

Turner, N.J. and A.F. Szczawinski. 1988. Edible Wild Fruits And Nuts Of Canada. Fitzhenry and Whiteside, Markham, Ontario.

Usui, M., Y. Kakuda, and P.G. Kevan. 1994. Composition and energy values of wild fruits from the boreal forest of northern Ontario. Canadian Journal of Plant Science 74:581-587.

Van der Gulik, T.W. 1987. B.C. Trickle Irrigation Manual. B.C. Ministry of Agriculture and Fisheries. Agriculture Engineering Branch. Abbostford, B.C.

Vose, B. 1989. Some thoughts on drought-proofing your trees. Pomona 22(3):4-6.

Wallace, J.A. 1978. Thoughts on the culture and propagation of *Amelanchier*. Proceedings of the Western Canadian Society for Horticulture 34: 94-96.

Wallace, J.A. and T.O. Graham. 1976. Outlook in Western Canada towards improvement of the genus *Amelanchier*. Proceedings of the Western Canadian Society for Horticulture 32:81-107.

Weaver, R.E. 1974. The shadbushes. Arnoldia 34(1):22-31.

Weber, G.P. and L.E. Wiesner. 1980. Tetrazolium testing procedures for native shrubs and forbs. Journal of Seed Technology 5(2):23-34.

Weber, G.P., Wiesner, L.E., and R.E. Lund. 1982. Improving germination of skunkbush sumac and serviceberry seed. Journal of Seed Technology 7(1):60-71.

Weir, B.J. 1996. Development and application of RAPD analysis for intra- and interspecific characterization within the genus *Amelanchier*. Ph.D. Thesis. Department of Biology, University of Saskatchewan, Saskatoon, SK.

Weir, B.J., R.N. Chibbar and R.G. St. Pierre. 1994. RAPD fingerprinting cultivars of a native fruit species (*Amelanchier alnifolia* Nutt., Rosaceae), a new Canadian horticultural crop. pp. 141-148 in R.P. Adams, J.S. Miller, E.M. Golenberg and J.E. Adams (eds.). Conservation Of Plant Genes II: Utilization Of Ancient And Modern DNA. Monographs in Systematic Botany. Volume 48. Missouri Botanical Garden, St. Louis, MO.

Weir, B.J., R.G. St-Pierre and R.N. Chibbar. 1996. Isolation of DNA for RAPD analysis from leaves of the saskatoon (*Amelanchier alnifolia* Nutt.) and other horticultural crops. Canadian Journal of Plant Science 76:819-824.

Westwood, M.N. 1993. Temperate-Zone Pomology. Physiology And Culture. Third Edition. Timber Press. Portland, Oregon.

Wiegand, K.M. 1912. The genus *Amelanchier* in eastern North America. Rhodora 14:117-161.

Weiterman, G. 1989. Understanding Your Soil Water Report. Saskatchewan Water Corporation. Handi-Facts. Moose Jaw, SK.

Wilkinson, K. 1990. Trees And Shrubs Of Alberta. Lone Pine, Edmonton, Alberta.

Williams, G. 1992. More on preventing birds from damaging strawberries. HortIdeas 9(4):42.

Wittwer, S.H. and N. Castilla. 1995. Protected cultivation of horticultural crops worldwide. HortTechnology 5(1):6-23.

Wong, H.R., J.C.E. Melvin and A.M. Harper. 1977. Common Insect And Mite Galls Of The Canadian Prairies. Information Report NOR-X-196. Northern Forest Research Centre. Canadian Forestry Service, Edmonton, Alberta.

Wright, P.H. 1973. Amelanchiers. Horticulture 51(3):62-63,70.

Young, J.A. and C.G. Young. 1992. Seeds Of Woody Plants In North America. Dioscorides Press, Portland, Oregon.

Young, M.J. and J. Sauls. 1989. Propagation Of Fruit Crops. Circular 456A. Florida Co-operative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida.
