REGION 4
Western WA

Title: Growing Biofuels in Western Washington

Co-PI's: Tim Miller and Craig Cogger

Graduate students: None

Technical Support: Carl Libbey at WSU Mount Vernon (partial funding), Liz Myhre at WSU Puyallup (partial funding)

Background: It is not known whether any of the biofuel crops currently grown for oil production (including, canola, flax, sunflower, mustard, sunflower, safflower, meadowfoam, and camelina), can be economically produced in western Washington. Previous testing at Mount Vernon has shown that, while meadowfoam, safflower, and sunflower can be grown in the region, yield or other production factors may not allow these crops to be produced profitably by growers. Simple agronomic production guidance is scarce for oilseed crops in this region; therefore, research thus far has focused on determining seeding dates, seeding rates, fertilizer requirements, harvest factors (seed moisture, maturity, etc.), and other production factors.

Objectives: The objective of this research is to determine optimal production strategies for various oilseeds in western Washington. Specific trials include:

1. Canola
    - A. Conduct fertilization regime trials with fall canola on organic ground at WSU Puyallup.
    - B. Conduct fertilization regime trials with spring canola on organic ground at WSU Puyallup.
2. Conduct seeding rate trials with camelina at WSU Mount Vernon.
3. Conduct seeding rate trials with flax at WSU Mount Vernon.
4. Conduct seeding rate trials with mustard at WSU Mount Vernon.

These trials will help to determine whether these crops may be profitably produced under western Washington conditions as well as identifying production obstacles that remain to be overcome.

Methods:

1A. <u>Fall canola trial</u>. Fall canola (cv. 'Athena') was seeded at approximately 8 lbs/acre into 10- by 20-ft plots on four planting dates on organically-certified ground at WSU Puyallup: August 13, August 26, September 12, and October 1, 2008. Craig Cogger's crew applied one of three fertilization regimes to the canola: 200 lb total N/acre applied (1) all in the fall, (2) all in the spring, or (3) split with 67 lb N/acre in fall and 133 lb N/acre in the spring; fertilizer was a pelletized feather meal. Seed and fertilizer was sprinkled on the surface of the soil as appropriate, then raked by hand to shallowly incorporate. The fourth seeding was dropped from the trial in spring, 2009 due to poor canola establishment. Injury to canola from winter flooding and goose browsing in December and January was estimated February 2. Percent crop and weed cover was visually estimated October 1, 2008 and January 28, 2009. Canola plants within a 12- by 20-inch quadrat were counted and clipped at ground level July 23, 2009. Excess stem material was trimmed off each plant, and remaining upper stems and racemes were placed into paper grocery bags and then stored in a screen house at WSU Mount Vernon NWREC for slow drying and seed ripening to occur (maximum daytime temperatures did not exceed 85 F during the drying process). After approximately three weeks of drying, seed was threshed by hand, passed over screens to remove large chaff, and freed of fine chaff and dust using a blower-style seed cleaner. Seed weight for each sample was then recorded. Yield data were analyzed using a general linear models procedure and means were separated using Fisher's Protected LSD at the P = 0.05 level. The design was a randomized complete block with three replicates.

1B. <u>Spring canola trial</u>. Spring canola ('Sunrise' and 'Clearwater') and spring rapeseed ('Gem' and 'Sterling') (all *Brassica napus*), 'IdaGold' white mustard (*Sinapis alba*) and 'Celine' camelina were seeded April 23, 2009 on organically-certified ground at WSU Puyallup. Canola, rapeseed, and mustard were seeded at 8 lbs/acre, while camelina was seeded at 5 or 8 lbs/acre. All plots received feather meal at 150 lbs N/acre, applied immediately before or after seeding, and then plots were raked by hand to shallowly incorporate both fertilizer and seed. Percent crop and weed cover was visually estimated May 28 and crop plants within a 12- by 20-inch quadrat were counted and clipped at ground level July 23. Excess stem material was trimmed off each plant, and remaining upper stems and racemes were placed into paper grocery bags and then stored in a screen house at WSU Mount Vernon NWREC for slow drying and seed ripening to occur (maximum daytime temperatures did not exceed 85 F during the drying process). After approximately three weeks of drying, seed was threshed by hand, passed over screens to remove large chaff, and freed of fine chaff and dust using a blower-style seed cleaner. Seed weight for each sample was then recorded. Yield data were analyzed using a general linear models procedure and means were separated using Fisher's Protected LSD at the P = 0.05 level. The design was a randomized complete block with three replicates.

2A. <u>Camelina seeding timing trial</u>. Plots (8 by 20 ft) were established at WSU Mount Vernon in late September, 2008. Fall camelina seedings were made on October 2, 16, and 30, 2008; spring seedings were made on February 3 and 17, March 2 and 26, April 20, and May 4, 2009. All camelina plots were seeded at 8 lbs/acre; the cultivar was 'Celine'. Seed was scattered over the soil by hand, then shallowly incorporated with a drag harrow immediately following seeding. Soil was too wet to cultivate for the February and March seedings, so glyphosate at 0.75 lbs ai/acre was applied to plots to control weeds that had grown over the winter; glyphosate was applied to plots to be seeded in February (immediately after the February 3 seeding) and March (immediately after the March 2 seeding) using a CO_2-pressurized backpack sprayer delivering 31 gallons/acre. Crop injury and weed control was visually estimated April 24. October, February, and March seedings were harvested August 28 using a small plot combine; April and May seedings were harvested September 9. Seed was passed over screens to remove large chaff, and freed of fine chaff and dust using a blower-style seed cleaner. Seed weight for each sample was then recorded. Yield data were analyzed using a general linear models procedure and means were separated using Fisher's Protected LSD at the P = 0.05 level. The design was a randomized complete block with three replicates.

2B. <u>Camelina seeding rate trial</u>. Plots (8 by 20 ft) were established at WSU Mount Vernon May 23, 2009. Seeding rates (cv. 'Celine') were 3, 4, 5, 6, 7, and 8 lbs/acre. Seed was scattered over the soil by hand, then shallowly incorporated with a rake immediately following seeding. Crop and weed cover were visually estimated June 26. Plots were harvested August 28 using a small plot combine. Seed was dried on trays in the greenhouse for a week, then passed over screens to remove large chaff, and freed of fine chaff and dust using a blower-style seed cleaner. Seed weight for each sample was then recorded. Yield data were analyzed using a general linear models procedure and means were separated using Fisher's Protected LSD at the P = 0.05 level. The design was a randomized complete block with three replicates.

3. Flax seeding rate trial. Plots (8 by 20 ft) were established at WSU Mount Vernon May 23, 2009. Seeding rates were 25, 30, 35, 40, and 45 lbs/acre. Seed was scattered over the soil by hand, then shallowly incorporated with a rake immediately following seeding. Crop and weed cover were visually estimated June 26. Plots were harvested September 9 using a small plot combine. Seed was dried on trays in the greenhouse for a week, then passed over screens to remove large chaff, and freed of fine chaff and dust using a blower-style seed cleaner. Seed weight for each sample was then recorded. Yield data were analyzed using a general linear models procedure and means were separated using Fisher's Protected LSD at the P = 0.05 level. The design was a randomized complete block with three replicates.

4. Mustard seeding rate trial. Plots (8 by 20 ft) were established at WSU Mount Vernon May 23, 2009. 'IdaGold' white mustard (*Sinapis alba*) and 'Pacific Gold' oriental mustard (*Brassica juncea*)) was seeded at 4, 6, 8, and 10 lbs/acre. Seed was scattered over the soil by hand, then shallowly incorporated with a rake immediately following seeding. Crop and weed cover were visually estimated June 26. Plots were harvested August 28 using a small plot combine. Seed was dried on trays in the greenhouse for a week, then passed over screens to remove large chaff, and freed of fine chaff and dust using a blower-style seed cleaner. Seed weight for each sample was then recorded. Yield data were analyzed using a general linear models procedure and means were separated using Fisher's Protected LSD at the P = 0.05 level. The design was a randomized complete block with three replicates.

Duration: Winter canola (WSU Puyallup) and camelina (WSU Mount Vernon) plots were initiated in fall, 2007 and 2008, while spring canola (WSU Puyallup) and flax, camelina, and mustard (WSU Mount Vernon) plots were initiated in spring, 2008 and 2009. All trials were completed in summer and fall, 2008 and 2009.

Results:
1A. Fall canola trial. Canola seedlings in the first planting were covering 72% of the ground at the October evaluation, compared to 34% cover in the second planting (Table 1). Canola plants in the September planting were not emerged sufficiently to gauge cover (<5%). By the January evaluation, a pattern had emerged: the later the seeding date, the lower the cover rating. When averaged across planting date, crop cover in October was greater in plots receiving fall fertilizer compared to non-fertilized plots; crop cover in plots receiving split applications of fertilizer was midway between fertilized and non-fertilized plots. Canada geese severely browsed the plots when their other grazing sites were covered with snow in December (Fig.1). Browsing was far greater in plots seeded in August than in plots seeded in September, perhaps because they had a greater quantity of forage. Browsing resulted in canola in non-fertilized plots having greater cover than fall-fertilized canola; canola receiving split fertilizer applications were again mid-way between fertilized and non-fertilized plots. Weed cover wasn't a factor

Figure 3. Goose browsing damage in early-seeded winter canola plots at WSU Puyallup 2008-09.

until the January evaluation, at which time later seeding dates showed greater weed cover. There was no significant weed cover response to fertilizer regime. Flooding in late December/early January was situated more on plots seeded August 13 than on either other seeding date and may have impacted canola recovery from browsing or ultimate seed yield. Flooding was scattered across all fertilizer regimes, however, so it is unlikely that flood injury was a factor in canola success or failure in those analyses.

Table 1. Vegetative measurement of organic winter canola at WSU Puyallup.

Treatment	Crop cover[a]		Weed cover[a]	Goose browsing	Flood damage
	Oct 1	Jan 30	Jan 30		
	%	%	%	%	%
Seeding date					
August 13	72 a	61 a	6 c	72 a	69 a
August 26	34 a	50 b	17 b	72 a	0 b
September 12	---	42 c	54 a	11 b	11 b
Fertilizer regime					
All fall	62 a	35 b	38 a	75 a	24 a
Split fall/spring	53 ab	38 ab	39 a	72 a	32 a
All spring	44 b	41 a	41 a	44 b	17 a

Means for the same treatment type within a column followed by the same letter are not significantly different (P = 0.005).
[a]Crop and weed cover estimated January 30, 2009.

Table 2. Crop density and yield of organic winter canola at WSU Puyallup.

Treatment	Crop density[b]	Seed yield[b]
	plants/1.67 ft^2	lbs/acre
Seeding date		
August 13	10.8 ab	5400 a
August 26	8.0 b	4999 a
September 12	12.9 a	2861 b
Fertilizer regime		
All fall	7.9 b	4616 a
Split fall/spring	10.0 ab	4424 a
All spring	13.8 a	4221 a

Means for the same treatment type within a column followed by the same letter are not significantly different (P = 0.005).
[a]Crop and weed cover estimated January 30, 2009.
[b]Canola plants sampled for seed yield July 23, 2009.

1B. Spring canola trial. Of all cultivars/species tested, IdaGold mustard provided the quickest canopy cover (85%) and lowest weed cover (15%) by mid-June (Table 3). Sunrise canola and Celine camelina at 8 lbs/acre resulted in significantly better crop cover in June than the other three canola cultivars or Celine seeded at 5 lbs/acre. Weed cover in June did not differ among the canola cultivars or Celine at 5 lbs/acre, although Celine at 8 lbs/acre. There was no significant difference in seed yield among tested cultivars and species.

Table 3. Organic spring oilseed crops at WSU Puyallup.

Cultivar (crop)[a]	Crop cover[b]	Weed cover[b]	Yield[c]
	%	%	lbs/acre
Sunrise (canola)	67 b	32 ab	2064 a
Clearwater (canola)	53 c	38 a	1863 a
Gem (rapeseed)	55 c	38 a	2005 a
Sterling (rapeseed)	52 c	38 a	1473 a
IdaGold (mustard)	85 a	15 c	1854 a
Celine (camelina), 5 lbs/acre	50 c	38 a	1488 a
Celine (camelina), 8 lbs/acre	73 b	25 b	1400 a

Means for the same treatment type within a column followed by the same letter are not significantly different (P = 0.005).
[a]Crops seeded April 23, 2009.
[b]Crop and weed cover estimated June 18, 2009.
[c]Crops sampled for seed yield July 23, 2009.

2A. Camelina seeding timing trial. Camelina seeded in October, 2008 was bolting in late April, 2009, with stem height significantly taller than with camelina seeded in 2009 (Table 4). The later the seeding date in October, the shorter the crop in April. Similarly, crop cover was 90% or more for camelina seeded October 2 or 16, and only 78% when seeded October 30. Spring seeded camelina did not exceed 20% cover in late April regardless of seeding date. Weed control was acceptably high for all seedings except October 30, indicating that that date is likely too late in the fall for optimal camelina performance. Weed control from February or March seeding dates was very good, but that is considered to result mostly from glyphosate application prior to seeding rather than competitive effect from camelina. Camelina seeded in April or May, however, was seeded into freshly-cultivated soil, so camelina rapidly and thoroughly competed with weeds in these plots resulting in near-complete weed control. Seed yield was uniformly low and did not differ greatly among any of the seeding dates.

Table 4. Effect of seeding date on camelina growth and yield at WSU Mount Vernon.

Seeding date	Crop height[a]	Crop cover[a]	Weed control[b]	Yield[c]
	inches	%	%	lb/acre
October 2	31 a	92 a	95 ab	985 ab
October 16	22 b	90 a	93 ab	1017 ab
October 30	9 c	78 b	78 c	763 ab
February 3	3 d	18 c	95 ab	873 ab
February 17	3 d	17 cd	88 b	743 ab
March 2	2 d	10 cd	93 ab	866 ab
March 26	1 d	8 de	90 b	518 bc
April 20	---	---	100 a	1128 a
May 4	---	---	100 a	1221 a

Means for the same treatment type within a column followed by the same letter are not significantly different (P = 0.005).
[a]Crop height (camelina stem length) and crop cover estimated April 24, 2009.
[b]Weed control estimated April 24, 2009. Plots seeded in February were treated with glyphosate February 3; plots seeded in March were treated with glyphosate March 2; plots seeded in April or May were cultivated prior to seeding.
[c]Plots seeded in October, February, and March harvested August 28; plots seeded in April and May harvested September 9, 2009.

2B. Camelina seeding rate trial. Cover of camelina seeded at 8 lbs/acre exceeded cover from camelina seeded at 3 or 5 lbs/acre at one month after seeding (Table 5). Greater weed suppression also occurred when camelina was seeded at 8 lbs/acre than at 3 or 4 lbs/acre. Yield was uniformly low, probably due to the late seeding date, and did not differ significantly by seeding rate.

Table 5. Effect of several seeding rates in camelina at WSU Mount Vernon.

Seeding rate[a]	Crop cover[a]	Weed cover[a]	Yield[b]
lbs/acre	%	%	lbs/acre
3	65 b	25 a	803 a
4	72 ab	23 a	849 a
5	68 b	22 ab	886 a
6	73 ab	18 ab	842 a
7	77 ab	17 ab	888 a
8	82 a	13 b	928 a

Means for the same treatment type within a column followed by the same letter are not significantly different (P = 0.005).
[a]Camelina seeded May 23, 2009.
[b]Crop and weed cover estimated June 26, 2009.
[c]Plots harvested August 28, 2009.

3. Flax seeding rate trial. Flax seeded at 40 lbs/acre had significantly more cover at one month after seeding than when seeded at 25 lbs/acre (Table 6). Flax at the 45 lbs/acre seeding rate provided more competition with weeds than when seeded at 25 lbs/acre. Yield was uniformly very low, probably due to the late seeding date, and did not differ significantly by seeding rate.

Table 6. Effect of several seeding rates in flax at WSU Mount Vernon.

Seeding rate	Crop cover[a]	Weed cover[a]	Yield[b]
lbs/acre	%	%	lbs/acre
25	28 b	45 a	390 a
30	40 ab	38 ab	372 a
35	43 ab	37 ab	518 a
40	55 a	35 ab	298 a
45	47 ab	33 b	370 a

Means for the same treatment type within a column followed by the same letter are not significantly different (P = 0.005).
[a]Flax seeded May 23, 2009.
[b]Crop and weed cover estimated June 26, 2009.
[c]Plots harvested September 9, 2009.

4. Mustard seeding rate trial. Both mustard species rapidly covered the soil in these plots, and there was not a large difference in cover at one month after seeding (Table 7). IdaGold cover exceeded Pacific Gold cover only at the 4 lbs/acre seeding rate; all other cover estimations were not significantly different. Weed cover with IdaGold at 4 or 8 lbs/acre was 5%, statistically similar to all other seeding rates except Pacific Gold at 4 lbs/acre (15%). The trend was for Pacific Gold mustard to not have as much cover, and therefore more weeds, than comparably seeded IdaGold. Although not statistically significant, IdaGold tended to have higher crop cover at lower seeding rates, while Pacific Gold tended to performed better in crop cover and weed suppression at higher seeding rates. Yield did not differ by seeding rate for either cultivar, although there was a trend for IdaGold to yield better than Pacific Gold. Yield from IdaGold seeded at 10 lbs/acre exceeded yield from Pacific Gold seeded at 4, 6, or 10 lbs/acre.

Table 7. Effect of several seeding rates in two mustard species at WSU Mount Vernon.

	IdaGold			Pacific Gold		
Seeding rate[a]	Crop cover[b]	Weed cover[b]	Yield[c]	Crop cover[b]	Weed cover[b]	Yield[c]
lbs/acre	%	%	lbs/acre	%	%	lbs/acre
4	95 a	5 b	1114 ab	80 b	15 a	965 bc
6	92 ab	7 ab	1115 ab	85 ab	12 ab	932 bc
8	92 ab	5 b	1084 ab	90 ab	8 ab	993 abc
10	90 ab	7 ab	1265 a	90 ab	8 ab	763 c

Means for the same treatment type within a column followed by the same letter are not significantly different (P = 0.005).
[a]Mustard seeded May 23, 2009.
[b]Crop and weed cover estimated June 26, 2009.
[c]Plots harvested August 28, 2009.

Discussion:

WSU Puyallup

Canola. Based on results from the last two years, it appears that fall canola needs to be seeded prior to September 12 in western Washington to grow and yield successfully. Seeding in mid-August resulted in nearly twice the seed yield than seeding in mid-September. Fertilizing in the fall resulted in a lower density of canola plants than fertilizing in the spring, resulting in a trend toward lower yields with spring-fertilized canola. Although not directly comparable, the yield potential of canola seeded in August seems to be about twice that of canola, rapeseed, or IdaGold mustard seeded in April, and about three times that of spring-seeded camelina.

Biofuel crops at WSU Mount Vernon NWREC.

Canola has not been tested at this location due to planting restrictions in place to protect the cabbage seed industry.

Camelina. In general, camelina performance has not been outstanding at this location in testing over the last two years. In both 2008 trials, the yield range was 1059 to 1559 lbs/acre, generally better than the 518 to 1221 lbs/acre harvested from both trials in 2009, but still probably not high enough to warrant much attention from west-side producers. Most seeding rates resulted in similar crop cover, weed suppression, and yield both years, so it is difficult to recommend a particular range of seeding rates as being optimal. The 2009 results also indicate that while camelina can survive western Washington winters, yield was not positively impacted compared to seeding in April and May.

Mustard. In general, mustard performance has not been outstanding at this location in testing over the last two years. Yields in 2008 were unacceptably low, and the range of 1084 to 1265 lbs/acre for IdaGold and 763 to 993 lbs/acre for Pacific Gold in 2009 are marginal at best. There was no obvious trend in the data over the two years of study to support a particular seeding rate recommendation.

Flax. Flax performance has been poor at this location in testing over the last two years. Getting flax to harvest maturity is a major concern with this species, as seed pods in both years were quite wet at harvest; no data was gathered on moisture content, however. Yields in 2008 ranged from 1099 to 1565 lbs/acre, but only from 298 to 518 lbs/acre in 2009. There was no obvious trend in the data over the two years of study to support a particular seeding rate recommendation.

Impact/Potential Outcomes: These data indicate that biofuel crop production in western Washington is not without challenges. Of all crops, fall canola looks most promising in the Puyallup area, provided the crop is seeded in August or earlier. Yields from late-summer seedings are probably adequate to provide the grower with some level of economic return and allowing for harvest in mid-summer, when conditions are likely best for that activity. Canola is not an option for growing in most of northwestern Washington due to potential for negatively impacting the cabbage seed industry (concerns with disease, cross pollination, increase in weedy Brassica volunteers, etc.). Camelina, flax, and mustard have not thus far been productive enough at Mount Vernon to garner much excitement, and flax in particular has the added concern of taking too long to mature seed in a timely way in this maritime climate.

Publications: Data have been provided to growers and industry representatives interested in producing biofuel crops in western Washington, or who are interested in being involved in biofuel processing. Presentations have been made at field days in Puyallup and Mount Vernon during the two years of funding for this research, as well as presentations of some of the production data during grower meetings on some of the various crops produced in the region.

Future directions in the upcoming year: Further testing at Puyallup will focus on bamboo. Bamboo offers potential as a multi-use crop, providing biomass for energy, fresh shoots for food production, and carbon sequestration through root and rhizome production in a no-till environment. A research grove established at WSU Puyallup in 2001 is mature and available for evaluating biomass production potential. The grove consists of seven species from the *Phyllostachys* genus (well-adapted to western Washington growing conditions), each replicated four times. Each plot measures 25 ft x 25 ft. Species include *Phyllostachys rubromarginata* (Rubro), *P. aurea* (Golden), *P. Nigra*, *P. aureosulcata alata* (Yellow Groove). *P. bambsoides* (Madake), *P. nuda*, and *P. vivax*, and represent a range of growth habits within the *Phyllostachys* genus.

The grove has been managed under low-input conditions to date (0 to 4 inches of irrigation per year post-establishment, occasional light applications of nitrogen, and sufficient pruning to provide access for shoot harvest). Shoot harvest began in 2006 and shoot yield has ranged from < 500 to > 5000 lb fresh shoots/acre depending on the variety and year under these low-input production conditions.

We propose to combine biofuel cropping system funding with funding from the American Bamboo Society to increase levels of inputs and production, and institute a biomass strip harvesting system, removing all of the biomass from 1/3 of each plot per year. Biomass yield will be measured along with edible shoot yield and results compared across varieties. We are currently negotiating with potential collaborators to measure the biomass heating value through combustion and pyrolysis. We also propose to do a retrospective C sequestration analysis, comparing organic C in the bamboo grove with historical values from the field, and current values from adjacent fields in similar soils under different management, including long-term tall fescue, long-term tall fescue established with compost, Christmas trees, organic row crop production under low and high amendment input levels, and low-input buffers with tillage and seasonal cover cropping.

Further biofuel testing at Mount Vernon will involve fertility testing in an effort to perhaps increase seed yields to acceptable levels. Multiple harvests will also be conducted to gain a better idea of seed moisture contents at various times through the summer, since high moisture at harvest will require seed to be dried before storage or extraction of oil can be accomplished.