REGION 4
Western Washington

Title: Growing Biofuels in Western Washington

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Background: It is not known whether 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, their yield or other production factors likely will not allow them to be produced profitably by growers, so current research is aimed at canola, mustard, and camelina. Simple agronomic production guidance is scarce for these 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. Testing from 2008-2010 at WSU Puyallup has centered on use of organic fertilizers on certified organic land, species, and seeding dates, while testing at WSU Mount Vernon NWREC has centered on species, seeding dates, seeding rates, and fertilizer rates.

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

1. Conduct fertilization trials using biosolids with fall and spring canola, yellow mustard, and camelina on organic ground at WSU Puyallup.

2. Conduct seeding rate and fertilizer rate trials with yellow mustard and camelina at WSU Mount Vernon NWREC.

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. Fall canola trial, WSU Puyallup. Fall canola (cv. 'Athena') (*Brassica napus*) was seeded at approximately 8 lbs/acre into 10- by 20-ft plots September 16, 2009. One of three fertilization regimes was applied to canola plots the day prior to seeding: 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 were sprinkled on the surface of the soil as appropriate, then raked by hand to shallowly incorporate. Percent canola and weed cover was visually estimated January 21 and March 3, 2010. Due to poor canola establishment, this trial was discontinued in April, 2010.

1B. Spring oilseed trial, WSU Puyallup. Spring canola ('Sunrise' and 'Clearwater') and spring rapeseed ('Gem' and 'Sterling') (all *Brassica napus*), 'IdaGold' yellow mustard (*Sinapis alba*) and 'Celine' camelina (*Camelina sativa*) were seeded April 23, 2010 on organically-certified ground at WSU Puyallup. All oilseed crops were seeded at 8 lbs/acre and then raked by hand to shallowly incorporate seed. Plots (10- by 20-ft) were treated with two sources of biosolids at two rates: Soundgro biosolids at 1 or 2 dry tons/acre (corresponding to an estimated 117 or 236 lbs total N/acre, respectively), or Everett biosolids at 6 or 12 dry tons/acre (corresponding to an estimated 213 or 426 lbs total N/acre, respectively) applied and mechanically incorporated the day prior to seeding. Percent crop and weed cover was visually estimated June 16 and crop plants within a 12- by 20-inch quadrat were clipped at ground level August 30. 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 greenhouse 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.

A second trial (not fully replicated due to space limitations) was established adjacent to the first trial, using 'Sterling' and 'Gem' rapeseed, 'IdaGold' mustard, or 'Celine' camelina seeded into 8- by 20-ft plots, top-dressed with Everett or Soundgro biosolids at the same rates described previously. Following seeding, plots were raked by hand to shallowly incorporate seed and biosolid materials. Crop and weed cover and yield data were collected at the same time as in spring oilseed trial described above. 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; not all species were grown with all biosolids source or application rate; therefore, data were pooled either across species or across fertilizer regime prior to ANOVA and means separation.

2. Spring oilseed trial, WSU Mount Vernon NWREC. 'IdaGold' yellow mustard (*Sinapis alba*) and 'Celine' camelina (*Camelina sativa*) were seeded May 7, 2010 at WSU Mount Vernon NWREC. Crops were seeded at 5 or 8 lbs/acre using a 6-row cone seeder. Plots (10- by 30-ft) were treated with urea (46-0-0) and mechanically incorporated the day prior to seeding; rates were equivalent to 0, 50, or 100 lbs N/acre. Crop and weed biomass was sampled July 22. Crop plants and weeds within a 12- by 20-inch quadrat were clipped at ground level, separated, then dried at 50 C for 48 hrs and weighed. Crop plants within a 12- by 20-inch quadrat were clipped at ground level September 30. 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 greenhouse 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 four replicates.

Results and Discussion:

1A. Fall canola trial, WSU Puyallup. Crop cover in January did not vary by fertilizer treatments, but by March, crop cover was significantly greater under conditions of low N (the fall application of 50 lbs N/acre or no added N in the fall resulted in 28 to 32% cover) (Table 1). Reduced crop cover may be a direct result of fall-applied N, but it may have resulted from the increased weed cover in January and March from the fall N application (over 70% for 50, 100, or 200 lbs N applied in fall). Given the high level of weed cover coupled with poor canola cover, it was unlikely that this trial would provide useful yield data; consequently, the trial was discontinued

Table 1. Percent canola and weed cover under different fertilizer regimes (2009-2010).

Treatment[1]	Crop cover		Weed cover	
	Jan 21	Mar 3	Jan 21	Mar 3
lbs N/acre	%	%	%	%
Fall 100	32	23 b	60 a	73 a
Fall 200	30	22 b	63 a	77 a
Fall/Spring 50/50	33	28 a	57 a	65 b
Fall/Spring 100/100	28	23 b	60 a	72 ab
Spring 100	30	32 a	37 b	57 c
Spring 200	32	32 a	37 b	55 c

Means within a column followed by the same letter or not followed by a letter are not significantly different ($P < 0.05$). Plots were fertilized September 15 and seeded September 16, 2009.

[1]Only fall treatments had been applied at these evaluations.

1B. Spring oilseed trial, WSU Puyallup. Crop and weed cover did not differ by oilseed cultivar/species at six weeks after seeding, although yellow mustard plots tended to be denser in crop canopy and contain fewer weeds (Table 2). Crop cover ranged from 82 to 97%, while weed cover was from 3 to 18%, indicating that all species were capable of suppressing weed growth in the absence of herbicides. Crop and weed cover also did not vary between fertilizer regimes at six weeks after seeding, with crop cover ranging from 82 to 89% and weed cover from 11 to 18% (Table 3).

Table 2. Percent crop and weed cover and oilseed yield (2010).

Cultivar/species	Crop cover[1]	Weed cover[1]	Yield[2]
	%	%	lbs/acre
Clearwater canola	82	18	4281 a
Sunrise canola	88	12	3511 ab
Gem rapeseed	88	12	2892 abc
Sterling rapeseed	88	12	3100 ab
IdaGold mustard	97	3	1923 bc
Celine camelina	84	16	1279 c

Means within a column followed by the same letter or not followed by a letter are not significantly different ($P < 0.05$). Fertilizer was applied and incorporated April 22 and plots were seeded April 23, 2010.

[1]Plant cover estimated June 16, 2010.

[2]Oilseed yield samples collected August 30, 2010.

Yield was significantly greater for canola and rapeseed (from about 2900 to 4300 lbs/acre) than for mustard or camelina (about 1900 and 1300 lbs/a, respectively) (Table 2). Although oilseed yield did not significantly differ by fertilizer regime, there was a trend for Soundgro biosolids to result in higher yields

than Everett biosolids on a pound-for-pound basis. The higher application rates also tended to result in more seed production than did the lower rates (Table 3).

Table 3. Percent crop and weed cover and oilseed yield under different fertilizer regimes (2010).

Nutrient source	Rate[1]	Crop cover[2]	Weed cover[2]	Yield[3]
	dry tons/acre	%	%	lbs/acre
Everett	6	82	18	2851
Everett	12	85	15	3190
Soundgro	1	89	11	2657
Soundgro	2	87	13	3017

Means within a column followed by the same letter or not followed by a letter are not significantly different ($P < 0.05$). Fertilizer was applied and incorporated April 22 and plots were seeded April 23, 2010.

[1]Soundgro biosolids equivalent to an estimated 117 or 236 total lbs N/acre; Everett biosolids equivalent to an estimated 213 or 426 total lbs N/acre.

[2]Plant cover estimated June 16, 2010.

[3]Oilseed yield samples collected August 30, 2010.

In the second trial (top-dressed and shallowly incorporated biosolids), neither crop nor weed cover differed significantly by oilseed species (Table 4). Crop cover ranged from 65 to 88% while weed cover ranged from 12 to 35%. As in the first trial, yellow mustard tended to have greater crop canopy and suppress weed growth better than rapeseed or camelina. There was also a trend toward greater crop cover and lower weed cover with Everett biosolids than with Soundgro biosolids on a pound-for-pound basis (Table 5), although these differences weren't statistically significant. Crop cover also tended to be greater and weed cover lower at the higher application rate for a given biosolid source. Although not directly comparable between trials, crop cover was about 10% less dense in these top-dressed plots compared when the biosolids were mechanically incorporated. Similarly, weed cover was about 10% greater in top-dressed plots.

Table 4. Percent crop and weed cover and oilseed yield (2010).

Cultivar/species	Crop cover[1]	Weed cover[1]	Yield[2]
	%	%	lbs/acre
Gem rapeseed	77	23	5448
Sterling rapeseed	65	35	4075
IdaGold mustard	88	12	3263
Celine camelina	70	30	1450

Means within a column followed by the same letter or not followed by a letter are not significantly different ($P < 0.05$). Plots were fertilized April 22 and seeded and shallowly incorporated April 23, 2010.

[1]Plant cover estimated June 16, 2010.

[2]Oilseed yield samples collected August 30, 2010.

Oilseed yield did not significantly differ by species (Table 4) or by fertilizer regime (Table 5). Again, although yields are not comparable between these two trials, yield tended to be higher for top-dressed plots compared to when biosolids were mechanically incorporated. This trend should be more thoroughly investigated during 2011.

Table 5. Percent crop and weed cover and oilseed yield under different fertilizer regimes (2010).

Nutrient source	Rate	Crop cover	Weed cover	Yield
	dry tons/acre	%	%	lbs/acre
Everett	6	73	27	2325
Everett	12	83	17	3418
Soundgro	1	68	32	3707
Soundgro	2	75	25	4786

Means within a column followed by the same letter or not followed by a letter are not significantly different ($P < 0.05$). Plots were fertilized April 22 and seeded and shallowly incorporated April 23, 2010.

[1]Soundgro biosolids equivalent to an estimated 117 or 236 total lbs N/acre; Everett biosolids equivalent to an estimated 213 or 426 total lbs N/acre.

[2]Plant cover estimated June 16, 2010.

[3]Oilseed yield samples collected August 30, 2010.

2. Spring oilseed trial, WSU Mount Vernon NWREC. Crop biomass at two months after seeding was greatest (10,300 lbs/acre) with yellow mustard seeded at 8 lbs/acre and fertilized with 100 lbs N/acre (Table 6). Mustard also produced about 7200 to 8100 lbs/acre of biomass when seeded at 5 lbs/acre and fertilized at 50 or 100 lbs N/acre, or when seeded at 8 lbs/acre and fertilized with 50 lbs N/acre. A comparable level of biomass (about 6000 to 7000 lbs/acre) was produced with camelina seeded at 5 lbs/acre and 100 lbs N/acre or seeded at 8 lbs/acre and fertilized with 50 or 100 lbs N/acre. In general, the higher the seeding and fertilizer rate, the greater the biomass production for either crop, although yellow mustard tended to produce more biomass at comparable rates than did camelina.

Table 6. Crop and weed biomass and oilseed yield under different fertilizer and seeding rates (2010).

Species	Fertilizer rate	Seeding rate	Crop biomass[1]	Weed biomass[1]	Yield[2]
	lbs N/acre	Lbs/acre	Lbs/acre	lbs/acre	lbs/acre
Camelina	0	5	2758 e	1214	1991 cd
Camelina	0	8	2384 e	651	3102 bcd
Camelina	50	5	5070 cd	836	2864 cd
Camelina	50	8	6032 bc	730	1629 d
Camelina	100	5	6937 bc	725	2462 cd
Camelina	100	8	6248 bc	1053	3368 a-d
Mustard	0	5	3418 de	330	3723 a-d
Mustard	0	8	5271 cd	126	3770 abc
Mustard	50	5	7253 bc	454	5015 ab
Mustard	50	8	7655 b	481	3886 abc
Mustard	100	5	8072 b	490	5199 ab
Mustard	100	8	10341 a	247	5409 a

Means within a column followed by the same letter or not followed by a letter are not significantly different ($P < 0.05$). Fertilizer was applied and incorporated May 6 and plots were seeded May 7, 2010.

[1]Plant biomass estimated July 9, 2010.

[2]Oilseed yield samples collected September 30, 2010.

Weed biomass at two months after seeding did not differ between crop species, N rate, or crop seeding rate (Table 6). Although not statistically significant, there was a trend toward greater weed biomass

with camelina than with mustard. It also appeared that when no N was applied to either species, the 8 lbs/acre seeding rate resulted in much more weed suppression than did the 5 lbs/acre seeding rate.

Yield of yellow mustard did not differ by fertilizer or seeding rate (Table 6); camelina yield also did not differ by treatments. In general, mustard outyielded camelina, with ranges from about 3400 to 5400 lbs/acre for mustard compared to about 1600 to 3100 lbs/acre for camelina.

Impact/Potential Outcomes: Camelina and yellow mustard biofuel plots were featured on the WSU Mount Vernon NWREC field tour (July 8, 2010; 150 people attending). Biofuel crops at WSU Puyallup were discussed with a small group from Oregon, including several canola growers (June 16, 5 attendees), and a summer cover crops tour where folks viewed mustards as compared with other summer covers (Aug 23, 40 attendees).

Publications: Growing biofuel crops in western Washington. 2010. Miller, T.W., C.G. Cogger, A.I. Bary, C.R. Libbey, and E.A. Myhre. Proceedings, Bioenergy Research Symposium, Seattle, WA.

Proposed Future Research/Extension: The 2010-11 biofuel project began with fall-planted canola ('Athena') and camelina ('Celine') at WSU Puyallup in September, 2010. Plots were fertilized with Everett or Soundgro biosolids as in the 2010 spring oilseed trial. These plots will be evaluated and harvested during 2011. Spring trials at WSU Puyallup and WSU Mount Vernon NWREC will include additional fertility trials with biosolids or conventional N sources for spring oilseeds, as well as a herbicide screen for camelina. Based on the trend in 2010 results at WSU Puyallup, it will also be of interest to further evaluate oilseed yields resulting from surface-applied biosolids compared to mechanically incorporated. Data from all these trials will help determine the agronomic production factors for these crops in western Washington and may help lead to herbicide registrations for these spring oilseeds.