Camelina: Effects of Planting Date and Method on Stand Establishment and Seed Yield

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Abstract

Camelina has drawn keen interest in recent years because of research showing the seed oil could be used for human and animal consumption as well as commercial and military aircraft fuel. The objective of our research was to evaluate the effects of several planting dates and two planting methods on camelina stand establishment and seed yield in the Pacific Northwest of the United States. Field experiments were conducted for three years at four distinct rainfed agro-environments in Washington, Oregon, and Idaho. Camelina was planted on an average of five dates at each site from early October to mid-April by either drilling seed at a shallow depth or broadcasting seed on the soil surface. The best plant stands were achieved with the late-winter and early-spring plantings. Both drilling and broadcast were effective for planting camelina with no overall advantage of either method at any site. Seed yields ranged from less than 90 lb/acre to 2600 lb/acre. Based on the overall differences in annual precipitation and other circumstances that occurred across the four agro-environments during the three-year study, we were able to conclude that (i) late February–early March is the best planting date range for optimum stands and seed yield and (ii) broadcasting is the best planting method because it requires the least amount of time and expense.

Introduction

Camelina is a short-season annual oilseed crop in the Brassicaceae family that has been produced for oil in Europe for 3000 years (Zubr 1997). European production of camelina was largely replaced by canola, but limited production of camelina continues in northern Europe. Camelina likely appeared first in North America as a contaminant in flax seed (Putnam et al. 1993). Camelina is a relatively new crop in the United States and Canada (Photo 1). Most production during the last 10 years has been in Montana and North Dakota, a region with summer-dominant rainfall. Montana's leading position amounts to 9000–20000 planted acres of camelina (NASS 2013).

Photo 1. Farmers learn about camelina at the Lind Field Day held at the Washington State University Dryland Research Station.

The oil content of camelina seed ranges from 38 to 43%, while the seed protein concentration varies from 27 to 32%. Similar to flax, a high concentration (36–39%) of linolenic acid, an omega-3 fatty acid, in the oil makes camelina a potentially attractive food oil crop (Gugel and Falk 2006). However, because camelina oil contains erucic acid, an omega-9 fatty acid, in concentrations that often exceed the 2% maximum standard set by the FDA (Putnam et al. 1993), the use of camelina as a food crop has been limited (Gugel and Falk 2006). Alternatively, camelina meal is approved and used on a limited basis in rations for beef cattle and chickens. The oil can also be used as a feedstock for biodiesel (Fröhlich and Rice 2005) and has been tested as a feedstock for aviation fuel (Shonnard et al. 2010).

Dependence on imported oil and environmental concerns about excessive use of petroleum-derived fuel has led the United States and other countries to seek alternative and renewable energy sources such as biofuel. Jet fuel derived from camelina oil has undergone extensive testing by commercial airlines and the U.S. military in recent years. Test results show that camelina-based hydrotreated jet fuel meets all jet engine performance expectations and significantly reduces greenhouse gas emissions compared to petroleum-based jet fuel (Shonnard et al. 2010).

Glucosinolate concentrations in camelina seed can vary among varieties (Schuster and Friedt 1998). Both the seed and raw oil have high concentrations of tocopherol, an antioxidant that inhibits rancidity and allows long storage without degradation (Eidhin et al. 2003).

Camelina may provide benefits when grown in rotation with crops in the grass family, including small grain cereals and cool-season grass seeds. In the Willamette Valley of Oregon, camelina is preferred over other potential bioenergy crops because it does not have the potential to cross with *Brassica* species vegetable seed crops that are widely grown there (Hansen 1998). Additionally, under certain conditions, camelina can be an economically viable crop without the use of herbicides (Gesch and Cermak 2011). McVay and Khan (2011) showed no significant seed yield reduction with up to 50% stand reduction at both the rosette and bolting stages. This plasticity also was evident for camelina oil content, which only diminished when stands were reduced more than 75% at bolting.

Previous studies on planting dates for establishment of camelina have been conducted in several environments and have provided mixed results. Urbaniak et al. (2008) reported that camelina seed yield in the maritime provinces of eastern Canada was not influenced by the planting date. In Nebraska, however, the highest seed yields were obtained when camelina was sown in late March until mid-April (Pavlista et al. 2011). Lower seed yields were observed with earlier planting dates in February or early March, and with later planting dates in late April through June. Fall-planted camelina seed yields were best in Minnesota in early and mid-October (Gesch and Cermak 2011).

The influence of planting date on camelina seed yield in the varied precipitation and soils of the Pacific Northwest states of Oregon, Washington, and Idaho, a region of winter-dominant precipitation, has not been previously investigated. Moreover, no studies have been published in the literature on methods of planting camelina. The objective of our study was to investigate how planting date and method affected the stand establishment and seed yield of camelina across four diverse crop production environments.

Materials and Methods

Overview

A three-year field experiment was conducted during the 2008, 2009, and 2010 crop years at four sites in the Pacific Northwest to determine the most suitable planting date(s) and method of planting for rainfed camelina production. Field sites were located on university-owned research farms near Lind, Washington; Pendleton, Oregon; Moscow, Idaho; and Corvallis, Oregon, where long-term average annual precipitation is 9.5, 16.4, 27.4, and 42.7 inches, respectively. The sites represent each of the four major rainfed agricultural production zones in the Pacific Northwest.

The climate throughout the Pacific Northwest is Mediterranean, which means that two-thirds of the precipitation occurs from October through March and one-fourth is from April through June. July, August, and September are the driest months. The soils at all four test sites are more than 6 feet deep and well-drained, with soil textures ranging from coarse silt loam (Lind) to silty clay loam (Corvallis). Precipitation (Table 1) was measured in all locations at official U.S. National Weather Service recording sites within 1000 feet of the experiments.

The experimental design was a split plot in a randomized block arrangement with planting date as the main plot and planting method as subplots. All treatments were replicated four times. The size of individual plots varied depending on the equipment and land available at each location. Camelina was direct-seeded into standing stubble of recently harvested (no summer fallow) winter wheat at Lind and Pendleton (Photo 2). Tillage was used for seedbed prepa-

Table 1. Crop-year (Sept. 1–Aug. 31) precipitation in inches at four sites during the three-year study.

	Lind			Pendleton			Moscow	Corvallis		
Month	2008	2009	2010	2008	2009	2010	2009	2008	2009	2010
Sept.	0.17	0.00	0.15	0.26	0.12	0.00	0.74	1.74	0.85	1.19
Oct.	0.67	0.25	1.54	1.30	0.21	1.76	0.78	4.34	1.49	2.94
Nov.	1.11	0.78	0.83	2.10	1.53	1.80	4.84	4.34	4.71	8.14
Dec.	1.18	1.50	1.27	2.35	2.81	1.74	3.83	9.44	6.01	5.45
Jan.	1.62	0.87	1.43	1.79	2.05	1.68	3.82	8.72	3.70	6.76
Feb.	0.23	0.91	0.81	0.63	1.41	0.71	1.99	2.68	3.31	4.38
Mar.	0.81	1.76	0.73	2.22	2.54	1.39	4.41	4.50	3.81	6.08
Apr.	0.20	0.90	1.20	0.50	1.77	2.76	2.17	2.38	1.29	4.38
May	0.10	0.84	1.84	1.30	1.42	3.94	2.99	0.38	3.65	3.30
June	0.48	0.22	1.37	1.33	1.15	2.87	1.46	1.04	0.62	2.75
July	0.00	0.10	0.32	0.12	0.00	0.01	1.27	0.05	0.79	0.10
Aug.	0.28	0.33	0.09	0.58	1.38	0.20	1.62	1.23	0.25	0.53
Total	6.85	8.46	11.58	14.48	16.39	18.86	29.92	40.84	30.48	46.00

Photo 2. Camelina seed was direct-drilled (shown here) and broadcast into standing wheat stubble at Lind, WA.

ration after wheat harvest at Moscow and Corvallis. The camelina variety Calena was planted at all locations with a sowing rate of 5 lb/acre, or about two million seeds/acre. Nitrogen fertilizer was applied at all sites at moderate rates based on soil test results. Averaged over the three years, nitrogen application rates at Lind, Pendleton, Moscow, and Corvallis were 25, 40, 70, and 60 lb/acre, respectively. An in-crop post-emergence grass weed herbicide was successfully used every year to control downy brome, volunteer wheat, and other grass weeds at Lind and Pendleton. In-crop herbicides were not used in Moscow or Corvallis.

Planting dates

Planting dates at all sites were intended for mid-October, mid-November, mid-December, mid-January, mid-February, early March, and whatever time was considered the latest feasible for plant establishment. The last feasible date for planting ranged from March 15 at Lind to April 17 at Corvallis and was based on long-term experience growing numerous spring-planted crops at these locations.

We realized at the inception of the experiment that some of the planned late-fall and early-to-mid winter planting dates would not be possible due to frozen soil, snow cover (Lind, Pendleton, Moscow), or saturated soil (Corvallis). Planting was conducted on five dates per crop year when averaged over locations and years. At the Moscow site, only 2009 crop-year data were collected, as the experiment was abandoned due to a soil herbicide carryover problem in 2008 and heavy broadleaf weed infestation in 2010. Therefore, seed yield data for only 10 site years is presented here.

Planting methods

Seed was planted both with a drill at a shallow (less than 0.5 inch) depth and by broadcasting on the surface on all planting dates (Photo 2). Drills and method of broadcasting varied at each location. At Lind, a Kile hoe-opener air drill was used to plant camelina seed in 4-inch paired rows with each opener on 12-inch row spacing. This same drill was used for the broadcast treatment, but with the openers operated 5 inches above the soil surface to ensure uniform air distribution of seed. A light five-bar tine harrow was pulled behind the drill for the broadcast treatment to gently incorporate seed into the soil. At Pendleton, drilling was done with a Fabro drill with Atom-jet shank openers on 12-inch row spacing. A Brillon drop seeder with dual culti-pack rollers was used for broadcast planting with the seed dropped between the dual rollers. Drilling at Moscow was accomplished with a double-disc drill on 7-inch row spacing and the broadcast treatment was established by hand spreading seed with no soil incorporation. At Corvallis, a double-disc drill with 6-inch row spacing was used for both drilling and broadcasting. For broadcasting, the tubes from the seed box to the openers were disconnected and a plywood board was inserted at an angle beneath the seed cups to ensure uniform dribbling of seed onto the soil surface. The seed was then incorporated with a one-bar spike-tooth harrow.

Field measurements

Camelina stand establishment was determined for all plots in mid-April (Lind) and immediately after seed harvest in July (Pendleton). With direct drilling, stand establishment was measured by counting individual plants in 3-foot-long row segments. A 3-foot-diameter hoop (Lind) or wire frame 3-foot-square area (Pendleton) was used to measure stands in the broadcast treatments. These measurements were obtained from three areas in each plot and then averaged.

At Lind, weed species were identified, counted, and collected in early July just before seed harvest within a 3-foot-square sampling frame randomly placed in each plot. Each weed species was counted, hand clipped at ground level, and placed in a paper bag. Above-ground samples of each weed species were weighed on a digital scale after drying in a low-humidity greenhouse for 30 days.

Grain yield was measured by harvesting the seed from plants in a swath through each plot using a plot combine with the cutting platform operated near the soil surface. Plot combines were equipped with specialized screens to properly separate camelina seed from the crop residue.

Water use efficiency (WUE) was calculated as pounds of seed yield per inch of growing-season (Sept. 1–Aug. 31) precipitation. The preceding wheat crop was assumed to have extracted all available soil water by the time of harvest. As camelina was planted after wheat harvest (i.e., no fallow), growing-season precipitation was the only source of water for camelina.

Results and Discussion

Plant stand establishment

Both direct drilling (Photo 2) and broadcasting were successful for achieving plant stands and the majority of time there were no significant differences in stand establishment between the two methods at either Lind or Pendleton. When there were differences, they were evenly divided in favor of either method (Table 2). We suspect that even though seed was placed less than 0.5 inch into the soil,

Table 2. Camelina plant populations at Lind, WA, and Pendleton, OR, as affected by direct drilling (DD) or broadcast (BC) method of planting on numerous planting dates during three years.

Plant population (plants/ft^2)											
2007-08				2008-09				2009-10			
Lind											
Date	DD	BC	LSD (0.05)[†]	Date	DD	BC	LSD (0.05)	Date	DD	BC	LSD (0.05)
Oct 21	5	7	ns[§]	Oct 17	3	6	ns	Oct 21	7	11	ns
Nov 20	1	6	3	Nov 17	6	16	4	Nov 18	7	8	ns
Feb 15	7	1	4	Feb 17	10	26	10	Jan 15	13	11	ns
Mar 15	4	1	2	Mar 1	8	20	6	Feb 11	19	8	ns
LSD (0.05)[‡]	2	1		Mar 15	15	17	ns	Mar 2	17	3	10
				LSD (0.05)	6	8		Mar 17	13	0	7
								LSD (0.05)	7	9	
Pendleton											
Date	DD	BC	LSD (0.05)	Date	DD	BC	LSD (0.05)	Date	DD	BC	LSD (0.05)
Oct 23	2	1	ns	Nov 17	1	3	ns	Nov 2	1	1	ns
Dec 21	0	1	ns	Jan 12	4	6	1	Jan 22	3	4	ns
Feb 12	3	4	ns	Feb 19	3	5	ns	Feb 10	3	3	ns
Mar 5	9	4	2	Mar 17	5	8	1	Mar 2	4	4	ns
Mar 22	4	2	1	Mar 27	6	7	ns	Mar 11	2	4	ns
Apr 1	5	3	ns	Apr 6	9	7	ns	Mar 24	4	5	ns
LSD (0.05)	3	2		LSD (0.05)	3	3		LSD (0.05)	ns	ns	

[†]Within-row values show LSD (0.05) for DD versus BC method of planting for each planting date.
[‡]Within-column values show LSD (0.05) for both planting methods over all planting dates.
[§]No significant differences.

fragile soil crusts that occur after rain showers may have sometimes hindered emergence in the direct-drilled treatment. Similarly, lack of rainfall following broadcasting of seed sometimes had a severe negative effect on broadcast plant stands, as can be seen in the Feb. 15 and March 15, 2008, and March 17, 2010, planting dates at Lind (Table 2) where rainfall did not occur for more than two weeks after planting. Soil surface drying and lack of timely rain was less of a problem at Pendleton (Table 2) due to more precipitation at that location compared to Lind (Table 1).

Significant differences in stand establishment as affected by planting date occurred every year except for 2010 at Pendleton. The fall and mid-winter plantings generally had lower plant populations than plots planted at the other dates (Table 2). Over-winter plant mortality was observed with dead camelina seedlings found intermixed with healthy seedlings in both planting methods. However, camelina seedlings in the two-leaf stage of development appeared to have excellent tolerance to extreme cold, as they withstood -9°F air temperature for eight hours with no snow cover and sustained winds of 20 mph at Lind in December 2008 with an approximated 70% survival rate. Such cold tolerance is similar to that of winter wheat, the dominant crop in the region.

Overall, stand establishment at Lind was greater than at Pendleton even though the seeding rate was the same at both locations and Lind has the harsher growing environment (Table 2, Fig. 1). We attribute these differences to the time at which stand data were collected. At Lind, stand counts were measured in mid-April compared to after seed harvest in July at Pendleton (i.e., because some plants died during the spring and early summer).

Statistical analysis showed that plant stands at both Lind and Pendleton were significantly affected by the year, date of planting, and method of planting; significant interactions of these factors also occurred. The interactions reflect the aforementioned wide variability of data within and across years. The trend was for better stands with the later planting dates at both locations (Fig. 1).

Weeds

Tumble mustard and tansy mustard, both winter annual broadleaf weed species, were a factor in the Lind experiment. Application of herbicides to control these weeds prior to the late-winter planting dates was not possible, as the fall and early-winter planting treatments were intermixed throughout the experiment area. Both of these mustard species are easily controlled when glyphosate or other nonselective herbicide is applied prior to planting camelina in mid-to-late winter or early spring. Lack of opportunity to control fall-germinating broadleaf weeds is a disadvantage of planting camelina in the fall or early winter.

Russian thistle (Young 1986) was, by far, the major spring annual broadleaf weed of importance at Lind. Russian thistle becomes established in April or later after severe frosts

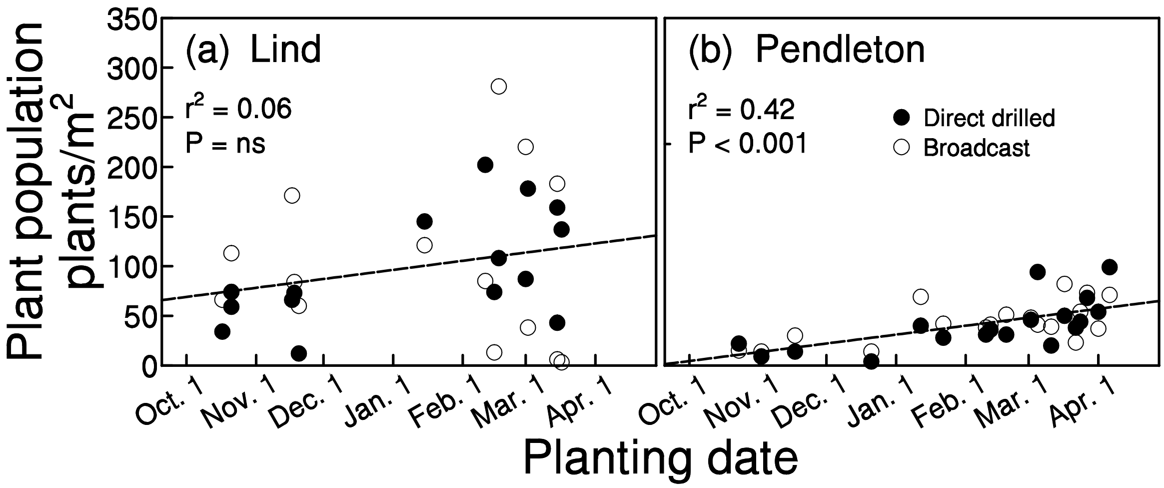

Figure 1. Overall effects of planting date and method on plant population at Lind and Pendleton.

end. The late-winter camelina planting averaged 24 Russian thistle plants per square yard compared to six plants per square yard for the fall plantings. The dry biomass of Russian thistle measured at camelina seed harvest in July averaged 13 and 238 lb/acre for the fall and late-winter camelina planting dates, respectively, showing a clear advantage of fall planting for weed control.

The application of grass weed herbicide to established camelina plants was effective in controlling downy brome, the major winter annual grass weed at Lind and Pendleton. This finding supports the incorporation of a broadleaf crop such as camelina in cereal-based cropping systems for winter annual grass weed suppression (Young et al. 1996). In late winter and spring plantings, downy brome was controlled with a pre-plant application of glyphosate.

Seed yield

1. Planting method

From a total of 55 plantings at four locations over three years, the planting method significantly affected the camelina seed yield of 13 plantings (24% of the plantings, Table 3). Of these 13, broadcasting produced higher seed yield than drilling for 10 plantings. The advantage of broadcast planting was most apparent at Pendleton where this method significantly increased seed yield over drilling for 44% of the plantings. There were no yield differences between the two methods at Pendleton for the rest of the plantings. Greater seed yield with broadcasting over drilling at Pendleton occurred mostly with the fall and mid-winter plantings and never with the spring plantings (Table 3). We do not have an explanation for this other than to speculate that winter annual weed pressure (not measured at Pendleton) was greater in the direct-drill treatment due to 12-inch-wide row spacing, whereas the broadcast seed provide better competition against weeds because it was more uniformly distributed. On the four planting dates (three at Lind and one at Moscow) where seed yield was significantly lower with broadcasting versus drilling, we suspect the reason was a dry surface soil combined with lack of precipitation for several weeks after planting. Seed yield differences between planting methods at Lind were always associated with differences in plant stand, but this was not always the case at Pendleton (Tables 2 and 3). The planting method had no effect on seed yield at Corvallis except for one planting.

Averaged over the three years, the planting method had a highly significant effect on seed yield at Lind and Pendleton. Neither planting method at Lind had an overall advantage over the other. At Pendleton, the broadcast method was associated with higher seed yield from the fall and winter plantings but not the spring plantings (Table 3). The method of planting had no significant effect on the seed yield at Moscow or Corvallis.

2. Planting date

Camelina seed yield trends as affected by planting date differed by location. Excluding the 2008 data from Lind (when near complete crop failure occurred due to extreme drought), there was a clear tendency for higher seed yields with late-winter and early-spring plantings compared to fall and mid-winter plantings at both Lind and Pendleton (Table 3, Photo 3). The opposite was true at Moscow, although we have only one year of data from that site. At Corvallis, the late-fall and mid-winter planting dates produced the greatest seed yield during all years (Table 3). Corvallis has the greatest annual precipitation (Table 1), but a significant portion of it can be lost through drainage. The silty clay loam soil at Corvallis is well-drained and dries quickly once winter rains diminish. Small, shallowly-rooted plants from spring plantings can easily become drought-stressed.

Downy mildew (Putnam et al. 2009) was evident in 2009 and 2010 at Corvallis and may have contributed to seed yield decline in those years. Extremely heavy rainfall and associated humidity at Corvallis in May 2009 (Table 1) likely contributed to the incidence of downy mildew. In plants where downy mildew was most severe, abortion of lower pods (manifested as red pods) in the inflorescence was observed. Unusually wet conditions between March and the end of June (164% of normal) in 2010 may have contributed to low seed yields in 2010 when downy mildew was again evident.

Table 3. Camelina seed yields using direct drill (DD) and broadcast (BC) methods on numerous planting dates at four locations over three years.

Plant population (plants/ft²)											
2007-08				2008-09				2009-10			
Lind											
Date	DD	BC	LSD (0.05)[†]	Date	DD	BC	LSD (0.05)	Date	DD	BC	LSD (0.05)
Oct 21	102	134	ns[§]	Oct 17	431	335	ns	Oct 21	835	743	ns
Nov 20	25	89	62	Nov 17	461	563	37	Nov 18	706	715	ns
Feb 15	118	37	38	Feb 17	498	504	ns	Jan 15	810	614	ns
Mar 15	52	4	ns	Mar 1	508	533	ns	Feb 11	840	709	ns
LSD (0.05)[§]	ns	47		Mar 15	521	520	ns	Mar 2	1193	853	ns
				LSD (0.05)	91	ns		Mar 17	889	463	360
								LSD (0.05)	382	ns	
Pendleton											
Date	DD	BC	LSD (0.05)	Date	DD	BC	LSD (0.05)	Date	DD	BC	LSD (0.05)
Oct 23	748	976	188	Nov 17	398	812	252	Nov 2	128	389	120
Dec 21	313	589	ns	Jan 12	829	1429	172	Jan 22	497	1025	463
Feb 12	1204	1182	ns	Feb 19	635	936	ns	Feb 10	800	1392	272
Mar 5	1531	1427	ns	Mar 17	1426	1582	102	Mar 2	1407	1434	ns
Mar 22	1329	1159	ns	Mar 27	1254	1518	ns	Mar 11	969	1164	ns
Apr 1	1298	1275	ns	Apr 6	1227	1294	ns	Mar 24	1385	1414	ns
LSD (0.05)	544	465		LSD (0.05)	517	419		LSD (0.05)	663	831	
Moscow[€]											
Date	DD	BC	LSD (0.05)	Date	DD	BC	LSD (0.05)	Date	DD	BC	LSD (0.05)
				Oct 31	2588	2277	ns				
				Dec 6	2264	2181	ns				
				Feb 17	2511	2076	296				
				Mar 27	1513	1464	ns				
				Apr 15	1529	1518	ns				
				LSD (0.05)	964	756					
Corvallis											
Date	DD	BC	LSD (0.05)	Date	DD	BC	LSD (0.05)	Date	DD	BC	LSD (0.05)
Nov 9	1494	2037	ns	Sep 30	405	388	ns	Nov 3	1397	1619	ns
Dec 13	888	497	ns	Oct 29	1465	1180	ns	Nov 23	1347	1278	ns
Jan 23	1868	1751	ns	Dec 1	1490	1649	ns	Feb 19	1687	1734	ns
Feb 18	1353	1568	ns	Jan 24	1418	1673	147	Mar 19	1273	1239	ns
Apr 13	612	656	ns	Feb 5	1676	1596	ns	LSD (0.05)	407	209	
Apr 17	265	234	ns	Feb 20	1270	1335	ns				
LSD (0.05)	436	1037		Apr 6	540	495	ns				
				LSD (0.05)	636	622					

[†]Within-row values show LSD (0.05) for DD versus BC method of planting for each planting date.
[‡]Within-column values show LSD (0.05) for both planting methods over all planting dates.
[§]No significant differences.
[€]Data were obtained during only one year at Moscow.

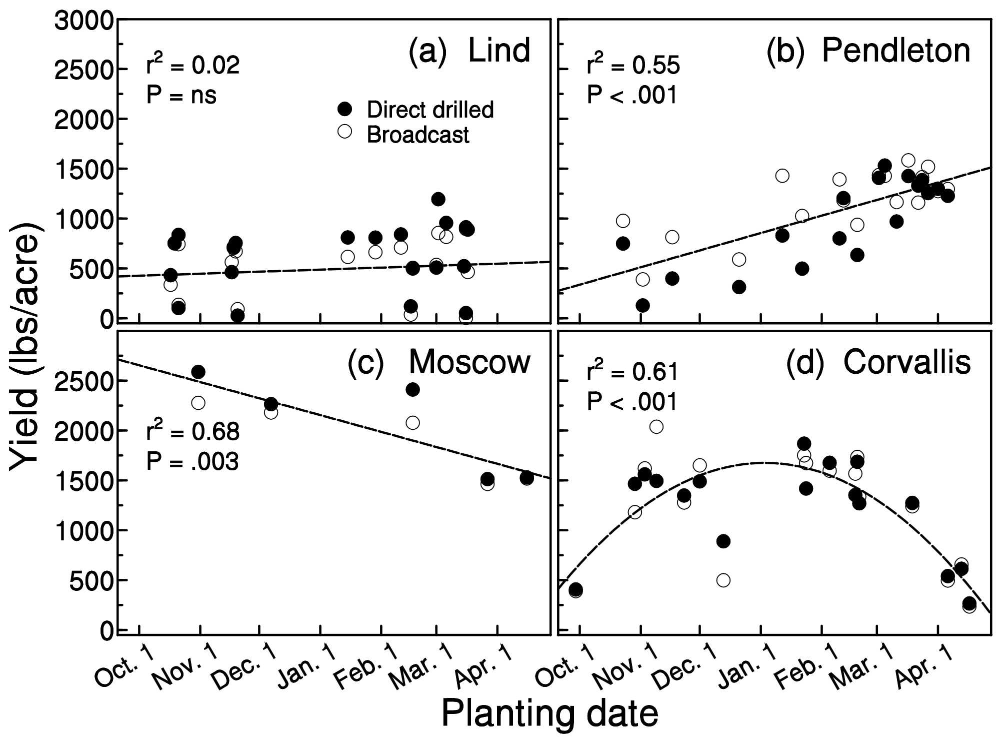

Figure 2. Overall effects of planting date and method on camelina seed yield at four locations in the Pacific Northwest over three years.

Graphs were created to show the relationships among camelina planting dates, planting methods, and seed yield averaged over three years at four sites. The planting date had no effect on yield at Lind (Fig. 2a). This is consistent with what Urbaniak et al. (2008) found in eastern Canada. At Pendleton (Fig. 2b), seed yield improved significantly and proportionately moving from fall to spring planting dates (Photo 3). On the other hand, at Moscow (Photo 4), the highest seed yields were achieved with fall plantings and yields decreased significantly when planting was delayed until the spring. Yet another unique yield response was measured at Corvallis, where the lowest yields occurred with early fall and spring planting dates and there was a broad planting window from early November through the winter when yields were relatively uniform (Fig. 3). The seed yield response pattern at Corvallis was similar to the one reported by Pavlista et al. (2011) in Nebraska where early and late planting dates produced the poorest seed yields. The highest seed yields at Corvallis were from late-fall and mid-winter plantings, whereas in Nebraska the highest seed yields were attained in late winter and early spring.

There were no camelina seed yield differences associated with planting dates when averaged over three years at Lind, but there were significant differences at Pendleton, Moscow, and Corvallis. The lack of differences at Lind were due to high year-to-year variability of precipitation (Table 1) and the fact that neither planting method showed a consistent advantage over the other. At Pendleton, most, but not all, fall and early-winter planting dates reduced seed yield compared to the spring plantings (Table 3). Seed yield relations were consistent at Moscow and Corvallis.

Water use efficiency

Water use efficiency was extremely low at Lind in 2008 because of near complete crop failure due to extreme

Photo 3. Camelina sown in the fall and in late winter at Pendleton, OR.

drought. Excluding the 2008 Lind data, WUE at Lind, Pendleton, and Moscow was relatively uniform, averaging 65 lb seed per acre per inch of precipitation (Fig. 3). The uniformity in WUE across these three diverse locations, where average annual precipitation ranges from 9.52 to 27.4 inches, indicates that camelina seed yield potential can likely be accurately predicted based on crop-year precipitation. This is an important factor for farmers to consider when deciding whether to grow camelina.

Water use efficiency at Corvallis averaged only 35 lb seed per acre per inch of precipitation and was consistently low for all three years of the experiment (Fig. 3). Saturated soils, downy mildew, and water drainage through saturated soils, as previously mentioned, were likely factors contributing to the low WUE. Corvallis receives an average of 42.7 inches

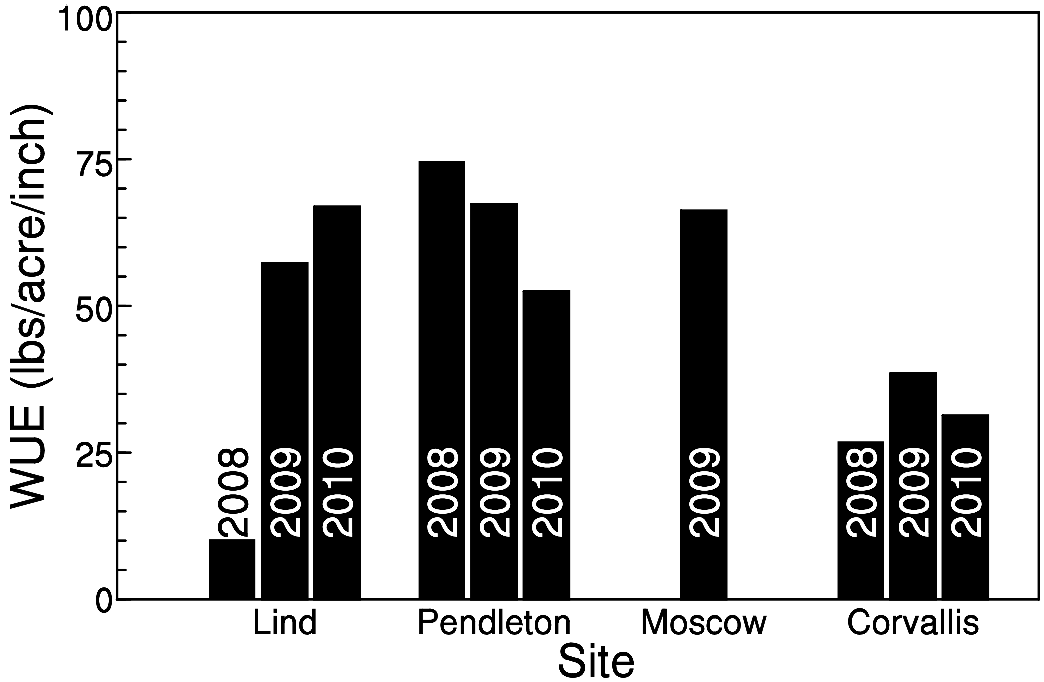

Figure 3. Water use efficiency (WUE) of camelina grown at four sites over three years. Data for each site are the average from all planting dates and both planting methods during each year.

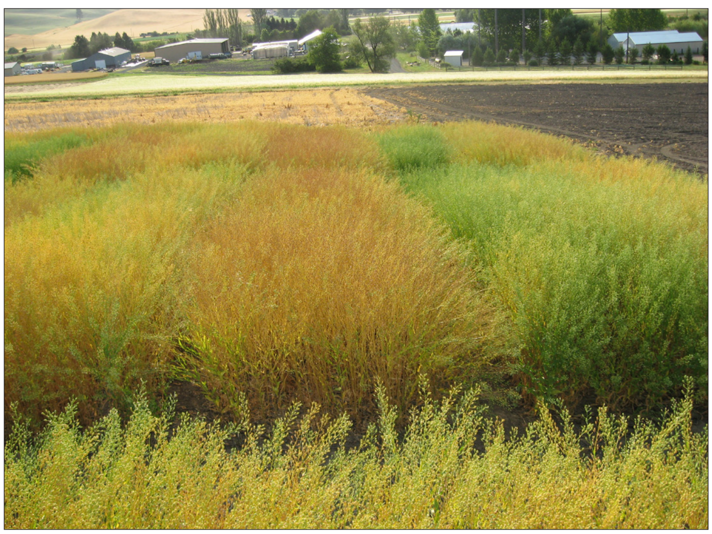

Photo 4. Camelina from several planting dates at Moscow, ID.

of annual precipitation and is a suitable environment for profitable production of many crops, but our data suggest that camelina is better suited to the drier Inland Pacific Northwest (i.e., Lind, Pendleton, Moscow).

Summary and Recommendations

Our data from 55 planting dates using two planting methods over 10 site years in the Pacific Northwest allowed us to draw several important conclusions:

1. Camelina can be successfully sown over a wide range of planting dates from early fall to early spring. Fall-planted camelina has excellent cold tolerance, similar to that of winter wheat. However, due primarily to lack of in-crop herbicides to control winter annual broadleaf weeds, we recommend that farmers apply glyphosate or other non-soil residual burn-down herbicide in mid-to-late February to control weeds, followed by late February–early March camelina planting.
2. Both drilling and broadcasting are effective methods for planting camelina. From an economic standpoint, we recommend farmers use broadcast planting combined with some form of light incorporation of seed into the soil. Broadcast air-driven applicators 60 feet or wider are common in the rental inventory of local chemical dealers. These applicators easily allow planting of 320 acres/day. Conversely, grain drills are not as wide, more expensive to rent or own, generally need to be operated at a slower speed, and thus require more time to plant equivalent land area.

Finally, although not part of this experiment, farmers need to be mindful that camelina produces relatively little residue. With heavy tillage, soil erosion may be a problem during or after camelina production. To reduce the potential for soil erosion, we recommend (i) camelina be planted directly into standing and undisturbed stubble of the previous crop (i.e., no tillage), and (ii) minimal or no tillage be conducted after camelina seed harvest and before planting the subsequent crop. This is especially important if a year-long fallow period is scheduled in the rotation after camelina seed harvest.

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