Growth, Seed Yield, and Oil Production of Spring *Camelina sativa* in Response to Irrigation Rate and Harvest Method, in the Klamath Basin, 2011

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Introduction

The recent increase in energy prices and political instability in the Middle East has sparked renewed interest in alternative energy sources and technologies both locally and nationally. Biodiesel is an appealing transportation fuel source for many reasons: it readily substitutes for petroleum diesel, it tends to burn cleaner with fewer pollutants, it can be made from many plant-based oil sources, and it can be produced on a large or small scale. Biodiesel can be made from many oilseed crops. However, the most prolific oil producers per acre tend to be tropical or subtropical crops such as palm oil, castor, and

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soybean. Some temperate oilseed crops, such as sunflower, meadowfoam, and flax, have higher value end-uses than biodiesel. Therefore, much of the research on oilseeds for biodiesel in temperate regions has focused on rapeseed/canola, and more recently, another oilseed crop called camelina (*Camelina sativa)*. Please see the separate report of canola research we conducted in 2010-2011.

Camelina is an ancient crop (grown as far back as 1000 BC) that was later used extensively as a source of edible oil as well as for oil lanterns for lighting in eastern Europe in the middle ages (Putnam et al., 1993). Its use decreased with the advent of improved trade for olive oil from southern Europe and, much later, the development of petroleum-based oils and then electric lighting in the 20th century. Camelina is of interest for dietary reasons due to its unusually high levels of Omega-3 fatty acids. It is of interest for biodiesel production because it seems to grow well in conditions of relatively poor soil, low fertility, and low moisture availability. Its seed contains 30-40% oil by weight, but seed yields are generally less than canola under ideal growing conditions, but may be similar under more stressful conditions. Both canola and camelina have been reported to exhibit some herbicidal properties in the following crop, which could potentially reduce weed control costs in crops seeded after these oilseed crops. Because camelina's fatty acid profile differs somewhat from canola's, it can be more easily converted into aviation fuel, another potential end-product.

Prior to about 2005, camelina was not a commercial crop in the US, but by 2007 about 15,000 acres of camelina was grown in the US, mostly in Montana, spurred by active private company contracting activity there. Acreage there has gradually increased, and interest has increased in other parts of the PNW and other regions of the country very recently, partially due to production incentives and research funding from Dept. of Defense and other sources due to camelina's potential use as a raw material to produce aviation fuel.

Research Justification and Objectives

We found minimal camelina research or commercialization efforts in Oregon prior to 2006. Fall-seeded camelina was tested at the Columbia Basin Ag. Research Center near Pendleton in the early 1960s, with mixed results (Don Wysocki 2008, pers. comm.). Two unrelated small trials were seeded at the Southern Oregon Research & Extension Center near Medford and at the Hyslop Farm near Corvallis in the mid-1990s. Those two trials did not produce much useful data due to poor crop emergence, growth and yield (Richard Roseberg 2006, pers. comm., Daryl Ehrensing 2008, pers. comm.). Nationally, most of the interest in camelina has been very recent, and commercial efforts have been centered in the western region, especially Montana, under conditions of limited moisture and soil fertility. This suggested that it may do well in parts of Oregon that are less than ideal for intensive cropping. The south-central region of Oregon has irrigation water available in certain areas, and reasonably good soils over larger areas. In the Klamath Basin, camelina may have a possible rotation fit with existing crops such as potatoes, grass and alfalfa hay, small grains, and pastures, especially in fields with less than optimal irrigation and fertility. Earlier studies conducted at the Klamath Basin

Research & Extension Center (KBREC) in 2007 and 2008 suggested that spring-seeded camelina would grow well here, but that it clearly benefited from some irrigation (Roseberg et al., 2007; Roseberg and Shuck, 2008). In 2009, we conducted two separate camelina studies at KBREC. In one study, the yield of spring-seeded camelina was again improved by a low level of irrigation (especially for later seeding dates), but yield was not increased with a higher rate of irrigation (Roseberg and Shuck, 2009). Early seeding dates also resulted in higher yield, especially where less irrigation was applied.

The earlier studies were harvested almost exclusively by the direct-combine method, however, there was some evidence that more seed could potentially be collected if the crop were swathed before complete maturity, allowed to dry in the field, and then combined, similar to the procedure often used for canola. An alternate procedure that is sometimes used in seed crops involves direct combining, followed several days later by a second combining operation (of the previously threshed material) to recover any immature seeds that were not threshed out of the seed pods during the first combining.

Thus, in 2011 we conducted a study examining the effects of irrigation rate and harvest method for spring camelina. The objective of this study was to measure the seed yield and oil content of camelina as influenced by irrigation rate and harvest method.

Procedures

This study was conducted at KBREC in a Poe fine sandy loam soil following non-irrigated fallow in 2010. This study was laid out as a split plot design with irrigation rate as the main plot and seeding date as the subplot. 'Calena' camelina seed was used for all plots. All plot areas were seeded to a depth of 0.25 inch on April 28 with a small commercial John Deere grain drill, (6-inch row spacing), at the rate of 8.0 lb/ac of raw seed. The entire trial area was fertilized at a rate of 53 lb/ac N, and 60 lb/ac S (applied as 21-0-0-24 at 250 lb/ac) banded at seeding. Sonalan® (ethalfluralin) herbicide was applied at 5.3 pint/ac (2.0 lb a.i./ac) incorporated before seeding using a roto-tiller on April 19. No additional fertilizer or herbicides were applied during the season.

Solid-set sprinklers arranged in a 40- by 40-ft pattern were used for irrigation. Irrigation rates were set based on weather data from the US Dept. of Reclamation Agricultural Meteorological (AgriMet) weather station at KBREC (US Bureau of Reclamation, 2011), which also calculated the Jensen-Penman evapotranspiration (Et). Three irrigation treatments were imposed (Table 1). After seedling emergence, the irrigation was applied so that the precipitation plus irrigation for the 'wet' irrigation treatment was approximately equal to 50% of Et and the precipitation plus irrigation for the 'medium' irrigation treatment was approximately equal to 25% of Et. The 'dry' treatment only received irrigation in May (during germination and soon after emergence), and thus the seasonal precipitation plus irrigation for the 'dry' treatment equaled about 12% of Et.

The harvested area for each plot was 36.0 by 4.5 ft, although some plots were slightly shorter due to a pre-harvest cutting error. There were three harvest methods. The first was 'combine once', where plots direct-combined once using a Hege (Hans-Ulrich

Hege) plot combine with a 4.5-ft-wide header. These plots were combined on August 23, a time that was estimated to include the largest percentage of mature seed on the plants. The second harvest method was 'combine twice', where plots were combined once, the threshed material was left to dry a few days in a windrow, then combined again to harvest any seed that may not have been fully dry (and thus remained un-threshed during the first combining). These plots were combined for the first time on August 10 (when it was estimated that over half of the seed pods were mature and few had shattered), and for the second time on August 15. This treatment also allowed a *de facto* comparison of direct combining on two dates, by comparing the yield and seed characteristics of the first cutting of the 'combine twice' treatment (done on August 10) with the results of the 'combine once' treatment (done on August 23). The third harvest method was 'swath/combine', where plots were first cut into windrows with a Swift (Swift Mfg Co.) plot swather, left a few days to dry, and then combined once with the Hege plot combine. These plots were swathed on August 10, and the 'dry' irrigation treatment was combined on August 12 and the 'medium' and 'wet' treatments were combined on August 15.


Swift Plot Swather


Hege Plot Combine

Data measured at KBREC included grain yield and test weight. Cleaned seed samples were sent to the Brassica Breeding and Research Lab (Dr. Jack Brown) at the University of Idaho to measure seed oil content, which also allowed calculation of oil yield.

All measured parameters were analyzed statistically using SAS® for Windows, Release 9.1 (SAS Institute, Inc.) software. Treatment significance was based on the F test at the P=0.05 level. If this analysis indicated significant treatment effects, least significant difference (LSD) values were calculated based on the student's *t* test at the 5% level.

Results and Discussion

Soil moisture was good during seedbed preparation, and resulting germination and stand density were good. Good availability of irrigation water and few hot days during the season (two days with maximum temperatures above 90^{o}F, with none over

100^{o}F), suggest that heat and moisture stress was minimal where sufficient irrigation was applied. Weed pressure was light and did not seem to impact crop growth.

Differences due to irrigation rate were not significant for any of the measured parameters, but there was a trend for yield to be highest under the 'medium' irrigation treatment. However, there were significant differences between harvest methods for seed yield, test weight, and oil yield, but not oil content (Table 2).

In the 'dry' treatment, the 'swath/combine' harvest method had the highest seed yield, followed by 'combine twice' and then 'combine once', although differences between these three treatments were not significant. In the 'medium' treatment, the 'swath/combine' method again had the highest seed yield, but here the 'combine once' yield was higher than the 'combine twice' yield, although that difference was not significant. In the 'wet' irrigation treatment, the 'combine twice' method had the highest seed yield, followed by 'swath/combine' and 'combine once'. The second combining step in the 'combine twice' treatment increased seed yield by 64% in the 'wet' irrigation treatment, but by less than 25% for the other two irrigation treatments. Thus in the 'wet' irrigation treatment, yield was clearly enhanced by processing the crop twice, either by two combining operations or by swathing before combining, suggesting that where crop vegetative growth is enhanced, and crop dry-down is delayed due to higher irrigation, that a method to more evenly dry out all the material prior to final combining is beneficial. In each case, the seed yield from the 'combine once' treatment was greater than the yield from the first combine operation of the 'combine twice' treatment, suggesting that if there is to be only one harvest operation, that delaying combining until more of the seed pods are mature and dry does not reduce yield compared to combining earlier (when very few of the seed pods have begun shattering and many are still partially green).

Test weights were fairly uniform across irrigation rates and harvest methods, although seed from the 'combine once' and 'swath/combine' treatments had the highest seed yield. There was no difference in oil percent due to harvest method or irrigation rate. It is interesting that the seed from the second combine operation in the 'combine twice' treatment had nearly the same oil percent as the other procedures. Thus, oil yield followed the same pattern as seed yields.

Summary

Spring-seeded camelina will produce a harvestable crop with limited irrigation under Klamath Basin mineral soil conditions. The additional moisture in the 'medium' irrigation treatment seemed to increase yields, but additional irrigation in the 'wet' treatment did not. The somewhat beneficial effect of irrigation observed here was not as strong as we have observed in prior studies at KBREC. From this study, it appears seed yield can be increased by processing camelina twice in some fashion during the harvest process when higher levels of moisture have been available (and plants are larger and greener) than where moisture was more limiting. Under drier conditions, the benefit of either the 'swath/combine' or the 'combine twice' method is not evident compared to direct combining one time. Also, combining the camelina twice is more labor intensive and time-consuming than the other two methods, so a potentially slight increase in seed yield might not be worth the extra effort and expense.

Future Prospects

Although weed competition was not a big factor in 2011, the ability of camelina to compete with weeds is a question that needs to be answered, as well as the related need to develop acceptable herbicide practices. It seems inputs are lower compared to other crops, so camelina may find a profitable place in Klamath Basin crop rotations, especially on non-prime farmlands. If it can be demonstrated that it also provides rotation benefits to subsequent crops, it would also be more viable on higher value, more intensively managed crop land.

A commercial biodiesel production facility is currently in operation near Klamath Falls, and a Willamette Valley-based company has been scouting for grower contracts in this area, but high grain prices have led growers to seed wheat and barley instead of the more speculative camelina. Based on our research information, a commercial 25-acre field of camelina was grown in the Rogue Valley in 2008 without irrigation, resulting in a fairly good stand and apparent harvestable seed yield. A few additional small fields reportedly were grown in the Rogue Valley and Klamath Basin in 2009 and 2010. Further demonstration fields and research studies would help identify camelina's potential and limiting factors in this region.

A meeting with industry representatives and growers was held in the Klamath Basin on March 24, 2011, with approximately 50 attendees. Interest level was good, and several growers indicated they would like to test camelina in small plots in the Klamath Basin, the Rogue Valley, and nearby valleys in northern California. The ability to be seeded earlier than most spring crops, along with the potentially producing a harvestable seed yield with limited (or perhaps even without) irrigation would be a huge benefit for growing camelina in this region.

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Table 1. 2011 Precipitation & irrigation for the spring camelina irrigation rate x harvest method trial. Klamath Basin Research & Extension Center, Klamath Falls, OR.

		"Wet" Block		"Medium" Block		"Dry" Block	
Month	Precipitation (inch)	Irrigation (inch)	Irrigation Applications	Irrigation (inch)	Irrigation Applications	Irrigation (inch)	Irrigation Applications
April 10-30	1.30	0.00	0	0.00	0	0.00	0
May	0.81	2.15	3	2.15	3	2.15	3
June	0.14	2.85	3	0.57	1	0.00	0
July	0.29	4.00	5	1.14	2	0.00	0
August	0.00	0.86	1	0.86	1	0.00	0
September	0.02	0.00	0	0.00	0	0.00	0
October	0.53	0.00	0	0.00	0	0.00	0
Total	**2.56**	**9.86**	**12**	**4.72**	**7**	**2.15**	**3**

Table 2. 2011 Response of spring camelina to irrigation rate & harvest method. Klamath Basin Research & Extension Center, Klamath Falls, OR.

Irrigation Rate	Harvest Method	Seed Yield (lb/ac)	Rank	Test Weight (lb/bu)	Rank	Oil %	Rank	Oil Yield (lb/ac)	Rank
Wet	One Combine Only	1204	10	51.4	4	35.2	9	422	10
	1st Combine Pass	1054	12	49.8	10	35.3	8	372	12
	2nd Combine Pass	674	13	50.8	6	34.6	11	233	13
	Total of 2 Combine Passes	1726	3	50.3	7	nm*	-	605	3
	Swath & Combine	1529	5	52.0	1	35.8	5	545	5
Medium	One Combine Only	1896	2	51.2	5	35.2	9	666	2
	1st Combine Pass	1456	6	50.2	8	35.6	6	519	7
	2nd Combine Pass	221	15	48.2	15	34.0	12	75	15
	Total of 2 Combine Passes	1677	4	49.8	10	nm*	-	594	4
	Swath & Combine	2148	1	52.0	1	35.4	7	760	1
Dry	One Combine Only	1264	9	51.9	3	35.9	4	455	9
	1st Combine Pass	1094	11	49.7	12	36.0	3	395	11
	2nd Combine Pass	248	14	48.3	14	37.1	1	92	14
	Total of 2 Combine Passes	1342	8	49.4	13	nm*	-	483	8
	Swath & Combine	1444	7	50.1	9	36.2	2	526	6
Mean		1265		50.3		35.5		449	
***P* (Irrigation Rate)**		**0.295**		**0.191**		**0.427**		**0.390**	
LSD (0.05)- Irrigation Rate		NSD		NSD		NSD		NSD	
CV Irrigation Rate (%)		32.7		1.5		4.6		37.9	
***P* (Harvest Method)**		**<0.001**		**<0.001**		**0.401**		**<0.001**	
LSD (0.05)- Harvest Method		353		0.6		NSD		123	
CV Harvest Method (%)		22.2		1.0		1.6		21.7	
***P* (Irrig. Rate X Harvest Method Interaction)**		**0.230**		**0.005**		**0.080**		**0.231**	

nm* Oil % value for total of 2 combine harvests was not meaningful.