



PHYSIOLOGY MATTERS: ADJUSTING WHEAT-BASED MANAGEMENT STRATEGIES FOR OILSEED PRODUCTION

Washington Oilseed Cropping Systems Series

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Abstract

The Washington State Oilseed Cropping Systems Research and Extension Project (WOCS) is funded by the Washington State Legislature to meet expanding biofuel, food, and feed demands with diversified rotations in wheat based cropping systems. The WOCS fact sheet series provides practical oilseed production information based on research findings in eastern Washington. More information can be found at: http://css.wsu.edu/biofuels/.

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Introduction

The wheat-dominated inland Pacific Northwest (iPNW) has a broad range of environments and soil types; however, the region lacks crop diversity. Many other semi-arid wheatgrowing regions throughout the world have successfully included oilseeds in their rotations for decades (Conley et al. 2004; Kirkegaard et al. 2008; Zentner et al. 2002). While interest in oilseed crops in the iPNW dates back to the 1970s (Divine et al. 1977) production has lagged due to socioeconomics, unique environmental conditions, and agronomic reasons (Pan et al. 2016a).

Growers in the iPNW have fine-tuned their agronomic management practices to meet the needs of wheat production for more than a century. Agronomic approaches to oilseed production require adjustments to account for physiological differences between the two types of crops. By coordinating production practices with growth stages and growing conditions, the impacts of moisture and temperature stress can be minimized. The iPNW has a winter precipitation pattern with high amounts of snow and rain occurring over frozen soils and less than 40% of total annual precipitation during the spring and summer (Schillinger et al. 2008). This requires crops to be more reliant on stored water and nutrients in the subsoils for sustaining growth and development due to greater water and heat stress during reproductive stages. Some of the greatest production challenges for iPNW crops are (1) plant establishment, (2) winter and early spring frost survival, and (3) water and nutrient use during the summer months.

Oilseeds are recognized as potential rotational crops due to their ability to extract deep soil moisture in water-limited environments more effectively than wheat or peas (Merrill et al. 2004). Opportunities for integrating oilseeds into traditional cropping sequences in the iPNW include (1) substituting spring canola or camelina for either spring wheat or legumes in high rainfall areas (>18"), (2) planting winter or spring oilseeds instead of winter or spring wheat in the intermediate rainfall zone (12–18"), and (3) replacing winter wheat with winter canola every fourth year in the low rainfall zone (<12").

Crop management is typically tailored to the physiological and morphological traits of each crop. Farm equipment, timing of farm operations, and agrichemical management are also designed in consideration of these traits. While canola producers can take advantage of wheat-based farm machinery and equipment, farm operations need to be tailored specifically to canola physiology and morphology to optimize yield and quality. A review of these differences between crops from planting to harvest, in the context of iPNW environmental stressors, provides insight into recommended modifications of wheat management strategies for canola production.

Seed Size

Wheat has a much larger seed size compared to canola and camelina (Figure 1; Vollmann et al. 1996) resulting in a lower number of seeds per pound and ultimately a higher seeding rate (lb/acre; Table 1). Seed size is affected by both variety and seed production environment (Lamb and Johnson 2004). When deciding on a seeding rate, both seed size and number of seeds per pound become an important factor when targeting specific population goals. Seven to fourteen plants per square foot are recommended to meet yield goals of spring canola (Canada Council) and 4–15 plants per square foot for winter canola (Boyles et al. 2009). In comparison, optimum spring wheat populations range from 30–32 plants per square foot, and



Figure 1. Seed comparison of camelina (left), canola (top), and wheat (right).

21–23 plants per square foot for winter wheat (Wiersma and Ransom 2005). Successful stand establishment of canola often improves weed control with canopy closure shading out weeds. If environmental conditions reduce the plant population, oilseeds are able to compensate for lower populations through secondary branching. Additionally, fewer plants allow water and nutrient reserves to be used more slowly.

The smaller seed size of canola and camelina alters seed zone requirements for optimal germination and emergence compared to wheat, which in turn affects depth of planting. Seed size affects how much storage capacity each species has in terms of nutrients and energy to support germination, shoot elongation, root elongation, and emergence. Larger seeds tend to germinate faster and are capable of emerging from deeper within the soil profile. Wheat can be planted deeper than canola and camelina because the seed has more nutrients and energy in storage. Some winter wheat varieties are bred to emerge from more than 4 inches (Schillinger et al. 1998). In contrast, canola generally emerges best when planted 1/2 to 2 inches below the surface when moisture conditions are adequate, but it can emerge from deeper placement when required to reach moisture. Camelina has been successfully planted either through broadcast seeding or drilling. However, seed should not be placed deeper than 1/4 inch in order to achieve successful germination (Hulbert et al. 2012). Shallow

seed placement is generally not a problem in irrigated areas where seedbed moisture can be controlled, but it can be a challenge in dryland regions of the iPNW when seed zone soil moisture is limiting at planting.

When to Plant

Soil moisture availability is an important consideration when determining optimum planting dates for oilseed crops. Stands of spring-planted canola or camelina are more consistent when planted before moisture levels decline since spring rainfall is generally sporadic in the region. Camelina seedlings are less sensitive to spring frosts than canola; therefore, camelina is often planted as soon as weed control measures, such as preplant herbicide applications, can be performed (Obour et al. 2006). Good camelina stands are more consistent when planted in late winter or early spring (Schillinger et al. 2012). While camelina can be fall-planted, it is generally grown as a spring crop.

Similar to spring wheat, spring canola is typically planted in March or April in the iPNW depending on soil moisture levels. Precipitation during May and June coincide with flowering and seed filling and directly impact spring canola yields. Spring canola is not commonly grown in iPNW rainfall zones receiving less than 12 inches of precipitation due to yield potential that is 1/2 to 2/3 as much as winter canola. In this rainfall zone, spring canola would be planted either for insurance purposes (e.g., winter-killed winter canola) or as an opportunity crop when sufficient moisture is present in lieu of fallow.

In recent years there have been many studies on planting dates of winter canola to optimize winter survival and nutrient and water use (Reese 2015). Winter canola germination and establishment requires soil moisture (approximately 18% soil water by weight at the seeding depth) and cool ambient air temperatures ($\leq 84^{\circ}F$) for 5 to 7 days after planting (Canola Council of Canada; Young et al. 2014). The common saying is to "plant as late as you can with as much moisture as possible." These conditions generally coincide with the month of August for the fallow region of eastern Washington (Young et al. 2014) and can be as early as mid-July for other areas within the iPNW. Winter wheat planting does not occur until early

Table 1. Average seed size and rates comparison for wheat, canola, and camelina.

Сгор	Grams per 1,000 seed weight	Number of seeds per lb	Plants per acre
Wheat	31–38	12,000–14,000	770,000 at 70 lb/acre
Canola	2–6	75,000–226,000	600,000 at 4 lb/acre
Camelina	0.8–2.0	226,000–566,000	1,584,000 at 4 lb/acre

fall (September–October), allowing more flexibility in the management schedule.

Morphology Differences

Morphology traits above and below ground differ between monocotyledous crops like wheat and dicotyledonous crops such as canola and camelina (Figures 2 and 3; Table 2). These traits cause the growth stages of the plants to differ (Table 3), resulting in different management requirements.

Roots

Oilseeds have a single taproot seminal axis with lateral roots and root hairs emanating from the taproot (Figure 4). In contrast, cereal crops have multiple seminal axes and shoot tillers which initiate from the seed (Klepper et al. 1984).



Figure 2. Growth stages of canola from emergence to harvest.

Table 2. Differences in morphology traits for dicots (canola and camelina) and monocots (wheat).

Morphology Trait	Dicot	Monocot
Embryo	Two cotyledons	One cotyledon
Roots	Taproot	Fibrous
Secondary branching	Present	Absent
Stem and vascular system	Bundles of vascular tissue in shape of a ring. Cortex and stele present.	Bundles of vascular tissue not in a specific shape or pattern. No cortex present.
Residue type	Herbaceous and woody	Herbaceous



Figure 3. Growth stages of camelina from emergence to harvest.

Table 3. Differences in growth stages between dicots (camelina and canola) and monocots (wheat).

Growth Stage	Dicot	Monocot
Germination and emergence	Taproot elongates, hypocotyl extends towards soil surface pulling the cotyledon leaves upward.	Five seminal roots are produced, coleoptile elongates to soil surface.
Leaf production/tillering	Secondary roots develop, first true leaf development followed by rosette establishment.	Seminal roots develop, appearance of first leaf followed by emergence of first tiller.
Stem elongation	Stem elongation initiated, flower and branch initiation begins.	Jointing starts, internode elongates, spikelet development, appearance of the flag leaf.
Inflorescence	Buds appear, but remain enclosed. Bolting occurs, buds open, buds turn yellow, secondary branching.	Booting and heading stage.
Flowering	Pollination and fertilization occur, petals drop, pods become visible.	Pollination and fertilization occur, embryo and endosperm begin to form.
Seed or grain development	Seed coat expands, embryo develops and grows.	Kernel formation (milk, dough, and hard dough stage).
Ripening	Stem and pods turn yellow and become brittle. Seed coat turns brown. Harvest begins when seed moisture is <10%.	Plant turns yellow and kernels become hard. Harvest begins when moisture is <20%.



Figure 4. Spring canola taproot.

As a result, oilseed seedlings are more sensitive to deepbanded ammonia-based fertilizers due to their reliance on the development of a single taproot, whereas cereals have numerous seminal axes to explore multiple soil layers. This basic morphological difference plays a key role in the management of banded fertilizer in oilseed crop production. Nitrogen fertilizers, such as urea and anhydrous and aqua ammonia, produce ammonia gas and ammonium ions as primary nitrogen forms around the fertilizer band; therefore, nitrogen fertilizers should not be banded directly below the canola seed since this increases the probability of the canola taproot encountering the toxicity zone (Pan et al. 2016b). Preplant or post-plant timing of nitrogen fertilizer is recommended to avoid fertilizer damage of the seedling taproot, or placement in a fertilizer band that is to the side and below the seed row should help avoid this problem (Pan et al. 2016b).

Root hair length and density of canola and camelina tend to be longer but less dense than wheat (Figure 5) and other crops (Hammac et al. 2011). This morphological trait may provide these oilseeds with the capacity to extract more water and nutrients in water-limited environments. In addition, allocation of carbon to support the growth of fine lateral roots is higher in oilseeds than in legumes, adding to the capability of oilseed roots to extract deep soil water and immobile nutrients.



Figure 5. Root hair comparison between canola (left) and wheat (right). Blue outline and shading indicates areas where root hairs are present.

Shoot Meristem (Crown)

Unlike cereal crops, which keep the crown protected below ground (Klepper et al. 1984), the crown of canola is above ground (Figure 6). This results in a fundamental difference in freeze tolerance: the exposed crown of canola is more vulnerable to sudden drops in air temperatures during late fall and winter, while cereals are more protected by the soil layer above the cereal crown and less prone to freeze damage. Soil can maintain temperatures ranging from 32 to 23°F when air temperatures reach 5 to -4°F. The higher the oilseed crown develops above ground, the more susceptible it is to cold air currents and other environmental extremes. Management practices growers have adopted to reduce excessive plant growth and stem elongation before winter include applying only starter fertilizer, delaying fertilizer application until late fall, selecting varieties that are not prone to bolting, or grazing in late summer-early fall.



Figure 6. Canola crown above the soil surface where it is easily exposed to the elements.

Winter Requirements

The size of winter canola plants entering winter months also correlates with winter survival. For the Pacific Northwest the general recommendation for the minimum size of canola plants going into winter is that of a dinner plate, or 8–12 inches in diameter (Figure 7). Small seedlings with 2–3 true leaves usually do not survive iPNW winters. This limits winter canola production in the non-irrigated annual cropping zone of the iPNW since very dry soils following harvest of the previous year's crop generally persist into October; by the time sufficient moisture has accumulated to establish a stand, the seedlings are typically small during the first hard frosts. When planted into fallow land, early-planted winter canola takes advantage of added growing degree days to produce more shoot and root biomass before winter dieback.

Winter canola, similar to winter wheat, requires a period of cold temperatures, or vernalization, to proceed with development into a reproductive phase. Vernalization is the cooling of vegetative plants required to trigger stem elongation and flowering (Zanewich and Rood 1995). Winter wheat and canola varieties have a vernalization requirement, while spring varieties generally do not. Winter wheat and canola typically out-yield spring types due to efficient utilization of winter and early spring precipitation and longer periods of growth and grain filling under relatively cool conditions. Camelina varieties are essentially all spring types since none have a vernalization requirement.

Flowering and Grain Filling

The challenges of minimizing moisture and temperature stress during flowering and grain filling of winter or spring wheat and canola are similar. In canola, environmental stresses during flowering and pod filling negatively impact grain yield



Figure 7. Desired size of winter canola going into winter is "dinner plate size."

(Figures 8 and 9; Angadi et al. 2000; Gan et al. 2004). Winter canola and winter wheat both flower and develop grain earlier than their spring counterparts. Thus, spring wheat and spring canola varieties best fit in the transitional, high rainfall, and high elevation zones where abiotic stresses are not as severe compared to the low rainfall fallow zone.



Figure 8. Example of heat stress negatively affecting seed pod development. Extreme heat can cause lack of new pod formation at the top of the meristem.



Figure 9. Aborted pods due to freezing temperatures during flowering.

Conclusions

The most critical challenges to the adaptation of oilseeds into iPNW wheat cropping systems include improving the consistency of winter canola establishment and winter survival in the low and intermediate precipitation zones. Spring oilseed production is a less viable option in the low precipitation zone but presents a better option in the annual cropping zone. Wheat-based management plans need to be altered to account for differences in the morphology of oilseed crops. Plant population, seed depth, planting date, and fertilizer timing and placement all need to be addressed to enhance freeze tolerance and overall success of oilseed crops in the iPNW.

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