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Camelina Production in Montana

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A new oilseed crop has created quite a flurry of activity in Montana. Research on all fronts, from how to best grow it, to developing end use products of the oil and meal of this unique seed, is currently underway.

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CAMELINA IS A NEW CROP FOR MONTANA.

A member of the mustard family, camelina is an oilseed crop that has demonstrated better drought tolerance and greater spring freezing tolerance than canola. Camelina appears resistant to flea beetles, a major economic pest of canola in Montana environments. Camelina has potential for successful dryland production across Montana, which should be a good choice for rotating with small grain crops.

The Montana Agricultural Experiment Station (MAES) began to develop this crop in 2004. A few producers, anxious to capitalize on this new commodity, have started planting camelina for commercial production. Best estimates of camelina acreage in Montana for 2006 ranged from 7,000 to 20,000 acres. In 2007, 24,000 acres of camelina were planted. This growth in interest and production acreage occurred prior to the completion of research on adaptation, best agronomic management, marketing, and use of the oil or the meal that remains once the oil has been extracted. Outlined in this publication is a short history and description of this crop. Also included are some highlights of ongoing research for use of camelina grain, oil, and meal.

Crop History and Adaptation

Camelina [*Camelina sativa* (L.) Crantz., Brassicaceae] is native to Central Asia and the Mediterranean with both annual and winter annual biotypes known to exist. It has been referred to in Europe for centuries as "gold-of-pleasure", an oilseed crop with evidence of cultivation dating back as early as 600 BC in the Rhine River Valley. Other common names include large-seeded false flax, or linseed dodder. Camelina oil was utilized for cooking and fuel oil and the meal was utilized for livestock. Production of camelina in Europe declined as canola production increased, but scattered acreages remain in Germany, Poland and Russia. In the 1980's, some germplasm screening and plant breeding occurred in the United States and Canada. Camelina is primarily known in North America as a weed species (*Camelina microcarpa*, or small-seeded false flax). There has been little research conducted on this crop worldwide, and its agronomic potential remains largely unknown.

Camelina plants are heavily branched, growing to heights of one to three feet. They become woody as they mature. It is a short-seasoned (85-100 day) crop, best adapted to cooler climates where excessive heat during flowering does not occur. The plants produce prolific small, pale yellow or greenish-yellow flowers consisting of four petals. Seed pods are approximately ¼ inch long containing numerous seeds. Seeds are very small (< 1/16 inch), pale yellow-brown, oblong and rough with a ridged surface. Under low magnification they look quite similar to wheat seeds. Oil content of the seed is relatively high, typically ranging from 30 to 40 percent on a dry matter basis.

Adaptation of camelina has not been widely explored, but the flax-growing regions of the northern Midwest should provide an ideal environment. Its drought and spring freezing tolerance may make it a good fit for areas in Montana where canola production is difficult. There are several winter annual biotypes available in the germplasm which could allow camelina to be grown as a winter crop in areas with mild winters. Research to determine best management practices could further expand the areas of adaptation.

Potential Markets

Americans have become more concerned with acquiring healthy food and clean sources of energy. This genuine concern for health and environment has created new markets for oilseed crops. With the right match of plant qualities, production potential and marketing opportunities, camelina may prove to be a profitable complementary crop to conventional wheat production in Montana.

With energy costs on the rise, biodiesel and ethanol get a lot of coverage in the popular press. Camelina can certainly be used for energy production. But higher value products such as culinary oil, cosmetics, animal feeds and biolubricants may provide greater economic return to the producer.

FIGURE 1A. Camelina in rosette stage.

FIGURE 1B. Camelina bolting to make seed.

FIGURE 1C. Seed pods of camelina on multiple branches.

Camelina oil has good potential for food and industrial use

Camelina oil has unique properties. The oil contains about 64 percent polyunsaturated, 30 percent monounsaturated, and 6 percent saturated fatty acids. Importantly, camelina oil is very high in alpha-linolenic acid (ALA), an omega-3 fatty acid which is essential in human and animal diets and has important implications for human health. The oil also contains high levels of gamma-tocopherol (vitamin E) which confers a reasonable shelf life without the need for special storage conditions. The unique properties of camelina oil could lead to development of a wide array of high value markets for the oil and its components in foods, feeds, cosmetics and industrial products (biolubricants). Some ideas currently being researched include:

- *Nutritional*: Using camelina oil to increase the nutritional value of a range of baked foods such as bread, and spreads including peanut butter.
- *Health*: Potential health benefits of omega-3 from camelina oil are being evaluated in a breast cancer risk study for overweight or obese postmenopausal women.
- *Biodiesel*: Camelina biodiesel has been produced and evaluated by commercial biodiesel manufacturers including Core IV, Wyoming Biodiesel, Peaks and Prairies and Great Northern Growers. Camelina biodiesel performance appears to be equal in value and indistinguishable from biodiesel produced from other oilseed crops such as soybean.
- *Biolubricant:* Camelina oil can be converted to a wax ester that will replace more expensive and less available Jojoba waxes in a range of industrial and cosmetic products.
- *Soil and seed amendments:* The gum layer that surrounds each camelina seed can be removed and utilized as a seed coating for other seeds to improve their germination in challenging environments. Camelina gum also has the potential to be used as a soil amendment to stabilize exposed soils for erosion control as in road construction.

Value-added applications and products for camelina meal

Camelina meal, the extruded product remaining after the oil has been removed, has the potential to enhance the food quality of fish, meat, poultry and dairy products. Camelina meal typically contains 10-12 percent oil (approximately 5 percent omega-3), 40 percent protein, and metabolizable energy as high as 1600 calories per pound. Camelina meal can be used for production of omega-3 enriched feed products. However, camelina meal contains anti-nutritive compounds called glucosinolates. At high concentrations, these compounds can reduce livestock performance and

health. In certain European countries, camelina meal is banned from livestock feeds but accepted in human foods. Camelina seed or meal has favorable fatty acid profiles and protein content when being considered as a livestock feed. But questions remain about its use in feed rations. Published data on feeding trials conducted in the European Union indicate highly variable results with both ruminants and non-ruminants.

As of January, 2008 the State Department of Agriculture is working with several Montana industries and the FDA to generate documentation of what is needed to acquire GRAS (Generally regarded as safe) status and AFFCO feed certification.

In contrast to European studies, preliminary research in Montana utilizing camelina meal for production of omega-3 enriched livestock products has been promising. In these early studies, Montana has utilized conservative levels of camelina meal in the feeds. Negative impacts on performance and growth have not been observed. Products (beef, dairy, and eggs) have increased levels of omega-3 fatty acid. Current research is evaluating higher levels of camelina meal to determine levels of camelina or glucosinolate that negatively impact performance or product quality. The MAES and MSU have ongoing research to evaluate the affect of the meal in feed rations and to determine optimum formulations for production of value-added, omega-3 enriched products.

Currently research in Montana is being conducted in the following categories:

- *Beef:* Montana's number one industry is beef cattle production. Camelina feeding trials are ongoing to develop omega-3 enriched beef. In 2006, camelina meal was evaluated on its acceptability, and potential to replace soybean meal (SBM) in finishing beef cattle. Steers were fed 4 and 9 percent (dry matter basis) of a high concentrate diet of either SBM or camelina meal. There were no statistical differences in the performance or weight gain of cattle fed SBM or camelina diets. Sensory evaluation of steaks did not reveal any detrimental effect on taste or consumer acceptability. The omega-3 content of the muscle was slightly elevated. In 2007, camelina meal was fed at zero, 10, 20 and 30 percent of the finishing diets of steers. This diet was used to determine if there was a decrease in the performance of finishing cattle while using camelina meal to replace corn and soybeans as both the protein and energy source of the diet.

  Concurrently camelina meal is being fed to 2 and 3 year-old beef cows to evaluate the potential to use the meal as a protein and energy source for breeding beef cattle. The objective of the trial is to determine if the beneficial effects seen in humans from consuming elevated levels of omega-3 also occur in beef cattle. If camelina meal can effectively be utilized for production of omega-3 enriched beef, beef will constitute the largest single market for camelina meal in Montana. For more information contact Darrin Boss, Northern Agricultural Research Center, Havre, Mont.

FIGURE 2. Camelina plants bloom with small, four petal, yellow flowers.

- *Dairy products:* Research with dairy goats is ongoing in Bozeman. The content of omega-3 in goat milk increased with increased camelina content in the feed. In addition, the ratio of saturated to unsaturated fatty acids in milk increased when animals were fed camelina meal. Dairy cow research with Montana camelina meal is ongoing at the University of Idaho. For more information contact Dave Sands or Alice Pilgeram, Montana State University, Bozeman, Mont.
- *Poultry:* The US Egg and Poultry Association provided supplemental funding to analyze camelina meal as an ingredient for production of omega-3 rich eggs. Feeding trials at the University of Georgia confirmed that laying hens fed diets supplemented with camelina meal had increased omega-3 content in eggs. For more information contact Dave Sands or Alice Pilgeram, Montana State University, Bozeman, MT.
- *Trout:* Farmed fish require a source of omega-3 fatty acid. Fish feeds are commonly supplemented with marine oils, a practice which increases pressure on native fisheries and could potentially introduce marine contaminants into closed hatchery systems. Camelina meal was used to partially replace marine fish oil in formulated feeds. Rainbow trout refused to consume the camelina meal presumably due to the off-taste of the meal or glucosinolates. But rainbow trout did consume feeds formulated with camelina oil. For more information contact Dave Sands or Alice Pilgeram, Montana State University, Bozeman, Mont.

Economic Evaluations

The economics and feasibility of on-farm biodiesel manufactured from camelina or other oils is currently being evaluated. Joel Schumacher has published three policy papers that are available on the MSU Ag Economics website (http://www.ampc.montana.edu/policypapers.html). For a good review of terminology and a general understanding of tax credits and federal programs available to those interested in biodiesel and ethanol production, read Policy paper 19: *Montana Oilseed Markets: Historical Price and Production Statistics*. A very short description of camelina production in Montana is addressed in Policy paper 16: *Oilseed, Biodiesel and Ethanol Subsidies & Renewable Energy Mandates: US Federal & Selected State Initiatives*. Small scale oil extraction and biodiesel manufacture are described in Policy Paper 22: *Small Scale Biodiesel Production: An Overview*.

Agronomic Research in Montana

Camelina has just recently been introduced to Montana. Experience with camelina during the past couple of years has been successful enough to warrant further exploration and development of this crop. Cultivar selection and agronomic trials continue to be conducted to determine proper planting rates, planting dates, fertility practices, and refinement of management techniques to improve overall growth of the crop.

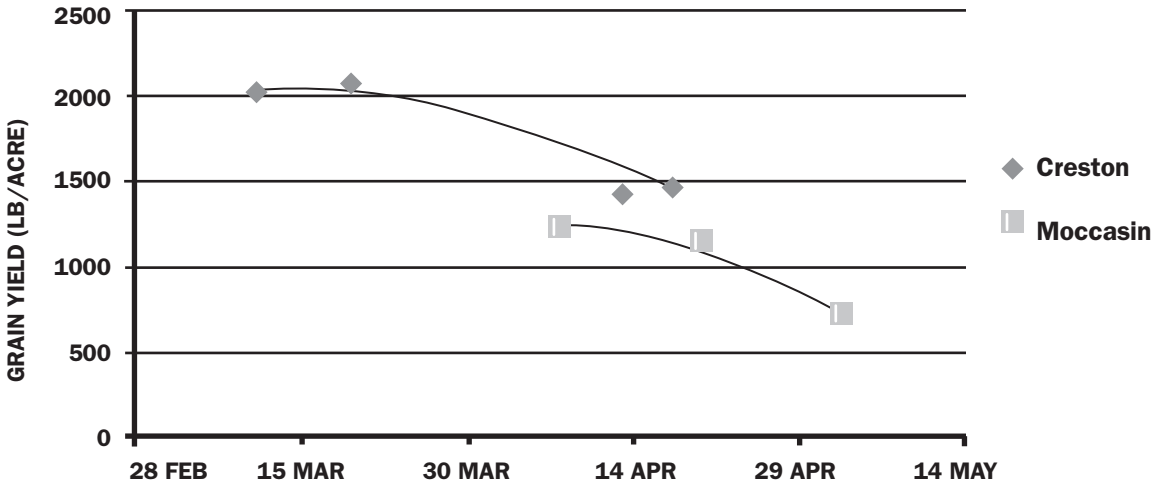
To address the growing interest in camelina production, a three-year study partially supported by a USDA-CSREES special grant was initiated in 2004 to evaluate several annual oilseed species for potential biodiesel and bio-lubricant production in Montana. This research was conducted primarily at the MAES Agricultural Research Centers. From that research and other studies, production potential in

TABLE 1. Research center trial averages and ranges for Camelina grain yields for several locations in Montana.

	Creston	Havre		Huntley		Moccasin		Sidney
Seeding date	3/23/06	5/4/05	3/31/06	5/2/05	5/4/06	2/4/05	4/10/06	5/13/06
	----------lbs/acre ----------							
average	1131	1661	1666	1150	942	781	1191	332
minimum	643	1585	1482	1148	812	669	1030	253
maximum	1334	1789	1765	1152	1109	878	1332	413
# of entries	10	4	9	2	9	4	8	3
Notes	a,g	b,f	b,f	b,g	b,f	b,c,d	b,d f	e,h

a: previous year fallow
b: previous year chem fallow
c: broadcast seeded
d: previous crop of small grain
e: previous crop of sugarbeets
f: direct seeded (no-till)
g: minimum tillage prior to planting
h: conventional tillage prior to planting

FIGURE 3. Camelina grain yields as affected by planting date at two Montana locations.



Montana for camelina has been assessed (Table 1). Each location used different methods for establishment as noted in Table 1. At most locations camelina was spring planted into wheat or other small grain stubble. In 2005 at Moccasin, camelina was broadcast seeded in early February rather than drilled. Burn down herbicides were used to control weeds prior to planting, but no herbicides were applied during the crop cycle as none are currently registered for this new crop. Fertilizer rates varied by site, but followed a general trend of approximately 30 lbs N/acre and 30 lbs P_2O_5/acre applied pre-plant.

In Montana, the best yields were obtained near Havre where over 1700 lbs/acre of camelina grain in dryland production has been achieved. At Huntley, yields were slightly lower nearing 1000 lbs/acre. Grain yields at Moccasin were similar to those of Huntley. In Eastern Montana (Sidney), camelina grain yields were substantially less averaging 330 lbs/acre. Oil percentage was determined on the majority of the plots harvested with values ranging from 29 to 40 percent, with an overall average of 31.7 percent. At Havre, oil percentages were higher, averaging 38 percent. Since 10-12 percent of the oil remains in the meal after processing, oil yield from camelina near Havre could be around 450 lbs oil/acre.

Some early selections for varieties more adapted to Montana have been made. These varieties showed better yield potential at most sites and contained approximately 4.5 percent more oil than the original selection of Celine (data not shown). Two improved varieties, Blaine Creek and Suneson, have been released by MAES. The potential for new varieties with even greater yield potential and higher oil content is possible. Evaluations of over 300 different selections from the existing germplasm were conducted in 2007.

Camelina is a cool season crop that needs to be planted early to attain maximum yields. Figure 3 shows the optimum planting date in Creston to be around the 15-20th of March. Delayed seeding into April and May severally decreased grain yield. At Moccasin, initial tests showed that planting dates in early April yield greater than late April or early May. Broadcast seeding at Moccasin in 2005 resulted in moderate yields averaging 780 lbs/acre. Seeds were broadcast on Feb 4, but emergence did not occur until late April. Sporadic emergence from broadcast seeding can lead to harvest problems because of uneven maturity. Dormant seeding of camelina as early as January or February may be possible, but research on this establishment method has not been completed, so dormant seeding is not currently recommended.

Field Selection and Rotation

A crucial first step in camelina production is field selection. No herbicides are currently labeled for use in camelina, therefore, it is critical to select fields where prior management has limited weed pressure and weed seed production was kept to a minimum. It is important to know the field's chemical history. Research on camelina's susceptibility to herbicide carryover has not been completed. The best recommendation for seeding camelina is to follow plant-back restrictions specified for canola on herbicide labels. If conditions warrant that canola should not be planted, do not plant camelina. A field bioassay is recommended if questions remain about residual herbicides. Currently, camelina production is recommended in conjunction with a small grain rotation. Because this crop is new to Montana, the effects that camelina may have on subsequent crops and rotations have not been adequately evaluated. To date, no crop suppression or injury to cereals following camelina production has been reported.

Seeding Rate

A seeding rate study conducted at Huntley in 2006 showed an increase in yield over the range of rates studied (Table 2). At this location for one year, grain yields were best when seeded at 6 and 8 lbs/acre, rather than rates of 1, 2, or 4 lbs/acre. The small seed of camelina would provide approximately 400,000 seeds/lb. Planting 1 lb/acre would provide a density of 9 seeds/ft^2. If all seeds germinated and produced plants, this population would be adequate. But small seeds placed shallow in the soil, and drilled through high residue levels can lead to poor germination and low plant populations. Planting a minimum of 3 to 5 lbs/acre is recommended to ensure a uniform, dense crop stand.

TABLE 2. Seeding Rates of Camelina at Huntley, Mont. 2006.

Seeding Rates	Grain Yield
------- lbs/acre --------	
1	752 b
2	778 b
4	795 b
6	977 a
8	953 a

Means followed by the same letter are not significantly different at the 5 percent probability level.

Seeding Method

Current recommendations are to drill camelina seed very shallow utilizing packer wheels to ensure good seed to soil contact and a firm seedbed. Seeding depth should be no more than ¼ inch with at least some seed visually apparent on the soil surface after planting.

Broadcast trials for camelina in Montana have not been very successful east of the continental divide or in high residue environments. Poor and uneven establishment following broadcast seeding have resulted in uneven stands and uneven maturity of plants at harvest. Some early Canadian research on wheat and barley showed pre-broadcast harrowing which exposed moist soil immediately prior to broadcasting seed was more effective than post-broadcast harrowing. If broadcast seeding is used, the operation should be followed with a roller harrow or other implement to mix the seed and soil together and press the seed into the soil. No-till seeding, which mulches the soil surface with previous crop residue, has been successful.

Soil Fertility

Montana State University has conducted few fertilizer response trials on camelina. The current recommendation is to follow fertility recommendations for canola production as outlined in *Fertilizer Guidelines for Montana Crops* (EB-161), with the exception of sulfur guidelines. In five different trials by the Western Triangle Agricultural Research Center (WTARC), no yield response to sulfur application was seen (data not shown). Therefore, no sulfur applications are currently recommended.

Camelina has a natural, pale green color which should not be confused with an indication of nutrient deficiency. Camelina has been promoted as a low-input, low-fertility crop, but studies conducted by scientists at WTARC showed yield increased with total N up to 80 lbs N/acre. Before planting camelina, soil nitrate should be measured to a 3 foot depth and N fertilizer then applied to provide a total amount of 80 to 90 lbs N/acre.

Further research on application rates and methods for camelina is needed, but based on our knowledge from other crops, broadcasting fertilizer prior to or post seeding should not cause any problems. Fertilizer could also be safely knifed in prior to seeding, which typically provides greater fertilizer use efficiency.

Weed Control

There are no herbicides registered for use on camelina as of spring 2008. Choosing fields with low weed pressure, good chemical or mechanical fallow techniques in association with uniform, dense camelina stand establishment are the best defenses against weed growth. Herbicide research is currently being conducted by Montana State University and it is hopeful that recommendations can be made within two to three years.

Disease and Insect Control

To date, insect infestations and damage have not been observed on camelina in Montana. Flea beetle, *Phyllotreta cruciferae*, Goeze [Coleoptera: Chrysomelidae: Alticinae], a major economic pest in canola production, has not been observed to cause damage to camelina. Because camelina is such a new crop, insect and disease monitoring should be on-going. Please report any suspicious disease symptoms or evidence of insect feeding to your county extension agricultural agent.

Near Kalispell, downy mildew (*Peronospora parasitica*) was observed in station nursery plots, production fields, and commercial fields. Downy mildew has not been observed on camelina east of the continental divide. Downy mildew is a seed-borne fungal disease. Seed from downy mildew infested fields should not be saved for planting in subsequent years. Planting pathogen-free seed has been an effective method of controlling downy mildew in other crops. In addition, dryland production, limited irrigation, or reduced plant populations that allow greater air movement through the canopy may help limit the extent of this disease. Downy mildew can also survive on crop residues, so rotation away from broadleaf crops is an important component of the cropping system. Varieties vary in their susceptibility to downy mildew, but resistance trials have not yet been completed in Montana. Fungicide seed treatments may reduce seedborne downy mildew, however no fungicides are registered on camelina at this time.

Growers should monitor for diseases common to other mustard-related plant species such as blackleg, sclerotinia stem rot, alternaria black spot, powdery mildew, black rot and aster yellows. Most of these diseases are typically found in high humidity and high moisture environments not usually associated with dryland production east of the continental divide. Development of disease problems can be minimized by using good crop rotation practices. To reduce the chances of disease occurrence, it is currently recommended that camelina should be grown no more than once every four years on any one field.

Harvest

Harvest dates vary from late June to late July depending on seeding date, precipitation, temperature and harvest method. Camelina can be swathed and then picked up with a combine, or it can be direct cut when ripe and the seed moisture is below 8 percent. Swathing can effectively take place once the first seedpods at the top of the plant begin to yellow. Due to a rapid ripening process, camelina swathing needs to proceed in a timely manner to eliminate the potential of pod shatter during the swathing operation. Swathing is recommended if notable lodging occurs or if there is a significant amount of green weed material in the field. If swathing, cut at a height that provides some protection against windblown wind rows.

In general, harvesting the crop directly is preferred, thus saving the time and inputs required for swathing. Slight shatter can occur if the crop is hit by high winds near maturity, however some varieties are less susceptible to shatter. Once the pods turn a golden to golden-tan color, camelina is ready to be direct combined. At this point the lower stems may still be green. Depending upon temperature, maturity will occur within days of the appearance of the first yellow pods in the field. A sample should be tested for moisture using the canola setting on the moisture meter. Harvest should not take place if seed moisture is greater than 8 percent.

When direct cutting, camelina will shatter if the pods are batted by the reel, therefore reel speed should match ground speed. Because the camelina canopy is fairly dense, a somewhat slow ground speed is necessary. Header height should be set as high as possible while still ensuring the entire crop is being harvested. A header height just below the bottom pods will help minimize green material being fed through the combine. To reduce the chance of pod shattering, the concave should be opened up to allow easy passage of the plant material without crushing or cracking the seeds. Producers have reported that a 9/64" screen installed over the lower sieves produces good separation of the seed from the seed pods and stem pieces, thus reducing the amount of plant material in the harvested product. Camelina seed is very small and light, so airflow should be monitored and adjusted as appropriate to remove as much inert material as possible while minimizing loss of seed.

Seed Storage

Camelina seed is very susceptible to damage from high moisture conditions. Seed moisture for storage is recommended at 8 percent or lower. Seed stored in moisture conditions exceeding 10 percent can result in a "clump" of seed bound together. This can lead to increased handling loss and the potential for spoilage.

Seed characteristics of camelina are different than those of other oilseed crops. Camelina is a very small seed (see Figure 4), but it does not roll like canola or flow like flax. Filling cracks by taping or caulking truck beds and storage bins should be done prior to harvest to prevent seed loss. To date, there have been no reported observations of insect damage to seed occurring during bin storage. Currently no bin insecticide treatments are registered for use on camelina seed, so none should be used.

FIGURE 4. Camelina seed (upper right) is very small as compared to canola (upper left) and flax seed (bottom).

Volunteer following harvest

Camelina seed that makes good soil contact after harvest usually germinates within two to three weeks following the first significant rain event. It may take several rain events to wash seed off of plant residue and onto the ground, so volunteer plants may continue to germinate throughout the fall. Volunteer camelina is easily controlled with typical fall chemical fallow operations. Seed that germinates following fall chemical operations is susceptible to frost and may be killed by winter temperatures. Seedlings that survive the winter can be readily controlled by chemical fallow operations in the subsequent years or by broadleaf herbicides utilized in cereal production practice.

What's Next?

At this point there are many more questions than answers when it comes to camelina production and use. Early experience in Montana has shown that with good management, and timely planting, good crop yields can be attained. As a broadleaf cool season crop, camelina could become a good complementary crop to wheat, providing a needed break from cereals in wheat production. Crop rotation is a great way to reduce disease and insect pressure for any crop, and there are few good economic crop rotation options for wheat in Montana. Weed control is a major limitation to camelina production. Currently there are no herbicides registered for use with this crop, which means rescuing a field that becomes infested with weeds is difficult. Swathing the crop and the weeds to allow for harvest becomes the only option.

Other questions about the use of camelina seed and meal also remain. The oil can be marketed for biodiesel, but due to the constraints of the oil seed crushing industry, camelina production in the near future will only be grown under private contract so that enough seed for a crushing run can be accumulated by the contracting company. As for the meal following the crushing operation, early trials show that camelina meal may be used for animal feed, but questions about how to best design diets are still being researched.

Other high value uses of camelina and its rich omega-3 oil remain to be discovered.

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