Bulletin No. 598
Revised February 1981

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Vegetable Oil as an Agricultural Fuel For the Pacific Northwest

C. L. Peterson, D. L. Auld, V. M. Thomas, R. V. Withers, S. M. Smith and B. L. Bettis

Continued production of agricultural commodities on the 12.7 million cultivated acres in the Pacific Northwest is dependent upon obtaining an economical and reliable source for the more than 5 million barrels of liquid fuel needed annually. The region's agricultural industry has been severely taxed by increased cost and limited supplies of conventional petroleum fuels. An economical liquid fuel produced from products grown in the area would provide an alternative fuel supply for the agricultural industry.

Recent research on agriculturally produced fuels has concentrated on alcohol. Using existing technology, alcohol production from corn or sugarbeets nets only one calorie for each calorie of input. Also at present, major engine modifications are necessary before alcohol can be used as a substitute for diesel fuel. Because most energy intensive operations in the agricultural industry are done by diesel engines, the technology to produce a substitute for diesel must be developed. This report defines the vegetable oil's potential as an alternative liquid fuel in the Pacific Northwest.

Oilseed Crop Production

Oilseed crops were grown on more than 80 million acres in the U.S. during 1978 and produced more than 3.2 billion gallons of vegetable oil. However, oilseeds are not a major crop in the Pacific Northwest. Total oilseed crop acreage in Oregon, Washington and Idaho is usually less than 30,000 annually. In 1979, a cooperative project among Oregon State University, Washington State University, the University of Idaho and the Pacific Northwest Regional Commission was initiated to introduce oilseeds as a cash crop in the tristate area.

Initial test results indicated sunflower, safflower and winter rape would produce the most gallons of vegetable oil per acre. Table 1 gives the potential commercial seed yields and the amount of extractable vegetable oil from these three crops for several production regions in the Pacific Northwest. Winter rape offers the greatest potential in the cooler dryland areas. Safflower appears to be best adapted to the warmer dryland areas, and sunflowers grow well in the irrigated warmer regions.

Oilseed crops generally require about the same fertilizer and cultural practices as cereal crops. In the Palouse region of northern Idaho and eastern Washington, winter rape, safflower or sunflower crop production would require less than 10 gallons of liquid fuel per acre (Table 2). With good yields, a grower could expect to produce from 85 to 105 gallons of extractable vegetable oil. The grower would net from 8.5 to 11.7 gallons of liquid fuel for each gallon invested in the production of an oilseed crop. In a dryland region, nearly all of the liquid fuel required for crop production could be produced on about 10 percent of the total acreage. Irrigated regions would require either higher oil yields per acre or an increased percentage of oilseed acreage if vegetable oils were used to move irrigation water.

Vegetable Oil Processing

Vegetable oil is removed from oilseed crops by processing the heated seed in an impeller which squeezes up to 94 percent of the oil from the seed. In large oil processing plants, solvent extraction requiring an energy intensive distillation process is used to remove the remaining oil. The raw vegetable oil is treated with an acid or strong base to sediment gum deposits, filtered, bleached and treated with an antioxidant to prevent chemical breakdown.

The by-product left after the oil has been removed from the seed is called "meal." Depending upon the crop and method of extraction, the meal contains from 35 to 50 percent protein and is an excellent animal feed. This meal can be an important feed supplement in finishing rations for beef, swine, poultry and other livestock.

Oilseed crop processing is extremely efficient and economical and can be adapted to almost any scale of operation. An oilseed press that can process 3,000 pounds of seeds per day can be purchased and installed for less than $10,000. This would allow oilseed processing plants to be maintained on individual farms. The amount of processing required to make the various raw vegetable oils into fuel grade products, though, is not known at this time.

Physical Characteristics

Vegetable oil consists of fatty acids 16 to 22 carbons in length attached to glycerol to form a triglyceride. Diesel contains chains that are 16 carbons in length (Table 3). Vegetable oils weigh slightly more than diesel and have 94 percent of the British Thermal Units (BTU) per gallon as diesel. No information is available presently on handling or storing vegetable oils as fuels.

Table 2. Estimated fuel production requirement and potential oil yield of three oilseed crops grown under dryland conditions in northern Idaho or eastern Washington.

Crop	Diesel fuel to produce the crop	Potential seed yield	Extractable seed oil	Ratio of increase
	(gal/acre)	(lb/acre)	(gal/acre)	
Safflower	9*	1,800	85	9.4:1
Sunflower	10*	1,800	85	8.5:1
Winter rape	9*	2,000	105	11.7:1

*Does not include energy input for production of agricultural chemicals, aerial applications or transportation to off-the-farm processing facilities.

Table 3. Chain length, specific density, kinematic viscosity and heat of combustion of three vegetable oils, butanol and No. 2 diesel.

Oil	Carbon chain length	Specific density	Kinematic viscosity	Heat of combustion
		(lb/gal)	(cSt)	(Btu/gal)
Winter rape oil*	16-22	7.6	51.3	130,450
Safflower oil*	16-18	7.7	32.7	130,900
Sunflower oil*	16-18	7.7	35.3	130,730
Butanol	4	6.8	2.4	102,200
No. 2 diesel	16	7.1	2.9	138,250

*Vegetable oils consist of three fatty acids attached to glycerol to make a triglyceride.

Table 1. Potential commercial seed yield and vegetable oil production of sunflower, safflower and winter rape at eight locations in Idaho, four locations in Oregon and four locations in Washington.

	Idaho							
Crop	Bonners Ferry	Coeur d' Alene*	Moscow	Grangeville	Parma*	Twin Falls*	Aberdeen*	Tetonia*
	Seed yield in pounds per acre							
Sunflower	1,200	2,000	1,800	1,500	2,200	2,000	1,800	1,800
Safflower	400	1,200	1,800	1,500	1,800	1,500	1,200	800
Winter rape	2,000	2,000	2,000	2,000	?	?	?	?
	Oil production in impeller extractable gallons/acre							
Sunflower	56	94	85	70	103	94	85	85
Safflower	12	57	85	70	85	70	57	28
Winter rape	105	105	105	105	?	?	?	?

	Oregon				Washington			
Crop	Corvallis*	Pendleton*	Medford*	Madras*	Prosser*	Lind*	St. John	Pullman
	Seed yield in pounds per acre							
Sunflower	2,000	2,000	2,200	1,800	2,200	2,200	1,800	1,800
Safflower	**	1,800	1,800	1,200	2,000	1,800	1,800	1,800
Winter rape	2,400	1,500	2,000	1,200	2,000	?	?	2,000
	Oil production in impeller extractable gallons/acre							
Sunflower	94	94	103	85	103	103	85	85
Safflower	**	85	85	57	94	85	85	85
Winter rape	126	79	105	63	105	?	?	105

* Irrigated locations
? This crop has not been evaluated at this location.
** This crop is not adapted at this location.

Vegetable oil is from 11 to 18 times more viscous than diesel. The viscosity of vegetable oil is its most limiting factor in using it as a fuel. Use of some vegetable oils in diesel engines without modifying fuel filtration systems may require dilution with either diesel or butanol (four carbon alcohol) to reduce oil viscosity.

Engine Testing

Sunflower oil, safflower oil and winter rape oil have been tested as diesel fuel substitutes in four agricultural diesel engines. A 52-horsepower Ford 4600 3-cylinder diesel tractor, a 172-cubic inch displacement diesel engine connected to an electric dynamometer and two Yanmar single cylinder diesel engines connected to electric generators have been used to test the potential of vegetable oil as a diesel substitute.

The Ford 4600 tractor was run initially on a 50 percent sunflower oil-50 percent diesel fuel mixture to demonstrate that the engine could perform with little or no loss of power. Since June 1980, the tractor has been operated for more than 90 hours on 100 percent safflower oil. This tractor has been used on the University of Idaho Plant Science Farm to cut hay and cultivate. No modifications were necessary to the tractor or to the other test engines to use the vegetable oils as a fuel.

The 4-cylinder diesel engine was used to drive a laboratory dynamometer to measure engine performance of vegetable oils alone and in mixtures with diesel fuel. Power output of the engine was nearly the same when operating on either vegetable oils or diesel, but a slight increase in power was measured when vegetable oils were used as a fuel (Table 4).

The fuel economy of vegetable oils and diesel was very similar. Because vegetable oils are heavier and have less energy per pound, the weight of vegetable oil used per hour was slightly higher. Fuel used in gallons per hour for vegetable oil and diesel was the same (Fig. 1). Fuel use vs. horsepower output for

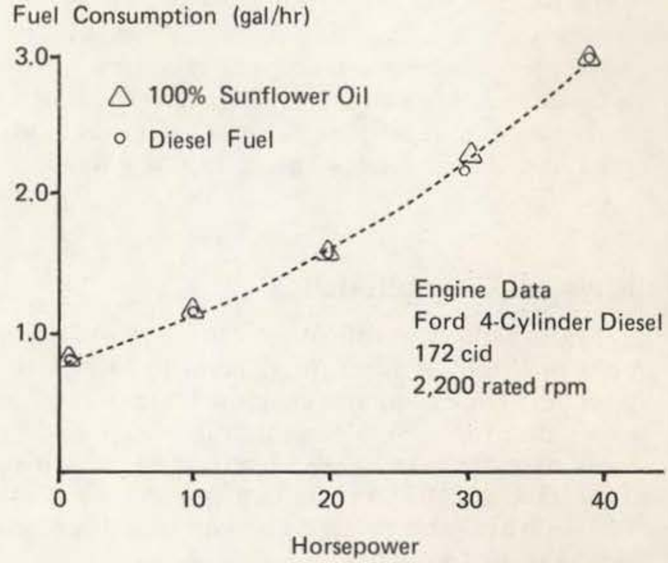


Fig. 1. Diesel engine performance using vegetable oils and vegetable oil-diesel mixtures as a fuel.

NOTE: Tests on 100% safflower oil and 75%, 50% and 25% mixtures of diesel fuel and the vegetable oils were also run. All of the data are so close to the indicated line that the points cover each other and consequently are not plotted separately.

Table 4. Diesel engine* performance using vegetable oil and vegetable oil-diesel mixtures as a fuel.

Fuel type	Horse-power	Fuel		BSFC**		Exhaust temp.	BTU's	Thermal efficiency	Fuel weight
		(lb/hr)	(gal/hr)	(lb/hp hr)	(hp hr/gal)	(°C)	(lb)	(%)	(#/gal)
100% Sunflower	39.6	22.3	2.9	0.56	13.7	660	16,976	26.6	7.7
75% Sunflower	40.0	22.7	3.0	0.56	13.4	667	17,564	25.7	7.6
50% Sunflower	40.5	22.4	3.0	0.55	13.4	671	18,174	25.3	7.4
25% Sunflower	39.7	21.0	2.9	0.53	13.7	659	18,810	25.6	7.3
100% Diesel	39.5	20.8	2.9	0.53	13.5	663	19,472	24.8	7.1
100% Safflower	39.4	21.6	2.9	0.56	13.7	659	17,000	26.7	7.7
75% Safflower	40.0	22.2	3.0	0.56	13.6	666	17,581	26.0	7.6
50% Safflower	40.0	21.6	2.9	0.54	13.7	659	18,186	25.8	7.4
25% Safflower	39.8	21.2	2.9	0.53	13.6	667	18,816	25.4	7.3
100% Diesel	39.0	20.7	2.9	0.53	13.4	661	19,472	24.6	7.1
100% Winter rape	38.8	21.4	2.8	0.55	13.8	692	17,164	26.9	7.6
75% Winter rape	39.5	22.8	3.1	0.58	12.9	704	17,700	24.9	7.5
50% Winter rape	39.7	22.6	3.1	0.57	13.0	715	18,279	24.5	7.4
25% Winter rape	39.2	21.8	3.0	0.56	13.0	710	18,852	24.2	7.2
100% Diesel	37.8	20.5	2.9	0.54	13.1	690	19,472	24.0	7.1

*Information in this table was obtained on a 172 cid Ford 4-cylinder, 2,200 rated rpm diesel engine.

**BSFC is Brake Specific Fuel Consumption and is a measure of work output per unit of fuel used.

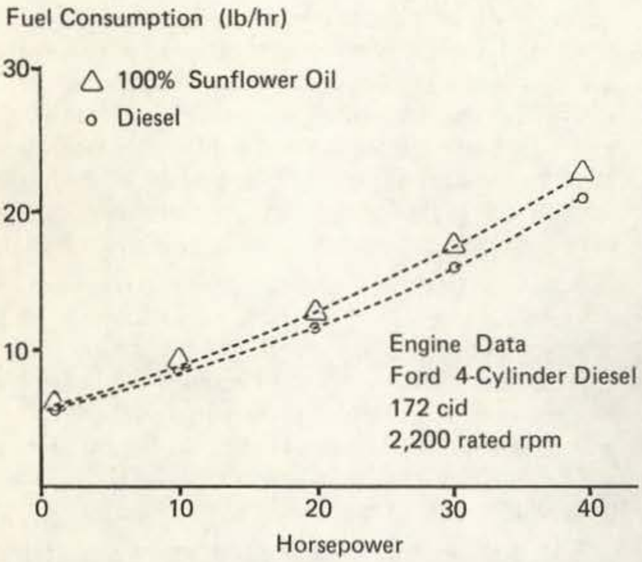


Fig. 2. Diesel engine performance of tests using vegetable oils and vegetable oil-diesel mixtures as a fuel.

NOTE: Tests on 100% safflower oil and 75%, 50% and 25% mixtures of diesel fuel and the vegetable oils were also run. All of the data are within the indicated lines and consequently were not plotted separately.

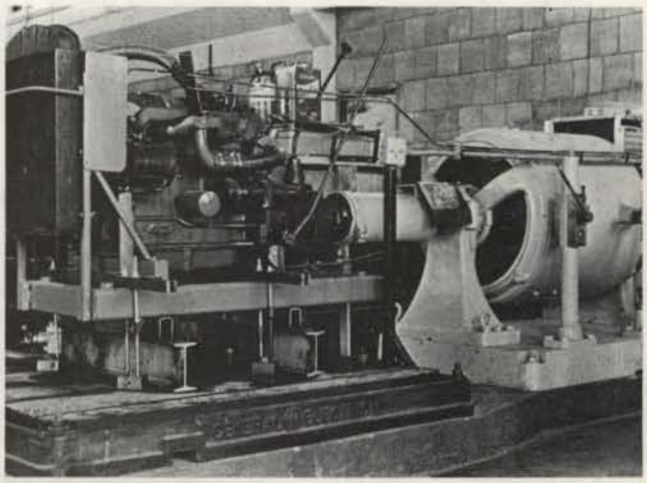
sunflower oil alone and in combination with diesel was nearly identical (Fig. 2). The data from sunflower oil are typical of that measured for the other vegetable oils.

Two Yanmar single-cylinder diesel engines were run to test longterm effects of using the vegetable oils. One engine was operated on diesel and the other engine on 100 percent safflower oil. The engine fueled by safflower oil had run for more than 700 hours when a fan belt broke and caused a premature shutdown. This engine also suffered a rocker arm failure. These problems were probably not related to the use of safflower oil as a fuel. Additional testing will be required before the longterm effects of running engines on vegetable oils alone or in combination with diesel fuel can be determined.

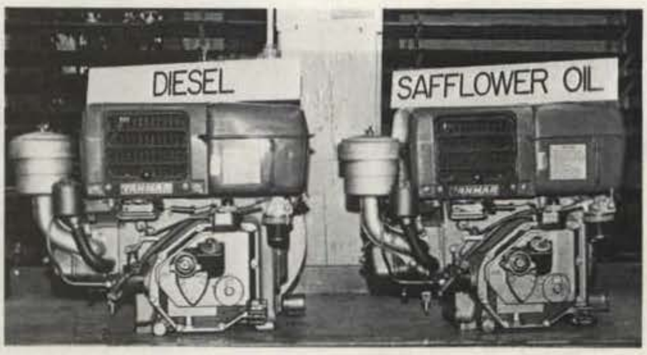
Oilseed Meals' Feeding Value

The feeding value of oilseed meals will vary depending on the composition of the seed and the method of oil extraction used. In general, meals produced by mechanical extraction of the oil from the seed contain more fat and fiber and a lower percentage of protein than those produced by solvent extraction using hexane. For example, sunflower meal from prepressed solvent extraction of dehulled seeds contains about 50 percent protein compared to 45 percent for that produced by mechanical methods.

Ford 3-cylinder diesel tractor.



Vegetable oil-powered, 172 cubic inch displacement diesel engine.



Yanmar single-cylinder diesel engines used to test longterm effects of using vegetable oils.

As a supplement in growing-finishing swine or poultry rations, sunflower meal is an unsatisfactory source of protein because it has a very low lysine content. For most efficient use of the meal in swine or poultry rations, sunflower meal can be combined with a protein supplement such as soybean meal that is rich in available lysine.

Meals produced from seeds that have not been dehulled have a high fiber content. These meals should only be fed to ruminants (beef and sheep).

A large portion (about 40 percent) of the safflower seed is composed of hull. After oil removal, the resulting product contains about 60 percent hulls and 18 to 22 percent protein. Various methods have been used to reduce the hull content. Most meals, however, contain seed with part of the hulls removed, yielding a meal containing 35 to 40 percent protein and 10 to 15 percent fiber. Dehulled safflower meal can be fed to swine and poultry but should be supplemented with soybean or meat meal to provide adequate levels of lysine and sulfur-containing amino acids. Safflower meal can be incorporated into ruminant rations without adverse side effects.

Crude protein levels of rapeseed meals range between 32 and 44 percent with the majority containing 35 to 37 percent protein. The amino acid profile of rapeseed meal is comparable to that of soybean meal.

Meal derived from older varieties of rape contains several compounds that can reduce animal performance and increase mortality. The adverse affects are caused by the high levels of erucic acid, glucosinolate and fiber present. Cattle and sheep are less susceptible than poultry or swine to the toxic effects of rapeseed meal. Meals derived from modern rape varieties do not have these problems and can be fed at that same level as soybean meal. Table 5 summarizes the approximate chemical composition of soybean, sunflower, safflower and rapeseed meals.

Vegetable Oil Economics

Often the question is asked, "How high will fuel prices need to rise before vegetable oils become an economic alternative to diesel fuel?" That question cannot be answered easily because the cost of producing an oilseed crop increases as fuel prices rise. This is because fuel is used to produce many of the production inputs such as fertilizers, chemicals, machinery and agricultural chemicals. Farmers need to know the cost to extract and process the oil from oilseed crops.

The cost of producing oilseed crops has been estimated for the 1980 growing season for several areas in Idaho. The cost would be equivalent in similar production areas of the Pacific Northwest. Cost data are presented for sunflower, safflower, winter rape and barley (Tables 6 and 7). The barley budget was included to allow comparisons with an existing crop.

Because sunflower and safflower are new crops for most growers, large variations in cost and yield are expected. As farmers gain experience, yields are expected to increase and become less variable. Winter rape is presently grown in a rather limited area of northern Idaho and in the Willamette Valley in Oregon. To farmers in other areas of these states, it would be a new crop.

The bottom line of the production cost tables indicates the price a grower would have to receive to cover all costs. These range from 12 to 15 cents a pound for sunflower (Table 6), about 14 cents for safflower (Table 7) and about 10 cents for winter rape (Table 7). The barley price was calculated at $127 per ton. The 1980 contract price for sunflower and safflower was approximately 11 cents per pound.

Table 5. The chemical composition of four types of oilseed meals on a dry matter basis.

Oilseed meal	Protein	Lysine	Fat	Fiber
	(%)	(%)	(%)	(%)
Soybean meal				
dehulled solvent extracted	49	3	1.0	3
with hulls solvent extracted	44	3	4.0	5-7
Sunflower meal				
dehulled solvent extracted	50	3	3	10-15
dehulled mechanically extracted	45	2.5	5-10	15
with hulls, mechanically extracted	28	1.0	1.0	25-30
Safflower meal				
with some hulls, solvent extracted	25	--	1.0	25-30
with some hulls, mechanically extracted	35	--	5-6	20
dehulled, mechanically extracted	45	1.5	8-9	10-15
Rapeseed meal				
solvent extracted	44	2.5	1.0	10
mechanically extracted	35	1.5	7.5	15

Table 6. Estimated production costs for sunflower in selected areas of Idaho, 1980.

Cost Item	Sunflower		
	North Idaho	Camas County	Power County
	(dry)	(dry)	(irrigated)[1]
Direct costs			
Seed	$ 10.72	$ 7.45	$ 10.08
Fertilizer	19.05	10.50	43.00
Chemical weed and insect control	27.29	---	6.94
Paraquat	9.94	---	---
Irrigation equipment	---	---	31.26
Machinery	18.16	13.32	14.57
Tractors	14.06	6.10	12.08
Trucks	2.26	4.20	10.11
Labor	9.46	9.32	16.25
Interest	4.13	2.44	5.48
Total direct costs	$115.07	$ 53.33	$149.77
Indirect costs			
Machinery	$ 19.45	$ 28.96	$ 23.94
Tractors and trucks	12.94	14.62	35.04
Irrigation equipment	---	---	65.30
Taxes	4.00	1.50	5.00
Overhead	3.91	2.24	6.47
Land[2]	50.00	40.00	80.00
Management	6.00	5.00	10.00
Total indirect costs	$ 96.30	$ 92.32	$225.75
Total cost	$211.37	$145.65	$375.52
Yield[3]	1,500 lb	1,200 lb	2,500 lb
Breakeven price per pound	$ .14	$ .12	$ .15

Source: Budgets prepared from data collected in 1979 and updated to reflect 1980 production costs.

[1]Irrigation was with wheel line sprinklers.

[2]Land values are conservative based on 5 percent return on the investment to be more comparable with actual return on farmland investment. Additional return may be realized from land appreciation.

[3]Yield estimates are not average yields but those that may be attained by better cultural practices.

Table 7. Estimated production costs for safflower, spring barley and winter rape in selected areas of Idaho, 1980.

Cost Item	Safflower	Spring barley	Winter rape
	Power County	Latah County	Latah County
	(dry)	(dry)	(dry)
Direct costs			
Seed	$ 12.50	$ 7.20	$ 1.68
Fertilizer	14.80	16.27	31.45
Chemical weed and insect control	6.94	18.50	5.65
Paraquat	---	---	---
Irrigation equipment	---	---	---
Machinery	15.02	20.98	13.19
Tractors	11.93	10.08	14.54
Trucks	1.21	[1]	2.70
Labor	8.77	10.19	9.31
Interest	2.76	2.71	3.13
Total direct costs	$ 73.93	$ 85.93	$ 81.65
Indirect costs			
Machinery	$ 25.32	$ 28.59	$ 22.62
Tractors and trucks	21.33	12.30	17.10
Irrigation equipment	---	---	---
Taxes	1.50	4.75	4.75
Overhead	2.87	3.18	2.94
Land[2]	40.00	50.00	50.00
Management	5.00	6.00	6.00
Total indirect costs	$ 96.02	$104.82	$103.41
Total cost	$169.95	$190.75	$185.06
Yield[3]	1,200 lb	3,000 lb	1,850 lb
Breakeven price per pound	$ .14	$ .06	$ .10

Source: Budgets prepared from data collected in 1979 and updated to reflect 1980 production costs.

[1]Trucks were included with other machinery on this budget.

[2]Land values are conservative based on 5 percent return on the investment to be more comparable with actual return on farmland investment. Additional return may be realized from land appreciation.

[3]Yield estimates are not average yields but those that may be attained by better cultural practices.

The average oil content for sunflower seed is about 40 percent. Assuming 90 percent of the oil can be extracted, 100 pounds of seed would yield about 36 pounds of oil and 64 pounds of meal. Assuming that the meal will pay only the cost of extraction and processing of the oil, then the cost per pound and per gallon of oil at various seed prices can be calculated from Table 8.

Recent seed prices have been about 10 cents per pound, making oil cost slightly more than $2 per gallon. This is considerably above present fuel oil prices. As yields increase with better knowledge of cultural practices, the cost differences between diesel fuel and vegetable oil fuels will diminish.

Table 8. Cost per pound and per gallon of sunflower oil at several projected seed prices.

Price per lb of seed	Cost per lb of oil	Cost per gal of oil
$ .08	$ .22	$ 1.69
.10	.28	2.16
.12	.33	2.54
.14	.38	2.93
.16	.44	3.39

Assumptions:
40 percent oil content in the seed.
90 percent of the oil is extracted.
value of meal equals extraction cost.
gallon of sunflower oil weighs 7.7 pounds.

Summary

Vegetable oil appears to have great promise as an alternative fuel for agricultural production. Use of only 10 percent of the crop acreage for oilseed production could make this region's agriculture industry nearly independent. Existing diesel equipment could probably use vegetable oil as a fuel without engine modification. The cost of using vegetable oil as a fuel could probably be significantly reduced by local processing or by increasing the amount of oil production per acre.

Economic considerations currently make use of vegetable oil as a fuel prohibitive. However, improvement in technology, rapidly rising fuel costs or national emergencies could make this fuel not only economically feasible but necessary to insure this region's continued agriculture production.

Acknowledgments

Potential oilseed seed yields for Washington were provided by Steve Ullrich, assistant professor of agronomy, and An Hang, assistant professor of agronomy, Washington State University. Oilseed yields for Oregon were provided by Gary Jolliff, associate professor of agronomy, and Jim Crane, research associate, Oregon State University. Doug Ryerson, assistant extension professor at the Kimberly Extension and Research Center, provided yield estimates for southern Idaho.

Physical characteristics of vegetable oils were determined by Don Driscoll and Erick Peterson, recent graduates of the University of Idaho, Department of Soil Science, as part of their undergraduate research course.

The Pacific Northwest Regional Commission Agricultural Task Force provided financial support for oilseed production research. George Brocke of Brocke and Sons, Kendrick, Idaho, recently purchased a small oilseed press for the University of Idaho. The other research in this paper was funded by the Idaho Agricultural Experiment Station.

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Published and distributed by the
Idaho Agricultural Experiment Station
R. J. Miller, Director

University of Idaho College of Agriculture
Moscow 83843

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