Value-Added Crops

Agriculture in the Classroom

Agriculture in the Classroom **99 Study Series**

Agriculture in the Classroom

Agriculture In The Classroom (Sask) Inc. is a non-profit organization funded by the agri-food industry with assistance from Saskatchewan Agriculture and Food. AITC is mandated to assist Saskatchewan learners and educators in increasing their awareness and understanding of the complexities and importance of agriculture through partnerships with educators, agri-business, and agriculture organizations. AITC's efforts enable more people to make informed choices and decisions related to food, the environment, lifestyles, and agriculture practices.

The agriculture and agri-food industry in Saskatchewan makes a significant contribution to the provincial economy, to the well being of both rural and urban communities, and to the environment. This industry is constantly evolving from the traditional family farm to large international agri-businesses. It is important to provide the general public with a greater awareness and understanding of industry changes and the impact they have on Saskatchewan people.

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While the material in this publication is deemed reliable and accurate to the best of AITC's knowledge, author contributors of the materials to this collaborative effort are solely responsible for the content and information which they have contributed to produce this booklet. The views of the authors and contributors do not necessarily represent the views of AITC.

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Value-Added Crops

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Value-Added Crops
Spices

Caraway

Coriander

Fenugreek

Spices and herbs have played a dramatic role in the development of Western civilization.

The numerous spices common today are used mainly for flavourings.
In ancient and medieval times, spices were considered rare and precious products and were used for medicines, perfumes, incense and flavourings. Herbs are the leaves, roots and flowers of plants and are mainly grown and processed for culinary, cosmetic, industrial, medicinal, landscaping, decorative and fragrance purposes. Spices are seeds, root, bark and flowers of plants that are grown, harvested and processed for use as food or beverage flavourings.

Several trends have been identified as contributing to the increased demand for herbs and spices: the trend toward a healthier lifestyle, increased acceptance of ethnic foods, greater consumption of convenience foods, and the growing market of medicinal herbs.

Saskatchewan Industry

The spice industry in Saskatchewan has grown significantly and continues to expand. The farm crisis of the 1980s stimulated prairie farmers to diversify their production and consequently they have become the most diversified group of producers in North America. The consumer move to demanding natural products as opposed to synthetically-produced spices has been instrumental in the development of the industry. This has resulted in the need for marketing and processing of the new crops being grown. As Saskatchewan farmers

Saskatchewan Spice

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Spices are one of the oldest traded commodities in the world

became involved in growing herb and spice crops, the Saskatchewan Herb and Spice Association was formed to help the industry along. Its role has been to: provide information about production techniques and market promotion; to hold conferences and crop tours; and to assemble the Grower's Guide to Herbs and Spices.

Support has been forthcoming from the Crop Development Centre at the University of Saskatchewan, Saskatchewan Agriculture and Food, and Agriculture and Agri-Food Canada. Since the early 1990s, research and development have been conducted on agronomic requirements, variety trials, methods of processing and on alternate end uses. A new spice breeding program has been added to the mandate of the Crop Development Centre. Dr. Bert Vandenberg is continuing to investigate the potential for successful herb and spice production in Saskatchewan.

There is a wide range of spices grown on the prairies, including coriander, dill, caraway, fenugreek, anise, cumin, monarda, mint and mustard. Uses for these spices vary. Some are used in dried form and include using the seed or vegetative parts of the plant (leaves and flowers). Other uses involve processing for the extraction of essential oils, that contain a high concentration of the aromatic and/or flavour components. Other potential uses are as forage crop for hay and industrial production.

Spices are one of the oldest traded commodities in the world. Most spices used in North America are imported from places that are traditional producers and consumers of spices, such as Mediterranean countries, Egypt, Israel and Europe. Markets in North America are, however, large and include the abundant urban areas on the east and west coasts of the continent. As a supplier to this market, Saskatchewan is a newcomer and, therefore, must prove itself to consumers. Farmers interested in growing spices need to be aware of price and market fluctuations and should investigate markets before seeding. It is a good idea to have a pre-arranged market with a processor or other buyer before production.

The future for spice production is bright, although the spice market can be unstable, regulations may be rigorous, and buyers can be subjective. Demand for natural products is increasing and Saskatchewan is perceived to have a clean natural environment. Compared to other areas, the production costs are low, yields are high and the industry can supply good quality products and service. The processing industry is also developing. In 1995, a report stated that spices produced in Saskatchewan were bagged and trucked out of province to be processed elsewhere. By 1997, there were two processor in Saskatchewan, Maple Ridge Farms Inc. in Prince Albert and Assiniboia Extractors. Cleaning is important as most consumers will not tolerate extraneous material such as insect parts and excrement. A high oil content is desirable for extraction.

Essential Oils

Essential oils extracted from seed have many uses. Most of the essential oils extracted in Saskatchewan are exported to the United States. These oils are volatile (evaporate quickly) and consist of the distinctive aroma and flavour of a specific plant. They are used in perfumes and cosmetics, and to flavour food, beverages, gum and toothpaste. They are very concentrated; for example, one or two drops of dill oil can flavour one jar of commercially produced dill pickles. Growing conditions significantly affect the quality of essential oils. The photoperiod (light intensity), temperature (i.e., daytime highs and night time lows) and soil quality will all have an effect on characteristics of the oils. As well, agronomic practices, including varying use of chemicals, fertilizers, and irrigation, will have an effect on oil characteristics. Extraction methods can influence quality. Buyers use two tests to determine quality: 1) Objective Test; and, 2) Subjective Test. The Objective

Test uses gas chromatography to measure quantity of components, and can also detect contamination. The Subjective Test is done by smell and is similar to wine-tasting.

Extraction methods include expeller pressing, steam distillation and chemical distillation. Of these methods, expeller pressing can extract about 75 per cent of the oil and produces the most aromatic, flavourful oil and meal. The meal is a by-product and is used mainly for animal feed but it has potential for use as a spice flour for baking and cooking. Spice essential oils, besides being used as flavourings, medicinal and food preservatives, also have industrial uses in paint strippers and solvents. Their utility extends to practical use as a fungal retardant in stored vegetables and as a sprout inhibitor in the seed potato market.

Mustard

Mustard belongs to the same family as canola, *Brassica*, and has been grown in Saskatchewan for many decades. The end products of mustard seed reflect the end uses of most spices grown. As a condiment spice, it is used in prepared mustards, sauces, flavourings and pickling. It is used as a food additive, protein extender and binding and thickening agent. Ground mustard is an ingredient in processed meats; mustard flour (dry mustard) flavours mayonnaise, salad dressings and some processed cheese products; and mustard bran is used to thicken sauces and soups. The oil extracted from mustard seed is used as an edible oil in the Indian sub-continent and as an additive in livestock feed. Essential oils have medicinal and food preservative properties. The meal that remains after oil extraction is used as livestock feed and fertilizer.

Other Spices

Dill, caraway, anise, and coriander all belong to the *Umbelliferae* (carrot) family. Anise is licorice flavouring and is used exclusively as a spice condiment and flavouring. Dill, caraway, and coriander are used to flavour soups, sauces, baked goods and pickles. Coriander is a major ingredient in Curry Powder and is used in manufacturing gin. Dill and caraway are used extensively in the bakery business to flavour pumpernickel and rye breads and bagels.

Fenugreek is in the *Leguminosae* family and can fix atmospheric nitrogen which reduces its need for nitrogen fertilization. It is used as maple flavouring, in medicines, as a protein additive and thickening agent, and also has anti-fungal properties.

Growing Spices

Trials analyzing agronomic requirements have only been conducted for a few years but will continue alongside a breeding program for hardy varieties. In general, these trials have shown that seeding rate for spices should be on the high side in order to produce a dense enough plant canopy to successfully compete with weeds since few herbicides are registered for use in these crops. Because most spices are small-seeded, seeding depth should be shallow. Application of fertilizer shows varying, but always positive, response. Disease and pest problems have been minimal so far, partly due to the presence of the essential oils the plant produces. These natural oils can attract birds and bees to aid in pollination and can also repel insects and parasites. Shattering (seed containers break and release seed) can be a problem so swathing is recommended and combining should take place in cool damp conditions (e.g., early morning).

As the saying goes, ‘variety is the spice of life’ and certainly spices have added to the variety of the Saskatchewan landscape. They have also contributed to the value-added economic base and are environmentally valuable in crop rotations because they can break some disease and pest cycles and are grown with minimal chemical application.

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Black Bean

Great Northern Bean

CDC Gold

Green Pea

Pulses provide the base for fine cuisine.

Peas

Desi

Pinto Beans

Eston Lentils

Kabuli

Red Mexican Beans

Laird Lentils

Yellow Peas

Value-Added Crops
Pulses

Lentil Field

The history of pulses dates back more than 10,000 years and spans the globe. Graphic records of their use have been found in the Egyptian pyramids. In Switzerland dry peas were discovered in a village dating back to the Stone Age. Lentils, sometimes thinly coated with gold, were one of the favorite dishes of the ancient Greeks. In Britain, peas were grown as early as the 11th century. Pulses played a colourful part in the history of North America as well. Hearty pea soup was introduced to Canadians by the French settlers. Baked beans were considered a staple for western ranchers riding the winter trail. They froze beans in batches, carved off their daily portion, and heated it over an open fire.

Where are Pulse Crops Grown in Saskatchewan?

The southern and western agricultural zones (brown and dark brown soils) are characterized by a long, hot growing season, with drought stress usually occurring in July and August. This is an ideal climate for top quality lentil and chickpea production. Dry peas are adapted to all of the growing regions. They do especially well under the cooler conditions of the northern and central agricultural zones (black and moist dark brown soils). Beans and faba beans are not widely produced and are susceptible to frost and drought. They are best produced under irrigation or in the thin black and moist dark brown soil zones.

Pulse Production

Between 1989 and 1999, Saskatchewan's pulse industry has grown by 900 per cent from 380,000 acres in 1989 to 3.25 million acres in 1999! The industry now accounts for about 15 per cent of farm crop receipts. This strong growth in pulse crops is projected to continue, reaching between six to eight million acres by 2010.

Canada is the world's leading exporter of peas and lentils with the bulk of production occurring in Saskatchewan. It is projected that Saskatchewan will also become the world's leading exporter of chickpeas by 2010.

What are Pulses?

Peas, beans, lentils, chickpeas and faba beans are pulse crops grown in Saskatchewan. The word "pulse" is derived from the Latin word, "puls", a potage or thick soup, and is used to describe the edible seeds of legumes.

New cultivars of peas, lentils, chickpeas and beans have been developed for Saskatchewan's growing conditions by the Crop Development Centre at the University of Saskatchewan. This will also increase Saskatchewan's competitiveness in world markets.

How Are Pulses Produced?

Lentil, pea and chickpea crops are typically seeded in late April and early May. Bean crops are seeded in late May to avoid late spring frosts.

A variety of seeding equipment is used, however many farmers are now moving to high capacity air seeders that require little or no seed bed preparation. This improves seeding efficiency, reduces soil tillage and provides an ideal environment for crop growth.

Pulse seeds are treated with an inoculant of Rhizobium bacteria to aid in nitrogen fixation, reducing dependence on nitrogen fertilizers. Most lentil and pea fields are rolled shortly after seeding to level the seed bed, break up lumps of soil and push stones into the ground. This allows the producer to harvest a cleaner, higher quality crop.

Harvest begins in August, usually in the southern-most parts of the province first. The lentils are either swathed first, allowed to sun-ripen, and then harvested, or treated with a crop desiccant which dries the peas enabling them to be direct-(straight)combined. In less favourable harvest conditions, the option of desiccating and combining can reduce the time requirement for harvest, thereby producing a superior product.

Peas can be swathed and, later, combined or direct-combined, depending on the producer's production system. Chickpeas are often direct-combined when mature. Beans are either undercut and windrowed before combining, or are direct-combined when mature.

Saskatchewan's cold winter climate is ideal for the storage of pulse crops. Temperatures are below freezing for six months of the year. Stored seed does not need to be treated with insecticides! This gives Canadian pulses an advantage over many foreign competitors.

Pulse crops have been an integral part of the shift from a wheat/fallow system to a more diversified system of crop rotations. Pulse crops are environmentally friendly as they fix nitrogen in the soil, reducing the need for nitrogen fertilizers. They also help build the quality of the soil.

What Challenges Do Producers Face?

Pulse crops generally require a significant investment in inputs (often up to $250/hectare) before the crop is harvested. Variable climatic conditions, pests and diseases all have a large influence on crop production and quality. This introduces a high degree of risk to producers. Producers market pulses in an open system. Although this provides producers with a great deal of flexibility it also requires the ability to understand how to market.

What Happens to Pulses After They Leave the Farm?

In 1998, Saskatchewan had 128 special crops processors (mostly pulse crops) employing more than 1,000 persons. The processors perform many operations depending on the market requirements. Some of these include cleaning, bagging, colour sorting, and splitting.

Some processors are affiliated with a grain company and others do their own marketing. Grain marketing companies sell products for both domestic and export use. In fact, Canadian peas, lentils, chickpeas and beans are exported to Europe, Africa, Asia, Middle East, and the Americas. The majority of the domestic use is in livestock feeds although there is a growing market for specialized human consumption.

Pulses in a Healthy Diet

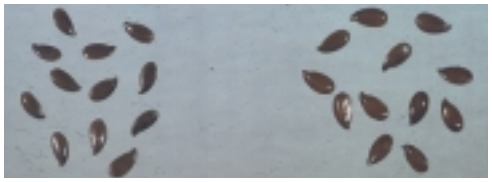
Peas, beans, lentils and chickpeas fit the overall healthy eating pattern encouraged by Canada's Food Guide to Healthy Eating. They are low in fat and good sources of protein, starch and fibre. For more information on the benefits of pulses and their preparation, refer to the cookbook *Discover the Pulse Potential*, available through many bookstores.

Saskatchewan Pulse Growers

Today, the Saskatchewan Pulse Growers represent more than 15,000 pea, lentil, bean and chickpea producers in Saskatchewan. A levy system enables this producer-run organization to support the pulse industry in the areas of research, extension and market development.

Flax Field

Flax Flower



Flax Seed

Value-Added Crops

Flax

Flax Bolls

Flax (*Linum usitatissimum*) has been grown in Saskatchewan since the formation of the province in 1905. The earlier flax crops were grown mostly for industrial oil uses and, to a lesser extent, for food and fibre.

Today flaxseed is also promoted as a functional food and the nutraceutical of the 21st century. It has been suggested that flax can aid in the prevention of cancer, coronary heart disease and sudden death from heart arrhythmias. Flaxseed supplies many essential nutrients including protein, essential fatty acids (EFAs), vitamins and minerals. Flax is also a source of soluble and insoluble dietary fibre and lignans.

Studies show that eating 50 grams of flaxseed a day can decrease total blood cholesterol levels and low density lipid cholesterol (LDL) levels, decrease the risk of heart disease and provide relief from constipation. Lignans and alpha-linolenic acid, an omega-3 fatty acid, contained in flaxseed have been indicated as having anti-cancer properties.

Since 3000 BC, cultivation of flax has been recorded for use both as food and clothing (linen) from the fibre. Around 650 BC, Hippocrates wrote about using flax for the relief of abdominal pains and Theophrastus recommended the use of flax mucilage as a cough remedy. King Charlemagne passed laws requiring the consumption of flax because he considered it important for health. Flax has been utilized over the centuries in many ways including use as a hot compress for treating both internal and external ailments.

Flax is a dicotyledonous plant. This means the seed contains two cotyledons which produce the first "leaves" as a seedling emerges. The cotyledon is green and can photosynthesize to provide the plant with energy and nutrients before the "true leaves" emerge. Flax plants have a single stem with narrow leaves. Flowers appear at the top of the stem on several branches. Flowering parts are always in units of five (sepals, petals and stamens). Flowers are usually blue, sometimes pink and white, and

Healthy Flax

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open shortly after sunrise; petals are shed in early afternoon. As the plant ripens, bolls or capsules are formed with five segments, each containing two seeds for a total of 10 seeds per boll. The boll turns brown when ripe; seeds will be loose and the boll will rattle when shaken.

Uses for Flax

Flaxseed can be used as food and is found in baked goods such as breads, muffins, bagels and cookies. Flaxseed adds a nutty flavour and it can be used as whole grain or flour. As well, chickens fed flaxseed produce omega-3 enriched eggs. Omega-3 fatty acids can reduce cholesterol and enriched eggs contain eight to 10 times more omega-3 fatty acids than regular eggs. Meat from chickens fed flaxseed is also rich in omega-3 fatty acids. Research is under way analyzing the feeding of flaxseed to dairy cattle to alter the fatty acids structure of dairy products. The pet food industry is also interested in flax since pets can reap the same health benefits as humans from consuming flaxseed.

Industrial uses for flax are becoming more popular again because flax is environmentally friendly. Linseed oil (from flax) is used to give furniture a durable finish that shows off the natural beauty of wood; it is also used as a paint base. Linoleum flooring is made from flax and is biodegradable when discarded. Flax products can also make concrete stronger and longer-lasting.

Linen made from weaving flax fibre makes beautiful and strong clothing which is a current favourite in the fashion industry. Biolin, a Saskatoon company, is researching and developing a method for growing fibre flax in Saskatchewan. Biolin is a locally-owned and operated company, at Innovation Place, that contracts the growing of fibre flax for sale all over the world, particularly in Pacific Rim countries.

Researchers at the Crop Development Centre at the University of Saskatchewan in Saskatoon have developed a new edible oilseed from flax called solin, which is of cooking grade. Oil from this seed is called solin oil. Solin seed has a yellow seed coat compared to the traditional brown seed coat of flax. Solin and flax are grown using the same agronomic practices. There are other yellow-seeded flaxes grown in other parts of the world that may be sold in Canada in health food stores, but they are not solin.

Growing Flax

Flax can be grown on fallow or stubble fields, and is predominantly a stubble-grown crop in continuous crop rotations. It is not recommended to grow flax on canola or mustard stubble. Flax has a long growing season and is usually one of the first crops seeded and last crops harvested. Seeds are often treated with a fungicide to avoid fungal diseases that can kill seedlings and lower yields. Flax will do well under irrigation. An ideal plant stand is about 300 to 400 plants per square metre.

Weeds can be a problem in flax crops because flax is a non-competitor with most other plants. Because the flax canopy (plant cover) is not as good as in canola or cereal crops herbicides are used to control weeds which can be a serious problem. Insect pests can be a problem and fields should be inspected regularly to assess damage. However, insect pests do not occur in sufficient numbers in Saskatchewan to cause economic loss of yield. The flax bollworm is one of a few insect pests that attack only flax. Diseases that can affect flax include rust and wilt, and plant breeders are working on resistant varieties. Control of diseases can be achieved by careful management practices, for example, allowing at least three years between flax crops in a rotation and avoiding legumes, sugar beets and potatoes in a rotation.

Harvesting occurs when the crop is considered ripe, that is, when 75 per cent of the bolls have turned brown. Swathing followed by combining is a preferred way to harvest flax (as opposed to straight combining) because the crop often ripens unevenly and swathing allows time for the crop to dry and ripen. Flax straw is tough and fibrous and breaks down slowly. It is, therefore, difficult to handle and must either be chopped, baled or burned. Because there is little plant residue on flax stubble, it is a good idea not to use summer-fallow the following year as soil erosion can occur. Flax seed must be carefully stored as it is more inclined to spoil or overheat during storage. Insects can also be a problem and care must be taken to ensure the seed is kept dry and cool to avoid infestation.

Conclusion

Flax seed is marketed and sold to processors where it is packaged as whole seed, made into flax flour, or pressed or crushed to make oil. Production of flax has increased on the prairies following the increased popularity of flax as a functional food. It is an important economic and agronomic crop for farmers to add to their rotations because they can reduce the risk that can be associated with relying on market prices for other crops. These crops can vary from year to year, sometimes with devastating effects when prices get very low. Used in crop rotations, flax can reduce disease and weed problems that occur when cereals are grown year after year on the same field. Flax fields add an aesthetic element to the landscape with a ‘sea of blue’, especially when grown next to a brilliant yellow canola field.

Hulled / Hull-less Barley

Wheat Field

Value-Added Crops
Cereals

Barley Field

Cereal crops have been grown in Saskatchewan since the settlers first arrived in the late 1880s and are some of the oldest domestically-grown crops in history. There are several theories about where agriculture originated. Scientists estimate humans have existed for about 75,000 years and most societies were nomadic hunter-gatherer cultures. The practice of agriculture requires people to stay in one place.

Around 9000 BC, humans began to cultivate crops. Recent theories suggest there were three main areas where the cultivation of crops originated and from which they extended. These include: the Fertile Crescent in Mesopotamia, now Iran and Iraq, and expanded to Africa; Central America (Mexico) with sub-areas in South America (Peru); and, in China with sub-areas in Southeast Asia. Cereals are grasses and belong to the *Poaceae* family of plants. They are monocotyledons, that is, they have one cotyledon, the part of the seed that emerges first and can photosynthesize before the first leaves emerge and begin photosynthesizing themselves. The process of photosynthesizing involves capturing energy from the sun to provide nutrients for the growth of the plant. The grass family is a large, widespread and variable group of plants that will survive in an extensive range of environments. These crops provide about 70 per cent of the world's nutrition and contain between 8 per cent and 15 per cent protein.

There are many different cereal crops: wheat, barley, oats, rice, corn, sorghum, rye and millet. All of these crops are grown in Saskatchewan to some extent. Corn is mostly grown as a vegetable crop, since the growing season in Saskatchewan is not long enough or hot enough for field corn. Sorghum is sometimes grown for feed and canary seed (a millet) is grown for the pet food market. Wild rice is grown in northern Saskatchewan for the specialty food market.

The main cereal crops that are traditionally grown in Saskatchewan are wheat, barley, oats and rye. These crops, especially wheat, have provided the mainstay for Saskatchewan farmers since settlement. They still make up most of the agricultural production despite diversification to some other crops, such as oilseeds, legumes and spices. Variable acreages of oats and rye are also grown.

The main cereal crops traditionally grown in Saskatchewan are wheat, barley, oats and rye.

Wheat

There are many types of wheat grown on the prairies: hard red spring (HRS), hard red winter (HRW), soft red spring (SRS), durum and Canadian prairie spring (CPS). Each has different characteristics and each has its own end use. Some are best for bread making, for cake and pastry flour, for commercial cereal, for pasta making and for livestock feed. Some wheat is made into ethanol which is mixed with gasoline to produce a fuel that emits lower carbon dioxide, a greenhouse gas. Ethanol production could play an important role in the recent drive to reduce greenhouse gas emissions.

HRS is a high-protein, high-quality wheat and is the best wheat for making bread. HRS grows well on the prairies and is in high demand around the world for mixing with lower-quality wheat for bread flour. HRW wheat does not have as high a protein content but is the major wheat traded on the world market. HRW is a fall-seeded crop as it requires vernalization (exposure to cold) in order to grow. A rosette (a short tight bunch of leaves) forms in the fall. As winter sets in, the leaves and roots die but the crown survives and growth continues from there in the spring. Winter wheat acreage varies in Saskatchewan. It is best grown on stubble because it provides protection from wind and cold. The stubble also traps snow and adds moisture to the soil. Another advantage of fall-seeded wheat is that it saves time for the farmer in spring because there is not as much seeding to do. The fall-seeded wheat will also be ready for harvest sooner than spring-seeded crops, thereby more evenly distributing the farmer's work load.

Durum wheat has a yellow-coloured kernel and is the wheat of choice for making pasta. It is a "bearded" wheat, having long awns on the seed head and is grown in Saskatchewan and the northern United States. There have been attempts to build pasta-making plants in Saskatchewan in order to benefit from value-added processing (this means adding value to a raw commodity before it leaves the province or reaches the consumer).

Canadian prairie spring (CPS) wheat is high-yielding, low-protein wheat produced by researchers in response to the change in the world wheat market. In the 1970s many European countries decided they would be self-sufficient food producers and subsidized their agricultural production to the point where there was a glut of wheat on the world market. This action lowered prices, so alternate wheat types were developed and CPS is one that has a unique end use. It is used for ethanol production and the waste meal is used for livestock feed. Poundmaker, an ethanol plant and feedlot are co-located at Lanigan, Saskatchewan.

Oats

Oats was once the fourth largest crop grown in Saskatchewan and the world; it was used primarily for horse feed. This decreased in the1950s when horse power was replaced in agriculture by machines. Oats has the hull attached, as well, but it is loose and easily removed. The primary use for oats is still as horse feed (85 per cent). Canadian oats is of high quality and much in demand for the thoroughbred horse industry in the United States. Approximately 10 to 15 per cent of oats produced is used for human consumption. They are popular in the health food industry as they contain a complex carbohydrate or glucose polymer (beta-glucan) that reduces blood cholesterol levels in humans. Some oats are uniquely processed into components for use in the cosmetics industry.

Barley

Barley grown in Saskatchewan has two main end uses: as a livestock feed (85 per cent) and as making malt (14 per cent) for the brewing industry. Some barley (one per cent) is consumed by humans as pot or pearl barley for use in soups and some ethnic dishes. It has adapted better than wheat to growing on the prairies. It is drought- and saline-tolerant, has a shorter growing season and maintains better yield under stress. There are two types of barley: six-row and two-row. This means the seeds form on the head in six or two rows. When threshed, barley retains some seed parts on the kernel, unlike wheat. This provides protection to the seed and plays a role in the malting process. This is referred to as hulled barley, but some hulless types of barley exist. Barley has blue and white seed coat colours.

Barley is valuable for use as animal feed because it contains lysine (an essential amino acid) that other feeds, like corn and wheat, do not contain. For use as feed, barley is dehulled (hull removed) and chopped for mixing with other feeds. During the malting process, barley seeds are germinated under 100 per cent humidity and cool temperatures (13º - 16º C). This process releases enzymes that convert starch in the endosperm into glucose sugars. These sugars are used in the brewing and distilling industries to produce alcohol. Uniformity is important in the malting process. Two-row barley is preferred as the seeds are not crowded growing in the head and tend to be of uniform size.

Rye

At one time rye was the major food cereal crop. It is still used for bread making but now its major use is as livestock feed. There are two types: spring-seeded and fall-seeded rye. It is high-yielding and very adaptable as it is cold- and drought-tolerant. It also does well in wet conditions and, therefore, can grow quite far north. There are advantages to seeding fall rye: it overwinters well, benefiting from spring moisture; it can be used for soil erosion control; and, it is very competitive with weeds, especially wild oats. It is used in livestock feed but at low rations because it contains pentosans (gummy substances) that slow digestion and create "sticky feces". It is also used in the distilling industry to make whisky. Some forage species of rye are grown as pasture crops, such as Altai wild rye and Russian wild rye.

Triticale

Triticale is a man-made cereal developed in the early 1950s from crossing wheat and rye. The cold tolerance of rye was not passed on in this species, but it is high-yielding and can be grown on acidic soils. It does not have the bread-making qualities of wheat so it is used mostly as feed grain and, in the food industry, for making crackers. It has good potential for Saskatchewan, but is a new crop and breeding programs are still under way.

Canola Field

Value-Added Crops
Canola

Canola is a relatively new crop and the first "double-low" variety (low in glucosinulates and erucic acid) was developed on the Prairies by Dr. Baldur Stefansson at the University of Manitoba in 1974. At the same time, parallel work was being done by Dr. Keith Downey at the Agriculture and Agri-Food Canada Research Centre in Saskatoon. The history of canola begins with the rapeseed plant which belongs to the Brassica genus.

Rapeseed has been grown on the Prairies since the early 1940s when the oil from the seeds was used to produce industrial-grade marine oil. Unfortunately, certain constituents prevented it from being used for human consumption. It contains glucosinulates, sulphur-based molecules that produce a sharp taste, and licosenic and erucic acids (long chain fatty acids). In the early 1970's Dr. Downey was able to alter rapeseed using conventional breeding methods and lower the levels of these components. The name canola comes from combining the words "Canadian" and "oil".

Canola is grown primarily in Western Canada. Fields of the yellow flowers are seen every summer in all soil zones of Saskatchewan. Farmers can use the same seeding and harvesting equipment for canola as they use in the production of cereal crops. Canola is a cool season crop that thrives in the long days of light and cool night temperatures of prairie summers. Each plant can grow anywhere from 0.6 metres (2 feet) to two metres (5 feet) tall. Clusters of four petaled yellow flowers form at the end of long racemes. Seed pods (called siliques), that are about 5 centimetres (2 inches) long and contain 20 or more green seeds, develop from each flower. As the seeds mature they become black or brownish-yellow in appearance and contain at least 40 per cent oil, giving canola the classification of oilseed crop.

Canola

is known in the industry as the "Cinderella Crop"

Types of Canola

Two types of canola are grown, a short growing season Polish type (*Brassica rapa*) and a long growing season Argentine type (*Brassica napus*). Careful management is required on the part of the farmer to insure the crop does not become diseased. Two main fungal diseases attack canola; sclerotinia and blackleg. Fungicides are sometimes applied to prevent crop losses.

Seeds are smaller than radish seeds and need a shallow, moist seed bed. Germination takes 4 to 10 days and seedlings form a rosette (a short tightly packed formation of leaves) from which the flower stock grows taller. Flowering lasts 14 to 21 days. Argentine canola is largely self-pollinating while the Polish type is cross-pollinated by bees or wind. After fertilization, the pods form and take 35 to 45 days to fill. After the seeds have ripened, the crop is swathed and dried for about 10 days before being combined. Canola can also be straight cut (direct-combined).

Pests

During the growing season, canola fields can be damaged by pests such as weeds and insects. Insects damage crops by eating leaves, flowers and pods. This reduces yield and can sometimes destroy whole crops. Weeds compete with canola plants for nutrients and water. However, as canola plants mature, they form a tight dense canopy and are then highly competitive. Pesticides, that go through a rigourous registration process, are used to prevent or reduce crop loss. Any chemicals used must be registered with the federal government and assessed by the provincial government regarding application.

Some of the pests that attack canola are becoming resistant to registered chemicals and new pests are appearing for which there are no registered pesticides. Some canola varieties resistant to pests and disease are available but losses still occur. Farmers are encouraged to utilize Integrated Pest Management (IPM) strategies. To be successful, IPM should reduce cost and risk for the producer while not increasing risk to the consumer. "IPM is a sustainable approach to managing pests by combining biological, genetic, physical and chemical tools in a way that minimizes economic, health and environmental risks" (Canola Council of Canada). An IPM strategy would include: using disease-resistant canola in a crop rotation to break disease cycles of cereal or legume crops; forecasting insect populations; scouting growing fields to determine if pest levels and conditions are present that would pose economic losses; and, using appropriate pesticides to control the problem. The strength of IPM is that it reduces reliance on any single control mechanism. Such reliance encourages the development of resistance to that single control technique. IPM uses all available control options, not necessarily the one lowest in cost.

Biotechnology

Biotechnology plays a role in canola production. Biotechnology is a term that outlines a broad set of scientific methods developed during the 1970s and 1980s. Generally, biotechnology refers to the study of how technology can be applied to living (or life) processes. Some people use it more narrowly to refer to genetic engineering through which genes of plants, animals and microbes are isolated and manipulated to change the genetic profile of these organisms for specific purposes. In canola, specific genes from another plant may be transferred to the canola plant without introducing undesirable traits. Biotechnology can improve the nutritional value of canola (for example, by increasing the oleic acid level, that lowers the undesirable low-density lipoprotiens (LDL) without affecting the desirable HDLs) as well as the agronomic characteristics (such as disease resistant varieties).

Through conventional breeding and/or

genetic engineering, canola has been modified to improve its nutritional value by manipulating the fatty acid profile for different uses. High stearic and lauric acid canola has been developed. High stearic acid canola is used to produce solid margarine without hydrogenation, a process that produces trans-fatty acids which may have negative effects on health. High lauric acid canola is used for food applications such as confectionery coatings, frostings and icings. These canola oils are also used in the detergent and soap industries, replacing imported palm kernel and coconut oils.

Biotechnology has been used to develop crop varieties resistant to certain herbicides. Application of herbicide to herbicide-tolerant canola kills the competing weeds but not the canola. This can lower costs of production for growers. Research is under way to modify canola so it will be resistant to insect and disease infestations as well. This will reduce the amount of chemical applications needed to control these pests. All in all, farmers will have access to canola varieties with improved agronomic performance traits such as yield, disease and pest resistance, and environmental stress (for example, drought). Another benefit of herbicide-tolerant canola is the soil conservation aspect due to reduced tillage, a practice traditionally used to control weeds.

One problem with genetically-modified canola products is that the European market will not import any genetically-modified organisms (GMO). At this time, European consumers are not comfortable with eating GMOs in their food supply even though research to date has found no health problems associated with foods containing GMOs.

Processing

Processing canola (crushing canola seed) produces two products: cooking oil for human consumption and meal which is used as a high protein supplement in feed rations for poultry, swine, cattle and fish. Strict procedures, among the most modern in the world, are followed in processing resulting in high quality end products. The oil produced from crushing seeds makes up approximately 78 per cent of the total production of edible oil in Canada. Canola oil is low in saturated fats and contains essential fatty acids (EFA) required for good health.

The crushing process has various stages. First, seed is cleaned to remove weed seeds and debris. Next is a preconditioning phase where seed is treated with mild heat and moisture. Then seed is rolled or flaked to increase the surface area to maximize oil recovery. Oil is mechanically removed using screw presses or expellers which condense the flakes into denser cakes referred to as ‘press cakes’. This procedure is sometimes repeated and oil produced in the first stage is sold at a premium as ‘First Press’ or ‘Expeller Press’ and marketed in specialty food stores. In order to recover as much oil as possible, the press cake is usually subjected to solvent extraction by using a food grade solvent, Hexane. Hexane is repeatedly passed through the press cake and the mixture of solvent and oil is sent through a series of evaporators where the solvent is recovered and reused. Concerns over the use of food grade solvents have prompted the canola industry to look at alternative methods of extraction, possibly a hot water method.

Refining the ‘crude oil’ product includes removing various compounds that interfere with stability and shelf-life. Removal of these compounds is done by a variety of methods, including water precipitation and treatment with organic acids. By-products of this process are added to the meal to improve nutritional value. Colour compounds, that are unattractive to consumers, exist after this treatment. These compounds are removed by bleaching where oil is moved through diatomaceous clay, a natural component. Deodorization is the final step in the refining of canola oil and all vegetable oils. Steam distillation is used to remove residual compounds that could

transmit undesirable odours and tastes. Canola oil is now ready to be packaged and sent to consumers. Further processing of canola oil into margarine can occur at this stage.

Another new and interesting use for canola oil is as biodiesel. Biodiesel is an environmentally safe alternative to petroleum-based diesel fuel, and is made from vegetable or animal fats. It is renewable, non-toxic, biodegradable and produces reduced exhaust emissions. It is a renewable energy source, and can be made not only from food grade canola, but also from waste frying oil, and from heat and frost-damaged canola seeds that are unusable in making edible oil. Biodiesel and biodiesel blends, that reduce engine wear and therefore lengthen engine life, have better lubrication properties than petroleum-based diesel. Research into using canola as a biodiesel is under way at the Agriculture and Agri-Food Canada Research Centre in Saskatoon in conjunction with the Department of Engineering at the University of Saskatchewan.

Conclusion

Canola has contributed greatly to the economic stability of Western Canada. It is now the first or second most valuable Canadian crop. It is a welcome diversification in crop rotations where it is important to break disease cycles in cereals, legumes and other oilseed crops and to control weeds. Canola is a great example of how important research and development conducted in the province can benefit Saskatchewan farmers and can contribute significant health benefits to the world.

Value-Added Crops Activity Sheets

1. Develop or design a device that will extract oil out of oil seeds.
a) Provide information about oil seed crops and the value-added ability of oils when separated from the seed.
b) Develop, design and produce a device that will crush approximately 100 seeds and be able to extract oil from the seeds. Collect the oil in separate containers.

Subject	Level
Science 10	Secondary

2. Test different stressors on the growth of canola plants.
a) Identify several opposite stressors like hot-cold, acidic soil–saline soil.
b) Grow agricultural crops varying pairs of stressors. Compare them to a control (normal conditions) crop.
c) Graph the results.
3. Organize a field trip to natural prairie and get students to collect (if allowed) or write about plants students think would be directly related to agricultural crops such as canola, flax, wheat, etc. Research to determine the accuracy of the observations.
4. Compare decomposition rates of canola or flax straw when put in ordinary composting vs. vermicomposting.
5. Compare glues made from different agricultural plant seeds and test the strength of each.

Subject	Level
Science 6-9, 10	Middle
Biology 20, 30	Secondary

6. Compare the amount of oil, protein and starch in the seeds of various agricultural plants.

Subject	Level
Science 6-9	Middle

7. Grind leaves of different agricultural plants in alcohol and prepare a paper chromatography test to see what different pigments are present in these various plants.

Subject	Level
Science 10	Secondary
Biology 20, 30	Secondary

8. Crop Seed Processing
a) Obtain "maps" showing the processing of seeds such as grains, oils and pulse. These usually show the steps in manufacturing as well as the machines required.
b) Enlarge and copy the maps on to 11 x 17 paper.
c) Cut the maps into puzzle pieces by separating the various stages of the manufacturing process.
d) Have the students sort the pieces and re-arrange them in the correct order.
e) Paste the pieces onto a bristle board background in order to re-assemble the maps.
f) Map the processing of canola from field to bottle.

Subject	Level
Science	Middle

9.
a) Sprout various seedlings. Periodically measure their growth and graph. The final graph records 90 days of growth.
b) Germinate one or more varieties of lentils. Measure the height and graph results. Plant seedlings, grow, measure and graph results.

Subject	Level
Science	Elementary
Mathematics	

10. Design a spreadsheet that shows average input costs for growing value-added crops.

Subject	Level
Info. Process. 10, 20, 30	Secondary

11. Take a farm field trip to observe and learn about the stages in growing a specific crop. Make a booklet on the story of a crop such as wheat, oats, barley, canola, lentils, edible beans, coriander, caraway, chickpea or dill. Include these topics:
    - Seed selection/cleaning
    - Soil preparation
    - Planting
    - Chemical or organic control of weeds and pests
    - Swathing, combining, binning of crop
    - Sale of commodity

    Use photos or draw pictures.

Subject	Level
Language Arts	Elementary
Social Studies 4, 5	Middle
Entrepreneurship 30	Secondary

12. Soil Texture Hand Testing

Materials 4 samples of soil (sandy, clay, loam and other)
Note *Do not label soil, let students predict*

Water
A cookie sheet or other working surface

1. Visually sample soil to be tested for pebbles, sand, organic matter etc.
2. Palm about a tablespoon or two of the sample and add water. Mix/knead the sample while continuing to add water until saturated.
3. Pinch the soil with thumb and index finger. If it sticks, it is greater than 27% clay, if not, it is less than 27% clay.
4. Wash the soil sample while swirling your fingers in it until you can feel the "grit" of sand. Estimate the percentage of sand.
5. Repeat steps 1-4 for the remaining soil samples.

13. Porosity

Materials Ant farm,
Sand, Clay soil

1. Set up the ant farm and add sand, clay and sand again until full.
2. Add water to top layer and observe how it moves as it soaks into the sand. It should fan out due to capillary action (attraction to sand particles).
3. Continue to add water until it enters the clay layer and beyond.
4. Observe the water to see how it moves. It should stay mainly in the clay due to the negative charges.

See Graphic A, Page 27

14. Soil Particle Charge

Materials 12v DC power supply
(or 2 x 6v in series)
2 probes & connecting wire
Clay soil and water (mud)

1. Place the probes in the mud, swirl and remove.
2. Clay soil/mud sticks to the positive electrode but not to the negative probe.
3. Disconnect power in order to clean probes and retry.

See Graphic B, Page 27

15. Soil Ion Flow Filter

Materials
Organic dyes
(FOC Blue #1,
FDC Yellow #5)
Clear plastic tube
Clay loam soil
Filter

1. Close one end of a tube with a filter and tape.
2. Put the soil into the tube.
3. Pour the dye solution (500 ml) into the tube.

Dyes
1. Make up 250ml of each of the two dyes in separate containers.
2. Explain that one is positive and the other is negative (but don't say which is which).
3. Mix the two dyes (yellow and blue = green).
4. Pour the green mix through the soil filter.

Outcome
Only the yellow dye passes through the soil, therefore it must be negatively charged. The positively charged dye binds to the negative particles in the soil.

See Graphic C, Page 27

16. Soil Pore Space Size and Capillary Action

Materials
3 tubes of soils (sandy, silty and clay) with filter ends as above
Tub of water

a) Place the tubes in the tub so water can be taken up.
b) Compare the amount, height and rate of the water uptake for the soil types.

See Graphic D, Page 27

Subject	Level
Science Studies 30	Middle
Agriculture	Secondary

17.
a) Make a collage using a variety of seeds (cereals, pulse, canola, flax, etc.)
b) Soak flax straw and select the long strings. Use the flax strings in string art.

Subject	Level
Arts Education	Elementary
	Middle

18. Identify the parts of plants and learn the functions of the parts. Then draw a "super-plant" which would contain the best parts from the different plants.

Subject	Level
Science	Elementary
Arts Education	

19. Write a play or puppet show of a canola plant's journey through life. Start with the seed being planted and move through its growth stages until the seed is harvested. Include conversations with soil, water, herbicides, machinery, etc. Present the show to younger grades.

Subject	Level
Science	Elementary
Arts Education	Middle

20. Compare two types of canola:
Polish type: (*Brassica rapa*)
Argentine type: (*Brassica napus*)
Use samples of each plant to compare size, leaves, stems and flowers.

Subject	Level
Science	Elementary

21.
a) Develop a book of recipes using canola oil, cereals or lentils.
b) Make a soup using lentils.

Subject	Level
Food Studies 10, 20, 30	Secondary
Mid Level Food Studies	Secondary
Comm. Cooking 10, 20, 30	Secondary

22. Do a germination test of 50 canola seeds. Do the same test using various amounts of fertilizer in the seed row. How sensitive is the germination to certain levels of fertilizer application?

Subject	Level
Science	Middle

23. Collect and display products that contain different cereal crops: wheat, barley, oats, rice, corn, sorghum, rye, and millet.

Subject	Level
Science	Elementary
	Middle

24.
a) Demonstrate how wheat is turned into bread.
b) Research what makes the elasticity in bread.
c) Research the advantages of whole-wheat flour compared to white flour.
d) Use 12-grain cereal (including flax) to make bread. Compare / taste test with commercial bread. Emphasize health benefits.

Subject	Level
Social Studies	Elementary
Food Studies 10, 20, 30	Secondary
Comm. Cooking 10, 20, 30	Secondary

25. Collect samples of flax. Investigate ways flax is used.

Subject	Level
Science	Middle

26.
a) Investigate the impact of value-added crops on the Canadian economy.
i. Identify a variety of value-added crops.
ii. Identify the various uses of each.
iii. Identify the foreign customer base for these products.
iv. Create a chart that would illustrate the percent of total crop sales value-added crops occupy in the period 1990 to 1999.
v. Identify the barriers Canadians face in exporting value-added products.
vi. Make a projection of what the next five years hold, in terms of new products, and the rationale for your projection.

b) Discuss Canada's position regarding value-added grains marketed to foreign countries.
i. Identify the countries that present the greatest barriers.
ii. Identify the reasons for these barriers.
iii. Pick three barriers and research the background and reasons for these barriers.
iv.Develop informational packages to counter their arguments.

c) Develop a model of value-added canola or lentil.
i. Include origin of the crop.
ii. List changes that have occurred to the grain to reach the state of value-added.
iii. Identify the processes involved.
iv. Describe the value-added components of the grain.
v. Define the impact of these components for the consumer.

d) Describe the impact of rail line and elevator closure on rural Saskatchewan.
i. Who has had the major decision-making power regarding closure?
ii. What has been the effect in rural centres when lines and elevators close? Consider population trends, shopping trends, spending trends, etc.
iii. Create a chart showing population trends in selected rural communities over a period from 1990 to 1999.
iv. Create a scenario for the look of rural Saskatchewan in the year 2020.

e) What is happening to the family farm?
i. What could one expect to find on a family farm in 1920, 1940, 1960, 1980 or 2000? Include:
- Size in hectares
- Types of farm machinery used
- Crops sown
- Farm income based on today's dollar

ii. Design the farm of 2020. Give reasons to support each of the descriptors you include.
iii. If you had your choice, which family farm would you choose and why?

Subject	Level
Economics 30	Secondary
Canadian Studies 30	Secondary
Agriculture Studies 30	Secondary

27. Mapping
a) Gather data on value-added crop exports to various countries.
b) Place the information on a world map.
c) Make some conclusions about the pattern of exports.
d) Present reasons that would justify your conclusions.
e) Use a world map and make your predictions about which countries would make up export partners. Provide reasons for your decisions.

Subject	Level
Agriculture Studies 30	Secondary
Economics 30	Secondary

28. Create a list of scientists who have worked in the area of value-added crops. Outline their major areas of research and the results of their work. Place this information on file cards that could serve as reference material for other students.

Subject	Level
Language Arts	Middle
Science 10	Secondary

29. Describe a gene. Outline various mechanisms for gene manipulation. Describe the mechanism used to test plants for the desired trait. Research how plants with this trait are isolated creating the desired strain.

Subject	Level
Biology 20, 30	Secondary

30.

a) Collect plants
   i. Describe the process of plant collection, preservation of the plant for mounting on a herbarium sheet and the labelling procedure required.
   ii. Have students collect, mount and identify samples of various cereal, oil and pulse crops grown in the region.
   iii. Have the students research each plant with emphasis on what products can be made from each type of plant. Summarize this information on file cards and attach to herbarium sheets.
   iv. Transfer the name and plant characteristics onto a second set of file charts and use these as a field guide for any field trips taken.

b). Jig Saw
   i. Divide the students into groups of five to study cereals, canola, flax or pulses.
   ii. Give each student in the group a fact sheet about the specific topic.
   iii. Have all students with oilseeds get together, similarly cereals and so on.
   iv. Instruct the students to read the article and, depending on the grade level, ask each of these "expert" groups to summarize the article and its main points. This could be as straightforward as defining each category and listing the various types found in each article to a written history of the grouping and an in-depth description of two or three examples. Make sure the members of each expert group help each other to get all the required information.

v. Have each expert return to his or her initial group to teach the rest of the group about the topic they were studying.

Subject	Level
Science 6-9	Middle
Biology 20, 30	Secondary

31. Sketches

a) Organize a field trip to collect specific plants.
b) Make sketches of these plants (could be water colours, oils, pastels, etc.)

Subject	Level
Art Education	Middle
Visual Art 10, 20, 30	Secondary

32. Initiate a meal a day program.

a) Collect a series of value-added recipes that could be used to form the basis of a family dinner or collect products that feature value-added grains.
b) Prepare these foods and create samples of each food to use in demonstrations..
c) Invite students and staff to taste these products.
d) Have the tasters record their reactions. Summarize and present results.

Subject	Level
Food Studies 10, 20, 30	Secondary

33.

a) Using the resource "Agricultural Statistics", a yearly Saskatchewan Agriculture and Food (SAF) report, create bar graphs and circle graphs for topics such as:
   i. Hectares seeded from 19—to 19—.
   ii. Amount exported as part of gross revenue.
   iii. Area and production by producing region (China, Canada, Europe, etc.)
   iv. Growth of canola production hectares sown and yield kg/ha years 1943-94.
   v. Comparison of fatty acids of Canadian vegetable oils (linseed, sunflower, soybean, rapeseed), palmtic, stearic, oleic, linoleic, linolenic, eicosenoic or erucic.
   vi. Circle graphs of various types of oil consumption, e.g. canola, soybean, palm, corn, sunflower.
   vii. Bar graph saturated polyunsaturated (linoleic, alpha linoleic), monosaturated canola, safflower, sunflower, corn, olive, soybean, peanut, cottonseed, lard, palm, beef tallow, butterfat or coconut oils.
b) Statistical analysis
   i. Increases in the grain trucking industry.
   • Examine the trend over the past ten years
   • Focus on number of companies, number of people involved in industry, distance grains are being trucked.
   ii. Crop prices versus value-added grains.

• Trace the selling price of wheat, barley, flax over the past ten years.
• Trace the selling price of canola and lentils over the past ten years.
• Make predictions about selling prices in the next five years.

Subject	Level
Mathematics	Middle
Biology 20, 30	Secondary

If you would take all the grains grown in one year in Canada and put them in grain containers, the train would stretch from the earth to the moon and back!

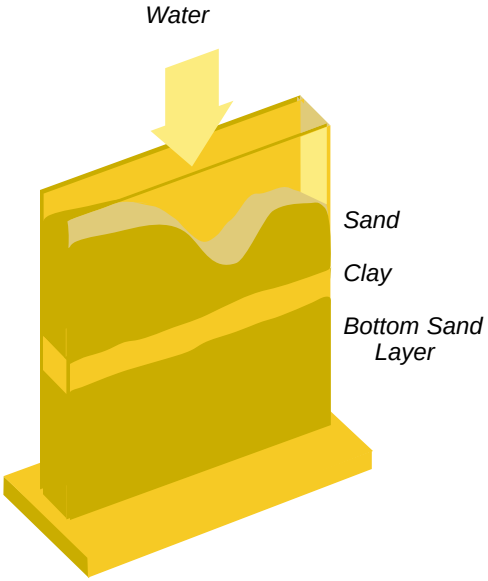
34.
a) Identify the occupations directly affected by agriculture.
b) Identify secondary occupations affected by agriculture and find the level of education required by each occupation.
c) Determine the percentage of people involved in the agriculture industry.
d) Create a description of some of the skills required by the present-day farmer.

Subject	Level
Work Experience	Secondary

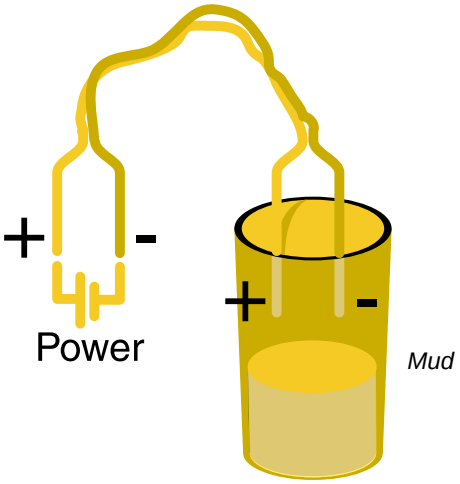
35.
a) Design a product that would have some unique characteristics (canola that has a cold-inhibitor gene). Include brief history, type of research done, name of new grain, etc.
b) Develop an information campaign you would use to interest a group of investors in a new product.
c) Design an ad campaign that could be used on television to convince consumers of the value of your new product.

Subject	Level
Language Arts	Secondary
Entrepreneurship	Secondary
Information Processing	Secondary

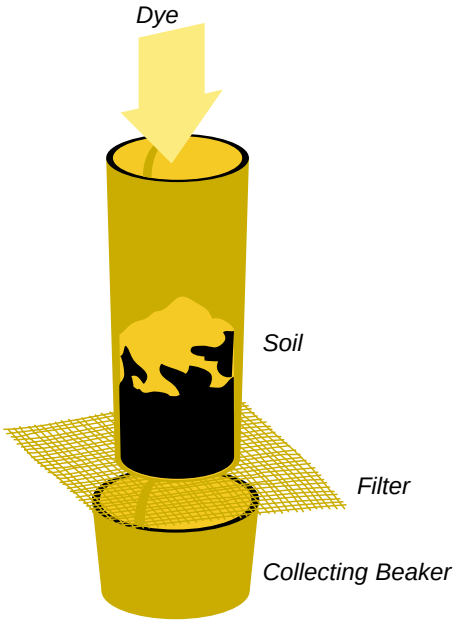
Graphic A



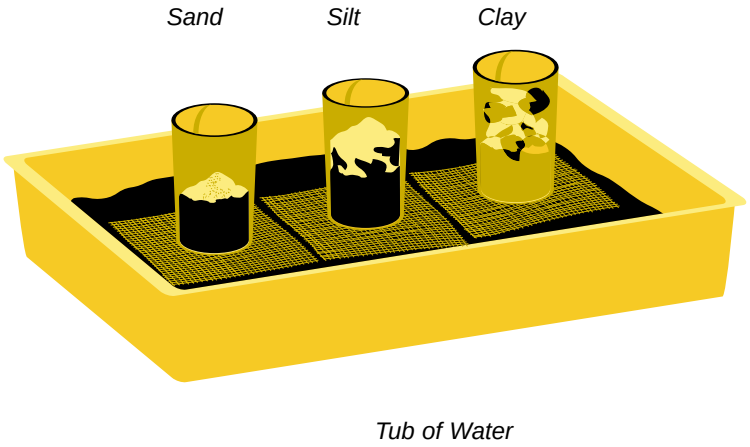
Graphic B



Graphic C



Graphic D



Resources

Organizations

Innovators in the Schools
800.336.7955 Toll free
306.933.7904 Saskatoon
306.791.7955 Regina

Canadian Institute for Environmental Law and Policy
416.923.3529

Canola Council of Canada
400 167 Lambard Ave
Winnipeg MB R3B 0T6
204.982.2100

Canada Grains Council
330-360 Main St.
Winnipeg MB R3C 3Z3
204.942.2254

Statistics Branch,
Saskatchewan Agriculture and Food
3085 Albert Ave.
Regina SK S4S 0B1
306.787.5947

Crop Development Center
U of S, Saskatoon SK
306.966.5855

Print and Video

Amazing Grains (Video)
McIntyre Media Ltd. (20 Minutes)
905.678.9866
mcintyre@istar.ca
www.mcintyre.ca

Nutrient Value of Some Common Foods (Booklet)
Agriculture and Agri-food Canada and Health Canada
613.759.1000

Canadian Agricultural Productivity
Auer, L. (Booklet)
Queen's Printer, Ottawa ON 1970

With the Grain (Book)
Sokolov, Raymond and Knopf, Alfred A.
NY 1996

Web Sites

www.canadagrainscouncil.ca

www.hwc.ca/links/hscience/biotech.html

www.kmpg.ca/bio

www.oecd.org/subject/biotech

www.pbi.nrc.ca

www.agr.ca

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