Safflower

in the Pacific North West

A report on 2007 trials

By Chris Bates

&

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Safflower in the PNW – 2007 trials

The following report discusses the potential viability of safflower as a rotation crop in the Pacific Northwest (PNW). This document reflects the research efforts of Cal/West Seeds, a farmer owned cooperative, to explore the market potential of safflower cropping to provide oil for biodiesel production and meal for livestock feed. Cal/West believes that as the demand increases for vegetable oil to produce biodiesel, safflower cropping can fill an oil supply need. As an independent consultant, I present the following research to farmers, researchers, entrepreneurs, and the general public to consider as we move forward with the development of the biofuels industry.

Cal/West Seeds suggests that safflower is an appealing crop to grow for several reasons. An annual crop that is typically planted mid-March to late April, safflower adapts easily to growing conditions. Adapted varieties are successfully grown from Montana to New Mexico. Its deep tap root makes it a very suitable dryland plant. Pollination does not require bees and harvesting can be done with a regular combine in late August or early September. Additionally, safflower cropping does not impose cross pollination risks to vegetable seed crops in the PNW and has low input costs compared to other oilseed crops.

In 2007, safflower seed trials were started for two market research reasons: 1) to establish the value of safflower oil as a biodiesel feedstock in the PNW and 2) to explore the potential of safflower cropping to offer farmers an alternative crop and market. The value of safflower cropping is discussed in this paper by reviewing the quality of grain yield, oil, and meal, the cost analysis of safflower production, and drawing conclusions from the research results.

Chris Bates, Corvallis, Feb 2008

Contents:

1. Grain Yield Trials

In the spring of 2007, safflower seed yield trials were established at various locations in the PNW. Trials will have to be repeated several years in order to get reliable yield data in the various regions. From already existing commercial scale production in Southeast Washington and Montana, Cal/West Seeds reports that the safflower can compete on net farm revenue per acre with other oilseed crops. The 2007 trials provide data from a broader production area.

Safflower Yield Trials 2007

Organizer	Location	
Oregon State University	Hyslop Farm	Corvallis, OR
Oregon State University	Columbia Basin Agricultural Research Center - Sherman Station	Moro, OR
Oregon State University	Columbia Basin Agricultural Research Center	Pendleton, OR
Col. Basin Community College	Col. Basin Community College	Pasco, WA
Washington State University	WSU Research Farm	Othello, WA
Washington State University	WSU Research Farm	Paterson, WA
Washington State University	Northwestern Washington Research & Extension Center	Mount Vernon, WA
University of Idaho, Extension Service	Riggers Farms	Reuben, ID
Montana State University	Northern Agricultural Research Center	Havre, MT

Comments regarding the various trial locations:

I. Hyslop Farm Corvallis

Two trial plots were planted-- irrigated and non-irrigated. The irrigated crops performed better than the non-irrigated crops. However, a relatively late planting (May 8, 2007) combined with a cool spring and summer caused limited flowering and very late maturing of crops in both trial plots. The non-irrigated crops were harvested September 20, 2007 and the irrigated crops were harvested on September 25, 2007. The trial was arranged by Daryl Ehrensing.

II. Columbia Basin Agricultural Research Center - Sherman Station

This is a dryland wheat area where safflower seems to be well adapted. Located east of the Cascade Mountain Range, the Columbia Basin site receives more heat units than areas west of the Cascades. The trial plots matured by the middle of August. Variety trial had two seeding rates. Planting date: April 18, 2007. In addition to the variety trials two “agronomy" trials using the same varieties and seeding rates in direct seed systems were seeded. One was a recrop situation and one on a chem. fallow. Planting date: April 25, 2007. The trial was arranged by Stephen Machado, Don Wysocki, Larry Pritchett, and Erling Jacobsen

III. Columbia Basin Agricultural Research Center – Pendleton

Two trial plots were conducted. A variety trial was conducted using two seeding rates (25 and 35 lb/acre) and two planting dates April 11 & 25, 2007. This trial was sown conventionally, with a Hege plot drill. The previous crop was winter wheat and land preparation was fall moldboard plowing followed by spring cultivation and fertilization. Nitrogen was applied at 60 lb/acre as dry urea. The second trial, with same varieties, was directed seed into the wheat stubble from the previous year (recrop). Soils are Walla Walla silt loam with an average depth of about 54 inches to basalt. The trial was arranged by Stephen Machado, Don Wysocki, Larry Pritchett and Nick Sirovatka.

IV. Col. Basin Community College

This trial was conducted in light, sandy soils with overhead sprinkler irrigation. The crop was planted May 8, 2007 and harvested October 1, 2007. Visual observation showed leaf diseases. The trial was arranged by Tim Woodward.

V. WSU Research Farm - Othello

The trial was conducted in light soils and was furrow irrigated once a week from April 15 to the end of August. The crop was planted April 10, 2007 and harvested September 25, 2007. The plants were well fertilized and flourished. Under optimum conditions, safflower really showed its potential. The trial was arranged by Ann Hang.

VI. WSU Research Farm – Paterson

This trial was planted April 25, 2007 and harvested Sep 19, 2007. An overhead sprinkler was used almost every day from the day of planting to 2-3 weeks before harvest. Weed competition and poor sandy soil resulted in low yield. The trial was arranged by Ann Hang.

VII. Northwestern Washington Research & Extension Center – Mount Vernon

This trial was planted west of the Cascades and far to the North. The safflower did flower, but the seed heads were empty. Planting was simply too late (May 3, 2007) in a spring and summer that was too cool to accumulate enough heat units. Sampling of flowerheads was done on September 12, 2007. The trial was arranged by Tim Miller.

VIII. University of Idaho, Extension Service - Riggers Farms

This on farm trial was planted in a wheat field at an elevation of approximately 3,000 ft. Planting was conducted in 2 acre blocks so as to allow for regular farm equipment to be used for field preparation, planting, and harvesting. The crop was planted on May 18, 2007 and harvested on September 21, 2007. The trial was arranged by Larry Smith.

IX. Montana State University - Northern Agricultural Research Center

This trial consisted of dryland, fallow, and no-till conditions. The crop was planted on April 24, 2007. The trial was arranged by Peggy Lamb.

1.1 Grain Yield

Safflower responds well to increased inputs, but it does require a certain amount of heat units and day light to fully benefit from the input factors. Typically, safflower is grown on dry land or only pre-irrigated land with minimal fertilizer and pesticide input. As the Othello trial site (V) shows, with optimum conditions on fertility and water, the yield can be over 6,000 lbs/acre. Also noted is that overhead irrigation (a pivot, wheel lines or set hand lines) contribute to leaf diseases as observed in Paterson (VI) and Pasco (IV). This is, however, only one year of data. In 2007, the weather conditions west of the Cascades were not favorable for safflower. Temperatures in the spring and summer were too cool. This resulted in a late harvest (too late?) and low yields. East of the Cascades, conditions seem much more favorable for safflower. The crop can be planted early enough and accumulate enough heat units to allow for a late August or early September harvest. That, in theory, makes it compatible in a wheat rotation and a potential alternative crop to break the wheat cycle. Price and yield will dictate whether it can be a competitive crop.

Table 1 (see Appendix A) lists the grain yield at the various sites referenced by Roman numeral. The data indicates that there appears to be some significant differences in potential yield among safflower varieties. Also, regardless of growing conditions, the same varieties are consistently the most successful at the various trial locations. Most dryland trial sites were recrop situations. Clearly, the yield potential is lower when water supply is limited. Variety CW 4440 showed poor establishment in all trials, most likely due the quality of the seed lot used.

Multiple years of data need to be collected to become more specific about which geographical regions and safflower varieties will be the most suited for crop production.

1.2 Oil Content and Oil Yield

Oil content varies between varieties, but also between locations. It is generally believed that oil content is genetically determined while the environment has some, but limited, influence. The 2007 trials are not conclusive as to which factor plays the greater determining role.

Table 2 (see Appendix B) shows the oil content per variety at each site. Not all trial sites provided oil content from the trial. For those that did, there are significant differences in oil content between varieties at each trial location. This is most likely the result of varietal characteristics. Between locations, the trial average varies considerably. Pendleton (III) is substantially lower than Moro (II) even though the same varieties were planted under comparable conditions. CBCC (IV) and Patterson (VI) are both quite low. CBCC (IV) had overhead irrigation and showed leaf disease in some varieties. Patterson (VI) had overhead irrigation and a very weedy stand. The Montana (IX) trial shows very high oil content.

Oil yield is a function of grain yield per acre and oil content. Therefore, to optimize economic value, oil yield should be the driving parameter to select a safflower variety that optimizes grain yield per acre and oil content. Oil yield is ultimately the most important number. It represents over 70% of the crop value (see section 4 titled “Cost of Production”). Since not all trial sites have oil content data, we can only compare those that did. Table 3 (see Appendix C) shows the oil yield per acre, with Othello (V) clearly with the highest yield, due to the high grain yield. Oil content at Othello (V) was about average compared to the other trial sites.

It is difficult to derive conclusions from these trials. Not all trials had the same varieties and we have only one year data. The results show that there is good potential for safflower and further yield trials need to be conducted. Preferably, a fixed set of varieties should be tested at various locations, so the results can be compared more meaningfully.

2. Oil Quality, Composition, and Biodiesel Processing

2.1 Oil Quality for Biodiesel

In the summer of 2007, a safflower seed crushing trial was conducted. The feedstock consisted of safflower that was produced in Eastern WA during 2006. More than 76,000 lbs. of safflower seeds were crushed by Touchet Seed & Energy (TS&E). TS&E used a cold press plus extruder seed crushing method that was followed by a centrifuge filter. Using a single three stage cold press, two small samples (about 50 lbs.) were crushed at Madison Farms. This was done so that a comparison between crushing methods and subsequent oil and meal quality could be made to that of TS&E. The oil from Madison Farms was collected unfiltered directly after being cold pressed. Ultimately, the resulting vegetable oil was processed into biodiesel by Sequential Biofuels in Salem, OR.

2.1.1 Crush results

Table 4 (page 8) illustrates the weight breakdown of the TS&E seed crushing test. The uncleaned weight at TS&E was determined by calculating back from the weight of the components after crushing, as the starting weight was not measured on the TS&E scales. The balance weight could be explained by the small samples used for the moisture content in the meal.

Based on the oil content of the seed, the TS&E method extracted about 75% (31.0%/41.14%) of the oil from the seeds, leaving the remaining oil in the meal. This seems to be in line with the results on canola, performed by this facility. While TS&E's extrusion process required some fine tuning, Madison Farms reported "very easy crushing" for the safflower compared to canola. By an average of the two samples (see Table 5), Madison Farms recovered 36.6%, or 89% (36.6%/41.14%) of the oil in the seed. This appears to be better by 14% (89% versus 75%) than TS&E. Still, it was a very small sample that was introduced to the crusher after it had been "primed" by previously crushed canola. The resulting meal quality suggests that about an equal amount of oil was left in the meal by the TS&E crushing method and the Madison Farms crushing method (see section 3 titled "Meal Quality").

TABLE 4 Touchet Seed & Energy Crush Test

Crush Results TS&E			**Percentage of Uncleaned weight**
Seed oil content (SGS North America, Inc. standard)			41.14%
Seed moisture content (Cal/West standard)			5.45%
Seed purity (Cal/West standard)			97.3%
Uncleaned weight	78,580	lbs	
Clean out from Clipper	1,741	lbs	2.2%
Net clean weight	76,839	lbs	97.8%
To Madison Farms	200	lbs	
Net crushed at TS&E	**76,639**	**lbs**	
			Percentage of net weight
Meal (including samples)	48,757	lbs	63.6%
Oil (including samples)	23,750	lbs	31.0%
Filter residue	4,358	lbs	5.7%
Moisture losses	(566)	lbs	-0.7%
Balance	**340**	**lbs**	0.4%

TABLE 5 Madison Farms Crush Test

	Sample 1			Sample 2			Average
Inweight	50.4	lbs		48.9	lbs		
Oil	19.2	lbs	38.1%	17.1	lbs	35.0%	36.6%
Meal	31.1	lbs	61.7%	30.3	lbs	62.0%	61.8%
Balance	0.1	lbs		1.5	lbs		1.6%

2.2 Oil composition and quality

2.2.1 Oil Composition

The safflower used for the crush trial was an oleic type (variety CW 990L), meaning that >70% of its oil is an oleic fatty acid (C18-1, an 18 carbon molecule with one double bond). This is genetically determined, with the actual percentage varying about +/- 5% as a result of the growing conditions. Oleic oils are highly valued for human consumption, but reportedly have desirable characteristics for biodiesel. The seed was sent to SGS laboratory for oil content and composition analysis:

TABLE 6 Fatty Acid Profile

Fatty Acid Profile SGS laboratory	
	Percentage of total
C14	0.09
C16-1	0.24
C16	5.10
C17	0.04
C17-1	0.17
C18	2.44
C18-1	79.60
C18-2	7.18
C18-3	0.02
C20	0.52
C20-1	0.44
C22	0.40
C24	0.06
Other	3.70

The analysis in Table 6 shows almost 80% C18-1, the oleic fatty acid. Unlike linoleic fatty acids (C18-3), a high content of oleic fatty acid is preferred as it provides a longer product shelf-life. Linoleic fatty acids are prone to rancidity and have a much shorter shelf-life than highly oleic oil. The fatty acid profile above reveals a high concentration of oleic fatty acids and a very low concentration (7.18%) of linoleic fatty acids already present in safflower. This suggests ideal quality oil for both food and biodiesel processing.

2.2.2 Oil Quality

Oil samples were taken from the TS&E holding tank. This oil was not de-gummed. A sample was sent to Whole Energy Fuels Corporation (Bellingham, WA), the University of Idaho Department of Biological and Agricultural Engineering (Moscow, ID), and Sequential Biofuels (Salem, OR) for analysis on purity.

The sample sent to Whole Energy Fuels Corporation, was tested without de-gumming the oil through a gravity settlement period. Whole Energy reported that water content is below the maximum allowed for biodiesel processing. Though they did not provide an industry standard for vegetable oil, Whole Energy reported (see Table 7) that the phosphorus and acid number are too high for direct processing to biodiesel (as a result of not being de-gummed).

TABLE 7 Whole Energy Water, Phosphorous, and Acid Test Results

TEST	METHOD	RESULTS	UNITS
WATER BY KARL FISCHER	D 6304	0.05	Vol%
PHOSPHORUS CONTENT	D 4951	0.0146	MASS %
ACID NUMBER	D 664	7.97	mg KOH/G
STONG ACID NUMBER	D 664	NIL	mg KOH/G

The sample sent to the University of Idaho, on the other hand, was allowed to sit before being tested. After a long period of settlement to allow for de-gumming, Dr. Jon Van Gerpen reported that the sample had about an inch of sludge (gum) on the bottom of the container. A subsample of the oil from the top of the container that did not contain any of the sludge was taken for analysis. The results are listed in Table 8.

TABLE 8 University of Idaho Phosphorous and MIU Test Results

University of Idaho	
Phosphorus In Vegetable Oil	121 ppm
MIU- Total	0.42%
Moisture & Volatiles By Hot Plate	<0.01 %
Insoluble Impurities	< 0.01 %
Unsaponifiable matter	0.42%

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The results of the University of Idaho sample reveal 0.42% unsaponifiable matter which is considered normal. This matter includes things like anti-oxidants that are desirable to have in the oil. According to Tyson Keever of Sequential Biofuels, the 0.42% MIU's is below their oil specification standard of <2% MIU's. The phosphorus content of 121 ppm is a positive result considering solvent extracted oils are usually over 900 ppm. Except for the sludge on the bottom of the bottle, the safflower sample provided a pretty clean oil (Van Gerpen).

Thus, as the test results from Whole Energy and the University of Idaho indicate, de-gumming safflower oil is a critical step to reducing the amount of phosphorous before biodiesel processing. The ASTM fuel standard permits a 0.001 maximum %mass of phosphorous content.

Based on a visual observation at Sequential Biofuels of the delivered oil from TS&E for biodiesel processing, 10-12% of gum was present in the virgin oil. (See picture on the left).

Sequential Biofuels reported that the acid value (measuring free fatty acid content) of the oil they received from TS&E was 0.46 mg KOH/g. This is below the 0.80 maximum limit allowed by the United States' ASTM D 6751 standard. It is important to have a low concentration of free fatty acids (FFA's) for two reasons. The catalyst used in the biodiesel producing reaction will first react with any FFA's forming soaps, which can form emulsions and disrupt the fuel making process. Also, there must be enough catalyst present to neutralize the FFA's in the oil feedstock to drive the fuel making process. Thus, increased cost and emulsion formation are the critical reasons why low FFA feedstocks are desirable (Independent Biodiesel Feasibility Group 2006:13; Haas and Foglia 2005:47).

There are additional reasons to keep both phosphorous content and the acid number low when using a feedstock to produce biodiesel. Phosphorous can damage catalytic converters used in emissions control systems. As emissions standards are tightened, catalytic converters are becoming more common on diesel powered equipment. Similarly destructive, biodiesel with a high acid number may increase the risk of corrosion within the fuel system (Independent Biodiesel Feasibility Group 2006:61-62).

2.3 Biodiesel Processing

Cal/West delivered the 22,490 lbs. (2,959 gallons) of oil produced by TS&E to Sequential Biofuels. However, the gum present in the oil hindered the biodiesel processing. After de-gumming, the volume of oil that remained needed to be supplemented by additional recycled cooking oil to make a full batch (3,000 gallons) of biodiesel. Therefore, there are neither direct results from pure safflower biodiesel nor feedback from the biodiesel users of pure safflower biodiesel. However, Sequential did report that they had no problems with the resulting biodiesel and that they considered safflower an excellent feedstock.

In addition, small samples of the de-gummed safflower oil were processed at Oregon State University (OSU). The results from gas chromatography (GC), viscosity, sediment, and cloud point observations confirmed documented characteristics from safflower oil based biodiesel, confirming its suitability for biodiesel.

During small batch processing of biodiesel, all batches were produced by using a technical grade ground sodium hydroxide catalyst and methanol. The reactions occurred at room temperature (25-28C) in a simple stirred tank reactor. Dr. David Hackleman reported that the biodiesel produced by the safflower oil had no observable variance from expectations. The GC results are consistent with observed [biodiesel processing] performed in the OSU laboratory with other vegetable oils, such as mustard seed, canola, soybean, rice, and sunflower.

Furthermore, the predicted fuel related parameters from the literature (Knothe, Krahl, and Van Gerpen 2005:281-284) comparing canola based biodiesel with safflower based biodiesel show no significant difference in Cetane Number, Gross Heat of Combustion, Kinematic Viscosity, Cloud Point or Flash Point. It is possible that safflower based material might have a higher Flash Point by 5% and a lower Kinematic Viscosity by 5% (Hackleman).

Additionally, Dr. Hackleman reiterates that safflower oil will need to be de-gummed prior to biodiesel manufacture. De-gumming is a necessary step in the preparation of biodiesel from safflower oil and is a well-known industrial practice (Knothe, Krahl, and Van Gerpen 2005; Kopas and Boomer 1981). During biodiesel manufacture, gum will tend to create foam reducing fuel yield. These compounds are deleterious to engine performance and form "carbon residue." De-gumming can be done by settling the oil in a tank and is a known standard process (Hackleman).

3. Meal Quality

The resulting meal from the crushing will have a certain feed value. Meal samples of both the extrusion process (Touchet Seed & Energy) and the cold process (Madison Farms) have been analyzed for feed value. At TS&E, meal samples were taken with low (<200 ºF) extruder temperatures and high (around 290 ºF) extruder temperatures to see if it would have any effect on the meal quality.

Table 9 (see Appendix D) shows the results of these meal analyses. There is a consistent difference in values between the two labs used. But with the same labs the analyses are similar. Dry matter content of the meal is around 97% for all samples. There does not seem to be a difference on the high or low extrusion temperature meal analyses. The Madison Farms meal is similar to TS&E's, also in crude fat content, suggesting a similar amount of residual oil left in the meal, from either seed crushing process. For comparison, a random canola meal analysis is listed from meal produced at TS&E. It shows similar fat content (pointing to similar oil recovery from safflower) and much higher crude protein content (50% higher than safflower meal). Safflower meal will be lower in protein and higher in fiber than canola meal, which makes it a less digestible and energetic feed (Hristov). Subsequently, the Relative Feed Value of canola is almost double that of safflower. The filter residue in TS&E's process, a peanut butter like substance, is mainly water, it contains only 10% dry matter. However, the Relative Feed Value of the dry matter is very high (215). This filter provides an important function by filtering any residual moisture from the oil, confirmed by the Whole Energy and University of Idaho oil analyses (discussed in subsection 2.2.2).

Meal value (price) is usually determined by crude protein content. In this respect, safflower meal with approximately 25% crude protein is approximately 13% lower in protein than canola meal. Still, the oleic fatty acids in safflower meal can be especially beneficial to poultry, for egg production. The major amino acids for dairy cows are good, too, with the exception of lysine (Hristov). Table 10 (see Appendix E) shows the amino acid profile of the safflower meal crushed by TS&E. Aspects such as high fiber, amino acids, and the oleic fatty acids of the crude fat can be an advantage, but only if the meal can be supplied on a steady, year round basis. Only then can livestock operators adjust their rations to utilize safflower meal. According to Nabil Said of Insta-Pro International (the manufacturer of the extruder process used in the crushing trial), the extruder process does break cell walls down much more extensively than a cold press-only process. This allegedly improves digestibility of the meal, even though this is not apparent in the standard analysis of the meal and the amino acid profile. Darwin Crosby of M & E Seed & Grain reports a 10% premium on the sale of meal of products crushed by the extruder process. This suggests that there is a value-added advantage to extruder processing. With this in mind, it will require marketing efforts to capitalize on the added value aspects of safflower meal that move beyond crude protein content.

4. Cost of production

The results of the "Safflower in the PNW" research will help us to define the true value of (high oleic) safflower as biodiesel feedstock, the meal as livestock feed, and the safflower crop to the farmer who will produce the crop. Revenue will be determined by:

- input cost to grow the crop
- yield
- oil value
- meal value
- cost of the crushing process

Based on an oil price of $ 0.30/lb ($ 2.30/gallon and 7.7lb/gallon) and a meal price of $110/ton received from the summer of 2007 trial quantities, the value of the safflower grain as feedstock for biodiesel was $0.068/lb. This would have been the price the farmer would have received when he delivered his crop to the crushing facility. In Table 11, the cost of crushing is listed as charged to Cal/West for its crushing trial. As stated earlier, the meal value should increase once a consistent supply can be offered to the market. The oil value was reduced due to the gum still present in the oil.

TABLE 11 Cost Analysis for Touchet Seed & Energy Seed Crushing Trial

Cost analysis safflower crush trial		Value/lb	value in 1 lb grain
Salable oil (90% of extracted oil)	27.70%	$ 0.300	$ 0.083
Gum (10% of extracted oil)	3.08%	$ -	$ -
other losses (mainly moisture)	5.00%	$ -	$ -
Meal	64.22%	$ 0.055	$ 0.035
cost of crushing	100.00%	$ 0.050	$ (0.050)
net per lb of grain			$ 0.068

The cost of processing vegetable oil into biodiesel is said to be around $1.00/gallon, equal to the Federal subsidy on biodiesel. Oil, at $0.30/lb, equates to $2.30/gallon. Hence, at retail levels of $3.00/gallon, the cost of distribution, blending and margins is approximately $0.70/gallon, or 30% of the feedstock value.

If we assume that diesel will go up to $3.50/gal at the pump, the value of the feedstock will change. Based on the $0.70/gal "bench mark" for distribution, blending and margins above, that would make the oil value $ 0.365/lb. If we also assume that the meal could go up to $150/ton due to consistent supply and the cost of crushing will remain the same but efficiency is improved with 5% (oil recovery 80% instead of 75% as in our trial), the value of safflower grain (with 41.14% oil content as in our trial) delivered to the crushing facility would become $0.105/lb; some 50% more than the value based on the trial parameters (see Table 12a):

TABLE 12a Cost Analysis with Improved Market Assumptions - safflower

Example 1 - safflower		Value/lb	value in 1 lb grain
Salable oil (90% of extracted oil)	29.60%	$ 0.365	$ 0.108
Gum (10% of extracted oil)	3.29%	$ -	$ -
other losses (mainly moisture)	5.00%	$ -	$ -
meal	62.11%	$ 0.075	$ 0.047
cost of crushing	100.00%	$ 0.050	$ (0.050)
net per lb of grain			$ 0.105

Canola meal has higher protein content and hence is more valuable than safflower meal. Under the same crushing and oil price conditions as safflower in Example 1 (table 12a), canola grain would have a value of $0.126/lb (table 12b):

TABLE 12b Cost Analysis with Improved Market Assumptions - canola

Example 1 - canola		Value/lb	value in 1 lb grain
Salable oil (90% of extracted oil)	29.60%	$ 0.365	$ 0.108
Gum (10% of extracted oil)	3.29%	$ -	$ -
other losses (mainly moisture)	5.00%	$ -	$ -
meal	62.11%	$ 0.110	$ 0.068
cost of crushing	100.00%	$ 0.050	$ (0.050)
net per lb of grain			$ 0.126

If we take the 2008 farm gate price level for safflower of $0.20/lb (basis fall 2007), oil as feedstock for the biodiesel industry should be valued at $0.686/lb, or $5.28/gal (see table 13).

TABLE 13 Cost Analysis Using the 2008 Farm Gate Price Level for Safflower

Example 2		Value/lb	value in 1 lb grain
Salable oil (90% of extracted oil)	29.60%	$ 0.686	$ 0.203
Gum (10% of extracted oil)	3.29%	$ -	$ -
other losses (mainly moisture)	5.00%	$ -	$ -
Meal	62.11%	$ 0.075	$ 0.047
cost of crushing	100.00%	$ 0.050	$ (0.050)
net per lb of grain			$ 0.200

Table 14 shows that even with a mandated B2 diesel blend, the retail price of B2 biodiesel will only increase with 1.5% based on today's market prices of safflower (or canola) oil. One can find larger fluctuations between retail pump prices on the same day in the same town, or with the same retail pump within a week.

TABLE 14 Cost Parameters for Examples 1 and 2

Example 1 parameters			
Fossil diesel retail price	$ 3.50	/gal	
blending and distribution cost	$ 0.70	/gal	
base price for biodiesel feedstock	$ 2.80	/gal	$ 0.365/lb
Example 2 parameters			
Fossil diesel retail price	$ 3.50	/gal	
blending and distribution cost	$ 0.70	/gal	
Cost of feedstock (=cost of Biodiesel)	$ 5.28	/gal	$ 0.686/lb
Premium for Biodiesel over Example 1	$ 2.48	/gal	
Added price for a 2% blend (B2)	$ 0.05	/gal	
retail price B2 blend	$ 3.55	/gal	

Based on the scenarios described in this section, the realistic farm value of safflower for biodiesel can be expected to move between $0.065 – 0.110/lb (Tables 11 and 12). Oregon growers can add the value of the $0.05/lb tax credit to this price. However, that is considerably below the current market for crop 2007 safflower, which is around $ 0.18 – 0.20/lb (Table 13), whether for human consumption oil or bird food.

At crusher level, close to 70% of the gross value is in the oil ($0.083 of the total gross revenue of $0.118 per lb of grain, table 11), so it will be paramount to have crushers that maximize the oil recovery. Leaving 25% of the oil in the meal (see subsection 2.1.1) is a costly affair. Besides not capturing this oil value, the meal value is reduced by increased fat (oil) content. When more oil is left in the meal, the percent of protein content is lower (see Table 15).

TABLE 15 The Impact of Crusher Efficiency on Meal Protein

Changes in protein level in meal as a result of crusher efficiency	**Trial**	**complete oil extraction**
Salable oil (90% of extracted oil)	27.70%	37.00%
Gum (10% of extracted oil)	3.08%	4.11%
other losses (mainly moisture)	5.00%	5.00%
meal	64.22%	53.89%
protein as percentage of meal (average)	25.00%	29.79%
Protein as percentage of grain	16.06%	16.06%

Solvent extraction will improve the oil recovery, but will bring substantial cost with it. It goes beyond the scope of this trial to determine if this method will be economical. There are also approximately 10% of gums that need to be separated from the oil. Finding a value stream for gums and filter residue will be important to maximize the return.

Safflower is relatively inexpensive to produce making it an attractive rotation crop (see Table 16). The cost of production relation between safflower, winter canola, and winter wheat will be more stable than the net revenue per acre. This is due to fluctuations in price and yield which determine gross revenue. Canola will have the highest cost variance, depending on insect presence and has a higher risk compared to wheat and safflower, due to potential winter kill and increased harvest risk (shatter).

TABLE 16 Safflower Cost Analysis

	Safflower	**Winter Canola**	**Winter Wheat**
seed cost	$20.00	$20.00	$22.00
Fertilizer	$50.00	$80.00	$100.00
Pesticides	$20.00	$40.00	$18.00
Irrigation	$60.00	$60.00	$ -
land preparation	$30.00	$30.00	$30.00
Harvest	$45.00	$60.00	$45.00
Total cost/acre	**$225.00**	**$290.00**	**$215.00**
Grain yield	2,500	2,500	4,800
Price/lb	$0.180	$0.200	$0.140
Total revenue/acre	$450.00	$500.00	$672.00
Net revenue/acre	**$225.00**	**$210.00**	**$457.00**

* Note: yield and price are for indication purposes only. Price is based on forward contracts for crop 2008 (basis fall 2007).

In time, crop rotation requirements may force farmers to alternate wheat with an oilseed crop. The farmer will look at net revenue per acre and here safflower will have to compete with wheat grain (now at record price levels). The farmer potentially can accept a lower net revenue per acre once in while from a rotation crop, if the lower net revenue is offset by higher yields and/or lower cost of production in wheat crops as a result of breaking the continuous wheat cycle. Safflower stands to be a competitive rotation crop that offers low risk and the potential of high revenue.

5. Conclusions

Safflower is well adapted to certain areas of the Pacific North West. Trials have shown that depending on input factors, very competitive yields can be obtained. Further studies need to be done to develop the optimal cultural practices, how it best can benefit a wheat rotation and ultimately which varieties are most suited to the optimum areas of production.

Safflower oil will, most likely, have a higher value in the food (human consumption) market than it will in the biodiesel industry. Especially the oleic types have excellent properties for human consumption, comparable to olive oil. The biodiesel industry will consider it just another feedstock, its value based on available alternatives. However, the developing biodiesel industry and State legislation to promote biofuels will have an impact on the production of oil crops. Oregon's tax credit for $0.05/lb of dedicated oil crop for feedstock for biodiesel processed in Oregon and Washington's B2 mandate (for 2% biodiesel inclusion in all diesel fuel sold in the state) are leading the way to create a certain minimum demand that needs to be met. The biodiesel industry will buy either locally (PNW) grown oil or import from other areas, such as the Midwest (soy bean oil), Canada (canola oil), and Malaysia (palm oil) based merely on price. Based on the fall 2007 market prices for 2008 crops, PNW grown feedstocks will increase the cost of B2 biodiesel by $0.05/gal over "imported", cheaper, feedstocks. This is only a 1.5% increase over fossil diesel (at $3.50/gal retail) and within normal price fluctuations seen on a weekly basis. This marginal increase would allow for a PNW grown feedstock supply, creating a sustainable PNW vegetable oil production industry. This could be a worthy investment for the PNW economy.

All biodiesel feedstocks can be used for human consumption as well and the increasing biodiesel market will take out the lower cost feedstocks first, thus increasing the market for the higher quality oils in the human consumption market. Safflower oil with its dual purpose properties can be produced for the higher valued human consumption market, while any surplus can be easily sold into the biodiesel market.

The increase in demand for oil crops can not be supplied by just one crop. A suitable crop such as canola fits the crop rotations of the PNW very well, but needs fairly long intervals between subsequent crops, 5 years being mentioned as optimal. Safflower also fits in such a rotation and can increase the potential acreage dedicated to oil crops:

One million gallons of biodiesel will require an equal amount of feedstock oil. Taking a reasonable average grain yield of 2,500 lbs/acre (safflower, canola) at a net recovery of oil of 30%, one acre of oil crop produces 100 gallon of oil. Thus, 1.0 million gallons requires 10,000 acres of oil crop production. In order to sustain this supply in a 1 : 5 crop rotation, it requires 50,000 (5 x 10,000 ac) acres of farm land. Reducing this to a 1 : 3 rotation by growing multiple oil crops such as canola or safflower (camelina and sunflower have lower yields per acre), the required farm land to sustain 1.0 million gallons of biodiesel is reduced to about 30,000 acres.

The Washington State B2 requirement is estimated to require approximately 30 million gallons of biodiesel per year. If Oregon would implement a B2 mandate, it would require approximately 15 million gallons of biodiesel annually. Combined, this requires about 450,000 acres of dedicated oil crops (45 x 10,000 acres), or 15% of the area now grown in wheat in these two states (3 million acres - 2006 and 2007 average, National Agricultural Statistics Service). With a 1 : 5 crop rotation, this means that 75% of all available land currently farmed in wheat will have to be rotated with an oil crop to have a sustainable B2 supply from regional resources, based on current diesel usage.

The PNW Biodiesel industry buys oil whereas the farmers raise and harvest grain. The missing link is the crushing industry waiting to be developed. With state mandates and incentives, a user market for the oil is created. This will bring the much needed investor's confidence in a stable market for the oil. Profitability of a crushing facility will be strongly influenced by its efficiency, feed prices and transportation cost of grain, oil and meal. Since 2/3rd of the volume produced by the crushing facility is meal, generating less than 1/3rd of the crusher's total sales, transport costs on the meal will have to be closely monitored. The biggest question remains, however, whether a PNW crushing industry will even have a crop to crush. This will greatly depend on the willingness of the consumer to pay a small premium for a B2 blend and on the net revenue per acre of the alternative crops the PNW farmers can grow. Alternatively, a PNW crushing industry should consider the ability to produce food grade oil to create the flexibility of having access to this higher value market. This may increase its chance of offering competitive oil crop contracts to PNW farmers.

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Appendix A

TABLE 1 Summary of Trial Results for Safflower Grain Yield in lbs/acre

	I - dryland		I - irrigated	
	lbs/acre	**percentage of trial mean**	**lbs/acre**	**percentage of trial mean**
CW 88OL	1,052	112%	2,291	111%
S 345	n/t		n/t	
ST 1 OLEIC 05	n/t		n/t	
CW 99OL	965	102%	2,159	105%
S 344	n/t		n/t	
ST 1 HYBRID 49	n/t		n/t	
S 719	n/t		n/t	
S 1133	n/t		n/t	
NUTRASAFF	n/t		n/t	
CW 74	1,005	107%	1,846	90%
CW 1221	937	99%	1,889	92%
CW 4440	841	89%	1,914	93%
CW 2889	858	91%	2,240	109%
MSU-NDSU Oleic 5	n/t		n/t	
Hybrid Oleic 16 norm seeding rate	n/t		n/t	
Hybrid Oleic 16 (14 lb/ac)	n/t		n/t	
S-5232	n/t		n/t	
CW 3268-8	n/t		n/t	
S-3125	n/t		n/t	
CW 3268-6	n/t		n/t	
S-5244	n/t		n/t	
S-1133	n/t		n/t	
S-4409	n/t		n/t	
S-1137	n/t		n/t	
S-6127	n/t		n/t	
S-3151	n/t		n/t	
S-2106	n/t		n/t	
Finch	n/t		n/t	
Montola 2003	n/t		n/t	
Montola 2004	n/t		n/t	
Morlin	n/t		n/t	
S 9262	n/t		n/t	
Mean	943		2,057	
LSD 0.05	214		187	
CV				

n/t = not in trial

Appendix A – continued

TABLE 1 Summary of Trial Results for Safflower Grain Yield in lbs/acre

	II - Direct Seed Recrop		**II - chem fallow Direct Seed**		**II - Conv Fallow**	
	lbs/acre	**percentage of trial mean**	**lbs/acre**	**percentage of trial mean**	**lbs/acre**	**percentage of trial mean**
CW 88OL	636	103%	1,082	105%	901	96%
S 345	722	117%	1,256	122%	823	88%
ST 1 OLEIC 05	754	122%	983	95%	908	97%
CW 99OL	647	104%	1,151	112%	1021	109%
S 344	583	94%	1,053	102%	997	107%
ST 1 HYBRID 49	n/t		n/t			
S 719	678	109%	1,191	116%	1043	111%
S 1133	683	110%	1,086	105%	1015	108%
NUTRASAFF	577	93%	925	90%	820	88%
CW 74	673	109%	1,077	105%	1047	112%
CW 1221	588	95%	1,196	116%	1035	111%
CW 4440	377	61%	491	48%	561	60%
CW 2889	579	93%	1,004	97%	1017	109%
MSU-NDSU Oleic 5	n/t		n/t			
Hybrid Oleic 16 norm seeding rate	595	96%	1,088	106%	1023	109%
Hybrid Oleic 16 (14 lb/ac)	n/t		n/t			
S-5232	n/t		n/t			
CW 3268-8	n/t		n/t			
S-3125	n/t		n/t			
CW 3268-6	n/t		n/t			
S-5244	n/t		n/t			
S-1133	n/t		n/t			
S-4409	n/t		n/t			
S-1137	n/t		n/t			
S-6127	n/t		n/t			
S-3151	n/t		n/t			
S-2106	n/t		n/t			
Finch	n/t		n/t			
Montola 2003	549	89%	812	79%	900	96%
Montola 2004	n/t		n/t		n/t	
Morlin	n/t		n/t			
S 9262	655	106%	1,052	102%	926	99%
Mean	620		1,030		936	
LSD 0.05	117		170			
CV						

n/t = not in trial

Appendix A – continued

TABLE 1 Summary of Trial Results for Safflower Grain Yield in lbs/acre

	III - Agronomy trial recrop		III - Seeding date April 11, conv recrop		III - Seeding date April 25, conv recrop	
	lbs/acre	**percentage of trial mean**	**lbs/acre**	**percentage of trial mean**	**lbs/acre**	**percentage of trial mean**
CW 88OL	802	104%	617	96%	558	98%
S 345	870	113%	620	97%	543	95%
ST 1 OLEIC 05	861	111%	743	116%	591	104%
CW 99OL	854	110%	751	117%	694	122%
S 344	798	103%	491	77%	629	110%
ST 1 HYBRID 49						
S 719	852	110%	698	109%	609	107%
S 1133	883	114%	723	113%	527	92%
NUTRASAFF	654	85%	485	76%	432	76%
CW 74	789	102%	839	131%	618	108%
CW 1221	751	97%	707	110%	549	96%
CW 4440	519	67%	396	62%	410	72%
CW 2889	692	89%	684	107%	564	99%
MSU-NDSU Oleic 5						
Hybrid Oleic 16 norm seeding rate	731	95%	599	93%	813	142%
Hybrid Oleic 16 (14 lb/ac)						
S-5232						
CW 3268-8						
S-3125						
CW 3268-6						
S-5244						
S-1133						
S-4409						
S-1137						
S-6127						
S-3151						
S-2106						
Finch						
Montola 2003	666	86%	602	94%	494	87%
Montola 2004	n/t		n/t		n/t	
Morlin						
S 9262	878	114%	671	105%	529	93%
Mean	773		642		571	
LSD 0.05						
CV						

n/t = not in trial

Appendix A - continued

TABLE 1 Summary of Trial Results for Safflower Grain Yield in lbs/acre

	IV		V		VI	
	lbs/acre	**percentage of trial mean**	**lbs/acre**	**percentage of trial mean**	**lbs/acre**	**percentage of trial mean**
CW 88OL	1,875	158%	6,363	127%	1,572	111%
S 345	1,524	128%	5,774	115%	1,582	112%
ST 1 OLEIC 05	1,413	119%	5,765	115%	1,977	140%
CW 99OL	1,342	113%	5,506	110%	1,905	135%
S 344	1,179	99%	5,424	108%	1,813	128%
ST 1 HYBRID 49	n/t		5,429	108%	2,236	158%
S 719	1,156	97%	5,188	104%	1,165	83%
S 1133	1,129	95%	4,732	95%	1,321	94%
NUTRASAFF	688	58%	4,215	84%	1,051	74%
CW 74	942	79%	4,681	94%	1,036	73%
CW 1221	524	44%	4,494	90%	948	67%
CW 4440	713	60%	3,816	76%	1,380	98%
CW 2889	789	66%	3,709	74%	553	39%
MSU-NDSU Oleic 5	n/t		n/t		n/t	
Hybrid Oleic 16 norm seeding rate	1,923	162%	n/t		n/t	
Hybrid Oleic 16 (14 lb/ac)	1,789	150%	n/t		n/t	
S-5232	1,512	127%	n/t		n/t	
CW 3268-8	1,381	116%	n/t		n/t	
S-3125	1,372	115%	n/t		n/t	
CW 3268-6	1,340	113%	n/t		n/t	
S-5244	1,218	102%	n/t		n/t	
S-1133	1,129	95%	n/t		n/t	
S-4409	1,033	87%	n/t		n/t	
S-1137	1,020	86%	n/t		n/t	
S-6127	963	81%	n/t		n/t	
S-3151	865	73%	n/t		n/t	
S-2106	836	70%	n/t		n/t	
Finch	n/t		n/t		n/t	
Montola 2003	n/t		n/t		n/t	
Montola 2004	n/t		n/t		n/t	
Morlin	n/t		n/t		n/t	
S 9262	n/t		n/t		n/t	
Mean	1189		5,005		1,411	
LSD 0.05	449		411		404	
CV	30		6		20	

n/t = not in trial

Appendix A – continued

TABLE 1 Summary of Trial Results for Safflower Grain Yield in lbs/acre

	VII		VIII		IX	
	lbs/acre	**percentage of trial mean**	**lbs/acre**	**percentage of trial mean**	**lbs/acre**	**percentage of trial mean**
CW 88OL	0		1,052	109%	n/t	
S 345	n/t		905	94%	n/t	
ST 1 OLEIC 05	n/t		n/t		n/t	
CW 99OL	0		984	102%	1,606	95%
S 344	n/t		975	101%	n/t	
ST 1 HYBRID 49	n/t		943	98%	n/t	
S 719	n/t		n/t		n/t	
S 1133	n/t		984	102%	n/t	
NUTRASAFF	n/t		725	75%	1,268	75%
CW 74	0		n/t		n/t	
CW 1221	0		n/t		1,946	115%
CW 4440	0		n/t		n/t	
CW 2889	0		n/t		n/t	
MSU-NDSU Oleic 5	n/t		1,133	118%	n/t	
Hybrid Oleic 16 norm seeding rate	n/t		n/t		n/t	
Hybrid Oleic 16 (14 lb/ac)	n/t		n/t		n/t	
S-5232	n/t		n/t		n/t	
CW 3268-8	n/t		n/t		n/t	
S-3125	n/t		n/t		n/t	
CW 3268-6	n/t		n/t		n/t	
S-5244	n/t		n/t		n/t	
S-1133	n/t		n/t		n/t	
S-4409	n/t		n/t		n/t	
S-1137	n/t		n/t		n/t	
S-6127	n/t		n/t		n/t	
S-3151	n/t		n/t		n/t	
S-2106	n/t		n/t		n/t	
Finch	n/t		n/t		1,847	110%
Montola 2003	n/t		n/t		n/t	
Montola 2004	n/t		n/t		1,759	104%
Morlin	n/t		n/t		1,683	100%
S 9262	n/t		n/t		n/t	
Mean	-		963		1,685	
LSD 0.05	N/A		N/A		192	
CV	N/A		N/A		9.6	

n/t = not in trial

Appendix B

TABLE 2 Summary of Trial Results for Safflower Oil Content

	I - dryland	I - irrigated	II - Direct Seed Recrop	II - chem fallow Direct Seed	II - Conv Fallow
	% oil	**% oil**	**% oil**	**% oil**	**% oil**
CW 88OL			41.3	41.6	41.2
S 345	n/t	n/t	41.1	42.4	42.0
ST 1 OLEIC 05	n/t	n/t	41.0	42.3	42.2
CW 99OL	n/t	n/t	40.4	42.8	41.8
S 344	n/t	n/t	40.2	41.4	41.4
ST 1 HYBRID 49	n/t	n/t	n/t	n/t	n/t
S 719	n/t	n/t	41.3	41.3	41.2
S 1133	n/t	n/t	42.1	43.1	43.5
NUTRASAFF	n/t	n/t	46.2	47.7	46.9
CW 74	n/t	n/t	40.8	41.4	41.7
CW 1221	n/t	n/t	40.5	42.9	42.4
CW 4440	n/t	n/t	38.2	37.7	38.1
CW 2889	n/t	n/t	41.1	42.4	41.5
MSU-NDSU Oleic 5	n/t	n/t	n/t	n/t	n/t
Hybrid Oleic 16 norm seeding rate	n/t	n/t	37.6	38.0	38.7
Hybrid Oleic 16 (14 lb/ac)	n/t	n/t	n/t	n/t	n/t
S-5232	n/t	n/t	n/t	n/t	n/t
CW 3268-8	n/t	n/t	n/t	n/t	n/t
S-3125	n/t	n/t	n/t	n/t	n/t
CW 3268-6	n/t	n/t	n/t	n/t	n/t
S-5244	n/t	n/t	n/t	n/t	n/t
S-1133	n/t	n/t	n/t	n/t	n/t
S-4409	n/t	n/t	n/t	n/t	n/t
S-1137	n/t	n/t	n/t	n/t	n/t
S-6127	n/t	n/t	n/t	n/t	n/t
S-3151	n/t	n/t	n/t	n/t	n/t
S-2106	n/t	n/t	n/t	n/t	n/t
Finch	n/t	n/t	n/t	n/t	n/t
Montola 2003	n/t	n/t	39.1	39.3	39.5
Montola 2004	n/t	n/t	n/t	n/t	n/t
Morlin	n/t	n/t	n/t	n/t	n/t
S9262	n/t	n/t	37.1	39.4	37.9
Mean	N/A	N/A	40.5	41.6	41.3
LSD 0.05					
CV					

n/t = not in trial

Appendix B – continued

TABLE 2 Summary of Trial Results for Safflower Oil Content

	III - Agronomy trial recrop	III - Seeding date April 11, conv recrop	III - Seeding date April 25, conv recrop	IV	V
	% oil	**% oil**	**% oil**	**% oil**	**% oil**
CW 88OL	38.7	38.1	37.5	36.6	39.8
S 345	39.6	40.2	39.1	39.8	40.3
ST 1 OLEIC 05	40.8	39.7	39.9	37.8	39.5
CW 99OL	39.2	39.8	41.4	36.4	40.4
S 344	39.2	38.1	39.0	37.4	39.1
ST 1 HYBRID 49	n/t	n/t	n/t	n/t	38.7
S 719	39.9	38.7	39.2	35.1	39.7
S 1133	42.0	41.5	40.0	34.4	40.8
NUTRASAFF	45.3	44.1	41.6	42.8	45.2
CW 74	39.2	39.0	37.8	31.7	39.0
CW 1221	40.8	40.1	39.4	36.3	39.0
CW 4440	38.3	36.4	36.2	34.8	42.1
CW 2889	40.5	38.8	37.3	35.0	38.3
MSU-NDSU Oleic 5	n/t	n/t	n/t	n/t	n/t
Hybrid Oleic 16 norm seeding rate	37.1	36.9	37.4	36.0	n/t
Hybrid Oleic 16 (14 lb/ac)	n/t	n/t	n/t	35.3	n/t
S-5232	n/t	n/t	n/t	37.9	n/t
CW 3268-8	n/t	n/t	n/t	34.9	n/t
S-3125	n/t	n/t	n/t	38.0	n/t
CW 3268-6	n/t	n/t	n/t	34.9	n/t
S-5244	n/t	n/t	n/t	34.8	n/t
S-1133	n/t	n/t	n/t	34.4	n/t
S-4409	n/t	n/t	n/t	33.4	n/t
S-1137	n/t	n/t	n/t	39.1	n/t
S-6127	n/t	n/t	n/t	28.2	n/t
S-3151	n/t	n/t	n/t	36.7	n/t
S-2106	n/t	n/t	n/t	33.5	n/t
Finch	n/t	n/t	n/t	n/t	n/t
Montola 2003	38.3	37.5	36.5	n/t	n/t
Montola 2004	n/t	n/t	n/t	n/t	n/t
Morlin	n/t	n/t	n/t	n/t	n/t
S9262	37.2	37.2	35.0	n/t	n/t
Mean	39.7	39.1	38.5	36.3	40.1
LSD 0.05				4.70	
CV				9.1	

n/t = not in trial

Appendix B - continued

TABLE 2 Summary of Trial Results for Safflower Oil Content

	VI	VII	VIII	IX	Average over all trials
	% oil	% oil	% oil	% oil	% oil
CW 88OL	35.7	0	n/t	n/t	38.9
S 345	37.4	n/t	n/t	n/t	40.2
ST 1 OLEIC 05	36.0	n/t	n/t	n/t	39.9
CW 99OL	36.0	0	n/t	45.8	40.4
S 344	39.0	n/t	n/t	n/t	39.4
ST 1 HYBRID 49	34.5	n/t	n/t	n/t	
S 719	36.6	n/t	n/t	n/t	39.2
S 1133	33.8	n/t	n/t	n/t	40.1
NUTRASAFF	40.5	n/t	n/t	53.9	45.4
CW 74	34.7	0	n/t	n/t	38.4
CW 1221	35.7	0	n/t	49.1	40.6
CW 4440	36.0	0	n/t	n/t	37.5
CW 2889	29.0	0	n/t	n/t	38.2
MSU-NDSU Oleic 5	n/t	n/t	n/t	n/t	
Hybrid Oleic 16 norm seeding rate	n/t	n/t	n/t	n/t	37.4
Hybrid Oleic 16 (14 lb/ac)	n/t	n/t	n/t	n/t	35.3
S-5232	n/t	n/t	n/t	n/t	37.9
CW 3268-8	n/t	n/t	n/t	n/t	34.9
S-3125	n/t	n/t	n/t	n/t	38.0
CW 3268-6	n/t	n/t	n/t	n/t	34.9
S-5244	n/t	n/t	n/t	n/t	34.8
S-1133	n/t	n/t	n/t	n/t	34.4
S-4409	n/t	n/t	n/t	n/t	33.4
S-1137	n/t	n/t	n/t	n/t	39.1
S-6127	n/t	n/t	n/t	n/t	28.2
S-3151	n/t	n/t	n/t	n/t	36.7
S-2106	n/t	n/t	n/t	n/t	33.5
Finch	n/t	n/t	n/t	40.6	40.6
Montola 2003	n/t	n/t	n/t	n/t	n/t
Montola 2004	n/t	n/t	n/t	41.2	38.8
Morlin	n/t	n/t	n/t	44.0	
S9262	n/t	n/t	n/t	n/t	37.3
Mean	35.8	-		45.8	39.9
LSD 0.05		N/A	N/A	0.94	
CV		N/A	N/A	1.12	

n/t = not in trial

Appendix C

TABLE 3 Summary of Trial Results for Safflower Oil Yield in lbs/acre

	II - Direct Seed Recrop		**II - chem fallow Direct Seed**		**II - Conv Fallow**	
	lbs/acre	**percentage of trial mean**	**lbs/acre**	**percentage of trial mean**	**lbs/acre**	**percentage of trial mean**
CW 88OL	263	104%	450	105%	371	96%
S 345	297	118%	533	124%	346	89%
ST 1 OLEIC 05	309	123%	416	97%	383	99%
CW 99OL	261	104%	493	115%	427	110%
S 344	234	93%	436	101%	413	107%
ST 1 HYBRID 49	n/t		n/t		n/t	
S 719	280	111%	492	114%	430	111%
S 1133	288	114%	468	109%	442	114%
NUTRASAFF	267	106%	441	103%	385	99%
CW 74	275	109%	446	104%	437	113%
CW 1221	238	95%	513	119%	439	113%
CW 4440	144	57%	185	43%	214	55%
CW 2889	238	95%	426	99%	422	109%
MSU-NDSU Oleic 5	n/t		n/t		n/t	
Hybrid Oleic 16 norm seeding rate	224	89%	413	96%	396	102%
Hybrid Oleic 16 (14 lb/ac)	n/t		n/t		n/t	
S-5232	n/t		n/t		n/t	
CW 3268-8	n/t		n/t		n/t	
S-3125	n/t		n/t		n/t	
CW 3268-6	n/t		n/t		n/t	
S-5244	n/t		n/t		n/t	
S-1133	n/t		n/t		n/t	
S-4409	n/t		n/t		n/t	
S-1137	n/t		n/t		n/t	
S-6127	n/t		n/t		n/t	
S-3151	n/t		n/t		n/t	
S-2106	n/t		n/t		n/t	
Finch	n/t		n/t		n/t	
Montola 2003	215	85%	319	74%	356	92%
Montola 2004	n/t		n/t		n/t	
Morlin	n/t		n/t		n/t	
S9262	243	97%	414	96%	351	91%
Mean	252		430		387	
LSD 0.05						
CV						

n/t = not in trial

Appendix C – continued

TABLE 3 Summary of Trial Results for Safflower Oil Yield in lbs/acre

	III - Agronomy trial recrop		III - Seeding date April 11, conv recrop		III - Seeding date April 25, conv recrop	
	lbs/acre	percentage of trial mean	lbs/acre	percentage of trial mean	lbs/acre	percentage of trial mean
CW 88OL	310	101%	235	94%	209	95%
S 345	345	112%	249	99%	212	97%
ST 1 OLEIC 05	351	114%	295	117%	236	107%
CW 99OL	335	109%	299	119%	287	131%
S 344	313	102%	187	75%	245	112%
ST 1 HYBRID 49	n/t		n/t		n/t	
S 719	340	111%	270	108%	239	109%
S 1133	371	121%	300	120%	211	96%
NUTRASAFF	296	96%	214	85%	180	82%
CW 74	309	101%	327	130%	234	106%
CW 1221	306	100%	284	113%	216	98%
CW 4440	199	65%	144	57%	148	68%
CW 2889	280	91%	265	106%	210	96%
MSU-NDSU Oleic 5	n/t		n/t		n/t	
Hybrid Oleic 16 norm seeding rate	271	88%	221	88%	304	138%
Hybrid Oleic 16 (14 lb/ac)	n/t		n/t		n/t	
S-5232	n/t		n/t		n/t	
CW 3268-8	n/t		n/t		n/t	
S-3125	n/t		n/t		n/t	
CW 3268-6	n/t		n/t		n/t	
S-5244	n/t		n/t		n/t	
S-1133	n/t		n/t		n/t	
S-4409	n/t		n/t		n/t	
S-1137	n/t		n/t		n/t	
S-6127	n/t		n/t		n/t	
S-3151	n/t		n/t		n/t	
S-2106	n/t		n/t		n/t	
Finch	n/t		n/t		n/t	
Montola 2003	255	83%	226	90%	180	82%
Montola 2004	n/t		n/t		n/t	
Morlin	n/t		n/t		n/t	
S9262	327	106%	250	99%	185	84%
Mean	307		251		220	
LSD 0.05						
CV						

n/t = not in trial

Appendix C – continued

TABLE 3 Summary of Trial Results for Safflower Oil Yield in lbs/acre

	IV		V	
	lbs/acre	**percentage of trial mean**	**lbs/acre**	**percentage of trial mean**
CW 88OL	687	142%	2,535	126%
S 345	607	126%	2,329	116%
ST 1 OLEIC 05	534	111%	2,280	113%
CW 99OL	489	101%	2,227	111%
S 344	441	91%	2,123	106%
ST 1 HYBRID 49	n/t		2,103	105%
S 719	406	84%	2,050	102%
S 1133	388	81%	1,933	96%
NUTRASAFF	294	61%	1,907	95%
CW 74	298	62%	1,827	91%
CW 1221	191	40%	1,755	87%
CW 4440	248	52%	1,608	80%
CW 2889	276	57%	1,422	71%
MSU-NDSU Oleic 5	n/t	n/t	n/t	
Hybrid Oleic 16 norm seeding rate	691	143%	n/t	
Hybrid Oleic 16 (14 lb/ac)	631	131%	n/t	
S-5232	573	119%	n/t	
CW 3268-8	495	103%	n/t	
S-3125	521	108%	n/t	
CW 3268-6	468	97%	n/t	
S-5244	424	88%	n/t	
S-1133	388	81%	n/t	
S-4409	345	72%	n/t	
S-1137	399	83%	n/t	
S-6127	272	56%	n/t	
S-3151	318	66%	n/t	
S-2106	280	58%	n/t	
Finch	n/t		n/t	
Montola 2003	n/t		n/t	
Montola 2004	n/t		n/t	
Morlin	n/t		n/t	
S9262	n/t		n/t	
Mean	482		2,009	
LSD 0.05				
CV				

n/t = not in trial

Appendix C – continued

TABLE 3 Summary of Trial Results for Safflower Oil Yield in lbs/acre

	VI		IX		
	lbs/acre	**percentage of trial mean**	**lbs/acre**	**percentage of trial mean**	**Average percentage of trial Mean (trials)**
CW 88OL	562	111%	n/t		108% (9)
S 345	629	124%	n/t		112% (9)
ST 1 OLEIC 05	712	140%	n/t		114% (9)
CW 99OL	686	135%	736	96%	115% (9)
S 344	631	124%	n/t		101% (9)
ST 1 HYBRID 49	772	152%	n/t		128% (2)
S 719	427	84%	n/t		104% (9)
S 1133	447	88%	n/t		104% (9)
NUTRASAFF	426	84%	683	89%	90% (10)
CW 74	360	71%	n/t		99% (9)
CW 1221	339	67%	955	125%	96% (10)
CW 4440	497	98%	n/t		64% (9)
CW 2889	161	32%	n/t		84% (9)
MSU-NDSU Oleic 5	n/t		n/t		
Hybrid Oleic 16 norm seeding rate	n/t		n/t		
Hybrid Oleic 16 (14 lb/ac)	n/t		n/t		
S-5232	n/t		n/t		
CW 3268-8	n/t		n/t		
S-3125	n/t		n/t		
CW 3268-6	n/t		n/t		
S-5244	n/t		n/t		
S-1133	n/t		n/t		
S-4409	n/t		n/t		
S-1137	n/t		n/t		
S-6127	n/t		n/t		
S-3151	n/t		n/t		
S-2106	n/t		n/t		
Finch	n/t		750	98%	98%
Montola 2003	n/t		n/t		
Montola 2004	n/t		725	95%	86%
Morlin	n/t		741	97%	
S9262	n/t		n/t		96%
Mean	508		765		
LSD 0.05			192		
CV			9.6		

n/t = not in trial

Appendix D

TABLE 9 Meal Sample Analyses for the Touchet Seed & Energy Extrusion Press Process and the Madison Farms Cold Press Process

	Press			**Sample ID**	**Analysis Lab**
High extruder temp >290F	TS&E	1 lb		TSEM-1	DairyOne
High extruder temp >290F	TS&E	1 lb		TSEM-2	Kuo
Low extruder temp <200F	TS&E	1 lb		TSEM-4	DairyOne
Low extruder temp <200F	TS&E	1 lb		TSEM-5	Kuo
Filter residue	TS&E	1 lb		TSEF-1	Kuo
	Madison Farms	1 lb		MFM-1	DairyOne
	Madison Farms	1 lb		MFM-2	Kuo
	TS&E			random canola meal	Kuo

		TSEM-1	**TSEM-2**	**TSEM-4**	**TSEM-5**	**MFM-1**	**MFM-2**	**TSEF-1**	**random canola meal**
		DM	**DM**	**DM**	**DM**	**DM**	**DM**	**DM**	**DM**
Dry Matter	%	100.00	100.00	100.00	100.00	100.00	100.00	100	100.00
Crude Protein	%	25.70	24.63	26.70	25.25	24.30	23.54	N.D.	38.07
Digestible Protein	%	24.30	18.59	25.20	19.16	23.40	17.60	N.D.	
Acid Detergent Fiber	%	38.60	37.33	38.50	37.55	42.50	36.25	5.71	20.49
Neutral Detergent Fiber	%	57.70	53.22	53.50	55.34	54.50	53.00	36.48	34.20
ADICP	%	1.40	3.74	1.50	3.69	0.90	4.00	N.D.	
NDICP	%	1.80	2.68	1.10	2.56	1.80	3.17	N.D.	
Crude Fat	%	11.60	11.86	12.20	12.02	12.60	12.26		13.30
Calculated TDN	%	63.00	50.80	63.00	50.54	64.00	52.09	88.49	76.47
Calculated ME	MCAL/LB		1.84		1.83		1.88	3.2	2.76
Calculated NEL	MCAL/LB	0.71	0.51	0.71	0.51	0.73	0.53	0.93	0.80
Calculated NEM	MCAL/LB	0.67	0.45	0.67	0.45	0.70	0.47	1	0.83
Calculated NEG	MCAL/LB	0.40	0.20	0.40	0.20	0.43	0.22	0.69	0.55
Calcium	%	0.27	0.30	0.28	0.34	0.27	0.28	0.13	0.50
Phosphorus	%	0.72	0.92	0.77	0.96	0.68	0.72	1	1.05
Magnesium	%	0.38	0.37	0.41	0.41	0.36	0.34	0.37	0.46
Potassium	%	1.15	1.13	1.20	1.27	1.05	1.32	0.68	1.32
Ash	%	5.18	4.54	4.93	4.64	3.75	10.12	4.11	5.91
Digestible Dry Matter	%		59.82		59.65		60.66	84.45	72.94
Dry Matter Intake	% BW		2.25		2.17		2.26	3.29	3.51
Relative Feed Value			105		100		106	215	198

Appendix E

TABLE 10 Amino Acid Profile of Safflower Meal Crushed by Touchet Seed & Energy

ESCL #		**8704**		**8705**
Units		**W/W%**		**W/W%**
Sample #		TSEM-3		TSEM-6
		TS&G high extruder temp		**TS&G low extruder temp**
Taurine		0.02		0.01
Hydroxyproline		0.14		0.15
Aspartic Acid		2.14		2.24
Threonine		0.69		0.73
Serine		0.81		0.84
Glutamic Acid		4.29		4.46
Proline		0.95		0.99
Lanthionine		0.00		0.02
Glycine		1.26		1.32
Alanine		0.95		0.99
Cysteine		0.36		0.39
Valine		1.22		1.27
Methionine		0.36		0.39
Isoleucine		0.86		0.89
Leucine		1.47		1.53
Tyrosine		0.57		0.60
Phenylalanine		1.00		1.04
Hydroxylysine		0.01		0.01
Ornithine		0.01		0.01
Lysine		0.75		0.79
Histidine		0.57		0.59
Arginine		2.02		2.12
Tryptophan		0.31		0.35
Total		20.76		21.72
Moisture		3.13		3.82
W/W%= grams per 100 grams of sample.				
Results are expressed on a dry matter basis.				