Phenology of Oilseed Crops for Bio-Diesel in the High Plains

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Oilseed crops are relatively new crops to the High Plains, mostly for use as vegetable and industrial oils, spices and bird feed. With increased fuel concerns, there is an expanded demand for bio-diesel substitutes. Crop areas of oil seed crops of the Brassicaceae, e.g., brown mustard (*Brassica juncea*), canola (*Brassica napus*) and camelina (*Camelina sativa*) can increase in the High Plains to help fulfill this demand. Studies on these crops as bio-diesels has shown potential. Although there are production guidelines available for brown mustard (Baltensperger et al. 2004) and canola (Rife and Salgado 1996; Boyles et al. 2006), datasets on their growth and development are minimal (Johnston et al. 2002). Climatic impact data on their life cycle also are minimal (Angadi et al. 2000). An understanding of the adaptability of crops to climate depends on characterizing their phenology and developing growth models. The long-term impact of this project is to identify life cycle models for brown mustard, canola, and camelina, and correlate these data to climate. The objective of these studies was to collect whole-plant phenology data on three oilseed crops with potential for bio-diesel production in the High Plains. Specifically, objectives were to determine appropriate dates for spring planting, and to measure phenology events that could be used as data for developing a growth model and formulate recommendations. These studies are Nebraska's portion of a five-state cooperative effort with Colorado, Kansas, South Dakota, and Wyoming.

METHODOLOGY

Brown mustard (*Brassica juncea* cv. Arid), canola (*B. napus* cv. Hyola401) and camelina (*Camelina sativa* cv. Boa) were received from Blue Sun Biodiesel and planted at the Panhandle Research & Extension Ctr., Scottsbluff, Nebraska. A planting data study was conducted comparing seeding dates of 24 Feb., 24 Mar., 7 Apr., 21 Apr., and 5 May, 2005. A separate phenology trial was planted on 5 May for which six plants were sacrificed at each reading date for measuring growth. Plots were four rows, 0.3 m wide and 3.2 m long. Precipitation plus irrigation for the five growing periods were 46, 45, 42, 38, and 36 cm, respectively. Conventional practices were used. Two trials were conducted, planting date and phenology. Developmental data were taken in the planting date study marking specific events and growth data were taken at 1, 2, 4, 6, 8, 9, and 12 weeks after planting (WAP) in the phenology study conducted only on plants seeded on 5 May. The seeding rate was 194 plants/m^2 resulting in 756 plants/plot. Bloom date was recorded when plants were in full flowering. Maturity date was recorded when the seeds were mature enough to harvest; seed were mature when they were hard, and their color was no longer green (dark yellow or tan for brown mustard, maroon or brown for canola, and dark orange or rust for camelina). Flea beetle damage was assessed on 20 May and did not change thereafter. Bird damage was assessed on 15 Jul., two weeks before harvest and progressed until harvest. Plots in the planting date study were harvested at maturity between 27 Jul. to 5 Aug.; phenology plots were harvested on the last date.

RESULTS AND DISCUSSION

In the planting date study, seeds of all three crops planted at the earliest date did not emerge until after 3 WAP; full emergence occurred by 3 WAP when planted on 24 Mar., and as planting was later emergence occurred sooner. With the February planting, there was a lower stand for brown mustard (43%), camelina (53%), and canola (85%) then other planting dates. This would agree with the negative effects of lower temperatures on germination and seedling growth reported on canola (Nykiforuk and Johnson-Flanagan 1994). Canopy heights were taken on 7 Jun. and 27 Jul. For the first three planting dates, most of the final height was attained by 6 Jun. for the last two planting dates, most canopy growth occurred between 6 Jun. and 27 Jul.

(Table 1). For brown mustard, blooming dates for planting at 24 Mar. and later were all significantly later from each other while for canola and camelina only the plants from the first planting bloomed significantly earlier than the other planting dates which were not significantly different from each other. Although not significant, in Saskatchewan (Kirkland and Johnson 2000) as well as here, canola tended to bloom earlier when seeded in April than in May. Maturity date for brown mustard was not affected by planting date. Canola had not yet matured by 15 Jul., regardless of planting date. Camelina plants seeded on 24 Feb. matured significantly earlier than those seeded on 24 Mar. and those seeded on 5 May matured significantly later than the 21 Apr. seeded plants. Flea beetle (*Phyllotreta* spp.) damaged was assessed on a scale of 9 (none), 1 (slight), 2 (some), 3 (significant), and 4 (severe). Flea beetle feeding was most severe with brown mustard and significant with canola, but camelina was unaffected. The sensitivity of spring-seeded canola has been noted in Canada (Dosdall and Stevenson 2005). Bird damage assessed two weeks before harvest was observed in brown mustard and was significantly worst with the 24 Feb seeded plants. Bird damage noticeably increased in all plots during the interval from assessment to harvest. Planting date did not affect damage to brown mustard but for canola sensitivity was greatest with 7 Apr. and 21 Apr. planting. In all three crops, the highest yield was significantly reached with the 24 Mar. planting (Table 1). Brown mustard showed considerable variation but canola and camelina indicate that planting in late March to early April may be best with regard to yield. This observation agrees with that on canola in Montana (Chen et al. 2005) and on canola and brown mustard in Saskatchewan (Kirkland and Johnson 2000; Angadi et al. 2004).

In the phenology study, emergence occurred by 1 WAP and peaked by 2 WAP for all three crops (Table 2). Canopy height was measured from 4 to 12 WAP and reached its peak for the three crops at 8 WAP. Canopy was measured up to 9 WAP after which time the rows had mostly closed. Leaf node number on the main stem below reproductive branches peaked at 6 WAP and defoliation began to be observed by 9 WAP. Stem length between 4 and 12 WAP increased linearly. The rates of elongation were 18 cm/week for brown mustard, 22 cm/week for canola and 12 cm/week for camelina. Roots as seen by their fresh and dry weights grew little during the first six seeks of growth. By 9 WAP, the root mass was great enough that accurate weight measures were not taken. Vine growth excluding pods significantly increased after 4 WAP with most growth occurring between 6 and 9 WAP at which time fresh weight reaches its maximum and dry weight for brown mustard and camelina likewise. The rates of fresh weight accumulation in the vine excluding pods between 4 and 9 WAP were 1.9 g/week for brown mustard, 4.5 g/week for canola, and 0.8 g/week for camelina. Dry weights show the same kind of accumulation. The slow growth of the root system supports the observations that irrigation and fertilization of these crops are critical during the first six weeks for plant growth and suggest why these crops may not be suitable for dryland production (D.D. Baltensperger, D.J. Lyon, and A.D. Pavlista, pers. comm.). Furthermore the dramatic job in vine weight from 6 to 9 WAP can be explained by the induced rapid root growth from 6 WAP. Defoliation or leaf senescence was evident at 12 WAP resulting in loss of fresh weight of vegetative vine. Pods were present at 9 WAP reaching their peak fresh weight at 9 WAP but continuing to accumulate dry weight to 12 WAP in brown mustard and canola but not in camelina. Yields from the phenology study correspond to those from the planting study. The highest yields were obtained from brown mustard and camelina (Table 2). Dividing yield per plant by the dry weight of the vine, including pods, gave an estimate of the harvest index. These indices calculated to be 0.066 for brown mustard, 0.021 for canola, and 0.130 for camelina. Comparisons of the yield data and indices calculations suggest that camelina would require less irrigation and fertilization, and be best suited for the High Plains than brown mustard and canola. Camelina has been reported to produce bio-diesel fuels that would be competitive with traditional petroleum products (Bernardo et al. 2003).

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Table 1. Canopy growth and development of brown mustard, canola, and camelina as influenced by planting date in Scottsbluff, Nebraska, 2005.

Seeding date	Canopy height (cm) 6 Jun	27 Jul	Bloom date	Maturity date	Bird damage[z]	Flea beetle damage[z,y]	Yield (kg/ha)
Brown mustard							
24 Feb	79 a[x]	99 b	6 Jun	15 Jul	55% a	4	520 b
24 Mar	82 a	111 a	6 Jun	15 Jul	15% bc	4	1050 a
7 Apr	60 a	115 a	9 Jun	15 Jul	25% b	4	780 ab
21 Apr	22 b	100 b	14 Jun	15 Jul	8% bc	3 ¾	840 ab
5 May	27 b	93 b	17 Jun	15 Jul	0% c	3 ½	760 ab
Canola							
24 Feb	71 a	89 abc	30 May	--	<1%	1 ¾ c	910 b
24 Mar	74 a	96 a	7 Jun	--	<1%	2 ¼ bc	1290 a
7 Apr	62 a	94 ab	10 Jun	--	0%	3 a	1010 b
21 Apr	21 b	86 bc	16 Jun	--	0%	2 ½ ab	380 c
5 May	25 b	84 c	19 Jun	--	0%	2 ¼ bc	500 c
Camelina							
24 Feb	58 a	72	30 May	9 Jul	0%	<1	530 c
24 Mar	64 a	64	4 Jun	12 Jul	0%	0	1150 a
7 Apr	53 a	64	8 Jun	11 Jul	0%	0	940 ab
21 Apr	23 b	67	14 Jun	12 Jul	0%	0	580 bc
5 May	28 b	67	19 Jun	16 Jul	0%	0	690 bc

[Z]Damage was assessed two weeks before harvest. At the time of harvest, yield loss due to bird damage was considerable in all crops and dates.
[Y]Flea beetle damage was on a 0 (none) – 4 (severe) scale.
[X]Data for each crop followed by the same capital letter are not significantly different at the 95% level.

Table 2. Growth pattern of brown mustard, canola and camelina planted on 5 May, 2005 at Scottsbluff, Nebraska.

	WAP	Brown mustard	Canola	Camelina
Emergence	1	50%	20%	88%
	2	98%	100%	98%
Canopy height	4	13 cm	16 cm	11 cm
	8	91 cm	77 cm	66 cm
Canopy width	9	42 cm	48 cm	37 cm
Leaf no.	6	9	7	14
Stem length[z]	4	22 cm	10 cm	19 cm
[z]	12	169 cm	185 cm	115 cm
Root FW[z]	6	0.76 g	0.88 g	0.26 g
Vine FW[z]	4	2.35 g	4.57 g	1.40 g
[z]	6	5.37 g	7.21 g	2.61 g
Vine FW[z,y]	9	11.7 g	27.0 g	5.32 g
Pod FW[z]	9	9.18 g	15.6 g	6.43 g
Root DW[z]	6	0.17 g	0.17 g	0.06 g
Vine DW[z]	4	0.35 g	0.83 g	0.18 g
[z]	6	0.81 g	1.04 g	0.48 g
[z,y]	9	3.00 g	5.10 g	1.66 g
Pod DW[z]	9	2.17 g	3.00 g	2.17 g
Yield		700 kg/ha	460 kg/ha	750 kg/ha
Yield/vine DW [x]	12	0.066	0.021	0.13

[z]Data are given on per plant basis.
[y]Pod weight were excluded.
[x]Pod weight are included.