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ALBERTA
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POTATO

PRODUCTION GUIDE

FOR COMMERCIAL PRODUCERS

Alberta
AGRICULTURE
AGDEX 258/20-8

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ALBERTA POTATO PRODUCTION GUIDE

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Brooks, Alberta
July 1992

ALBERT POTATO PROPRIETOR GUIDE

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PREFACE TO THE SECOND EDITION

This is the second edition of the *Alberta Potato Production Guide* for commercial producers. This book is intended to provide potato producers with some of the technical information they require to plant, grow, harvest and store quality potatoes.

Potato growing is complex and requires both technical knowledge and management skill. The potato farm operator must apply this knowledge and skill to ensure profitable yields of quality potatoes for the fresh, processing, or seed markets. The last decade of this century will bring about major changes to agriculture and to Alberta's potato industry. Growers who respond to changing technology in times of demanding markets and harsh economic realities will survive. Those that continue to ignore better ways of growing high yields of top-quality potatoes will be eliminated by the market place.

Management recommendations in this book are based on results of research conducted in Alberta or based on the experience of commercial growers. Several sections deal with general aspects of potato production and soil management that may not apply to experienced growers. This information will, however, be useful to those starting a potato production operation and hopefully serve as a refresher for others.

A major change has been made in this second edition. All specific recommendations for pest control products have been removed. The herbicides and insecticides listed for control of weeds and insects are listed in *Crop Protection with Chemicals*, Agdex 606-1. Use it in conjunction with the *Alberta Potato Production Guide*.

The assistance of the many people who helped with the second edition of the *Alberta Potato Production Guide* is appreciated. Thanks to the following: Colin McKenzie, Rudy Esau, Dennis Darby, Jim Holley, Terry Petrow, Cathy Feth, and Sandra Day. Several other people also reviewed various portions and their help is appreciated.

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July 1992

GROWING QUALITY POTATOES IN ALBERTA

The History of Potatoes

The potato is a member of the nightshade family (*Solanaceae*) and originated in the Peruvian and Bolivian Andes of South America. Related plants in the nightshade family include peppers, eggplants and tomatoes, and weeds like hairy nightshade and black nightshade. The same potato species as the one we cultivate today (*Solanum tuberosum*) and related species were gathered and cultivated for thousands of years before the European explorations. Potatoes were taken first to Spain around 1570 and about 20 years later to England. They first reached North America from England in the early 1600s. Potato production spread from these two early European introductions and they are now grown in nearly every part of the world.

During the early period of cultivation in Europe, North America and elsewhere, potatoes were grown decade after decade from original selections and no new cultivars were introduced. Following the Irish potato blight in the 1840s, crossing was increased in North America and many new cultivars were selected in the last half of that century. From this early breeding work the forerunners of modern potato varieties were developed.

Common cultivars of 25 to 100 years ago included: Early Rose, Green Mountain, Irish Cobbler, White Rose, Early Ohio, Burbank and Red McLure. Russet Burbank was selected over 100 years ago and still remains one of the most widely grown varieties in North America. Records from Manitoba show that Irish Cobbler, Gold Coin, Netted Gem (Russet Burbank) and Early Ohio were recommended varieties in 1926.

Potato Production in Alberta

Records of potato production in the early history of Alberta are scarce. Small-scale potato production in home and market gardens presumably spread with settlement. On October 3, 1810, Daniel Harman, the agent for the North West Trading Company post in Dunvegan, wrote, "... we harvested the potatoes that were planted on May 10 and found the nine bushels planted produced 150 bushels ..."

The best account of early potato production in Alberta is recorded in *Development of Horticulture*

on the Canadian Prairies which was compiled by the Western Canadian Society for Horticulture in 1956.

By the 1930s commercial potato production was well established and records of the Western Canadian Society for Horticulture show that 6,000 ac (2,430 ha) of irrigated potatoes were grown in the Lethbridge area in 1937. It was a record year and the crop averaged 6.3 ton/ac (14.2 t/ha).

During the 1930s and 1940s certified seed production and grading regulations were implemented and table stock quality improved. In the early part of the 1940s the industry was set back by a severe outbreak of bacterial ring rot which damaged established export markets. By the mid 1950s, quality, markets and credibility had been re-established and Alberta potatoes received good publicity with their performance at the Toronto Royal Agricultural Fair.

During the past two decades major changes have been made in management techniques, mechanization, storages, packaging facilities and in processing. From 1985 to 1990 Alberta's potato growers produced between 220,000 and 300,000 tonnes of potatoes annually on 24,000 to 28,000 acres (9 700 to 10 400 ha).

The Potato Plant and Tubers

Potato tubers are not roots, but enlarged portions of underground stems called a rhizomes or stolons (figure 1). Eyes are the buds from which next season's growth will sprout. Eyes are concentrated near the apical end of the tuber and are fewer near the stolon or basal end.

The tuber skin is composed of two layers of cells: a layer of single cells called the epidermis, and several layers of corky cells called the periderm (figure 2). The cells in the periderm layer may contain a red pigment that produces red-colored potatoes. Next to the periderm is the cortex followed by the vascular ring which contains the cells that transport food products to the tuber from the above-ground stems. The internal part of the tuber is called the medulla, which is the part of the tuber that contributes to the bulking of potatoes. Excess food produced by the potato plant is transported to the medulla via the vascular ring. Cells in the medulla increase in

Figure 1. Diagram of potato plant. **Note:** For simplicity one main stem is shown. Productive plants have two or more main stems.

number and size, as they are supplied with food, and the tuber increases in size.

Potato Plant Growth

Growth and quality of potatoes are influenced by environmental factors such as temperature, moisture, light, soil type and nutrients. Many factors that

influence potato growth are uncontrollable: length of growing season, air and soil temperatures, light intensity and duration, humidity and wind. Other factors that affect growth can be controlled by the grower: variety, size of mother seed tubers, seed-piece cutting, seed-piece types, seed size, planter operation, plant stand, stem population, moisture, nutrition, pest management, planting date

Figure 2. Cross-section of potato tuber.

and harvest date. Only when all factors are at optimum levels can profitable yields of quality potatoes be attained.

In Alberta, the upper limits of yield are likely about 30 ton/ac (70 t/ha) given optimum inputs and ideal environmental conditions. Growers occasionally, but not consistently, have achieved yields as high as 24 ton/ac (55 t/ha).

Temperature — Potatoes are a cool-season crop and they grow well in Alberta. Yields are highest when average daytime temperatures are about 21°C. Cool night temperatures are important because they affect the accumulation of carbohydrates and dry matter in the tubers. At lower night temperatures, the respiration process is slowed, less dry matter is burned up and is stored in the tubers as starch. The optimum soil temperature for initiating tubers is 16-19°C. Tuber development declines as soil temperatures rise above 20°C and tuber growth practically stops at soil temperatures above 30°C.

Development of sprouts from seed pieces is more rapid at higher temperatures. Very little sprout elongation occurs at 6°C, elongation is slow at 9°C and maximizes at about 18°C. The number of tubers per plant is greater at lower temperatures than at higher temperatures, whereas higher temperatures favor development of large tubers. Second growth of tubers, associated with irregular moisture levels, can also develop under high temperatures. Second growth may occur in Russet Burbank fields in Alberta because of high temperatures in late July.

Moisture — Potatoes require a continuous supply of soil water and good soil aeration. Yields are greatest when soil moisture is maintained uniformly above 60 to 70 per cent of total available capacity.

Tuber set is affected by moisture levels at the time of tuber initiation and there are generally fewer tubers set when moisture at tuber initiation is less than 70 per cent of total available capacity. The amount of water needed by potatoes varies with the amount of fertilizer used, soil type, temperature, air movement, plant and stem populations and cultural practices. During the growing period too little moisture, and fluctuating moisture, generally cause more problems than excessive moisture. Experience in Alberta indicates that water shortages are more common than excesses in moisture. Low or fluctuating moisture levels can contribute to scab, hollow heart, knobby tubers, low dry matter, low tuber set and low yield. Excess moisture can result in poor aeration and water logging, which will reduce root growth and yields. An excess of moisture may also lead to enlarged lenticels or openings of the skin on tubers which detract from their appearance. Water-soaked soil at harvest can cause bitterness of Russet Burbank tubers.

Light — Intensity and duration of light affects potatoes. When light intensity is high, tuber initiation and development start earlier, maximum stem length is reached earlier, yields are higher and tubers contain more dry matter than at lower light intensities. However, at very high light intensities the plant may die earlier and tuber weight may be limited by this early senescence. When the duration

of light is long, vegetative top growth, particularly stem elongation is enhanced; but when light periods are shorter, stolons are shorter and the rate of tuber set increases.

Tuber Initiation and Growth

Tuber initiation or tuberization starts when tubers begin to swell at the ends of stolons. This occurs between early June and mid-July in Alberta, depending on location, planting date, climate, soil type, and cultivar. Tubers form when the plant produces more carbohydrates than are required for vine growth. Varying climate and moisture conditions cause uneven tube set and growth.

The number of tubers formed per plant is called tuber set. Early in the year, 20 to 30 small tubers may form; however, only 5 to 15 mature tubers are normally found on each plant at harvest. Some of the small tubers that are initially set are used by the growing plant and the number that are finally retained and grow is directly related to available moisture and nutrition. Optimum moisture and nutrient levels are therefore critical to the maintenance and development of tubers very early in the growing season. The effect of uniform high levels of moisture has been well documented in Alberta. (See Irrigation Section). Maintaining high levels of moisture (above 70 per cent of available moisture capacity) has been shown to produce high tuber set compared to lower moisture levels.

Uneven growth of the potato plant, and therefore uneven growth of tubers, can result in tuber abnormalities. Fluctuating temperatures, moisture, and nitrogen, especially in the formative stages, can cause malformed tubers. The uneven growth will be made worse by poor plant stands and by variations in seed-piece types.

Producing Profitable Yields of Quality Potatoes

Potato growers want and need to produce profitable yields of quality potatoes. Yield is important because the crop must generate enough income to cover costs and return a profit. Quality is important because the potatoes must be marketable with minimal grading or processing cost. Production inputs that produce high quality potatoes also tend to produce the maximum economic yield. The following is a brief summary of the major factors the producer can influence to produce profitable yields

of quality potatoes. More detailed discussion of these practices is presented in subsequent sections.

Marketing — A crop is only profitable when it is sold at a reasonable price; therefore, growers must target production to suit a projected market, not market to suit production. Market projections must consider volume and quality requirements.

Over one-half of the potatoes produced in Alberta are sold to processors for French frying or chipping, and all of these are grown under contract. Many fresh-market growers produce potatoes for specific packers, although they may not sign a contract they discuss market agreements early in the crop year. Prospective seed growers need to be aware that credibility and reputation as a supplier of quality potato seed may take several years to establish. Provisions for low-waste harvesting, handling, storage and marketing must be made in advance of production.

New growers who wish more information about processors, fresh packers and marketing in general are invited to contact:

The Potato Growers of Alberta,
Suite 230, 2116 - 27 Avenue, N.E.,
Calgary, Alberta, T2E 7A6
(phone 403/291-2430, FAX 403/291-2641).

All potato growers producing more than 5 acres (2 ha) of potatoes are required by legislation under the Agricultural Products Marketing Act, to be licensed by the Potato Growers of Alberta (PGA). New growers should contact the PGA office for a licence.

Site Selection — In choosing a site for a potato farm a prospective potato grower has to be aware of two general factors: climate and soil. Potato production should be confined to those areas shown on the accompanying climate map with 100 or more frost-free days (figure 3). Certain micro-climates outside of this zone, such as in river valleys, may be suitable; and conversely, some small areas within the 100-day-or-more zone may be subject to abnormal early or late frosts. Areas with longer frost-free periods have the potential to produce the highest yields, however, other factors such as soil type, availability of irrigation water and nearness to markets have to be considered. A long frost-free season allows the grower a wider choice of cultivars, a longer harvest period and generally contributes to the production of high yields of mature potatoes.

Average Frost-Free Days (0°C Base)

		Last Spring Frost	First Fall Frost
120 or more	May 10 to 15	Sept 15 to 20
100 to 120	May 15 to 25	Sept 5 to 15
80 to 100	May 25 to June 5	Aug 25 to Sept 5
80 or less	After June 5	Before Aug 25

Produced by the Alberta Bureau of Surveying and Mapping © 1984

Figure 3. Average frost-free days.

Deep, well-drained, coarse-textured soils such as loamy sands, sandy loams and loams are the best soils for potato production. Coarse-textured soils tend to warm up sooner in the spring, are easily worked and have good drainage. However, very coarse soils (sands) have a low water-holding capacity and require irrigation in most parts of Alberta to produce consistent yields of quality potatoes. Irrigated sands will also require the addition of nitrogen through the irrigation system during the growing season. Finer-textured soils with high amounts of clay can be difficult to work into a clod-free seed bed and they become sticky when wet or lumpy when dry. Clay soils adhere to tubers and they may require considerable washing. Poorly drained soils can result in delayed tillage or harvest operations and potatoes may be more subject to disease.

Cultivar and Seed Selection — The most commonly grown cultivars are described in detail in the next section. New producers need to become familiar with varieties, so they can select the best ones for their market and climate. Varieties are commonly described by their maturity (early, mid, late), skin color (white, russet, buff, red), skin texture (smooth, netted), flesh color (white, cream, yellow), flesh texture (dry and mealy or, wet), and tuber shape (round, oval, oblong, long). There are about 25 cultivars grown in Alberta; however, less than 10 varieties account for over 90 per cent of the potatoes produced in recent years.

The importance of using certified seed cannot be overemphasized. Potatoes are grown from fleshy tubers and bacterial, fungal and viral diseases can be carried from generation to generation. The primary reason for the potato seed-certification regulations is to maintain disease-free stocks of potato seed and therefore keep diseases to a minimum in commercial fields. If these diseases were left unchecked, production of potatoes would soon decline. Many diseases merely reduce plant vigor and yield, but others will kill the crop under the right conditions. The objective of certified seed regulations and of using certified seed is to keep diseases at very low levels.

The Canadian potato seed certification program relies on many groups to maintain excellent quality seed for Alberta's seed growers and their buyers. Disease freeing of tubers is done by Agriculture Canada; early generation seed stock for seed growers is supplied by Alberta Agriculture; certified seed is produced by elite and certified seed growers;

and Agriculture Canada inspects seed fields and tests and certifies seed lots.

There are seven classes of certified seed, each representing one generation: Pre-Elite; Elite 1, 2, 3 and 4; Foundation; and Certified. An elite seed grower receives nuclear seed from Alberta Agriculture's seed potato program at the Alberta Tree Nursery and Horticulture Centre near Edmonton. Pre-Elite seed stock is produced from this, and it in turn is planted the following year to produce Elite 1 seed. Subsequently after six years Certified-class seed is produced. There are no seed classes below "Certified", therefore all certified seed is a maximum of six generations away from the completely disease-free nuclear source (figure 7). Most seed sold in Alberta is Elite 3, 4 or Foundation. This flush-through system helps maintain a supply of quality seed for Alberta potato producers.

Planting — Three factors are of paramount importance to a potato crop: stand, stem population and vigor. Establishing a stand of uniformly vigorous seedlings with an adequate number of stems is demanding and no amount of other cultural inputs such as fertilization, irrigation and pest control will compensate for a poorly planted crop. Potato plants adjacent to a "miss" will have an increased yield, but the increase does not make up for the zero yield of the missing plant. Usually the tubers produced by plants next to a miss are oversized, misshapen and have a higher incidence of hollow heart in susceptible cultivars. Potato producers achieve good stands by maintaining and operating their planters properly and by cutting uniformly sized seed pieces. Seed pieces that are uniform in shape and size can only be cut from a mother seed lot with a narrow range in size with few tubers over 8 ounces (225 g).

Plants must be vigorous and strong to produce large yields. Large, uniform seed pieces with few cut surfaces produce strong plants. A seed lot should have an average seed-piece weight of 2 ounces (60 g) with no pieces less than 1.5 ounces (45 g) or greater than 3 ounces (90 g). Because seed-piece sizing is so important, potato producers should purchase uniform seed tubers ranging from 2 to 8 ounces (60-250 g) in weight. Large mother seed tubers (greater than 10 oz) result in many seed pieces with a few or no eyes. These pieces reduce plant stand, have fewer stems, and result in much size variability.

Potato growers who want high yields treat the cut seed lot with a registered fungicidal treatment to

reduce seed-piece decay and improve stand and plant vigor. Cut seed must be kept out of the sun and drying wind to prevent moisture loss and is usually planted within a day of cutting. Cut seed that must be stored is suberized in warm humid conditions to promote rapid healing of the cut surface. Cut seed that is to be suberized and stored is not treated until planting time.

Fertility and Irrigation — The coarse-textured, well-drained soils used for potatoes will require adequate amounts of nutrients to produce profitable yields and growers should soil test annually. Typically, nitrogen and phosphorus are the two nutrients applied to potatoes, although potassium is often required, especially in southern Alberta. Potatoes forage for nutrients and water up to a depth of about 2.5 ft (75 cm) and soil sampling to at least 2 ft (60 cm) is recommended to get an accurate assessment of available nitrogen. Tissue sampling and analysis (especially of irrigated potatoes) helps a grower monitor nitrogen levels and add nitrogen as required to maintain growth and plant health. However, it must be stressed that over application of nitrogen can delay maturity, reduce dry matter yield and increase the incidence of hollow heart.

Irrigation in central and northern Alberta is good insurance in some years, and mandatory every year in southern Alberta to produce high yields. A uniform supply of moisture (above 60 to 70 per cent of available moisture capacity) generally increases tuber set and yield, and reduces the number of deformities.

Pest Management — Diseases, insects and weeds can ravage potatoes if left unchecked. New growers must become familiar with pests if they expect to grow quality potatoes and make a profit. The importance of pest management is best stressed by reviewing the seed potato certification program in Alberta and in Canada. A handful of tubers that are completely disease free are released by Agriculture Canada, propagated by Alberta Agriculture and then go through four to seven years of growing and inspection on seed farms before certified seed is available for commercial growers. This whole process is aimed primarily at disease control.

The best tool available to commercial growers to control disease is to use certified classes of seed. Producers also need to be concerned about seed piece decay, early blight, and storage diseases like soft rot and dry rot. Bacterial ring rot, which has nearly disappeared in Alberta, will always be a major

concern because it is highly contagious and destructive if left uncontrolled. All commercial potato fields in Alberta are inspected for ring rot every year, and for this reason all potato growers with 5 acres, or more, are required to be licensed by the Potato Growers of Alberta.

A rotation with a minimum of three other crops between potatoes is required to sustain potato production over a long period. Shorter rotations result in a steady increase in soil-borne diseases.

Insects such as the Colorado potato beetle can completely defoliate a potato crop if left unchecked. Wireworms, which are ever present in newly broken pasture land, cause unsightly tunnels in tubers which can result in losses on the grading line and reduction in grade if damage is severe. Seed growers need to control aphids to prevent the spread of viruses that may cause loss of certification.

Weed control in potatoes is not normally a problem because the combination of cultivation and herbicides is usually effective. However, a few weeds left unchecked in the spring may become an unmanageable problem by fall. Severe weed infestations reduce yields, interfere with harvest and are a bountiful weed seed source for subsequent crops.

Harvest Management — Getting a bumper crop of potatoes to market or into storage while maintaining excellent quality involves planning and good management. Vine killing is usually done 10 or more days before harvest to ensure a good skin set and reduce skinning. Harvest equipment must be in good working order and personnel must be trained to operate harvesters so that bruising is minimized. Bruises, cuts and scrapes are typically caused by roll-back, drops and sharp edges on harvesters; all of which can be reduced by machinery modification, chain-speed monitoring and maintenance.

Storage Management — Seed must be stored for eight months, through to the next crop year, without rotting or sprouting. Potatoes for French frying and especially chipping must have low levels of sugars so that they will produce light colored fries or chips throughout the storage season.

Obviously a grower must place a good quality crop into storage to take quality potatoes out. Management throughout the season (cultivar selection, seed cutting, planting, fertilization, irrigation, pest control and harvest management) contributes to the quality of tubers placed in storage.

Cold, freezing weather during harvest in late September and early October can severely affect quality. Following adverse harvest weather, heavy culling and curing potatoes with high volumes of air may enable a producer to keep a problem crop for a reasonable amount of time.

Sanitation of storages and equipment helps reduce losses caused by disease. Maintenance of proper temperatures, humidity and airflow prevent heat build up and rots, reduces shrink to a minimum, and maintains processing quality. To do all of this, growers require facilities that have the necessary environmental controls.

Potato Quality

Nutritional Quality — Potatoes are a non-fattening, nutritious and wholesome food which supply many important nutrients to the diet. Potatoes contain approximately 78 per cent water, 22 per cent dry matter and less than 1 per cent fat. About 82 per cent of the dry matter is carbohydrates which occur mainly as starch, however some sugars are also present in small amounts.

Potatoes contain 11 per cent protein by dry weight, which is less than that of soybeans; however, the nutritional quality of potato protein is better than that of soybeans. Potatoes contain at least 12 essential vitamins and minerals. They are an economical source of vitamin C, and contain thiamine, iron, folic acid and some fibre.

Fresh-Market Quality — Quality is an important factor influencing consumer preference and saleability of potatoes. Good quality potatoes are clean, uniform in shape and size, and have a unmarked skin, firm flesh and shallow eyes. Consumers don't like the waste caused by trimming potatoes with deep eyes and surface defects. Other tuber defects which may adversely influence quality are greening, second growth, growth cracks, scab, storage rots, internal black spot, skinning, bruising and mechanical damage.

In addition to physical quality and appearance, potatoes must also have good cooking and eating quality. The main culinary quality factors of home-prepared potatoes are texture, color, flavor and odor. The texture of cooked potatoes is directly related to the dry matter content or the specific gravity, and is described as mealy and dry or soggy and wet. Potatoes such as Russet Burbank, which have a high dry matter content, usually have a dry,

mealy texture when baked. However, they may slough or break up when boiled which is a problem when preparing boiled potato pieces. They do make excellent mashed potatoes. Potatoes such as Norland, with a lower specific gravity, are inclined to be somewhat soggy and wet when baked, but hold together quite well when boiled.

White-fleshed potatoes, when boiled or baked, are expected to be a creamy white color. Yellow-fleshed varieties should retain their yellow color during cooking as well.

White- or yellow-fleshed potatoes should exhibit minimal after-cooking darkening. This darkening, which is often more prevalent at the stem end of the tuber, is believed to be caused by a dark pigment formed by the reaction between chlorogenic acid and iron, both naturally occurring compounds in potatoes. Research at the Agriculture Canada Research Station, Lethbridge, showed that Russet Burbank potatoes grown in central Alberta had a significantly higher chlorogenic acid content than potatoes grown in southern Alberta. Varieties such as Norland, which naturally contain higher amount of chlorogenic acid, blacken more than varieties containing less chlorogenic acid. In the home, after-cooking darkening may be controlled with lemon juice (which contains citric acid). In the commercial potato processing industry sodium acid pyrophosphate is used.

Cooked potatoes are expected to have "normal" potato flavor and aroma, without off-flavors or off-odors. One group of chemicals in potatoes which contribute to the characteristic potato flavor when present in small amounts, are alkaloid compounds, such as solanine and chaconine. Collectively these compounds are referred to as total glycoalkaloids or TGAs. They are usually present at low levels (2-15 mg/100 g fresh tuber weight); however, when TGA levels increase to 20 mg/100 g the potatoes are bitter. Above 20 mg/100 g, the potatoes are considered unfit for human consumption because the glycoalkaloids have reached toxic levels.

The development of bitterness in potatoes is often signalled by surface greening of the tubers, although the development of bitterness compounds and green color are independent. A green pigment, chlorophyll, forms when potatoes are exposed to light. This same light also triggers chemical reactions in the outer layer of the potato tuber leading to increased TGA levels. Light-green potatoes are harmless if peeled. Moderately green tubers should

not be used for consumption without first tasting the peel of several raw tubers.

Bitterness or burning indicates that TGA levels are too high and the potatoes should be discarded. Elevated TGA levels in potatoes may result not only from exposure to light but from harvesting immature potatoes, bruising, skinning and improper storage temperature. Wet conditions before harvest, and chilling or freezing may also cause high TGA levels. Cold potatoes can be slowly warmed up to 15°C for 10 days after harvest; however, growers should seek further advice on the storage of chilled tubers. Unlike other problems associated with potato quality, such as after-cooking darkening, TGA accumulation cannot be counteracted with chemicals or special processing techniques. Glycoalkaloids do not leach from potatoes into blanching or cooking water, nor are they destroyed during the high temperatures associated with boiling, baking or deep frying.

Quality of Pre-peeled Potatoes — Some potatoes (often cull material) are used to produce pre-peeled products for the food-service industry. These potatoes are peeled by chemicals, hot water or abrasion. Following peeling and trimming, the potatoes are packed for shipment to the user or distributor. These pre-peeled potatoes must be refrigerated at all times since they have a limited shelf life. Pre-peeled potatoes are treated with anti-browning agents.

Potato Chip Quality — Four important factors affect chip quality: the yield of chips from fresh potatoes, the color of chips, the oil content of the chips and chip flavor. One of the most important qualities of chipping potatoes is high specific gravity. The yield of potato chips increases as the specific gravity, or dry matter, of the fresh potatoes increases. Potato chipping is a water-removal process, hence the higher the water content of the potato the more water will be lost to evaporation and the lower the yield of chips. Potatoes with more solids (higher specific gravity) will lose less water and the chip yield will be higher. In addition to its direct influence on chip yield, specific gravity has a direct bearing in the amount of oil absorbed by the potato slices during the deep frying process. Slices from low

specific gravity tubers absorb more oil than slices from tubers with high specific gravity. Some oil absorption by the potato slices during deep frying is desirable for flavor development. However, too much oil absorption results in greasy chips with a high oil content. Production costs are therefore increased because more oil is used in the frying process.

Quality potato chips have a light color and little vascular discoloration. Processors have little control over chip color (manipulation of oil temperature, slice thickness and length of frying period) because the color of potato chips is largely determined by the sugar content of the potato tuber. Potatoes with high sugar levels make dark chips. When potato slices are fried, the reducing sugars react with proteins and amino acids to form dark products in a non-enzymatic browning reaction. The concentration of chemical constituents, such as reducing sugars, depends on many factors including variety, growing conditions, maturity and storage conditions.

Potato chips must have a pleasing and desirable flavor. Thus potatoes should not be bitter or have other off-flavors. The flavor of potato chips is more complex than that of boiled, baked or mashed potatoes, since the cooking temperatures are much higher, and the absorbed oil contributes to the overall flavor profile of the product.

French Fry Quality — Good quality French fries have a uniform light cream to golden color. They have a good potato flavor free from rancidity, bitterness, and are free from a scorched taste and off odors. Their texture consists of external surfaces that are moderately crisp, showing no separation from the inner portion. The inside is tender, mealy and free from sogginess. Other undesirable defects include sunburn, carbon spots and light and dark brown areas.

As in the case of potato chips, the color of french fries also depends on the reducing-sugar content of the potatoes; however, French fry processors have more control over reducing-sugar levels because of the blanching process. Mealiness, crispness and lack of oiliness in French fries increases with specific gravity.

PRODUCTION MANAGEMENT

This section deals with potato variety descriptions, seed cutting, planting, plant growth, tuber set, tuber development, field sprout inhibition, top killing and harvest management. Soil management, fertilization, irrigation and pest management are presented in other sections.

Varieties

Variety Selection

Processing — Cultivars for processing are specified in the contract between grower and processor. The french fry industry requests either Russet Burbank or Shepody, although new varieties may also be contracted. Chip processors require Superior or Atlantic for early out-of-the-field chipping, and Norchip for their mid-season and out-of-storage needs. (After the summer of 1991 the continued use of Conestoga was in question because glycoalkaloids levels were often higher than chipping industry standards.)

Fresh Market — The main fresh-market cultivars grown in Alberta in 1990 and 1991 were Russet Burbank, Norkotah, Sangre and Norland. Carlton, Norgold and Yukon Gold are preferred by a few growers. Several other cultivars are commonly grown for the fresh market, but the total area is very small and growers select these types because of personal preference, local growing conditions, or for specialized markets.

Seed Production — The demand for potato seed of a specific variety is directly related to the area of commercial potatoes produced in Alberta and in other areas that traditionally buy seed from Alberta. Therefore seed growers need to grow established cultivars. From time-to-time they may wish to speculate on the acceptance of new potato cultivars that are released from breeding programs. A few promising new cultivars are licensed every year. However, in the long run, few of the new licensed varieties become firmly established. Sometimes a seed grower's efforts at producing new cultivars will be lost, but these losses can be overcome with profits made from production of seed of a suddenly popular cultivar. Sangre and Norkotah were examples of cultivars that gained rapid industry acceptance and seed growers who picked up seed early made good profits because of limited supplies

in a rapidly expanding market. Seed growers need to be aware of variety developments and take advantage of them when possible.

Variety Descriptions

Ten varieties accounted for 23,600 ac (9 500 ha) or 97 per cent of the potato area grown in Alberta in 1991. The other 700 ac (280 ha) consisted of about fifteen cultivars. These other cultivars included: Bintje, Pontiac, Monona and others. Following are descriptions of the ten leading cultivars grown in Alberta in 1990 and 1991. Figure 4 shows the shapes used to describe potato varieties. Seven of the commonly planted cultivars are shown in color plates at the centre of this book.

Figure 4. Shapes used to describe potato varieties.

Russet Burbank

Primary use: French fry

Secondary use: Fresh market. Good baking and boiling.

Maturity: Late

Tuber **Shape:** Long, slightly flattened
Eyes: Shallow to medium depth
Skin color : Tan/russet
Skin texture : Netted
Flesh color : White
Flesh texture : Dry, mealy

Flower color: White

Specific gravity: High

Resistance: Moderately resistant to scab, blackleg

Susceptibility: Subject to second growth, knobiness, hollow heart. Susceptible to leaf roll, verticillium wilt, virus X and Y.

Storability: Stores well, long dormancy.

Shepody

Primary use: French fry

Secondary use: Fresh market

Maturity: Mid-season

Tuber **Shape:** Oblong to long
Eyes: Shallow
Skin color: Buff
Skin texture: Smooth to light net
Flesh color: White
Flesh texture: Dry, mealy

Flower color: Light violet

Specific gravity: High

Resistance: Moderate resistance to Rhizoctonia

Susceptibility: Susceptible to potato viruses S, X and Y, leaf roll. Moderately susceptible to common scab and hollow heart.

Storability: Stores well, medium dormancy.

Norchip

Primary use: Chipping

Maturity: Mid-season

Tuber **Shape:** Round to oval
Eyes: Shallow
Skin color: Creamy white
Skin texture: Smooth
Flesh color: White
Flesh texture: Dry, mealy

Flower color: White

Specific gravity: High

Resistance: Moderately resistant to scab, verticillium wilt, virus Y.

Susceptibility: Blackleg, leaf roll, virus X, growth cracks.

Storability: Stores well, requires sprout inhibition for long-term storage.

Sangre

Primary use: Fresh market

Maturity: Mid-season

Tuber **Shape:** Oval
Eyes: Shallow
Skin color: Red
Skin texture: Slightly rough
Flesh color: White
Flesh texture: Somewhat dry and mealy

Flower color: Lavender

Specific gravity: Medium

Resistance: Moderately resistant to leaf roll, net necrosis, and rarely exhibits hollow heart, internal discoloration and blackspot.

Susceptibility: Susceptible to verticillium, early and late blight. Highly susceptible to blackleg.

Storability: Stores well, long dormancy. Holds bright red color well past Norland.

Comment: There were disease problems with commercial Sangre fields in 1990 and 1991. Sangre is very susceptible to blackleg and soft rot of seed pieces and the acreage planted to Sangre was expected to drop rapidly in 1992 and beyond.

Russet Norkotah

Primary Use: Fresh market, particularly suited to count pack.

Maturity: Mid-season

Tuber **Shape:** Oblong
Eyes: Shallow
Skin Color: Tan/russet
Skin Texture: Netted
Flesh Color: White
Flesh Texture: Somewhat dry and mealy

Flower Color: White

Specific Gravity: Medium

Resistance: Resistant to common scab and silver scurf.

Susceptibility: Susceptible to most viruses, early blight, verticillium wilt, and hollow heart.

Storability: Stores well, medium dormancy.

Atlantic

Primary Use: Chipping

Maturity: Early

Tuber Shape: Round to oval

Eyes: Shallow

Skin Color: White

Skin Texture: Lightly netted

Flesh Color: White

Flesh Texture: Dry, mealy

Flower Color: Pale lavender

Specific Gravity: High

Resistance: Resistant to tuber net necrosis and virus

X. Some resistance to common scab, late blight, pink eye and verticillium wilt.

Susceptibility: Subject to hollow heart at wide spacing or when grown in hot, sandy soils.

Storability: Stores well, but generally not recommended for out-of-storage chipping. Medium dormancy.

Norland

Primary use: Fresh market only. Good boiling quality.

Maturity: Early

Tuber Shape: Round to oval

Eyes: Shallow

Skin color: Red

Skin texture: Smooth

Flesh color: White

Flesh texture: Somewhat wet

Flower color: Purple

Specific gravity: Medium

Resistance: Moderately resistant to scab, leaf roll, verticillium wilt, viruses X and Y.

Susceptibility: Highly susceptible to silver scurf.

Storability: Short dormancy. Red color tends to fade in storage.

Yukon Gold

Primary use: Fresh market. Excellent baking. Tends to slough when boiled.

Secondary use: Makes good quality, yellow-flesh chips from the field.

Maturity: Early mid-season

Tuber Shape: Round

Eyes: Shallow. May be pink.

Skin Color: Yellowish white

Skin Texture: Finely flaked

Flesh Color: Yellow

Flesh Texture: Dry, mealy

Flower Color: Violet to light violet

Specific Gravity: High

Resistance: Resistant to mild mosaic. Moderately resistant to physiological leaf roll.

Susceptibility: Susceptible to rugose mosaic, somewhat susceptible to scab and viral leaf roll.

Norgold Russet

Primary use: Fresh market only. Good boiling and baking

Maturity: Early mid-season

Tuber Shape: Oval-oblong

Eyes: Shallow

Skin color: Tan/russet

Skin texture: Netted

Flesh color: White

Flesh texture: Dry, mealy

Flower color: Pink

Specific gravity: Medium to high

Resistance: High resistance to scab.

Susceptibility: Subject to hollow heart.

Storability: Stores well, medium dormancy.

Superior

Primary use: Chipping

Secondary use: Early fresh market

Maturity: Early mid-season

Tuber Shape: Oval

Eyes: Medium in depth

Skin color: Creamy white

Skin texture: Smooth

Flesh color: White

Flesh texture: Dry, mealy

Flower color: Pale lilac

Specific gravity: Medium

Resistance: Moderately resistant to common scab.

Susceptibility : Susceptible to verticillium wilt and potato virus.

Storability : Not a storage potato.

Comments: Superior was the eleventh most common cultivar produced in Alberta in 1990 (262 ac). It is grown primarily for chipping, however it is also planted for early fresh market. Excellent flavor.

Planting Management

No amount of cultural and pest management will make up for a poorly planted crop. The importance of selecting disease-free seed lots with few, if any, tubers greater than 8 oz cannot be overemphasized. Smaller, uniformly sized, seed tubers result in uniform, blocky seed pieces; a higher proportion of correctly sized and productive seed pieces; and better planter performance. All of these factors contribute significantly to high plant stands of uniform plants that result in high yields of top-quality uniform tubers.

Three general factors contribute to achieving a high stand of uniform plants that produce a profitable and quality potato crop. These are: seed lot tuber size and condition, cutting management, and planter management.

Seed Selection and Seed Standards

Seed Selection — Selection of seed stock of high quality is necessary for maximum yields of commercial potatoes. Characteristics of high-quality seed are: trueness to cultivar, freedom from seed-borne diseases, physical soundness, average size and uniformity of size. The seed should have been produced under suitable growing conditions and stored at temperatures of 3–5°C. Bacterial and viral diseases that reduce the yield of potatoes may not produce visible symptoms on the outer surface of the tubers, so visual appearance is not necessarily an indication of quality seed. A plant from an infected seed piece can serve as a source of infection for the spread of diseases to other plants in the field through insect vectors or mechanical contact.

The majority of seed tubers should weigh less than 8 ounces (225 g) with few, if any, more than 10 ounces (300 g).

Large mother tubers (more than 10 ounces or 300 g) are undesirable for three reasons. First, when cut, they produce too many pieces that are either too small or too large. Small seed pieces (less than 1.5 ounces or 45 g) produce weak, unproductive plants. Large seed pieces (greater than about 3 ounces or 90 g) are not appreciably more productive than 2-ounce (60 g) seed pieces, yet they cost more. Secondly, large, variably sized and variably shaped seed pieces do not flow well and may not be picked up by the planter cups and may cause a reduction in stand. Thirdly, on the average, seed pieces cut from large mother tubers are not as

productive as pieces of the same weight cut from smaller tubers. Some pieces have fewer eyes and produce plants of varying productivity. Many seed pieces cut from 12- or 14-ounce (350 to 400 g) seed tubers have no eyes at all and result in reduced stand.

Seed Standards — Certified, Foundation, Elite 4 or 3 seed is used to produce commercial potatoes in Canada. These classes must meet the standards set out under the regulations for seed potato certification administered by the Food Production and Inspection Branch of Agriculture Canada. To be certified, seed fields must be free from disease as determined by field inspection during the growing season. Since 1991 all seed lots must be tested for the bacterial ring rot organism before they are sold to another grower or replanted by the seed grower.

In 1990, potato growers in Alberta requested the Alberta government to pass legislation that would require all potato growers to plant certified seed starting in 1993. This legislation was passed in 1992, and anyone planting potatoes with the intent of selling them (no matter how small the area) will be required to plant certified classes of seed in 1993. Exemption permits, allowing a grower to plant other-than-certified seed for special uses, are available.

Seed should be inspected upon delivery and if commercial growers have concerns they should contact both the seed grower and the Food Production and Inspection Branch of Agriculture Canada immediately and request a re-inspection. The commercial grower should have the seed tags (in the case of bagged lots) or a bulk certificate (in the case of bulk lots) so the proper information can be obtained about the lot of seed lot purchased. Seed tags or bulk certificates are a grower's assurance that seed potatoes have been purchased.

Seed Cutting

The importance of proper seed cutting cannot be over emphasized because the cut seed lot has a direct bearing on plant stand, vigor and yield. Unless producers do the best job possible of cutting they will not achieve the best crop possible. The cost of producing a field of low-yielding hills is the same as producing a field of high-yielding hills.

Uncut seed lots that vary in size are difficult to cut to a uniform size and shape, and the resulting variation contributes to frequent planter errors such as doubles and misses. Also seed lots that vary in size produce plants that vary in productivity.

The object of cutting is to produce seed pieces uniform in size with an average weight of approximately 2 ounces (60 g) and as few cut surfaces as possible. The seed lot that will be cut should be as uniform as possible ranging up to about 8 ounces (225 g) with few, or no piece greater than 10 ounces in size (225-300 g). Research in Alberta using seed pieces taken from commercial cutting operations has firmly established that growers should try to maximize the number of seed pieces with single cuts and minimize the portion four- and six-drop pieces. (Explanation: A large tuber cut in six pieces produces “6-drop” pieces.) This, of course, can only be done if the mother seed lot contains no or few tubers over 8 ounces (225 g). Great hill-to-hill yield variability is largely caused by seed piece size variation and from pieces cut from large tubers (figures 4, 5 and table 1).

A 1985 seed piece survey in Alberta found that slivers and other unplantable tuber waste accounted for up to nine per cent of the cut seed lot. This represents a severe waste for the potato grower for three reasons. First, these pieces have been paid for at the going seed rate. Secondly, many of these pieces will end up in the planter where they may result in double drops. And thirdly, if planted singly, these chips or slivers will result in a miss or an unproductive plant. Research in Washington State has shown that small seed pieces less than 1 ounce (35 g) should be removed from a cut seed lot before planting because the loss of seed cost is more than compensated for by replacing it with a larger, more-productive seed piece.

Determining Seed Size — A seed lot with an average seed-piece weight of 2 ounces (60 g) will produce high yields, provided the lot contains a high portion of single cuts, and provided there is not an excessive variation in range of sizes. Upon starting to cut each different seed lot growers should take a small pailful of cut potatoes weighing about 10 lb (5 kg) and check the average weight and composition.

Weigh the sample exactly and divide the weight by the number of seed pieces. For example a 12.5 lb sample with 97 pieces has an average weight of just

over 2 ounces ($12.5 \text{ lb} \times 16 = 200 \text{ ounces}$ divided by $97 = 2.06 \text{ ounce average}$). To determine how the sample is composed, the lot can then be separated into whole pieces, halves, and three-, four-, and six-drop pieces with two and three cut surfaces.

A definite recommendation on the portion of the various pieces is not possible; however, for economy and performance a lot containing 20 per cent whole seed, 60 per cent halves, and 20 per cent with two or more cuts would be considered very good. Realistically, growers will usually find a higher proportion of two or more cuts, but they should adjust the cutter to attain the highest portion of single cuts and the lowest portion of three-cut pieces possible, and still maintain the minimum two-ounce average. Small tubers of less than 3 ounces (80-90 g) should be removed before reaching the cutters and left as whole seed pieces. The cut seed lot should also be separated into size groups to determine if the majority of pieces are between 1.5 and 3.0 ounces (45 to 90 g).

Again, seed lots with few tubers over 8 ounces (225 g) will produce cut seed lots that are more productive than seed lots that contain many 10- and 12-ounce (300-350 g) tubers.

Whole Versus Cut Seed — Whole seed generally yields more than seed lots containing pieces with a wide range in the number of cut surfaces; however, research in Alberta and elsewhere has shown that whole seed is not significantly better than halves of similar size. But there are distinct advantages of using whole seed, especially for the seed grower. Uniform lots of small whole tubers ranging in size from 2 to 2.5 ounces (60 - 70 g) will produce plants with high vigor, high stem counts, high tuber set and a potentially high yield of uniform tubers that tend to be smaller because of the heavier set. Elimination of the cutting process reduces the spread of tuber-borne diseases which is an advantage to both seed and commercial growers.

The capital and operating costs of cutting, plus the reduced productivity of cut-seed lots must be weighed against the reduced costs and high productivity of whole seed tubers.

Table 1. Percentage of undersized and oversized seed pieces cut from mother tubers of five different sizes.

	Size of mother tubers				
	4 oz	6 oz	8 oz	10 oz	12 oz
Undersized	18%	14%	7%	8%	11%
Oversized	6%	5%	11%	17%	30%
Total undesirable	24%	19%	18%	25%	41%

- Seed pieces cut from small tubers (above) are more productive on average than those cut from larger mother tubers (below)
- Growers should avoid cutting seed from tubers greater than about 8 oz (225 g) like those below

Figure 5. Seed-piece types (cut from different sized seed tubers).

Figure 6. Distribution of seed-piece sizes cut from large and small mother tubers (not to scale).

Seed Piece Requirements

The amount of seed required per acre will depend on average seed weight, between-row and in-row spacing. In Alberta, rows are planted 36 inches (90 cm) apart and seed is placed from 6 to 15 inches (15-38 cm) apart in the row. The closest in-row spacing is used by irrigated seed growers, and the

widest spacing is used by dryland commercial growers. The most common spacings for commercial potatoes are 8 to 12 inches (20-30 cm) under irrigation and 11 to 15 inches (30-40 cm) in dryland.

Tables 2 and 2a lists the amount of seed required for different in-row spacings from 5 inches to 14 inches at 36 inches between rows.

Seed Spacing — Normally seed pieces are spaced between 6 and 15 inches, (15 and 38 cm) apart and this wide variation depends on many factors. The closer spacings are used for seed crops and irrigated potatoes, and the widest spacings are used for fresh market dryland crops. Cultivar, fertility, pre-planting moisture and length of season will also affect spacing. Table 3 lists recommended spacings for the most common varieties in Alberta.

Seed-spacing research and seed-production experience at the Alberta Special Crops and Horticultural Research Center at Brooks has shown the maximum seed yields, under irrigation, can be obtained at 4 to 5 inches (10-12 cm) in-row spacing. Even after the extra costs of high planting rates are deducted, the highest dollar returns for irrigated seed growers are at these very close in-row spacings. In addition to high yields the seed tubers are very small and uniform in size.

Planting for Better Stands, Yield and Quality

High plant stands of uniform plants contribute to high yields of uniformly sized potatoes. As discussed previously, seed-piece size and uniformity contribute to uniform hill-to-hill production. Uniformly sized seed also contributes to high stands because of better planter performance.

Blanks in the field resulting from weak seed pieces or from planter misses result in reduced yields. Plants adjacent to a miss compensate partly by being more productive; however, the increase yield is not sufficient to compensate for the “zero” yield of the

Table 2. Weight of seed required for rows spaced 36 inches apart using 2-ounce seed pieces.

In-row spacing	5	6	7	8	9	10	11	12	13	14
Pounds of seed per acre	4400	3600	3100	2700	2400	2200	2000	1800	1700	1600

Note: The difference for each 1" reduction in spacing is not uniform. That is, a reduction from 13" to 12" requires about 100 pounds more seed. But a reduction from 8" to 7" requires about 400 pounds more seed.

Table 2a. Weight of seed required for rows spaced 90 cm apart using 60 g seed pieces.

In-row spacing (cm)	15	20	25	30	35
Kg of seed per ha	4400	3300	2700	2200	1900

missing plant. Plants next to misses produce large tubers that bruise more easily and are subject to hollow heart, knobs and deformity, so the compensation is of little value.

An unproductive seed piece costs as much to plant and grow as a higher-yielding piece. Taking this argument further, production costs for a field with a poor stand of variable plants are essentially the same as those for a field with a high stand of uniform plants with a high stem count. Ideally then, growers must attempt to plant vigorous high yielding seed pieces and achieve near-perfect plant stands at the same time.

Plant Stands — Typical plant stands in Alberta range from about 60 per cent to 95 per cent and average about 75 to 85 per cent. To determine plant stand, calculate the distance required for 100 plants based on the desired in-row spacing. For example, a seed grower with a six-inch in-row spacing should find 100 plants in 50 ft of row (100 plants x 6-in. = 50 ft). If the grower finds only 85 plants in the 50 foot row there is a 85 per cent stand or an average in-row spacing of 7 inches. To correct a plant stand problem a grower must know why misses occur. Poor stands results from three main causes: planter misses, “blind” seed pieces and seed piece decay.

Sanitation, Handling and Storage of Seed

Lots — Seed lots should be stored, cut and handled under sanitary conditions to prevent the spread of disease and reduce losses from rot organisms. The seed-storage area should be cleaned and disinfected and dirt floors should be scraped to fresh soil. Walls, floors and all surfaces that will come in contact with the seed lot should be disinfected with bleach,

quaternary ammonium compound or an equivalent, such as Roccal, Shur-Gain or Bardac.

Potato pilers, cutters and planters should be cleaned with high-pressure washers and subsequently disinfected.

Before cutting, seed should be warmed to about 15°C for 10 days unless sprouts have already appeared. This warming process helps break the dormancy maintained during cold storage and will speed up emergence. Most potato growers plant within one day of cutting. However, with the proper conditions, seed pieces can be cut and suberized (a process that seals the cut) and stored for several weeks. Tubers will suberize when kept at about 15-20°C, high humidity and good air movement for about five days. If cut pieces are to be stored after suberization is complete, they should be cooled down. Pre-cutting seed can help reduce the rush at planting time, however it should only be attempted if the recommended temperature, air flow and humidity can be achieved. If these conditions are not attainable, growers are advised to cut just before planting. Precautions should be taken at all times (during and after cutting and at planting time) to ensure the seed pieces are not exposed to drying conditions and direct sun.

Seed-piece treatments must be applied to all seed lots after cutting as insurance against adverse post-planting conditions. (Whole-seed tubers planted with a cup planter do not require seed-piece treatments.) Be certain that the fungicide applicator is calibrated since seed-piece treatments may reduce plant vigor if applied too heavily. Well-suberized seed is not normally treated; however if growers choose to treat, they should do so after cuts are

Table 3. Recommended spacing ranges for the most common potato varieties grown in Alberta.

Variety	In-Row Spacing (inches) Production Method and Market				
	Irrigated			Dryland	
	Seed	Fresh Market	Process	Seed	Fresh Market
Russet Burbank	5-6	10-12	10-12	9-12	12-15
Shepody	5-6	8-10	8-10	8-12	12-15
Norchip	4-5	-	7-8	8-12	-
Sangre	5-6	8-10	-	8-10	12-15
Norkotah	5-6	9-10	-	8-12	12-15
Atlantic	5-6	8-10	8-10	8-12	-
Norland	5-6	8-10	-	6-10	12-15
Yukon Gold	5-6	8-10	8-10	6-10	12-15
Norgold	5-6	8-10	-	6-10	12-15
Superior	5-6	8-10	8-10	6-10	12-15
Carlton	5-6	8-10	-	6-10	12-15

healed and prior to planting, not immediately after cutting.

Planter Management — Establishing a high stand is critical if high yields of quality potatoes are desired. To this point we have stressed seed-size, cutting management, seed handling and disease prevention, all of which contribute to plant stand. Mechanical operation of the planter itself contributes significantly to plant stand. Planters should be maintained in good working order and be run by competent people. Research in Washington State has shown that most commercial planters operate best at approximately 3 mph (5 kph) or 4.4 ft/sec (1.34 m/sec) and none operate well above 4 mph (6 kph). Planters should be calibrated for each seed lot by running seed out over a set distance and checking for accuracy of spacing and for misses.

Pick-type planters require constant monitoring and worn or damaged spikes must be replaced. Seed must be able to flow freely to the picker bowl and must not be knocked off before the picker arm opens.

Cup-type planters must be equipped with cups suited to the majority of seed pieces. Large pieces, especially long half slabs may fall out of the cups and small seed pieces may double up. Again the importance of a uniform seed lot must be stressed because the more uniform the weight and shape of seed pieces the better the performance of the planter. As with pick planters, cup planters must be kept clean and adjusted to ensure proper flow and pickup of pieces.

Seed pieces are normally planted 1 to 3 inches (2-8 cm) below field level or about 4 to 6 inches (10-15 cm) below the crest of the planter hill.

Shallow planting may result in uneven emergence if seed pieces are planted into dry soil. However, deep planting into cold soil can delay emergence and reduce vigor.

Stem Populations

Potato planting recommendations always emphasize “plant stand establishment”. However, the number of stems in the plants that make up plant stand is very important because the number of tubers set is closely related to the stem population. A 100 per cent stand of plants with one stem (although unlikely to happen) will not produce a good crop because there are too few stems.

Potato spacing studies in Alberta have shown that there must be a minimum average of two stems per linear foot. (100 stems for each 50 ft of row.) Yields appear to increase as the number of stems increase up to three or more per linear foot. The marketable yield of Shepody is reduced if there are less than two stems per foot, yet very few commercial fields are found with this many stems. Research indicates that stem populations for varieties like Shepody must be increased if growers are to get high yields of quality tubers. Data for Norchip and Russet Burbank are less conclusive, but show gradual increases in marketable yields as stem populations increase from two to three per linear foot. To produce high yields of small seed tubers, stem populations should be as high as four or five per linear foot under irrigation.

Fortunately the factors that contribute to high plant stands also contribute to high stem populations. The two critical factors in achieving high stands are: an average seed-piece weight of 2 ounces and a narrow size range of cut pieces. Seed lots of small seed tubers, with few seed tubers greater than 8 ounces, are the only way growers can cut these desirable seed-piece lots and achieve high stem populations.

Rotation

Potatoes must be rotated with other crops to prevent a buildup of diseases. Some diseases are quite adequately controlled in a one- or two-year rotation, however others require longer periods. A four-year rotation is therefore strongly recommended. Cereal grains are generally the best to use in the three years between potato crops.

Rhizoctonia and fungal wilts are two diseases that require at least a four-year rotation to prevent the buildup of destructive populations or to reduce populations to tolerable levels. Rhizoctonia causes unsightly black spots on tubers, but this disease is most destructive when it attacks the underground stems and stolons. The fungus attacks stems thus restricting their function, and when it infests stolons, young tubers may be pruned away. The total number of tubers set, and therefore yields, may be severely reduced. Although grains are recommended in the rotation, large amounts of straw may increase the levels of rhizoctonia. Grain straw should be baled from fields used in a potato rotation.

Wilt diseases are caused by fusarium and verticillium fungi. Once established they will persist in the soil for many years and even a four-year rotation is not adequate to significantly reduce levels. The best

control is prevention through the use of certified seed and at least a four-year rotation.

General Cultural Practices

Planning for Early and Timely Harvest

Early harvest can mean one of two things. The first is the traditional early harvest for the early July to mid-August market. The second is the timely harvest of the main potato crop before adverse weather sets in. Growers can follow a few steps to achieve either of these objectives.

Growers should plan to complete potato harvesting in September before cold weather chills or damages the tubers. However, harvest often continues well into October, and the risks to crop quality and the potential for major loss are increased dramatically. Cold tubers are damaged at harvest more easily than warm tubers, and severe frost may damage tubers so severely they should not be harvested. Late crops harvested in cold and freezing conditions may result in problems in storage and may reduce processing quality. No one can change the weather, but the following management practices will help produce early market potatoes and assist with timely harvest.

Fall Soil Preparation — Days can be added to the season only in the spring. Although in conflict with soil conservation practices, fall cultivation of fields to be planted to potatoes reduces the amount of spring work and possibly advances the planting date. As discussed in the Soil Management section, there are methods of controlling erosion in fall-worked fields. Grain stubble can be plowed or disced and spiked as preferred. Phosphorus and potassium can be applied in the fall because it is very immobile and will not be lost.

Planting — Soil temperatures should be at least 5°C before potatoes are planted. In a warm spring this can occur as early as the first week in April in southern Alberta, however some discretion is advised. Growers obviously place the crop at some risk if they plant too early, even if soil temperatures are high enough. In several years during the 1980s early planted potatoes were often chilled or frozen before they emerged resulting in reduced stands and seed piece decay. Research at Brooks has shown that there is little or no advantage to very early planting, and in most years there is much risk. Therefore, growers are advised to plant no earlier than April 15 in southern Alberta. There is virtually no difference in quality and yield of Russet Burbank and Norchip

when these varieties are planted between April 20 and about May 10. Early varieties will produce good yields of high quality crops by mid-July if planted in the first part of this suggested planting window.

Potato plants that have emerged and then frozen to the ground will regrow rapidly and within a few days appear to be unaffected. However, when compared with later-planted crops that are not frozen, they will mature later and the processing quality reduced.

Cultivar and seed selection is critical to early harvesting. Early cultivars like Norland, Superior, Carlton, Atlantic, Shepody and Norgold Russet are planted to produce early and mid-season crops. Russet Burbank accounts for nearly one-half of the potato area in Alberta, however it is late maturing and must be managed properly if it is to be harvested before it is damaged by frost.

Seed pieces planted early into cool soil may decay. Seed-piece treatments will reduce or prevent seed decay or seedling death and are highly recommended. Seed lots should be prewarmed to break dormancy prior to cutting and planting so that sprouts are starting to swell, but not elongating, at planting time. Control of weeds, insects and disease is necessary to keep the potatoes growing vigorously, so they will produce acceptable early yields.

Fertility — Growers should follow the fertilizer recommendations in this guide, paying particular attention to nitrogen. Excess nitrogen can delay tuber set and maturity.

Irrigation — Moisture levels of at least 60 per cent of available capacity are required throughout the growing season. Contrary to popular belief potatoes do need adequate moisture in the early stages of growth. Tuberization starts very early (when plants are as small as 8 to 10 inches) and a minimum moisture of 70 per cent of available capacity at the pre-bloom stage can help increase tuber set and yield. (Refer to the Irrigation Section).

Cultivation

Soil Compaction — Large equipment, including trailers for hauling potatoes, can cause soil compaction. As cropping becomes more intense, especially under irrigation, compaction can affect potatoes and other crops. Potatoes are sensitive to the physical condition of the soil. Dense soil interferes with root penetration and therefore plant

growth. Generally, plant growth is slower and less vigorous and potato yields are reduced if the soil is compacted.

Compaction can result in hard pans, poor water and air penetration and clodiness, and may result in nutritional deficiency (especially phosphorus), delayed maturity, restricted root development and distorted tuber shape.

Fall plowing or subsoiling should improve the structure of compacted soil caused by the operation of heavy tillage equipment and harvesting machinery. These operations, however will increase the soil-erosion potential of the soil and growers may have to consider other options. Fall-seeded grains, followed by sub-soiling may improve soil compaction and provide adequate protection from erosion.

Cultivation — Cultivation of potatoes is required for weed control and for hilling; however, excessive cultivation is not only unnecessary, but it may add to compaction below the working level and cause yield-reducing root damage.

Aeration of most soils used for potato production should not be necessary. Cultivation after the application of pre-emergent herbicides tends to promote weed seed germination and may reduce the effectiveness of the chemical.

Hilling — Potatoes are hilled to protect tubers near the soil surface from greening and frost damage. Hilling also kills or buries weed seedlings. Inadequately hilled rows may crack as tubers grow and they may erode following irrigation leaving the tubers exposed.

In Alberta, growers use either disc/shovel or rolling-type cultivators for hilling. Hills should be high enough so that the highest tubers will be covered by about 4 inches (15 cm) of soil. The furrows created should be fairly shallow as deep troughs tend to overheat, dry out, restrict root growth and actually damage roots. The soil creating the hill should not bury new potato shoots. Hilling when the plants are above 8 or 10 inches may cause excessive root damage and diseases may be spread from plant to plant.

Field Application of Sprout Inhibitors

One chemical, maleic hydrazide (MH), commonly available as Royal MH60SG is registered for field application to prevent sprouting in storage. There are many advantages to field applying a sprout inhibitor:

- It can be applied to very small plots of potatoes.
- Potatoes are not subject to in-storage stress, which is associated with heat-generated application of CIPC.
- Storages or other potato lots designated for seed are not contaminated when they come in close contact with potatoes that have been field inhibited with MH.
- Field treating reduces the likelihood of volunteer potatoes appearing in the following spring.

The disadvantage of using maleic hydrazide is that it is an extra field operation and the crop must be closely monitored to ensure the application is correctly timed.

MH must be translocated to the tubers and therefore it must be applied after tuber formation and while vines are still green and active. Normally MH is applied two to three weeks past full bloom, but at least two weeks prior to vine killing. Tubers should be at least 2 inches (5 cm) in diameter at time of application. Growers should apply MH following the label recommendations of the manufacturer.

The manufacturer of Royal MH60SG has warned against the use of this product on irrigated Russet Burbank as there is some indication that stem end cracking and elephant hide may result. Growers of irrigated Russet Burbank should check with the manufacturer regarding current recommendations before using it.

Harvest Management

Vine Killing

Potato vines are chemically dried or mechanically removed for one or more reasons:

- to remove vine growth that interferes with mechanical harvest,
- to mature the tubers and set the skin thus reducing skinning, bruising and storage shrinkage,
- to terminate growth (and kill vines) for early market harvest,
- to terminate growth, control size and set skin for seed potatoes,
- to prevent spread of virus diseases by aphids in seed fields in August.

Both chemical and mechanical methods are used for vine killing. Diquat (Reglone) is the main chemical top killer used in Alberta. It causes relatively slow vine death. If vine growth is heavy, diquat may have to be applied more than once. Mechanical

rotobeaters or shredders stop crop growth instantly, and although used very little in Alberta, they are available through potato machinery dealers. There is a trend elsewhere towards a combination of mechanical and chemical killing.

Growers should allow a minimum of 10 days between top killing and harvest. Consult the product label for application procedures and rates for the specific field conditions. Rates vary according to vine growth, maturity and rate of kill desired.

Effects of Vine Killing on Yield and Quality —

The resulting yield of potatoes is reduced by vine killing, and the earlier that vines are killed the more the yield is reduced. However, studies at Brooks have shown that potato plants that are sprayed with a desiccant continue to bulk and will yield significantly more (up to 20 per cent) than plants that have had tops mechanically removed at the same time.

For many years growers were told that desiccants should be applied in a split application to cause a slow vine death, and therefore reduce the chance of stem-end discoloration. However, research in Alberta and Idaho shows that more rapid killing methods do not contribute to this disorder and therefore a split application should not normally be required. A single application of the desiccant applied at least 10 days before harvest is suitable under most conditions to kill vines. Heavy vine growth will require a second application. After 10 days vines should be sufficiently dead to allow for an easy harvest, and the skin should be adequately set to reduce skinning and bruising.

Stem-End Discoloration (SED) — Stem-end discoloration is a darkening of the vascular tissue and/or the cortex at the stem end of the tuber. In severe cases it may occur throughout the tuber. The speed of vine killing does not normally influence the amount of stem-end discoloration. However, all methods of vine killing, including frost, may cause an increase in SED if the vines are immature or if the plants are under moisture stress. Growers must therefore use production methods that promote early growth and maturity.

Reducing Harvest Damage

The amount of bruising and mechanical damage at harvest is influenced by: soil conditions, cultivar and tuber maturity, tuber temperature, and harvester condition and operation.

The chapter, Bruise Prevention, describes the causes of bruising and preventative measures in more detail. The following is a brief overview of the cause of bruising and bruise prevention at harvest.

Temperature — Alberta's potato producers often do not have the luxury of choosing their harvest dates. Crops are frequently harvested in late September and throughout October, so every harvest hour can count. Despite this pressure, growers should try to avoid harvesting potatoes when tuber temperatures are below 5°C. At low temperatures the tubers are very brittle and subject to bruising and shattering.

To reduce the probability of harvesting in cold conditions, growers need to plan their harvest prior to planting. Cultivar selection, planting date, fertility, irrigation, and vine killing all influence the harvest date. Growers who settle for a good yield and timely harvest are further ahead than those who continuously strive for maximum yield and often experience huge yield and quality losses caused by a late harvest during cold weather.

Harvester Operation and Adjustment — The harvest operation typically accounts for most of the mechanical damage received by potatoes. Other procedures that cause damage include: unloading the haul truck to the piler, piling, scooping and reloading to the truck, second truck unloading and subsequent handling during packaging or processing.

Growers and their hired labor must be familiar with both the machinery and field conditions. The harvester operator (if not the owner) must be aware of problem areas so the necessary adjustments can be made. Since operators cannot see the digging operation completely they must rely on the knowledge and experience of pickers and truck drivers to help. Therefore all harvest staff must know what to look for to ensure that the least damage possible is done to the tubers.

Blade Height — The first bruise hazard encountered by potatoes are at the blade and primary chain. As potatoes and soil are raised by the blade they must make a smooth transition onto the primary chain. If the rear of the blade is too low the tubers will hit the front of the chain. Growers should adjust the position of the blade so that the rear of the blade is nearly level with the front of the chain bed.

Chain and Link Coverings — Rubber-coated chains that reduce tuber damage are available. All chains above the primary chain can be rubber

coated. Chain links on older harvesters should be covered with stiff belting or with wooden boards to prevent tubers from coming in contact with them. Rubber coatings, belts and boards should all be checked frequently by the crew and operator. Belted chains with no link ends to scrape and bruise potatoes are available on newer harvesters.

Primary and Secondary Chains — Depending on soil type, the primary chain should be travelling at about ground speed. In heavier soils the speed should be slightly faster and in very sandy soils it can be slightly slower. The objective is to achieve good soil loading on the lower end of the primary chain to prevent rolling and bounce. Most of the soil should have been removed by the time potatoes reach the top of the primary chain. Hydraulic shakers help to agitate the chain better than common star shakers. Star shakers will wear and break and must be inspected and replaced as necessary.

Bruising occurs as potatoes drop onto the secondary chain and hit the deviner. The primary chain can usually be lowered by about 1 inch (2-3 cm) which is enough to decrease bruise levels. Lowering the deviner chain reduces tuber bounce as tubers hit the chain and drop to the secondary chain. Many harvesters have a split secondary chain and tubers are damaged when they hit the inside links. These can be covered with a rigid piece of plastic, such as a one half portion of PVC pipe. The side links on the secondary chain should be covered with belting.

The secondary chain is driven by a large-diameter drive that can be placed on the underside so that the drop distance to the rear-cross chain can be lowered. "Dog-legging" of the secondary chain is a major job that should be done in winter.

A full-width secondary chain is preferred over a split-secondary chain. However staggered-length, split secondaries are preferred over two secondaries with even ends. The outside chain of the staggered split pair travels farther to the back of the rear-cross chain and the tubers are therefore placed uniformly on the rear cross.

Rear cross and Side Elevator — The rear cross should extend out over the lower end of the side elevator. This helps prevent tubers from being damaged on the frame between the two chains. The drop to the side elevator can also be lowered on some harvesters.

Speed and loading of the side elevator are critical. Typically the speed should be down to one-third to

three-quarters of the ground speed depending on yield. Yields of less than 8 t/ac (20 t/ha) will be carried up a side elevator travelling at about one-third of ground speed. As yields increase to 16-20 t/ac (40-50 t/ha) the side elevator must travel at two-thirds of ground speed (or more) to carry the load properly.

Several bruising problems are caused by incorrect elevator speeds. Excessive speed causes bounce and rollback on the elevator, and it causes tubers to be thrown onto the roller table. A slow side elevator causes excessive piling and rollback. Rollback on the side elevator can be reduced with a hugger belt draped down on the elevator. However such a belt can increase rollback if the elevator flights are broken or missing. The most effective elevator consists of a flightless belt with a driven, flighted hugger belt on top. This dual belt system carries tubers upward and gently drops them to the dirt eliminator. A flighted lower belt often "flings" the tubers from the elevator. The drop to the dirt table can also be reduced by "dog-legging" the side elevator; again, a major job that is better left for the winter months.

Roller, Picking Table and Boom — Rollers on the dirt eliminator should rotate fast enough to help remove clods but tubers should not spin excessively or bounce. The transition from rollers to the picking table should be smooth.

Again the boom should be fully loaded, like the side elevator, so that tubers help each other up. The speed of the boom should be slightly less than the side elevator. Typically this is about one-quarter to two-thirds of ground speed depending on yield. As with all other chains the rollers and chain ends must be covered with belting to protect tubers and all flights must be damage free.

Boom height is a problem for all growers. Maintaining a low drop without damaging previously loaded potatoes is difficult even with boom guards. An infra-red boom-height adjuster can be installed for about \$4,000. The sensor "feels" the infra-red radiation emitted by the tubers and automatically adjusts the boom height to remain constant over the pile.

Types of Harvest Bruising

There are two major types of potato bruises caused at harvest. While both are caused by the potato hitting or being hit by another object, they occur under different conditions and for different reasons.

Blackspot bruises occur when the impact is hard enough to rupture individual cells below the skin without actually breaking the skin. These bruises are not visible. After two days the damaged tissue will turn dark gray or black and can only be seen after the skin is peeled.

Shatter bruises are thin cracks or splits in the tuber skin. They are more common on large tubers than on small ones. Because the flesh is open, diseases such as fusarium dry rot or bacterial soft rot can infest the tubers and cause a tissue breakdown. (Thumb nail cracks are a form of shatter bruise that commonly occurs when cold tubers are roughly handled out of storage and on packing lines).

Other general forms of bruises or mechanical damage include skinning, cutting and scraping. Skinned or scraped areas may turn dark as if scorched when exposed to drying conditions. All of these types of damage adversely affect the appearance of potatoes and often result in rot and decay.

Several factors influence the amount and severity of bruising. Soil clods that often result from working wet soils in spring can persist throughout the season and can contribute to blackspot and skinning. Irrigation before harvest can soften clods and reduce damage. Other soil conditions that affect damage are nutrient levels and moisture. High nitrogen will delay maturity and promote skinning and blackspot. Dry soil also promotes blackspot but decreases the amount of shatter. However, shatter increases in wet soils and black spot decreases. The colder the potatoes the easier they bruise, but the amount of bruising is reduced if the tubers are slightly dehydrated, that is, a bit short of water. Warm tubers are damaged less when water levels in the tubers are high.

Bruise Prevention at Harvest

The following is a summary of recommendations that will help growers reduce harvest damage of potatoes.

1. Kill vines at least 10 days prior to harvest.
2. Overhaul and properly adjust all harvest equipment prior to harvest.
3. Ensure soil temperature is 5°C, or preferably higher, before harvesting (compromise may be necessary late in season).
4. Ensure that equipment operators understand the importance of keeping bruising at a minimum and how to properly adjust and operate the equipment to accomplish this.
5. Ensure all chain or conveyor links and flights are properly padded, except the primary beds.
6. Use ample padding on deflectors, sharp points and any other place where bruising can possibly occur on harvesting equipment.
7. Adjust the digger blade so potatoes will not be bruised or cut and, at the same time, the proper amount of soil will be carried up the primary and secondary beds.
8. Maintain a proper forward-speed-to-chain ratio to ensure proper soil separation and, at the same time, keep the conveyors as full of potatoes as possible.
9. Keep chain agitation at minimum wherever possible. Give serious consideration to the installation of a hydrostatic agitation device on the primary beds to help control agitation more precisely.
10. Keep beds and conveyors sufficiently tight to avoid sagging and whipping.
11. Reduce drops to 15 cm or less including the loading boom drop. Consider installing deflector lip on the end of the boom to reduce bruising.
12. Check frequently for bruising at various points on harvesting and equipment.
13. Remove as many stones from fields as economically feasible.

SEED POTATO PRODUCTION

The information provided in this section is general information. Persons wishing to grow certified classes of potato seed for the first time must contact the Food Production and Inspection Branch of Agriculture Canada to get the exact regulations about growing potato seed. This should be done a minimum of three months before planting.

Introduction

The aim of seed growers is to produce disease-free seed. To ensure good seed health, diseases and other pests must be controlled and the crop must be stored and handled carefully. Successful production of high-quality disease-free seed potatoes requires good management and strict disease-control procedures.

Although the potato certification regulations list the disease tolerances for seed, growers should strive to produce seed with disease levels well below the tolerances. This will enhance their reputations as seed growers, increase the value of their crops and minimize potentially costly disease outbreaks.

This section deals with seed production from a disease control point of view. However, other factors, such as size of seed tubers, affect the quality and productivity of seed lots. Seed growers should refer to the Planting Management section of this book for information on the production of suitably sized seed tubers.

Seed Potato Production Cycle

There are seven classes of seed potatoes in the Canadian potato certification scheme: Pre-Elite,

Figure 7. Certified seed production.

Elite 1, Elite 2, Elite 3, Elite 4, Foundation and Certified. Each class represents one generation; therefore, up to seven years pass from the time Pre-elite seed is planted by an Elite seed grower until the commercial grower plants certified seed. The tolerances for disease increase slightly with each generation beyond Elite 2.

There are two general classes of seed growers in Alberta: Elite and non-Elite seed growers. Elite growers receive nuclear seed and produce pre-Elite, Elite 1, Elite 2, Elite 3, and Elite 4 seed potatoes. Non-Elite growers plant Elite 2, or lower classes, and from this produce Elite 3, Elite 4, Foundation and Certified classes of seed potatoes (figure 7). To qualify as an Elite grower, an individual must have five consecutive years of seed-growing experience, be a self-contained operation and plant Elite 3 class or higher.

Nuclear seed and tissue-culture plantlets are produced by the Alberta Tree Nursery and Horticulture Centre (ATNHC) in Edmonton, as well as by private laboratories and greenhouse operators in the province.

The Seed Potato Certification Program is administered by the Food Production and Inspection Branch of Agriculture Canada. Any person wanting information about becoming a seed grower should contact the Agriculture Canada office nearest to them.

Commercial and seed potato growers wishing to purchase seed should contact the Potato Growers of Alberta office in Calgary to obtain the current issue of the Alberta Seed Potato Directory. This directory lists growers, varieties, seed area planted, seed classes, and the addresses and phone numbers of Alberta's seed growers.

The cultivars grown by seed growers depend upon the needs of the commercial market. The main cultivars grown in Alberta are discussed in the Production Management section. Demand for other cultivars is limited and therefore, these cultivars should be grown on a limited scale for specialty markets, or under contract with packers or processors.

Disease Control — The Alberta Seed Potato Program at ATNHC receives disease-free seed tubers from Agriculture Canada in Vancouver. These tubers have undergone elaborate disease-freeing procedures. Staff in the Seed Program then multiply these disease-free stocks for distribution as nuclear seed to Elite growers.

Some nuclear seed is also produced by private growers. A variety of methods are used to monitor disease levels in the nuclear stocks, and to eliminate low levels of diseases if they become re-established. Test plants (plants that react in a specific way to infection by a specific pathogen) may be used to check for diseases. *Gomphrena globosa* is used to detect potato virus X; Rutgers tomato is used to detect potato spindle tuber viroid; *Chenopodium quinoa* is used to detect potato virus S; and *Nicotiana glutinosa* is used to detect potato viruses X, S and Y. Serological methods such as latex agglutination, slide agglutination, and ELISA (Enzyme-Linked Immuno-Sorbent Assay) are used to detect a number of the virus diseases. Culturing and staining methods are used to detect bacterial and fungal diseases. The PAGE (Polyacrylamide Gel Electrophoresis) test and Dot Blot test are used to detect potato spindle tuber viroid (PSTV).

At the nuclear stage, plants that test positive for any one of these diseases are discarded. Disease-free plants are further increased in the greenhouse by meristem culturing or rooted-cutting techniques. In Alberta, the initial increase is by meristem culturing. Tubers from these greenhouse-grown plants are then increased by seed potato growers in Alberta.

Diseases such as potato virus X (PVX), potato virus S (PVS), potato spindle tuber viroid (PSTV), blackleg, bacterial ring rot (BRR), fusarium wilt, verticillium wilt and potato leaf roll virus (PLRV) can re-infect seed potato stocks within one or two years. To prevent or slow down this re-infection process, Elite seed stocks must be grown under strict sanitary conditions.

Sanitation

Without adequate sanitation, diseases such as bacterial ring rot and blackleg can infect seed stocks from contaminated equipment or storages.

All seed growers must be aware of sanitation procedures and apply them rigorously. Sanitation consists of cleaning and disinfecting all equipment, storages, tools and pallet boxes that come in contact with the potatoes. Since most disinfectants are inactivated by soil and plant debris, it is essential that this material be removed from the equipment by a thorough cleaning with a hot-water or steam cleaner prior to disinfection. Then the equipment is thoroughly soaked with a disinfectant such as: bleach (sodium hypochlorite 10%); quaternary ammonium (such as Roccal, Shur-Gain disinfectant,

or Bardac 2210); or formaldehyde. Follow the manufacturers' recommendation regarding the safe use of these products because they are all potentially hazardous to humans.

Sanitation also includes disposal of cull potatoes, and roguing and removal of diseased plants from the field. Cull potatoes should be removed from the farm as soon as possible and fed to cattle or buried in a landfill site. When roguing, diseased plants must be removed from the field and disposed of. They can become a source of continuing infestation by the disease if left in the field.

Whole Versus Cut Seed

North America potato growers have cut seed for nearly 200 years and we can expect that they will continue to do so for many more years. However, seed growers can benefit from planting small whole seed tubers.

Planting whole seed tubers eliminates the need to plant the higher classes of seed in tuber units because every plant grows from a different whole seed piece. If one plant is diseased only that one plant has to be removed. This makes roguing simpler. If seed is planted in tuber units, a diseased plant must be removed along with neighboring plants on the assumption that they may have the disease.

Small whole seed tubers eliminate expensive and time-consuming cutting. Because cutting is eliminated the chance of spreading diseases from tuber to tuber is greatly reduced.

The trend in commercial and seed potato production is to plant seed cut from smaller seed tubers. Seed growers can supply smaller seed tubers to their buyers if they plant whole seed because "single drops" set more tubers per plant than cut seed. Because of the increased competition the tuber size of the resulting seed crop is reduced.

Other advantages of whole seed are that plants are more uniform in their growth and therefore result in more uniform tubers at harvest time. Uniformity is further enhanced because whole seed results in near-perfect stands and this in turn results in fewer oversized and misshapen tubers.

All growers, especially seed growers, should look at the advantages of whole seed and assess the benefits of using them in their operation.

Preparation of Seed

Elite seed growers produce their own seed, and certified growers purchase Elite 3, Elite 4 or Foundation seed from Elite growers.

The first consideration when purchasing seed for recertification is disease and size quality. Buying from a grower with a good reputation will reduce the risk of receiving diseased seed and increase chances of obtaining good seed. Growers purchasing seed from outside Canada should check with the Agriculture Canada, Food Production and Inspection Branch, Calgary, (phone 292-4986) before buying the seed. Some seed potatoes from the United States can not be recertified in Canada.

Seed potatoes, whether purchased or produced by the seed grower, should be warmed to 10-15°C for two weeks prior to handling. During grading and transporting, seed potatoes should not be bruised or stressed in any manner. Rots, if any, should be removed prior to cutting. Cut seed should be treated with a fungicide and planted within a few hours of cutting. If not planted immediately, the seed pieces should be suberized as outlined below for precut seed.

Cutters must be kept clean, sharp and disinfected. Sharp knives result in clean cuts that suberize quickly and reduce decay. Seed cutters must be adjusted to produce uniform seed pieces.

Precut Seed — Precutting of seed gives the producers more flexibility at planting time. Seed potatoes can be precut up to four weeks prior to planting provided they are treated properly. Potatoes that are to be precut should be warmed to 10-15°C and 95 per cent relative humidity prior to cutting and maintained at 15-20°C, and high humidity, for two to four days after cutting to promote healing of cut surfaces. If the potatoes are to be kept longer, they are then cooled to 4°C for the duration of storage and warmed again prior to planting. Seed-piece treatment should not be necessary after suberization. If seed treatment is required, it should be applied just prior to planting but not after cutting. Precutting seed must not be attempted if the environmental conditions described here cannot be met.

Seed-piece Treatments — Fungicidal treatments that prevent seed-piece decay and fungal seedling disease are recommended, particularly if seed pieces are planted in cool wet soil or if a cool wet spring is anticipated. Several fungal diseases can decay seed pieces resulting in missing or weakened plants.

Registered seed-piece treatments are listed in table 11 found in the Pest Management section of this book. Growers are responsible for the correct application of seed-piece treatments and must follow registered application procedures on the product label.

Planting

Higher classes of seed (Elite 1 and 2) are planted first so they can be top-killed early to reduce infection by virus-carrying aphids. Cup-type planters reduce the risk of disease spread and therefore are better than pick-type planters for planting seed potatoes.

Tuber-Unit Planting — Tuber-unit planting is a process where all seed pieces cut from a single tuber are planted consecutively in a row and are separated from seed pieces of another tuber. The federal seed regulations require that Pre-Elite, Elite 1 and Elite 2 seed be planted as whole seed or in tuber units. Growers should contact the Agriculture Canada Food Production and Inspection office nearest them to obtain details of the tuber-unit planting regulations.

Tuber-unit planting is used to identify tuber-borne diseases, separate them from current-season infections and make roguing easier. (All plants originating from an infested tuber are usually infected; however, when diseases are introduced in the current season only one or two plants are infected.)

Tuber units are planted either by hand (in very small plots), or with a tuber-unit planter. A tuber-unit planter is a manually fed planter that allows tuber units to be planted consecutively with or without the extra space. To facilitate planting, seed tubers can be pre-cut part way through and then separated into seed pieces at the moment they are placed into the planter cups. For larger areas, where manual cutting and planting is not practical, whole tubers can be planted using cup-type or tuber-unit planters.

When cutting seed tubers for tuber-unit planting the knife must be dipped into a disinfectant such as 10 per cent bleach or a quaternary ammonium solution after each tuber is cut. Examples of hand cut seed pieces from tubers of various sizes are shown in figure 8.

As tubers are cut, the seed pieces are dropped consecutively 15-30 cm apart in an open furrow. All pieces from one tuber are then followed by a double space as shown in figure 9. (See tuber standards for certified seed potatoes at the end of this chapter.)

Fertility

Fertilizer should be applied as recommended by a soil analysis report. Total nitrogen to a depth of 24 inches (30 cm) should be about 125 to 175 lb/ac (110-160 kg/ha), and phosphorus about 100 lb/ac (90 kg/ha). Although most Alberta soils are not deficient in potash, grower experience and research has shown that when levels are below 350 lb/ac (315 kg/ha), potassium should be applied.

Maintenance of Seed Potato Fields

Diseases in seed potatoes must be controlled so that certification at the planned class is assured. The presence of seed-borne diseases may require that fields be rogued to keep the level of disease below the tolerances for that seed class. Although not always practical, or possible, growers should strive for complete freedom from disease in all classes of seed potatoes. (Refer to the disease-control section).

To reduce or prevent the spread of viral diseases in seed fields, sucking and chewing insects such as aphids and leafhoppers must be controlled with insecticides. Growers who are in high-risk areas should use a soil-applied insecticide at planting and foliar insecticides during the growing season to reduce the spread of viral diseases. Refer to the section on insect control.

Weeds must be controlled in seed potato fields to allow for proper inspection and roguing. For weed-control procedures and chemicals refer to the section on pest management.

Irrigation and Disease Spread — Irrigation water can spread some diseases, such as blackleg and wilts. Wheel-type and pivot-type sprinkler systems may spread blackleg, potato virus S, potato virus X and potato spindle tuber viroid. Precautions like disinfecting wheels should be taken when moving equipment from field to field or from plot to plot, to prevent the spread of these diseases.

Roguing — Roguing is the removal of diseased plants from a field. All diseased plants including the new tubers and seed-pieces should be removed from the field. After handling diseased plants, avoid handling healthy plants and disinfect hands and tools as soon as possible. Fields should be inspected for disease on a regular basis.

All hand cut pieces should weigh between 1.5 and 2 oz.

Figure 8. Hand-cut seed pieces.

Figure 9. Tuber-unit planting of seed potatoes. This diagram shows a blank space between seed pieces cut from different seed tubers. Seed regulations require that some Elite classes be planted in this manner. New growers are advised to check with their seed inspector for details prior to planting.

Harvest Management

The performance of disease-free seed potatoes is often directly related to the physical health of the tuber. Healthy, sound tubers will perform better than bruised or damaged tubers because they may be less prone to seed-piece decay or soft rot. Cool-weather harvesting, excessive chain speeds, high drops and lumpy soil may result in tuber damage. If some bruising has occurred, a post-harvest treatment with Mertect will help protect the tubers from storage decay.

Prior to harvesting and loading, all equipment must be cleaned and disinfected. Chains and conveyors should be maintained, repaired and adjusted properly to prevent bruising and scraping. Potatoes should not be dropped more than 6 inches (15 cm) in any harvest or piling operation.

Potato vines are top killed at least 10 days prior to harvest with diquat (Reglone) to mature the tubers and make harvesting easier. Mature tubers have better skin set and are less affected by normal harvesting procedures.

Seed potatoes should be top-killed as soon as they reach a sufficient size. Generally Pre-Elite, Elite 1 and Elite 2 should be top-killed by August 20. All vines and leaves must be completely dead within 10-15 days of vine killing to prevent late-season spread of leaf roll.

Fields are normally harvested 10 to 20 days after top-killing. A longer period in the ground after top-killing is undesirable as it may increase the incidence of rhizoctonia in the harvested seed.

Storage Management

Each class and variety of seed must be stored separately to prevent mixing. Sprout inhibitors must not be applied to seed potato fields or in storages that are to be used for seed potatoes. Commercial potatoes that have been sprout inhibited with CIPC must not be moved to where seed potatoes will be stored at a later date. Residues will evaporate and re-establish in the new storage and subsequently may retard sprouting of seed in the future.

Thoroughly clean and disinfect storage facilities and all grading and handling equipment after planting is completed and again prior to harvest. Cure potatoes at 13-16°C and a relative humidity of 90-95 per cent for 8-15 days to heal wounds and bruises. Seed potatoes should be stored at a temperature of 3-5°C with a relative humidity of 90-95 per cent for long-term storage. Allow only authorized personnel into the storage and visitors should disinfect their footwear before entering.

Grading

Remove all culls from the seed farm as soon as it is practical.

Alberta seed growers normally sell their seed in bulk, which must be graded according to the seed regulations unless the buyer specifies otherwise. Seed regulations allow Class A seed to range in tuber diameters from 45 mm to 70 mm for long varieties, and from 50 mm to 80 mm for round varieties. Seed lots with this size variation result in highly variable seed pieces which cause unacceptable hill-to-hill variations. Growers may get a copy of the new regulations from the Food Production and Inspection Branch Agriculture Canada, in Calgary. (See table 4 and figure 10.)

When commercial growers pick up seed potatoes at a seed farm, their trucks must be disinfected before entering the seed farm property. This should be done away from the seed farm especially if the truck has hauled commercial potatoes.

Marketing

New seed potato growers need to consider both where and how they will market their seed. This information will assist them in deciding the quantities and cultivars to be grown.

Marketing of seed potatoes is the responsibility of the individual seed grower, although Edmonton Potato Growers Ltd. does market for its member growers and some additional growers under a special agreement. The Potato Growers of Alberta, Alberta Agriculture and the Alberta Seed Potato Growers Association co-operate in promoting the sale of seed potatoes to export markets, particularly in Washington, Oregon and California. Growers selling independently should contact the office of the Potato Growers of Alberta for marketing information, advice and contacts. The Alberta Seed Potato

Growers Association publishes an annual directory that lists all seed growers.

Summary of Seed Potato Certification Regulations

Application for crop inspection — Applications must be made on forms supplied by Agriculture Canada and received in the Food Production and Inspection Branch, in Calgary by June 16 of the current crop year. This deadline must be met to permit the scheduling of inspections. When the potatoes that will be planted were purchased from another seed grower, the application for inspection must be accompanied by a tag or a copy of the bulk certificate from each lot of seed planted. (The remainder of the tags from bagged seed must be kept as they will be required when the first inspection is made.)

All seed lots must be tested for bacterial ring rot before tags or bulk certificates will be issued, or before planting by the grower.

A map of the exact location of each field with the distance from the home site in kilometres is required. It is also important to put as much information as possible about each field (i.e., landmarks such as, surrounding crops, nearby commercial potato fields, and buildings on the property). Growers should also note all accesses to each field.

Conditions to be met for crop inspection — The person or agency applying for inspection of a crop to produce Pre-Elite, Elite 1, Elite 2, must have successfully grown seed potatoes for five consecutive years. New seed growers will only be accepted where the inspector has verified adequate control measures to prevent bacterial ring rot before the arrival of new seed. All land used for planting must have been free from potato production in the previous two years.

Table 4. Size classes of seed potatoes.

Variety Shape	Class A	Class B
Long	45 to 70 mm	30 to 45 mm
Round	50 to 80 mm	30 to 50 mm

- Notes: 1. Class "A" size range is too wide and will result in hard-to-plant, variable and unproductive seed pieces.
2. Class "B" is essentially single-drop seed. The upper range is a bit too large.
3. Seed buyers may specify other size ranges or weights for the seed they purchase.

Figure 10. Actual legal size ranges of class 'A' seed.

Seed potatoes may also be imported for re-certification from the United States providing that:

- prior authorization has been obtained from the program officer for seed potato certification,
- the source, all lands and buildings have been free of bacterial ring rot for at least five year,
- post-harvest test results and summer field readings are available,
- field and storage inspection records show no presence of PSTV in the crop,
- the winter test records verify the absence of PSTV,
- the number of generations removed from the disease-free clonal selection or nuclear stock is known.

The above information must be completed and signed by the head of the State Certification Program. Any imported seed planted without approval will be considered non-certified and may put the farm's entire production in jeopardy.

In addition to the above, a 1,000-tuber sample must be collected and tested for bacterial ring rot. Should the test read positive for BRR and the seed already planted, the entire seed operation would be considered contaminated and no inspection would be performed on the farm, thereby eliminating all seed lots from certification. To avoid complications, a grower should refrain from planting the imported lot until all tests have been completed.

All equipment used to plant, cultivate or harvest the crop must be thoroughly disinfected and free from pathogens. Crop inspection or a growing crop certificate will be refused if an inspector suspects that equipment used might be contaminated and would adversely affect the crop. Any community equipment used must be disinfected under the supervision, and to the satisfaction, of the inspector.

No crop inspection will be made if:

- potato seed plots equal to, or less than, 0.25 acres (0.1 ha) in size are not totally planted in tuber units,
- an inspector is unable to conduct a visual inspection as a result of late planting, lack of cultivation, lack of vigor, the existence of weeds, leaf injury or pesticide injury,
- the crop is growing on a farm where commercial potato stock (non-certifiable) is planted,

- seed is growing on a farm where potatoes infected with BRR were produced or found in the previous year (or until the farm is no longer considered infected),
- the crop is planted in a field where non-certified or BRR-infected potatoes were grown in the previous two years. (Any field where there has been an occurrence of BRR must be kept free of any potatoes including volunteers for a full two years),
- the crop is located within 60 metres of other potatoes which show viral disease levels exceeding the limits specified for the certified class,
- the crop has been treated with or exposed to a sprout inhibitor.

Subject to the above, the growing crop will be inspected two or three times during the growing season (depending on the class of seed) by an Agriculture Canada inspector. A growing crop certificate will be issued for all crops that meet the requirements. However, it will not be issued when the crop, or another crop derived from the same parent stock is suspected to be contaminated with bacterial ring rot. BRR found at any time in the inspection process will disqualify all of the grower's seed from certification. PSTV found at any time will disqualify only that lot (field) of seed in which it is found.

Tuber inspections and storage — Inspections will be made to determine adequacy of storage facilities and procedures. Each variety and class of seed potatoes must be stored in such a manner as to prevent any mixtures. Non-certified potatoes must be kept completely separate from certified classes. At shipping, tubers must be graded to standards and have been tested for bacterial ring rot before tags or bulk certificates will be issued.

Tuber Standards for Certified Seed Potatoes

Following are the grade standards for seed potato tubers.

Disease or defect	Per cent by count	
	at shipping	at destination
Soft rot or wet breakdown	0.1	0.5
Dry rot including late blight	1.0	1.0
Scab and rhizoctonia combined		
a) light	10.0	10.0
b) moderate	5.0	5.0
Stem-end discoloration caused by top killing, frost heat, or drought	4.0	4.0
Malformed or damaged	2.0	3.0

In any lot, the number of tubers that are affected by light and moderate scab and rhizoctonia combined shall not exceed 10 per cent of the total number of tubers in the lot. The following definitions for scab and rhizoctonia are as follows:

- “light scab” - 1 to 5 per cent of the tuber surface is covered with common scab lesions,
- “light rhizoctonia” - 1 to 5 per cent of the tuber surface is covered with rhizoctonia sclerotia,
- “moderate scab” - 5 to 10 per cent of the tuber surface is covered with common scab lesions,
- “moderate rhizoctonia” - 5 to 10 per cent of the tuber surface is covered with rhizoctonia sclerotia.

Tubers in a lot of any class that show symptoms of leaf roll necrosis shall have the presence of the disease confirmed by laboratory tests and shall not exceed the percentage permitted for viral disease for that class.

In any lot, the number of tubers in the aggregate that is affected by disease and defects, not including light scab, light rhizoctonia and stem-end discoloration, shall not exceed 5 per cent of the total number of tubers in the lot.

At the point of shipping, not more than 5 per cent of the tubers in a lot shall be affected by pressure bruising on over 10 per cent of their surface.

At the point of shipping, not more than 10 per cent of the tubers in the lot shall have sprouts longer than 2 cm.

In any lot, at least 98 per cent of the tubers shall be firm and well shaped.

No tubers in any lots shall be washed.

Re-inspection of any lot of certified seed potatoes will be made at the buyer's request providing the

request is submitted within two working days of receipt of the lot.

Disease Standards for Certified Seed Potatoes

Pre-Elite, Elite 1 and Elite 2 must be inspected three times during the growing season and on the third inspection be found free of any visible symptoms of disease. All of the aforementioned classes must be grown in identifiable tuber units, the only exception to this is Elite 2 which, if post-harvest tested and found to contain less than 0.1 per cent disease may be mass planted.

Following are the maximum percentages of diseased plants allowed in a growing crop planted to produce the various classes of seed at the time of field inspection (table 5).

Table 5. Disease tolerances for seed potatoes.

Elite 3	Inspection		
	First	Second	Third
PSTV	0.0	0.0	0.0
BRR	0.0	0.0	0.0
All viruses	0.25	0.1	0.1
Blackleg, wilts, viruses	0.5	0.25	0.25
Varietal mix	0.1	0.0	0.0
Elite 4			
PSTV	0.0	0.0	
BRR	0.0	0.0	
All viruses	0.5	0.1	
Blackleg, wilts, viruses	1.0	0.25	
Varietal mix	0.1	0.0	
Foundation			
PSTV	0.0	0.0	
BRR	0.0	0.0	
All viruses	0.5	0.2	
Blackleg, wilts, viruses	1.0	0.5	
Varietal mix	0.1	0.05	
Certified			
PSTV	0.0	0.0	
BRR	0.0	0.0	
Any one virus	1.0	0.5	
All viruses	2.0	1.0	
Blackleg, wilts, viruses	3.0	2.0	
Varietal mix	1.0	0.1	

PSTV = Potato Spindle Tuber Viroid

BRR = Bacterial Ring Rot

BRUISE PREVENTION

This chapter is a condensation of a report prepared by Dr. Lisa O. Knowles for the Alberta Potato Research Association in 1989. The report is available from the Potato Growers of Alberta. The Alberta Potato Research Association is funded by potato growers and by one of Alberta's potato processors.

Introduction

Mechanical damage to potatoes is costly for growers, packers and processors. Potatoes are damaged internally and externally by equipment, stones, clods and other potatoes as they are dug, elevated, dropped, loaded, unloaded, piled and moved again. Injuries occur during harvesting, shipping, grading and distribution, although the harvesting operation is usually the greatest cause of damage. Severely damaged tubers are an obvious (and direct) cash loss to growers because they are graded out at the packing or processing plant. Slightly and moderately injured tubers increase labor costs for removal of damaged potatoes or parts of tubers during packaging or processing. Bruised tubers reduce the quality of fresh or processed potatoes, thus reducing returns to the packer, processor and grower. Damaged tubers also increase the loss in storage. Respiration is increased by the injury and the additional heat and carbon dioxide produced will retard the healing process. The increased ventilation required to eliminate the heat of respiration and carbon dioxide results in more weight loss. Bruised potatoes are more susceptible to diseases such as soft rot and dry rot.

Mechanical injuries are divided into external and internal types. Growers must be aware that the most visible injuries are not always the most serious, and the absence of external injury does not necessarily mean that the tubers are free from internal damage.

There are three types of external injuries. Scuffing or skinning results from skin removal when tubers rub against other tubers or equipment. Flesh wounds such as cuts, slices, and gouges are usually incurred on the digger blade or at the edges of chains and elevators. Shatter bruises are single open cracks or star-shaped cracks caused by impact of cold tubers with hard surfaces. Shatter bruise increases as the temperature decreases.

Blackspot bruise is the most significant internal injury. Blackspot bruises, usually about the size of a

dime, form below the skin (which is unbroken) and therefore the damage is not readily apparent until the tuber is peeled or cut. They are not immediately apparent at harvest and may take several days to appear. Blackspot results principally from impact, but also forms at pressure points on tubers in prolonged storage. The spots, more prevalent on the stem end, can discolor to blue, grey, black or brown and are unacceptable to processors and fresh consumers. Blackspot bruise increases as the temperature at harvest increases.

The Extent of the Problem

Mechanical damage has been studied for decades and is well documented in Europe and North America. Early studies showed that mechanical damage reduced marketable pack-out significantly. A study in 1957 sampled Russet Burbanks at several points between the harvester in Idaho and retail stores in Dallas, Texas. Over half of the potatoes were damaged, and 12 per cent were classified as having serious bruise by the time they were loaded on the harvest truck. Only 23 per cent of tubers were completely free from bruise in the storage bin, and only 6 per cent were uninjured after removal from storage and hauling to a warehouse. Additional injuries occurred during grading, loading, shipping and distribution to retail outlets. By the time they were sold about one-third of the tubers had serious bruise damage.

Another study in 1962 in Washington State showed the extent of mechanical injury to Russet Burbank at harvest, grading and shipping. Injury levels were assessed by the amount of peeling required to remove the defect, and ranged from blemished (corrected by normal peeling), to serious damaged that resulted in over 10 per cent loss by peeling. In this study the harvesting process alone caused some degree of external injury to 38 per cent of all tubers and 42 per cent had some blackspot. The grading process resulted in an additional 11 per cent external and 12 per cent blackspot injury. During shipping by rail between Washington and Chicago, external injury increased 3 per cent, and blackspot by 10 per cent. At the Chicago terminal market, 58 per cent fall tubers had external injury and 60 per cent suffered from blackspot.

European studies showed similar results. The Potato Marketing Board in England found in a 1973 study that 21 per cent of tubers coming off the harvester had flesh damage and 13 per cent were bruised. In 1981 the Board studied 548 farms in England and Scotland and found that 30 per cent of all processed potatoes were bruised and 9 per cent had severe external damage of all types. Of those leaving the farm, 20 per cent were bruised and 8 per cent had severe external damage.

Although extensive studies like these have not been carried out in Western Canada, smaller studies and experience of packers and processors indicate that a similar situation exists here. Alberta's processors report that damaged lots of potatoes increase costs in several ways. Damaged potatoes require two or three times the number of staff on the trim line. Actual trim losses reduce the percent pack-out, and the quality of the finished product is inferior, thus reducing the value.

The financial loss from mechanical damage is rather difficult to assess but has been estimated in the United States at 20 per cent of producers' gross income. An accurate estimate of the loss in Alberta is very difficult, however, using the gross farm-gate income for potatoes, the losses here could be expected to be between \$5 and \$8 million annually.

Because of different growing conditions (equipment, climate and soil type) in Alberta, the United States and Europe, it is not possible to predict from studies elsewhere how much damage is occurring at present in Alberta. A considerable amount of injury does occur during the harvesting and handling of potatoes in Alberta and in most cases the harvesting machinery will be a significant source of damage. Therefore, the question is: How much of this damage can be eliminated? External (shatter) and internal (blackspot) bruises at harvest have received the most attention, and therefore, the following discussion concentrates on mechanical damage at harvest.

Factors Determining Susceptibility to Bruising

The amount of bruise damage is determined by the amount of force upon the tuber and the susceptibility of the potato tissue to injury. Forces on the tubers can be manipulated through harvester and equipment management. Susceptibility of the tissue is influenced by the variety, the environment and management practices. Varietal factors, like specific

gravity, are not directly manageable from a bruise point of view. (Potatoes with a high dry matter content bruise more easily than low dry matter potatoes in similar conditions, however high dry matter is a desirable processing trait, and cannot be reduced for the sake of bruise reduction.)

Variety — There are substantial differences in bruise susceptibility among potato varieties. Because the effect of variety on blackspot is influenced by location and can interact with temperature, there may be difference in "bruise ranking" from one year to the next. Therefore no specific recommendations can be made regarding cultivar selection for bruise control, and growers must learn to manage other aspects of their operations. Most cultivars grown in Alberta are high dry matter potatoes and therefore susceptible to bruise damage. Low dry matter varieties, like Norland, may be less susceptible to shatter bruise and blackspot bruise than others such as Russet Burbank and Norchip; however, they are more sensitive to skinning, and like all varieties no practical differences exist in susceptibility to cuts and gouges by machinery.

Tissue Susceptibility — Biochemical and physical conditions both determine tuber susceptibility to damage. Biochemistry relates more specifically to internal blackspot and determines the potential of the tissue to turn dark when cell membranes are broken. Skin and internal tissue strength can be related to certain types of field damage such as shatter bruise. The elastic properties and firmness of the tuber may play a role in internal and external damage and are influenced by the strength of cell walls, the stiffness of intercellular adhesion and sap pressure within cells.

Tuber firmness influences bruise susceptibility. Flaccid tubers are more likely to suffer from blackspot bruise but are quite resistant to shatter

Figure 11. Effect of tuber hydration level on shatter and blackspot bruise at 7 to 10°C.

POTATO CULTIVARS

Russet Burbank – main crop fresh market and french fry.

Norchip – main crop chipping.

Superior – early chipping and fresh market.

Norgold Russet – mid-season fresh market.

Shepody – mid-season french fry.

Norland – fresh market.

Carlton – early fresh market.

DISEASES OF POTATOES

Bacterial Ring Rot – tuber symptoms.

Bacterial Ring Rot – milky ooze from stem.

Early Blight.

Lenticular Soft Rot.

Leaf Roll.

Rhizoctonia Canker.

Tubers with storage fungal diseases (Silver Scurf, Skin Spot) plus pressure bruise. Peeled tubers with these disorders cause problems for processors.

DISORDERS OF POTATOES

Tordon injury on foliage.

Secondary tubers and knob formation caused by heat and moisture stress on Russet Burbanks.

INSECT PESTS

Colorado Beetle – larvae and adult.

Colorado Beetle – eggs on underside of leaf.

Wireworm damage.

Wireworms.

bruise. Firm tubers are resistant to blackspot and very sensitive to shatter. Moderate moisture levels appear to be the best compromise for reducing either since excessive moisture will increase tuber firmness and increase shatter and dry soil will cause tubers to be soft and very susceptible to blackspot bruise (figure 11).

Tuber temperature is universally recognized as an important factor in bruising and researchers consistently agree on its effects on bruising: bruise resistance increases as tuber temperature increases. Tuber temperature is related to soil temperature, and therefore less bruising occurs when soil temperatures are warmer at harvest (figures 12 and 13), giving the producer some measure of control over bruising. Weather is never totally predictable in Alberta; however, growers who plan to complete the main potato harvest in September can expect less damage than those who, because of excessive acreage, plan to complete harvest in October when soil temperatures often approach freezing.

Tuber maturity is important because skin set, tuber size and cellular factors, all affected by maturity, are related to damage susceptibility. Generally mature potatoes are more resistant to bruising, and bruising increases as planting is delayed. Adequate skin set ensures resistance to shatter bruising and skinning injury. Water loss from skinning damage results in a decrease in tuber turgor and thus an increase in bruising during subsequent handling. Vine-killing is a cultural practice that can have an important effect on the condition of tubers at harvest. When vines are destroyed during a period of active growth, about 10 to 20 days before digging, skin set will be improved and blackspot reduced. Larger tubers bruise more readily than smaller tubers because they have more energy of impact compared with smaller tubers falling the same distance. Although yields increase, growers run the risk of increasing bruise damage by delaying harvest because tubers may become too

Figure 12. Relationship between soil temperature, tuber damage, and time of day during potato harvest.

large. Planting at recommended spacings will maximize yields of uniform, adequately sized tubers that are more resistant to bruising than large tubers grown at wide in-row spacing.

Although the causes are not clear, potassium fertilization may reduce blackspot bruise. Several factors that are altered by high applications of potassium have been used to explain the effect. Specific gravity has been shown to decrease as application rates of potassium increase. Potassium may have an effect on cell size and the physical properties of the cell wall. It may affect the ability of the tuber to form colored oxidation products caused by cell damage.

The role of nitrogen fertilization in internal bruising is less clear as research results have been inconsistent. No matter what the effects of nitrogen, growers must manage their nitrogen fertilization to assure adequate specific gravity, sizing and yields. Studies in Alberta have shown that elevated levels of nitrogen result in slightly lower specific gravities, which (based on other research) would tend to reduce bruising. However, studies conducted over several years also showed that the number of oversized tubers increased when nitrogen levels were higher than recommended, and oversized tubers are more prone to bruising.

The Harvester as a Source of Damage

Mechanized harvesting is a major source of damage to the potato crop. The susceptibility to damage varies with the field and tuber conditions described previously, but in all cases, the harvester must be operated in a manner that will minimize tuber damage. Bruise levels on a properly operated

Figure 13. Effects of forward speed and soil temperature on potato tuber damage.

harvester will likely be around 10 per cent under ideal conditions. As harvester operation deviates from optimum, the percentage of tubers suffering bruise damage will increase to 30 per cent in relatively bruise-resistant tubers or as high as 65 per cent in susceptible tubers. Therefore, even under the best circumstances, incorrect harvester operation has an adverse effect, but it has the most serious effects on susceptible tubers.

The harvester moves a great deal of soil along during operation and the condition of soil can influence bruising. Tubers harvested when the soil is relatively dry, and therefore eliminated easily through the chain, are more severely injured than tubers harvested following rain or irrigation. Hard and dry soil forms clods and although clods may bruise some tubers directly, it is the increased chain agitation required to break them up which causes the most serious damage. Stones carried on the harvester are also a source of external damage.

The digger blade is the first point of contact between tubers and the harvester. These blades are usually flat and may or may not be split into two sections. The presence of vines, roots, weeds and unfavorable soil conditions can make the blade difficult to operate. Damage can occur when the angle of the blade is too low causing tubers to hit the front of the primary chain. This problem is remedied by an adjustment which sets the blade nearly level with the upper level of the primary chain so that tubers roll more easily onto the primary (figure 14). If the blade is not set deep enough, potatoes will be sliced by the blade. However, if the blade is considerably lower than that required to lift tubers, excessive and unnecessary amounts of soil will flow onto the harvester.

The primary chain is normally the initial site of soil removal. The most prevalent cause of damage is rapid soil elimination and a lack of soil cushion on the primary chain because of slow forward speed,

high chain speed relative to the forward speed, or excessive agitation. In the past, bruising was believed to be reduced when soil was carried through the harvester as a cushion. However, soil present with the tubers after leaving the harvester will increase bruising because of the subsequent handling required to remove it.

Studies in Washington have shown that soil load levels between 65 and 83 per cent on the primary chain do not significantly affect bruising on any subsequent part of the harvester. Full tuber loads on rear cross and elevator chains are more important than using soil as a buffer. The proper selection of chain-speed/ground-speed ratios can be used to achieve adequate tuber loading. As the primary-chain/ground-speed ratio increases from less than 1 to 2.0, damage increases only slightly, but soil flowing onto the secondary chain is greatly reduced, especially in sandy soils. Increasing tractor gear (increasing ground speed 30 per cent with each gear), while holding primary chain speed constant results in much more soil loading onto the primary chain, with less falling through. For each shift up in gear, soil on the secondary chain is doubled. Tuber flow is unaffected by changes in the primary chain speed because it is determined by yield and ground speed. A primary chain speed increase will then remove more soil without increased damage.

The removal of soil from the primary chain is facilitated by the agitation of that chain as it runs over elliptically-shaped sprocket wheels. This agitation is normally in the vertical plane and has been identified as a serious source of damage when the soil cushion is inadequate. In sandy soils, which sieve rapidly, this cushion is soon lost and damage occurs as tubers bounce along the bare rods or chain. In the presence of stones, the problem is worsened.

Potato bruising on secondary, rear cross and elevator chains is reduced when they are loaded to capacity with tubers because tubers are an effective cushion.

Tubers jam into front of primary chain

Primary Chain

Tubers ride onto primary with less impact

Figure 14. Blade positioning for reduced tuber damage.

Optimum loading of these chains is achieved again by selecting the appropriate chain-speed/ground-speed ratio. Once the primary-chain/ground-speed ratio is set, tuber loading on subsequent chains can be modified by changing tractor gear. Shifting up tractor gear to increase tuber load on these chains is more effective in reducing damage than carrying heavy soil loads on the primary chain.

The drop to the side elevator is one of the most serious injury points on the harvester, increasing the damage by 6 per cent or more (figure 15).

The final point of tuber injury during harvesting is the drop into the truck. Automatic height controls for the conveyor are available. A sensor mounted on the end of the conveyor keeps the drop height between 4 and 8 inches (10 to 20 cm). Regardless of the presence of this feature, large stones mixed with the potatoes will present a bruising problem during the loading process.

Damage After Harvest

Following harvest and delivery into a bulk truck, there are numerous places where tubers are damaged further. Damage is cumulative and each handling operation from field to consumer must be monitored for successful damage reduction. Transport systems, grading equipment and handling in and out of storage can be sources of bruising because impacts occur anywhere potatoes are dropped or crushed in transit.

Studies in Washington have shown that damage can more than double between the harvester and the storage pile if extensive soil removal is necessary. British studies attributed severe external damage to transport and unloading at the storage. The causes include lack of cushioning in the trailer, excessive drops during store filling or grading, and careless operation of loading buckets.

Bruises incurred when tubers are dropped are dependent upon several factors. First, the temperature of the potato during handling has a significant effect on blackspot and shatter susceptibility. The height of the drop affects bruising, with greater damage occurring at greater heights. Wood or metal surfaces do not absorb impact energy, while cushioned or padded surfaces can absorb some of the energy and reduce bruising severity.

In summary, careless operating is the cause of much of the post-harvest injury to potatoes. Excessive drop heights, lack of padded surfaces and handling at cool temperatures all increase bruising of tubers during transport from field to purchaser.

Strategies for Reducing Bruising at Harvest

Understanding the cause of tuber damage during harvesting and handling helps to identify practices that should reduce potato bruising. The individual grower or handler must then decide which of these recommendations are practical for a particular situation, and what the trade offs might be.

Figure 15. Damage accumulated through a potato harvester.

Planting Management — The damage-reduction process begins with seedbed preparation. Clods formed by plowing and cultivating wet soil remain intact during the growing season and eventually are harvested along with the tubers, thus increasing bruise. Soils with excessive numbers of stones should be avoided.

Planting and growing management techniques can be used to reduce bruising. Poor stands and erratic spacing increase the number of oversized tubers which bruise more easily than smaller tubers. Small mother seed tubers result in better stands of more uniform plants and more uniformly sized tubers. Application of correct amounts of nitrogen will reduce the number of oversized tubers and thus reduce bruising. Excessive nitrogen also delays tuber sizing, thus increasing the possibility of late-season harvest in cold weather.

Crop Maturity — The decision of when to harvest will be dependent upon the maturity of the potatoes, the soil and tuber temperature, and soil moisture. Tubers should be mature with well-set skins. Skin set is enhanced by vine killing at least 10 days prior to harvest. When soil moisture is high or temperatures are low, skin set may be delayed. However, growers need to weigh the advantages of improving skin set by delaying harvest against the risks of cold weather.

Tuber Temperature — Tuber pulp temperature should be over 7°C, therefore growers need to harvest as early as possible without sacrificing yield. Because of our uncertain weather in the fall this is often impossible to achieve. Early September weather may first be too warm, and suddenly turn very cold. As days become cool, and when area to be harvested is not too large, the harvest period should be shifted to the late afternoon and early evening to take advantage of the warmest soil temperatures. On cold days, harvesting should be limited to short periods during the warmest part of the day. Since soil temperature does not change much on overcast days, harvesting on overcast days preceded by cold nights should be avoided. For many growers, these recommendations are difficult to follow, but a critical management question is raised: How many acres of potatoes can one farm operation grow and expect to harvest without risk of harvesting in cold weather?

Soil Moisture — The timing of the final irrigation is an important management factor. Tubers of moderate turgor are least susceptible to damage. That is, limp and excessively firm tubers bruise more.

The optimum soil moisture level, to ensure correct tuber moisture levels, is 70 to 80 per cent of available capacity. Excessively wet soils will be difficult to separate and very hard, dry soils will form clods more readily.

Harvester Management — Harvester adjustments, which can be realistically made by the grower, have a dramatic effect on occurrence of blackspot and shatter bruise. Although more difficult in practice than theory, the principles of harvester adjustment are:

- to remove as much soil as possible on the primary chain, and
- load the rear cross, elevator and boom chains to capacity so that tubers cushion each other.

The total volume of material entering the harvester is dependent upon blade depth and forward speed. The volume of material (soil + tuber) on the primary and secondary chains is not related to actual chain speed, but to the chain-speed/forward-speed ratio. These ratios need not change for different tuber yields unless the differences are extreme. The volume on the subsequent chains, carrying mainly tubers, is dependent upon yield and these chains must operate faster for increases in yield. Soil type will affect the primary and secondary chain speeds: slower speeds are needed in sandy soils to compensate for the more rapid loss of soil from these chains. Carrying a heavy soil load on the primary chain is less important in reducing damage than having subsequent chains loaded with tubers.

Following is a brief description of the harvester chain speed adjustment process.

Tractor ground speed must be checked accurately. The slowest ground speed and lowest engine rpm that will be used in the wettest part of the field is determined. The secondary chain speed is set at 0.5 m/s (1.6 ft/sec). The rear cross, elevator and boom chains are set at 1/2 the ground speed, but not less than 0.5 m/s (1.6 ft/sec) to assure that tubers are adequately transferred to the next chain. The primary chain speed is set at 1.0 - 1.2 times ground speed for sandy soil and 1.3 - 1.5 times ground speed for heavier soils.

After setting the chain speeds, the harvester is run through a typical part of the field. The chain loading must be closely observed to see that rear cross, elevator and boom chains are at their capacity without tuber roll back or drop-off. If loads are inadequate, the tractor may be shifted up one gear. If

too much soil is entering the truck, then the primary chain speed must be increased as necessary (up to 30 per cent). The investment of time in harvester adjustment can have dramatic pay-back.

High-energy impacts into the truck should be avoided by using automatic boom height control or by padding the truck bed.

Handling

Handling during transport, grading and transfer into and out of storage should follow the principles established for minimizing bruise. Temperature during handling, as always, should be considered. Recommendations for optimum temperature vary, but should be at least 10°C. The number of falls within a handling system should be minimized and drop heights should be limited to 10 inches (25 cm) or less. Where this is not possible, the surface receiving the falling tubers should be padded with plastic or rubber foam material. The consequences of long drops, as when filling stores or trucks, can be reduced by use of automatic height-control devices or downward-travelling conveyors, decelerating channels, and cascade-type delivery chutes. Slow speeds on conveyors are desirable. To achieve higher transport rates, tuber load could be increased. All conveyors and elevators should have careful and skilled supervision.

Despite the many avenues available to growers and handlers in the pursuit of bruise reduction, the effort put forth must be based on financial incentive. Growers without contracts seem to give the problem much less consideration than contract growers, when quality incentives are written into contracts. Bruise-free incentive clauses for both fresh-market and processing potatoes would help reduce bruise damage. Without incentive clauses growers who strive to reduce damage are penalized.

A bruise reduction program should include good field management from planting to harvest, improvement and/or adjustment of harvesting and handling equipment, education of all operators during digging, hauling and piling, and a system of monitoring bruising throughout the harvesting-to-piling process. The decision must be made as to whether the costs of the bruise-reduction practices are justified given the additional return from the contract.

Once the industry is motivated to the practice of bruise reduction, there remains only the implementation of appropriate educational programs. Education of personnel is a crucial consideration in potato bruise reduction. Operator error is cited as the cause of mechanical injury as often as a design flaw or a failure of the equipment.

SOIL MANAGEMENT, FERTILITY AND IRRIGATION

Soil Management

Texture, drainage, salinity, pH, organic matter content, erodibility, fertility and the presence of stones are important aspects of soil quality to consider when producing potatoes.

Soil Texture and Drainage

Soil texture is defined by the proportion of clay, silt and sand particles. Clay particles are very small, silt particles medium sized, and sand particles the largest.

Soil tests identify five texture classes for mineral soils:

1. very coarse (sand, loamy sand)
2. coarse (sandy loam)
3. medium (loam, clay loam, sandy clay loam and sandy clay)
4. fine (silt loam, silty clay loam)
5. very fine (clay, heavy clay)

A sixth group, organic soils, have no 'texture' since they contain very little or no mineral particles. Organic soils are not usually used for potato production in Alberta, but can be productive soils and interested producers should contact Alberta Agriculture for more information. Well-drained, coarse textured soils such as loamy sands, sandy loams and loams are the best soils for potato production. The good drainage properties of these soils reduce the possibility of disease and reduce the risk of wet soils that delay harvest.

A soil that contains a large amount of clay (a fine textured soil) becomes sticky when wet and lumpy when dry. If the soil is dry at harvest, it is difficult to separate the soil lumps from the potatoes. Tubers harvested from a clay soil will also require considerable washing to remove soil particles.

Soil Salinity

Soil salinity, often incorrectly referred to as alkalinity, is a problem in many parts of Alberta. Saline soils are often formed in areas where there is an excess of water which rises to the surface and evaporates, leaving salts at the soil surface. Saline soils often develop near irrigation canals and may also be caused by the use of irrigation water that has a high salt content. These soils crust easily and are difficult

to till if they are too wet or dry. Saline soils may form lumps making harvesting of potatoes difficult.

Soil salinity is measured by passing an electrical current through a soil paste. The higher the salt the more current that passes. This electrical conductivity (EC) is measured as deciSiemens/m or millimhos/cm and normally ranges from less than 1 (salt free) to 10 or more on very saline soils. A reading of less than 4 is required for potatoes.

Plants growing in saline soil may suffer from nutrient imbalances or from a lack of water because they are unable to withdraw water from the soil. In these areas it is preferable to grow crops such as barley, some forages or sugarbeets which have some salt tolerance. On moderately saline soils growth of potatoes will be reduced and leaves may be darker and have burned edges. In severely saline areas potatoes will not grow, and the area will be white or contain salt tolerant weeds such as kochia or wild barley.

Saline areas can be improved by subsurface drainage. For assistance with drainage design or evaluation of salinity, growers should consult with an Alberta Agriculture irrigation specialist.

Soil pH

Most Alberta soils have a pH in the range of 5 to 8, which is suitable for potato production. Some acid soils in central or northern Alberta may have surface or subsurface layers that are below pH 5. Surface layers can be improved by liming; however, if the soil at a depth of 6 to 24 inches (15 to 60 cm) is acidic, it is preferable to grow an acid tolerant crop such as timothy. High pH, or alkaline soils, occur when lime layers are near the surface in eroded or saline soils and may have reduced availability of phosphorus and other nutrients. Potato scab is more prevalent on soils with a pH above 5.2 and appears to worsen on more alkaline soils.

Soil Organic Matter

Soil organic matter consists of plant tissues and animal wastes in various stages of decomposition. It is required to sustain the long-term productivity of soil. First, it behaves as a revolving nutrient bank account. Second, it acts as an agent to improve soil

structure, maintain tilth and minimize erosion. Organic matter does not add any “new” plant nutrients but releases food in a form available to plants through the process of decomposition. To maintain organic matter, the rate of addition of crop residues and manure must equal the rate of decomposition. Continuous production of row crops such as potatoes or sugar beets usually results in a rapid decline of soil organic matter because bare soil between rows is similar to summerfallow and the total amount of residue added is small. Organic matter is maintained with rotations that include perennial forage crops, or by production of cereal crops where residues are not removed and minimum tillage is practised.

Manure is a valuable source of organic matter and plant nutrients. Manure may be applied in the fall at rates of up to 40 tons/ac (100 t/ha) every three to four years. Rates will vary depending on the type, age and method of storage of the manure. Some manures contain excessive amounts of salts and at high application rates could injure plants. Growers are advised to have a manure sample analyzed at a soil laboratory because excessive nitrogen will delay maturity. Manure containing straw from a grain crop that was treated with the herbicide picloram (Tordon) will cause potatoes to grow abnormally.

Soil Erosion

Soil loss by wind erosion can occur in Alberta as a result of the combination of climate, soil and management practices in potato production. First of all, most potato production in Alberta is in the southern part of the province where winds, particularly the chinook winds of winter, often melt snow and leave fields bare and subject to erosion. Secondly, potatoes are usually grown on sand or sandy loam soils, which are subject to erosion by wind. Thirdly, tillage and harvest practices of potato production leave fields bare many months of the year. The fall before potatoes are planted, fields are often plowed to prepare a seedbed for spring potato planting and residues left after potato harvest do not afford protection from wind erosion. The result is that for a single crop of potatoes the soil is usually in an unprotected state during the winter before planting and the winter after harvest.

Soil formation is a natural and ongoing process, but if wind erosion is visible, soil losses are greater than rates of formation. One storm that removes a one-quarter inch (7 mm) layer of soil results in the

loss of 40 tonnes of top soil per acre and will require at least 10 years to be replenished assuming no further erosion occurs.

The Soil Conservation Act passed by the Alberta Legislative Assembly in 1962, and revised in 1980, provides for a fine if a producer fails to comply with an erosion control notice issued by a soil conservation officer. More importantly, measures to stop or prevent soil erosion can be undertaken by a county or other government agency at the expense of the landowner. The land owner is also responsible for problems caused by drifting soil that fill irrigation or road ditches.

There are many options a producer can consider to control or limit wind erosion:

- Delay cultivation of cereal stubble until spring.
- Seed oats, winter wheat, fall rye or barley in August after harvest of early potatoes.
- Aerial seed in August into late potatoes prior to harvest.
- Seed winter wheat at a low rate as a companion crop in an established potato field and allow it to volunteer.
- Plant potatoes in rows at right angles to the prevailing winds to reduce drifting in the spring.
- Cultivate blowing fields with a row of lister shovels spaced about 1 metre apart on the back of a heavy-duty cultivator.
- Apply manure to fields at 30-40 ton/ac (70-90 t/ha) and leave on the surface to reduce drifting.

For assistance with soil erosion problems producers can contact their county agricultural fieldman, district agriculturist or soil conservation specialists from Alberta Agriculture Conservation and Development Branch or from the PFRA.

Fertility and Fertilizers

Soil Testing and Sampling Guide

Soil testing is an important tool for assessing soil fertility and making proper fertilizer recommendations. It is an aid for studying soil changes resulting from cropping practices and for solving some cropping problems.

Soil testing is most effective if proper and representative samples are taken. Contact a district agriculturist, fertilizer dealer or soil testing laboratory for further information. Private labs are located in Lethbridge, Brooks, Crossfield and Edmonton. They are listed in the yellow pages under Soil Testing.

Sampling Procedure — Fields for spring planting should be sampled after October 1 in the year before potatoes are planted. Problem soil areas may be sampled any time. Frozen and water-logged soils should not be sampled because of the difficulty of obtaining a representative sample.

Fields with different crop or management histories should be sampled separately. Fields larger than 60 to 75 acres should be divided into two or more sites for sampling. Avoid unusual areas such as old straw, hay or manure piles, waterways, saline spots, eroded knolls and old fence rows. Select 15 to 20 sampling sites in the field to be tested.

For improved nitrogen evaluation, particularly on irrigated potato soils, separate samples should be taken from 0-6, 6-12, and 12-24 in. depths at each site. Place cores in clean pails or bags then mix cores taken from same depths, crushing lumps in the process.

Drying and Submitting — Remove one to two pounds of each soil sample and air dry to stop nitrate build-up. To air dry, spread a thin layer of soil on a clean piece of paper and dry at room temperature for one to two days. Do not dry the samples with artificial heat.

Sampling Equipment — Representative soil samples can best be obtained by using core sampling tools which are generally available from district extension offices or fertilizer dealers. Information on a depth sampler may be obtained from any soil testing laboratory.

Place a plastic sample bag inside the sample box, then fill the box completely. Tie the bag and close the box and label each box with your name, address, postal code, sample number, and measurement of depth of the sample. Provide complete information for each soil sample on the sheet supplied for samples to be sent to the laboratory of your choice. Any unusual problems should be noted in detail.

Private soil testing laboratories should be consulted prior to submitting samples.

Nutrients Measured in a Soil Test

The plant nutrients that are likely to be lacking in Alberta soils used for potatoes are nitrogen, phosphorus, and occasionally potassium. Sulphur is a macro-nutrient that is required in moderate amounts by crops. It is not deficient in irrigated areas but may be deficient in black soils in central Alberta. With the exception of nitrogen, few soils are so

deficient in one or more of these nutrients that obvious symptoms develop on the plants, but unseen deficiencies may result in reduced yield, lower quality or increased disease. Deficiencies of micronutrients have seldom been documented.

Fertilizer requirements will vary from field to field and from year to year; therefore, soil tests should be used as a tool to determine the kind and rate of fertilizer to apply. General recommendations given for crops should only be used as a guide when a soil test is not available.

Nitrogen — The nitrogen test measures available nitrogen (nitrate) in the soil at the time of sampling. To determine nitrogen fertilizer requirements, soil samples should be taken in late fall or early spring because nitrate nitrogen moves readily with soil moisture. On irrigated soils, soil samples should be taken to a depth of at least 2 feet (60 cm). Soils that have recently been manured or broken from a legume or grass-legume mixture will release large amounts of nitrogen during the growing season. This information should be supplied with the soil samples so that nitrogen fertilizer recommendations can be adjusted.

Phosphorus — The level of available phosphorus in a particular field does not change dramatically from year to year unless very high rates of phosphate fertilizer or manure are applied. A soil test for phosphorus can be used as a guide to phosphate fertilizer requirements for two to three years. Periodic measurement of soil phosphorus is required to see if the level of this nutrient is changing over time.

Potassium — Some soils in west-central Alberta and northeastern Alberta are often moderately low in available potassium, but most soils in southern Alberta are high in available potassium. Some sandy soils may be deficient for potatoes which have a very high potassium requirement. A soil test should be used to identify a need for potassium fertilizers. Periodic soil tests will provide an assessment of changes in the potassium level over time.

Sulphur — Some soils in central, northern and western Alberta are deficient in sulphur. The test for sulphur is done in areas where it is known to be deficient and will be done in other areas upon request. Irrigated soils in southern Alberta receive about 18-45 lb/ac (20-50 kg/ha) of sulphur from each 12 inches (30 cm) of irrigation water applied, so they are not deficient in sulphur.

Tissue Testing for Nitrogen

Sampling and analysing potato leaf stems (petioles) is a useful management tool, especially for irrigated potatoes. Growers who have irrigation and plan to apply nitrogen one or more times through the season must take tissue tests to determine the correct amount of nitrogen to add.

Petiole sampling and testing is simple and inexpensive. Nitrate nitrogen is usually the only nutrient tested for. The test costs about \$10 to \$15 per sample. This is a small price to pay when a shortage of nitrogen can mean the loss of yield and an excess will reduced quality and wastes money.

Forty or fifty petioles are needed for each nitrate tissue test. Petiole samples must be taken from representative plants throughout the test area. As shown in figure 16, the leaves are stripped from the petioles and discarded. The petioles are stored in a clean paper bag and sent to the testing laboratory as soon as possible. Growers should contact the lab before taking samples to inform them of the arrival of samples. Some labs provide both sampling and testing services.

The results of the nitrate test will be given in either percent nitrate nitrogen or in parts per million (ppm). Petiole nitrate nitrogen declines throughout the summer and may differ between early and late varieties (figure 17). Generally nitrate nitrogen will be between 15,000 and 20,000 ppm during the early stages of growth and decline as the potatoes mature. By the time the crop is top killed nitrate nitrogen will have declined to about 5,000 to 10,000 ppm.

Role of Major Plant Nutrients

There are basically two types of plant growth. The first is vegetative, which results mainly in an increase in size of plant parts and involves cell growth. Nitrogen plays a major role in this type of growth. The second type, differentiated growth, involves the formation of flowers, fruit and seeds. Phosphorus plays a leading role in this type of development.

Potatoes require 16 essential elements to function properly. Thirteen of these elements must be taken up from the soil. The other three: carbon, hydrogen, and oxygen, come from air and water. Some elements are taken up by plants in relatively large quantities (macronutrients); and others in very small amounts (micronutrients). The specific roles of plant

The 4th or 5th petiole from the top of the plant is used for tissue analysis of nitrate nitrogen.

Figure 16. Petiole sampling procedure for potatoes.

nutrients are complex and not all are well understood. Some of their basic functions and effects on plant growth may be helpful when observing crops.

Nitrogen — A deficiency of nitrogen can cause small leaves and stems, pale yellowish green color, reduced tuber size and yield and reduced protein content. The lower leaves may be affected first, but other leaves follow. Yellowing progresses to drying up and shedding of leaves. Excess nitrogen results in succulent, weak stems and delayed maturity.

Phosphorus — This nutrient stimulates root formation and early plant growth. It also promotes seed and fruit formation and hastens maturity. A deficiency of phosphorus may result in smaller than normal plants or stunted growth. Purplish discoloration of mature leaves may occur on some crops.

Potassium — Unlike nitrogen and phosphorus, which make up part of the plant structure, potassium plays a regulatory role. But like the other two, it is also required in relatively large amounts. Potassium affects the appearance and disease tolerance of potatoes. Scorching or firing along the leaf margins of older leaves is the most common symptom of potassium deficiency.

Sulphur — New leaves of deficient plants are pale-yellow and older leaves are green.

Micronutrients

All macronutrients and micronutrients are required for optimum crop production. Micronutrients are required in small quantities for plant growth but they

are not less important to plants than other nutrients. Plant growth and development may be retarded if any one of these elements is lacking in the soil or if one nutrient is not adequately balanced with other nutrients.

There are seven micronutrients required by potatoes. The types and amounts required are:

Boron	0.03 kg/ac	Manganese	0.06 kg/ac
Chlorine	11.00 kg/ac	Molybdenum	—
Copper	0.03 kg/ac	Zinc	0.04 kg/ac
Iron	0.40 kg/ac		

Soil and tissue tests aid in determining whether or not a particular nutrient is responsible for poor production and provide the basis for deciding the type and amount of fertilizer needed to correct a nutrient shortage. One of the more serious limitations of the soil test has been the lack of suitable tests for micronutrient availability. Only in the last few years have soil tests been accepted for use in predicting the availability of copper, iron, manganese and zinc. Soil tests are meaningful only when they can be related to field conditions. The relationships can be established through correlating soil tests with fertilizer trials in the field on soils with both deficient and adequate nutrient levels. The results are used by soil laboratories as a basis for making fertilizer recommendations. At present, soil tests for micronutrients on the high pH soils of southern Alberta do not accurately predict the available micronutrient levels in soil. If this is true, then only plant tissue testing would be acceptable in identifying micronutrient deficiencies.

Nitrate N (thousand ppm $\text{NO}_3\text{-N}$)

Figure 17. Target range for petiole nitrate nitrogen in irrigated potatoes in southern Alberta.

Plant tissue tests also aid in determining if a particular nutrient is responsible for poor crop growth; however, it is difficult to predict from a tissue test the amounts of nutrients needed to correct a shortage. As with soil analysis, tests involving plant tissue must be calibrated with field fertilizer trials, which is a complex process. The reason for the difficulties is that measured nutrient concentration, which is the basis of the tests, varies considerably with the stage of plant development and the portion of the plant sampled.

Soil-applied micronutrients may be broadcast and incorporated or banded into the soil, applied individually or mixed with other fertilizers. There is conflicting information on which types of micronutrient fertilizers are most effective and whether soil or foliar applications of micronutrients are best.

Micronutrient fertilizer trials have been conducted on potato varieties at a number of locations in Alberta.

To date, no significant response has been obtained even when soil tests indicated low levels of micronutrients. Therefore, applying micronutrient fertilizers based solely on a soil test is not recommended. Recommendations should be based on soil tests, tissue tests and close visual examination. If micronutrient fertilizers are used, initial applications should be put on in test strips in a field to verify if a yield response has occurred. Because some crops are injured by very low levels of micronutrients, care must be taken not to over apply these expensive nutrients.

Commercial Fertilizer Recommendations

Pricing Fertilizers — The Fertilizer Act requires that fertilizers be labelled according to their guaranteed analysis in terms of percent by weight of nitrogen (N), phosphate (P_2O_5) and potash (K_2O). For example, 100 lb of 12-51-0 contains 12 lb of nitrogen (N), 51 lb of phosphate (P_2O_5), and no

Table 6. Soil test ratings and general fertilizer recommendations for nitrogen, phosphorus, and potassium for irrigated potatoes in Alberta.

Soil Test Rating		Nitrogen lb/acre N		Nitrogen recommendation N (lb/acre)	Phosphorus lb/acre P 0-6 in.	Phosphate recommendation ^{1,2} P_2O_5 (lb/acre)	Potassium lb/acre K 0-6 in.	Potash recommendation ¹ K_2O (lb/acre)
		0-6 in.	0-24 in.					
Deficient	Low -	0-7	0-17	170	0-10	90	0-50	100
	Low	8-13	18-32	160	11-20	80	51-100	80
	Low +	14-20	33-50	150	21-25	70	101-150	60
Moderately Deficient	Medium -	21-30	51-70	135	26-30	60	151-200	50
	Medium	31-40	71-90	120	31-40	50	201-250	40
	Medium +	41-50	91-115	100	41-50	40	251-300	30
Marginal to Adequate	High -	51-60	116-140	80	51-70	30	301-400	0
	High	61-75	141-170	50	71-90	20	401-600	0
	High +	75+	170+	20	91+	10	601+	0

Source: Alberta Agricultural Soil and Feed Testing Laboratory.

Table 7. Soil test ratings and general fertilizer recommendations for nitrogen, phosphorus, and potassium for irrigated potatoes in Alberta.

Soil Test Rating		Nitrogen kg/ha N		Nitrogen recommendation N (kg/ha)	Phosphorus lb/ha P 0-15 cm	Phosphate recommendation ^{1,2} P_2O_5 (kg/ha)	Potassium kg/ha K 0-15 cm	Potash recommendation ¹ K_2O (kg/ha)
		0-15 cm	0-60 cm					
Deficient	Low -	0-8	0-20	190	0-10	100	0-55	110
	Low	9-15	21-35	180	11-20	90	56-110	90
	Low +	16-25	36-55	170	21-30	80	111-170	70
Moderately Deficient	Medium -	26-35	56-80	150	31-35	70	170-225	55
	Medium	36-45	81-100	130	36-45	65	226-280	45
	Medium +	46-55	101-130	110	46-55	45	281-340	35
Marginal to Adequate	High -	56-70	131-160	90	56-80	30	341-450	0
	High	71-85	161-190	60	81-100	20	451-670	0
	High +	86+	191+	20	100+	10	671+	0

Source: Alberta Agricultural Soil and Feed Testing Laboratory.

¹ Recommendations listed are general. Specific recommendations will vary depending on location in the province, soil zone, soil texture, soil pH, field cropping history and free lime in the soil.

² Recommendations for phosphate are for row or band application. Rates for broadcast applications should be double that in the table.

potash (K_2O). Fertilizer should be purchased on the basis of the price per unit weight of nutrient not on the price of fertilizer material.

Fertilizer Recommendations — Tables 6 and 7 show general fertilizer recommendations for increasing the three major nutrients as indicated by soil tests for potatoes grown under irrigation. These rates are based only on the level of nutrients in the soil. Adjustment to these recommendations would need to be made depending on the other factors such as legume plowdown, manure application, the amount of irrigation and the planned harvest date.

Nitrogen Fertilizer — Nitrogen moves readily in moist soil and therefore need not be applied near the seed pieces to be effectively used. However, surface application or shallow incorporation can result in reduced uptake if the seedbed remains dry during the early growing season. Nitrogen applied as anhydrous ammonia in a band at a depth of 4-6 inches (10-15 cm) or banded at planting may be more effective when the surface soil remains dry for an extended period during the early growing season.

Nitrogen fertilizers can be applied in either late fall or spring with similar results. Nitrogen has a greater opportunity to move deeper into the root zone if it is fall applied, and therefore may be more effective than when broadcast in spring under dry conditions. Fall application of nitrogen should be delayed until the soil temperature has fallen to $10^{\circ}C$ or less.

Following are common nitrogen sources available with comments on their uses and activity.

Ammonium nitrate (34-0-0) does not volatilize as much as urea when surface applied without incorporation; however, it is subject to leaching losses on sandy soils. It is used with ammonium phosphate to make 23-23-0 and 26-13-0.

Ammonium sulphate (21-0-0-24S) contains 24 per cent sulphur and is mixed with ammonium phosphate to make 16-20-0. It is more acidifying than other nitrogen fertilizers and should not be used continuously on acid soils.

Urea (46-0-0) volatilizes when not incorporated into the soil and significant losses can occur if applied under warm dry conditions on sandy soils, and on soils with a pH of 7.5 or higher. It is used with ammonium phosphate to form 27-27-0.

Anhydrous ammonia (82-0-0) is injected at a depth of 4-6 inches (10-15 cm) with a narrow shank applicator. The soil must be worked sufficiently so

that it closes behind the shank and prevents escape of ammonia gas. It is suitable for fall or spring application. Anhydrous ammonia is a pressurized gas and should be handled with caution. For further information see your fertilizer dealer.

Urea-ammonium sulphate is available in a dry form (34-0-0-11S) or as a solution (20-0-0-5S) and may be used when sulphur is required.

Urea-ammonium nitrate solutions (28-0-0 and 32-0-0) can be uniformly applied and are easy to handle; however, losses may occur if it is sprayed on a heavy trash cover and not incorporated.

Phosphate Fertilizer — Phosphate fertilizer does not move readily in soil, so it must be placed near the seedling roots to be most effective. Phosphate is most readily available in several forms of monoammonium phosphate (11-48-0, 12-51-0, 11-54-0 and 11-55-0).

Diammonium phosphate (18-46-0) can also be used if a higher ratio of nitrogen is required. There is evidence indicating that diammonium phosphate is slightly less efficient than monoammonium phosphate on soils with high levels of calcium.

Potassium Fertilizer — Potassium will move in the soil more readily than phosphorus, but for annual crops, potassium fertilizers are more efficient when drilled near seed pieces. Broadcast applications can be used at about twice the rate used for drill-in applications and can be made in either fall or spring.

Muriate of potash (0-0-60 or 0-0-62) is the most commonly available potassium fertilizer. It is used directly as a broadcast application or mixed with phosphate and nitrogen fertilizers to make fertilizer grades such as 10-30-10, 8-24-24, 13-13-13, and others. The cost of potash in some of the blends tends to be much higher than in 0-0-60 or 0-0-62 forms.

Sulphur Fertilizer — Sulphur in the sulphate form moves readily in moist soils. Soluble sulphate fertilizers provide a readily available sulphur source in either broadcast or drill-in applications. Irrigation water in southern Alberta supplies sulphur.

Sulphur fertilizers include ammonium sulphate (21-0-0-24S) and urea-ammonium sulphate available as 34-0-0-11S or in solution as 20-0-0-5S. The urea forms are less acidic and therefore recommended for use on acid soils that are sulphur deficient. Sulphur can also be applied as elemental sulphur (90%) or as gypsum (18%).

Fertilizer Placement and Application

The following are brief descriptions of methods commonly used to apply fertilizer to potatoes.

Broadcasting — Broadcasting is a relatively inexpensive method of applying fertilizers; however, it is not the most efficient method when rows are spaced far apart and plant roots do not meet between rows.

Top dressing — Top dressing refers to broadcasting fertilizer on a field when a crop is growing. The fertilizer is normally not incorporated but irrigation may be used after fertilization to move nitrogen into the soil. Top dressing is normally restricted to ammonium nitrate because other forms of nitrogen are likely to cause burning of the leaves. Top dressing, banding and fertigation are primarily used to apply nitrogen to maturing crops when nitrogen levels may be low, yet the crop still has a high nitrogen demand.

Drilling — Drilling is the application of fertilizer near the seed in the same drill row or furrow. Applicators should be set so that as little fertilizer as possible is placed directly with the seed pieces. Some mixing of seed, fertilizer and soil should occur. Phosphorous fertilizers are commonly applied to large-seeded vegetable crops by drilling.

Banding — Banding is the application of fertilizer in a continuous band to the side and below the seed at the time of planting. Banding is an efficient method of applying phosphorous fertilizer. Side-dressing refers to banding fertilizers in the soil to the side of the crop row after plants are established. Care should be taken not to damage crop roots.

Fertigation and Foliar Feeding

Fertigation — Fertigation is a method of applying liquid fertilizers through an irrigation system. The most commonly used fertilizer for fertigation is nitrogen as 28-0-0. The advantages and disadvantages of using fertigation as a method of applying nitrogen are listed below.

Advantages

- Easy to apply,
- Uniform application,
- In-season nutrient deficiencies can be corrected,
- Efficiency of nitrogen use on coarse-textured soils is improved,
- Nitrogen can be applied as the crop needs it,
- It may aid in preventing NO_3N leaching.

Disadvantages

- The form of nitrogen fertilizer used is more expensive,
- Foliar testing to monitor nutrient levels is required,
- Efficiency of nitrogen fertilizer use on medium textured soils is unchanged,
- Excess nitrogen applied after the commencement of flowering of late potatoes may delay maturity, reduce dry matter content and increase the occurrence of hollow heart,
- Significant volatilization of urea in solution fertilizer may occur, resulting in significant N losses.

Phosphorus applied through fertigation to cereals has not been shown to be any more advantageous than granular phosphate banded in the spring. Because phosphorus does not move in the soil and is required early in the growing season, it is not considered compatible with fertigation or foliar applications.

Foliar Feeding — Foliar feeding is a technique of applying soluble fertilizers in a spray form. Potatoes will take up nitrogen through the leaves and foliar feeding with a ground sprayer can be used to supply nitrogen to deficient plants not grown under sprinkler irrigation. There are no data available to suggest it is economically superior to more conventional techniques.

Manure

Animal wastes add both organic matter and nutrients to the soil. However, when manure has to be hauled long distances, the benefits are outweighed by trucking costs because of the high application rates that are needed. The amount of nutrients in manure will depend on several factors: the type of animal, the type of feed, the feeding method, age of the manure and method of storage. Fresh manure is usually high in nitrogen, but nitrogen can volatilize into the air and be leached out by rain. The levels of nitrogen in old manure may be low. As a rough guide, a grower could expect that a 10-15 tonne application of pig, beef or dairy manure would add about 50 to 150 pounds each of nitrogen, phosphorus and potassium. When using manures in combination with commercial fertilizers, reduce the amounts of fertilizer by taking into account the nutrients added by the manure. Because fresh manure contains seeds, caution is advised when buying and spreading manure. Manure that is known to have weed seeds in it is usually suitable for spreading after it has been piled for one or two years. Bedding straw may contain residues of

Tordon, which can cause abnormal potato growth. (See page 37).

The Effects of Nutrients on Quality

Nitrogen — Excessive levels of nitrogen applied initially or during the growing season will delay the maturity of potatoes. One set of experiments conducted over a six-year period by Alberta Agriculture included a treatment where 55 lb/ac (50 kg/ha) of extra nitrogen was applied to potatoes at the end of June or the first of July. The potatoes had also received about 100 lb (90 kg/ha) of nitrogen at seeding. The effect of the additional nitrogen was:

- increased marketable yield by 10-16 per cent,
- increased yield of extra large tubers by 120-200 per cent,
- reduced the yield of small and Canada #1 small tubers by 10 per cent,
- reduced specific gravity,
- reduced the dry matter content of tubers by 0.5 per cent on Russet Burbank and Norchip, with little difference on Norlands,
- increased the prevalence of small brown spots and hollow heart in the tubers.

Other effects of the mid-season application of nitrogen were to increase the tuber protein content and reduce the sugar content. It has been reported that extra nitrogen applied at seeding time increased yield because more tubers were formed (Agriculture Canada, Lethbridge).

Phosphorus — Phosphorous fertilizer has not been found to influence the quality of tubers; however, reports from Europe indicate the addition of high rates of phosphate fertilizer reduced bruising of tubers.

Potassium — Potatoes have a higher requirement for potassium than most other crops. Experiments in the United States have indicated that potassium applied to soils, that were not regarded as deficient, reduced disease levels in potatoes and thus increased yield. Yield responses to potassium fertilizers have only occasionally been reported in Alberta. Experiments from Europe indicate that the addition of potassium fertilizers reduced the number of bruised tubers and tubers that were subject to inner blackening. Potassium slightly decreases the dry matter content of tubers. An average of 46 experiments from Europe reported that an additional 220 lb/ac K₂O (200 kg/ha) reduced the dry matter content of tubers by 0.5 per cent.

Irrigation

About three-quarters of Alberta's total potato area is grown in southern Alberta and is irrigated. Some potato farms in central and northern Alberta also have irrigation. Adequate rain or irrigation is necessary to produce high yields of top-quality potatoes. Increased use of irrigation and improvements in irrigation equipment and management have been the major reasons why average yields of potatoes in Alberta have increased from about 4.5 t/ac (11 t/ha) in 1953 to 1958 to an average of about 12 t/ac in 1985 to 1989.

Irrigation Management and Timing

Potatoes tend to be more sensitive to soil moisture stress than most crops and therefore require frequent light applications of water, especially after tuber formation. When optimum soil moisture conditions are continuous, as compared to intermittent, the average size of the potato tubers is reduced, but the number and yield of potato tubers produced is increased and the uniformity of shape and size of the tubers improved. Excessive irrigation may result in disease and possible creation of water tables that lead to salinity problems.

With optimum soil moisture conditions and soil fertility levels throughout the growing season, the yield of main crop potatoes can range well over 20 t/ac (50 t/ha). Total water consumption for the season is about 20 inches (500 mm).

Potato roots go down to about 30 inches (75 cm), which is shallower than for cereals or alfalfa. The availability of soil moisture for use by potatoes root zone varies with soil texture:

Loamy sand- fine sandy loam	3-5 in. (75-140 mm)
Loam	6-8 in. (150-200 mm)
Clay loam- silty clay loam	7-9 in. (180-230 mm)

The allowable soil moisture depletion level refers to the percentage or amount of soil moisture that can be extracted from the root zone without causing a significant yield reduction of quality tubers. The recommended maximum allowable depletion level is 30 per cent for seed potatoes and 35 per cent for commercial potatoes. This means, that after field capacity of the field has been reached, only 30 to 35 per cent of the available water in the root zone can be used by the crop before a measurable reduction in yield or quality occurs, unless more moisture is received.

The timing of irrigation and the amount of water to be applied to a potato crop depends on its rooting depth, the water holding capacity of the soil and the level of water depletion the potato crop can tolerate. For example, a loam soil holds 5 inches (160 mm) of water in the entire potato root zone. Because the allowable depletion level for commercial potatoes is 35 per cent, then 1 3/4 inches (45 mm) of water is available for plant use.

Daily moisture use varies with the stage of potato development and weather (figure 18). During the early stages of development consumptive use is low, but as the crop matures its average water use increases to about 1/4 inch (6 mm)/day. If 1 3/4 inches (45 mm) of water is available for crop use, then that much water will be required every seven or eight days during the peak period of consumptive use, assuming the weather is warm and no rainfall occurs. Coarse textured soils have about 1 to 1 1/2 inches (25-40 mm) of water available in the root zone which can be safely depleted between irrigations. Fine textured soils have about 2-2 1/2 inches (50 - 65 mm) of available moisture in the root zone. As texture changes so does the amount of water that should be added with each irrigation and the time interval between irrigations.

Figure 18. Average daily evapotranspiration (ET) from potatoes during the growing season.

The simplest way to determine soil moisture content is to use the “feel method”, which is presented in table 8. By squeezing a handful of soil firmly, the amount of moisture present can be determined by the feel and appearance. The moisture content of each quarter of the root zone should be determined in order to calculate the moisture present in the entire root zone.

Table 8. Irrigation of potatoes.

		Feel or Appearance of Soils		
		Sandy Loam	Loam	Clay Loam
During tuber initiation moisture should not fall below 70% of available capacity → → After tuber set, maximum depletion should not be below 65% of available capacity	At field capacity 100%	Upon squeezing, no free water appears on soil, but wet outline of ball is left on hand.	Same as sandy loam.	Same as sandy loam.
	75% to field capacity	Forms a weak ball, breaks easily, will not slide.	Forms a ball and is very pliable; sticks readily if relatively high in clay.	Easily ribbons out between fingers, has a slick feeling.
	50 to 75%	Tends to ball under pressure but seldom will hold together.	Forms a ball; somewhat plastic; will sometimes stick slightly with pressure.	Forms a ball, will rib on out between thumb and forefinger.
	25 to 50%	Still appears to be dry, will not form a ball with pressure.*	Somewhat crumbly, but will hold together from pressure.	Somewhat pliable, will ball under pressure.*
	0 to 25%	Dry, loose, single-grained flows through fingers.	Powdery, dry, sometimes slightly crusted but easily breaks down into powdery condition.	Hard, baked, cracked. Sometimes has loose crumbs on surface.

* Ball is formed by squeezing a handful of soil firmly.

The most critical period to avoid moisture stress for potatoes is from the time the plants are about 8 inches (20 cm) high to the beginning of the vine ripening. Shortage of irrigation water during this period will reduce yield and tuber quality.

The Effects of Irrigation on Quality

Table and Processing Potatoes — Frequent irrigation to avoid periods of moisture stress will influence the yield, grade, number, size and the quality of the tubers. The effect of maintaining the available moisture above 60 per cent as compared with maintaining it above 40 per cent was measured on three varieties of potatoes for six years by Alberta Agriculture. The effects of more frequent irrigations to maintain available water above 60 per cent were:

- increased marketable yield by 7 per cent, 5 per cent and zero per cent on Russet Burbank, Norland and Norchip potatoes, respectively
- increased yield of small and Canada #1 small tubers by 23 per cent, 40 per cent and 10 per cent on Russet Burbank, Norland and Norchip, respectively
- increased dry matter of Russet Burbank, a late maturing variety, with little difference on Norland and Norchip

- increased presence of small, brown spots in the centre of the tubers of Russet Burbank potatoes
- reduced protein content of tubers
- reduced number of irregular shaped culls and Canada #2 tubers.

Seed Potatoes — Frequent irrigation and avoiding moisture stress at the time of tuber initiation increases the number of tubers and reduces the average size of the tubers. This is important for a seed producer who wishes to produce small whole tubers.

Irrigation Methods

There are a number of irrigation methods that can be used for potatoes, however wheelmove and pivot systems are the most common. Whichever system is used, it must be capable of supplying frequent light amounts of water every few days.

Assistance with design of an irrigation system, drainage of problem areas and with irrigation management is available from the Irrigation Branch of Alberta Agriculture. Offices are located in Airdrie, Brooks, Bow Island, Lethbridge, Medicine Hat, Strathmore, Taber and Vauxhall. The Airdrie office serves central and northern Alberta.

PEST MANAGEMENT

Potato growers and farmers in general are becoming increasingly familiar with the term pest management as opposed to pest control. All potato growers know that weeds, insects and disease are not controlled in the sense that they are eliminated, and growers can grow potatoes with manageable amounts of various pests and still produce profitable yields. Only one group of potato growers can tolerate a zero level of pests and those are the Elite seed growers. Seed regulations require that there are no visible diseases in the Elite classes.

Cultural practices are an important part of pest management. Registered pesticides obviously have a role in controlling pests like weeds, Colorado potato beetle and seed piece decay; however, cultural and general management practices play an equally important role. Consider how the following can influence the incidence of weeds, insects and diseases: crop rotation, soil texture and drainage, certified seed, sanitation, storage ventilation and temperature control, cut seed-piece suberization, cultivation and hilling, fertilizer and irrigation management, vine killing and cultivar selection. All of these play a role in pest management and are used by growers along with chemical pesticides to manage pest levels within acceptable limits.

Notice — Specific recommendations for pest control products are not included in this manual. The annual book, *Crop Protection with Chemicals*, Agdex 606-1, lists most of the pest control products registered for potatoes. This book is revised annually and is available each spring from all Alberta Agriculture district offices.

Insect Management

Chewing insects cause serious yield and quality losses in potatoes by feeding on and damaging leaves, stems or tubers. Sucking insects such as aphids and leafhoppers cause indirect losses by transmitting viral diseases.

Effective insect control depends on a combination of cultural and chemical practices. Insecticides can reduce wireworm populations, however growers can expect reduced potato quality if they plant potatoes in new grass/pasture breaking. Good weed control in and around potato fields removes alternative food sources for many of the pest insects, particularly

early in the spring before the crops have emerged from the ground. Despite the effectiveness of cultural practices in reducing insect populations, insecticides will be used in most potato insect control programs for the foreseeable future.

Some insects such as the Colorado potato beetle readily develop resistance to a variety of insecticides. Reliance on only one or two of the recommended chemicals should be avoided. Alternating the use of several insecticides, particularly those of different chemical groups, such as carbamates and organophosphates, will reduce the development of resistance and increase the effectiveness of the sprays applied. Insect control products are listed in table 9. Application of lower dosages than recommended may allow the target insect to develop resistance more quickly; higher doses may damage the crop or make it unfit for consumption.

Aphids

Aphid control is not normally required in fresh market and processing potatoes. However, aphids transmit viruses from plant to plant and their identification and control is extremely important in potato seed fields. Aphids are small, soft-bodied insects that appear any time after mid-June. They reproduce rapidly and are capable of developing huge populations in a short time. Although aphids are normally wingless, winged forms may appear when environmental conditions deteriorate. The winged aphids fly to other plants and frequently transfer viruses to uninfected plants.

Potato Aphids (PA) — The potato aphid is the largest and most numerous of the two aphid species found in potato fields. They feed on over 30 different plant species, including members of the nightshade family of which potatoes are a member. They are usually green in color, however individuals may be red, brown, yellow, orange, or even purple. These aphids are usually found on the underside of potato leaves and they transfer the viruses causing mild mosaic and rugose mosaic. They are a poor vector of leaf roll virus; however, since the green peach aphid, discussed below, is a very effective vector of leaf roll, growers should be able to distinguish between the two or control all aphid populations. In addition to virus spread, a toxin produced by the insects is injected during the feeding process and may cause

mottling, curling and premature death of the leaflets. Large quantities of honey dew excreted by the insects may cause the tops of the plants to become sticky if populations are extremely large.

Potato aphids overwinter in the egg stage on rose bushes. Wingless females hatch from these and produce living young females, some of which develop wings and fly to new hosts. There are several generations of winged and wingless forms during the summer. Winged males and females fly to rose bushes during late summer and early fall where the females give birth to wingless females that mate with the winged males and produce the winter eggs (figure 19).

Green Peach Aphids (GPA) — Green peach aphids are highly efficient vectors of the potato leaf roll virus. Like potato aphids, they inject a toxin

during the feeding process, which may cause leaf deformities, streaking and even leaflet death.

The GPA does not overwinter outdoors in Alberta and populations are maintained from year-to-year by overwintering in greenhouses or other heated structures such as root cellars. In the spring winged females fly to weeds and are carried outside with bedding plants. They multiply rapidly for several weeks and by July they move to potatoes and fly from field to field, transmitting the viruses to healthy plants. Winged females usually appear in the fall and some of these are successful in becoming established in commercial greenhouses or root cellars (figure 20).

Monitoring Aphid Numbers

Seed potato growers must control problem populations of aphids to maintain seed quality. The amount of potato leaf roll virus (PLRV) that spreads

Table 9. Summary of insecticides used on potatoes.

Product name	Aphids	Insects Controlled			Leafhopper	Wireworm
		Colorado potato beetle	Tuber flea beetle	Potato flea beetle		
Ambush		X		X	X	
APM	X	X			X	
Belmark	X	X		X	X	
Cygon	X				X	
Cythion	X	X			X	
Cymbush/Ripcord 400		X	X	X	X	
Decis		X		X	X	
Dyfonate					X	
Endosulfan	X	X	X	X	X	
Furadan	X	X		X	X	
Guthion	X	X			X	
Lagon	X				X	
Malathion	X	X			X	
Marlate	X	X			X	
Monitor	X	X		X	X	
Pirimor	X					
Pounce		X	X	X	X	
Sevin		X		X	X	
Supracide		X		X	X	
Thimet	X	X		X	X	X
Thiodan	X	X	X	X	X	
Thionex	X	X	X	X	X	

Note: Products listed here are reported in either, or both, *Crop Protection with Chemicals*, Agdex 606-1 and the *Western Committee on Crop Pests Report, 1991*. Registrations change and growers must verify current registrations. The grower assumes all responsibility for the correct application of registered products. They must be applied as directed on the product label. No claims about the effectiveness of any products listed here are intended or implied.

in a field will be directly proportional to the level of aphid vectors present in a field. To assist growers with monitoring and recording, two aphid charts are available from:

Alberta Seed Potato Program,
 Alberta Tree Nursery and Horticulture Centre
 R.R. 6, Edmonton, T5B 4K3
 Phone 422-1789.

These charts provide growers with information on when and how often monitoring should be done, and when control procedures should be started.

To determine the potential for leaf roll spread, aphids must be counted using the leaf-count system starting in early July. Fields are divided into four plots, 25 leaves are taken from each of the four plots, and potato aphids and green peach aphids are counted on each compound leaf sampled. Because it is difficult to identify aphids when they are young, it is necessary to use a ten-powered magnifying lens. The large body size and elongated shape of the potato aphid distinguish it from the smaller oval-bodied green peach aphid. However, identification of young aphids can be difficult and growers may wish assistance (See back cover).

Economic Threshold — The number of aphids is totalled and compared with the economic threshold for that field. The economic threshold of a field is the population level of an insect at which the benefits of control exceed the costs of control. The economic threshold for green peach aphids (GPA) is based on the number of aphids per 100 leaves. The level of

potato leaf roll virus in the field, and the nearness to other sources of aphids and PLRV affect the threshold level. Use the following procedure to determine the economic threshold of GPAs for a field. The total points represent the number of GPA per 100 compound leaves, and indicate when control should take place.

Level of PLRV in the field	
None	_____ 10 points
Trace	_____ 5 points
Moderate	_____ 2 points
	_____ points
Distance to other potato fields, greenhouses, nurseries, or market gardens.	
Close	_____ 0 points
Far	_____ 5 points
	_____ points
	Total _____ points

For example, a field with a trace of PLRV (5) and close to other potato fields or greenhouse (0), has an economic threshold of 5. If more than 5 green peach aphids are found on 100 compound leaves then control should take place. The threshold for the potato aphid is 30 times that for GPA. In the above example the GPA threshold is 150 aphids per 100 leaves.

Leafhoppers

The six-spotted leafhopper, found throughout potato-growing areas of Canada, spreads pathogens

Figure 19. Annual cycle of the Potato Aphid.

Figure 20. Annual cycle of the Green Peach Aphid.

causing aster yellows or purple-top wilt disease. The sucking adults feed on infected plants and then spread the disease to healthy potatoes.

Leafhopper eggs overwinter on fall-sown cereals and grasses and hatch in May into tiny black wingless nymphs. These become light yellow after the first molt and grow rapidly to reach maturity in about three weeks. The wedge shaped adults are 3 to 4 mm long, and olive green to dark greenish brown in color. As cereals and grasses mature in early summer, adult six-spotted leafhoppers disperse to other plant species, including potatoes.

Newly developed adults can also migrate in large numbers from the southern United States into the prairie provinces. They lay eggs on cereals, as well as on grasses and early vegetables.

Another species, the potato leafhopper, sometimes occurs in southern Alberta. While feeding, the potato leafhopper injects a toxin into the plant that results in hopperburn, a yellowing and curling of the tips and margins of the leaflets, which ultimately turn brown and brittle. The plants can die early and the yield may be reduced.

Cultural control of these insects consists of keeping the fields and nearby crops as well as headlands and adjoining areas free of weeds to reduce breeding sites. Where leafhopper populations are large, and especially if purple-top wilt has been found in a grower's field or on neighboring farms, control measures must be taken.

Colorado Potato Beetle

The black and yellow-orange striped Colorado potato beetle is known to every potato producer. The adult beetles overwinter in the ground and in spring they emerge to feed on any plants belonging to the nightshade family, moving to potatoes when the shoots first appear.

The orange eggs are laid in bunches of a dozen or more on the undersides of leaves and depending on temperature, hatch in 4-9 days. The hunch-backed red to pink larvae have black heads and a series of prominent black spots on both sides. The voracious larvae rapidly pass through four stages (instars) and are fully grown within two to three weeks. The 10-13 mm long larvae then work their way into the soil, and change to yellowish, motionless pupae. They emerge as adults 5-10 days later. There is only one generation per year.

In addition to the damage caused by feeding, which if uncontrolled can completely strip potato plants within a short time, the Colorado potato beetle is thought to be capable of transmitting spindle tuber and bacterial ring rot.

Potato beetles are apparently unaffected by high concentrations of toxic glycoalkaloids, the naturally occurring bitter compounds in potatoes. Their efficient detoxification system may also play a part in detoxifying insecticides and the beetle can develop resistance to a number of insecticides. The development of insecticide resistance can be reduced by alternately applying pesticides belonging to different chemical families, for example, chlorinated hydrocarbons and organophosphates.

Tuber Flea Beetle

The tuber flea beetle, *Epitrix tuberis*, has been a serious pest of potatoes in the state of Washington and in British Columbia since the 1920s. However, it was not found in Alberta until 1974, when it was discovered in several Edmonton home gardens. Since then it has been found throughout the province in home gardens. As recently as 1991 it had not been found in commercial potato fields.

The adult is a small beetle (2 mm) with a dull black oval body covered with fine hairs and with reddish antennae and legs. The beetle has enlarged hind legs and is able to jump considerable distances, thus the term "flea". Flea beetles may spread bacterial pathogens and the spindle tuber viroid. Damaged tubers may be unmarketable and are readily infected by scab and rhizoctonia.

The adults overwinter in or on the soil in protected places and emerge by June and begin feeding on various species of weeds and later on garden plants.

The adults lay eggs on the soil around the bases of host plants. After hatching, the larvae (small "maggots") develop in the soil, taking between three and four weeks to complete development. The pupal stage lasts for another seven days. There is only one generation per year in northern and central Alberta, but there may be two generations in southern Alberta.

The adults chew "shot holes" into the leaves of potatoes, and a variety of crop plants, including tomato, pepper, eggplant, bean, cabbage, corn, cucumber, lettuce, radish, spinach and various weeds. Larvae feed on the surface of the tubers, and may tunnel to a depth of 6 mm. This results in a

corky brown surface area, which may be mistaken for common scab. Another flea beetle, *Epitrix cucumeris*, is less destructive to the tubers, but it can cause more foliar damage. Two other species of flea beetles, the potato flea beetle and the western flea beetle, are also found in Alberta. They are controlled by the same chemicals that are applied for the tuber flea beetle.

Cultural Control — Commercial potatoes should be planted as far as possible from a previously infested site, and when possible, away from urban areas known to have tuber flea beetles. Volunteer potato plants and weeds should be destroyed, and piles of plant material should be removed.

Wireworms

Several species of wireworms infest potatoes in Alberta. The yellow-brown “worms” are the larvae of slender black beetles known as “click beetles”. The adults do not attack potatoes, however the larvae (“wireworms”) feed on potato seed pieces, reducing yields and even killing the vines. They chew pits and tunnels in tubers and reduce their saleability. The wounds also allow blackleg and rhizoctonia disease organisms to enter.

Adults emerge in the spring from the soil where they wintered. Shortly after mating, the female beetles lay up to 300 eggs in the soil. Depending on environmental conditions, the larvae require between 2-5 years to reach their full size of approximately 2 cm.

A population density of one or more wireworms per square metre can cause serious economic losses to a potato crop. While most fields will not reach this level in Alberta, new fields that have been in sod during the previous year may harbor wireworms, and it is therefore advisable to test for them in such fields. Baiting provides a poor estimate of wireworm density in a field, but it is a quick way of determining if the pest is present. Carrots and two or three tablespoons of coarse ground whole-wheat flour are placed into a scrap of nylon mesh (pantyhose works well) and buried 4 to 6 inches (10-15 cm) into the soil. The tail of the nylon is left out as a marker. Several baits should be buried randomly over the field. Baits do not work in soil that is either excessively wet or too dry.

Growers who detect wireworms should contact the entomologist at the Alberta Special Crops and Horticultural Research Center (see back cover) regarding expected damage if wireworms are

present. Alternate fields should be considered if populations are high.

Columbia Root Knot Nematode

The Columbia root knot nematode, *Meloidogyne chitwoodi*, is not known to be present in Alberta, but has caused severe losses to potato growers in Washington, Oregon, Idaho and in northern California. Millions of dollars are spent each year to control this and related species. The Columbia root knot nematode is able to move only a few metres annually on its own, but it is spread readily through the transport of infested potatoes, in soil clinging to farm implements and in irrigation water.

The potential impact of the Columbia root knot nematode on Canadian agriculture is so serious that areas in which the pest occurs are under federal quarantine, and no plant material from such quarantined areas may be imported into Canada. If the presence of the Columbia root knot nematode is suspected (in potatoes or other crops such as cereals), samples of the suspect plant material should be sent immediately to the nearest diagnostic laboratory (see back cover).

Root knot nematodes seriously affect root growth, yield and quality of potatoes. The above ground symptoms are not readily apparent, but they may consist of various degrees of stunting, lack of vigor, and wilting under moisture stress. Infested roots have knot-like cysts that are readily identified. Potato tubers may be heavily infected without showing external symptoms. In some cultivars, such as Russet Burbank, small raised galls or swellings appear on the tubers above the nematodes, and the internal tissue below the galls is necrotic and brownish. Galls may be solitary or bunched. Adult females are visible just below the surface as glistening white, pearl-shaped bodies surrounded by a brownish layer of tissue.

Weed Control

Competition studies between potatoes and annual weeds indicate that a weed-free period from planting to the time of canopy closure is critical for the prevention of yield losses. To control weeds, growers should use all available methods: preventative, cultural and chemical. Preventative methods should be geared to controlling weeds in headlands and shelterbelts and preventing the entry of new weeds via equipment, livestock, and manure. Ideally, escaped weeds should not be allowed to set seed.

Hilling is not only an important cultural operation for protecting the tubers, it will also control the majority of weeds that have emerged at that time. This operation, however, disturbs treatments of preplant incorporated herbicides and may bring new weed seeds to the soil surface. Pre-emergence herbicides should be applied just after hilling when potatoes are at the ground crack stage. Additional cultivation after the application of pre-emergence herbicides should be avoided if possible. If post-emergence herbicides are used, the best results can be achieved by applying herbicides when broadleaved weeds are small (3 cm or less) and actively growing. Where weed pressure is anticipated to be severe, growers should consider a combination of pre-plant incorporated herbicides for broad-spectrum weed control.

The major weeds that Alberta potato growers are likely to encounter are redroot pigweed, lamb's-quarters, wild buckwheat, wild oats and green foxtail. In addition, kochia can be a problem weed in southern Alberta. Volunteer wheat and barley are occasional problems following a dry fall in a cereal crop rotation. In central Alberta and the Edmonton area, potato growers may also encounter hemp nettle, chickweed and corn spurry infestations. Smartweeds frequently infest low-lying areas of a field. These weeds can be controlled by selecting the proper herbicidal program. However, wild tomato (*Solanum triflorum* Nutt.), hairy nightshade and wild sunflower, which may also occur in some fields, must be controlled by other means. These weeds can be controlled in a crop rotation with cereals where effective herbicides are used, however, some reinfestation will occur because of seed dormancy.

Perennial weeds, like Canada thistle and perennial sow thistle, should be eliminated prior to planting because no chemicals are registered for their control in potatoes. Quackgrass, a serious weed if permitted to grow unchecked, can now be suppressed by several post-emergence herbicides in combination with cultivation.

To plan a weed control program for a particular field, growers should identify the major weed species and match these with one or more of the appropriate herbicidal treatments. Growers should have a good knowledge of their weed problems from previous years because this information is essential for selecting pre-plant incorporated herbicides. Several other factors affect the success or failure of a herbicide: timing, rate and accuracy of application. Post-emergence herbicides must be

applied at the most susceptible stage of weed growth. Early treatment is recommended in cases where leaf stages of the weed are not indicated. Equipment (nozzles, gauges and pumps) should be in good condition and the application rate of the sprayer should be carefully calibrated to the desired output. Organic matter and soil texture affect the rates of pre-plant and pre-emergence herbicides. When a range of rates is given, the low rate is for low organic matter soils and sandy soils. Similarly, if a range is given for post-emergence herbicides, the lower rate should be used for light infestations and good growing conditions.

Herbicidal Residues

Alberta potato growers should refrain from using Tordon 202-C (picloram + 2,4-D) and Glean (chlorsulfuron) on land rotated to potatoes. When these herbicides have been applied at the recommended rates, the following guidelines apply:

Following the use of Tordon 202-C, potatoes should not be grown until the fifth year. Manure from animals which have been fed Tordon 202-C treated straw will contain residues of picloram at levels sufficient to injure potatoes. Potatoes that have absorbed picloram will have severely cupped leaves (fiddleheading) and abnormal leaf veins. (See color photograph).

In the Brown and Dark Brown soil zones of Alberta, land treated with Glean should not be used for potato production for a minimum of four years following the year of Glean application. In the Black soil zone with pH less than 7.5, this waiting period can be reduced to two or three years because the rate of breakdown for Glean is increased by lower soil pH. Growers should conduct a field bioassay test according to label directions before planting potatoes.

Banvel residues produce similar symptoms to those caused by picloram. Banvel applications in the spring of the preceding year at rates recommended for cereals should not cause any injury. However, post-harvest treatments or higher rates of Banvel will likely injure potato crops in the following year. Sprayers that have been used to apply either Banvel or Tordon 202-C should be thoroughly cleaned prior to use on potatoes. Where Lontrel (clopyralid) has been used, potatoes should not be grown in the year after treatment.

Where Treflan or Rival (trifluralin) have been used at recommended rates in the previous year, growers can plant potatoes without risk.

Atrazine, used to control weeds in corn, can result in potentially harmful residues. The carryover of atrazine is related to the rate of application and since these rates vary widely, no generalized safe cropping interval can be recommended. Growers should conduct a bioassay test by growing potatoes in the treated soil and compare these to potatoes grown in similar soil but free of any herbicides.

Similar precautions to those suggested for atrazine also apply to Princep (simazine), Velpar (hexazinone), and Sinbar (terbacil). Simazine can be used in corn and alfalfa, whereas Velpar and Sinbar are used only in alfalfa. Problems with atrazine, simazine and terbacil have not been reported to the Regional Crops Laboratory in Brooks, Alberta, but nevertheless these herbicides could create problems with potatoes.

Growers planning to lease land should obtain a record of the herbicides used during the past five years for the fields concerned. They would be well advised to include a statement in their lease agreement indicating that neither Tordon 202-C nor Glean had been applied in the previous four years.

The following herbicides have some restrictions that affect potatoes and should be checked for residues: Ally, Assert, Muster and Pursuit.

Consult the current edition of *Crop Protection with Chemicals*, Agdex 606-1 for detailed information concerning herbicides registered for potatoes, varietal restrictions (if any), application rates, pre-harvest intervals and weeds controlled. Growers should use this reference as a guide and consult the herbicide label for specific instructions. Table 10 lists those herbicides currently registered for use in potatoes and some of the weeds that these products control.

Table 10. Summary of herbicides registered for use on potatoes and the weeds controlled.

Herbicide & application timing	Redroot pigweed	Smart-weeds	Mustards	Lamb's quarters	Russian thistle	Wild buckwheat	Kochia	Wild oats	Barnyard grasses	Green foxtail	Vol. barley	Vol. wheat	Quack-grass
Before planting													
Dual 960E										R	R		
Eptam 8E	R			R				R	R	R	R	R	R
Eptam 8E + Lexone/Sencor	R		R	R				R	R	R	R	R	R
Lexone	R	R	R	R									
Roundup/Laredo/Wrangler for control of perennial weeds													
Sencor	R	R	R	R	R								
After planting, but before crop emergence													
Afolan/Linuron 400L	R	R	R	R		R	R		R				
Dual 960E (irrig. only)									R	R	R		
Eptam 8E	R			R				R	R	R	R	R	
Gramoxone kills top growth of perennial weeds, kills most annuals													
Lexone	R	R	R	R									
Lorox	R	R	R	R		R			R				
Patoran FL	R	R	R	R					R	R			
Patoran FL + Dual 960E	R	R	R	R					R	R			
Sencor	R	R	R	R	R								
After crop has emerged													
Eptam 8E (Sprinkler)	R			R				R	R	R	R	R	
Gramoxone kills top growth of perennial weeds, kills most annuals													
Lexone	R	R	R	R									
Excel Super								R	R	R	R		
Sencor	R	R	R	R	R								
Sencor/Lexone + Fusilade II	R	R	R	R	R			R	R	R	R	R	R
Poast								R	R	R	R	R	R
Fusilade II								R	R	R	R	R	R

R = herbicide is registered for control of weed specified

Notes: Check Sencor, Lexone, Dual, Gramoxone labels regarding susceptible potato cultivars.

Recropping restrictions should be noted for Sencor and Lexone, Eptam 8E + Lexone/Sencor

Disease Management

Potato plants are susceptible to a wide variety of diseases that can severely reduce yield, quality and storability of tubers. Diseases occur in the field and in storage and are caused by infectious bacteria, fungi, viruses and related organisms.

Most infectious potato diseases can be controlled by using certified seed, proper sanitary practices, crop rotation, and pesticides. The following are the most serious diseases of potatoes in Alberta. Table 12 lists chemicals used for control of potato diseases.

Bacterial Diseases

Bacterial Ring Rot — Bacterial ring rot is a highly infectious disease caused by the bacterium *Corynebacterium sepeconomicum*. It has caused serious losses in Alberta in the past and is a pest in The Agricultural Pests Act of Alberta. All commercial fields over 5 acres are inspected for bacterial ring rot and if the disease is detected, the owner of the infested potatoes will be ordered to comply with the regulations set out in The Agricultural Pests Act. Any person who plants 5 acres or more of potatoes intended for sale must obtain a license from the Potato Growers of Alberta to assist with inspection.

Foliar symptoms of the disease vary with the variety of potato grown and stage of the growing season. Symptoms of the disease are not always expressed or may be masked by other stresses on the plant. The lower stem of infected plants will exude a milky ooze when cut and squeezed. A cheesy cream-colored liquid oozes from the vascular system when an infected tuber is cut and squeezed. Severely infected tubers turn dark brown or black and completely rot away inside.

During seed cutting, bacteria from infected tubers are smeared on the cutting knives and healthy seed pieces then become infected. Ring rot bacteria can survive for five years in dried potato stems and for two years on dry burlap, plastic or plywood surfaces. The bacteria, however, live only a short time in soil and are normally killed between fall and winter if all plant debris is plowed down.

Bacterial ring rot is controlled by:

- planting certified seed,
- thoroughly cleaning and disinfecting equipment, tools, trucks and storage (see Seed Potato section),
- disposing of any crop that is found to have ring rot,
- leaving infected crop unharvested,
- sprout inhibiting infested potatoes,
- rotating other crops, other than sugar beets, after potatoes,
- plowing under infected potato debris or unharvested potatoes prior to winter,
- allowing at least one year before replanting potatoes in an infested field,
- disposing of all used sacks.

Bacterial Soft Rot — Bacterial soft rot is a common and often serious storage disease of potatoes. It is caused by the bacterium *Erwinia carotovora* var. *carotovora* and certain other species of soil- and tuber-borne bacteria. Infected tubers are slimy and foul smelling. Bacterial soft rot commonly invades frozen tubers and those that have moisture on the surface. Leak-infected and fusarium dry-rotted tubers are prone to soft rot. Moisture may condense on cold seed pieces that are planted into warm, moist soil and soft rot can develop.

Table 11. Chemicals used for control of potato diseases.

Product	Dry rot	Early blight	Rhizoctonia	Scab	Seed decay
Captan	+		+	+	+
Difolatan		+			
Dithane M-22		+			
Dithane M-45		+			
Easout	+				+
Manzate 22	+	+			+
Polyram	+			+	+
Tuberseal					+
Zineb 75-W		+			
Mertect	+		+		
Dyrene		+			
Bravo		+			

The grower assumes responsibility for the correct application of registered chemicals.

Soft rot may also cause rapid and severe breakdown of washed and packaged fresh-market potatoes if they are not completely dried prior to packaging. Early season potatoes with immature skin are most susceptible to this soft rot.

Bacterial soft rot is controlled by:

- warming cold seed tubers prior to planting to approximately the same as the soil temperature,
- minimizing mechanical damage during harvesting, handling, and packing operations,
- avoiding frost injury or properly drying frosted tubers in storage,
- using clean water that is changed often or chlorinated during washing operations,
- removing potato cull piles, discarded vegetables and plant refuse from fields and storage,
- controlling other tuber diseases,
- preventing condensation water from forming on tubers by ensuring that cold tubers are ventilated with cool air (See Storage section).

Blackleg — Blackleg is a common disease of potato plants caused by the bacterium *Erwinia carotovora* var. *atroseptica*. Symptoms of the disease include stunting, yellowing and rolling of leaves, and slimy black tissue on the lower stem. Tuber soft rot may also develop. Blackleg bacteria overwinter in the soil and on tubers.

Blackleg is controlled by:

- planting certified seed which is blackleg free,
- cleaning and disinfecting seed cutters, handling equipment, and trucks,
- planting in warm soil,
- preventing stem damage during cultivating, rouging and harvesting,
- rouging diseased potato plants.

Common Scab — Common scab is a bacterial disease caused by *Streptomyces scabies*. The scab organism occurs naturally in the soil where it lives on plant debris. The bacteria causes scab-like lesions on the tuber surfaces. Scab does not affect the yield of potatoes, but severely infected tubers are unsightly and deep scabs may require deep peeling by consumers and processors. Scab is worse when soil moisture is low and after applying barnyard manure. Scab increases as pH (alkalinity) increases.

Common scab is controlled by:

- planting scab-free or treated seed on land free from scab,
- growing legumes or grains for three or four years between potato crops,
- green manuring,
- treating seed tubers with Polyram or captan,
- planting moderately resistant cultivars such as Russet Burbank, Norgold Russet, Norchip, Norland and Superior,
- maintaining adequate soil moisture.

Fungal Diseases

Early Blight — Early blight is an infectious foliar disease of potato plants caused by the fungus *Alternaria solani*. The fungus grows on leaves and forms brown to black spots, up to 5 mm in diameter, in the leaf tissue. The angular spots usually have distinct concentric rings, giving the appearance of a target board. The spots increase in size and, if unchecked, the entire leaf may die. The fungus overwinters in dead vines and leaves. High humidity or water on the leaf surface is necessary for infection.

Early blight is controlled by:

- rotating potatoes with small grains,
- plowing down all crop residue,
- planting disease-free seed,
- irrigating according to soil moisture requirements of the crop,
- maintaining adequate nitrogen,
- allowing tubers to mature in the ground before harvesting,
- spraying with a recommended fungicide.

Start chemical control when most of the lower leaflets (next to the ground) contain one or more spots. Treat the field after irrigation when the soil has dried sufficiently to allow equipment to go through. Continue application after each irrigation until conditions for disease development no longer exist or the recommended preharvest interval is reached.

Late Blight — In 1991 late blight was found in several fields in southern Alberta and several bins of stored potatoes suffered severe losses. In 1992 late blight attacked most fields in southern Alberta and caused trace to severe losses. Prior to these outbreaks the disease had only been seen on occasion and never as severe as in these two seasons. The heavy rains during May and June of these two years coupled with a very mild winter of 1991/92 likely lead to a build up of the disease.

Near-normal rainfalls in the other years will likely prevent outbreaks of the disease, however the disease must be monitored and controlled.

Late blight is an infectious foliar disease caused by the fungus *Phytophthora infestans*. The fungus grows on leaves and forms lesions at the leaf tips and margins. The fungus will form a whitish mold on the underside of leaves if the damp conditions persist and, if left unchecked, will spread rapidly throughout the field killing plants within days.

The fungal spores can wash into the soil and infect tubers. Tubers may start to rot in the field or the late blight rot can grow in storage. Infected lots must be graded prior to storing. Infected lots put into storage must be dried with high air flows of dry air for a minimum of three days (and up to two weeks) to dry all rot.

The fungus survives in infected tubers that overwinter (volunteers) and in cull piles.

Late blight is controlled by:

- applying preventative fungicides, such as Bravo or Dithane M45 prior to row close,
- continuing fungicidal sprays, including Ridomil MZ, every 10 to 14 days depending on weather and irrigation,
- planting disease-free seed,
- maintaining adequate nitrogen,
- burying culls or spreading culls on fields prior to, or during, winter,
- controlling volunteers.

For best control a minimum of one application of fungicide must be made before the top growth fills in the rows in late June or early July. Subsequent fungicide applications may be required depending on weather conditions or irrigation practices.

Rhizoctonia disease — Leaves, stems, and tubers can all be invaded by *Rhizoctonia solani*, however symptoms may not appear on all three. Leaves may be pale green, curl upward in a tight roll, and be purple or light bronze. Brown cankers may develop on stems at or just below the soil surface. Small aerial tubers sometimes grow where leaves join the main stems. Rusty brown cankers also may develop on stolons, and severe infections will “prune” developing tubers from the ends of stolons. A white felt-like covering may grow on lower stems. Small hard black patches, called black scurf, may grow on tubers and reduce their visual quality if severe. The fungus is soil-borne and can live on soil debris and other plants.

Rhizoctonia is controlled by:

- growing cereals for at least three years between potatoes,
- baling straw from cereal crops,
- planting certified seed free of black scurf,
- not planting potatoes after sugar beets or legume crops,
- planting in warm well-drained soil,
- not over irrigating,
- controlling weeds,
- treating seed pieces with captan (WP),
- treating potatoes going into storage with Mertect (SN,WP).

Seed-Piece Decay — Several species of soil and seed-borne fungi and bacteria cause seed-piece decay. Seed-pieces may dry rot or soft rot depending upon the micro-organisms involved. Decay can be aggravated by insect injury, freezing, low soil temperatures, excess soil water or fertilizer and improper use of seed treatments.

Decay organisms attack frozen seed pieces, enter through wounds including cut surfaces or through mechanically damaged tissue.

Decay is controlled by:

- cutting, treating, and planting seed potatoes the same day,
- protecting cut seed from the hot sun or a drying wind,
- planting whole seed,
- treating seed pieces prior to planting,
- planting in warm moist soil to promote wound healing and rapid sprout growth,
- warming seed to near soil temperature prior to planting.

If cut seed is to be stored, it is held at 10°C - 15°C and a high relative humidity for two or three days to promote rapid healing. Pre-cut seed is not treated going into storage but prior to planting.

Leak — Leak is a warm-weather disease caused by the fungus *Pythium ultimum*. Diseased tissue of tubers infected with leak is soft, watery, granular and dark grey or black. Severely infected tubers may drip or leak, however in less advanced stages, infected tissue may only be seen when tubers are cut. There is usually a distinct line between healthy and diseased tissue. Tubers may develop soft rot and then become slimy and foul smelling. The fungus is present in many soils and attacks the roots of many different plants. The fungus overwinters in plant debris particularly in wet soils.

Leak is controlled by:

- growing potatoes on well-drained soils,
- harvesting when tubers are mature,
- harvesting below 20°C especially if the soil is moist,
- storing promptly after digging at recommended temperatures and humidity,
- cooling tubers harvested in hot sunny weather to below 10°C and marketing them immediately.

Dry Rot — Dry rot is a common storage disease of potato tubers caused by several *fusarium* fungi present in soil. The disease usually causes extensive tissue decay and collapse. Diseased tissue, exposed by cutting, is brown, grey or black and dry to slightly moist and cheesy. Cavities are often formed within the tuber. There may be white or pink mold near the edges of decay areas, and the mold growth is often seen on the surface of tubers in storage. The amount of decay in storage depends upon the amount of fungus in the soil, the amount of mechanical damage done to the tubers during digging and harvesting, and on the susceptibility of the potato variety.

Dry rot is controlled by:

- treating seed pieces with a recommended fungicide prior to planting,
- treating tubers going into storage with Mertect,
- handling treated seed with clean, disinfected equipment,
- harvesting during cool dry weather,
- preventing bruising during harvesting, handling and grading operations.

Fusarium and Verticillium Wilts — Wilt diseases caused by *Fusarium* spp. and *Verticillium* spp. are becoming increasingly important in seed potato production in Alberta. Plants infected with wilts start to show symptoms in the middle of the growing season. Individual leaves first turn pale green or yellow, leaves on affected stems then wilt, and finally the entire plant dies prematurely. The lower stems of diseased plants and tubers have brown discoloration in the vascular tissue when cut open. Both *Fusarium* spp. and *Verticillium* spp. are soil-borne fungi and, once established, can live for long periods in the soil even if a potato crop has not been planted for many years. The disease can become established through the use of infected seed.

Wilts are controlled by:

- preventing wounding and bruising at harvest,
- treating seed pieces with chemicals recommended for seed-piece decay,
- planting certified seed free from wilts,
- not contaminating clean fields with soil from diseased fields, diseased tubers or plant refuse.

Viral Diseases

Potato Leaf Roll — Potato leaf roll is the most important viral disease of potatoes in Alberta. The virus that causes the disease is spread primarily by the green peach aphid, however; it is also carried and spread by infected seed tubers. Leaf roll symptoms vary depending upon the stage of infection. Plants from infected seed tubers are stunted and immature leaves may have internal chlorosis. Mature leaves may be pale green, stiff and unrolled, and may have purplish edges. Tubers from plants infected in the current season develop fine lines of discoloration in the tuber.

Leaf roll is controlled by:

- planting certified seed, free of leaf roll,
- controlling aphids.

Spindle Tuber — Spindle tuber is a serious disease of seed potatoes caused by the spindle tuber viroid. Plants infected with spindle tuber viroid are upright, dwarfed and much thinner than normal vines. The stems are often more branched and branches form very sharp angles where joined to the stem. Affected tubers are dwarfed and are usually narrow and spindle-shaped. Eyes are numerous and the tubers are often cracked. Spindle tuber is spread by insects such as aphids, grasshoppers, Colorado potato beetles and flea beetles, as well as seed-cutting knives, planters and infected seed.

Spindle tuber is controlled by:

- planting certified seed,
- controlling insects,
- removing diseased plants, ensuring that the entire plant is removed,
- planting whole seed,
- avoiding leaf contact by people and equipment during field operations,
- washing knives and other equipment with detergents, household bleach or quaternary ammonia compounds, especially between seed lots.

Mosaic — There are three forms of mosaic viruses: simple, mild and rugose mosaics. Mosaic is caused by potato viruses A, X, S and Y, alone or in combination. Infected plants have yellow mottled leaves that may be wrinkled, distorted or reduced in size. Mosaic viruses are spread by insects, infected seed-pieces, cutting knives and by contact with infected plants.

Mosaic is controlled by:

- planting certified virus-free stock,
- controlling insects, especially aphids,
- removing plants with obvious mosaic, including seed-pieces, as soon as they are detected,
- avoiding rubbing potato foliage with clothing and machinery,
- disinfecting cutting knives and equipment as often as possible with household bleach, soapy water or quaternary ammonia compounds.

Witches' Broom — Witches' broom of potatoes is caused by a virus-like mycoplasma. Infected plants are dwarfed, leaves are a lighter green than normal, and the leaf margins are reddish-yellow. The plants develop many more shoots than normal and become unusually bushy. Stolons of infected plants are long, abnormally white, and have chains of small tubers. The disease is spread through infected tubers; however, in Western Canada, two species of leafhoppers transmit the disease from legumes to potatoes.

Witches' broom is controlled by:

- planting certified disease-free seed,
- eliminating from planting stocks all tubers that have premature hair-like sprouts,
- rouging infected plants,
- controlling leafhoppers.

Environmental Diseases

Blackheart — Blackheart of potatoes results from a poor oxygen supply to tubers in storage. The centre of an infected tuber is grey-blue-black. Blackheart is prevented by proper ventilation and by storing potatoes at recommended temperatures.

Low Temperature Injury — Low temperature or freezing injury can occur to potatoes that are exposed to a heavy frost in the soil or to tubers that have been excessively chilled in storage. Frozen tissue, upon thawing, discolors and breaks down into a soft watery mass. Chilling injury often results in streaks of discoloration in the vascular tissue of the tuber. Frozen or chilled potatoes should not be

used for seed because the cut surfaces may not heal and seed-piece decay will result.

Low temperature injury can be reduced or prevented by:

- storing at temperatures above 3.0°C,
- ventilating frosted tubers in storage,
- culling frozen potatoes prior to storage and regrading frozen potatoes if necessary after some period in storage.

Hollow Heart — Hollow heart, a cavity near the centre of the tuber, results from rapid tuber growth. The disorder is found primarily (but not only) in large potatoes. Walls of the cavities are white to light brown. The disorder is important because affected tubers have no external symptoms. They can only be removed with expensive X-ray grading equipment. Hollow heart is promoted by growing conditions that cause rapid tuber enlargement. Poor stand increases the amount of hollow heart.

Hollow heart is controlled by:

- planting susceptible varieties at closer spacings,
- maintaining uniform soil moisture throughout the entire growing season,
- planting to maximize stand of uniform plants and minimize misses.

Malformed Tubers — Secondary growth, knobs, and other tuber deformities may be caused by extreme soil temperatures. Other conditions such as nutrient and water imbalances, have been implicated in irregular tuber development. Growth cracks may arise from rapid tuber growth and are often the result of improper fertilizer placement.

Reduce or prevent malformed tubers by:

- maintaining uniform soil moisture, particularly during tuber development,
- applying recommended fertilizer rates,
- establishing a high stand of uniform plants to control tuber growth rates.

POTATO STORAGE AND HANDLING

The potato tuber is a living organism that has specific storage requirements that must be met for it to maintain its life processes. Failure to recognize this and provide the necessary conditions can lead to disastrous consequences.

The aim of storage management is to preserve the tuber in the best possible condition, with minimum loss in quality or material. No storage is able to improve the product placed in storage, but much can be done to minimize losses.

The potato tuber is the storage organ of the potato plant. In nature the tuber enables the potato plant to survive the winter by providing food reserves, in the form of starch, and allows the young potato plant to start growing the following spring. It is these food reserves that growers, consumers and processors are interested in.

Potato tubers are living organisms that consume oxygen and give off carbon dioxide and heat. Storages therefore require good climate control to maintain quality. High temperatures cause the tuber respiration rate to increase and oxygen and food reserves are used up quickly resulting in excessive shrinkage. Freezing or near-freezing temperatures can damage and kill cells. If the air surrounding the tuber has low humidity, water will move from the tuber to the air, resulting in excessive weight loss. If the oxygen content falls too low, cells within the tuber die and blackheart forms. Sprouting is also a natural biological function of the tuber; however, it is not desirable in fresh market or processing potatoes. Potato tuber diseases are caused by micro-organisms or adverse environmental conditions and they can result in large storage losses. Diseased seed may result in weak potato plants that do not yield well.

Storage Structures

A potato storage should be well insulated to stabilize temperatures and to maintain the high humidity required. The structure must be of adequate strength to hold the high pressure of piled potatoes, wind and snow loads. A good ventilation system capable of accurate temperature control, humidification and through-the-pile air distribution is required. The storage should be easy to clean, sanitize and maintain; and it should provide for convenient access and handling of potatoes.

A loading shed or porch at the entrance to the storage is essential. It allows potatoes to be loaded in severe weather without risk of cold damage to potatoes and discomfort to workers.

A good loading shed should be large enough for loading trucks and manouvering grading equipment. It should be insulated and heated with a concrete floor. A good size for most equipment is 50 ft (15 m) wide.

A variety of well-insulated, structurally sound buildings can be used for potato storage. Several types common to Alberta are illustrated in figures 20 and 21. Growers who would like assistance with storage design are requested to contact the Farm Structures Engineer at the Alberta Agriculture, Lethbridge regional office (See back cover).

Ventilation

Ventilation is the single most important factor for maintaining correct temperature, relative humidity and air quality in the storage. Several ventilation systems can be used, but the most common is a fan and duct system which blends air to the correct temperature, adds humidity and blows air through the potato pile. Ventilation rates for various types of potatoes are:

	cfm/ton	L/s/t
Seed	12-15	6-7
Table	15-16	7-8
Processing	18-20	9-10

The ventilation fan should be selected to provide the desired air flow at a static pressure of 1.0 inches - 1.3 inches (300 - 350 Pa). Air blending louvres are sized for a maximum air velocity of 1000 ft/min (5 m/s).

Correct duct size and spacing is equally important in achieving efficient, balanced air distribution. Duct design is a compromise between large ducts for efficient air distribution and smaller ducts for economy. Smaller ducts require a higher air velocity for a given air flow. This higher velocity means greater pressure loss, less uniform air distribution, and more fan power. Table 12 provides a practical guideline for duct design.

Figure 20. Typical potato storage plan, single bin or double-wide.

Figure 21. Typical potato storage plan and alternate building types.

Table 12. Maximum duct length (metres) for round ducts spaced at 3.0 m (10 ft) in potato storage bins.

Duct size		Duct Area m ²	Ventilation rate			
			8 L/s/t (15 cfm/ton)		10 L/s/t (19 cfm/ton)	
			Pile depth - m (ft)		Pile depth - m (ft)	
(mm)	(in)		4.0 (13)	5.0 (16)	4.0 (13)	5.0 (16)
250	10	0.05	4.6	3.7	3.7	3.0
300	12	0.07	6.6	5.3	5.3	4.2
375	15	0.11	10.4	8.3	8.3	6.6
410	16	0.13	12.4	10.0	10.0	8.0
450	18	0.16	15.0	12.0	12.0	9.5
510	20	0.20	19.0	15.3	15.3	12.0
610	24	0.30	27.4	22.0	22.0	17.5

Notes to duct design table:

1. Maximum duct velocity is 6.0 m/s (1200 ft/min).
2. Duct spacing is 3.0 m (10 ft); for closer duct spacing, maximum duct length can be increased in proportion to closer spacing.
3. Duct length should be shortened proportionally for greater pile depth or increase air flow.
4. This table can be used for other duct shapes of equivalent area.

Design Example:

What ducts are appropriate for a 15 m (45 ft) wide bin to be ventilated at 8 L/s/t (15 cfm/ton); pile depth 5 m (16 ft).

Answer:

Look in column 2 under 5.0 m depth for a length close to 15 m. 15.3 m is opposite a 510 mm (20") duct. Perhaps a 450 (18") duct is more practical. Its maximum length is shown as 12.0 m, therefore it should be spaced at $12.0/15 \times 3.0 \text{ m} = 2.4 \text{ m}$ (8 ft).

If the pile is shallower near the walls so it averages 4.0 m deep, 375 or 410 mm (15" or 16") ducts at 2.4 m (8 ft) spacing would be adequate.

Air systems that permit regulating air flow to certain areas are best from the point of view of management. Indoor-outdoor differential controls permit optimum use of outdoor air for cooling (figure 22). It is preferable to ventilate the least time necessary to maintain the desired temperature, as weight loss is proportional to the time ventilation is operated, not the volume of air moved. It is therefore better to run a higher volume of air intermittently, than a lower volume continuously.

Storage Cycle

Several distinct storage phases exist. The best management of each depends on tuber conditions, weather and the end use or type of crop. These conditions and related management practices are summarized in table 14 and discussed below.

Preharvest Period — Season-long management affects the storageability of potatoes and growers should aim to place a mature, disease-free and bruise-free crop into storage. Most storage problems usually start in the field before harvest begins. Good storage helps manage these problems and lessen their effects, but storage will never improve a

poor-quality crop. Vine killing a minimum of 10 days before harvest will help mature potato skins and prepare them for harvest and handling. If adverse conditions or special storage needs are known, allocate the appropriate storage space.

The storage should be prepared well in advance of harvest. Check all mechanical systems, and clean and repair ducts. Use an accurate thermometer to check ventilation controls and check operation of the humidification system.

Thoroughly disinfect the storage, and handling and harvesting equipment. Dampen earth floors, if any, in storages.

Harvest Period — Storage management will be easier and the quality of potatoes coming out of storage will be better if bruising and damage is minimized at harvest. Weather has a great effect on the potato harvest. Producers should try to avoid harvesting tubers when it is colder than 5°C because potatoes are very susceptible to shatter bruise at these low temperatures. Tubers at 18–20°C and under slight moisture stress are highly susceptible to black spot bruise. The ideal harvest temperature is between 10° and 15°C.

Adverse weather may result in severely injured, frosted, chilled or diseased potatoes. When feasible, these should be separated from normally healthy ones prior to storing.

Postharvest Curing Period — The first week or two of storage are critical to long-term storage quality of potatoes.

Potatoes normally should be cured at about 15°C and 95 per cent relative humidity for two weeks to promote wound healing and skin set or suberization. (Bacterial soft rot and frozen potatoes are the exception). Healing takes place most quickly at 20 - 25°C, as does the development of soft rot organisms; therefore, 15° is a good compromise for most situations. During this period, the storage must be inspected frequently, particularly if problem conditions exist.

There is not complete agreement on what the preferred ventilation should be during this suberization period. Near ideal conditions often exist in the pile with no air flow. This minimizes weight loss; however, at least some ventilation is desired twice a day to provide oxygen and reduce pile sweating. Sweating, or condensation on surface tubers, results when the upper tubers are cooler than those inside the pile. A small amount is usually harmless, but any excess moisture will encourage soft rot. With good humidity control and capacity, more or continuous ventilation is recommended. Always run the humidifier with outdoor air when ventilating to reduce weight loss.

If cooling is required to bring the pile temperature down to 15°C, cool as quickly as possible, but never use air much colder than the desired storage temperature as tubers near the air ducts will be overchilled. A ventilation system with an outdoor temperature sensor is beneficial for cooling when outdoor temperatures are low enough.

Cold tubers should be warmed to curing temperature slowly, by increasing temperature about 1°C per day. Warmer air applied to cool tubers will cause condensation on the tubers, which makes them more susceptible to soft rot infection.

Mid and Long-Term Storage — The objective is to maintain a consistent, ideal environment for the duration of the storage period. Long term storage demands more critical control than short term storage. Recommended conditions depend on crop conditions, variety and intended use. General recommendations for storage temperatures are:

Seed potatoes	4-5°C
Table stock	6-7°C
Processing	
- French fries	7-8°C
- chips	9-10°C

Ventilation can be either intermittent or continuous. Intermittent ventilation, 2-6 hours, twice a day, results in minimum weight loss and is generally recommended for table and seed potatoes. Continuous ventilation results in the most uniform conditions desired for chipping potatoes. Continuous ventilation may not be necessary in milder weather.

Marketing Period — Fresh and processing potatoes are particularly susceptible to injury during unloading, trucking and processing, especially if they are cold. Potatoes should be at least 7°C before they are moved. Chipping potatoes are stored at 9 or 10°C and are not normally prewarmed, however care in handling is still necessary. A storage facility containing several smaller (300-500 ton) bins is far more flexible than a storage with only one or two 1500-ton units. Small units can be individually preconditioned prior to opening and moving.

Growers with chipping contracts may be required, upon direction from their contracting processor, to recondition Norchip prior to shipping and processing. When Norchip fail to produce light colored chips, reconditioning at temperatures ranging from 12-18°C or warmer may be required.

The increased temperatures cause an increase in respiration and a lower sugar level which result in lighter chips. Growers are advised to prewarm Norchip only following consultation with their processor as the higher temperatures can cause problems if the potatoes are not processed within one month after warming. The higher temperatures also cause more shrink, and may reduce specific gravity. Although sprout inhibited, potato dormancy will be broken sooner and a condition called "irreversible senescence sweetening" may occur. This "old age" sweetening cannot be corrected.

Seed potatoes, when marketed late in the season, should also be prewarmed to break dormancy prior to planting and reduce injury.

Post-Storage Management

This period is often neglected by producers. After potato bins are emptied, the storages, ventilation systems and other equipment should be rechecked. Fans, louvers and drive belts are checked; minor repairs are made; and parts ordered or repaired as required. Clean the storage of all potato residue and loose soil, and disinfect the storage to prevent build-up of disease organisms.

Sprout Inhibition

Processing and fresh-market potatoes to be stored past January are normally treated with sprout inhibiting chemical, and this is usually applied in November or December.

The chemical CIPC is registered for use on storage potatoes in Canada and is one of two common methods of sprout inhibition. This chemical is applied by specialized equipment and done by contractors in Alberta. Processors and packers can supply names of sprout-inhibitor contractors.

The advantages of in-storage sprout inhibition are: it eliminates one field operation (compared with applying MH60SG); and it allows some flexibility of treatment based on the in-storage crop condition and marketing schedule. The disadvantages are: either all the potatoes, or none, in a storage bin are treated; the storages used for treatment cannot be used to store seed potatoes at a later date; and potatoes treated with CIPC cannot be kept in a storage near seed potatoes.

Application methods for CIPC have changed in recent years. Growers are advised to follow storage-management recommendations provided by the applicator after the CIPC has been injected into the storage.

CIPC is highly corrosive. Fans, controls and refrigeration coils should be covered with plastic before using the sprout inhibitor. Shut off electrical power and clean fans and controls of sprout-inhibitor residue before continuing normal operation. CIPC is considered to be slightly toxic when inhaled or absorbed through the skin. Wear protective clothing and avoid inhalation and skin contact when cleaning storage equipment after treating with CIPC.

Seed potatoes obviously are not sprout inhibited. They should not be stored in a storage that has been used for sprout inhibitor treatment or has held

potatoes treated with CIPC. Storing at 4°C will generally suppress sprouting and control decay organisms in seed tubers.

Special Storage Problems

Tables 13 and 14 summarize some of the special crop conditions and storage problems often encountered. A good storage ventilation system helps deal with many potato problems, and can save a lot of potatoes. A storage system cannot improve poor quality potatoes.

Wet potatoes — These are susceptible to bacterial soft rot, and should be dried quickly. Operate the ventilation system continuously (with outside cooling air when it is available). Direct more air to the wet portion of the pile, if at all possible. Check potatoes about 18 inches (50 cm) below the surface as they are the last to dry. Temperature can be at 10-15°C, unless soft rot is evident in which case the temperature should be lowered. Return to normal operation with high humidity as soon as free moisture is removed. A severely wet crop, with soft-rot infection, should be stored separately, or not at all.

Frozen and/or severely chilled potatoes — Unfortunately, these conditions occur frequently in Alberta, often affecting the last part of a grower's crop. Two problems are faced: preserving the crop in storage and maintaining the quality of chill-injured potatoes for processing. Some crops do not recover from chilling injury at harvest.

Frozen tubers should be removed as completely as possible before going into storage. It is, however, not possible to remove all frozen tubers as breakdown may not occur until several days, or a few weeks, after harvest. Fortunately a lot containing up to 5-10 per cent frozen potatoes can usually be stored successfully, if there is good ventilation.

Frozen tubers will break down and rot. Continuous ventilation, with the humidifier off, can dry these rotting tubers before the decay spreads throughout the storage. This may take up to two months, following which the tubers should be stored as cool as possible to prevent the spread of disease. The normal and desirable high-temperature curing can not be practised on this type of crop. Over-ventilation at lower humidity results in excessive shrink losses, however this is better than losing the entire crop.

Chilled potatoes that are not in danger of breakdown can be treated more normally. They are ventilated continuously with high-humidity air. However, they must be warmed slowly to prevent condensation on the tubers which will encourage soft rot. A temperature increase of 1°C per day until tubers reach the desired curing temperature is suitable.

Because chilled potatoes may not respond to conditioning for processing, they should be checked for processing quality by the contractor. Chilled Norchip may respond erratically to reconditioning and therefore testing of sample lots is strongly recommended.

Disease and Rot — In attempting to store potatoes that have obvious tuber disorders, a grower should first ascertain the type of disease or diseases present as control procedures may differ significantly. One control method may encourage proliferation of a second disease organism.

Soft rot is a common storage disorder and is treated in the same way as frozen potatoes. The lot is ventilated continuously and kept as cool as possible (5-7°C). Normal curing must not be attempted since high temperatures accelerate soft rot bacteria.

Storage Inspection

Frequent checking of both the storage systems and the crop is essential. The storage should be designed to provide easy access to potato bins for inspection. Walk planks on the surface and soft-soled shoes help reduce damage to surface potatoes. Pile inspection should be done at a few locations by digging below the pile surface where the warmest and dampest potatoes are usually found. Temperature probes, or electronic temperature sensors are helpful in checking for heating, indicating a potential problem. Pile temperature can be checked by lowering a thermometer into a vertical electrical conduit placed into the pile during filling. Odors can be one of the best indicators of storage conditions and impending disease or decay problems. Producers should use their sense of smell frequently in addition to mechanical and electrical monitoring devices.

Table 13. Management of some storage problems.

Sprouting

- Keep below 5° (seed) or 7° (table stock)
- Apply chemical sprout inhibitor (not seed potatoes)
- Keep temperature steady

Shrinkage and Softening

- Minimize damage
- Control sprouting
- Store mature crops
- Cure adequately
- Store at coolest temperature acceptable for market
- Ventilate intermittently as required for temperature control
- Maintain high humidity, particularly when outside air is used for cooling

Pressure Bruising

- Store mature crop, top-kill if required
- Cure adequately
- Keep pile depth reasonable
- Minimize shrinkage (high humidity)
- Damage is related to time in storage; short term can be stored deeper

Bruising

- Minimize damage
- Mature crop
- Use a fungicide when filling storage

Bacterial Soft Rot

- Do not store diseased potatoes
- Keep temperature low (5°C)
- Ventilate continuously without humidity
- Do not cure at higher temperatures
- Try to avoid harvesting wet potatoes

Color of Fry or Chip

- Use recommended fertilizer and cultural practices
- Mature crop
- Cure adequately
- Keep temperature uniform
- Store at recommended temperature
- Precondition before marketing as directed
- Watch for pre-harvest crop stresses
- Try to avoid pre-harvest chilling injury
- Consult with processor

Condensation on Pile or Ceiling

- Ventilate through the pile
- Ventilate continuously; some air can be passed to recirculate over the pile
- Add heat to back of storage so it warms the air returning over the pile about 2°C
- Have adequate ceiling insulation
- Dark colored ceiling is better

Table 14. Potato storage management summary.

Storage period	General requirements	Crop Conditions				
		Normal	Very wet	Chilled	Frosted	Disease/rot
Pre-Harvest	Check equipment Clean & disinfect storage & handling equipment. Mature crop/top kill.	Apply pre-harvest irrigation as required for softening soil.		Harvest chippers earlier than (A) or (C) to reduce risk of poor chip quality.	Prepare to segregate this crop (if feasible) in storage.	Prepare to segregate this crop in storage. May be able to segregate areas of field.
Harvest	Go gently. No drops more than 15 cm. Watch chain speeds. Maintain and fix chains.		May avoid low areas or segregate in storage.	Try to dig during warm part of day if possible. Be extra gentle. prior to storing.	Segregate if serious amount. Cull noticeable frost damage on piler.	Segregate if serious amount. Increase hand sorting on harvester.
Post-Harvest	Cure at 15°. Keep humidity high since weight loss can be rapid.	Cure at 15° for 2 weeks. Ventilate at high RH. Lower slowly to storage temp.	Cure at 15°. Ventilate continuously with humidifier off. Return to normal when dried.	Ventilate and slowly increase temperature to 15°. Check all frequently.	Ventilate. Keep at 8-10°. Reduce humidity to 80%.	Ventilate. Lower temperature to 5-8° quickly.
Storage	Store at 6° (Fresh). Store at 8-10° (Process). Store at 4° (Seed). Check storage & crop quality frequently.	A) Ventilate intermittently B) Continuous or intermittent ventilation. C) Intermittent ventilation.	Check more frequently. Check chip quality (B).	Check all frequently. Check chip quality early (B).	Check frequently. Ventilate till decay dried. Prepare to market early. May not chip. Check early and often.	Check more frequently. Direct more air to worst spots. Seed may not pass.
Marketing	May vary over extended time, or be rapid.	Try to warm to reduce damage. (B) Precondition. (C) Prewarm to break dormancy.	May have to be moved early.	May have to be moved early. May not chip or Test healing ability of seed potatoes. Test sprouting of seed.	May have to be moved early. May not chip or fry.	May have to be moved early.
Post-Storage	Clean, repair. Inspect for damage.					Disinfect as soon as possible.
Storage/crop types:		A. Table stock for the fresh market B. Processing potatoes, conditions vary according to type and end use C. Seed potatoes				

Handling Potatoes

Mechanical damage is the most important factor affecting potato quality since it is largely controllable and because it causes losses in all areas of the industry. Proper handling of potatoes by growers, packers and processors can greatly reduce mechanical damage to potatoes. The following is a summary of some of these practices:

1. Potatoes should be at least 7°C before they are moved out of storage and to the packaging facility or processor.
2. If a front-end loader is used to carry potatoes from the pile to the conveyor hopper it must be designed to cause minimum damage and be operated properly.
3. Drops anywhere in the system should not exceed 6 inches (15 cm).

1. Fan room and mixing chamber	6. Return air from over pile
2. Fan; approximately 8 L/s per tonne	7. Return air louvers and control motor
3. Branch ducts under pile at 3.0 m o.c.	8. Fresh air louvers and control motor
4. Main plenum	9. Door to isolate louvers in cold weather
5. Humidifier	

Figure 22. Proportioning louver ventilation system used in new storage facilities in Alberta.

4. All pilers, loaders, hoppers and packing line equipment should be equipped with padding or deflectors where potatoes hit. Sharp points and pinching or scraping conditions must be eliminated.	5. As with the harvest operation all personnel should be trained to operate equipment properly, but more importantly they should be made aware of the importance of bruise prevention and encourage to look for deficiencies in the system.

APPENDIX

Glossary of Frequently Used Terms

The following are descriptions of terms frequently used in crop production.

Active ingredient: That portion of a pesticide formulation that is toxic to pests. Most pesticide products contain only a portion of active pesticide, the rest is carrier. For example: 10G means 10% active ingredient in granular form; 5EC mean 5% active ingredient as a emulsifiable concentrate.

Available Moisture: Available moisture capacity or total available capacity is the amount of water in a soil between field capacity and wilting point. For potatoes the moisture should be maintained at about 65-70 per cent of available capacity.

Bacteria: Very small single-cell organisms that may attack plants and cause disease. Most bacteria are beneficial. Soil bacteria aid in breakdown of organic matter.

Banding: Placement of fertilizer or pesticide, at the time of planting, in a continuous band to the side and usually below the seed.

Broadcast: To spread fertilizer or pesticide over the entire area of the soil surface or the entire crop area prior to planting.

Carrier: An inert material mixed with active pesticide ingredients to make a pesticide formulation. Example: Finely divided clay or talc is used as a carrier in dust forms of insecticides.

Certified seed: Any of the eight classes of potato seed as defined in the federal seed regulations. The classes are: Nuclear; Pre-Elite; Elite 1, 2, 3, 4; Foundation and Certified.

Cultivar: A horticultural classification that means cultivated variety. In most cases cultivars are "man made" as opposed to naturally growing plants. Russet Burbank and Norchip are cultivars of potatoes. The term variety is often used (scientifically incorrectly) in crop production to mean cultivar.

Days-to-harvest: The period of time which must elapse by law between the application of a pesticide and the actual harvest of the crop.

Drill: To place fertilizer or pesticide with or near seed in the seed drill or furrow.

Elite seed: Certified seed of four classes (Elite 1, Elite 2, and Elite 3, Elite 4) each representing a higher generation away from the virus-free, pre-Elite or nuclear source.

Emulsifiable concentrate: A liquid pesticide consisting of active ingredient, solvent and emulsifier that mixes with water to form an emulsion (e.g., diazinon 50 EC). The "50" means 50 per cent of the volume is pesticide.

Fertigation: The process of applying soluble fertilizer materials through the irrigation system.

Foundation seed: Certified seed normally grown from Elite 4 seed and normally representing the fifth generation away from the pre-Elite source.

Fumigation: The use of pesticides in a gas form to destroy pests or disease organisms.

Fungi (singular fungus): A large group of simple plants which lack chlorophyll, and that require a source of material to live on. Some are parasitic and attack living plants. Soil fungi aid in breakdown of organic matter.

Germination: **1.** The beginning of the growth process of a seed when it is placed in suitable moisture and temperature conditions. **2.** The number of seeds that will germinate (given in percentage).

Granular pesticide: A pesticide formulation in the form of relatively coarse particles which is applied dry with a spreader, seeder, or special applicator (for example, Furadan 10G).

Green manure: A crop, such as oats, that is grown and plowed down as a source of organic matter and nutrients for the soil.

Herbigation: Applying herbicides through an irrigation system.

Humus: That part of organic matter in the final stages of decomposition which is normally slow to be totally broken down both physically and chemically because of its composition and structure.

Incorporate: To thoroughly mix a pesticide or fertilizer with the soil so that it is uniformly concentrated to a specified depth.

LD₅₀: Abbreviation for the dose of a pesticide (or other toxicant) that kills 50 per cent of the organism being tested. It is usually expressed as mg per kg of body weight. (An LD₅₀ of 500 means that 50% of the test organisms [eg. laboratory rats] will die if fed 500 mg per kg of body weight).

Macronutrient: An essential nutrient which is required by plants in large quantity. Nitrogen and phosphorus are macronutrients.

Micronutrient: An essential plant nutrient which is required by plants in very small amounts. Boron, zinc and manganese are micronutrients.

Mycoplasma: Bacteria-like organisms which may cause plant diseases.

Nematicide: A pesticide to control nematodes.

Nematode: A very small worm-like animal that lives in the soil. Some species may cause severe crop damage by attacking and living in root tissue. Normal sizes range from 0.8-3 mm.

Nuclear: Disease-free, greenhouse-grown seed tubers sold by Alberta Agriculture or nuclear growers to Elite seed growers. The first generation of eight seed classes.

Nutrient: A chemical element that is required for crop growth. There are 16 essential elements required for crop growth of which 13 are obtained from the soil. The other three, carbon, hydrogen and oxygen, come from water and air.

Organic matter: Plant or animal residues in varying stages of decomposition. Undecomposed plant material is normally referred to as trash and doesn't become organic matter until it starts to break down.

Post-emergence: After a crop emerges from the soil.

Pre-Elite: Virus free potato seed stock used by Elite seed growers to produce Elite I seed.

Pre-emergence: The time after planting seed but before a crop emerges. Many herbicides are applied after planting but pre-emergent to the crop.

Re-entry time: The minimum time allowed between the time of spraying a pesticide and the time at which the area may be entered by people unless protective clothing and breathing aids are used.

Residue: That portion of pesticide or fertilizer that remains in the soil or on crop plants after application. Amounts of residue decrease with time. Pesticides may leave residues from several hours to several years.

Residue tolerance: The maximum amount of a pesticidal residue that may lawfully be present in or on a food product offered for sale. It is expressed in parts per million (ppm) or parts per billion (ppb).

Seed certification: The process of application and field inspection to check for the incidence of specified diseases and ascertain if the level of disease qualifies a seed lot for certification at a certain class. Normally Elite 1 planted, produces Elite 2, etc.; however, because disease incidence may be above the level specified for that class a seed lot may be "bumped" to another class. For example Elite 3 (planted) that is planned to produce Foundation may be given Certified class certification.

Seed-piece treatment: Chemical treatment of seed to eliminate or reduce organisms which may cause seed-piece decay, seedling death or disease in a growing crop. Chemical treatments include fungicidal and insecticidal applications to the seed.

Side dress: To apply fertilizer in the soil along side of a crop row after the crop is established.

Surfactant: A compound which increases the spreading ability of a liquid (emulsifiers, soaps, wetting agents, detergents, and spreader stickers) and aids in the effectiveness of some herbicides and insecticides. Do not use a surfactant unless recommended by the pesticide manufacturers as many pesticides contain surfactants already and adding one may result in crop damage.

Systemic pesticides: A pesticide which is absorbed by and flows through the system of a plant or animal so that the plant or animal becomes toxic to the pest to be controlled. When referring to a herbicide, the chemical is absorbed by the weed and it is killed internally.

Top-dress: To apply fertilizer, by broadcasting, to the entire growing area after a crop is established.

Toxicity: The poisoning ability in speed and severity of a pesticide. The toxicity of a chemical to humans is usually based on its assumed (or known) effect on humans, and its known effect on test animals.

Tuber: Botanically, a swollen underground stem. The potato is a tuber and not, as often thought, a large root.

Tuber-unit planting: The process of planting all the seed pieces from one tuber consecutively in a row. They are kept separate from seed pieces of other tubers by leaving a gap between units from one tuber.

Variety: A botanical classification used to group or separate plants within a given species. The term variety is commonly used to mean cultivar (cultivated variety).

Virus: A submicroscopic particle of nucleic acid and protein. All plant viruses are parasitic.

Virus freeing: A process of completely freeing tubers from all known viruses. Also used as a general term to signify freeing from all disease.

Weed: A plant growing where it is not wanted.

Wettable powder: Dry formulation of a pesticide which is normally mixed with water to form a sprayable suspension (for example, Guthion WP).

Wetting agent: See surfactant.

Wireworm: A small 'worm-like' or 'caterpillar-like' insect that lives in the soil and is the larval stage of a click beetle. These usually white, ivory or tan colored insects have hard, shiny outside coverings and can cause damage to seeds, root crops and potatoes. Normal sizes range from 1 to 2.5 cm in length.

Potato Grades

The following descriptions (especially those for fresh potatoes) are offered as a guide only and have no official sanction. Consult the Canadian Agriculture Products Standards Act (CAPS Act) and seed regulations for precise legal descriptions.

Potato growers and packers are required to supply potatoes that meet certain standards: standards set by law or by contractual agreement. All potatoes whether fresh, processing or seed must meet general requirements regarding: varietal characteristics, size, physical condition, freedom from disease, cleanliness, packaging and labeling.

Seed Potatoes — Seed growers and interested commercial growers who want copies of the detailed seed regulations should contact either the Food Production and Inspection Branch in the city nearest them or can contact:

Officer-In-Charge
Room 474, 220-4th Ave. S.
Calgary, AB T2G 4X3
Phone: 292-4986
Fax: 292-6629

Current regulations define seed size diameter, however the supplier is obligated to deliver seed as requested by the purchaser. If a buyer requests certain specifications, such as size ranges well below the legal tolerances, then the seed grower should supply seed within the specifications agreed to. Should he not wish to conform to the buyer's request, then the seed grower has the option not to agree to the specifications and perhaps lose a sale.

Seed buyers should be familiar with seed standards as they allow for a wide range in seed weights. Current allowable sizes for seed are:

Class A

Long varieties 45-70 mm
Round varieties 50-80 mm

Class B

Long varieties 30-45 mm
Round varieties 30-50 mm

The size ranges of Class A seed are far too wide for practical seed cutting. Narrower ranges (eg. 45 to 60 mm) allow for easier cutter adjustment and the resulting seed pieces are more productive.

Process Potatoes — The requirements for potatoes delivered for processing are established by the processing company. Dockage is determined at time

of delivery either by the processor, or by an Agriculture Canada inspector.

Processors require that potatoes meet general physical requirements similar to fresh market potatoes: clean, free from damage and decay. A 50 mm (2 in.) minimum diameter is normally required by chipping processors. French fryers require a minimum diameter of 45 mm (1.75 in.) and a minimum length of 75 mm (3 in.).

More importantly the potatoes must meet the company's minimum requirements for processing. The chips or fries produced from a potato lot must be light in color. A french fry processor can manipulate the frying process to vary product color; however, a chip processor has very little control over the color of the final product. Dark chips and fries are produced from potatoes with high sugars.

Fresh Potato Grades — Table potato grades are defined in federal regulations called the Canadian Agricultural Products Standards Act. Alberta legislation provides for grades that differ from federal grades; however, these special grades apply only to potatoes marketed in Alberta. Currently there is an Alberta grade, Alberta No. 1 Small, that allows for small potatoes, 25-50 mm (1-2 in.) in diameter, to be marketed in Alberta, from July 1 to September 15 of each year.

There are four Canadian grades for potatoes: Canada No. 1, Canada No. 1 Large, Canada No. 1 Small and Canada No. 2. The majority of Alberta potatoes are marketed as Canada No. 1 or Canada No. 2.

Following is a summary of potato grades. Contact the Food Production and Inspection Branch for assistance with grade definitions. **These descriptions are for information only and have no legal authority.** The responsibility for complying with the official grades lies with the person or agency packaging the potatoes.

Canada No. 1 potatoes have similar varietal characteristics; are firm; are not pointed; dumbbell shaped or deformed; have well-set skins; are reasonably clean; are free from damage, decay and injury. Round potatoes have a minimum diameter of 57 mm (2.25 in.) and a maximum diameter of 90 mm (3.5 in.). The size regulations for long cultivars is somewhat more complicated and packers should become familiar with them. Long varieties have a

minimum diameter of 50 mm (2 in.) and a maximum diameter of 90 mm (3.5 in.); however if tubers are at least 90 mm (3.5 in.) long then they may have a diameter of 45 mm (1.75 in.); BUT in all cases, Canada No. 1 (long) potatoes must have a diameter of at least 57 mm (2.25 in.) in at least 60 per cent of the lot by number.

Canada No. 1 large potatoes have a minimum diameter of 75 mm (3 in.) and a maximum diameter of 115 mm (4.5 in.). Canada No. 1 Small potatoes have a minimum diameter of 38 mm (1.5 in.) and a maximum diameter of 57 mm (2.25 in.). Both of these grades comply with the other requirements of Canada No. 1 potatoes.

Canada No. 2 potatoes are similar to Canada No. 1 potatoes in their general appearance; however they differ in size. They have a minimum diameter of 45 mm (1.75 in.) and a maximum diameter of 115 mm (4.5 in.) but have a diameter of not less than 50 mm (2 in.) in at least 75 per cent of the lot by weight.

The regulations provide for New Potatoes that are shipped before September 15 of the crop year. They must comply with other Canada No. 1 regulations; however, they can be smaller. Round and long potatoes shipped before September 15 can have a minimum diameter of 48 mm (1.9 in.).

The regulations recognize the difficulty in fitting biological specimens into rigid categories and therefore have allowable tolerances. Generally lots may contain undersized or oversized potatoes up to 5 per cent by weight. They also allow for specified quantities of tuber defects.

Metric Conversion Table

Approximations:

- 0.5 hectare = 1 acre
- 1 kg/ha = 1 lb/ac
- 1 metre = 1 long yard
- 1 kilogram = 2 heavy pounds
- 64 hectares = one-quarter section

One hectare is 100 m x 100 m or 10,000 m²

One one-quarter section measures 800 m x 800 m =

640,000 m² = 64 ha

Metric Weights and Measures

- 1 cc = 1 mL = 1 gram (of water)
- One litre = 1000 mL (or 1000 cc)
- One cubic metre = 1000 L
- One cubic metre water = 1000 L = 1 tonne
- One tonne = 1000 kg
- One kilogram = 1000 g
- One metre = 100 cm
- 1000 metres = 1 kilometre

For exact conversion use the following:

To Convert	Into	Multiply By
Hectares	Acres	2.47
Square metres	Square feet	10.76
Kilograms/hectare	Pounds/acre	0.9
Tonnes/hectare	Tons/acre	0.47
Tonnes	Tons	1.1
Litres	Gallons	0.22
Litres/hectare	Gallons/acre	0.09
Metres	Feet	3.2
Kilometers/hour	Miles/hour	0.6
Metres/minute	Feet/minute	3.28
Centimetres	Inches	0.4
Millimetres	Inches	0.04

INFORMATION SOURCES FOR POTATO GROWERS

Information or Assistance Required	Contact	Address & Phone
Licencing, marketing, seed potato sources	Jan Brown Ed Van Dellen	Potato Growers of Alberta Suite 230, Stockman's Centre 2116 - 27 Avenue, NE Calgary, AB T2E 7A6 Tel. 291-2430, Fax 291-2641
General potato production information	Clive Schaupmeyer	Alberta Special Crops and Horticultural Research Center, SS4, Brooks, AB T1R 1E6 Tel. 362-3391 Fax 362-2554
Pre-Elite seed, potato seed production information	Jim Letal	Alberta Tree Nursery and Horticulture Centre R.R. 6 Edmonton, AB T6H 5T6 Tel. 422-1789, Fax 472-6096
Seed certification, inspection of farm for seed production, seed regulations	Terry Petrow	Potato Certification Program Feed Production & Inspection Branch Agriculture Canada 220 - 4th Ave. S Calgary, AB T2G 4X3 Tel. 292-4986, Fax 292-6629
Potato storage design	Dennis Darby	Alberta Agriculture Service Center, Lethbridge, AB T1J 4C7 Tel. 329-5114
Disease control	Dr. Jim Holley	Alberta Special Crops and Horticultural Research Center SS4, Brooks, AB T1R 1E6 362-3391, Fax 362-2554
	Jim Letal	Alberta Tree Nursery & Horticultural Centre R.R. 6 Edmonton, AB T5B 4K3 Tel. 422-1789, Fax 472-6096
Insect control	Jim Jones	Alberta Special Crops and Horticultural Research Center SS 4, Brooks, AB T1R 1E6 362-3391, Fax 362-2554
	Michael Dolinski	O'Donoghue Building 7000 - 113 Street Edmonton, AB T6H 5T6 Tel. 427-7098, Fax 142-9745
Weed Control	Rudy Esau	Alberta Special Crops and Horticultural Research Center SS 4, Brooks, AB T1R 1E6 Tel. 362-3391, Fax 362-2554
Irrigation & Fertilization	Dr. Colin McKenzie	Alberta Special Crops and Horticultural Research Center SS 4, Brooks, AB T1R 1E6 Tel. 362-3391, Fax 362-2554