WASHINGTON OILSEEDS COMMISSION
Final REPORT FOR 2017 PROJECT

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Title: Determining the sensitivity of spring canola to low pH and aluminum toxicity

Soil pH has been on the decline in northern Idaho and eastern Washington for decades. The primary cause of this reduction in pH is the regular use of ammonium-based fertilizers. When these forms of fertilizer are converted to nitrate by bacteria, positively charged hydrogen ions are released into the soil reducing the pH. Few options exist for mitigation of soil acidification aside from planting tolerant crops and liming. Of the crops grown in the inland Pacific Northwest, there are few crops (e.g. triticale, oats) that have high tolerance to aluminum toxicity. While mechanisms of aluminum tolerance are known within wheat, and regionally adapted cultivars of wheat have been screened for tolerance, other common crops such as canola has received little attention.

The objectives of this project were to continue evaluation of a genetically diverse collection of spring canola breeding lines or cultivars for tolerance to aluminum toxicity, and to evaluate the crop response of canola to lime application. To accomplish this a series of field trials were conducted in Moscow, ID and Rockford, WA in fields with documented acidification issues and known aluminum toxicity.

Tolerance in spring canola germplasm:
During 2016, 220 spring canola germplasm accessions the USDA Plant Introduction collection and the UI canola breeding collection were tested for tolerance to aluminum toxicity. Tolerance was estimated by determining how well a variety responded to lime application and those that did not respond to lime application were assumed to be more tolerant than those which had greater response. Using this criterion, we selected the 15 lines that were most responsive to liming and the 15 lines that were least responsive to liming and tested these in a second trial at Moscow in 2017. The field in Moscow had a soil pH of 4.1 and according to a sample collected after harvest, the application of 3 tons/A of fluid lime increased the soil pH to an average of 4.3 in the top 6 inches. Seeding of this trial was delayed due to wet soil conditions in this field and was not seeded until May 25. May 15 is a typical cut-off for spring canola to achieve a good yield. Due to the soil pH at this site, the average yield without lime was 322 lb/A and with lime it was increased to 362 lb/A. Flowering date and vigor rating (1-9, with 9 being good vigor) were recorded for each entry with vigor rating occurring on June 26 and July 11. The vigor scores recorded on June 26 ranged from 4.3 to 7.8 and were always higher when grown in a limed plots. There was a significant increase in plant vigor ratings from 5.1 in the no lime soils to 7.0 in the limed plots. The later vigor rating (July 11) showed less of a response to liming and many of the plants in the no lime portions of the field had increased vigor. This is likely due to plant roots growing through the upper later of acidity and reaching a depth at which soil pH was higher. All soils that have been examined in northern Idaho and eastern Washington have stratification, with most of the acutely acidic soil occurring in the upper 6

to 9 inches. At a depth of 12 to 24 inches, the soil pH is usually near 6 or higher. Flowering date also was significantly impacted by liming, resulting in an earlier flowering date (1 day sooner) compared to the no lime plots. While yield was improved by the addition of lime, the increase was not significant.

The relative response of each of the 30 breeding line to the application of lime was evaluated. The increase in vigor in limed versus no lime plots increased by 0.8 to 3.0 with an average of 1.9. The yield response to lime application varied from a 18% decrease in yield to a 62% increase in yield relative to the no lime plots (Figure 1). Of the 30 lines tested, 21 had a positive response to lime application. In comparing the yield response of lines between 2016 and 2017, only nine of the lines were positive in both years and three of the lines were negative in both years. The other 18 lines had a different response to lime in each year of the study. The lines tested in 2017 were the 15 most responsive and the 15 least responsive to lime application. Due the variable response between years, it is likely that high error as a response of low yield and within trial variability interfered with the yield response to lime. Based on this data, it is difficult to ascertain whether there is differential tolerance to aluminum toxicity within spring canola germplasm tested. In addition, both aluminum tolerant and intolerant varieties of wheat will positively respond to lime application. Due to similar yields among most of the lines in the absence of lime, it is unlikely that differential tolerance to aluminum exists within the lines of spring canola tested.

Table 1. Vigor, flowering date and yield for breeding lines seeded into plots with and without NuCal fluid lime.

Treatment	Vigor (1-9) June 26	Vigor (1-9) July 11	Flowering (Days After Planting)	Yield (lb/A)
Lime	7.0 a	7.1	41.5 b	362
No lime	5.1 b	6.8	42.4 a	322
LSD (0.05)	1.0	ns	0.7	ns

Note: Values are an average of all 30 lines tested in the study. Values with different letters are significantly different. The comparisons with 'ns' were not significantly different from each other.

Spring canola cultivar response to liming:

At both Moscow and Rockford, 24 entries from the Pacific Northwest Canola Variety Trial were tested. Cultivars or selections were tested with and without liming in replicated field trials. Most of these varieties are *Brassica napus* (canola) with the exception of the following:

Early One	*B. rapa* (canola)
Goldrush	*B. rapa* (canola)
IndiGold	*B. juncea* (Indian condiment mustard)
Oasis	*B. juncea* (canola-quality Indian mustard)
Pacific Gold	*B. juncea* (Indian condiment mustard)
IdaGold	*Sinapsis alba* (yellow condiment mustard)
IH.7.5.9	Interspecific Yellow mustard x Indian mustard hybrid

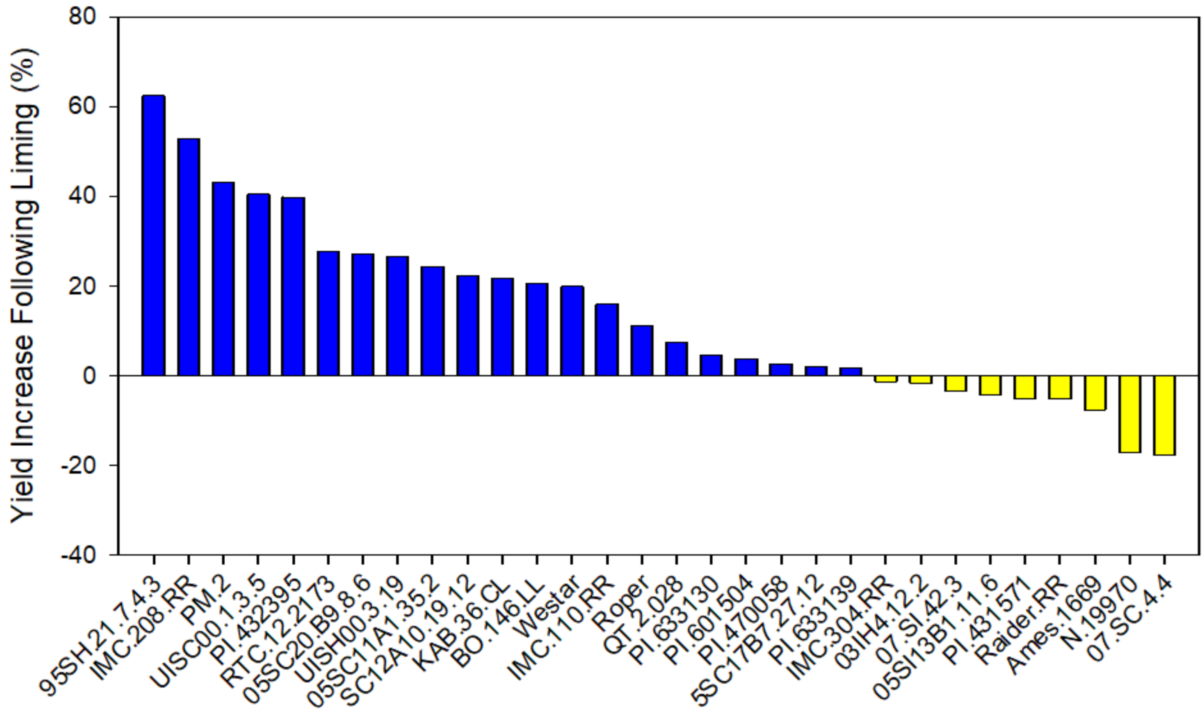

Figure 1. Response of spring canola germplasm lines to lime application. Values are the percent increase or decrease in yield with lime application relative to the no lime plots.

The cultivar trial in Moscow was seeded on May 25 and the Rockford trial was seeded on May 26. As previously mentioned, these seeding dates were markedly later that optimal seeding dates to achieve high spring canola yields but could not be avoided due to the unusually wet spring in 2017 and the need to apply lime prior to planting. Both variety trial locations were treated with 3 ton/A of NuCal fluid lime prior to planting in the spring of 2017. After harvest, soil samples to a depth of 6 in were pulled from the no lime and limed portions of the plots. The Moscow location had a pH of 4.0 in the no lime and 4.4 in the limed portions while Rockford increased from a pH of 4.6 in the no lime to 5.8 in the limed portion. Vigor rating was recorded for both locations along with yield and seed oil content. In addition, a second vigor rating and flowering data were collected from the Moscow location.

A universal vigor response to liming was seen with all varieties increasing in vigor with the application of lime at Moscow and in the combined data. However, there was no significant vigor rating response at Rockford. The increase in vigor rating ranged from 2.5 to 5.5 at Moscow and -1.5 to 1.8 at Rockford (Table 2). The greatest increase in vigor occurred at Moscow with a significant increase from an average of 3.3 in the no lime to 6.8 in the limed plots. Flowering date was recorded only for the Moscow trial and was found to be 2.6 days earlier for the limed plots compared to the no lime. The earlier flowering date as a result of liming ranged from 0.3 to 7.6 days with the greatest response occurring for *B. juncea* (6.5 days), *B. rapa* (2.6 days) and the interspecific hybrid (3.5 days). Despite the low yield, there was a significant increase in yield at both Moscow and Rockford in response to lime application. There was also a significant increase in oil content at Moscow with lime application and while not significant, there was a 0.8% increase in oil content at Rockford.

The average yield for canola cultivars tested at Moscow and Rockford is shown in Table 3. There is a similar ranking of cultivars at both locations. However, at Moscow the yield of *B. rapa*, *B. juncea* and *S. alba* cultivars were the lowest in the trial, and much of the yield response was due to the limed plots with very low or no yield occurring in the no lime plots. These data indicates that *B. rapa*, and more especially *B. juncea* and *S. alba* lines are more sensitive than *B. napus* cultivars to aluminum toxicity. This is similar to finding from a study conducted in 2008 to examine crop tolerance to aluminum in Rockford in which the spring canola was more vigorous than mustard and yielded more than twice that of mustard (Schroeder and Paulitz, unpublished).

Table 2. Vigor, flowering date and yield for canola and mustard cultivars from the Pacific Northwest Canola Variety Trial seeded into plots with and without NuCal fluid lime.

Treatment	Vigor (1-9) June 26	Vigor (1-9) July 11	Flowering (Days After Planting)	Yield (lb/A)	Oil Content (%)
Combined					
Lime	6.3 a	--	--	381 a	37.5 a
No lime	4.5 b	--	--	244 b	36.7 b
LSD (0.05)	0.5	--	--	50	0.7
Moscow					
Lime	6.8 a	5.5 a	39.7 b	379 a	37.1 a
No lime	3.3 b	3.5 b	42.3 a	197 b	36.3 b
LSD (0.05)	0.9	0.9	0.4	126	0.6
Rockford					
Lime	5.8	--	--	383 a	37.8
No lime	5.6	--	--	292 b	37.0
LSD (0.05)	ns	--	--	31	ns

Note: Values are an average of all 24 cultivars tested in the study. Values with different letters are significantly different. The comparisons with 'ns' were not significantly different from each other.

The yield increase at Moscow and Rockford with lime application is expressed as a percent increase in yield with liming relative to no lime in Figure 2. The yield was positively impacted for all cultivars tested in at both locations with the exception of HyCLASS 955 RR and Early One at Rockford. Note that mustard lines have been removed from this graph because a percent increase could not be expressed for IdaGold and Oasis since the yield for these cultivars was 0, and because of extremely poor yield in the no lime plots the yield of Pacific Gold and IndiGold mustards increase by 3,296 and 7,831%, respectively. At Moscow, the percent yield increase with liming for *B. napus* and *B. rapa* varieties ranged from 24 to 300%. At Rockford, there was a -26 to 239% increase across all cultivars. HyCLASS 955 RR and Early One both had a negative response to lime application at Rockford, but in Moscow these two varieties had a 63 and 32% increase in yield following lime application, respectively. Due to variability within the field, the negative response to liming is probably an artifact and does not accurately represent the response of these varieties to lime. The impact of aluminum toxicity on mustard lines was less noticeable in Rockford since the soil pH was not as severely acidic compared to Moscow.

Table 3. Average yield for each cultivar seeded at Moscow and Rockford in limed and no lime plots in 2017.

	Moscow		Rockford	
Cultivar	Yield (lb/A)	Rank	Yield (lb/A)	Rank
HyCLASS 930 RR	647	1	572	2
DKL 70-07 RR	623	2	457	6
DKL 55-55 RR	545	3	555	3
Star 402 RR	536	4	501	4
HyCLASS 955 RR	524	5	652	1
6080 RR	420	6	420	7
V12-1 RR	381	7	350	9
InVigor L140P LL	351	8	316	12
5535 CL	347	9	248	16
Empire	340	10	484	5
Westar	290	11	243	17
07.SI.8.A10	267	12	201	21
InVigor L120 LL	265	13	297	14
CS 2200 CL	247	14	231	19
Profit	218	15	227	20
C 1516 SU	192	16	168	23
C 1511 SU	175	17	195	22
IndiGold	161	18	304	13
Oasis	100	19	101	24
Pacific Gold	96	20	345	11
IH.7.6.5.9	79	21	345	10
Early One	41	22	248	15
IdaGold	35	23	241	18
Goldrush	24	24	395	8
LSD (0.05)	111	--	100	--

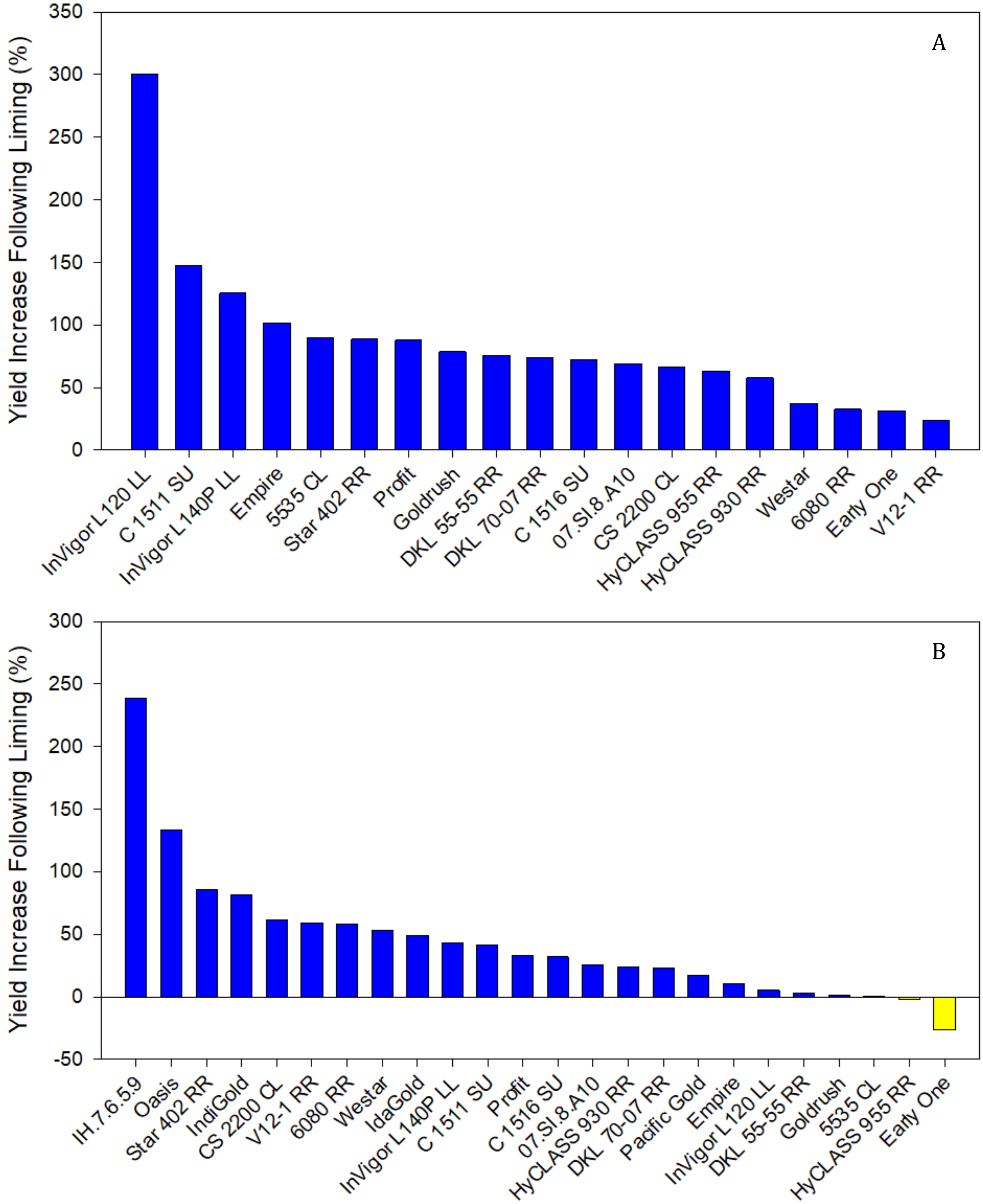

Figure 2. Response of spring canola cultivars to lime application at Moscow, ID (A) and Rockford, WA (B). Values are the percent increase or decrease in yield with lime application relative to the no lime plots.

Conclusions:
Aluminum toxicity was more severe in Moscow compared to Rockford. Even with the application of 3 ton/A of ultramicronized lime at this location, the yields are likely still be depressed by the soil pH. Other trials planted on the same day in other areas of the research farm in Moscow had much better vigor and yield. This location would probably benefit from an additional application of lime to bring the pH up to 5.5 to 6.0. Retesting these cultivars and elite breeding lines in a year with more favorable seeding conditions would provide a better idea of the response to lime application and soil pH.

Data from the germplasm trial as well as the spring canola cultivars from the variety trial screening demonstrated that none of the *B. napus* germplasm lines or cultivars were more or less tolerant than other *B. napus* lines or cultivars. Nearly all cultivars and lines responded positively following lime application and there was not a trend between 2016 and 2017 or between locations to suggest differential tolerance. However, the vigor and yield data at Moscow strongly supports the idea that *B. rapa*, *B. juncea* and *S. alba* are more sensitive to aluminum toxicity than *B. napus*. Given those finding, if a grower has a field with documented or suspected low pH, we recommend that the condiment mustard species and *B. rapa* and *B. juncea* canola cultivars should be avoided.

Based on this work, we would suggest that *B. napus* canola is moderately tolerant to aluminum toxicity. At the same field location in Moscow, pea, lentil and barley varieties have extremely reduced vigor and rarely produce seed. Likewise, aluminum sensitive wheat varieties will not tiller, have very poor growth and usually die before the end of June. However, in fields with documented soil acidification and aluminum toxicity, lime application would be very beneficial for spring canola production. Following lime application, the canola varieties tested in this study had significantly improved vigor earlier flowering date, higher yield and greater oil content.