Winter canola response to soil and fertilizer nitrogen

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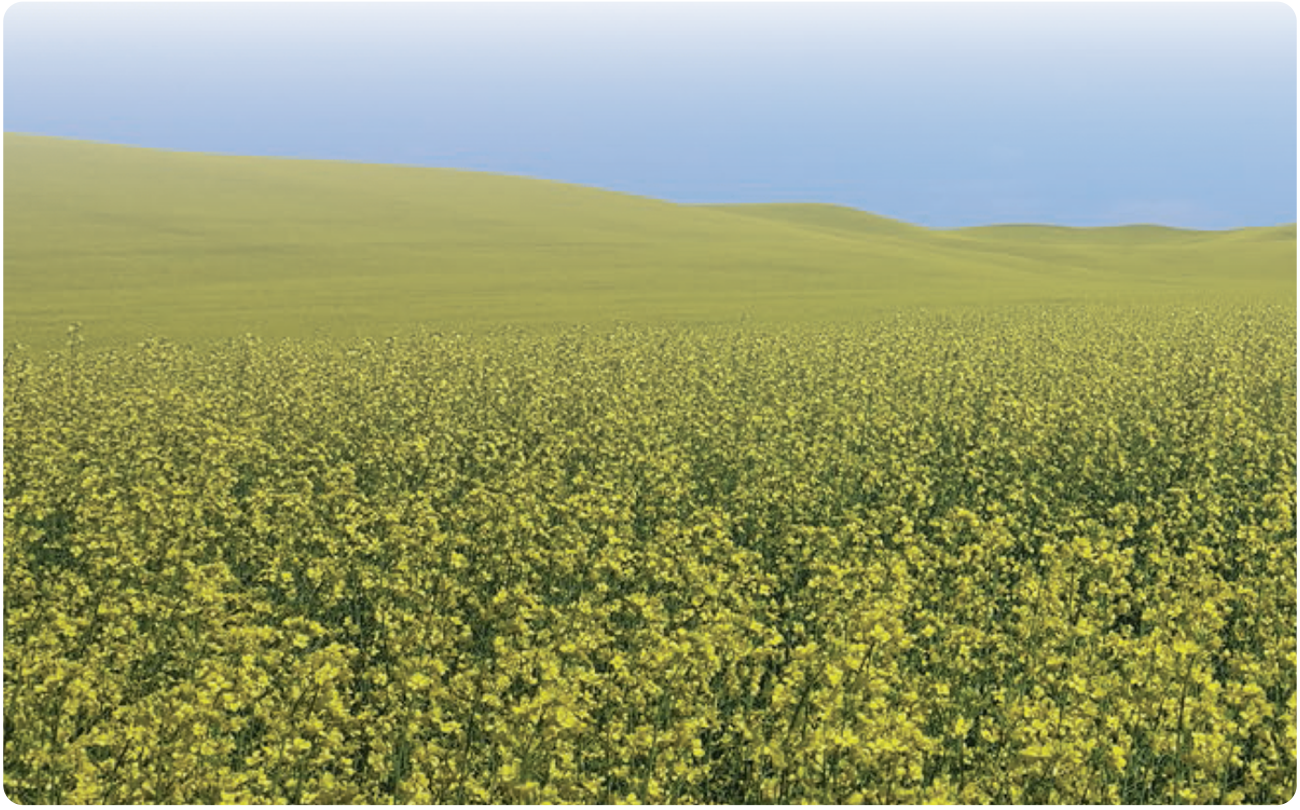

Photo courtesy of Haiying Tao.

Winter canola (WC) offers not only marketable products but also excellent rotational benefits through disease, weed, and pest control in the dryland cropping systems of the inland Pacific Northwest (iPNW). However, little regional fertility research has been conducted on WC. The objectives of this study were to (i) determine the influence of soil N supply and fertilizer N rate and timing effects on WC yield in four iPNW agroecological classes and (ii) evaluate how N availability and fertilizer N application timing affect WC seed quality.

Abbreviations:

AC	annual crop;
AECs	agroecological classes;
AFT	annual crop–fallow transition;
GF	grain–fallow;
iPNW	inland Pacific Northwest;
IR	irrigated;
SC	spring canola;
WC	winter canola.

Winter canola (WC) offers not only marketable products but also excellent rotational benefits through disease, weed, and pest control in the dryland cropping systems of the inland Pacific Northwest (iPNW). Winter canola is planted in all four agroecological classes (AECs) in the iPNW where precipitation and soil and air temperatures vary greatly: (i) annual crop (>450 mm annual precipitation), (ii) annual crop–fallow transition (300–450 mm annual precipitation), (iii) grain–fallow (<300 mm inches annual precipitation), and (iv) irrigated. Previous studies have shown that spring canola (SC) grown in different AECs responds differently to N fertilization. Higher unit N requirements were found in low-yield-potential regions where water stress occurs (Pan et al., 2016). Differences in yield potential and seasonal growth habit between SC and WC may require different N rate and timing recommendations for WC compared with SC.

Previous research found that the response of SC yield, oil concentration, and protein concentration to applied N is strongly influenced by soil N supply (soil test residual inorganic N and N mineralization estimates) and available water. Unlike SC, WC has the advantage of fall vegetative growth, which takes up substantial amounts of N that would otherwise be subject to loss during the intermediate and high-rainfall areas' rainy season. Furthermore, WC has three distinct phases of N use. In fall, the crop accumulates between 25 and 30% of its N, taking up from 35 to 130 lb/ac (Reese, 2015). Overwinter, approximately two-thirds of this accumulated N is retained in the plant to fuel spring growth while one-third is released back to the soil via leaf litter, of which approximately 50% is taken back up by the

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plant during the rest of the canola growing season. Upon spring green-up, the crop undergoes a period of rapid N uptake that continues through flowering and then accumulates the remaining N for seed production. Timing of N applications must be managed to ensure N availability during peak uptake periods while minimizing excess N.

The objectives of this study were to (i) determine the influence of soil N supply and fertilizer N rate and timing effects on WC yield in four AECs of the iPNW and (ii) evaluate how N availability and fertilizer N application timing affect WC seed quality.

Methods

We conducted seven on-farm experiments over two crop years, from 2016 to 2018, across Washington and Oregon (Table 1). Study sites represented all four AECs of the iPNW. Site management practices were determined by each collaborating grower. The typical seeding rate was 4 lb/ac, and the typical row spacing was 12 to 16 inches. Soil test P levels were greater than the agronomic threshold of 16 ppm in all sites but Hartline and Odessa. Farmers typically apply 10 to 40 lb/ac P_2O_5 with seed or banded at planting. We applied 50 lb/ac S in the fall at each site.

We used a split-plot experimental design with either three or four replications. Main plot treatments were three N application timings: fall, spring, and split (50% of total N rate applied in fall and again in spring). Fall applications occurred between three to five weeks after planting. Spring applications occurred at spring green-up, between February and April, depending on the site. Either surface-applied granular urea or injected liquid urea ammonium nitrate (UAN) fertilizer was used in the fall; granular urea was surface-applied in the spring. In the 2016–2017 crop year, subplot (30 by 40 ft) treatments consisted of a control plus three N rates: (i) recommended rate by Washington State University Extension (Koenig et al., 2011), (ii) 50% higher than the recommended rate, and (iii) 50% lower than the recommended rate. Because we observed limited yield response to N rate in the 2016–2017 crop year, we increased the range of fertilization rates (0, 40, 80, 120, 160, and 200 lb/ac) in the 2017–2018 crop year.

TABLE 1. Field and management information for the seven studied sites

Site	AEC[a]	Soil type	Rotation[b]	Yield goal	Recommended N rate[c]	Cultivar[d]	Planting date	Harvest date	Soil test at surface 6-inch depth[e] pH	OM	P	K	S
				lb/ac	lb/ac					%	——ppm——		
2016–2017													
Hartline WA	GF	Magallon sandy loam	SW-F	1600	34	Claremore	Aug. 27	Jul. 8	6.5	0.9	8	506	6
Odessa WA	IR	Renslow silt loam	WW-F	3100	167	Amanda	Sep. 12	Jul. 14	7.2	2.0	12	220	10
St. John WA	AFT	Athena silt loam	WW-F	3100	66	Edimax	Sep. 3	Jul. 23	5.1	3.2	24	694	21
2017–2018													
Almira WA	GF	Bagdad silt loam	SW-F	2700	109	Claremore	Aug. 27	Jul. 24	5.6	1.2	28	566	23
Echo OR	IR	Ritzville very fine sandy loam	WW-F	3100	154	Edimax	Sep. 6	Jul. 3	7.4	1.0	25	485	40
Endicott WA	AFT	Hermiston silt loam	WW-F	2700	87	HyClass 225W	Aug. 12	Jul. 31	5.5	1.6	32	620	20
Latah WA	AC	Naff-Garfield complex	WW-F	2900	36	HyClass 225W	Sep. 15	Aug. 6	5.0	2.5	30	472	22

[a]AEC, agroecological class; GF, grain-fallow; AFT, annual crop–fallow transition; AC, annual crop; IR, irrigated.
[b]WW, winter wheat; SW, spring wheat; F, Fallow.
[c]Based on unit N requirement of 7 lb N per 100 lb seed yield (Koenig et al., 2011).
[d]Claremore, Amanda, NS HyClass are open-pollinated varieties, and EdiMax is a hybrid variety.
[e]pH: 1:1 soil: H_2O method; OM, soil organic matter, Walkley-Black method; P and K, phosphorus and potassium, Olsen method; S, sulfur, $Ca(H_2PO_4)_2{*}H_2O$ extraction method (Miller et al., 2013).

We collected soil samples to a depth of 6 ft immediately after planting and prior to fall fertilization and again between February and March prior to spring fertilization. We divided soil cores into 1-ft segments to determine root-zone-available N and water at soil depth in the 6-ft profile. We estimated soil N supply (soil test inorganic N in the fall + estimated N mineralization) before fertilizer application and total N supply (soil test inorganic N in the fall + estimated N mineralization + fertilizer N). We harvested a 15 by 3 ft^2 area in each subplot and air-dried seeds for >48 hours in a greenhouse that reached >122°F during the day. Samples were analyzed for yield and seed oil and protein concentrations. In each plot, we also cut, dried, and then weighed an 11 ft^2 section of plant biomass to estimate total biomass yield at harvest.

We used the Mitscherlich growth factor response model (Pan et al., 2016) to study the yield responses to total N supply for individual site-years. We used Proc GLIMMIX in Statistical Analysis Software (SAS) to compare yield and protein and oil concentrations among the different treatments. We treated site-year, N fertilizer rate and timing, and fertilizer rate and timing interaction as fixed effects and block as a random effect. Because site-year had significant effects on yield, oil concentration, and protein concentration and because of treatment differences between the two crop years, we further analyzed these effects for each site-year.

Results

Effects of Soil N and Fertilizer N Rates on Yield

Soil N supply was high at all sites, ranging from 82 to 200 lb/ac (Table 2). Dryland WC yields were highly variable, ranging from 1,900 to 4,300 lb/ac. Of the AECs, we found the highest yields in annual crop (AC), followed by annual crop–fallow transition (AFT), and then grain–fallow (GF). At Hartline in 2017, high seed loss occurred at harvest due to combine malfunction; therefore, yield data from that site are not included. Odessa yields were abnormally low for an irrigated (IR) site. In comparison, yields at Echo were more representative of expected yields under IR conditions. Infestations of tumble mustard (*Sisymbrium altissimum*) and tansy mustard (*Descurainia pinnata*) were present in the Odessa field, which likely contributed to the reduced yields. No diseases in any field were observed by farmers.

At only one site was the Mitscherlich model statistically significant (Figure 1). At Odessa, where yield was lowest and total N supply was below 90 lb/ac, yield response to total N supply plateaued at 130 lb/ac. At the other sites, we found no yield response to N fertilizer applications. Lack of yield response was likely due to high soil N supply at planting (Table 2). These findings are similar to those of a recent SC study in Washington. Pan et al. (2016) observed a yield response to increasing N supply

TABLE 2. Agroecological zone, available soil water to 180 cm, precipitation from fall soil sampling through harvest, total available water (H_2Ot), inorganic soil N, estimated N mineralization, N supply, and seed yield at each winter canola site by year

Site-year	AEC[a]	Soil H_2O	Precipitation[b]	H_2Ot	Inorganic N[c]	Mineralized N[d]	Soil N supply[e]	Seed yield
		mm			lb/ac			lb/ac
2016–2017								
Hartline	GF	37	297	334	80	13	93	-[f]
Odessa	IR	37	400‡	437	47	34	82	2039
St. John	AFT	264	417	681	135	48	184	3181
2017–2018								
Almira	GF	238	222	460	84	19	103	1902
Echo	IR	93	590‡	683	77	15	92	3153
Endicott	AFT	476	366	842	101	24	125	4349
Latah	AC	344	471	795	162	37	199	3863

[a]AEC, agroecological class; GF, grain–fallow; AFT, annual crop–fallow transition; AC, annual crop; IR, irrigated.
[b]Precipitation + irrigation.
[c]NO_3^- + NH_4^+ to a 180-cm depth.
[d]Percent organic matter in the top 30 cm × 19 kg N/kg.
[e]Soil N supply = inorganic N + mineralized N.
[f]- = no data due to combine malfunction at harvest.

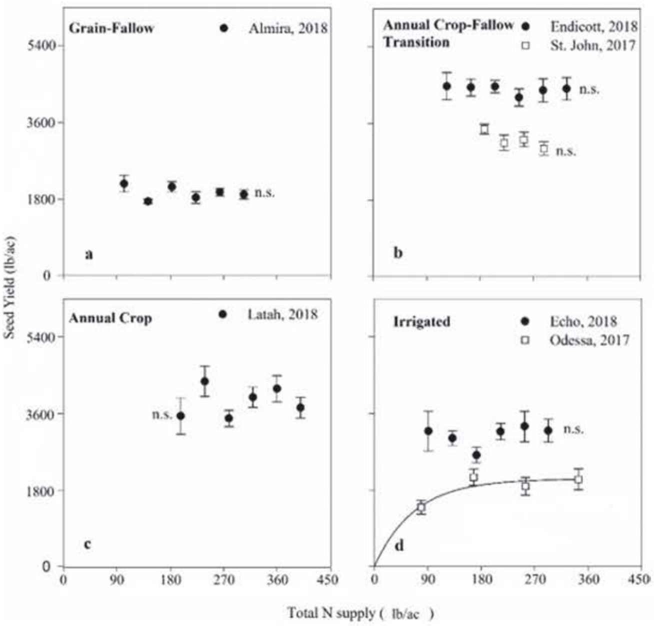

Figure 1. Winter canola yield response to total N supply at sites across the four agro-ecological classes: (a) grain–fallow, (b) annual crop–fallow transition, (c) annual crop, and (d) irrigated during the 2016–2017 and 2017–2018 crop years.

at one of five sites where soil N supply was above 90 lb/ac. In contrast, yield response to increasing N supply was observed at six of seven sites where N supply was below 90 lb/ac.

Effects of Soil Water on Yield

We found that total available water is one of the primary drivers of WC maximum yield (Figure 2). For every 1 mm increase in available water, we found a 5.7-lb seed increase ($r^2 = 0.98$). In comparison, Pan et al. (2016a) showed SC seed yield increased 2.8 lb for each 1 mm increase in available water. The higher yield response to available water for WC reflects a greater water use efficiency (WUE) compared with SC. This greater WUE can be attributed to WC taking advantage of fall and winter precipitation; this is when 70% of the annual precipitation occurs in the iPNW—and to deeper roots that can reach soil water at a greater depth. The x-intercept, which can be considered the theoretical minimum water required to produce a canola crop, was 110 mm, which is greater than the threshold for wheat production (Schillinger et al., 2008).

Effects of N Rate and Timing on Seed Quality

Across all site-years, N rate and timing had significant effects on seed oil and protein concentrations (Table 3). Oil concentration was significantly higher in the control than all other treatments across all AECs. In general, the higher the N rate, the lower the oil concentration and the higher the protein concentration. Seed protein concentration decreased as total N supply increased to approximately 170 lb/ac but increased dramatically as total N supply increased from 170 to 450 lb/ac. Seed oil concentration increased as total N supply increased up to 170 lb/ac but decreased dramatically as total N supply increased from 170 to 450 lb/ac. The increase in protein concentration was stronger than the decrease in oil concentration in response to increased N supply (Figure 3).

We found that timing of N application had a significant effect on seed oil concentration with different responses observed across the AECs (Figure 4). Fall application resulted in the highest oil concentrations and lowest protein concentrations; spring or split applications resulted in similar oil and protein concentrations. In the GF, AC, and IR AECs, fall N applications resulted in the highest oil concentrations compared with split and spring applications. In AFT, fall N applications resulted in higher oil concentrations than spring-applied N. We found the lowest seed oil concentrations with spring-applied N in all AECs. The AC zone experienced the greatest reduction in response to spring application with oil concentration decreasing by 10% compared with the control. In AC and IR, we also found significant differences in oil concentration response between split and spring N applications. This finding may be due to higher soil water availability and corresponding

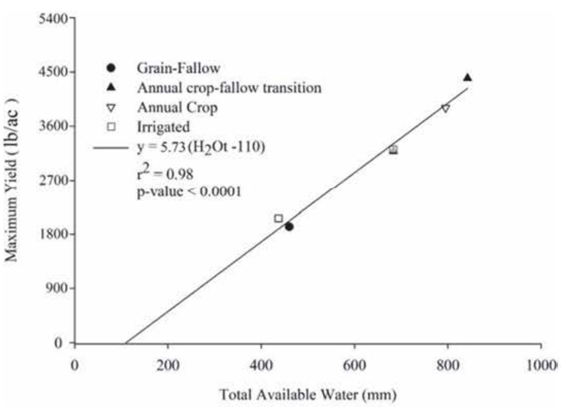

Figure 2. Relationship between total available water (fall stored soil water + precipitation + irrigation) and maximum yield of winter canola.

TABLE 3. Seed oil and protein concentrations in response to different N rates and timings at the seven winter canola site-years during the 2016-2018 crop years[a]

Parameter	Category[b]	Mean oil concentration	Mean protein concentration
		%	
N timing**	Fall	43.3 a	22.1 b
	Split	42.2 b	22.5 ab
	Spring	42.2 b	22.8 a
N rate (lb/ac)**	0	44.5 a	21.1 b
	14	43.1 abc	22.6 ab
	28	42.6 abc	22.1 ab
	33	43.8 ab	21.9 ab
	40	43.5 ab	21.6 b
	43	43.2 abc	21.6 ab
	66	42.6 abc	22.7 ab
	80	43.6 ab	21.7 ab
	87	42.4 abc	22.5 ab
	99	42.6 abc	22.7 ab
	120	42.3 bc	23.1 a
	160	41.9 bc	23.3 a
	174	41.2 bc	23.0 ab
	199	41.8 bc	23.5 a
	262	39.6 c	24.2 a
Site × year**	St. John 2016	45.6 a	19.4 c
	Latah 2017	44.6 ab	22.6 b
	Almira 2017	43.2 bc	22.6 b
	Hartline 2016	42.5 bcd	22.3 bc
	Odessa 2016	41.9 cde	20.7 cd
	Endicott 2017	40.2 de	26.1 a
	Echo 2017	40.0 e	23.5 b

**Significant at .01 probability level.
[a]means followed by the same letter are not significantly different at $p < .1$ at Almira site-year and at $p < .05$ for all other site-years within each N application timing.
[b]Fall = 100% fertilizer N was applied in fall after seeding. Split = 50% fertilizer N was applied in fall and 50% was applied in spring. Spring = 100% fertilizer N was applied in March through April. Rates varied across sites in the 2016–2017 crop year based on the yield goal method; rates were 0, 40, 80, 120, 160, 200 lb N/ac.

N leaching losses at the time of fall-applied N in the split treatment. Consequently, sites with only spring-applied N had a greater amount of available N for crop uptake and, thereby, a stronger oil concentration response. In addition, variable oil and protein response to N applications in different sites can be attributed to different cultivars responding differently. Furthermore, temperature and water stresses can also influence oil and protein concentrations.

Relationship between Canola Seed Oil and Protein

Winter canola oil and protein concentrations exhibited an inverse linear relationship across all site-years. The physiological reason for the reversed relationship between oil and protein concentrations is the competition for carbohydrate skeletons during protein and fatty acid metabolism

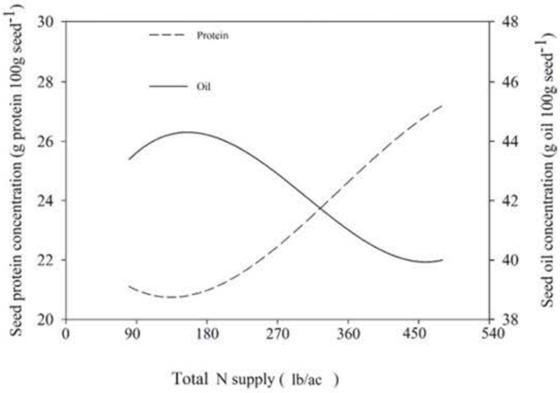

Figure 3. Seed protein and oil concentrations in response to nitrogen supply (fall preplant N + fertilizer N + estimated mineralized N) during the 2016–2017 and 2017–2018 crop years at seven winter canola field sites (n = 332).

(Mitra & Bhatia, 1979; Hocking et al., 1997). Both protein and fatty acid synthesis require carbon compounds produced from the decomposition of carbohydrates. Increased N supply enhances synthesis of proteins at the expense of fatty acid synthesis, resulting in a lower oil concentration. Gao et al. (2010) found that urea additions changed the seed fatty acid profile, increasing the less desirable total saturated fatty acid concentration (palmatic + stearic + arachidic acid) and decreasing the oil quality index ratio, defined as (oleic acid)/(linoleic + linolenic acid).

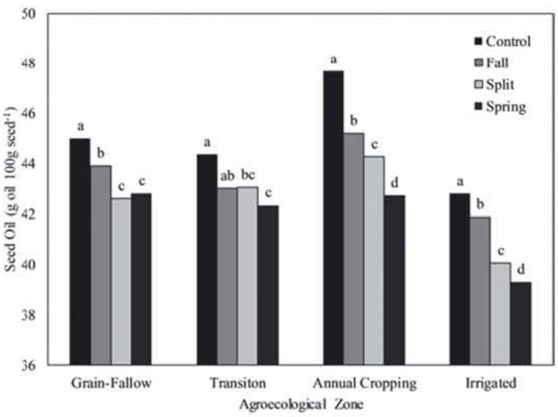

Figure 4. The relationship between mean seed oil concentration and timing of N application for the different agroecological classes. Data for each time of application were averaged across N rates. Seed oil concentration marked by different letters above the bars are significantly different within each agroecological class.

Conclusion

We found that WC yield in the iPNW was influenced mainly by total available water. Nitrogen fertilizer was a factor in yield response only when soil N supply was below 90 lb/ac. When N supply was above this threshold, WC produced high yields without additional N. We found opposite responses of oil and protein concentrations to N rate and timing. Higher N rates resulted in lower oil concentrations and higher protein concentrations. Of the AECs, this relationship was strongest for spring-applied N in AFT, followed by AC and IR. These findings emphasize the need to consider soil N levels in fertilizer decisions. The current yield-goal-based N recommendation should be modified to integrate the soil test threshold. Oil concentration was highest when N was applied in fall and lowest when N was applied in spring in fields high in soil N.

References

Gao, J., Thelen, K.D., Min, D.-H., Smith, S., Hao, X., & Gehl, R. (2010). Effects of manure and fertilizer applications on canola oil concentration and fatty acid composition. *Agronomy Journal*, *102*, 790–797. https://doi.org/10.2134/agronj2009.0368

Hocking, P.J., Randall, P.J., & DeMarco, D. (1997). The response of dryland canola to nitrogen fertilizer: Partitioning and mobilization of dry matter and nitrogen, and nitrogen effects on yield components. *Field Crops Research*, *54*, 201–220. https://doi.org/10.1016/S0378-4290(97)00049-X.

Koenig, R.T., Hammac, W.A., & Pan, W.L. (2011). *Canola growth, development, and fertility. Fact Sheet FS045E*. Pullman, WA: Washington State Univ. Ext.

Mitra, R., & Bhatia, C.R. (1979). Bioenergetic considerations in the improvement of oil content and quality in oil-seed crops. *Theoretical and Applied Genetics*, *54*, 41–47. https://doi.org/10.1007/BF00265707

Pan, W.L., McClellan Maaz, T., Hammac, W.A., McCracken, V.A., & Koenig, R.T. (2016). Mitscherlich-modeled, semi-arid canola nitrogen requirements influenced by soil nitrogen and water. *Agronomy Journal*, *108*, 884–894. https://doi.org/10.2134/agronj2015.0378.

Reese, M. 2015. *Dryland winter canola water and nitrogen use in eastern Washington* (M.S. thesis). Pullman, WA: Washington State University.

Schillinger, W.F., Schofstoll, S.E., & Alldredge, J.R. (2008). Available water and wheat grain yield relations in a Mediterranean climate. *Field Crops Research*, *109*, 45–49. https://doi.org/10.1016/j.fcr.2008.06.008

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