Crambe:
An Economic Assessment of the Feasibility of Providing Multiple-Peril Crop Insurance

Prepared by the Economic Research Service
for the Risk Management Agency, Federal Crop Insurance Corporation

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Executive Summary

Crambe is a cool-season oilseed that grows best in semi-arid regions with warm days, cool nights, and low humidity. The crop is grown for its oil, which contains high amounts of erucic acid, a 22-carbon fatty acid. Erucic acid is used to make intermediate chemicals, such as slip agents, emollients, and surfactants, that are used as inputs in the manufacture of such items as plastic bags, cosmetics, personal care products, and laundry detergents. Industrial rapeseed is the traditional source of erucic acid for the world market. In the United States, crambe has begun to tap into this market. Industrial rapeseed and crambe are the only commercial sources of erucic acid.

A few attempts at commercial crambe production have occurred since the plant was first introduced into the United States in 1940. However, the most sustained commercial effort began in 1990 in North Dakota with a partnership among the High Erucic Acid Development Effort, a government-sponsored research consortium; National Sun Industries, an oilseed crushing firm specializing in sunflowers; and several North Dakota farmers. Approximately 2,200 acres of crambe were harvested in 1990. Production peaked in 1994 at 59.2 million pounds. No commercial acreage was planted in 1995, primarily because much of the crambe oil produced in 1994 had not been sold prior to spring planting. About 19,600 acres of crambe were harvested in 1996. Production totaled 29.8 million pounds, with an average yield of 1,520 pounds per acre.

Neither the Census of Agriculture or USDA's National Agricultural Statistics Service collect data on crambe acreage or production. Estimates are available from the North Dakota State University (NDSU) Extension Service and the American Renewable Oil Association (AROA), a crambe growers organization formed in 1993.

In 1996, AROA set up a separate steering committee and business to develop a production, processing, and marketing infrastructure for novel oilseeds in the Northern Great Plains. The grower-owned company, AgGrow Oils, plans to offer stock to growers in December 1996, construct a 150- to 250-ton-per-day crushing facility in 1997, and begin operation with the 1997 crop. Negotiations are underway that include contracting for 30,000 to 60,000 acres of crambe annually.

Industrial rapeseed oil is the traditional and dominant source of erucic acid in world and U.S. markets. World consumption of high-erucic-acid oils for industrial applications is estimated at about 125 million pounds per year. Industry sources estimate the U.S. supply of industrial rapeseed oil at about 5 million pounds of domestic production and around 25 to 30 million pounds shipped in from Canada and Europe. Although no data are available from industry sources or USDA on U.S. crambe-oil production, crambe oil reportedly gained acceptance in the U.S. high-erucic-acid market in the early 1990's when Humko Chemical, a division of Witco Corporation, began relying on it as a domestic source of erucic acid. Humko currently uses both industrial rapeseed and crambe oils.

World supplies of high-erucic acid oils have declined in the last few years as many countries have switched from older rapeseed varieties to canola types. World supplies are expected to remain tight. Although Canadian production is fairly stable, European production is below expectations again in 1996. Prices for erucic-acid oils have increased as supplies have tightened.

The meal left over after crambe seed is crushed and the oil extracted is used for livestock feed. Crambe meal was approved as a feed additive by the Food and Drug Administration on June 5, 1981, with the proviso that it be fed only to feedlot cattle and at a level not to exceed 4.2 percent of the diet. The meal has been accepted commercially by feed companies for feedlot cattle because of its attractive price and satisfactory animal performance. The meal sells at roughly half the price of sunflower seed meal and one-third the price of soybean meal

Stand establishment and harvest are critical times for crambe production. Stand establishment is tricky with crambe because of its small seed. Farmers have to learn how to select fields, prepare the soil, and plant the seed to get the crop established. Timely harvest is important to avoid high shattering losses. Ill-timed or incorrect harvesting could cause major shattering losses, as could high winds just prior to harvest.

Production perils occur throughout the growing season. Early season weeds may affect stand establishment. Prior to harvest, yields can be reduced due to late-season weeds or high winds. Another peril that can affect yield is excessive moisture, which promotes diseases.

Ad hoc disaster payments follow the trend of crambe production. During 1990-94, payments increased as acreage expanded. Sixty-five percent of the payments occurred in 1993, when North Dakota experienced significant yield losses due to disease infestations and commercial production was attempted in Colorado, Kansas and Nebraska. North Dakota accounted for 88 percent of the $193,496 paid for crambe yield losses during 1990-94. Farmers in the high-acreage counties of Barnes, Benson, Cass, and Wells received between $17,000 and $35,000 in total payments, while farmers in the other 17 North Dakota counties received less than $10,000 per county.

Farmer inquiries about the availability of crambe insurance have roughly paralleled acreage. Interest was higher in the early 1990's when acreage was up, but in the last few years, with acreage down, interest has been lower. Demand will probably increase again in the next few years if planned acreage increases occur. Crambe is grown under contract, so the contract price could be used as a basis for setting reference prices. Individual yield data could be calculated from individual acreage data and warehouse receipts, which are available from agronomist John Gardner, who is working with AgGrow Oils while on leave from the NDSU Extension Service.

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Introduction

Crambe (*Crambe abyssinica* Hochst.) is a cool-season oilseed that grows best in semi-arid regions with warm days, cool nights, and low humidity. The crop is grown for its oil, which contains high amounts of erucic acid, a 22-carbon fatty acid. Erucic acid is used to make intermediate chemicals, such as slip agents, emollients, and surfactants, that are used as inputs in the manufacture of such items as plastic bags, cosmetics, personal care products, and laundry detergents. Industrial rapeseed is the traditional source of erucic acid for the world market. In the United States, crambe has begun to tap into this market. Industrial rapeseed and crambe are the only commercial sources of erucic acid.

A few attempts at commercial production have occurred since crambe was first introduced into the United States in 1940. However, the most sustained commercial effort began in 1990 and is centered in North Dakota.

Crambe has some advantages for North Dakota farmers who are looking for an alternative broadleaf crop. Thus far, it has demonstrated excellent resistance to flea beetles and most other insect pests now prevalent in the Northern Plains. Unlike sunflowers, it is not readily consumed by migratory birds or other wildlife. Crambe has been adopted by farmers as an alternative that complements traditional crops, has crop rotation benefits, and is capable of generating modest economic returns (Gardner et al., 1992). In their projected crop budgets for 1996, the North Dakota State University (NDSU) Extension Service estimates that crambe will have the highest returns per acre in north central North Dakota, and will be number two or three in the southwest and south central portions of the state (Gardner).

Neither the Census of Agriculture or USDA's National Agricultural Statistics Service collect data on crambe acreage or production. Estimates are available from the NDSU Extension Service, National Sun Industries, and the American Renewable Oil Association (AROA), a crambe growers organization formed in 1993.

This report examines those aspects of the U.S. crambe industry that relate to the demand for crop insurance and the feasibility of developing a crambe insurance policy.

U.S. Research and Production History

Crambe (*Crambe abyssinica* Hochst.) is believed to be a native of the Mediterranean area. It is an erect annual herb with numerous branches that can vary in height between 24 and 40 inches, depending on the season and plant density. Its leaves are large, oval-shaped, and smooth. Crambe flowers are very small, white, and numerous. Flowering is indeterminate (new flowers appear on the branches as older ones are pollinated and produce seed), but the early-formed pods usually adhere until later ones mature. *C. abyssinica* is primarily self-pollinated. The round seeds are borne singly and are about 1/8 inch in diameter. Each seed is enclosed in a hull or pod which usually remains on the seed after harvest. The hulls are typically light brown in color (Lessman and Anderson; Endres and Schatz.) Crambe seed is very light, only weighing 25 pounds per bushel, mainly because of the hull that surrounds each seed (Carlson and Van Dyne).

Crambe was introduced into the United States in 1940 by the Connecticut Agricultural Experiment Station. In 1957, USDA began screening a large number of plant species as potential new crops. Among 8,000 species evaluated between 1957 and 1983, crambe emerged as a promising oilseed because of its high erucic acid content. USDA's Agricultural Research Service (ARS) and state agricultural experiment stations began production trials, variety development, and utilization research. The Texas Agricultural Experiment Station began agronomic research in 1958, followed by Purdue University in 1962 (Johnson and Sell).

At least three crambe varieties were developed and released during three decades of research and development. Meyer, the most widely grown variety during the early and mid-1990's, was developed by the Purdue Agricultural Experiment Station and released in the mid-1960's. BelAnn and BelEnzian were developed and released by ARS at Beltsville, Maryland, in 1985. Meyer and BelAnn currently are available for commercial production (Johnson and Sell; Gardner).

Private companies also have been investigating crambe during the last 30 years. For example, the Pacific Vegetable Oil Company in Nebraska and the Coast Trading Company in Oregon contracted with farmers to produce crambe on a commercial scale and experimented with its processing; between 1964 and 1975, from 550 to 2,500 acres were grown in North Dakota, Montana, and other northern states. In 1972, Crambe, Inc., of Indiana contracted with farmers in Ohio, Michigan, Illinois, and Indiana to produce 4,500 acres of crambe. Long-term interest, however, was thwarted by the lack of markets for the oil and the higher profitability of other crops (Twigg).

Another attempt at commercial production was made in Kentucky in 1981. Humko Chemical of Memphis, Tennessee, contracted for 1,000 acres of crambe to be grown at the price of 11.5 cents per pound. However, an apparently widespread aphid epidemic destroyed 80 percent of the acreage (Gardner et al., 1991). Also, yields had been decreasing since 1978 in field studies in western Kentucky. The declines were attributed to the recycling of seed infected by the fungus *Alternaria brassicicola* (Gillis).

A broader research and commercialization effort began in the late 1980's. Supported by ARS and USDA’s Cooperative State Research Service (now the Cooperative State Research, Extension, and Education Service [CSREES]), a group of individuals representing private industry, academia, and government met in Kansas City, Missouri, in December 1986 to identify specific crops whose products appeared to have significant potential for use as industrial feedstocks. Crambe was selected as one of the crops because of the market potential for erucic acid and its derivatives. The Crambe Project, as the endeavor was called, was supported by Iowa State University, the Kansas Board of Agriculture, Kansas State University, the University of Missouri, and New Mexico State University, plus ARS and CSREES. The Crambe Project became the High Erucic Acid Development Effort (HEADE) in 1990 and research was expanded to include industrial rapeseed. Eventually, consortium members also included the land grant universities of Georgia, Idaho, Illinois, Nebraska, and North Dakota (Van Dyne et al.).

Some of HEADE's funding came from a Special Grant appropriation, which was administered by CSREES. Federal funds were matched by state funding on approximately a dollar-for-dollar basis. Federal appropriations for the project reached $500,000 in the early 1990's, but funding was discontinued in fiscal 1995 (Van Dyne et al.).

Although federal funding has ceased, internal funds and cooperative interactions with seed, biotechnology, and chemical companies and with growers have enabled several universities to continue breeding, agronomic, animal feeding, and chemical research on crambe and rapeseed. NDSU and the Universities of Georgia, Idaho, and Nebraska are funding projects through their plant and animal sciences, chemistry and engineering, and extension departments (Carlson et al.). The breeding program at NDSU has isolated numerous crambe genotypes that perform better than currently grown varieties. Breeding efforts are continuing to combine all desirable traits (higher yields, higher oil and erucic acid content, lower glucosinolate content, and improved plant resistance to diseases, insects, and seed shattering). Crambe research is also underway in a number of European countries.

The Crambe Industry

Several factors must come together for commercial production of any new crop. Farmers must be willing to grow the crop. A buyer or buyers must be identified who will be willing to buy the output (seed, forage, or fiber). Researchers are also key, as they help farmers and buyers learn how to produce and process the crop.

The current effort to commercially produce crambe began in the spring of 1990 with a three way partnership among HEADE, National Sun Industries, and several North Dakota farmers. Under the direction of John Gardner, superintendent/agronomist of NDSU’s Carrington Research and Extension Center, HEADE was responsible for soliciting farmers in central North Dakota to grow crambe and providing them with Meyer crambe seed and production information. The farmers were to grow the crambe and deliver it to National Sun’s crushing plant in Enderlin, North Dakota, for a price between 7.5 and 10.5 cents per pound, dockage free. National Sun, under the direction of president Jeff Berkow, agreed to process the crambe into oil and meal, market the products, and pay farmers (Gardner et al., 1991; Johnson and Sell).

National Sun Industries, headquartered in Minneapolis, Minnesota, was interested in crambe for several reasons. First, declining sunflower production in North Dakota in the late 1980's had the company searching for additional oilseed volume for its Enderlin plant. Second, crambe fit the plant's crushing schedule. Crambe could be the last oilseed processed before the plant's annual cleaning and maintenance period, allowing processing of edible oilseeds (sunflower, canola, and soybeans) once crushing resumed (Johnson and Sell).

In 1990, 2,359 acres of crambe were planted in North Dakota (Table 1) and approximately 2,200 acres were harvested (Gardner et al., 1991; Carlson et al.). The crop was delivered to National Sun's Enderlin plant, and farmers received 9.5 cents per pound, less dockage, on a 10-percent moisture basis. According to National Sun, about 1,500 tons of crambe seed were processed into 500 tons of oil, 850 tons of meal, and 150 tons of hulls. The oil was marketed to Calgene Chemical for 27 cents per pound and the meal to Foxley Cattle Company of Bartlett, Nebraska, for $80 per ton (Gardner et al., 1991).

Table 1. North Dakota crambe production, price, and value, 1990-96

Year	Number of producers	Planted acres	Yield	Production	Price	Value
			lb./acre	1,000 lb.	$/cwt.	$1,000
1990	33	2,359[1]	988	2,330[2]	9.50	221
1991	72	4,418[1]	1,153	5,160[2]	9.50	490
1992	247	23,204[3]	1,057	24,538[2]	9.75	2,392
1993	420	57,683[3]	972	56,090	10.00	5,609
1994	350	43,925[1]	1,350	59,200	10.00	5,920
1995	na	400[4]	na	na	na	na
1996	145	22,000[1]	1,520	29,800	11.5-12.0	na

na = Not available. [1]Contracted acres. [2]Net crop crushed. [3]Acreage certified by the Farm Services Agency. [4]1995 acreage was grown to increase seed stock.
Sources: Johnson and Sell (1990-93 data, original figures were from National Sun Industries); Johnson, 1996 and Gardner (1994-96 data).

In 1991, 4,475 acres of crambe were planted and approximately 3,860 acres were harvested. Except for 57 acres in Roseau county, Minnesota, all the acreage was in North Dakota. After cleaning, National Sun crushed 5.16 million pounds of seed. Dockage was down from 14.76 percent in 1990 to 10.28 percent in 1991, as farmers became more familiar with crambe production and harvesting (Gardner et al., 1992).

Crambe acreage expanded again in 1992 and 1993. In 1993, National Sun contracted with farmers in North Dakota and Minnesota to plant approximately 55,000 acres of crambe. National Sun also contracted with farmers in Colorado, Kansas, and Nebraska to plant 5,500 to 6,000 acres. The High Plains crop was to be processed at the company's new multiseed crushing facility in Goodland, Kansas (Anonymous).

However, the attempt to produce crambe in the area around Goodland, Kansas, and in Colorado's San Luis Valley was disappointing (Carlson et al.). Not being familiar with the crop, farmers had problems with stand establishment (Baltensperger; Gardner). Seed dormancy and poor germination may have contributed to the establishment problems in some areas (Gardner). In western Nebraska and Kansas and eastern Colorado, hot summer weather also arrived earlier than usual in 1993. None of the dryland, spring-planted crops did well that year (Baltensperger). Commercial production remains concentrated in North Dakota.

In 1993, crambe growers in North Dakota formed the American Renewable Oil Association to promote certified seed production, encourage varietal improvement and production research, and support pesticide registration. As of July 1996, approximately 250 crambe growers are members of the association (Gardner).

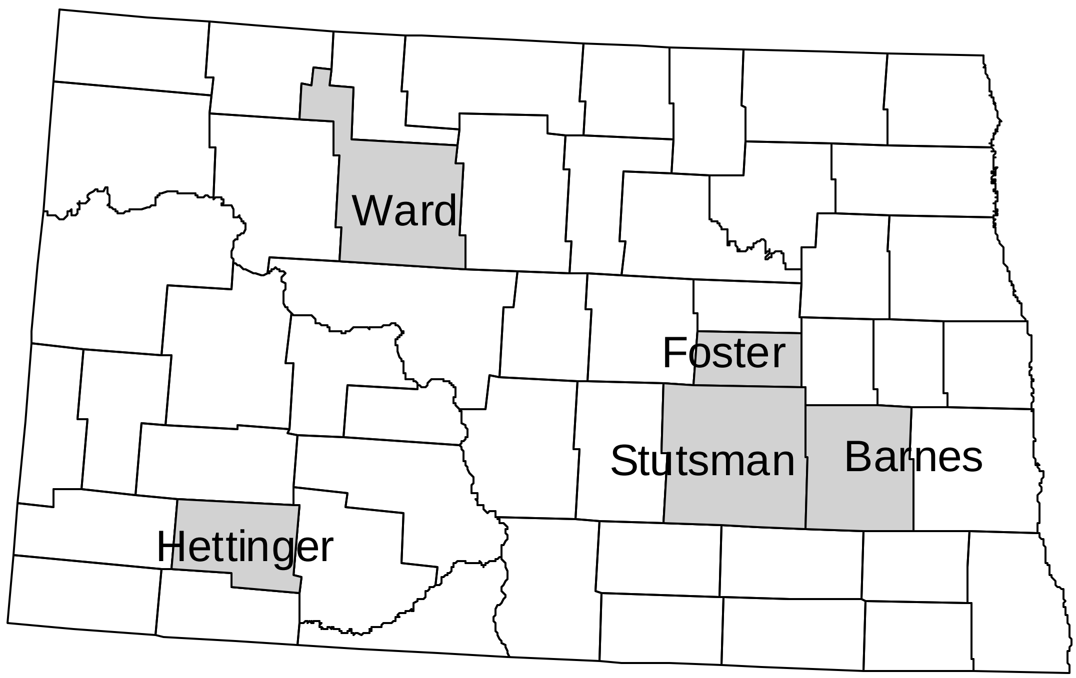
In 1994, National Sun's parent company decided to discontinue crushing operations and shift to more lucrative value-added food processing (Pasternak; Van Dyne et al.). As a result, National Sun leased the Enderlin plant to Archer Daniels Midland Company (ADM). ADM, which is using the Enderlin plant to process sunflowers, was not interest in buying crambe. Therefore, AROA negotiated with ADM to process the 1994 crop. The association assumed the responsibility of marketing the oil and the meal.

No commercial acreage was planted in 1995, primarily because much of the crambe oil produced in 1994 had not been sold prior to spring planting. Recent efforts to develop additional markets for high-erucic-acid oils had failed, resulting in excess supplies. A few fields of crambe were planted and harvested in 1995 for seed stock (Van Dyne et al.).

In 1996, AROA contracted with 145 producers to grow crambe on 22,000 acres. All the acreage was in North Dakota. About 19,600 acres were harvested during the beginning of September. Production totaled 29.8 million pounds, with an average yield of 1,520 pounds per acre. There is no predetermined contract price this year, but producers are likely to receive between 11.5 and 12 cents per pound (Gardner). ADM will process the crop. AROA has contracted with Witco Corporation to buy the oil (Van Dyne et al.) and will market the meal to feed manufacturers for beef finishing rations (Gardner).

AROA has set up a separate steering committee and business to develop a production, processing, and marketing infrastructure for novel oilseeds in the Northern Great Plains. The grower-owned company,

Figure 1. Crambe's principal growing regions are located in different parts of North Dakota



AgGrow Oils, plans to offer stock to growers this December, construct a 150- to 250-ton-per-day crushing facility in 1997, and begin operation with the 1997 crop. Negotiations are underway that include contracting for 30,000 to 60,000 acres of crambe annually and other novel oilseeds such as high-oleic sunflower and safflower, flax, and possibly specialty canolas (Gardner).

Crambe production in North Dakota began in the central and eastern portions of the state, but wet conditions during the past few years have moved production west (Carlson et al.). Today, the three principal growing regions surround the counties of Barnes, Foster, and Stutsman in the central region, Ward county in the northwest, and Hettinger county in the southwest (Figure 1).

Crambe growers tend to be grain producers with varying sizes of operations. In the central part of North Dakota, farmers grow crambe along with wheat, barley, sunflowers, and dry beans. In the western part of the state, crambe is grown in rotation with wheat and barley.

The High-Erucic-Acid Oil Market

Both crambe and industrial rapeseed are grown for the erucic acid in their oils. Industrial rapeseed is the traditional and dominant source of erucic acid. Crambe oil is only commercially available in the United States. Other world markets rely on industrial rapeseed oil as their source of erucic acid. When referring to erucic-acid-oil markets, research literature and industry publications often only mention industrial rapeseed oil. (See Appendix One for more information on industrial rapeseed.)

Although industrial rapeseed has a higher oil content, crambe has more erucic acid in its oil (Table 2). If crambe seed is dehulled, the oil content also approaches 50 percent. Industrial rapeseed and crambe are the only commercial sources of erucic acid. There is no practical method for making erucic acid from petrochemicals (Leonard, 1996).

Table 2. Composition of crambe and industrial rapeseed

Constituent	Industrial rapeseed	Crambe
	Percent (dry matter basis)	
Oil	42.0	35.3
Fatty acids		
Erucic	49.8	59.5
Oleic	14.9	16.1
Linoleic	10.1	8.2
Linolenic	5.1	2.9
Eicosenoic	10.9	3.3
Palmitic	2.7	1.7
Behenic	0.7	2.2
Stearic	1.1	0.8
Others	4.7	5.3
Protein (Nx6.25)	25.6	20.1
Crude fiber	7.3	14.3
Ether extract	2.5	--
Nitrogen-free extract	20.4	25.4

Source: Carlson and Van Dyne.

Supply

Charles Leonard, an oleochemical industry expert, estimates world consumption of high-erucic-acid oils for industrial applications at about 125 million pounds per year (Leonard, 1994). The United States' share is estimated at 35 million pounds (Carlson et al.). This is up from a 1991 industry estimate of 25 to 30 million pounds (Fitch-Haumann). Other major users are Europe and Japan.

Two 1996 articles in the *Chemical Marketing Reporter*, quoting industry sources, estimate the U.S. supply of industrial rapeseed oil at about 5 million pounds of domestic production and around 25 to 30 million pounds shipped in from Canada and Europe (Dolack; Chapman, May 1996). USDA estimates differ substantially from industry figures. USDA estimates show industrial-rapeseed-oil production declining during the 1990's from 6.96 million pounds in 1990/91 to 836,000 pounds in 1995/96, while imports have fluctuated from 6.6 million pounds to 20.4 million pounds during the same period (Table 3).

Table 3. Industrial rapeseed oil: U.S. supply, disposition, and price, 1987/88-1996/97

Marketing year[1]	Supply: Beginning stocks	Supply: Production	Supply: Imports	Supply: Total	Domestic disposition[2]	Ending stocks	Season average price
	1,000 pounds						Dol./lb
1987/88	800	6,785	17,637	25,222	22,699	2,522	0.236
1988/89	2,522	6,858	35,274	44,654	40,188	4,465	0.256
1989/90	4,465	8,184	29,407	42,057	37,851	4,206	0.278
1990/91	4,206	6,960	20,406	31,571	28,414	3,157	0.245
1991/92	3,157	5,705	8,737	17,599	15,839	1,760	0.226
1992/93	1,760	3,707	11,076	16,543	14,889	1,654	0.244
1993/94	1,654	4,140	6,581	12,375	11,138	1,238	0.291
1994/95	1,238	2,346	10,864	14,448	13,003	1,445	0.296
1995/96[3]	1,445	836	11,614	13,895	12,506	1,390	0.285
1996/97[4]	1,390	769	12,364	14,523	13,070	1,452	0.273

[1]October 1 to September 30. [2]Trade data do not distinguish between industrial rapeseed oil and canola oil exports; therefore, all exports are allocated to canola oil. [3]Preliminary. [4]Forecast.
Source: USDA Interagency Commodity Estimates Committee for Oilseeds, Oils, and Meals.

Although no data are available from industry sources or USDA on U.S. crambe-oil production, crambe oil reportedly gained acceptance in the U.S. high-erucic-acid market in the early 1990's when Humko Chemical, a division of Witco Corporation, began relying on it as a domestic source of erucic acid

(Gallagher, December 1994). Humko currently uses both industrial rapeseed and crambe oils (Santos, 1996).

World supplies of high-erucic acid oils have tightened in the last few years as older rapeseed varieties have been replaced with canola types. For example, Poland and the former East Germany historically have been heavy producers of industrial rapeseed oil because much was used for edible purposes. However, since the breakup of the Eastern Bloc, industrial rapeseed has yielded to canola because industrial rapeseed oil cannot be sold to European Union countries for edible purposes (Santos, February 1995). Erucic acid-containing rapeseed varieties are now considered specialty crops in Canada and Europe (Carlson et al.). China, Russia, and India still allow high-erucic-acid rapeseed oil to be used for edible consumption (Leonard, 1994; Santos, February 1995).

World supplies are expected to remain tight. Although Canadian production is fairly stable, European production is below expectations again this year. According to a spokesman for Croda Universal, Inc., which is headquartered in the United Kingdom, the 1996 European harvest of industrial rapeseed will be 1,000 hectares short of what is needed (Chapman, May 1996). The U.S. market will likely be served mostly by imports from Canada and domestic production. Calgene Chemical, a subsidiary of Calgene, Inc., of Davis, California, has an agreement with CanAmera Foods of Oakville, Ontario, North America’s largest rapeseed processor, to distribute some of CanAmera’s industrial rapeseed oil in the United States (Bahner; Leonard, 1996).

Prices for erucic-acid oils have increased as supplies have tightened. Higher world prices have been felt in erucic-acid product markets. Three producers of erucamide--Witco Corporation, Croda Universal, Inc., and Akzo Nobel Chemicals, Inc.--raised the prices of their erucamide products by 20 cents per pound in April and May 1995 due in part to high prices of high-erucic-acid oils (Santos, May 1995; Schearer, April and May 1995). Because of current high prices and the prospects of continued tight supplies, the companies increased their erucamide prices again in May and June 1996; Akzo by 8 cents per pound and Witco and Croda by 25 cents per pound (Shearer, 1996; Chapman, May and June 1996). While U.S.-based Witco uses both crambe and industrial rapeseed oils, the other two manufacturers use only industrial rapeseed oil.

Current Uses

The primary market for high-erucic-acid oils is erucamide. Plastic-film manufacturers have used erucamide for decades in bread wrappers and garbage bags. It lubricates the extruding machine during manufacture of thin plastic films. After processing, the erucamide migrates to the surface of the films and keeps them from clinging together. Two cheaper amides, stearamide and oleamide, cannot individually provide the critical properties that erucamide does. Therefore, erucamide is preferred, even at about twice the price (Carlson and Van Dyne; Leonard, 1994).

Charles Leonard estimates that 48 million pounds of high-erucic-acid oils are used worldwide in making about 15 million pounds of erucamide per year (Table 4). Erucamide is sold by a half dozen oleochemical producers in the United States, Europe, and Asia. Witco is the largest worldwide producer and marketer, supplying product from its Humko production facility in Memphis, Tennessee. Erucamide market growth roughly parallels the growth of polyolefin film sales, which in recent years has been in the range of 4 to 6 percent per year (Leonard, 1994).

Another major use of high-erucic-acid oils is in the production of erucyl alcohol. Principally used in cosmetics, about 10 million pounds of erucyl alcohol are manufactured in the world annually. The manufacture of behenyl alcohol is estimated to consume an additional 18 million pounds of high-erucic-acid oils. Behenyl alcohol is used as a pour point depressant, which keeps crude oil liquid and free flowing before it is refined (Leonard, 1994 and 1996).

Table 4. Estimated worldwide use of high-erucic-acid oils for industrial applications

Derivative	Application	Volume of oil used	Volume of derivative produced
		1,000 pounds	
Erucamide	Slip agent	48,000	15,000
Erucyl alcohol	Emollient	30,000	10,000
Various fatty nitrogen derivatives	Hair care and textile softening	18,000	6,000
Behenyl alcohol	Pour point depressant	18,000	6,000
Esters and others	Lubricants	6,000	4,000-5,000
Gyceryl tribehenate	Food emulsifier	2,500-3,000	2,500-3,000
Silver behenate	Photography	~750	~250
Total		123,250-123,750	43,750-45,250

Source: Leonard, 1994.

Cationic surfactants that function as active ingredients in personal care products, laundry softeners, and other household products appear to be an up-and-coming use for high-erucic-acid oils. Some companies in Japan and the United States are using cationic surfactants derived from 22-carbon fatty acids, such as those found in industrial rapeseed, crambe, and meadowfoam oils, as the active ingredient in hair conditioners. At least two U.S. companies are doing research in this area. An estimated 18 million pounds of high-erucic-acid oils are used worldwide to manufacture roughly 6 million pounds of cationic surfactants (Leonard, 1994 and 1996).

Because rapeseed and crambe oils have a high degree of lubricity, they also are used either directly as lubricants or in lubricant formulations. They are used as spinning lubricants in the textile, steel, and shipping industries; as cutting, metal-forming, rolling, fabricating, and drilling oils; and as marine lubes (Carlson and Van Dyne). For example, Calgene Chemical offers a line of erucic-acid esters to the textile and automotive fluids industries (Bahner). International Lubricants, Inc., of Seattle, Washington, sells erucic-acid-oil-based automatic transmission fluid additives, cutting oils, hydraulic oils, and power steering fluids. The transmission fluid additives are currently used by five European automobile manufacturers and U.S. transmission repair shops (Van Dyne et al.), and are newly available in retail auto parts stores.

One of the selling points of the erucic-acid-oil products offered by International Lubricants is their enhanced biodegradability compared to their petroleum-based counterparts. Thus, they are said to be more environmentally friendly (Carlson and Van Dyne). Several companies are reportedly in the market for industrial rapeseed and canola oils for lubricant applications because of their environmental attributes, which has caused a recent increase in demand (Dolack).

Another use of erucic-acid oils in response to environmental concerns is in the production of concrete mold-release agents. Leahy-Wolf Company of Franklin Park, Illinois, has developed and patented a biodegradable concrete-release agent based on industrial rapeseed oil, and is marketing it through U.S. distributors. Construction companies and precasters of concrete structures, such as sewer pipes, vaults, and bunkers, coat their molds and forms with release agents to facilitate the release of the hardened concrete. Often these compounds, which are traditionally petroleum-based, leach out of the mold or concrete and end up in the groundwater. Construction firms and precasters have had to modify their operations, however, to meet increasingly strict state and local regulations that limit the release of petroleum-based chemicals into the environment (Dean, p. 1-2; Buckhalt et al.; Leahy).

Potential Uses

The market for crambe oil has not expanded like growers and researchers had hoped. Large-volume uses that looked promising have fallen flat. Using crambe oil to produce nylon 13-13 (a nylon made from 13-carbon chains instead of the more common 6-carbon chains) did not materialize because other raw materials are cheaper. Procter and Gamble used crambe oil to produce Caprenin, a low-fat chocolate substitute designed to replace imported cocoa butter. Hershey and M&M Mars purchased Caprenin for experiments with reduced-calorie candy. Considerable test marketing occurred, but there has been no large-scale effort to sell products based on Caprenin and no indication that such an attempt will be made (Leonard, 1994; Gallagher, November 1994; Pasternak).

Over the last 10 years, HEADE funded various types of product development research. The products explored include surfactants, lubricants, paints and coatings, and various polymer types and applications (Table 5). Some of these projects are ongoing and may result in new uses for high-erucic-acid oils. For instance, scientists continue to research a catalytic process for cleaving erucic acid to brassylic and pelargonic acids. These chemical intermediates would then be available for use in polymers, coatings, lubricants, and other functional fluids (Van Dyne et al.).

The Market for Crambe Meal

The meal left over after crambe seed is crushed and the oil extracted is used for livestock feed. The protein content of the meal varies depending on the amount of hulls on the seed when it is crushed. With the hulls, crambe meal contains 22 to 28 percent protein. The partially dehulled meal produced by National Sun in 1991, due to partial harvest dehulling and intentional process dehulling, contained 34 to 35 percent protein. If completely dehulled, crambe meal contains 48 to 50 percent protein, a level similar to soybean meal. Crude fiber levels also vary with the amount of hulls present from more than 20 percent to less than 10 percent (Table 6) (Carlson et al.).

Table 5. Current and potential uses for crambe and industrial rapeseed oils

Intermediates	Consumer products
Triglycerides	Pharmaceuticals, lubricants, heat transfer fluids, dielectric fluids, waxes
Erucic acid	Erucamides (slip agents), plasticizers, amines (surfactants, antistats, flotation agents, corrosion inhibitors)
Behenic acid	Antifriction coatings, mold release, mixing and processing aids, flow improvers, food items
Erucyl alcohol	Surfactants, slip and coating agents
Behenyl alcohol	Surfactants, slip and coating agents, pour point depressants
Wax esters	Lubricants, cosmetics, functional fluids
Fatty acids	Existing C_{14}-C_{20} fatty acid markets
Brassylic acid	Nylons, perfumes, plasticizers, polyesters, synthetic lubricants, paints and coatings
Pelargonic acid	Plasticizers, plastics, coatings, perfumes, cosmetics, flavors, lubricants

Source: Carlson and Van Dyne; Leonard, 1996.

Table 6. Major constituents in defatted crambe meal

Content	With hull	Partially dehulled	Totally dehulled
		Percent dry matter	
Protein	27.7	34.6	49.5
Crude fiber	22.0	na	6.5

Crude fat	na	0.8	na
Acid detergent fiber	na	34.7	7.5
Ash	7.7	8.4	9.9
N-free extract	40.0	na	35.5
		Micro moles per gram	
Glucosinolates	45-70	56.0	80-100

na = Not available.
Source: Carlson et al., 1995.

Both crambe and industrial rapeseed meals contain glucosinolates, natural compounds found in all cruciferous plants. Glucosinolates are responsible for the sharp flavors of certain vegetables, such as radish, horseradish, cabbage, brussel sprouts, broccoli, and mustard (Carlson et al.). However, in livestock feed, glucosinolates are a problem. Single-stomached animals, such as swine and poultry, can develop toxicity problems from ingesting glucosinolates, while ruminant animals, such as cattle and sheep, exhibit greater tolerance (Endres and Schatz). Glucosinolates also affect iodine metabolism in dairy cattle (Wheeler). Therefore, the main use of glucosinolate-containing meals is in beef cattle feed.

Before an oilseed meal or other product can be used in commercial livestock feed, the Food and Drug Administration (FDA) must sanction its use and set the parameters for usage. Based on a petition filed by USDA, crambe meal was approved as an additive on June 5, 1981, with the following guidelines:

> "Crambe meal (heat-toasted) is the seed meal of *Crambe abyssinica* obtained after the removal of oil from the seed and hull. The oil may be removed by prepress solvent extraction or by solvent extraction alone. The resulting seed meal is heat-toasted and shall contain not less than 24 percent crude protein, not more than 11 percent moisture, not more than 4 percent oil, and not more than 26 percent crude fiber. It is to be used only in the feed of feedlot cattle, and at a level not to exceed 4.2 percent of the diet. Further specifications on crambe meal are: glucosinolates, calculated as epiprogoitrin, not more than 4 percent; goitrin, not more than 0.1 percent; nitrile, calculated as 1-cyano-2-hydroxy-3-butene, not more than 1.4 percent. At least 50 percent of the nitrogen shall be soluble in .5 *M* sodium chloride. Myrosinase enzyme activity shall be absent." (Price et al.)

In comparison, mechanically extracted industrial rapeseed meal must have at least 32 percent protein and no more than 12 percent crude fiber, according to the Official Publication of the Association of American Feed Control Officials (Carlson and Van Dyne).

Crambe meal has been accepted commercially by feed companies for feedlot cattle because of its attractive price and satisfactory animal performance (Carlson et al.). The meal sells at roughly half the price of sunflower seed meal and one-third the price of soybean meal (Gardner). These ratios are changing slowly as feed manufacturers become more familiar with crambe meal. Because of the smell and taste of glucosinolates, animals tend to sort and not eat the meal. To minimize this problem, researchers and feed companies have mixed crambe meal with other feed components and pelleted the rations (Van Dyne; Carlson et al.).

To aid in the marketing of crambe meal to feeders and feed formulators, HEADE sponsored a number of feeding trials (Van Dyne et al.). The USDA petition to FDA was largely based on four long-term beef finishing trials at Purdue University in the 1970's (Carlson and Van Dyne). However, results of recent feeding trials conducted by NDSU researchers with commercial crambe meal produced in Enderlin, North Dakota, suggest that the FDA-approved level may be conservative. The performance of animals fed crambe meal was approximately equal to that of animals receiving soybean meal. Tests included feedlot steers, backgrounding animals (animals fed a high roughage diet prior to receiving finishing rations), and beef cow-calf operations. Researchers suggest that additional experiments are needed to address the FDA restrictions with the goal of increasing or removing the 4.2 percent limit and allowing crambe meal in other phases of beef production (Van Dyne; Carlson, et al.).

HEADE also sought to increase the value of crambe meal by examining ways to extract glucosinolates from the meal. If a way is found to economically removed glucosinolates, dehulled crambe meal would be useful in poultry and swine diets. Additional projects were funded to evaluate glucosinolates as potential herbicides, nematicides, insecticides, fungicides, and chemoprotectants/antitumor agents (Van Dyne et al.). Preliminary results of research conducted at the University of Minnesota suggest that glucosinolates may be a natural biocide in controlling pests such as nematodes, houseflies, corn rootworms, mosquito larva, and spider mites (Van Dyne; Dean, p. 4).

Cultural and Management Practices

Crambe production in the 1990's has been centered in North Dakota. Unless otherwise noted, information on cultural and management practices is from NDSU's 1993 crambe production guide (Endres and Schatz).

Climate and Soil Requirements

Crambe is a cool-season crop that grows best in semi-arid regions with warm days (70 to 90ºF), cool nights (50 to 65ºF), and low humidity (Gardner). Present varieties require between 83 and 106 days from date of planting to reach physiological maturity. It is similar to oats in planting and harvesting dates (Carlson and Van Dyne).

Crambe is well adapted to fertile, well-drained soils with a pH of 6.0 to 7.5. When crambe is grown on soil with poor internal drainage, good surface drainage is essential. Crambe seed is moderately tolerant of saline soils during germination if soil temperatures range from 50 to 86°F. As soil temperatures drop below 50°F in saline soils, germination rates decrease. Established crambe plants are similar to wheat in their tolerance of saline soil.

Crambe is best suited to silt-loam soils that do not crust. Soils that have potential for crusting should be managed carefully to prevent emergence problems. While crambe requires adequate soil moisture for flowering, podset, and filling, a dry period as the plant approaches maturity is beneficial.

Varieties

Two crambe varieties, Meyer and BelAnn, are available for commercial production (Gardner). NDSU initiated a crambe breeding program in 1991. Work is continuing on varieties that contain all the desired characteristics (Hanzel). Germplasm from this program has been grown in variety trials in Iowa, Kansas, and Nebraska.

Planting

Stand establishment is a critical phase of crambe production. A vigorous stand that emerges early will take advantage of cooler temperatures and available soil moisture and be more competitive with weeds. The seedbed for crambe should be firm in order to place seed at a uniform and shallow depth. The seedbed should be prepared to avoid wind erosion; seedlings are easily damaged by drifting soil. Crambe should be sown 3/4-inch deep and no deeper than 1.5 inches.

As with any new crop, farmers have to learn how to produce the crop. Stand establishment is tricky with crambe because of its small seed. Farmers have to learn how to select fields, prepare the soil, and plant the seed to get the crop established.

Crambe should be sown in late April to early May when the greatest risk of frost has passed. Seedlings can tolerate temperatures as low as 24°F for several hours. A significant decrease in seed yield and oil content can be expected if seeding is delayed until late May or June.

Small grain seeding equipment, including double disc opener press drills and air seeders, can be used to seed crambe. However, uniform stand establishment may be more difficult with air seeders. A crambe seeding rate of 15 to 20 pounds live seed per acre is recommended. At 60,000 to 80,000 seeds per pound, this seeding rate should provide a targeted stand of 1 million plants per acre. Using the recommended rate is suggested if soil crusting is anticipated and also will result in crambe plants being more competitive with weeds and maturing more uniformly. Row widths of 6 or 7 inches generally give the highest yields.

Barely domesticated, it is not surprising that crambe seed exhibits a post-harvest dormancy. In an annual crop, such a trait makes it difficult to accurately estimate germination percentages and can lead to volunteer plants emerging in the field several years after the crop is harvested (Carlson et al). Recommended planting rates take dormancy into consideration and it should not affect yields. Volunteer crambe plants are not a problem in grain crops, such as wheat and barley, because crambe can be controlled with a broadleaf herbicide. Volunteer plants could be a problem, however, in broadleaf crops, such as canola and sunflower.

Fertility Requirements

Crambe's response to soil fertility is similar to that of small grains, mustard, and canola. Farmers should conduct soil tests to determine the need for primary nutrients. In general, about 5 pounds of nitrogen is required for each 100 pounds of yield expected per acre. Farmers should avoid using more than 10 pounds of actual nitrogen with the seed at planting, as germination injury can occur. Crambe is responsive to phosphorus fertilization at rates of 25 to 50 pounds per acre.

Crop Rotations

Rotating crambe with other crops is recommended to avoid a buildup of insects, diseases, and weeds. Crambe should not be planted after itself or closely related crops, such as canola or mustard. Crambe should follow small grains, corn, grain legumes, or fallow. These rotations provide a break in pest cycles and provide soil conditions that can be easily managed to prepare for crambe production. Crambe also is suitable as a companion crop for alfalfa or in establishing other biennial or perennial forage-type legumes.

Small grains should perform well following crambe. Crambe stubble provides an acceptable cover for trapping snow, controlling erosion, and establishing fall-seeded crops in a no-till production system. When planting fall-seeded crops, care must be taken to minimize stubble disturbance as crambe residue is brittle and easily destroyed. Also, volunteer crambe is easily managed in succeeding crops using tillage and/or herbicides.

After the crambe harvest in 1991, the NDSU Extension Service mailed participating farmers (71) a voluntary survey to help identify production practices and problems. Fifty-one farmers (72 percent) responded. Asked about rotations, farmers reported that crambe predominantly followed a small grain crop (86.3 percent), but also flax (3.9 percent), fallow (3.9 percent), and various other crops (5.9 percent). Those who previously grew crambe in 1990 rated the crop that followed crambe to have performed equivalent to that of one following a small grain (54.2 percent) or row crop (37.5 percent). Volunteer crambe was easily managed in succeeding crops (96 percent) through either use of tillage, herbicides, or a combination of both (Gardner et al., 1992).

Harvesting

Crambe matures in 1 to 2 weeks after flowering. Timely harvest is important to avoid high shattering losses. During warm, dry weather the crop should be monitored daily or every other day to determine the correct time for harvest. Ill-timed or incorrect harvesting could cause major shattering losses, as could high winds at this critical time.

Crambe is physiologically mature when 50 percent of the seeds have turned brown. The appearance of the plant at maturity may vary. Some leaves may turn yellow and drop off, while stems and other leaves remain green. Attention should be directed to the seeds and seed-bearing branches to determine the onset of harvest. For most farmers, a learning period is necessary to identify the optimum harvest time (Carlson and Van Dyne).

Crambe may be straight cut or swathed (cut and laid into windrows). Both harvest methods have been successful, but the choice depends on acreage, harvest equipment, weather conditions, uniformity of maturity, and weed density. Straight combining is recommended for a mature, clean, low-moisture crop. If the majority of seed pods are brown, straight combining is recommended as swathing may cause excessive shattering. Crambe seed moisture should be 14 percent or less for straight combining. Crambe seed containing greater than 14 percent moisture will cause harvest problems due to difficulty moving the green plant material through the combine. At seed moisture less than 12 percent, high shattering potential exists. If approximately 100 crambe seeds per square foot are present on the ground from shattering, a 60-pound-per-acre yield loss occurs.

Swathing may be necessary if maturity is variable, where some plants are beginning to shatter while others are still slightly green. If a sufficient number of green weeds are present, swathing may be required. Crambe should be swathed when at least 50 percent of the seeds have turned brown. If most of the seeds have turned brown before swathing, the swathing and combine operations may cause excessive shattering. When swathing, reel speed should be reduced to one-half to two-thirds of that for small grains. Seed shatter can be minimized by swathing during a time of day when humidity is high. Swathing should be done just below the lowest seed pods, leaving the stubble as high as possible. This will allow the windrow to settle into the stubble and reduce the yield loss due to wind. Compared to small grains, crambe will dry quickly after a rain in a swath or if the crop is standing.

It is important that the combine be adjusted correctly when harvesting crambe. The first priority should be to harvest as much of the seed as possible with a minimum of seed damage. The seed should be harvested with the hulls intact, using the sieve settings for small grains adjusted as appropriate. When straight combining, the reel speed should be set to move only slightly faster than the ground speed of the combine. This is essential to reduce seed shattering.

Crambe yields in North Dakota have averaged an estimated 1,300 pounds per acre during 1990 to 1994. Yields on individual fields have ranged from about 800 to 2,600 pounds per acre during this same period (Gardner). Individual yield data on the 1996 crop are available from agronomist John Gardner, who is working with AgGrow Oils while on leave from the NDSU Extension Service.

Crambe seed should be stored and marketed at 10-percent moisture or less. Because of crambe's small seed size, dockage has been a problem with commercially grown crambe. When farmers have delivered seed, dockage has ranged from 6 to 8 percent (Carlson and Van Dyne, Gardner).

Costs of Production

Crambe is an annual crop that can be produced in North Dakota with the farmers' existing small-grain planting and harvesting equipment (Johnson and Sell). Because crambe has a low test weight, 25 pounds per bushel, and is a relatively bulky crop, transportation costs are greater than for small grains and corn, but similar to sunflower (Endres and Schatz). To combat high transportation costs as crambe production in North Dakota has shifted west away from the Enderlin plant, AROA has arranged for group rail shipment to the Enderlin plant (Carlson et al.).

Cost of production data are available for North Dakota. NDSU has published estimated crambe budgets since 1991. Estimated variable costs of production have ranged from $38 to $45 per acre. In 1996, crambe's estimated variable costs are similar to those for flax, rye, and winter wheat (Swenson and Aakre). NDSU crambe budgets for 1991, 1993, and 1996 are in Appendix Two.

Since commercial crambe production is located in North Dakota, meaningful data on production costs in other states are not available.

Production Perils

Stand establishment and harvest are critical times for crambe production. Weeds or late planting are production perils that may affect stand establishment. Prior to harvest, yields can be reduced due to late-season weeds or high winds. Another peril that can affect yield is excessive moisture, which promotes diseases. Information in this section, unless otherwise noted, is from NDSU's 1993 production guide (Endres and Schatz) and agronomist John Gardner.

Frost

The NDSU Extension Service recommends planting crambe in late April to early May when the greatest risk of frost has passed. However, frost is not a serious risk. Researchers and Extension personnel have seen crambe tolerate temperatures down to 24ºF.

Wind Damage

Crambe seedlings are easily damaged by drifting soil. However, this should not be a problem if farmers keep some residue cover in the field so the soil does not blow. Maintaining a higher level of organic matter in the field may also reduce the susceptibility to wind erosion.

In preparing for harvest, farmers can either windrow their crop or let it dry down while standing. Because crambe dries relatively quickly, high winds can lead to high shattering losses if a farmer has left his crop to field dry.

Drought and Excessive Heat

Crambe requires adequate soil moisture for flowering, podset, and filling. In North Dakota, crambe's tolerance to drought is equal to, or slightly less, than small grains. It is more drought tolerant than corn, canola, mustard, or soybean at all stages of growth.

Yields can be reduced if the drought is severe. During 1988-89, a couple of the driest years on record in North Dakota, test plot yields declined up to 50 percent. Under more normal circumstances, crambe does better under slightly drier conditions than slightly wetter ones.

Heat stress at the flowering stage can be detrimental to yields, but no more than for small grains.

Excessive Moisture and Hail

If seeding is delayed until late May or June because of wet weather, the flowering period is shortened. Less flowering results in fewer seeds and, thus, a significant decrease in seed yield and oil content may occur.

In addition, excessive moisture promotes the appearance of diseases, such as sclerotinia and alternaria, which can limit yields. For example, if excessive moisture is present during flowering, sclerotinia infection and yield losses may be high. Excessive moisture throughout the 1993 growing season in North Dakota resulted in significant yield loss due to sclerotinia and alternaria.

Crambe does not shatter during heavy rains, either in windrows or while field drying. So, excessive moisture in not a problem as the crop nears harvest. In fact, crambe dries more quickly than small grains and can be harvested sooner.

The risk of hail is similar to that of other spring-planted crops grown on the High Plains.

Weeds

Crambe is not a strong competitor with weeds during early vegetative development. Typically, it takes 3 or 4 weeks after emergence for a complete crop canopy to form. Weed control is critical during this period.

Late-season weeds can also interfere with harvest. After the crambe harvest in 1990 and 1991, the NDSU Extension Service mailed participating farmers a production practices survey. In 1990, farmers indicated that 8 percent of the acreage was not harvested due to weed infestations. No herbicides had yet been labeled for crambe. Late-season broadleaf weeds were most often mentioned as the most serious problem. Kochia (*Kochia scoparia*), ragweed (*Ambrosia artemisiifolia*), and pigweed (*Amaranthus retroflexus*) were frequently reported. These were also the weeds that made harvest difficult without swathing (green leaves and stems can easily gum up a combine). Wild mustard (*Brassica kaber*) was also frequently mentioned, which was confirmed by inspecting samples delivered to the Enderlin plant. Many loads contained from 10 to 15 percent wild mustard seed (Gardner et al., 1991). In 1991, farmers again reported annual broadleaf weeds as a problem (54.8 percent), followed by annual grasses (21.4 percent) and perennial broadleaf weeds (11.9 percent) (Gardner et al., 1992).

Treflan is now labeled for crambe as a pre-plant, soil-incorporated treatment to control annual grasses, such as foxtail, and certain broadleaf weeds. Wild mustard continues to be a problem. Future harmonization with Canadian pesticide regulations may increase the options for control. Crambe is susceptible to damage from drift of many broadleaf herbicides, certain soil-applied herbicides, and certain herbicide residues.

Diseases

Only a few diseases have been observed on crambe in North Dakota. It is susceptible to sclerotinia stem rot (white mold), but less so than sunflower and dry bean. Excessive moisture conditions in North Dakota in 1993 resulted in significant yield loss due to sclerotinia, as well as alternaria leaf spot. To control sclerotinia, the NDSU Extension Service recommends growing a minimum of three nonsusceptible crops before returning to crambe, canola, sunflower, or other susceptible crops (Johnson and Sell). Other potential diseases in North Dakota include blackleg and pythium root rot.

One of the problems with crambe production in Kentucky in the late 1970's and early 1980's was the prevalence of alternaria (Gardner et al., 1992; Gillis). Alternaria can infect the seed, causing a subsequent reduction in germination and vigor when later planted. In North Dakota, AROA has responded by establishing regular testing and a network of certified seed growers (Carlson et al.).

Insects

Insects that have potential for causing economic damage to crambe include aphids, cabbage maggots, grasshoppers, diamondback moth, leafhoppers, and lygus bugs. Aphids were responsible for destroying the commercial field trial of crambe in Kentucky in 1981.

Only grasshoppers have caused significant injury to crambe in North Dakota (typically in field margins). Crambe is most susceptible to grasshoppers at the seedling stage; they tend to choose other crop foliage as crambe develops. In the 1991 NDSU production survey, 3.9 percent of the respondents reported insect problems, all related to grasshoppers. Several farmers mentioned that crambe seemed the last crop of choice for grasshopper feeding among traditional cereal grains and row crops in their area (Gardner et al., 1992). Crambe is resistant to flea beetles, a major insect pest of canola and industrial rapeseed (Anderson et al.).

Through the coordinated work of federal and state researchers, crambe has been coupled with rapeseed and canola in terms of federal pesticide regulations. Manufacturers, however, still must list the specific oilseed (canola, rapeseed, crambe) on the label (Carlson et al.).

Ad Hoc Disaster Assistance for Crambe

Ad hoc disaster assistance was available to crambe growers for losses due to natural causes during 1990-94.[1] Since crambe production was not eligible for crop insurance during that time, crambe producers were required to realize a yield loss of at least 40 percent in order to receive ad hoc disaster payments. Data on ad hoc disaster payments indicate potential high-loss areas, and may also point to areas where there may be high demand for crop insurance.

Ad hoc disaster payments follow the trend of crambe production. Payments increased as acreage expanded. Sixty-five percent of the payments occurred in 1993, when North Dakota experienced significant yield losses due to disease infestations and commercial production was attempted in Colorado, Kansas and Nebraska (Table 7).

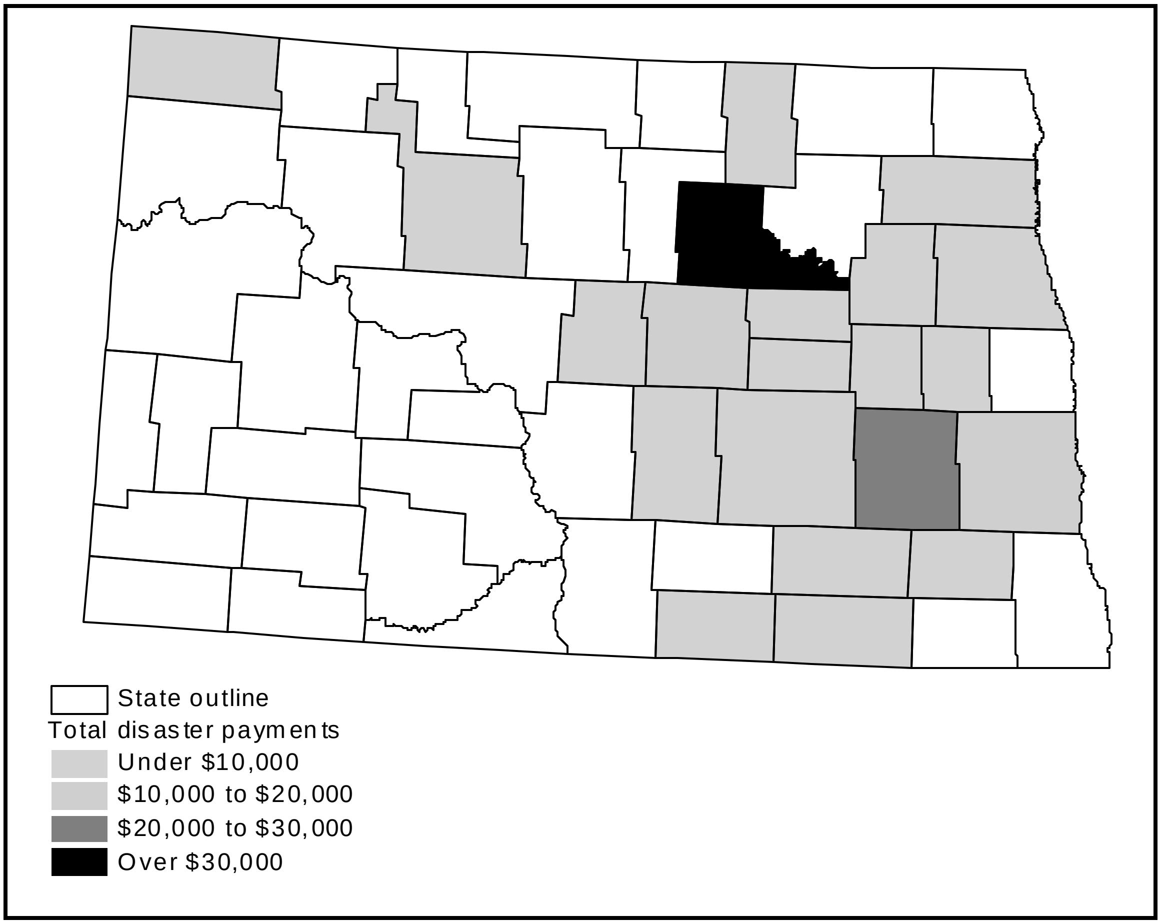
Table 7. Ad hoc disaster payments by state, 1990-94

State	1990	1991	1992	1993	1994	Total
			Number of counties			
North Dakota	2	1	10	19	9	21
Colorado				6		6
Kansas				1		1
Minnesota				2		2
Nebraska				1		1
			Total payments			
North Dakota	$1,416	$104	$14,491	$102,300	$51,277	$169,588
Colorado				12,596		12,596
Kansas				1,232		1,232
Minnesota				5,501		5,501
Nebraska				4,579		4,579
U.S. total	$1,416	$104	$14,491	$126,208	$51,277	$193,496

Source: USDA, Farm Service Agency, ad hoc disaster assistance files, 1988-94, compiled by

[1] Ad hoc disaster assistance was available 1988-94, but commercial crambe production began in 1990.

Figure 2. Ad hoc disaster payments for crambe in North Dakota, 1990-94



the General Accounting Office.

North Dakota accounted for 88 percent of the $193,496 paid for crambe yield losses during 1990-94. Farmers in the high-acreage counties of Barnes, Benson, Cass, and Wells received between $17,000 and $35,000 in total payments, while farmers in the other 17 counties received less than $10,000 per county (Figure 2).

Insurance Implementation Issues

Adverse Selection

Since crambe has only been in commercial production since 1990, its short production history could cause problems in setting premium rates and determining underwriting procedures. Individual yield data are available from agronomist John Gardner, (701) 652-1990.

Setting Reference Prices

FCIC provides reference prices (price elections) for insured crops, which become the basis for assigning values to yield losses. When purchasing insurance, growers must chose a price election. A reference price for crambe could be based on the price AgGrow Oils is offering farmers for growing crambe. If the price was set higher, moral hazard may be a concern in times of marginal yields. The information needed to set the reference price for 1997 and subsequent years would be available from AgGrow Oils, (701) 652-1990.

Moral Hazard

Farmers grow crambe under contract and do not bear the usual risks associated with fluctuating market prices. Growers would not likely have an incentive for moral hazard if the price election is set appropriately. Farmers have a responsibility to AROA (AgGrow Oils for the 1997 and subsequent crops) to harvest and sell to them all the crambe seed they harvest. The contracts are based on acreage. Growers receive the agreed upon price on the bushels sold, regardless of the amount.

Moral hazard may be a problem when farmers opt not to harvest crambe because of heavy weed or disease infestations or serious shattering losses, choosing to save harvesting costs and collect the insurance instead.

Availability of Individual Yield Data

Agronomist John Gardner has individual acreage data and warehouse receipts. This information could be used to calculate individual yields.

Estimating "Appraised Production"

Appraised production for crambe could be estimated by harvesting a sample of plants from small plots and measuring the yield and quality of recoverable seed from the sample. These estimates could be converted to a per-acre basis by multiplying the average recoverable yield per plant times the number of plants per acre. The number of plants per acre can be estimated based on plant spacing.

Demand for Insurance

Farmers have inquired about the availability of crambe insurance. The interest has roughly paralleled acreage. Interest was higher in the early 1990's when acreage was up, but in the last few years, with acreage down, interest has been lower. Demand will probably increase again in the next few years if planned acreage increases occur. The inquiries have been for buy-up insurance (Hagel).

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Appendix One

Industrial Rapeseed in the United States

Industrial Rapeseed in the United States

Rapeseed (*Brassica campestris* and *Brassica napus*) is cultivated throughout the world and is often the oilseed of choice in cooler climates and at higher elevations (Downey and Robbelen). Traditionally, rapeseed has had erucic acid in its oil. However, canola and other special types of rapeseed, such as high-lauric canola, have been bred or genetically engineered to contain different fatty acids in their oils. Canola oil is used for edible consumption and, according to Food and Drug Administration standards, must contain less than 2 percent erucic acid. Canola is the name generally applied to rapeseed that has low amounts of erucic acid in its oil and low levels of glucosinolates in its meal. Rapeseed used for industrial purposes, on the other hand, must contain at least 45 percent erucic acid. Rapeseed containing high amounts of erucic acid is often referred to as industrial rapeseed or high-erucic-acid rapeseed.

Canola and industrial rape plants and seeds are identical. Only testing can determine the seed characteristics. Cross pollination can occur if the two types are planted in adjacent fields, resulting in an oil with an intermediate erucic acid content that would be useless for either application. In the Pacific Northwest, where both types are grown, a couple states have designated production regions to address the cross-pollination issue. Idaho established six production areas in 1986 and Washington state finalized rules and regulations for 12 production districts in 1988 (Carlson and Van Dyne).

Industrial rapeseed has been grown in the Pacific Northwest--eastern Washington, Idaho, and Montana--for over 40 years. It was also produced in the South for a few years during the late 1980's and early 1990's (Fitch-Haumann; Glaser et al.). Harvested acreage of industrial rapeseed has declined from 19,400 acres in 1987/88 to 2,400 in 1995/96 (Table A-1). During the same period, production has dropped from 22 million pounds to an estimated 3 million pounds (Table A-2). Higher canola yields and higher prices for competing crops have limited farmer interest in industrial rapeseed.

In the Pacific Northwest, industrial rapeseed is produced both for birdseed and oil (Fitch-Haumann; Thostenson). Historically, birdseed has accounted for at least 50 percent of production, according to Andrew Thostenson, a former merchandiser with Spectrum Crop Development, a canola and rapeseed merchandizing firm in Clarkston, Washington. After becoming familiar with canola, birdseed manufacturers now buy either industrial rapeseed or canola, whichever is cheaper (Thostenson).

The only known U.S. crusher of industrial rapeseed is Koch Agricultural Services of Great Falls, Montana (Brown; Chambers). According to Gordon Svenby, a merchandiser with the company, Koch was signing contracts with farmers in May 1996 to plant industrial rapeseed this fall. The company contracts for seed and buys it on the open market (Chambers). In addition, unprocessed seed is exported to Japan, where it is crushed and the oil used as lubricants in the steel manufacturing industry and the meal used as fertilizer (Van Dyne; Brown).

Table A-1. Industrial rapeseed: U.S. acreage planted, harvested, yield, production, and value, 1987/88-1996/97

Marketing year[1]	Planted acreage	Harvested acreage	Yield	Production	Value
	1,000 acres		Pounds per acre	1,000 pounds	$1,000
1987/88	20.0	19.4	1,133	21,981	na
1988/89	13.5	13.1	1,204	15,822	na
1989/90	14.0	13.6	1,410	19,143	2,010
1990/91	15.0	14.6	1,561	22,717	2,333
1991/92	18.2	15.6	1,035	16,146	1,634
1992/93	12.0	9.8	1,475	14,455	1,449
1993/94	7.2	6.1	1,220	7,442	761
1994/95	7.4	6.7	1,880	12,596	1,292
1995/96[2]	2.5	2.4	1,255	3,012	383
1996/97[3]	1.4	1.4	1,333	1,800	245

na = Not available. [1]June 1 to May 31. [2]Preliminary. [3]Forecast.
Source: USDA Interagency Commodity Estimates Committee for Oilseeds, Oils, and Meals.

Table A-2. Industrial rapeseed: U.S. supply, disposition, and price, 1987/88-1996/97

Marketing year[1]	Supply: Beginning stocks	Supply: Production	Supply: Total[2]	Disposition: Crush	Disposition: Loss, seed, and residual	Disposition: Total[2]	Ending stocks	Season average price
	1,000 pounds							Dol./lb
1987/88	2,198	21,981	24,179	22,245	827	23,072	1,107	0.100
1988/89	1,107	15,822	16,930	15,575	613	16,188	741	0.111
1989/90	741	19,143	19,885	18,294	710	19,003	882	0.105
1990/91	882	22,717	23,599	21,475	845	22,319	1,279	0.103
1991/92	1,279	16,146	17,425	16,546	613	17,158	267	0.101
1992/93	267	14,455	14,722	14,026	496	14,522	200	0.100
1993/94	200	7,442	7,642	7,307	285	7,592	50	0.102
1994/95	50	12,596	12,646	12,211	398	12,609	37	0.103
1995/96[3]	37	3,012	3,049	2,833	102	2,935	114	0.127
1996/97[4]	114	1,800	1,914	1,805	71	1,876	38	0.136

[1]June 1 to May 31. [2]Trade data do not distinguish between industrial rapeseed and canola; therefore, all imports and exports are allocated to canola. [3]Preliminary. [4]Forecast.

Source: USDA Interagency Commodity Estimates Committee for Oilseeds, Oils, and Meals.

Appendix Two

North Dakota
Crambe Production Budgets

Estimated 1991 Crop Budget for Crambe
East-Central North Dakota

	Per acre
INCOME	
Sale of crop (1,300 lbs./acre at $9.50/cwt.[a])	$123.50
VARIABLE COSTS	
Seed (18 lbs./acre at $0.25/lb.)	$4.50
Fertilizer (50 lbs./acre anhydrous, 50 lbs. 10-34-0)	9.88
Herbicides (none currently approved)	0.00
Insecticides (none)	0.00
Fuel	4.65
Lubrication	0.55
Repair and supplies	5.80
Crop insurance (none)	0.00
Custom service (soil tests)	0.75
Custom harvesting (combining and trucking)	14.50
Interest on operating (6 months at 11.5%)	1.50
TOTAL VARIABLE COSTS	$42.13
FIXED COSTS	
Depreciation on machinery	$25.05
TOTAL ALL COSTS	$67.18
RETURN TO LAND, LABOR, AND MANAGEMENT	
Over variable costs	$81.37
Over all costs	$56.32

[a]Contract price offered by National Sun Industries at delivery to Enderlin, North Dakota.

Source: Maurice Zink and Steve Zwinger, *Budget Summaries for Alternative Crop Production in East-Central North Dakota*, North Dakota State University, Carrington Research Extension Center, March 1991.

Estimated 1991 Crop Budget for Crambe
Foster County, North Dakota

	Economic cost per acre	Cash costs per acre
INCOME		
Sale of crop (1,014 lbs./acre at $9.50/cwt.)	$96.33	$96.33
DIRECT COSTS		
Seed	$4.68	$4.68
Herbicides	6.83	6.83
Fungicides	0.00	0.00
Insecticides	0.00	0.00
Fertilizer	3.06	3.06
Crop insurance	4.00	4.00
Custom work	0.00	0.00
Fuel	4.22	4.22
Lubrication	0.63	0.63
Repairs	7.31	7.31
Machinery/tractor rental	0.00	0.00
Drying	0.00	0.00
Hauling	5.58	5.58
Hired labor (machine time + 10%)	0.00	0.00
Interest on operating (6 months)	2.18	2.18
TOTAL DIRECT COSTS	$38.48	$38.48
INDIRECT (FIXED) COSTS		
Cash rent	$31.50	$31.50
Tractor investment	4.30	--
Self-propelled imp. investment	4.37	--
Pulled implement investment	4.54	--
Depreciation on machinery	27.33	--
TOTAL INDIRECT COSTS	$72.04	$31.50
TOTAL ALL COSTS	$110.53	$69.98
RETURN TO LABOR AND MANAGEMENT		
Over direct costs	$57.85	$57.85
Over direct and fixed costs	($14.20)	$26.35

Source: Randall S. Sell, David L. Watt, and Roger G. Johnson, *Crambe as a Specialty Crop in North Dakota*, Ag. Econ. Rept. 286, North Dakota State University, Department of Agricultural Economics, Fargo, North Dakota, May 1992.

Estimated 1993 Crop Budget for Crambe
South-Central North Dakota

	Profitability per acre[a]	Cash flow per acre[a]
MARKET INCOME[b]	$124.80	$124.80
DIRECT COSTS		
Seed	$4.50	$4.50
Herbicides	6.24	6.24
Fungicides	0.00	0.00
Insecticides	0.00	0.00
Fertilizer	8.93	8.93
Crop insurance[c]	8.45	8.45
Fuel and lubrication	5.76	5.76
Repairs	7.95	7.95
Drying	0.00	0.00
Miscellaneous	1.05	1.05
Operating interest	2.04	2.04
TOTAL DIRECT COSTS	$44.92	$44.92
INDIRECT (FIXED) COSTS		
Miscellaneous overhead	$3.87	$2.09
Machinery depreciation	14.79	--
Machinery investment	7.53	15.41
Land taxes	3.29	3.29
Land investment	25.08	9.70
TOTAL INDIRECT COSTS	$54.57	$30.49
TOTAL ALL COSTS	$99.49	$75.41
RETURN TO LABOR AND MANAGEMENT	$25.31	--
NET CASH FLOW	--	$49.39

[a]Assuming market yield of 1,300 lbs. per acre.
[b]Market price of $0.10 per lb. minus $0.004 per lb. transportation costs, assuming 100 miles from market.
[c]Crop insurance premium for 65% of market yield.

Source: Greg Endres and Blaine Schatz, *Crambe Production*, North Dakota State University Extension Service, Fargo, North Dakota, November 1993.

Estimated 1996 Crop Budget for Crambe
South-Central North Dakota

Market yield 1,250 lbs./acre Market price $0.10/lb.	Profitability per acre	Cash flow per acre
MARKET INCOME	$125.00	$125.00
DIRECT COSTS		
Seed	$5.04	$5.04
Herbicides	6.20	6.20
Fungicides	0.00	0.00
Insecticides	0.00	0.00
Fertilizer	12.38	12.38
Crop insurance	0.00	0.00
Fuel and lubrication	5.30	5.30
Repairs	8.69	8.69
Drying	0.00	0.00
Miscellaneous	1.00	1.00
Operating interest	1.93	1.93
TOTAL DIRECT COSTS	$40.53	$40.53
INDIRECT (FIXED) COSTS		
Miscellaneous overhead	$4.09	$2.20
Machinery depreciation	15.57	--
Machinery investment	8.38	16.70
Land taxes	3.67	3.67
Land investment	25.48	11.34
TOTAL INDIRECT COSTS	$57.19	$33.91
TOTAL ALL COSTS	$97.72	$74.44
RETURN TO LABOR AND MANAGEMENT	$27.28	--
NET CASH FLOW	--	$50.56

Source: Andy Swenson and Dwight Aakre, *Projected 1996 Crop Budgets, South Central North Dakota*, North Dakota Extension Service, Fargo, North Dakota, December 1995.

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