ASSESSMENT OF BIODIESEL FEEDSTOCKS IN OREGON

Prepared for

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by

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EXECUTIVE SUMMARY

Recent volatility in petroleum prices has increased public interest in and demand for biodiesel in Oregon. Biodiesel is a renewable fuel for diesel engines that can be made from vegetable and animal fats. Since they are often considered waste products, used vegetable oils and animal fats are the least expensive biodiesel feedstocks. Local supplies of waste oil are limited, and broad use of biodiesel will quickly require production of oil directly from agricultural crops.

The Portland Development Commission requested this study to evaluate crops that have potential as biodiesel feedstocks and where they may be grown in Oregon. It will also discuss oilseed extraction methods and resulting products as well as costs of transporting oilseeds and their byproducts. The report will examine the viability of a Portland-based biodiesel refinery with a capacity of one half million gallons annually.

Although a wide variety of oil-bearing crops are grown around the world, many are poorly adapted for commercial production in the Pacific Northwest. Canola stands out among possible oilseed crops as having high seed yield and oil content, resulting in the highest oil yield per acre of any crop currently available. In addition, there is an active canola breeding and production research program in the region. Fall planted canola in particular is very well suited to the winter rainfall pattern of the region and can be grown without supplemental irrigation, significantly reducing production costs and environmental impact.

Recent yield trials in the Willamette Valley have shown that available winter canola varieties can produce in excess of 4,000 lbs. of seed per acre. Other production regions under consideration are the Columbia Basin (dryland and irrigated), Central Oregon near Madras, and Northeast Oregon in the LaGrande area. Even though yields may be lower (2,000 to 3,000 lbs. per acre) outside the Willamette Valley, canola may serve as a valuable rotation crop in these areas.

Using canola in a crop rotation with grass seed and wheat may have many benefits for Oregon growers. Canola plants have strong taproots that penetrate compacted soil layers that fibrous roots of grass seed and cereal crops cannot. Growing canola can significantly improve soil tilth and increase water infiltration rates in compacted soils, reducing tillage costs and improving performance of following crops. Including canola in the crop rotation will also help growers control grass weeds, which are becoming greater problems in both grass seed and wheat production. This is particularly important in the Willamette Valley where grass weeds have become a major problem in grass seed production fields, and growers have few non-grass crop rotation options.

Processing oilseeds produces two primary products, vegetable oil and oilseed meal. Markets exist for a number of vegetable oil products including food products, bio-based industrial products, and biodiesel. Compared to other products, biodiesel is a relatively low value end-use for vegetable oil. Oilseed meal is a major co-product of oilseed processing, which can amount to two thirds by weight of the seed entering the processing plant. Meal is generally sold as a source of protein in animal feed rations, and meal sales constitute an important part of processing plant economics.

The business model for oilseed processing has traditionally involved construction of large-scale, centralized processing plants. Providing feedstock to these plants requires extensive crop production covering large acreage, transport of bulk seed from a wide geographic area, and significant on-site storage capacity. Large-scale plants normally use organic solvents such as hexane to efficiently extract oil from crushed seed. Such plants have not been built in the region due to their high initial capital cost and the high cost of transporting raw seed to the extraction plant.

Another approach to oilseed processing involves the use of small, decentralized mechanical oilseed crushers that extract vegetable oil without the use of solvents. This technology allows extraction of oil on-farm or by small local enterprises, virtually eliminating transportation costs. Filtered, virgin oil is sold for edible or industrial use, and the meal is usually consumed by animals on-farm or sold to local dairies. Pendleton Grain Growers (Pendleton, OR), and Madison Farms (Echo, OR) are currently operating experimental oilseed extraction facilities using mechanical screw presses to extract oil from locally grown canola.

In this report various extraction plant scenarios are examined. These are based on 4,000 and 10,000 acre farms with and without irrigation growing canola in rotation with other crops. The number of these decentralized plants required to supply the half million gallon biodiesel plant is surprisingly small; from 2 to 8, depending on farm size and availability of irrigation. A single larger plant can achieve the same result drawing from a relatively small grower base.

Extraction facilities should be located close to both crop production areas and to meal consumers to minimize transportation costs. Both unprocessed seed and meal are bulk products that must be handled in large volume, and their relatively low value cannot justify long distance transport at current prices.

Establishment of a local oilseed industry to produce biodiesel in Oregon is a complex process that will require extensive knowledge of crop production, oilseed processing, transportation logistics, and marketing. This report makes a number of conclusions regarding the current state of our knowledge and recommendations to promote future success of this industry.

Conclusions

1. In the near term, winter canola offers the most promise as a biodiesel feedstock crop in Oregon. It produces the most oil per acre of any available crop.

2. Yield of spring canola is generally much lower than winter types. Without available irrigation in eastern Oregon, spring canola is subject to highly variable yield.

3. Canola oil can be extracted using simple mechanical screw press technology, allowing construction of decentralized extraction plants at relatively low cost.

4. As the price of canola seed approaches $0.13 per pound, there is little operating margin for the extraction plant at current oil and meal prices.

5. Extraction facilities should be located close to both crop production areas and to meal consumers to minimize transportation costs.

6. A number of other crop species should be investigated for their future potential as oilseed feedstocks.

Recommendations

1. Establish variety yield trials throughout the major production areas of the state to determine expected canola seed yield.

2. Determine canola crop production costs for each production area.

3. Evaluate the potential of higher value markets for vegetable oil including food grade oil and high value bio-based products.

4. Conduct minimum tillage trials throughout Oregon to minimize production costs.

5. Carry out screw press performance trials to help processors with equipment selection.

6. Study the feed value of mechanically pressed canola meal, including an economic analysis of the value of residual oil in feed rations.

7. Review and revise the Oregon Department of Agriculture *Brassica* production rules to allow more flexibility in canola and mustard production and research. The current rules are not based on the best available science and are currently limiting production, investment, and research.

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Introduction

Biodiesel is a renewable fuel for diesel engines that can be made from vegetable and animal fats. Used vegetable oils and animal fats, known as yellow grease, are the least expensive biodiesel feedstock, since they are often considered waste products. Local supplies of used oil are limited, however, and broad adoption of biodiesel will quickly require production of virgin oil from agricultural sources. Many crop plants synthesize and store oil in their seeds, and farmers can harvest and extract this oil for use in a variety of products including biodiesel.

Because of the extensive production of soybeans in the U.S. Midwest, soybean oil is by far the major source of vegetable oil used for biodiesel production in the United States. The majority of all biodiesel currently sold in the Pacific Northwest (PNW) is made from Midwest soybean oil and is imported as finished biodiesel. This has been a good way to test and establish markets for biodiesel with minimal investment in local infrastructure, but development of an Oregon industry to produce locally-grown oilseed crops as feedstocks for biodiesel is only beginning.

Vegetable oil and oilseeds can be imported to the PNW to supply feedstock for local biodiesel refining, and this is currently the most economical source of large volumes of feedstock vegetable oil. Established oilseed industries in the U.S. Midwest, Canada, and overseas can deliver reliable supplies of vegetable oil at very competitive prices. Oilseed and raw oil imports into the PNW will probably occur in the short term, but imports will not have a positive impact on the local agricultural economy or on local growers. Large grain trading corporations are already showing interest in entering this market, which may affect availability and price and make oilseed imports less economical in the future. Expansion and sustainability of the biodiesel industry in Oregon will ultimately depend on the availability of inexpensive, locally grown oilseed crops.

As petroleum prices have increased and become more volatile over the past several years, agricultural producers in the PNW have become more interested in production of biodiesel. Much of this interest comes from a desire to reduce fuel costs for their own farming operations and to gain a measure of independence from increasingly volatile petroleum markets. Growers in both Eastern and Western Oregon are also increasingly aware of the need to diversify crop production away from the grass seed and wheat dominated agricultural system currently in place. Oilseeds will have a place in Oregon agriculture if the risks of production can be reduced to manageable levels and if returns to growers are sufficient to allow them to grow oilseed crops profitably.

This report will evaluate crops that have potential as biodiesel feedstocks and where they may be grown. It will also discuss oilseed extraction methods and resulting products as well as costs of transporting oilseeds and their byproducts.

Potential Oilseed Feedstock Crops

A wide variety of crop plants have been developed as commercial sources of vegetable oil. Unfortunately, many oilseed crops such as oil palm, coconut, cotton, sesame, and peanuts are tropical or semi-tropical crops and cannot be grown economically in the PNW. Other oilseed crops are adapted to production in the temperate climatic zone, but most have limitations that make them less than ideal for production in the PNW.

Ideal Properties of Biodiesel Feedstock Crops

- Well adapted to PNW climatic conditions and soils
- High seed yield
- High seed oil content
- Low production costs
- Oil can be extracted without use of solvents
- Active crop breeding and production research programs in the PNW

Although several oilseed crops can be grown in the PNW, at present only canola is sufficiently developed to be a local source of feedstock vegetable oil for biodiesel. Possible crops that might be used in Oregon are reviewed below.

Soybeans. Although soybeans are the most widely produced oilseed crop in the world, they are poorly adapted to environmental conditions found in the PNW and will probably never be a major source of vegetable oil in the region. Soybeans are primarily adapted to regions with abundant summer rainfall as well as warm day and night temperatures during the growing season. Soybeans grown under irrigation in warmer regions of the PNW can produce reasonably good yield, but yield is generally quite low without supplemental irrigation throughout the region. Since no soybean breeding program exists in the region, development of well-adapted varieties is unlikely.

Since soybeans are relatively low in oil content (20%), they are grown primarily as a source of protein, and soybean oil is considered a byproduct of protein production. Soybean oil is extracted from the seed using organic solvents (hexane). There are currently no solvent extraction facilities in the region, and none are likely to be built.

Sunflowers. Sunflowers are native to North America and grow wild in many parts of the country. They are a spring planted annual crop that can be grown under dryland or irrigated conditions. Although sunflowers are considered somewhat drought tolerant, they mature late in the growing season, and their yield potential without irrigation is probably limited in the PNW. There are active public and private sunflower breeding programs in the U.S. and Europe, but little production research has been done in the PNW during the last 25 to 30 years. The potential of sunflowers should be investigated under dryland and irrigated conditions in both eastern and western Oregon.

Flax. Flax is an ancient crop with both oilseed (linseed) and fiber (linen) varieties. From the 1870's until the 1960's the Willamette Valley was a major center of fiber flax production, but there has been no significant oilseed flax production in Oregon for many decades. Oilseed flax is generally planted in early spring and will tolerate some frost. Flax matures rapidly with the onset of hot, dry weather often producing a crop in 90 to 100 days from planting. Spring flax usually yields 1,500 to 2,000 pounds of seed per acre. A winter hardy flax variety was developed at OSU during the 1950's that yielded 2,500 pounds of seed per acre in eastern Oregon. Flax oil can easily be extracted from the seed with mechanical presses.

Yellow Mustard. Yellow mustard (*Sinapsis alba*) is a rapidly maturing, spring planted crop that has potential as a biodiesel feedstock in Oregon. In high rainfall areas of northern Idaho yellow mustard has produced 3,000 pounds of seed per acre. Oil content of currently available yellow mustard varieties is much lower (27%) than many other oilseed crops, and the meal is high in glucosinolates, compounds that make yellow mustard meal unusable as animal feed. The University of Idaho has released one commercial variety of yellow mustard, and development of new cultivars is under way.

Camelina. Camelina (*Camelina sativa*) is an annual member of the mustard family. It germinates very rapidly and competes effectively with weeds. In Montana camelina is broadcast seeded in early spring, often when snow is still on the ground, and harvested in mid-summer. Yields of 1,500 pounds per acre are common under dryland conditions in Montana. With further development camelina may eventually be an excellent candidate for oilseed production in lower rainfall areas of Eastern Oregon.

Meadowfoam. Meadowfoam (*Limnanthes alba*) is an Oregon native oilseed species that contains oil with properties similar to sperm whale oil. Since this crop grows well on poorly-drained soils, it was developed by OSU as a rotation crop for grass seed production in the Willamette Valley. Current marketing efforts have not allowed extensive production to meet growers' rotation crop needs, and meadowfoam is currently produced on only about 3,000 acres in the Willamette Valley. With wholesale oil prices ranging from $4.00 to $6.00 per pound, meadowfoam oil is much too valuable to be used as biodiesel feedstock. Meadowfoam oil recovery also requires solvent extraction, and all meadowfoam seed is shipped out of state for processing.

Industrial Hemp. Industrial hemp (*Cannabis sativa*) is grown in a number of countries as an oilseed crop and is often suggested as a possible crop solution to environmental and energy problems. Hemp seed yields are relatively low (600-1,000 pounds per acre) compared to most other oilseed crops, and hemp oil is currently quite expensive, even in countries where production is encouraged. Because of the predominantly winter rainfall pattern in the PNW, industrial hemp will almost certainly require supplemental irrigation to maximize production. Production of industrial hemp is currently not feasible in the U.S. due to severe legislative restrictions.

Canola. Rapeseed (*Brassica rapa* and *B. napus*) is an industrial oilseed crop that has high levels of erucic acid and glucosinolates. Erucic acid makes rapeseed an excellent industrial oil, but is undesirable in edible oil. Glucosinolates are sulfur-containing compounds that make mustard taste hot and make rapeseed meal unpalatable to animals. Canola was developed from rapeseed in Canada during the 1960's as a source of edible oil and meal by reducing the amount of both undesirable compounds produced in the seeds. Canola is the generic name given to rapeseed varieties that contain low levels of both erucic acid (less than 2%) and glucosinolates (less than 30 umol/gram).

Canola is well adapted to the maritime Mediterranean climate of the PNW. Canola varieties include both winter and spring types. Winter canolas are planted in the fall and harvested early in the following summer, while spring canolas are spring planted and mature quickly by mid-summer. This adaptation to early ripening fits well with the prevailing rainfall pattern in Oregon, allowing canola to take full advantage of available precipitation. Both spring and winter canola can benefit from supplemental irrigation, especially in low-rainfall areas of Eastern Oregon. Under favorable growing conditions canola can produce high seed yield. Oil content of canola seeds is typically about 40%, but the oil content of newer varieties can range from 45 – 47%. With the combination of high seed yield and high oil content, canola produces more oil per acre (150 to 200 gallons) than any other crop currently available in the PNW.

Figure 1. Winter canola in early bloom near Echo, OR, April 2006.

The presence of an active crop improvement effort is essential to establishment of a successful oilseed industry in the PNW, and the region is fortunate to have a canola and mustard breeding program located at the University of Idaho. For many years Dr. Jack Brown (University of Idaho, Moscow, ID) has been developing winter canola and spring mustard varieties that perform well under PNW growing conditions. In recent years his program has released a number of superior canola varieties, and many new experimental lines are in yield trials in the region.

Using canola in a crop rotation with grass seed and wheat may have many benefits for Oregon growers. Canola plants have strong taproots that penetrate compacted soil layers that fibrous roots of grass seed and cereal crops cannot. Growing canola can significantly improve soil tilth and increase water infiltration rates in compacted soils, reducing tillage costs and improving performance of following crops. Including canola in the crop rotation will also help growers control grass weeds, which are becoming greater problems in both grass seed and wheat production, by allowing the use of selective herbicides that will control grass weeds during growth of the canola crop. This is particularly important in the Willamette Valley where grass weeds have become a major problem in grass seed production fields, and growers have few non-grass crop rotation options.

Because of potential disease problems, canola must be grown in rotation with other crops and should only be grown one year out of four in any particular field. Although *Brassica* production districts were established to minimize cross-pollination among vegetable crops, some people involved in vegetable seed production have suggested that large-scale production of canola will result in the introduction and spread of several plant diseases including blackleg, *Sclerotinia* stem rot, and club root. These diseases have been common in vegetable crop and seed production for many years, however, and they can probably also be found in both native and feral *Brassica* species.

Blackleg, the most serious disease of canola, is caused by the fungus *Leptosphaeria maculans*. This disease is carried over from season to season on infected plant residue and spreads by airborne spores or through infected seed. Blackleg can cause yield reductions up to 50% due to premature ripening and stem breakage. This disease is controlled though use of certified, fungicide-treated seed, resistant varieties, and crop rotation to minimize buildup of disease inoculum.

Sclerotinia Stem Rot (or White Mold), caused by the fungus *Sclerotinia sclerotiorum*, is virtually ubiquitous and can attack nearly 400 species of plants including sunflower, potatoes, safflower, beans, peas, and alfalfa. Increased production of canola may increase *Sclerotinia* inoculum where it is grown, but other crops such as bush beans and fresh market or cannery vegetables may already be providing large sources of inoculum in close proximity to vegetable seed production fields. Canola will likely only be produced with several miles of separation from known *Brassica* seed production fields, reducing potential impact on vegetable seed production fields.

Club root is an important disease of cabbage, cauliflower, brussels sprouts, broccoli, and Chinese cabbage caused by *Plasmodiophora brassicae*. Canola is only mildly susceptible to club root, and it is generally not considered a major problem in current canola production areas. Other local crops that can be infected by this organism include orchardgrass, perennial ryegrass, red clover, and strawberries.

Various oilseed crops are compared for range of seed yield, oil content, and extraction method in Table 1.

Table 1. Seed yield, oil content and extraction method for some oilseed crops.

Crop	Seed Yield (lb/acre)	Oil (%)	Extraction Method
Soybean	1,000 - 4,000	20	Expeller/Solvent
Sunflower	1,500 - 2,500	40	Screw Press
Flax	1,500 - 2,500	40	Screw Press
Yellow Mustard	2,000 - 3,000	27	Screw Press
Camelina	1,500 – 2,000	27	Screw Press
Meadowfoam	400 - 1,000	32	Solvent
Industrial Hemp	600 - 1,000	30	Screw Press
Canola	2,000 - 4,000	40-45	Screw Press

Canola Yield in the PNW

The Pacific Northwest Canola Variety Trial program was established in 1994 to determine the yield of spring and winter canola cultivars in a number of locations in Oregon, Washington, and Idaho. In Oregon, Pendleton has been included as a trial location for many years, and Hermiston was recently added.

Winter canola yield varies widely from year to year in Pendleton and Hermiston trials. Canola production carries significant risks for eastern Oregon growers. Fall can often be very dry in the PNW, and successful crop establishment can be quite risky for growers without supplemental irrigation. Canola is also subject to cold injury under extreme conditions in eastern Oregon and crops are regularly lost to winterkill. Spring and summer drought can also severely reduce yield. Table 2 shows mean seed yield across many commercial varieties and experimental lines of canola grown in Pendleton and Hermiston from 2002 through 2005.

Table 2. Mean seed yield (pounds per acre) of winter canola varieties grown near Pendleton, OR (dryland) and Hermiston, OR (irrigated), 2002 - 2005.

	Location	
Year	Pendleton	Hermiston
2002	2789	3081
2003	2410	2470
2004	Winterkill	3633
2005	2546	2764
Average	2582	2987

In 2004, winter canola yield trials were planted at the Oregon State University research farm near Corvallis, the first time in nearly 20 years that canola trials were conducted in the Willamette Valley. Seven different commercial and experimental canola cultivars were planted in September 2004 and harvested in late June 2005. Canola yields (in pounds of seed per acre) at several different rates of spring applied nitrogen fertilizer are shown in Table 3.

Table 3. Seed yield of winter canola (lbs/acre) grown near Corvallis, OR 2004-05.

	Spring Nitrogen Rate (lb N/acre)		
Cultivar	0	50	100
	(lb/acre)		
Athena	2994	3387	4491
Baldur	3636	4428	4650
Ceres	3012	4017	3872
Kronos	3486	4287	4331
UIC 02.2	3367	3739	4819
UIC 03.1	2966	4021	4525
UIC 03.5	2819	3820	4185
Mean Yield	3186	3957	4410

When the last extensive winter canola trials were conducted in the early 1980's, Willamette Valley canola seed yield averaged approximately 2,300 pounds per acre. Winter canola yields in the 2004-05 Willamette Valley trial were very good, averaging over 4,400 pounds of seed per acre following early spring application of 100 pounds per acre of nitrogen, a moderate amount of fertilizer compared to most crops grown in the area. This level of crop performance is especially remarkable considering that grass seed and winter wheat yields in the area were reduced by 40% or more in 2005 season due to high rainfall during late spring and extremely high pest (meadow vole) damage and that the Willamette Valley was declared and agricultural disaster area. Even from this limited data it is apparent that available canola cultivars can produce quite high seed yields in western Oregon. Additional breeding efforts and development of improved management practices will probably result in increased average canola yield in the future.

Spring canola yields vary widely from year to year and among locations within years throughout the PNW. Results of several years of spring canola trials grown near Pendleton and Hermiston are presented in Table 4. No spring canola trial results are currently available from the Willamette Valley.

Table 4. Mean seed yield (pounds per acre) of spring canola varieties grown near Pendleton, OR (dryland) and Hermiston, OR (irrigated), 2001 - 2005.

	--------------- Location ---------------	
Year	Pendleton	Hermiston
2001	169	
2002	Drought	
2003	424	
2004	1812	1735
2005	201	1554
Average	652	1645

In general spring canola produces about one-half of the seed yield of winter canola grown in the same location. Late frosts and spring drought can greatly reduce spring canola yield. High temperature events often occur rapidly in late spring, and in response canola will lose its flowers or stop flowering, resulting in significant yield loss, even when irrigation is available.

Oilseed Processing

Processing oilseeds produces two primary products, vegetable oil and oilseed meal. In addition to biodiesel, markets exist for a number of vegetable oil products including food products, such as margarine and cooking oil, and bio-based industrial products, like biodegradable hydraulic fluid and motor oil. Biodiesel is a relatively low value end-use for vegetable oil. Oilseed meal is a major co-product of oilseed processing, which can amount to as much as two thirds by weight of the seed entering the processing plant. Meal is generally sold as source of protein in animal feed rations, and meal sales constitute an important part of processing plant economics.

Figure 2. Canola seed in the combine after harvest.

The business model for oilseed processing has traditionally involved construction of large-scale, centralized processing plants. Large-scale processing plants typically extract oil from 1,000 to 2,000 tons of oilseeds per day. Providing feedstock to these plants requires sustained and extensive crop production covering large acreage, transport of bulk seed from a wide geographic area, and significant on-site storage capacity. Large-scale plants normally use organic solvents such as hexane to efficiently extract oil from crushed seed. These solvents are expensive, volatile, and explosive and require expensive capital equipment to safely contain the extraction process. Following extraction, the solvent must also be removed from the oil and meal, recovered with minimal losses into the environment, and recycled back into the extraction process. Each of these operations involves the use of specialized equipment and a well-trained labor force.

Advantages of Centralized Oilseed Processing Facilities:

- High oilseed throughput
- Good control of both oil and meal quality (constant lab testing)
- Low residual oil content (typically < 2%) remaining in the meal
- Low labor costs per gallon of oil

Disadvantages Centralized Oilseed Plants

- High capital cost ($15 – 20 million)
- Siting permit issues for solvent extraction facilities (VOC emissions)
- High transportation and storage costs for large volumes of oilseeds

Over the past 30 to 40 years several feasibility studies have been conducted to assess the potential of building a centralized, solvent extraction plant in the PNW. The consensus of the available studies has been that a centralized extraction facility cannot be justified due to the high capital cost of construction, high transportation costs to move relatively low value oilseeds to the central plant location, and the lack of current large-scale production of oilseed crops by growers in the region. Entrepreneurs and economic development agents in the region have been frustrated for many years by a chicken-or-egg conundrum regarding establishment of oilseed infrastructure in the PNW. Investors will not commit the capital required to build a centralized plant unless they are assured a large, sustained supply of oilseeds, and growers cannot afford to grow large volumes of oilseed crops before an extraction facility exists. As a result, the agricultural and industrial infrastructure needed to support a large-scale oilseed industry in the PNW has not been developed.

Another approach to oilseed processing involves the use of small, decentralized mechanical oilseed crushers that extract vegetable oil without the use of solvents. This concept has been used very successfully in Europe and Asia for local production of cooking oil, biodiesel, and oilseed meal for animal feed. This technology allows extraction of oil on-farm or by small local enterprises, virtually eliminating transportation costs. Filtered, virgin oil is sold for edible or industrial use, and the meal is usually consumed by animals on-farm or sold to local dairies.

Advantages of On-Farm Oilseed Processing Facilities:

- Low capital cost ($100,000 – $250,000)
- No waste products
- Minimal siting issues – on-farm or industrial sites will work
- Small footprint and low power usage
- Low raw material transportation and storage costs
- Create rural jobs and value-added opportunity

Disadvantages On-Farm Oilseed Processing

- Low throughput
- Possible quality control issues (no on-site lab)
- High residual oil content (8-12%) remaining in the meal

It may be possible to offset the disadvantages of decentralized oilseed extraction through the use of technology. Automation can be used to reduce labor costs in an extraction plant by reducing the need for continuous oversight of extraction processes. Quality control may be improved with on-site instrumentation or by sending samples to a central, commercial lab for testing oil quality as well as protein and residual oil content of meal. With reliable automation, it may be possible to run the extraction facility around the clock with very few employees, improving returns and lowering labor costs per gallon of oil.

Decentralized Processing Equipment

There are several manufacturers of oilseed extraction equipment in the United States, however, they primarily service the large-scale oilseed extraction industry. Although they are probably capable of engineering and manufacturing very high quality, small-scale oilseed crushers, they do not appear to have much interest in producing equipment for on-farm use. The smallest crushers these firms currently produce are in the 100 ton per day size range.

In contrast, many European and Asian manufacturers produce small-scale oilseed crushing equipment that could be used in decentralized or on-farm processing facilities. These machines rely on continuous screw press mechanisms similar to the one pictured in Figure 3. Seed enters the press chamber through a funnel hopper and is pushed toward

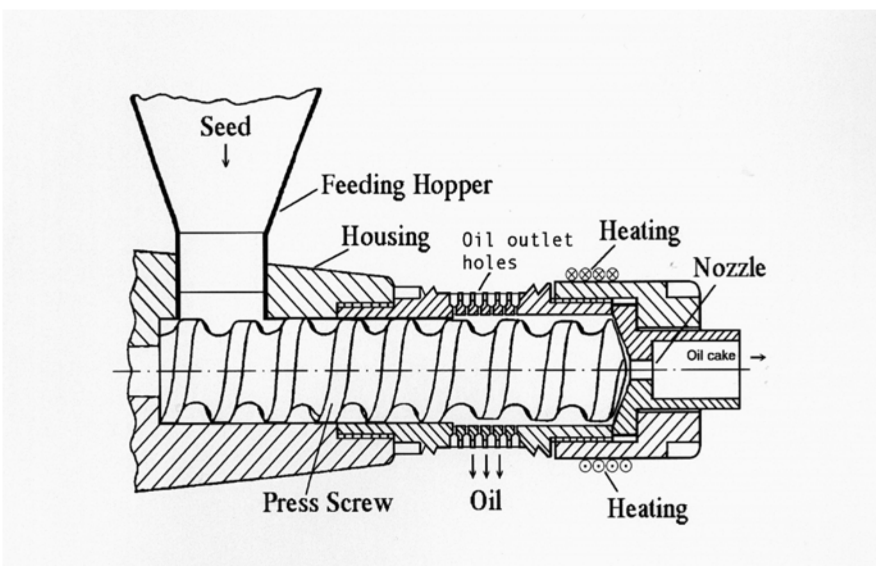

Figure 3. Cross section view of an oilseed screw press.

the nozzle by rotation of a screw. Pressure is exerted on the seed as it is pushed against resistance of the nozzle or choke plate. Oil is released from the seed under pressure and escapes from the crushed seed through holes or slots surrounding the barrel containing the screw. The meal is extruded through a hole in the nozzle or around the edges of a choke plate. Working pressure of the crusher may be adjusted by changing the nozzle diameter or by adjusting clearance between the screw and the choke plate.

While this appears to be a very simple mechanical device, considerable engineering expertise is required to design and manufacture a press that will efficiently maximize oil extraction while minimizing damage to and impurities in the oil. Oil and moisture content of the seed, temperature, screw rotation speed, and working pressure of the crusher can all significantly affect the amount and quality of oil extracted as well as the quality and residual oil content of the meal.

Small crushers range in size from desktop units that will crush a few pounds of seed per hour to presses that consume 10 tons per day. In general European and Japanese crushers are much more expensive than those from Chinese and Indian manufacturers, and the quality of the more expensive units appears to be much higher than the less expensive models. Many growers in Oregon are currently investigating the purchase of small-scale screw presses with the intent of on-farm oilseed production and oil extraction. Very little objective information is currently available on the performance of imported mechanical screw presses, and growers and processors should be wary when ordering equipment.

Figure 4. European installation of modular Komet screw presses.

There are currently only two canola oilseed extraction facilities operating experimentally in Oregon. One is owned by Pendleton Grain Growers (PGG, Pendleton, OR), and the other is under construction at Madison Farms (Echo, OR). Both started operation in 2006 and are using mechanical screw presses to extract oil from locally grown canola.

PGG is using German-made Komet (IBG Monforts Oekotec GmbH, Mönchengladbach, Germany) screw presses similar to those shown in Figure 4. After some initial setup concerns and press adjustments, the presses have been operating well and producing oil at the manufacturer's rated capacity. With no flaking or heating pre-treatment, canola seed is taken from storage and crushed by these presses. After extraction the oil is placed in settling tanks to allow suspended solids (primarily particles of crushed seeds) to separate by gravity, and the oil is pumped off the top of the tanks. Oil quality appears to be quite good which should allow marketing into food as well as industrial oil markets. Meal is extruded from the end of the press barrel and breaks up into easily handled pellets. Residual oil content of the meal is approximately 8%, indicating quite efficient extraction for a mechanical press. PGG is using an unheated facility to house its oilseed processing operation, and monitoring process parameters as well as oil and meal quality during cold weather operation will be needed to ensure uniform product production.

Madison Farms is experimenting with a pair of Chinese-made presses imported by PWRSolutions, Inc.of Portland, OR. These presses are quite inexpensive (approximately 1/20th the cost of equivalent capacity European presses), and they appear to be ruggedly built but somewhat crude in manufacture. Preliminary tests at Madison Farms indicate that these machines will not efficiently crush canola without pretreatment to increase the moisture content of the seeds. Because their design uses an adjustable choke plate to set the working pressure of the press, meal is extruded around the edges of a conical plate resulting in thin flakes of meal rather than pellets.

Figure 5. Canola meal in pellet form.

Meal Utilization and Marketing

Canola meal from screw press extraction usually contains 35-38% protein, making it an excellent source of protein for dairy and beef cattle, swine, and poultry. Canola meal is particularly advantageous in dairy rations since 35% of the total protein in the meal is bypass protein, which improves milk production. In addition, canola meal handles well (good flowability) and presents no problems with storage. There are no undesirable substances in canola meal and cows will readily consume it. As long as rations are properly balanced there are no limitations to the use of canola meal for dairy cows. Diets based on canola meal can support milk yields equal to or superior to those based on soybean meal.

Feed processors, feedlots, and dairies are currently importing oilseed meal into the PNW, so a ready market already exists for high quality meal. Canola meal ranges in price from $140 - $200 per ton, and prices on the world market have been trending upward for several years. Local meal producers will enjoy a significant shipping advantage over Midwest and Canadian oilseed processors, and this advantage will improve with increasing petroleum costs.

Since mechanical pressing cannot remove as much oil as solvent extraction, screw pressed canola meal often contains 8-12% residual oil. This residual oil provides an additional energy source in animal rations. Feeding trials using mechanically pressed meal should be conducted to determine the additional value of this oil to animal producers.

Oregon Canola Production Potential

The object of the investigation in terms of production capacity in the state is to identify some likely growing areas where canola can be produced. Canola production history, though spotty, is largely in the Columbia Basin. Two agricultural areas in the Columbia Basin, one irrigated and one dryland, were chosen as well as Northeastern Oregon, focusing on current grower interest, production base, and ease of transportation.

The Willamette Valley was also chosen as a production area, due to grower interest, the need for a rotation crop for grass seed, and proximity to the oil market. Central Oregon around Madras is also included. Although Klamath Falls area is a possibility for canola production, climatic concerns and lack of data kept this area from consideration in this study. Certainly, in all areas, variety and production trials would be a welcome addition to the scarce data on production of canola.

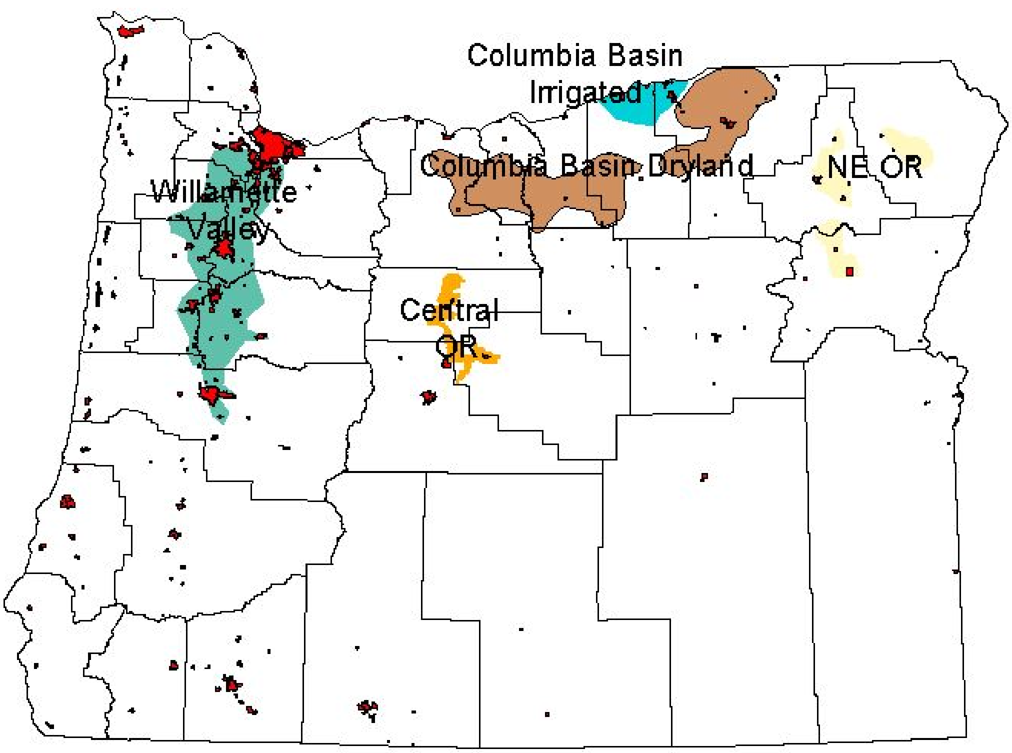

Figure 6. Map of possible canola production areas in Oregon.

Two sources of land base information were considered, the 2002 Census of Agriculture and the 2004 OSU Extension Estimates. In general, the Census of Agriculture data shows a much greater land base than the OSU estimates, probably the result of the mandatory participation of the Census of Agriculture and voluntary nature of the OSU figures.

Table 5. Total Acres available in Oregon by agricultural region

Area	2002 Ag Census acres	2004 OSU Extension Estimated acres
North East (LaGrande)	423,011	251,625
Irrigated Columbia Basin		91,600
Dryland Columbia Basin	2,231,793	980,413
Central (Madras)	231,530	114,881
Willamette Valley	1,261,788	800,241

The approximate number of acres in the areas defined by the study are summarized in Table 5. Due to the potential build up of disease problems, canola can only be grown one year in four in any particular field. Table 6 shows the estimated number of acres of canola that could be grown each year with canola on a 4 year rotation.

Table 6. Total acres available on 4 year rotation with canola

Area	2002 Ag Census acres	2004 OSU Extension Estimate acres
North East (LaGrande)	105,752	62,906
Irrigated North Central		22,900
Dryland North Central	557,948	245,103
Central (Madras)	57,882	28,720
Willamette Valley	315,477	200,060

Table 7 calculates the potential tons of seed for each area based on expected yield. The yield estimates vary due to differences in climate, soil, and irrigation.

Table 7. Total potential canola seed production

Area	Yield (lb/acre)	2002 Ag Census acres (tons seed)	2004 OSU Extension Estimate acres (tons seed)
North East (LaGrande)	2000	105,752	62,906
Irrigated Columbia Basin	2500		28,625
Dryland Columbia Basin	2000	557,948	245,103
Central (Madras)	3000	86,823	43,080
Willamette Valley	4000	630,954	400,120

Table 8 shows the total potential annual oil production from canola in each production area assuming extraction of 80 gallons of oil per ton of canola seed.

Table 8. Potential canola oil production (gallons)

Area	Yield (lb/acre)	2002 Ag Census acres (gal oil)	2004 OSU Extension Estimate acres (gal oil)
North East (LaGrande)	2000	8,460,160	5,032,480
Irrigated Columbia Basin	2500		2,290,000
Dryland Columbia Basin	2000	44,635,840	19,608,240
Central (Madras)	3000	6,945,840	3,446,400
Willamette Valley	4000	50,476,320	32,009,600

Table 9 calculates the potential value of the canola oil based on an oil price of $2.10 per gallon.

Table 9. Potential value of Canola oil ($2.10 / gal)

Area	Yield (lb/acre)	2002 Ag Census acres ($)	2004 OSU Extension Estimate acres ($)
North East (LaGrande)	2000	$17,766,336	$10,568,208
Irrigated Columbia Basin	2500		$4,809,000
Dryland Columbia Basin	2000	$93,735,264	$41,177,304
Central (Madras)	3000	$14,586,264	$7,237,440
Willamette Valley	4000	$106,000,272	$67,220,160

Table 10 indicates the potential production of canola meal (tons) and its estimated value. Meal tonnage is calculated as 66% of seed weight and the value is based on a price of $140 per ton.

Table 10. Tons of Canola Meal @ 66% of seed weight and $140/ton

Area	Yield lb/acre	2002 Ag Census acres tons meal / $ value	2004 OSU Extension Estimate acres tons meal / $ value
North East (LaGrande)	2000	69,796 / $9,774,000	41,518 / $5,813,000
Irrigated Columbia Basin	2500		18,893 / $2,645,000
Dryland Columbia Basin	2000	368,246 / $51,554,000	161,768 / $22,648,000
Central (Madras)	3000	57,303 / $8,022,000	28,433 / $3,981,000
Willamette Valley	4000	416,430 / $58,300,000	264,079 / $36,971,000

Table 11 summarizes the data in Tables 5-10 and provides the total potential acreage, seed and oil production, and value for canola that could be produced in the five areas listed.

Table 11. Summary of Potential Canola Production in Oregon*

	2002 Ag Census acres	2004 OSU Extension Estimate acres
Total acres available	4,148,236	2,238,756
Annual acres, 4 year rotation	1,037,059	559,689
Canola seed production, tons	1,381,477	779,834
Canola oil production, gallons	110,518,160	62,386,720
Canola meal production, tons	911,774	514,690
Oil value @ $2.10/gal	$232,088,136	$131,012,112
Meal value @ $140/ton	$127,648,474	$72,056,662
Gross Farm Gate Value	$359,736,610	$203,068,774

Farm Level Production

Growers will consider canola production based on seed price and cost of transport to market. Cultural costs are relatively low for canola, but historically there has been little local market in Oregon for canola seed. The lack of regional processing facilities has made canola purely an export crop with growers paying shipping costs to the export loading terminal. Decentralized oilseed extraction finally offers growers the potential to find local markets.

Gross return to growers at various seed prices and yields are shown in Table 12.

Table 12. Per acre gross return to grower at various seed prices and yields

Yield (lb/acre)	$0.09	$0.10	$0.11	$0.12	$0.13	$0.14	$0.15
2,000	180	200	220	240	260	280	300
2,200	198	220	242	264	286	308	330
2,400	216	240	264	288	312	336	360
2,600	234	260	286	312	338	364	390
2,800	252	280	308	336	364	392	420
3,000	270	300	330	360	390	420	450
3,200	288	320	352	384	416	448	480
3,400	306	340	374	408	442	476	510
3,600	324	360	396	432	468	504	540
3,800	342	380	418	456	494	532	570
4,000	360	400	440	480	520	560	600
4,200	378	420	462	504	546	588	630
4,400	396	440	484	528	572	616	660
4,600	414	460	506	552	598	644	690
4,800	432	480	528	576	624	672	720
5,000	450	500	550	600	650	700	750
5,200	468	520	572	624	676	728	780
5,400	486	540	594	648	702	756	810
5,600	504	560	616	672	728	784	840
5,800	522	580	638	696	754	812	870
6,000	540	600	660	720	780	840	900

While all growers like to see each crop return a profit, it is the crop rotation profitability that is the crucial long-term measure. There are benefits to some crops that even if they do not cover all costs for the year, are still viable in context of the crop rotation. Reasons for this include using an alternate crop to break a weed cycle or increase soil fertility. Canola can play this role in certain situations.

By extracting the oil and producing oilseed meal on-farm, the grower creates two income streams. These are represented below in 3 tables. Tables 13 and 14 present the value of oil and meal at various prices per gallon and ton. Table 15 presents possible combined values of oil and meal.

Table 13. Per acre canola oil value at various canola seed yields

Seed Yield (lb/acre)	Oil Yield (gal / acre)	Oil Price ($/gallon)						
		$1.90	$2.00	$2.10	$2.20	$2.30	$2.40	$2.50
2,000	81	153	161	169	177	185	194	202
2,200	89	169	177	186	195	204	213	222
2,400	97	184	194	203	213	223	232	242
2,600	105	199	210	220	231	241	252	262
2,800	113	215	226	237	248	260	271	282
3,000	121	230	242	254	266	278	290	302
3,200	129	245	258	271	284	297	310	323
3,400	137	260	274	288	302	315	329	343
3,600	145	276	290	305	319	334	348	363
3,800	153	291	306	322	337	352	368	383
4,000	161	306	323	339	355	371	387	403
4,200	169	322	339	356	373	390	406	423
4,400	177	337	355	373	390	408	426	444
4,600	185	352	371	390	408	427	445	464
4,800	194	368	387	406	426	445	465	484
5,000	202	383	403	423	444	464	484	504
5,200	210	398	419	440	461	482	503	524
5,400	218	414	435	457	479	501	523	544
5,600	226	429	452	474	497	519	542	565
5,800	234	444	468	491	515	538	561	585
6,000	242	460	484	508	532	556	581	605

Table 14. Canola meal value per acre at various seed yields

Seed Yield (lb/acre)	Meal Yield (lb /acre)	Meal Yield (tons/acre)	Meal Price ($ / Ton)						
			130	140	150	160	170	180	190
2,000	1,400	0.70	91	98	105	112	119	126	133
2,200	1,540	0.77	100	108	116	123	131	139	146
2,400	1,680	0.84	109	118	126	134	143	151	160
2,600	1,820	0.91	118	127	137	146	155	164	173
2,800	1,960	0.98	127	137	147	157	167	176	186
3,000	2,100	1.05	137	147	158	168	179	189	200
3,200	2,240	1.12	146	157	168	179	190	202	213
3,400	2,380	1.19	155	167	179	190	202	214	226
3,600	2,520	1.26	164	176	189	202	214	227	239
3,800	2,660	1.33	173	186	200	213	226	239	253
4,000	2,800	1.40	182	196	210	224	238	252	266
4,200	2,940	1.47	191	206	221	235	250	265	279
4,400	3,080	1.54	200	216	231	246	262	277	293
4,600	3,220	1.61	209	225	242	258	274	290	306
4,800	3,360	1.68	218	235	252	269	286	302	319
5,000	3,500	1.75	228	245	263	280	298	315	333
5,200	3,640	1.82	237	255	273	291	309	328	346
5,400	3,780	1.89	246	265	284	302	321	340	359
5,600	3,920	1.96	255	274	294	314	333	353	372
5,800	4,060	2.03	264	284	305	325	345	365	386
6,000	4,200	2.10	273	294	315	336	357	378	399

Table 15. Per acre canola meal plus oil values at various price combinations.

Seed Yield (lb/acre)	Oil Price ($/ gal)	$1.90	$2.00	$2.10	$2.20	$2.30	$2.40	$2.50
	Meal Price ($/ ton)	$130	$140	$150	$160	$170	$180	$190
2,000		244	259	274	289	304	320	335
2,200		269	285	302	318	335	352	368
2,400		293	311	329	347	365	383	402
2,600		317	337	357	376	396	415	435
2,800		342	363	384	405	426	447	468
3,000		366	389	412	434	457	479	502
3,200		391	415	439	463	487	511	535
3,400		415	441	466	492	518	543	569
3,600		440	467	494	521	548	575	602
3,800		464	493	521	550	579	607	636
4,000		488	519	549	579	609	639	669
4,200		513	545	576	608	639	671	703
4,400		537	570	604	637	670	703	736
4,600		562	596	631	666	700	735	770
4,800		586	622	658	695	731	767	803
5,000		611	648	686	724	761	799	837
5,200		635	674	713	752	792	831	870
5,400		659	700	741	781	822	863	903
5,600		684	726	768	810	853	895	937
5,800		708	752	796	839	883	927	970
6,000		733	778	823	868	913	959	1004
meal value		564,200	607,600	651,000	694,400	737,800	781,200	824,600
oil value		950,000	1,000,000	1,050,000	1,100,000	1,150,000	1,200,000	1,250,000
total		1,514,200	1,607,600	1,701,000	1,794,400	1,887,800	1,981,200	2,074,600

Table 16. Comparison of farm gate value of canola seed vs value of processed oil and meal.

Oil Price ($/ gal)	$1.90	$2.00	$2.10	$2.20	$2.30	$2.40	$2.50
Meal Price ($/ ton)	$130	$140	$150	$160	$170	$180	$190
Total Meal Value	564,200	607,600	651,000	694,400	737,800	781,200	824,600
Total Oil Value	950,000	1,000,000	1,050,000	1,100,000	1,150,000	1,200,000	1,250,000
Combined Value of Oil and Meal*	1,514,200	1,607,600	1,701,000	1,794,400	1,887,800	1,981,200	2,074,600
Seed Price ($/lb)	$0.09	$0.10	$0.11	$0.12	$0.13	$0.14	$0.15
total farm gate value*	1,116,000	1,240,000	1,364,000	1,488,000	1,612,000	1,736,000	1,860,000

* based on 6,200 tons canola seed for 0.5 million gallon biodiesel plant.

Table 16 shows that as seed price approaches $0.13 / lb, there is little margin left to process seed into oil and meal using a benchmark price of $2.10 / gallon oil and $150 per ton for meal on an industry-wide basis. Upward pressure on canola seed prices would call into question the operation of a centralized extraction plant if it is expected to operate at a profit. Farmers processing on-farm may be willing to subsidize either crop prices or extraction operations and / or take advantage of internal efficiencies to operate successfully at higher canola seed prices.

Extraction Plant Sizes

Several scenarios were used to examine the concept of decentralized processing of canola oil to feed a Portland based biodiesel plant. Considered here are a multi-farm plant in which growers in a small radius from the plant provide the feedstock, as well as on-farm crushers built on 4,000 and 10,000 acre farms. In all cases scenarios are shown for both irrigated and dryland crop production. Table 17 describes the parameters of a crushing plant that is supplied by several farms. It is over-sized, and can supply well over the required capacity of canola oil.

Note that about 5,000 acres of irrigated canola production are required annually to produce the 9,000 tons of seed needed to run the extraction facility through the year, while approximately 9,000 acres and dryland canola are needed to produce the same amount of seed. Since canola can only be grown every 4th year in rotation with other crops, this requires a total land base of 20,000 irrigated or 36,000 dryland acres to supply the press. This is an area of 32 and 60 square miles respectively of farmland, or about 1 or 2 townships, a township being 36 square miles. Located at the center of such an area, no grower would have over a 3 or 6 mile haul, respectively, to the press, and it is likely that the growers would absorb transport of a distance roughly double that. Of course, grower participation and yields will differ. Note that all production areas considered in this report will at first cut support a centralized press of sufficient capacity to supply a 0.5 million gallon biodiesel plant.

Table 17. Multi-farm press to produce 0.5 million gallons per year.

Description			
		Irrigated	Dryland
Basis	tons/hr	1.5	1.5
Acres Canola		5143	9000
Average Yield	lb/acre	3500	2000
Average Canola Production/Year	lbs	18,000,000	18,000,000
Average Canola Production/Year	tons	9000	9000
Pounds of Oil Produced/Year	0.3	5,400,000	5,400,000
Gallons of Oil Produced/Year	80.65	725,806	725,806
Plants required for .5 MM gal		0.7	0.7
Oil Price / Gal	$2.10	$1,524,194	$1,524,194
Tons of Meal Produced/Year	0.7	6,300	6,300
Meal Price / ton	$150.00	$945,000	$945,000
Oil + Meal Value		$2,469,194	$2,469,194
Canola Seed Cost	$0.10	$1,800,000	$1,800,000
GROSS INCOME		$669,194	$669,194
Tons seed (annual)		9000	9000
Hours / Day	20		
Days / Year Plant Operation	300		
Tons / Hour Scalped Seed		1.50	1.50
Tons Seed / day		30.00	30.00
Gallons oil per day	80.65	2,419	2,419
Gallons per hour		121	121
Gallons per minute		2.0	2.0
Tons meal per day		21.0	21.0
Tons meal per hour		1.1	1.1

The following table provides a very rough and very conservative view of viability. Plant cost, especially, is greatly exaggerated. Note that canola meal is a part of the income stream, and marketing this co-product is an essential element, greatly influencing siting of the plant to take advantage of this asset. Clearly, a multi-farm press, as a stand-alone enterprise, appears worthy of further consideration.

Table 18. Multi-farm canola oil extraction plant profitability

Assumptions	
1.5	Tons / Hour Seed Processed
20	Hours / Day
300	Days / Year Plant Operation
0.4	Oil Content
0.75	Oil Press Efficiency
7.44	Pounds of Oil / Gallon
$2.10	Oil Price
$150.00	Meal Price
$0.10	Canola Seed Price ($ / lb)
$5.00	Seed Transport ($ / ton)

		Quantity	Unit price	Revenue
Income	Oil (gallons)	725,806	$2.10	$1,524,193.55
	Meal (tons)	6,300	$150.00	$945,000.00
Total Income				**$2,469,193.55**
Expenses	seed (lbs)	18,000,000	$0.10	$1,800,000.00
	Transport charge (in or out)			$45,000.00
	labor	1	$40,000.00	$40,000.00
		1	$24,000.00	$24,000.00
	$1 MM plant, capital expense equipment @ 5 yr payback		$275,000.00	
Total Expenses				**$2,184,000.00**
NET				**$285,193.55**

On-farm presses also allow for very small scale production of canola oil. These presses could be added to compliment a crop farm looking to canola as a rotation crop, or as an animal based operation looking for a feed supplement in the canola meal. The latter is a natural fit, as the transportation of both seed feedstock and meal is minimal.

The relationship between seed, oil and meal prices is a delicate balance determining whether the pressing operation is viable on-farm. Only 2 or 3 large farms are needed to effectively supply the necessary canola oil feed stock for a 0.5 million gallon biodiesel plant. The efficiencies and internal marketing of canola meal such operations may enjoy over a centralized plant are likely worth considering.

Table 19. On-farm production of canola oil for dryland and irrigated farm of various sizes

Description		Large Scale On-Farm	Large Scale On-Farm	Small Scale On-Farm	Small Scale On-Farm
Production System		irrigated	dryland	irrigated	dryland
Farm Size	Acres	10,000	10,000	4,000	4,000
Acres in Canola / Year		2000	2000	800	800
Low Yield		3000	1800	3000	1800
High Yield		4000	2200	4000	2200
Average Yield		3500	2000	3500	2000
Average Seed Production	lb	7,000,000	4,000,000	2,800,000	1,600,000
Average Seed Production	tons	3500	2000	1400	800
Pounds of Oil	0.3	2,100,000	1,200,000	840,000	480,000
Gallons of Oil/Ton	80.65	282,258	161,290	112,903	64,516
Plants required for .5 MM gal/Year		1.8	3.1	4.4	7.8
Oil Value	$2.10/gal	$592,742	$338,710	$237,097	$135,484
Tons of Meal	0.7	2,450	1,400	980	560
Meal Value	$150/ton	$367,500	$210,000	$147,000	$84,000
Oil + Meal value		$960,242	$548,710	$384,097	$219,484
Canola seed Price	$0.10	$700,000	$400,000	$280,000	$160,000
GROSS INCOME		$260,242	$148,710	$104,097	$59,484
Tons seed (annual)		3500	2000	1400	800
Hours / Day	20				
Days / Year of Operation	300				
Tons / Hour Seed		0.58	0.33	0.23	0.13
Tons seed / day		11.67	6.67	4.67	2.67
Gallons oil per day	80.65	941	538	376	215
Gallons per hour		47	27	19	11
Tons of Meal / day		8.2	4.7	3.3	1.9

Transportation of Seed, Oil, and Meal

Since transportation distances are relatively short in a decentralized oilseed processing system, barge and rail transport are not practical, and only truck transport of seed, meal, and oil will be considered.

There are two caveats in any discussion about trucks: 1) any time a low value commodity is put on a truck, a large percentage of the value of the commodity is spent on transport. Canola meal especially may lose the advantage of being locally produced if transportation costs are not kept as low as possible. 2) No matter how good or efficient a truck transport system looks on paper, in actual practice it will cost more and be less efficient than expected. This is the nature of trucks. The less trucking involved, the more efficient the system, and the more competitive all value streams will be over time. This will be the case in lowering transportation costs of locally produced canola seed to the press from farms. Minimizing transportation costs will be especially important when moving the meal from the extraction plant to the end user, since most dairy or animal feeding operations are extremely sensitive to feed component costs and monitor them carefully.

From a transportation viewpoint, siting the oil extraction plant(s) near both the production source of the canola seed and cattle or dairy operations or other consumer that can utilize the meal is most desirable. Perhaps an integrated animal and agricultural operation would produce canola meal to feed its own animals, and vegetable oil would be sold as the by-product of their operation. This approach not only has the advantage of no or short hauls for everything but the oil to market, it can also shift the cost of transport of the seed to the farmer, who in many cases bears the cost of moving product beyond the farm gate to the buyer terminal. If the distance is short enough, the farmer may absorb the cost. If the distance is not so short, the farmer's willingness to produce the crop at a given price may decrease.

Trucking costs will range from about $1.50 to 2.50 per mile for 25 to 30 tons, depending on the truck, the haul, and whether or not there is a back-haul to help defray round trip costs. With fuel prices and fuel surcharges in flux at this writing, we can expect adjustments in transport costs in the future. Efficiencies designed into the system now will reap benefits in the future.

On shorter hauls, where it is often unlikely or impossible to find a back-haul, hauling costs are often based on the time required and load capacity of the truck. If the trucking equipment is at all specialized, there is further likelihood that the truck will be loaded in only one direction, and the equipment dedicated at least partially to the haul. Table 20 shows the cost per truck load from a variety of possible oil extraction locations to Portland based on an hourly rate for each trip. A conservative view is taken; where the truck will be loaded in only one direction and the round trip cost cost is roughly double the one-way cost. The cost of running a truck empty is a very high percentage of the cost loaded.

Table 20. Cost per truck load, based on hourly rate and estimated hours round trip.

	Miles*	Round Trip Hours	Truck Costs ($/Hour) $60	$65	$70	$75	$80	$85
Salem	50	3	165	180	195	210	225	240
Corvallis	80	4	220	240	260	280	300	320
Eugene	110	4.5	248	270	293	315	338	360
Madras	150	7	385	420	455	490	525	560
Hermiston	180	8	440	480	520	560	600	640
Pendleton	200	8.5	468	510	553	595	638	680
LaGrande	275	11	605	660	715	770	825	880
Klamath Falls	280	11	605	660	715	770	825	880

*miles from Portland

The real measure in transportation of bulk commodities is cost per ton. This is an additional cost a user of any commodity adds to the price in weighing alternative feed stocks or feed components in an animal ration. In reviewing estimates per ton in Table 21 for moving seed to a press or meal away from a press, it is apparent that the cost of bulk materials is influenced heavily when transportation by truck is required.

Table 21. Cost per ton, based on load net weight of 25-31 tons, depending on vehicle configuration.

Tons Hauled Truck $ / hour	25 $60	25 $65	29 $70	29 $75	31 $80	31 $85
Salem	6.60	7.20	6.72	7.24	7.26	7.74
Corvallis	8.80	9.60	8.97	9.66	9.68	10.32
Eugene	9.90	10.80	10.09	10.86	10.89	11.61
Madras	15.40	16.80	15.69	16.90	16.94	18.06
Hermiston	17.60	19.20	17.93	19.31	19.35	20.65
Pendleton	18.70	20.40	19.05	20.52	20.56	21.94
LaGrande	24.20	26.40	24.66	26.55	26.61	28.39
Klamath Falls	24.20	26.40	24.66	26.55	26.61	28.39

Transport of Canola Oil to Portland Biodiesel Plant

If the cost of trucking seed and meal can be minimized by proper extraction plant siting, the remaining cost of transportation involves moving the canola oil from the extraction plant to the biodiesel plant based in Portland. Movement of bulk liquids by truck is similar to that of other bulk materials. Shorter hauls will have higher cost per mile, and may have dead-head miles that will be compensated as well. It is likely, in fact, that the cost at a given rate per mile may be doubled to reflect the dedicated nature of the specific haul.

As possible plant sites become more apparent, each haul will have to be examined in specific detail to learn which carriers can provide the necessary service most economically based on other business in the region. It may also emerge that the biodiesel plant or the extraction facility may take on the role of providing transportation of the oil as well.

Bulk Transporter, a trade journal, indicates that vehicles used to transport petroleum include 4,500-gallon, three-compartment tank trucks with 4,800-gallon, two-axle tank trailers. Also in combination with the tank trucks are four-axle 7,000-gallon trailers. The units are used for their flexibility in tight areas at commercial facilities where a larger semi-trailer is harder to maneuver.

If the average tanker truck trailer combination hauls 9,000 gallons, the following table indicates the number of loads each plant size situation will require. This will help determine the path of truck procurement for the purpose of providing oil to a one half million gallon biodiesel facility.

Table 22. Number of truckload needed annually for various sized extraction plants.

Type of Extraction Plant		Oil Production (gal/year)	Required Press Plants for 0.5 MM gallons	9,000 gallon truck loads annually
Multi-Farm Plant	irrigated	725,806	0.7	81
Multi-Farm Plant	dryland	725,806	0.7	81
Large Scale On-Farm	irrigated	282,258	1.8	31
Large Scale On-Farm	dryland	161,290	3.1	18
Small Scale On-Farm	irrigated	112,903	4.4	13
Small Scale On-Farm	dryland	64,516	7.8	7

If the biodiesel plant has a 0.5 million gallon capacity, it will move a total of 1 million gallons of oil in and biodiesel out, about 111 truckloads at 9,000 gallons each. This volume likely justifies the biodiesel plant take under consideration the operation of a dedicated tanker.

Table 23 indicates some possible prices for various hauls for canola oil to the biodiesel plants from various production areas / press sites. The possibility of back haul situations seems reasonably high for moving bulk liquids into Portland. This may make the cost of moving oil relatively cheap compared to transporting bulk commodities, as well as only transporting about 30% of the press outputs by weight any distance by truck.

Use local knowledge on truck size and local conditions to estimate cost. In some cases, figures should be doubled when no back-haul can be procured. Similar cost will be incurred in delivery of biodiesel to bulk customers.

Table 23. One-way cost per load of hauling canola oil to Portland.

Cost per Mile	miles	$1.25	$1.50	$1.75	$2.00	$2.25	$2.50
Salem	50	$63	$75	$88	$100	$113	$125
Corvallis	80	$100	$120	$140	$160	$180	$200
Eugene	110	$138	$165	$193	$220	$248	$275
Madras	150	$188	$225	$263	$300	$338	$375
Hermiston	180	$225	$270	$315	$360	$405	$450
Pendleton	200	$250	$300	$350	$400	$450	$500
LaGrande	275	$344	$413	$481	$550	$619	$688
Klamath Falls	280	$350	$420	$490	$560	$630	$700

In summary, the low cost solution for feedstock transportation is to eliminate transport costs as much as 85% by locating the press plant at or near both canola seed source and end user of the canola meal. Selecting the production area closest to the end consumer and locating the biodiesel plant as close to the press and the consumer as possible will reduce costs.

Current Limitations on Canola Production in Oregon

The Brassicaceae is a large and widespread plant family which contains many important crops including broccoli, cauliflower, cabbages, turnips, radishes, rapeseed, canola, mustard, and a variety of other crops.

In the early 1990's the legislature gave the director of the Oregon Department of Agriculture authority to regulate the production of plants in the *Brassica* family (rapeseed) throughout Oregon. The purpose of this law was to minimize cross-pollination conflicts among vegetable seed growers and seed companies producing these crops. In 1993, Oregon Administrative Rules (Chapter 603, Division 52) were adopted establishing rapeseed production districts and isolation requirements for producers. A system of pinning maps was also established in the Linn and Marion county extension offices to facilitate maintenance of isolation distance between vegetable seed fields. Under this system, growers or seed companies use pins in a map to identify vegetable production fields on a first-come-first-served basis. Producers attempt to maintain a 3 mile isolation distance between *Brassica* crops that have a probability of cross-pollination.

Increasing fuel prices in the last several years have resulted in greatly increased grower interest in producing canola for biodiesel due to its excellent adaptation to the PNW. In response to this interest and concerns from Willamette Valley vegetable seed producers, the ODA revised the *Brassica* rules in 2005, severely restricting areas in the state where canola can be grown as an oilseed crop. Districts where vegetable seed production is protected are shown on the map in Figure 2.

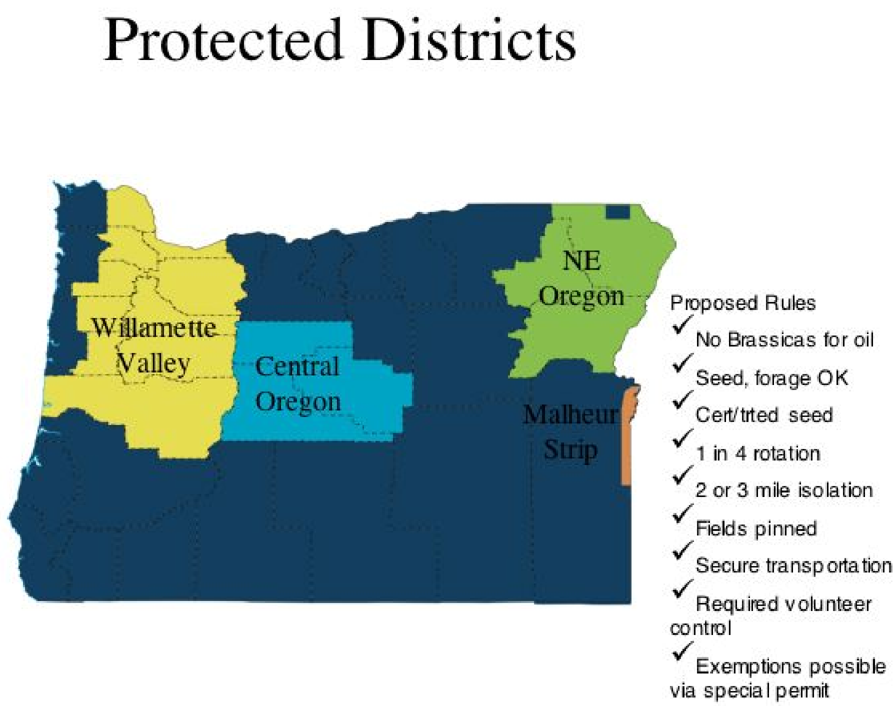

Fig. 2. Protected *Brassica* production districts under the 2005 canola rules.

Within the protected districts, growing any *Brassica* species for oil production is prohibited. Under current rules, producers wishing to grow *Brassicas* for oil within a protected district may request an exemption from the director of the ODA. Several applications for exemption were submitted to the director in 2006. On June 23, 2006 The Capital Press published an article regarding the decision made by the director. Current rules will be open for review and modification in 2007.

A2R Farms near Corvallis applied for a permit to produce canola for on-farm production of biodiesel. In addition, growers in Central Oregon and a researcher at the Madras Experiment Station also requested canola production permits.

On June 23, 2006 the Capital Press carried an article describing the director's decision. In spite of their willingness to exceed eligibility requirements established by the ODA, A2R Farms was denied a permit. The commercial growers in Central Oregon were also denied permits, but a permit was issued to allow research on the Central Oregon experiment stations provided that no genetically modified canola was included in the trials.

Oregon Business Energy Tax Credit

The Oregon Department of Energy currently offers the Business Energy Tax Credit (BETC) to individuals or entities who invest in renewable energy resources, including production of biodiesel. The Business Energy Tax Credit is currently 35 percent of eligible project costs. The credit is taken over 5 years with 10 percent taken in each of the first two years and 5 percent in each of the last 3 years. The tax credit would apply to oilseed extraction equipment, biodiesel processing equipment, and farm equipment used in the production of oilseed crops used as biodiesel feedstock.

Non-profit and public agencies are also allowed to participate in this program by means of a Pass-through Option. Under the Pass-through Option, a non-profit project owner may transfer the tax credit from the project to a business partner in exchange for a lump-sum cash payment. Currently the Pass-through Option rate for a one year BETC is 30.5 percent, and the rate for a five year Pass-through is 25.5 percent.

Use of this tax credit is an important incentive that will have a significant impact on investment in oilseed production and processing equipment.

Conclusions

1. In the near term winter canola offers the most promise as a biodiesel feedstock crop in Oregon. It produces the most oil per acre of any available crop. Seed yield of modern winter canola is much higher than is generally known. Winter canola varieties are available off-the-shelf that can produce relatively high seed and oil yield with relatively low production costs. In addition, there is an active crop improvement program already working in the PNW which will continue to develop varieties well-adapted to PNW growing conditions, increasing crop productivity in the future.

2. Spring canola can be grown in both eastern and western Oregon, but yield of spring canola is generally much lower than those of winter types. From the current data, it appears that without available irrigation in eastern Oregon spring canola is subject to highly variable yield.

3. Feasibility studies of large-scale, centralized oilseed extraction facilities have not proven them to be economically viable due to high initial capital cost and the high cost of transporting raw seed to the extraction plant. Preliminary results indicate that canola oil can be successfully and efficiently extracted from the seed using simple mechanical screw press technology, allowing smaller scale, decentralized extraction plants to be constructed at relatively low cost. The decentralized extraction plant model also minimizes transportation costs of raw material.

4. Profitability of decentralized oilseed extraction is quite sensitive to oilseed price. As canola seed price approaches $0.13 per pound, there is little operating margin for the extraction plant at current oil and meal prices.

5. Extraction facilities should be located close to both crop production areas and to meal consumers to minimize transportation costs. Both unprocessed seed and meal are bulk products that must be handled in large volume, and their relatively low value cannot justify long distance transport at current prices.

6. A number of other crop species should be investigated for their future potential as oilseed feedstocks. Reliance on a single crop carries risks of weather related crop failure over wide geographic areas as well as risk of problems from plant disease and insect pests.

Recommendations

1. Minimal data currently exists for canola seed and oil yield even in the major agricultural production regions of Oregon. As a result, there is a pressing need to establish long-term variety yield trials throughout the major production areas of the state to determine expected canola performance.

2. A detailed study of canola crop production costs should be conducted for each of the potential production areas outlined in this study. These will give growers more confidence and better information on which to make production decisions.

3. Evaluation of the potential of higher value markets for vegetable oil in the PNW is needed. This should include study of existing and potential food grade oil markets as well as the use of vegetable oil in bio-based products such as lubricating oil, hydraulic oils, and other high-value, specialty products.

4. The use of minimum tillage methods for canola crop establishment offers the best possibility to reduce canola production costs, and may also reduce production risks for growers. Extensive minimum tillage trials should be conducted in each potential production area to determine the best practices for successful application of this technology under the varying field conditions found in Oregon.

5. Unfortunately, very little is known beyond manufacturers specifications concerning the performance and efficiency of mechanical screw press crushers. Many growers and entrepreneurs are currently purchasing crushing equipment with very little objective information regarding their performance. Screw press performance trials should be carried out as soon as possible to minimize problems.

6. The animal feed value of cold pressed canola meal should be studied. This should include an economic analysis of the value of residual oil in feed rations.

8. The Oregon Department of Agriculture *Brassica* production rules should be reviewed and revised to allow more flexibility in canola and mustard production and research. The current rules are not based on the best available science and are currently limiting production, investment, and research.

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