Environment, Genotype and GxE Effects on Camelina Seed Quality for Fuel and Feed

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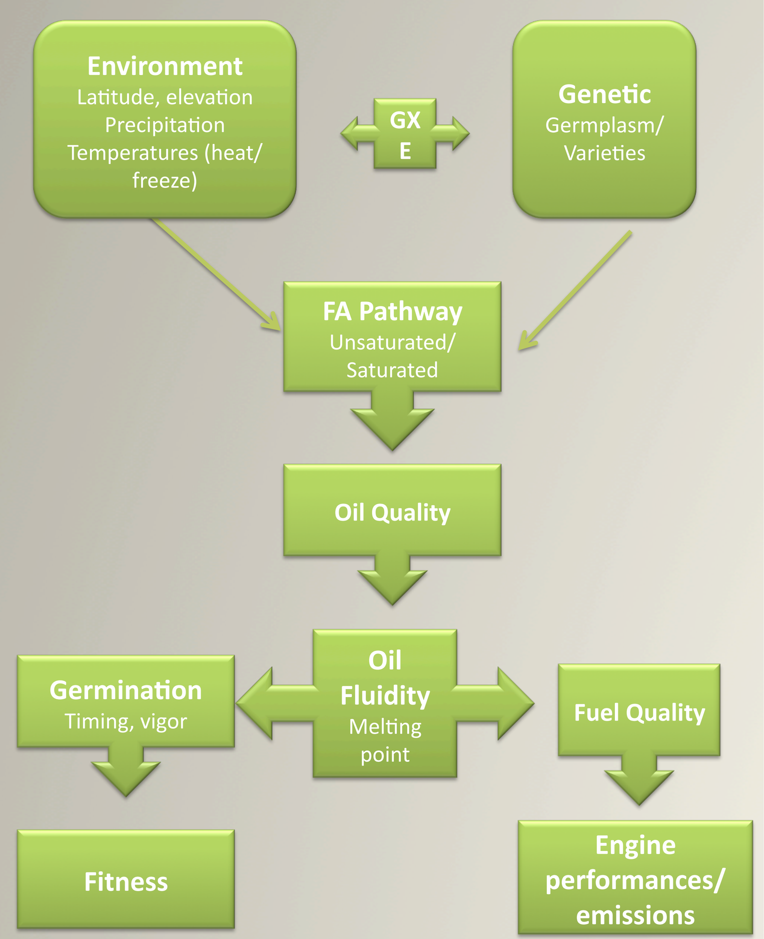
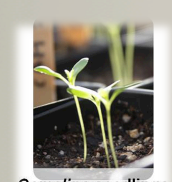
Questions: ***Is camelina oil composition stable across environments and varieties? Could better desaturation pathway efficiency lead to better oilseed fitness in the High Plains?***





Camelina seedlings

Review

•Unsaturated Fatty Acid (FA) content decreases as the temperature increases in Brassica species (Canvin,1964; Williams et al., 1991)

•Solar radiation and maximum temperature influence linoleic and oleic acid content in sunflower (Seiler, 1983).

•Efficiency of FA synthesis pathways varies within Brassica species (Velasco et al.; 1998)

•Large biogeographic FA diversity known in camelina germplasm (Ghamkhar et al., 2010)

•Chilling resistance due to higher polyunsaturated FA content (PUFA) in leaf membranes (Lyons et al., 1964; St John and Christiansen, 1976)

•Faster germination with higher levels of PUFA (Enjalbert and Johnson, 2006).

•Timing of germination is linked to fitness (Weiner, 1985; Silvertown 1988)

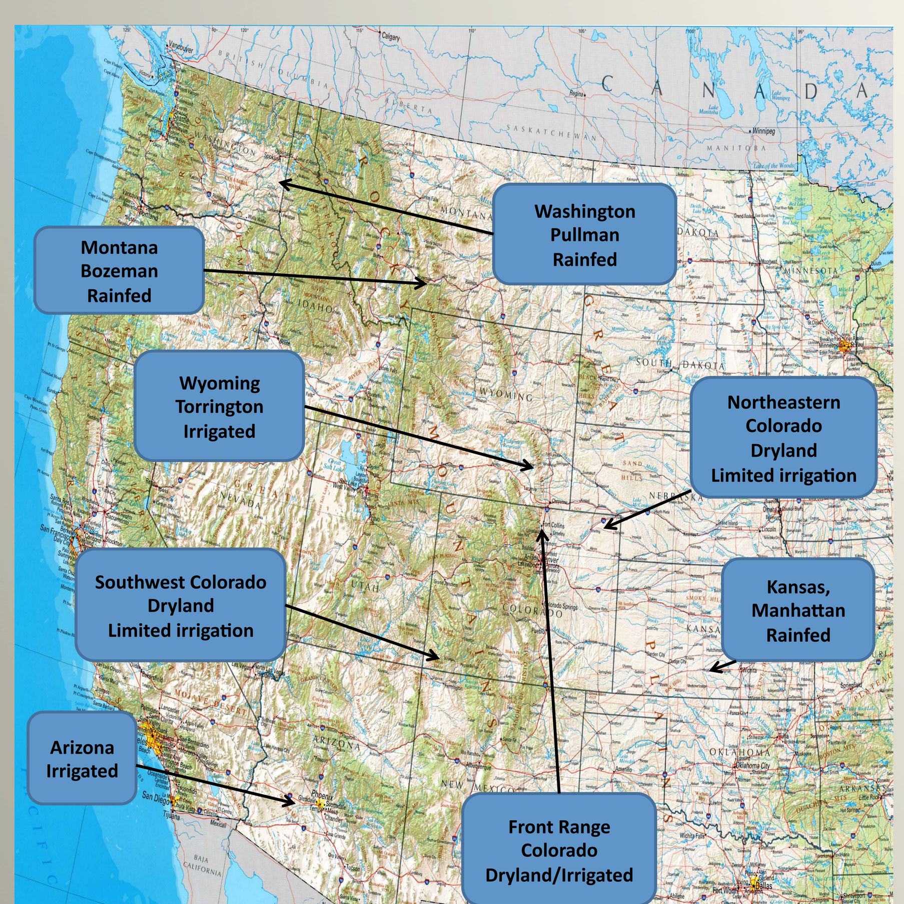
•Quantity and quality of FA play a role in fitness (Linder, 2000)

•High variation in melting points (Linder, 2000):
•Stearic FA 18:0 = 69 °C
•Linolenic FA 18:3 = -10°C

•Higher PUFA in fuel could increase NOx emissions and build-up in engines (Anderson and Olsen, 2009)

Objectives: ***Is there GXE interaction for oil composition? What environmental factors impact oil composition? What are the variety Elongation Ratio (ER) and Desaturation Ratio (DR) efficiencies and their correlation to environmental factors? Is there GXE interaction for yield and factors affecting yield? Is there a correlation between yield and FA synthesis pathways?***

Methods and Materials



Plant material:
•8 camelina varieties differing in maturity and from three breeding programs

Field experiments:
•Two years: 2009 and 2010
•8 locations (see map)
•Plots size: 2 m X 5 m
•Design: RCBD

Data Collected:
•Height, flowering, yield, oil content.
•Oil profile: fatty acid composition (FA) and FA pathway ratios such as Elongation Ratio (ER), Desaturation Ratio (DR), Oleic Desaturation Ratio (ODR), and Linolenic Desaturation Ratio (LDR)

ER= (C20:1+C22:1)/(C20:1+C222:1+C18:1+C18:2+C18:3)
DR= (C18:2+C18:3)/(C20:1+C22:1+C18:1+C18:2+C18:3)
ODR= (C18:2+C18:3)/(C18:1+C18:2+C18:3)
LDR= (C18:3/(C18:2+C18:3)

•Soil sample, weather and geographical data

•Analytical methods:
• ANOVA: with environments as random effects
• Pearson correlation

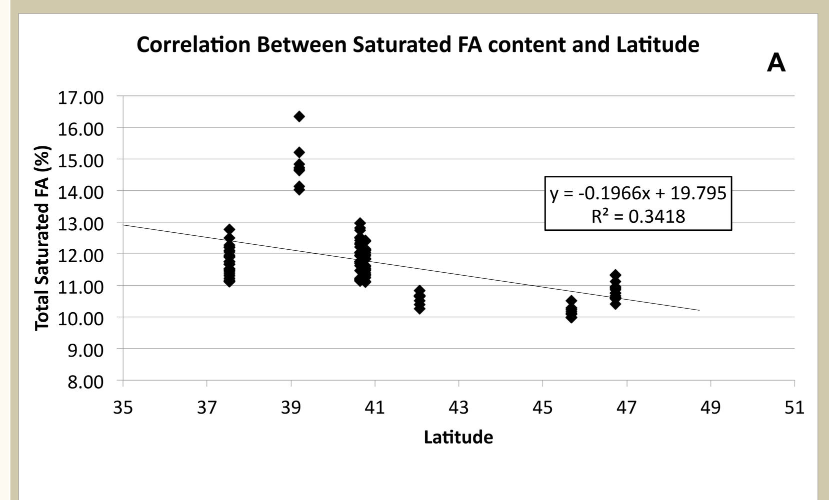
Company	Variety	Maturity	Comments
MSU	Suneson	Medium	
MSU	Blaine Creek	Meddium	
Blue Sun Biodiesel	BSX G74	Late	
Blue Sun Biodiesel	BSX G22	Early	early
Blue Sun Biodiesel	Cheyenne	Medium	
Europe	Celine	Medium	
Europe	Ligena	Late	Tall, high yielding
Great Plain Oil	Yellow Stone	Early	Earliest maturity, highest level of C18:3 FA

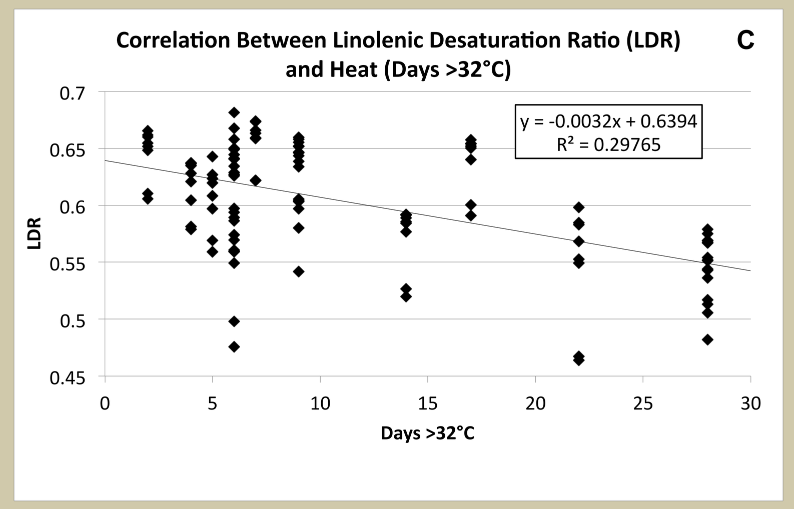
Year	City	Elevation (meters)	Latitude	Water Trt	Precepitation + Irrigation	days>32C	Days<5C	GDDs (F/C)	pH	OM	Nitrate-N	Bicarb-P	Sulfate-S	Yield
		meters	deg		inches	#	#	F	#	%	lbs/ac	ppm	ppm	lbs/ac
2009	Bozeman MT	1509	45.68	Rainfed	5.1	7	58	.	.	.	.			.
2009	Pullman WA	717	46.73	Rainfed	6.44	2	36	2088/1142		2.7	160	106	72	2954
2009	Ft Collins CO	1557	40.65	Dryland	9.13	6	22	2107/1153	7.9	1	78	60	30	1504
2009	Ft Collins CO	1557	40.65	Irrigated	13.03	6	22	2107/1153	7.9	1	78	60	30	2076
2009	Illif CO	1165	40.77	Dryland	10.29	14	5	2896/1591	8	2.2	49	14	173	1449
2009	Torrington WY	1251	42.063	Rainfed	16.93	17	60	2563/1406	7.3	1	181	7	4	1844
2009	Yellow Jacket CO	2103	37.53	Dryland	2.2	6	6	2385/1307	7.1	0.9	75	29.6		410
2009	Yellow Jacket CO	2103	37.53	Irrigated	18.8	6	6	2385/1307	7.1	0.9	75	29.6		876
2010	Maricopa AZ	358	33.05	Irrigated	10.08	22	25	.	7.7	1	224	12	83	.
2010	Pullman WA	717	46.73	Rainfed	7.67	4	59	.	5.3	2	72	20	8	1285
2010	Ft Collins CO	1557	40.65	Dryland	6.89	9	17	2031	8.1	2.3	60	59	57	566
2010	Ft Collins CO	1557	40.65	Irrigated	16.89	9	17	2031	8.1	2.3	60	59	57	1516
2010	Manhattan KS	311	39.2	Rainfed	12.53	6	12	.	5.8	2.1	90	19	9	.
2010	Illif CO	1165	40.77	Irrigated	11.26	28	33	2106	8.1	2.6	50	15	54	1216
2010	Illif CO	1165	40.77	Dryland	8.26	28	33	2106	8.1	2.6	50	15	54	1021
2010	Yellow Jacket CO	2103	37.53	Dryland	4.47	5	35	2637	7.1	0.9	.	.		605

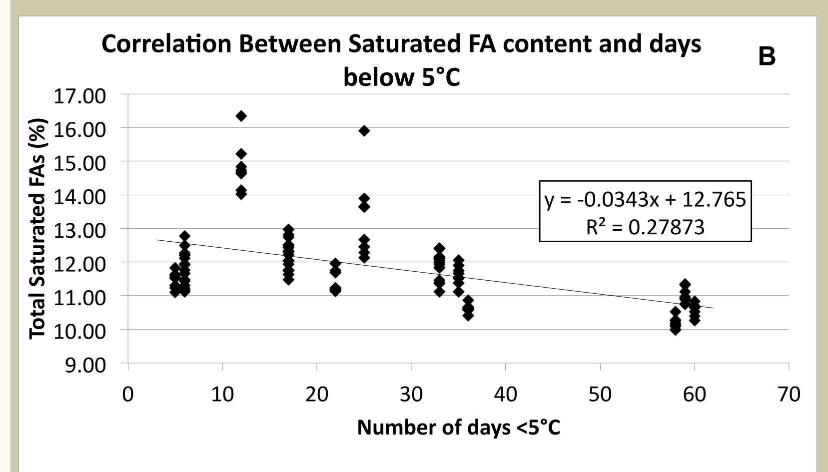
Is camelina oil quality stable across environments and varieties?

Effect	DF	Yield	Oil	C18_1	C18_2	C18_3	C20_1	C22_1	SAT	POLY	Fatty Acids Ratios ER	DR	ODR	LDR
		p	*p*	*p*	*p*	*p*	*p*	*p*	*p*	*p*	*p*	*p*	*p*	*p*
ENV	14	***	**	***	***	***	***	***	***	***	***	***	***	***
ENTRY	7	***	*	***	***	***	***	***	**	***	***	***	***	***
ENV*ENTRY	90	***	ns	0.02	0.04	ns	ns	0.11	ns	ns	ns	ns	0.02	0.09
CV		15.7		4.80	5.80	3.70	4.01	6.94	5.34	2.10	4.10	2.30	1.70	3.29
R square		0.95		0.90	0.89	0.94	0.87	0.91	0.81	0.91	0.89	0.85	0.89	0.92
Mean		1321		17.55	19.90	31.40	14.01	2.99	11.56	52.10	0.20	0.60	0.75	0.60

ANOVA table with multiple traits reported. (*significant at p ≤ 0.05; ** significant at p ≤ 0.01, *** significant at p ≤ 0.001, "ns" if p>0.1).





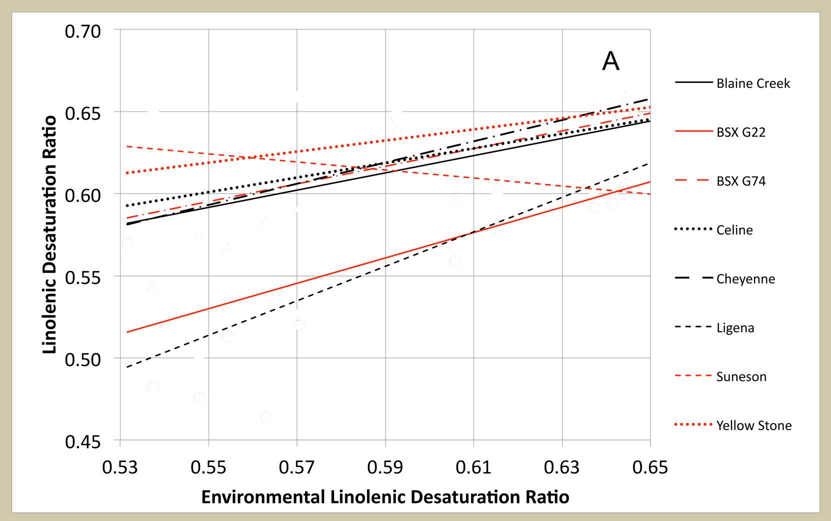


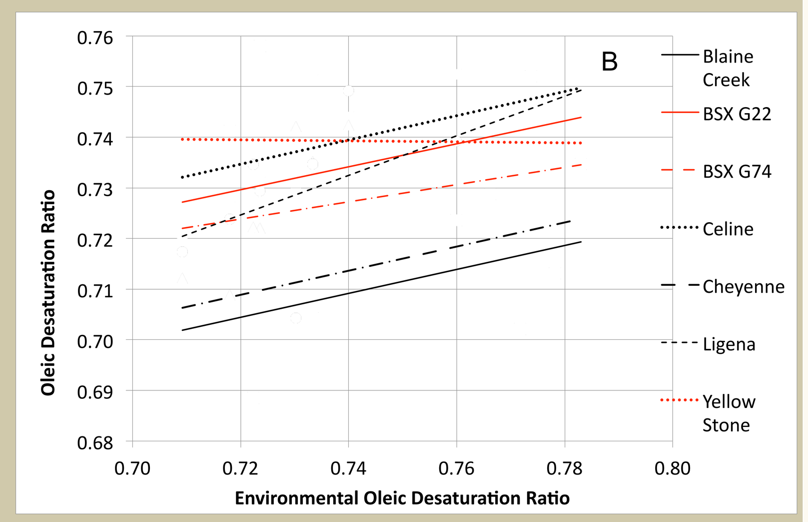
• (A) Gradient North/South for saturated FA. More northerly, lower saturated FA

• (B) Lower temperature decreases the level of saturated FA.

• (C) Higher temperature decreases the linolenic desaturation pathway efficiency

Pearson correlation between: (A) saturated FAs and latitude (p<.0001), (B) Saturated FAs and days below 5°C (p<.0001), and (C) linolenic desaturation ratio and heat (p<.0001),.





LDR (A) and ODR (B) graphs showing genotype and GXE interaction effects for oil profile desaturation pathways

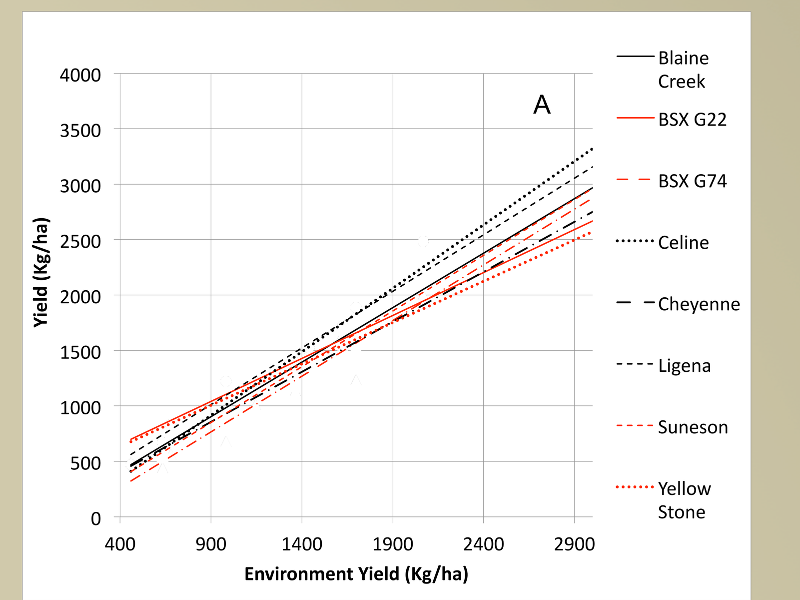
• Within the desaturation pathway, LDR and ODR estimate the efficiency of desaturation from oleic to linolenic acid.

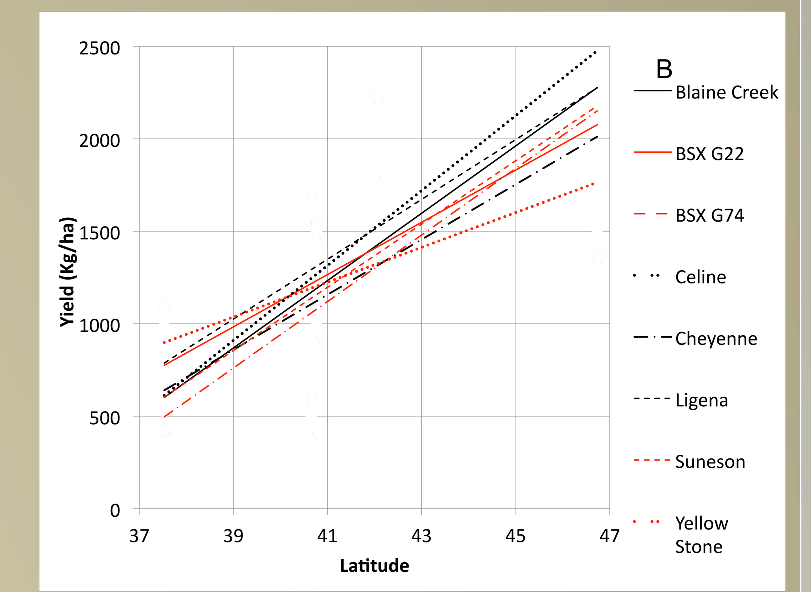
• The GXE significance levels are, respectively, *p*=0.09 and *p*= 0.02.

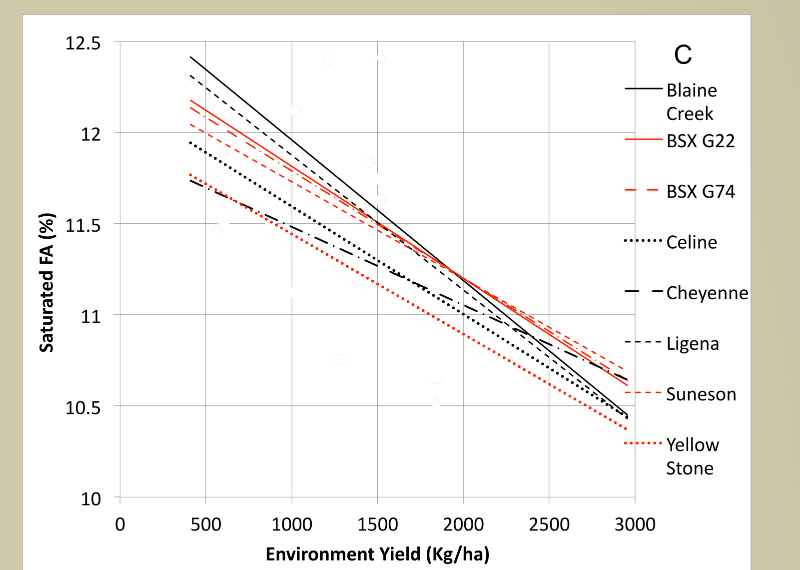
• LDR and ODR being temperature sensitive, (A) and (B) show that some camelina lines are more sensitive than other to change in temperature.

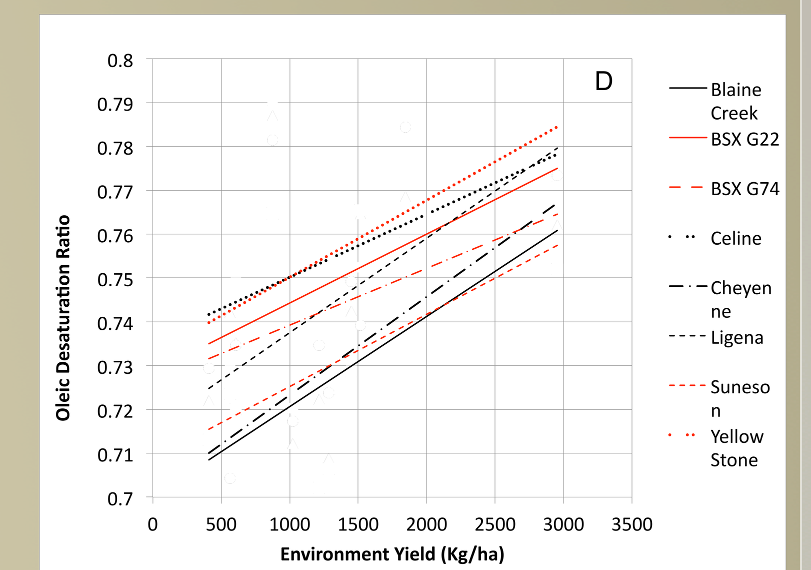
• Ligena revealed the strongest oil profile response to environment change while Yellow Stone remains stable.

Could a higher desaturation pathway efficiency could lead to better oilseed fitness in the High Plains?









Yield performance (A), yield vs. latitude (B), saturated FA content vs. yield (C) and ODR vs. yield (D)

• The GXE effect for yield was highly significant. Celine and Ligena were highest yielding in favorable environments while Yellow Stone yielded the best in drier environments (A).

• The North/South yield gradient observed in (B) can be explained by a strong positive correlation between yield and low temperature and a negative correlation between yield and heat.

• In higher yielding environments, desaturation pathways were more efficient (C) and (D).

Conclusions

• Temperature impacted FA synthesis pathway, leading to higher levels of saturation at higher environmental temperatures in more southern locations
• The strong GXE interaction for yield is mainly explained by temperature response
• Genetic, environment and GXE effects impact camelina oil profile. However, is this variation large enough to affect fuel emissions and engine performance?
• Genetic, environment and GXE effects were significant for desaturation ratios
• The level of desaturation may affect yield by influencing time of germination
• Can oil profile be a screening tool for adaptation/fitness of new oilseed species/varieties? Germination timing and oil profile studies might elucidate this idea