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CANOLA GROWTH, DEVELOPMENT, AND FERTILITY

Washington Oilseed Cropping Systems Series

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Canola Growth, Development, and Fertility

Canola growth and development

Canola stand establishment and seedling survival in the inland Pacific Northwest tends to be more variable than cereals. This is largely attributable to its "epigeal emergence" whereby the cotyledons and the shoot growing point emerge above the soil surface, increasing the plant's exposure to environmental stress. In contrast, cereals exhibit "hypogeal emergence," resulting in the shoot growing point remaining below ground and therefore more protected from extreme aerial climatic conditions. Seeding during favorable temperature and moisture conditions is therefore more critical for canola than for wheat stand establishment.

Canola also has an indeterminate growth habit. This means that individual plants are capable of expanding to utilize available space, water, and nutrient resources by increasing the length and number of lateral branches and pods per branch, and therefore seed yield. This largely explains why uneven stands of canola are still capable of producing high yields. In fact, canola is reported to be capable of producing near maximum yields with stand reductions of 50% or more (OMAFRA 2011).

Canola will continue to flower and develop seed until stress terminates these processes. Canola is more sensitive to heat stress at flowering than wheat since flowering and seed initiation occur over a long period of time, and a long duration of flowering is directly related to high seed yields. Collectively, the greater sensitivity of canola to environmental stresses at seedling establishment and at flowering accounts for higher yield variability with canola than with wheat.

Canola root systems exhibit typical taproot architecture shaped like an inverted cone where soil volume in contact with roots decreases with depth. Canola has an extensive root system (Weiss 1983) and root hairs (Hammac et al. 2011), which give it high root surface area and potential to remove nutrients from soil. The rooting depth for winter and spring canola has been reported as 65 and 46 inches, respectively (Johnston et al. 2002). However, Johnston et al. (2002) reported a deeper penetrating root system is often a response to limited water. In addition to nutrient uptake, canola's root system provides stability against lodging (Goodman et al. 2001).

The proportion (%) of total aboveground plant dry matter that is seed (harvest index, HI) ranges from 20 to 35% for canola compared to a relatively stable average of 40% for wheat (Hocking and Stapper 2001, Hocking et al. 1997). Reported HI values vary widely in part because the date of planting and the timing of stress markedly affect seed yield, and many leaves senesce before maturity (Hocking et al. 1997, Major 1977). In Montana, Jackson (2000) also found spring canola returned about twice as much post-harvest residue to the soil as comparable yields of spring wheat.

Canola fertility

Canola follows dry matter and nitrogen (N) uptake patterns similar to wheat (Figure 1). Maximum dry matter and N accumulation occur between the beginning of stem elongation/branching and the end of flowering. Stress during this time will limit dry matter accumulation, N uptake, and seed yield by limiting lateral branching and flowering. Dry matter and N peak during seed fill and then decline as seed matures due primarily to leaf senescence and pod shattering.

Table 1 summarizes nutrient uptake, partitioning, and removal estimates for canola and wheat. On an equivalent yield basis, canola accumulates more nitrogen (N), phosphorus (P), potassium (K) and sulfur (S) than wheat. Due in part to a low HI and high nutrient concentration in the residue, canola also leaves more nutrients in the field after harvest than comparable yields of wheat. For example, Jackson (2000) reported 40% of N, 30% of P, and 85% of K accumulated by spring canola remained in the residue left after harvest. Cycling of nutrients in this residue to subsequent crops is likely one important rotational benefit of canola (Kirkegaard et al. 1994, 1997).

The following sections discuss major nutrient responses, recommendations, and management for canola.

Nitrogen (N)

Canola seed yield responds well to applied N when residual soil levels are low (Grant and Bailey 1993, Hocking and Stapper 2001, Jackson 2000). In Montana, Jackson (2000) measured canola seed yield responses of 2,000 to 3,000 lb/acre when up to 225 lb N/acre was applied to soils with available N below 50 lb/acre. Similar yield responses were obtained when 90 lb N/acre was applied at a site with similar residual N levels in Australia (Hocking and Stapper 2001). A few references state that canola N requirements are similar to those of wheat, though most acknowledge that canola requires more N than an equivalent yield unit of wheat (Grant and Bailey 1993).

Gan et al. (2007) and Hammac et al. (2010) showed that canola had little or no yield response to N application when residual soil N was moderate to high. Similarly, grain N increases very little with an increasing N rate as maximum yield is approached. Nitrogen fertilization resulted in linear decreases in canola seed oil concentration (Jackson 2000, Ramsey and

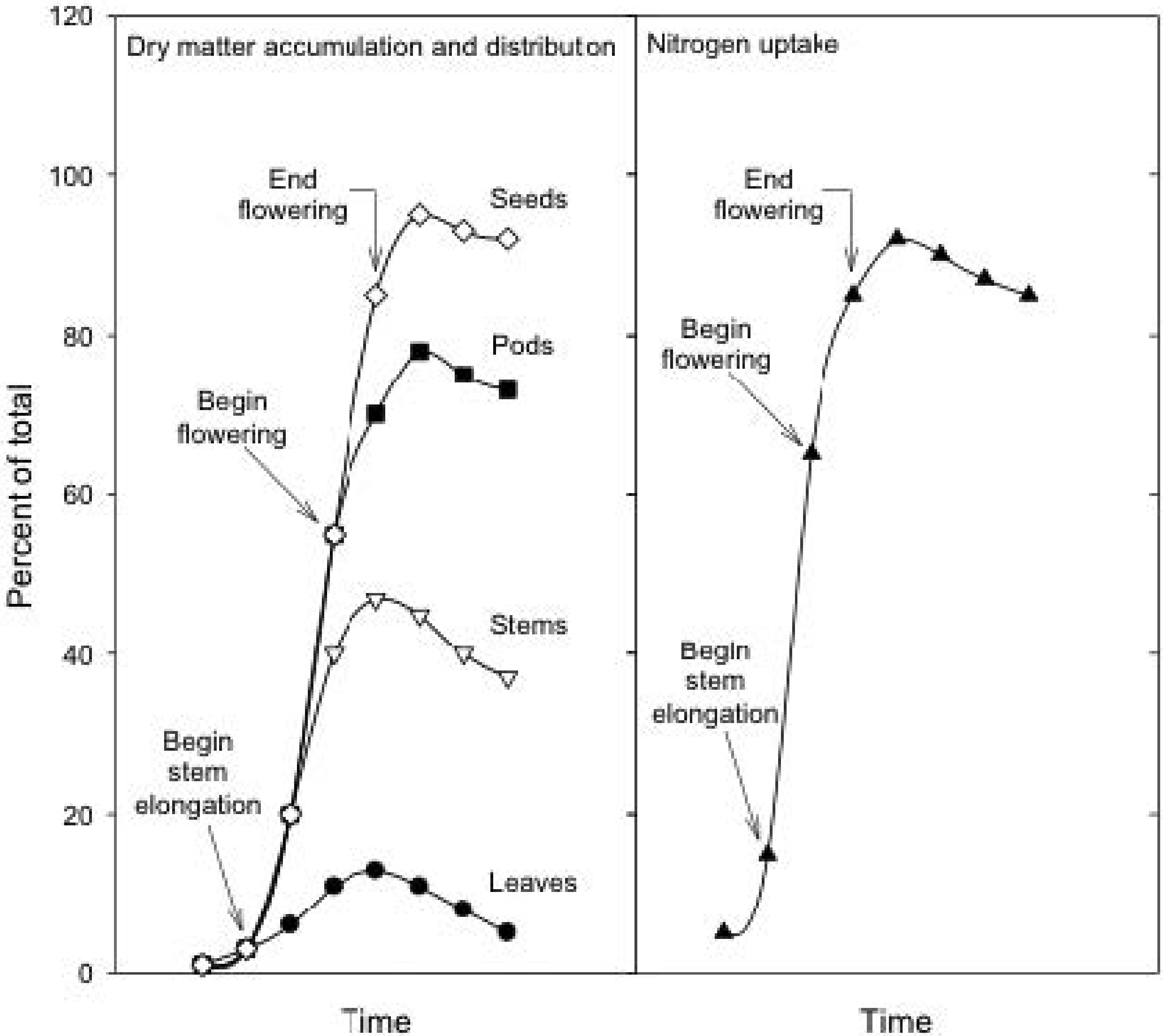

Figure 1. Generalized dry matter accumulation and distribution and nitrogen uptake patterns for canola. Adapted from Hocking and Stapper (2001), Hocking et al. (1997), and Major (1977).

Callinan 1994, Sheppard and Bates 1980, Smith et al. 1988, Taylor et al. 1991). However, due to relatively larger seed yield responses to applied N, total oil yield still increased with N fertilizer up to rates that optimized yield. Excessive rates of N reduce seed yield due to lodging and delayed maturity (Grant and Bailey 1993, Jackson 2000, Sheppard and Bates 1980).

Table 2 summarizes base N recommendations for canola from several U.S. Extension fertilizer guides and one publication from Canada. Recommendations are similar to hard red spring wheat and higher than those commonly reported for soft white wheat in the Pacific Northwest.The formula for determining a canola N fertilizer recommendation is also similar to that of wheat:

Fertilizer N recommendation = (yield goal × base N recommendation) – soil N contributions

Several studies have evaluated split applications of N for canola and rape. Wright et al. (1988) found no advantage with split applications of N made at sowing and rosette stages compared to similar rates applied only at sowing for spring rape in Australia. Similarly, Hocking and Stapper (2001) found no advantage with split applications of N made at sowing and stem elongation for spring canola. Nitrogen recommendations for winter canola grown in the United States (Boyles et al. 2006) state that low (< 1/3 total) rates of N should be applied in the fall to reduce the risk of winter injury.

Table 1. A comparison of average nutrient uptake and removal between canola and wheat.[1]

Nutrient		Crop		
		Canola	Soft white winter wheat (10% protein)	Dark northern spring wheat (14% protein)
		lbs per 100 lb seed yield		
Nitrogen				
	Uptake	5.8	2.2	3.2
	Removal	3.4	1.8	2.5
	% Removed	59	70	80
Phosphorus (as P_2O_5)				
	Uptake	1.9	0.9	1.1
	Removal	1.3	0.7	0.9
	% Removed	68	80	80
Potassium (as K_2O)				
	Uptake	4.1	2.7	2.7
	Removal	0.6	0.6	0.6
	% Removed	15	22	22
Sulfur				
	Uptake	1.0	0.5	0.8
	Removal	0.6	0.2	0.3
	% Removed	60	40	40

[1] Source: USDA Plants Database, Nutrient Uptake Tool (http://npk.nrcs.usda.gov/), and Jackson (2000).

Table 2. A summary of base N requirements for canola from various U.S. states and Canada. For comparison, the soft white winter wheat base N recommendation is 4.5 lb/100 lb yield (2.7 lb N/bushel) and the dark northern spring wheat base N recommendation is 6.0 lb/100 lb yield (3.6 lb N/bushel).

Source of recommendation	Winter canola	Spring canola
	lbs N/100 lb seed yield	
Colorado (San Luis Hills Farm 2007)	—	6
Great Plains Canola Handbook (Boyles et al. 2006)	5	—
Montana State University (Jackson 1999)	—	7 to 8
North Dakota State University (Fransen 1999)	5	—
Oregon State University (Wysocki et al. 2007)	7	7
Ontario, Canada (Alberta Agriculture 2002)	5.9 to 11[1]	3.9 to 6.1[1]
South Dakota State University (Boyles et al. 2006)	6.5	6.5
University of Idaho (Mahler and Guy 2002)	8.1 to 10.7[2]	7.7 to 10.5[2]
Washington (reported as "grower experiences" from 2 workshops held in 2000, Herdrich 2001)	6 to 8	6 to 8

[1] Nitrogen recommendations depend on the yield level and fertilizer:canola price ratio. See Alberta Agriculture (2002) for details.
[2] Nitrogen recommendations depend on the yield level. See Mahler and Guy (2002) for details.

Phosphorus (P)

Both research results (Bolland 1997, Grant and Bailey 1993) and Extension recommendations (Franzen 1999, Jackson 1999) suggest that canola is highly efficient at recovering P from soil and fertilizer sources. Canola has the ability to exude hydrogen ions (Hinsinger 2001) and organic compounds (Hocking 2001) such as citric and malic acids, which acidify the root zone and allow mineral P to become plant available. Research comparing the P requirements of canola and wheat in Australia showed that canola required 30 to 58% less P than wheat to maximize seed yield (Bolland 1997), though many states assume P recommendations are similar between canola and wheat (Alberta Agriculture 2002, San Luis Hills Farm 2007, Bolland 1997, Franzen 1999, Grant and Bailey 1993, Jackson 1999, Mahler and Guy 2002). Oilseed rape responded to up to 14 lb P2O5/acre when banded and 50 lb P2O5/acre when broadcast at low P-testing sites in Canada. Average soil test-based P recommendations for dryland canola are summarized in Table 3.

Starter applications of P are likely as efficient for canola as other crops. However, the amount of soluble N that can be placed along with P should be less than 5 lb/acre to prevent seed burning and emergence problems (Grant and Bailey 1993).

Table 3. Phosphorus fertilizer recommendations for dryland canola.

Soil test P (ppm) 0 to 12-inch depth		Application rate lb P_2O_5/acre[1]
Acetate (Morgan) method	Bicarbonate (Olsen) method	
0 to 2	0 to 4	30
2 to 4	4 to 8	20
4 to 6	8 to 12	10
>6	>12	0

[1]These recommendations assume fertilizer is banded below the soil surface. For broadcast-incorporated applications, multiply the rates in this table by 2.

Potassium (K)

Canola accumulates relatively large amounts of K, but only a small portion of this is removed in the seed (Table 1; Jackson 2000). No response to applied K was observed with spring rape when soil test levels were approximately 60 mg/kg in Canada (Sheppard and Bates 1980). Grant and Bailey (1993) suggest K would only be required if exchangeable K levels in a soil test are well below 100 mg/kg, and likely as low as 35 mg/kg. Few U.S. Extension publications suggest the need to fertilize canola with K.

Sulfur (S)

Several authors emphasize the importance of S fertilization and that widespread occurrences of S deficiency are likely in canola-producing areas (Grant and Bailey 1993, Jackson 2000, Mahli et al. 2007, Nuttall and Ukrainetz 1991). Mahli et al. (2007) measured an average seed yield response of approximately 1000 lb/acre with various Brassica species in Canada when the soil test for SO4-S (0 to 2 feet) was below 40 lb/acre. Jackson (2000) found spring canola responses to S fertilization (0 to 40 lb S/ac) of approximately 400 lb seed/acre even when the soil test for SO4-S exceeded 100 lb/ac at the 0 to 2-foot depth. Nuttall and Ukrainetz (1991) found a linear reduction in seed yield with the time of S application after seeding, indicating the importance of S fertilization at or before seeding and not later. Jackson (2000) suggests S is necessary when a soil test for SO4-S (0 to 2 feet) is below approximately 60 lb/acre in Montana. Grant and Bailey (1993) indicate a response to S can be expected when a soil test for SO4-S (0 to 2 feet) is below approximately 28 lb/acre. Standard rates of S recommended in many U.S. Extension fertilizer guides range from 20 to 30 lb/acre.

Micronutrients

Few published reports were found where canola responses to micronutrients were evaluated. Grant and Bailey (1993), in a review of literature, suggest boron may be the most important micronutrient deficiency for canola. Requirements for copper and manganese are thought to be lower for canola than for cereals.

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Abstract

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