2022 Final Report

from the

East Central Research Foundation

Project Title: Barley MAX Experiment 2
SFP #20190403

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Project Identification

1. **Project Number:** SFP #20190403
2. **Producer Group Sponsoring the Project:** Saskatchewan Barley Development Commission
3. **Project Location(s):** Yorkton, Melfort, Prince Albert and Swift Current, SK
4. **Project start and end dates (month & year):** April 2020 to February 2023
5. **Project contact person & contact details:**

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Objectives and Rationale

6. **Project objectives:**

Yield is primarily driven by nitrogen fertilizer rates, which are generally kept low in malt barley production to prevent higher than desirable protein levels. New barley varieties have improved agronomics that will allow producers to increase nitrogen rates to achieve higher yields, while maintaining malt quality protein levels. Experiment 2 will determine optimum nitrogen fertilizer recommendations for production of new malt barley varieties in comparison to a recent industry standard variety.

7. **Project Rationale:**

Western Canadian barley acres have shrunk by more than 50 per cent in the past 20 years. With the lowest rate of gain among major crops and competition with other low-cost feed options, fewer producers are choosing to grow barley. Yet, there remains optimism that barley can be competitive with other cropping options.

Compared to other crop types, the acceptance of new varieties with improved disease resistance and higher yields is limited. As a result, the majority of barley production is with 20-year-old technology. There are strong indications that the industry is shifting to newer varieties with improved agronomics, but the optimum agronomic input packages are not known for these newer varieties.

Barley is generally either malt or feed, with a significant price difference sometimes in

place. As a result, producers are incentivized to manage for malt and sacrifice yield in order to do so. Research is needed to help producers increase their yields, while maintaining malt quality.

Significant advancements in barley agronomy were made under one of the recent barley clusters, but the inputs investigated have not been looked at in a comprehensive package in Saskatchewan, with the most up-to-date varieties.

8. Methodology:

Trials were established at Yorkton, Prince Albert, Melfort and Swift Current from 2020 to 2022. Each trial was setup as a 2-order factorial with 4 replicates. The malt barley varieties AC Metcalfe, AAC Synergy and CDC Bow were each tested at 60, 120, 180 and 240 lb/ac of soil + fertilizer N (Table 1). Originally, the N values were supposed to be in kg/ha but a mistake in the protocol sent to sites used lb/ac and we have maintained these units between site-years for consistency. The background level of soil N in the top 12 inches varied between location and these levels were taken into consideration when determining rates of applied fertilizer N. The plot size, row spacing, and fertilizer application techniques for seeding varied between locations depending on available equipment. Each location also applied 26.8 lb P_2O_5/ac and 13.4 lb K_2O/ac with every treatment. Herbicides and insecticides were applied based on industry standards and as required at each location. A complete list of operations and dates are available in Tables 2-4.

Table 1. Treatment List

Treatment #	Variety	N (Soil + fert)
1	AC Metcalfe	Background N
2	AC Metcalfe	60 lb N/ac
3	AC Metcalfe	120 lb N/ac
4	AC Metcalfe	180 lb N/ac
5	AC Metcalfe	240 lb N/ac
6	AAC Synergy	Background N
7	AAC Synergy	60 lb N/ac
8	AAC Synergy	120 lb N/ac
9	AAC Synergy	180 lb N/ac
10	AAC Synergy	240 lb N/ac
11	CDC Bow	Background N
12	CDC Bow	60 lb N/ac
13	CDC Bow	120 lb N/ac
14	CDC Bow	180 lb N/ac
15	CDC Bow	240 lb N/ac

Table 2. Dates of operations for 2020

Operations in 2020	**Melfort**	**Prince Albert**	**Swift Current**	**Yorkton**
Pre-seed Herbicide Application	**May 24** (Heat LQ + Glyphosate 540)	**N/A**	**May 4** (Glyphosate + AIM + Merge)	**N/A**
Seeding Date	**May 22**	**May 23**	**May 16**	**May 8**
Emergence Counts	**June 12**	**June 9**	**May 28**	**May 27**
In-crop Herbicide	**June 23** (Prestige XC) **July 3** (Axial)	**June 10** (Infinity)	**May 29** (Liquid Achieve + Buctril M & Turbocharge)	**June 2** (Prestige) & June 8 (Axial)
Fungicide	**July 24** (Prosaro)	**July 21** (Twinline)	**N/A**	**July 1** (Trivapro A &B)
Heading Date	**July 22**	**July 17-20**	**July 21**	**July 6**
Days to Maturity	**Aug 17-21**	**Aug 13-20**	**Aug 6**	**July 30**
Lodging Rating	**Aug 31**	**Sept 2**	**N/A**	**N/A**
Harvest	**Sept 15**	**Sept 9**	**Aug 18**	**Aug 20**

Table 3. Dates of operations for 2021

Operations in 2021	**Melfort**	**Prince Albert**	**Swift Current**	**Yorkton**
Pre-seed Herbicide Application	**May 14** (Glyphosate 540 + Heat)	**N/A**	**May 3** (Glyphosate + AIM +Merge)	**N/A**
Seeding Date	**May 10**	**May 22**	**May 11**	**May 11**
Emergence Counts	**June 2**	**June 8**	**June 9**	**June 4**
In-crop Herbicide	**June 8** (Prestige) **June 22** (Axial)	**June 15** (Dyvel)	**June 7** (Liquid Achieve + Buctril M + Turbocharge)	**June 7** (Prestige) **June 16** (Axial)
Fungicide	**N/A**	**N/A**	**N/A**	**June 28** (Trivapro A +B)
Heading Date	**July 12**	**July 19**	**July (various)**	**July 16**
Days to Maturity	**Aug 3**	**Aug 25**	**Aug (various)**	**July 26**
Lodging Rating	**N/A**	**Aug 17 & Sept 8**	**N/A**	**N/A**
Harvest	**Aug 11**	**Sept 8**	**Aug 30**	**Aug 27**

Table 4. Dates of operations for 2022				
Operations in 2022	**Melfort**	**Prince Albert**	**Swift Current**	**Yorkton**
Pre-seed Herbicide Application	**May 12** (Liquid Avadex 1.2L/ac) **May 21** (Roundup Transorb HC 540 g)	**May 21** (Roundup Transorb @ 1L/ac)	**May 12** (Glyphosate + Aim + Merge)	**None**
Seeding Date	**May 16**	**June 2**	**May 17**	**May 23**
Emergence Counts	**June 7**	**June 22-23**	**June 15**	**June 6**
In-crop Herbicide	**June 22** (Axial) **June 28** (Prestige XC)	**June 28** (Infinity + Puma Advance)	**June 8** (Liquid Achieve + Buctril M)	**June 8** (Akito and Axial separate passes)
Fungicide	**July 18** (Caramba)	**None**	**none**	**July 6** (Trivapro AB)
Heading Date	**July 20**	**Various**	**Various**	**n/a**
Days to Maturity	**Aug 16 -22**	**Various**	**Various**	**Aug 12**
Lodging Rating	**Aug 24**	**Aug 22**	**NA**	**Sept 6**
Harvest	**Sept 8**	**Sept 2**	**Aug 17**	**Sept 6**

9. Results:

Growing Season Weather

Mean monthly temperatures and precipitation amounts with long-term (1981-2010) averages for 5 sites are listed in Table 5 and 6. In 2020, seasons were warmer than the long-term average at Yorkton and Swift Current and cooler at Prince Albert. Melfort experienced near normal temperatures. Precipitation was near normal at most locations except Yorkton, which experienced drought with only 66% of average long-term precipitation received. In 2021, temperatures were well above the long-term average at all locations and drought was widespread. Melfort, Prince Albert, Swift Current and Yorkton only received 61%, 72%, 74% and 54% of long-term average precipitation, respectively. In 2022, temperatures were near normal in Melfort and Prince Albert. Yorkton experienced above average temperature and temperatures were well above average at Swift Current where drought was experienced. While precipitation was well below average at Swift Current, the remaining sites received adequate to excellent levels of precipitation. The Yorkton site experienced hail in 2022, but the crop recovered.

Table 5. Mean monthly temperatures and long-term (1981-2010) normals for the 2020, 2021 and 2022 growing seasons at 4 sites in Saskatchewan.

Location	Year	May	June	July	August	Avg. / Total
		----------*Mean Temperature (°C)* ----------				
Melfort	2020	10.1	14.3	18.8	17.6	15.2
	2021	9.6	18.2	20.1	16.9	16.2
	2022	9.9	15.2	18.2	18.7	15.5
	Long-term	***10.7***	***15.9***	***17.5***	***16.8***	***15.2***
Prince Albert	2020	9.2	13.4	17.6	16.1	14.1
	2021	10.1	18.3	20.3	17.0	16.4
	2022	10.5	15.5	18.3	18.5	15.7
	Long-term	***11.4***	***15.9***	***18.5***	***17.1***	***15.7***
Swift Current	2020	*10.9*	*16.6*	*18.2*	*19.5*	*16.3*
	2021	9.5	18.4	21.7	18	16.9
	2022	10.9	15.9	19.8	20.9	16.9
	Long-term	***10.9***	***15.3***	***18.2***	***17.6***	***15.5***
Yorkton	2020	10.5	16.4	19.9	18.3	16.3
	2021	8.9	19.1	21.0	17.3	16.5
	2022	10.6	15.7	18.6	18.9	16
	Long-term	***10.4***	***15.5***	***17.9***	***17.1***	***15.2***

Table 6. Precipitation amounts and long-term (1981-2010) normals for the 2020, 2021 and 2022 growing seasons at 4 sites in Saskatchewan

		---------- *Precipitation (mm)* ----------				
Melfort	2020	26.7	103.7	52.4	18.5	201.3
	2021	31.4	37.6	0.2	69.3	138.5
	2022	90.8	78.1	34.9	36.5	240.3
	Long-term	***42.9***	***54.3***	***76.7***	***52.4***	***226.3***
Prince Albert	2020	68.4	91.4	32.2	33.2	225.2
	2021	30.1	80.3	8.6	59.9	178.9
	2022	17.9	75.7	63.7	37.8	195.1
	Long-term	***40.4***	***79.6***	***84.6***	***42.9***	***247.5***
Swift Current	2020	36.3	80.0	62.5	6.5	185.3
	2021	35.0	29.6	38.9	55.8	159.3
	2022	51.2	37.7	90.4	7.5	187
	Long-term	***44.1***	***74.5***	***51.9***	***43.2***	***213.7***
Yorkton	2020	16.7	33.6	80.1	49.3	179.7
	2021	24.6	18.1	35.2	69.7	147.6
	2022	137.9	57.9	38.4	90.8	325
	Long-term	***51***	***80***	***78***	***62***	***272***

Background levels of soil N were variable between site-years (Table 7). Background soil N for Melfort (2020-2022), Prince Albert (2020-2021), and Yorkton (2020-2021) exceeded the 60 lb N/ac treatment. Thus, no additional N was added to this treatment for these locations and it had the same N fertility level as background N treatment. At Prince Albert and Swift Current in 2022, soil N exceed 120 lb/ac so no additional N would have been added to the 60 and 120 lb N/ac treatments. In other words, the background N, 60 lb N/ac and 120 lb N/ac treatments were all at the same level of fertility for these treatments. Rate of soil + fertilizer N were consistent for 180 and 240 lb/ac levels between all locations.

Table 7. Soil Test Nitrate Levels for each location (lb/ac) in 2020, 2021 and 2022.

Nitrate Levels (lbs NO_3-N/ac)	**Melfort**	**Prince Albert**	**Swift Current**	**Yorkton**
2020				
0-15cm (0-6in)	21	18	20	15
15-30cm (6-12in)	24	28	11	10
15-60cm (6-24in)				
30-60cm (12-24in)				
Total 0-60cm (0-24in)	67 est.	69 est.	47 est.	38 est.
2021				
0-15cm (0-6in)	34	21	14	22
15-30cm (6-12in)	28			
15-60cm (6-24in)		33	30	29
30-60cm (12-24in)				
Total 0-60cm (0-24in)	93 est.	54	44	77 est.
2022				
0-15cm (0-6in)	21	50	9	23
15-30cm (6-12in)	23	42		
15-60cm (6-24in)			150	81
30-60cm (12-24in)				
Total 0-60cm (0-24in)	66 est.	138 est.	159	104

For statistical analysis, trials were grouped into high and low yielding site-years. The high yielding group consisted of Melfort (2020 & 2022), Prince Albert (2020-2022), Swift Current (2020) and Yorkton (2022). The low yielding group consisted of Melfort (2021), Yorkton (2020-2021) and Swift Current (2021-2022). On average, the high yielding group produced 4980 kg/ha (92.6 bu/ac) of grain at 12% protein and the low yielding group produced 2176 kg/ha (40.5 bu/ac) of grain at 15% protein. Drought was responsible for the low yields. The site-years were separated into groups to highlight how environment affects the response of each malt barley variety to increasing nitrogen. The impact of variety and level of soil + fertilizer N on barley emergence, maturity, lodging and yield are summarized in Tables 8 and 9 in the appendix for the high and low yielding sites, respectively. Seed quality parameters in the tables include grain protein, thins, plumps, 1000 kernel weight, 4 ml and 8 ml germination tests. Mean separations for the seed quality parameters are not presented as each value is based on a single sample bulked over 4 replications. Individual site-year analyses are found in the appendix (Tables 10-21).

Emergence

Crop emergence varied between site-years. For the low yielding group, emergence varied from 175 plants/m^2 at Swift Current (2021) to 278 plants/m^2 at Yorkton (2020). For the high yielding group, emergence varied from 164 plants/m^2 at Prince Albert (2021) to 321 plants/m^2 at Yorkton (2022). Increasing rate of N significantly reduced emergence for both the low and high yielding groups (Tables 8 & 9). However, the reduction was not large enough to greatly affect yield.

Maturity

AAC Synergy was later maturing than AC Metcalfe for both low and high yielding groups (Tables 8 & 9). However, maturity differences between varieties were not large and rankings were not consistent between site-years. Added N delayed maturity for both low and high yielding groups which is a well-recognized response to increased N fertilizer.

Lodging

While lodging was higher for Metcalfe compared to the other varieties for the high yielding group, differences were usually small. However, there were some significant interactions. At Prince Albert (2020), CDC Bow and AAC Synergy were substantially more resistant to lodging at the highest rate of N than AC Metcalfe (data not shown). At Melfort (2022) and Yorkton (2022), CDC Bow was substantially more resistant to lodging than the other two varieties at the highest rate of N (data not shown). This is in keeping with regional information which rates lodging resistance for CDC Bow as "Very Good" compared to "Fair" for the other varieties.

Yield, Protein and Economics

For the high yielding group, AAC Synergy was significantly higher yielding than CDC Bow which was significantly higher yielding than AC Metcalfe (Table 8). The trend was similar for the low yielding group, except only AAC Synergy was significantly higher yielding (Table 9). For both groups, AC Metcalfe had higher grain protein than AAC Synergy which is likely related to its lower yield potential.

For both the low and high yielding groups there was a significant variety by N interaction. For the low yielding group the yield of AC Metcalfe was less responsive to added N than AAC Synergy. However, the response to added N was modest for all varieties in the low yielding group and was not always positive (Figure 1). In contrast, grain protein was highly responsive to increasing N (Figure 2). While levels of grain protein were higher for AC Metcalfe compared to the other varieties, the protein levels were too high for malt, regardless of the level of N or variety. However, the higher level of grain protein for AC Metcalfe implies it requires less N than the newer varieties.

Figure 1. Effect of Increasing N on Yield of Three Malt Barley Varieties for Low Yielding Site -years.

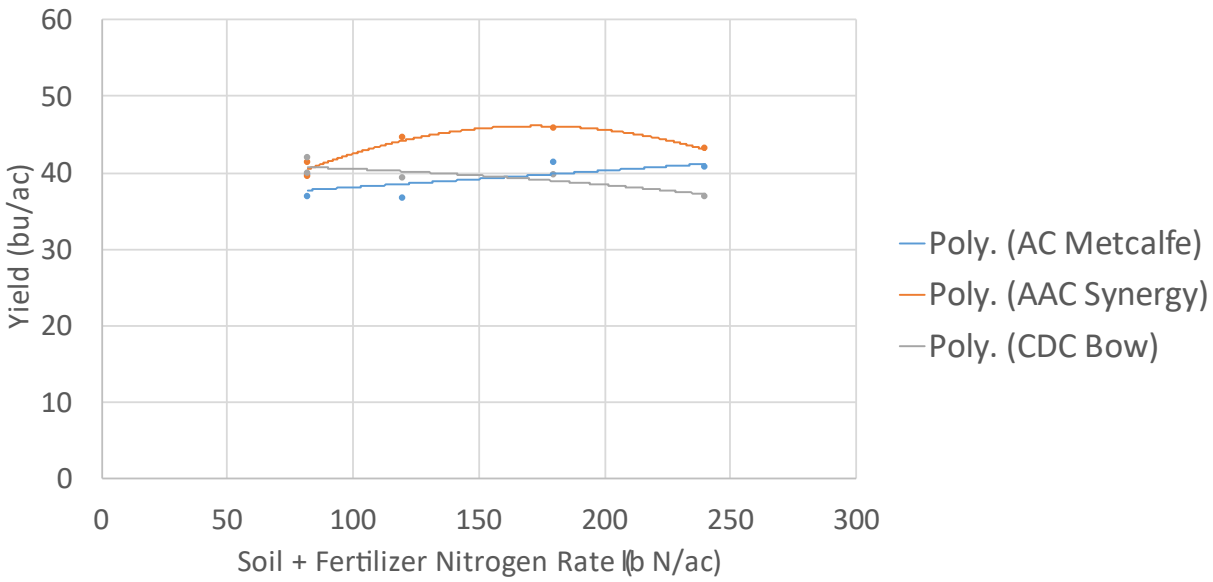
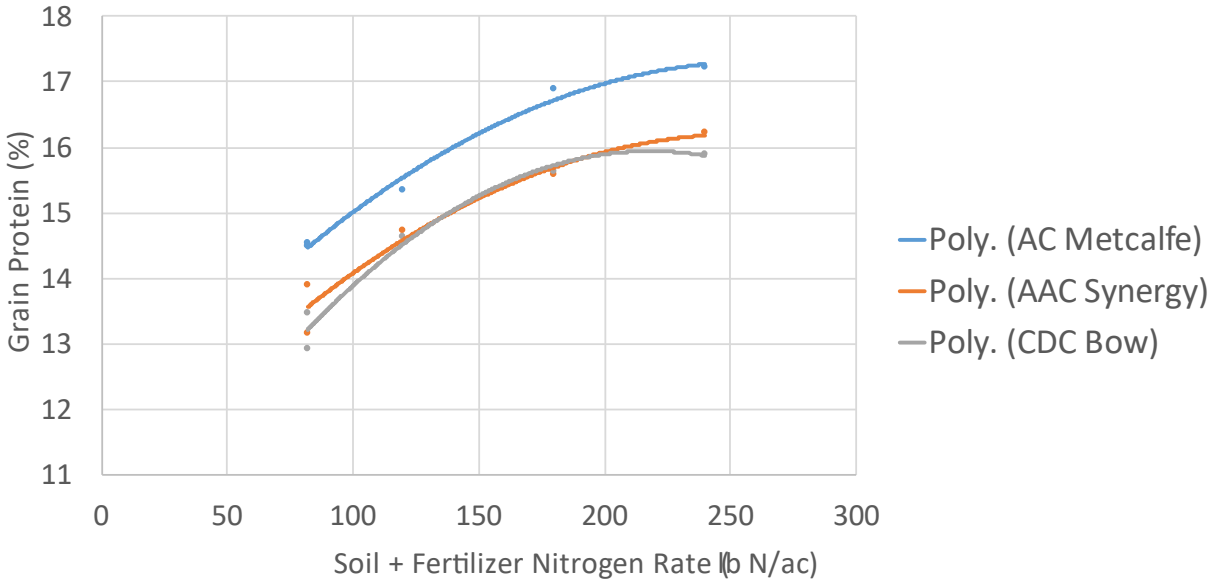


Figure 2. Effect of Increasing N on Grain Protein of Three Malt Barley Varieties for Low Yielding Site -years.



In contrast, yields were much more responsive to added N for the high yielding group and grain protein was at lower levels (Figure 3 & 4). The yields of AAC Synergy and CDC Bow were responsive to higher rates of N than AC Metcalfe. In addition, grain protein for

AAC Synergy and CDC Bow was considerably lower compared to AC Metcalfe. These differences mean the optimum rate of N to achieve malt is lower for AC Metcalfe compared to the other varieties. To illustrate this difference, an economic comparison using only AAC Synergy and AC Metcalfe will be made as the economics for AAC Synergy and CDC Bow would be very similar based on their comparable yield and grain protein responses to added N.

Figure 3. Effect of Increasing N on Yield of Three Malt Barley Varieties for High Yielding Site-years.

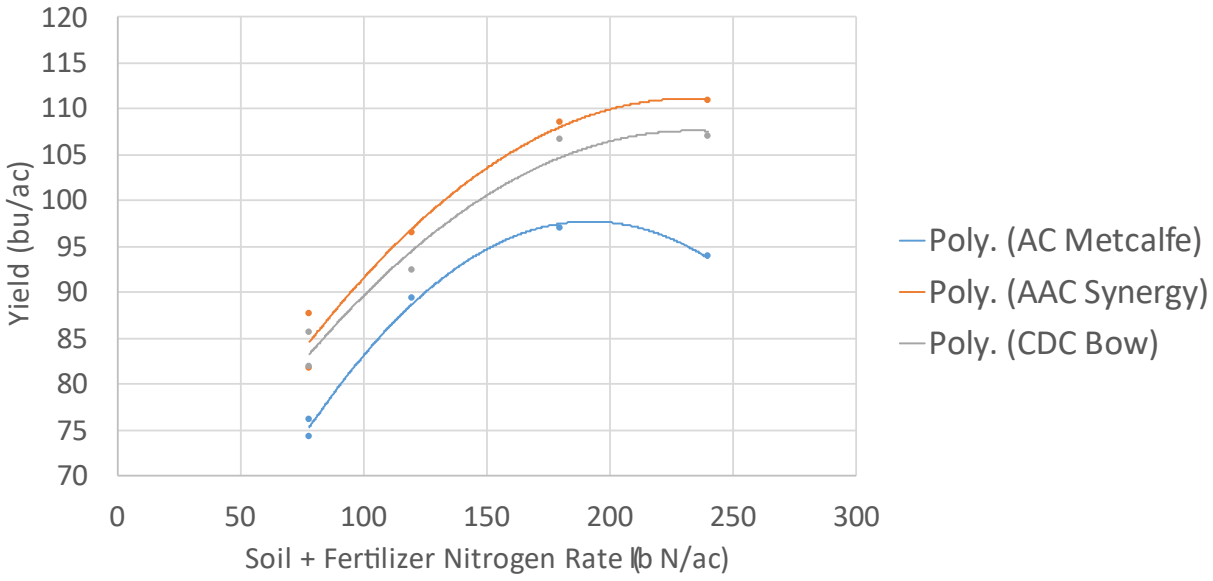
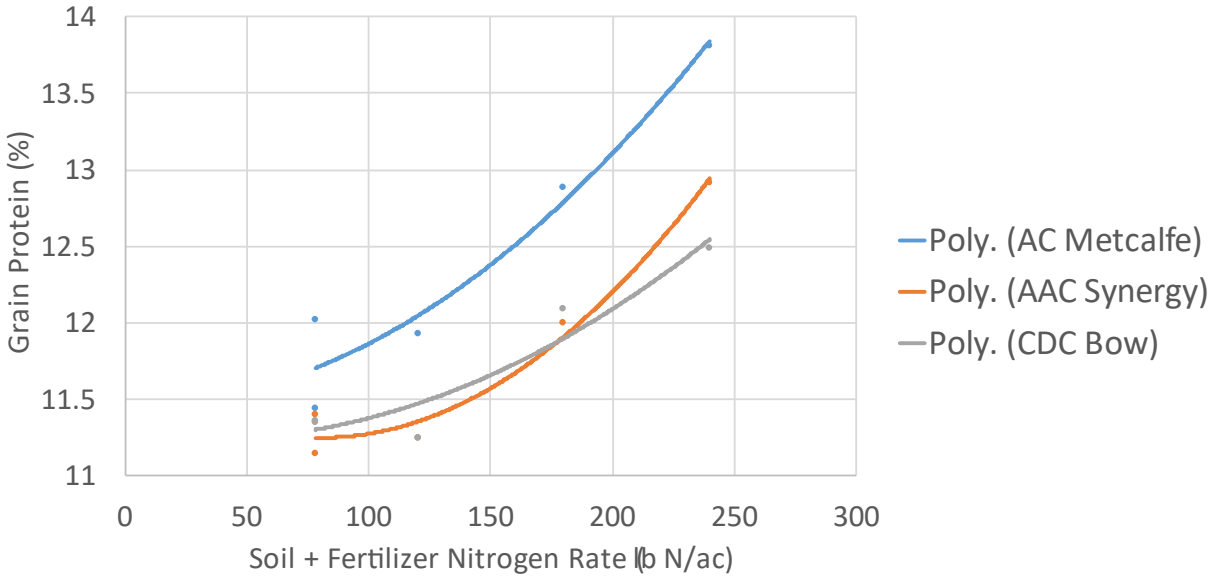
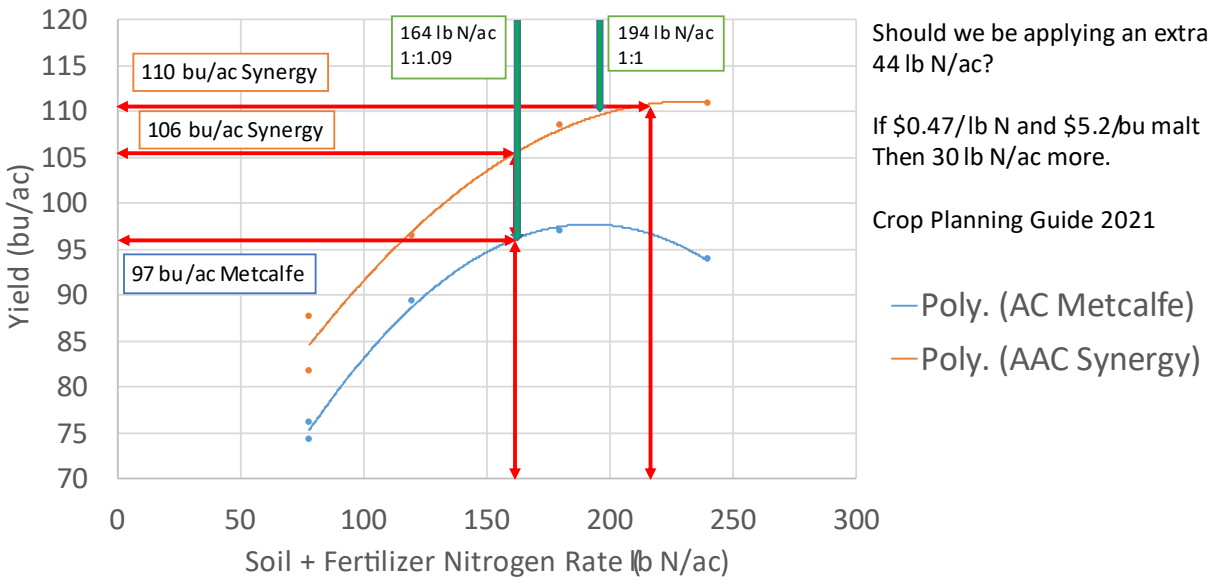


Figure 4. Effect of Increasing N on Grain Protein of Three Malt Barley Varieties for High Yielding Site -years.



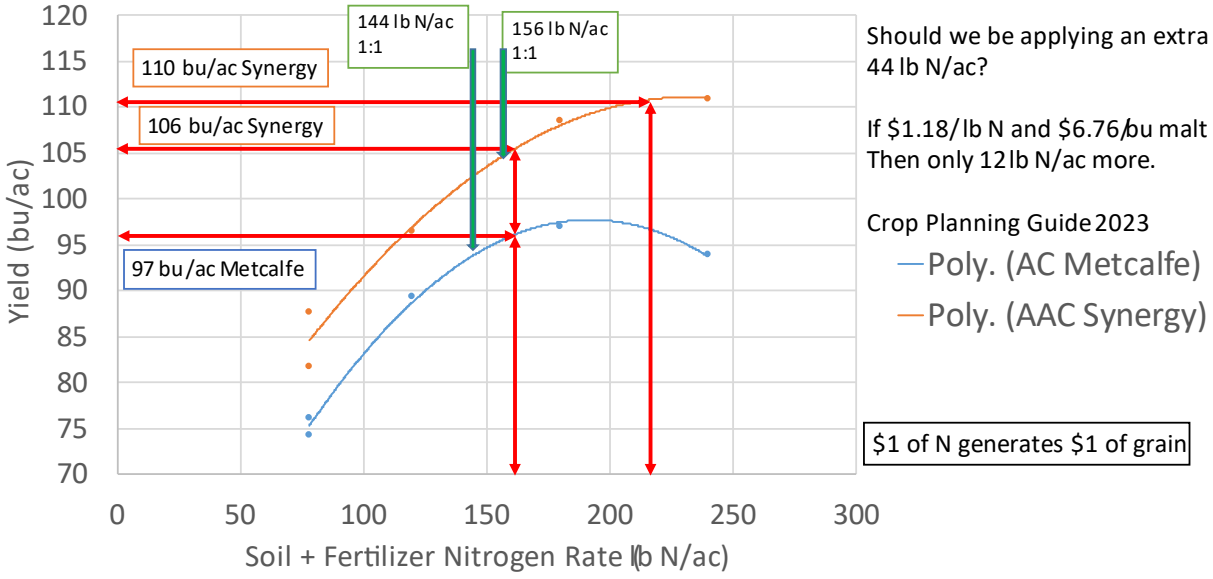
Let us assume barley grain with a protein greater than 12.5% will not be accepted for malt. For Metcalfe, 12.5% grain protein is not reached until soil + fertilizer N has reached 164 lb N/ac (Figure 4). In contrast, levels of soil + fertilizer N can be increased until 208 lb N/ac before 12.5% protein is reached with AAC Synergy. In other words, another 44 lb N/ac can be added to AAC Synergy relative to AC Metcalfe before grain protein is too high for malt quality. However, this does not mean an extra 44 lb N/ac should be applied as the economics need to be considered. At the rate of N that results in 12.5% grain protein for Metcalfe, Metcalfe yielded 97 bu/ac and Synergy yielded 106 bu/ac, a difference of 9 bu/ac (Figure 5). But the N rate for AAC Synergy can still be pushed another 44 lb N/ac before 12.5% protein is exceeded. This raises the yield of AAC Synergy another 4 bu/ac to 110 bu/ac. Potentially an additional 13 bu/ac of malt can be produced by growing AAC Synergy instead of AC Metcalfe. If an N price of $0.47/lb and $5.20/ bu of malt are used based on Saskatchewan Crop Planning Guide 2021 assumptions, then the most economic rates of soil + fertilizer N was 164 lb/ac for Metcalfe and 194 lb/ac for AAC Synergy. This difference is 30 lb N/ac which may not be a perfectly fair comparison. At 194 lb/ac level of N fertility, the last dollar spent on added N is returning a dollar worth of malt grain for AAC Synergy. However, the last dollar spent of N for AC Metcalfe is providing $1.09 in malt grain. More N can not be added in the AC Metcalfe scenario to be at a 1:1 marginal return because grain protein of 12.5% would be exceeded. If we reduce the N rate for AAC Synergy so the marginal returns of added N are equal between the varieties at 1:1.09, then AAC Synergy should only be receiving an additional 22 lb N/ac more than AC Metcalfe.

Figure 5. Effect of Increasing N on Yield of Three Malt Barley Varieties for High Yielding Site-years.



If a poorer economic scenario based on 2023 Saskatchewan Crop Planning Guide assumptions of $1.18/ lb N and $6.67/bu of malt is used, then only 12 lb N/ac more is required for AAC Synergy to maximum returns. This assumes 1:1 marginal return on N for both varieties.

Figure 6. Effect of Increasing N on Yield of Three Malt Barley Varieties for High Yielding Site-years.



Other seed quality factors

Other seed quality factors measured included thins, plumps, 1000 kwt, 4 ml energy germination and 8 ml water sensitive germination. For the high yielding group, increasing N rate tended to decrease % plumps. On average, plumps were below 95% for AC Metcalfe which is low for malt quality (Table 8). In contrast, % plumps were unaffected by increasing N for the low yielding sites and were within acceptable levels for malt for all varieties (Table 9). Percent plumps were very low for all varieties at Swift Current 2020 (Table 12), and for AC Metcalfe at Prince Albert 2022 (Table 19). The reason for this is not clear. Both of these site-years were high yielding. On average, 4 ml germination was quite poor for the high yielding group and even poorer for the low yielding group. Increasing N did not appear to affect germination rates for either group. However, germination varied greatly between sites. Germination rates were acceptable for malt at multiple locations which tended to be from the high yielding group but not always. These included Melfort 2020, Swift Current 2020, Melfort 2021, Melfort 2022, Prince Albert 2022, Swift Current 2022 (Tables 10, 12, 14, 18-20). Eight ml germination rates were lower for both groups but the decline was not excessive, indicating water sensitivity was not an issue for either group.

Extension

- ECRF presented the results from this trial at WARC's Crop Opportunity webinar on March 2, 2021 and March 2, 2023.
- Some information is being used in presentations by SaskBarley, including Top Notch Farming online in 2021 and at five locations in 2023..
- The Ministry presented on Barley MAX at the Conservation Learning Centre's virtual field day in 2020, available on their YouTube channel. https://youtu.be/7D3qiOnfxHM
- ECRF has created the following videos which are posted on line and were used at conference webinars:
    - https://www.youtube.com/watch?v=IQyE2RqjrQ8 (16 views + viewed at the Agronomy Research Update on November 29, 2021 by 750 attendees)
    - https://www.youtube.com/watch?v=Q2PqdHCbDwk&t=8s (121 views + viewed at ECRF/Parkland College webinar on March 5, 2021 by 70 attendees)
    - https://www.youtube.com/watch?v=nz2hYCxsBjg
    -
- SaskBarley has posted videos on their YouTube channel, which includes a presentation made for Top Notch Farming Webinar in 2021. Barley MAX information was also included in a AgriVisions meeting (approx. Feb 7, 2022). https://www.youtube.com/channel/UCKVWV8OUR_ocevE-al5LFEg/playlists

  https://www.lloydex.com/_files/ugd/2ab3f7_90040d7445c04d2c96e75c1254320b11.pdf

- SaskBarley wrote about the Barley MAX trial in their Spring 2021 Newsletter https://barleybin.ca/wp-content/uploads/2021/08/Spring2021-SB-Newsletter.pdf

Conclusions and Recommendations

Under low yielding environmental conditions, varietal yields were unresponsive to added N and grain protein levels were excessive for malt quality. However, grain protein was still lower for the newer varieties AAC Synergy and CDC Bow compared to AC Metcalfe. This implies that AC Metcalfe would require less N compared to the newer varieties. Under high yielding environmental conditions, AAC Synergy could be fertilized with 44 lb N/ac more than AC Metcalfe before exceeding 12.5% protein and being rejected for malt. However, doing so would be risky and uneconomical. Under a good economic scenario with $0.47/ lb N and $5.20/bu malt barley price, AAC Synergy could be receive 22 to 30 lb N/ac more than AC Metcalfe, depending on risk tolerance. Under poorer economic conditions, assuming $1.18/ lb N and $6.67/bu malt barley price, AAC Synergy would require only 12 lb N/ac more than AC Metcalfe. AAC Synergy will require more N than AC Metcalfe assuming both malt varieties are valued the same. However, exactly how much more will depend on environmental and economic conditions. In contrast, optimum rates of N would not vary much between the newer malt barley varieties AAC Synergy and CDC Bow, as their yield and protein responses to added N were essentially the same.

Supporting Information

10. Acknowledgements:

This project was funded through the Strategic Field Program (SFP) and Saskatchewan Barley Development Commission.

11. Appendices

Table 8. Main effects of variety and nitrogen rate on various parameters of barley averaged over all high yielding sites (Melfort 2020&2022, Prince Albert 2020-2022, Swift Current 2020 and Yorkton 2022.

	Emergence (plants/m^2)	**Maturity (Julian days)**	**Lodging (0-9)**	**Yield (kg/ha @13.5%)**	**Protein (%)**	**Thins (>5/64",%)**	**Plumps (>6/64", %)**	**Thousand kernel Weight (g)**	**4ml Energy Germination (%)**	**8ml Water Sensitive Germination (%)**
Variety (V)										
AC Metcalfe	242 a	229.8 b	1.23 a	4630 c	12.4	6.4	91.5	45.9	87.6	68.3
AAC Synergy	209 c	230.5 a	0.83 b	5218 a	11.7	3.6	95.0	49.0	86.9	72.1
CDC Bow	225 b	230.1 b	0.72 b	5091 b	11.7	4.0	94.5	49.0	82.2	62.8
LSD	6	0.33	0.17 b	114	NA	NA	NA	NA	NA	NA
Nitrogen Rate (Soil + fertilizer) (lb N/ac)										
Background N[1]	223 bc	230.4 ab	0.61 c	4328 c	11.3	3.6	95.0	48.3	85.6	67.3
Background N[1]	229 b	230.1 bc	0.75 c	4402 c	11.6	4.1	94.3	47.7	85.0	65.6
120	233 a	229.6 d	0.69 c	4986 b	11.5	4.1	94.3	48.0	86.7	68.4
180	226 b	229.9 cd	1.02 b	5593 a	12.3	5.2	93.0	47.8	84.9	68.2
240	216 c	230.5 a	1.57 a	5588 a	13.1	6.3	91.2	48.0	85.6	69.2
LSD	8	0.43	0.22	148	NA	NA	NA	NA	NA	NA
V by M interaction	NS	0.036	<0.0001	0.008	NA	NA	NA	NA	NA	NA

[1]Background level of N averaged over the high yielding site-years was 82 lb N/ac.

Table 9. Main effects of variety and nitrogen rate on various parameters of barley averaged over all low yielding sites (Melfort 2021, Yorkton 2020-2021 and Swift Current 2021-2022.

	Emergence (plants/m^2)	**Maturity (Julian days)**	**Lodging (0-9)**	**Yield (kg/ha @13.5%)**	**Protein (%)**	**Thins (>5/64",%)**	**Plumps (>6/64", %)**	**Thousand kernel Weight (g)**	**4ml Energy Germination (%)**	**8ml Water Sensitive Germination (%)**
Variety (V)										
AC Metcalfe	217 a	213.7 b	0.91 a	2097 b	15.7	2.5	96.4	43.7	76.7	59.1
AAC Synergy	208 b	214.1 a	0.95 a	2305 a	14.7	2.6	96.3	45.3	77.8	67.6
CDC Bow	219 a	214.0 ab	0.98 a	2127 b	14.5	1.9	97.1	45.1	68.3	53.8
LSD	6	0.3	NS	88	NA	NA	NA	NA	NA	NA
Nitrogen Rate (Soil + fertilizer) (lb N/ac)										
Background N[1]	216 ab	213.4 c	0.97 a	2084 c	13.5	2.4	96.5	44.4	73.2	57.9
Background N[1]	220 a	213.4 c	0.93 a	2201 ab	14.0	2.1	96.7	44.7	73.3	58.5
120	220 a	213.8 c	0.88 a	2157 bc	14.9	2.4	96.7	44.5	74.2	61.4
180	210 bc	214.3 b	0.98 a	2275 a	16.0	2.4	96.5	44.8	75.4	61.9
240	207 c	214.8 a	0.97 a	2165 abc	16.4	2.4	96.6	45.0	75.3	61.2
LSD	7	0.4	NS	114	NA	NA	NA	NA	NA	NA
V by M interaction	NS	NS	NS	0.008	NA	NA	NA	NA	NA	NA

[1]Background level of N averaged over the high yielding site-years was 78 lb N/ac.

Table 10. Main effects of variety and nitrogen rate on various parameters of barley at Melfort 2020.

	Emergence (plants/m^2)	Maturity (Julian days)	Lodging (0-9)	Yield (kg/ha @13.5%)	Protein (%)	Thins (>5/64",%)	Plumps (>6/64", %)	Thousand kernel Weight (g)	4ml Energy Germination (%)	8ml Water Sensitive Germination (%)
Variety (V)										
AC Metcalfe	209.4 b	231.2 b	0	3649.9 c	11.2	4.8	94.6	46.1	99.1	88.4
AAC Synergy	208.3 b	232.6 a	0	4443.1 a	10.5	1.8	97.7	49.8	98.2	90.6
CDC Bow	221.0 a	232.2 a	0	4195.5 b	10.7	2.1	97.5	49.4	97.6	79.2
LSD	10.8	0.8	NS	217	NA	NA	NA	NA	NA	NA
Nitrogen Rate (Soil + fertilizer) (lb N/ac)										
Background N[1]	228.4 ab	231.3 bc	0	2795.6 d	10.6	3.1	96.2	46.7	98.7	81.3
Background N[1]	220.2 b	231.8 bc	0	2525.8 d	10.3	3.0	96.4	46.9	97.3	77.5
120	237.6 a	230.8 c	0	3817.9 c	10.1	2.7	97.0	47.7	97.8	87.8
180	205.3 c	232.2 b	0	5509.5 b	10.8	2.8	96.9	49.5	98.3	91.5
240	172.9 d	233.8 a	0	5832.0 a	12.2	3.0	96.5	51.3	99.3	92.2
LSD	13.9	1.0	NS	281	NA	NA	NA	NA	NA	NA
V by M interaction	NS	NS	NS	0.037	NA	NA	NA	NA	NA	NA

[1]Background level of N was 67 lb N/ac.

Table 11. Main effects of variety and nitrogen rate on various parameters of barley at Prince Albert 2020.

	Emergence (plants/m^2)	**Maturity (Julian days)**	**Lodging (0-9)**	**Yield (kg/ha @13.5%)**	**Protein (%)**	**Thins (>5/64",%)**	**Plumps (>6/64", %)**	**Thousand kernel Weight (g)**	**4ml Energy Germination (%)**	**8ml Water Sensitive Germination (%)**
Variety (V)										
AC Metcalfe	228.3 a	228.2 b	2.02 a	4323.0 b	12.4	2.5	96.9	51.2	52.3	25.3
AAC Synergy	233.4 a	229.4 a	0.50 b	4761.9 a	12.0	1.3	98.0	53.8	40.4	20.3
CDC Bow	239.4 a	227.5 b	0.25 b	5021.6 a	11.7	0.8	98.5	53.4	14.6	7.1
LSD	NS	1.0	0.59	294	NA	NA	NA	NA	NA	NA
Nitrogen Rate (Soil + fertilizer) (lb N/ac)										
Background N[1]	232.3 a	228.8 a	0.25 c	3576.6 d	11.4	1.4	98.1	53.5	35.3	17.3
Background N[1]	238.2 a	228.2 a	0.32 c	4297.3 c	11.3	1.1	98.2	53.0	34.2	17.5
120	228.2 a	228.3 a	0.40 bc	4874.8 b	11.7	1.3	98.1	53.3	36.0	15.8
180	230.0 a	228.3 a	1.15 b	5280.3 a	12.1	1.6	97.7	52.6	36.3	20.0
240	239.8 a	228.1 a	2.50 a	5481.8 a	13.4	2.5	96.9	51.7	37.0	17.2
LSD	NS	NS	0.76	380	NA	NA	NA	NA	NA	NA
V by M interaction	0.03	NS	<0.0001	NS	NA	NA	NA	NA	NA	NA

[1]Background level of N was 69 lb N/ac.

Table 12. Main effects of variety and nitrogen rate on various parameters of barley at Swift Current 2020.

	Emergence (plants/m^2)	Maturity (Julian days)	Lodging (0-9)	Yield (kg/ha @13.5%)	Protein (%)	Thins (>5/64",%)	Plumps (>6/64", %)	Thousand kernel Weight (g)	4ml Energy Germination (%)	8ml Water Sensitive Germination (%)
Variety (V)										
AC Metcalfe	168.8 b	218.3 ab	1	4387.1 b	13.4	17.7	76.9	41.3	100.0	97.8
AAC Synergy	174.8 b	218.0 b	1	4867.0 a	13.1	12.9	82.7	43.7	99.5	98.8
CDC Bow	192.8 a	218.8 a	1	4474.5 b	13.2	15.8	78.4	41.9	99.7	98.2
LSD	15.9	0.5	NS	237	NA	NA	NA	NA	NA	NA
Nitrogen Rate (Soil + fertilizer) (lb N/ac)										
Background N[1]	193.3 a	218.1 a	1	4392.7 b	11.5	10.3	86.1	43.6	99.7	97.9
60	191.3 ab	218.3 a	1	4371.0 b	12.5	13.0	82.1	43.0	99.7	97.5
120	185.3 ab	218.8 a	1	4798.0 a	12.8	13.5	82.0	42.3	99.8	98.5
180	171.5 bc	218.1 a	1	4855.1 a	14.2	18.2	76.2	41.7	99.7	99.0
240	152.6 c	218.5 a	1	4464.2 b	15.4	22.4	70.0	40.9	99.8	98.5
LSD	20.5	NS	NS	305	NA	NA	NA	NA	NA	NA
V by M interaction	NS	NS	NS	NS	NA	NA	NA	NA	NA	NA

[1]Background level of N was 47 lb N/ac.

Table 13. Main effects of variety and nitrogen rate on various parameters of barley at Yorkton 2020.

	Emergence (plants/m^2)	Maturity (Julian days)	Lodging (0-9)	Yield (kg/ha @13.5%)	Protein (%)	Thins (>5/64",%)	Plumps (>6/64", %)	Thousand kernel Weight (g)	4ml Energy Germination (%)	8ml Water Sensitive Germination (%)
Variety (V)										
AC Metcalfe	280.6 a	210.5 a	0	2473.2 a	14.3	1.2	98.4	48.0	91.3	51.9
AAC Synergy	274.0 a	210.7 a	0	2718.6 a	13.7	0.9	98.7	50.3	85.8	72.9
CDC Bow	280.6 a	211.0 a	0	2564.3 a	13.4	0.9	98.7	50.1	52.3	42.1
LSD		NS	NS	NS	NA	NA	NA	NA	NA	NA
Nitrogen Rate (Soil + fertilizer) (lb N/ac)										
Background N[1]	280.7 a	210.3 a	0	2229.8 a	11.6	0.7	99.1	49.7	73.0	48.7
60	284.2 a	210.4 a	0	2550.4 ab	12.5	0.7	98.9	49.7	73.0	51.5
120	281.8 a	210.6 a	0	2613.9 bc	14.8	1.2	98.3	49.6	78.3	59.2
180	268.2 a	211.1 a	0	2913.0 c	14.8	1.2	98.5	49.5	80.2	61.5
240	277.1 a	211.1 a	0	2619.5 bc	15.3	1.3	98.3	48.9	77.8	57.3
LSD	NS	NS	NS	344	NA	NA	NA	NA	NA	NA
V by M interaction	NS	NS	NS	NS	NA	NA	NA	NA	NA	NA

[1]Background level of N was 38 lb N/ac.

Table 14. Main effects of variety and nitrogen rate on various parameters of barley at Melfort 2021.

	Emergence (plants/m^2)	Maturity (Julian days)	Lodging (0-9)	Yield (kg/ha @13.5%)	Protein (%)	Thins (>5/64",%)	Plumps (>6/64", %)	Thousand kernel Weight (g)	4ml Energy Germination (%)	8ml Water Sensitive Germination (%)
Variety (V)										
AC Metcalfe	204.4 a	215.3 a	1 a	3146.9 b	13.5	1.4	98.2	45.9	97.1	89.7
AAC Synergy	215.8 a	215.2 a	1 a	3448.1 a	12.1	1.8	97.8	46.4	96.6	90.2
CDC Bow	212.2 a	215.2 a	1 a	2925.6 b	12.7	1.3	98.4	47.7	97.1	84.2
LSD	NS	NS	NS	251	NA	NA	NA	NA	NA	NA
Nitrogen Rate (Soil + fertilizer) (lb N/ac)										
Background N[1]	228.2 a	215.0 b	1 a	3003.3 a	11.3	1.5	98.0	46.2	97.5	90.3
Background N[1]	219.2 ab	215.0 b	1 a	3281.2 a	11.9	1.5	98.1	46.4	97.5	86.7
120	215.3 ab	215.0 b	1 a	3036.6 a	11.2	1.6	98.0	46.3	94.7	88.5
180	207.3 b	215.2 b	1 a	3397.9 a	14.1	1.4	98.3	46.7	99.2	88.8
240	183.7 c	215.9 a	1 a	3148.6 a	15.2	1.6	98.0	47.9	95.8	85.8
LSD	14.3	0.2	NS	NS	NA	NA	NA	NA	NA	NA
V by M interaction	0.02	NS	NS	0.004	NA	NA	NA	NA	NA	NA

[1]Background level of N was 93 lb N/ac.

Table 15. Main effects of variety and nitrogen rate on various parameters of barley at Prince Albert 2021.

	Emergence (plants/m^2)	**Maturity (Julian days)**	**Lodging (0-9)**	**Yield (kg/ha @13.5%)**	**Protein (%)**	**Thins (>5/64",%)**	**Plumps (>6/64", %)**	**Thousand kernel Weight (g)**	**4ml Energy Germination (%)**	**8ml Water Sensitive Germination (%)**
Variety (V)										
AC Metcalfe	222.1 a	237 a	0.80 a	5639.1 a	13.5	2.7	96.3	47.2	71.2	33.3
AAC Synergy	131.7 b	237 a	0.95 a	5128.2 a	13.0	2.6	96.4	46.7	76.9	32.2
CDC Bow	137.4 b	237 a	1.60 a	4912.6 a	12.6	3.3	95.8	46.0	79.8	32.7
LSD	18.0	NS	NS	NS	NA	NA	NA	NA	NA	NA
Nitrogen Rate (Soil + fertilizer) (lb N/ac)										
Background N[1]	175.5 a	237 a	0.5 a	5122.3 a	12.8	2.8	96.1	47.4	75.8	33.0
60	161.2 a	237 a	1.33 a	4874.9 a	13.8	3.3	95.8	45.8	76.2	29.0
120	169.0 a	237 a	1.00 a	5449.2 a	12.9	2.9	96.1	46.8	83.8	36.3
180	158.0 a	237 a	1.33 a	5825.3 a	13.6	2.8	96.4	46.8	70.2	30.5
240	155.0 a	237 a	1.42 a	4861.3 a	12.0	2.7	96.5	46.3	73.8	34.8
LSD	NS	NS	NS	NS	NA	NA	NA	NA	NA	NA
V by M interaction	NS	NS	NS	NS	NA	NA	NA	NA	NA	NA

[1]Background level of N was 54 lb N/ac.

Table 16. Main effects of variety and nitrogen rate on various parameters of barley at Swift Current 2021.

	Emergence (plants/m^2)	**Maturity (Julian days)**	**Lodging (0-9)**	**Yield (kg/ha @13.5%)**	**Protein (%)**	**Thins (>5/64",%)**	**Plumps (>6/64", %)**	**Thousand kernel Weight (g)**	**4ml Energy Germination (%)**	**8ml Water Sensitive Germination (%)**
Variety (V)										
AC Metcalfe	184.8 a	219.4 a	1 a	881.3 c	16.8	3.1	94.5	40.0	84.7	48.7
AAC Synergy	151.4 b	219.0 a	1 a	1243.8 a	15.5	2.9	94.9	42.4	93.2	69.7
CDC Bow	187.8 a	218.6 a	1 a	1059.8 b	14.9	2.5	95.6	40.6	84.7	37.6
LSD	12.4	NS	NS	92.1	NA	NA	NA	NA	NA	NA
Nitrogen Rate (Soil + fertilizer) (lb N/ac)										
Background N[1]	172.6 a	218.6 a	1 a	875.6 2	13.5	3.3	94.3	40.2	83.5	45.7
60	185.0 a	218.5 a	1 a	900.5 b	14	3.1	94.3	40.2	86.5	47.8
120	180.0 a	218.8 a	1 a	1163.0 a	16.3	2.4	96.1	41.2	85.2	55.0
180	168.7 a	219.3 a	1 a	1173.3 a	17.4	2.6	95.0	41.8	89.8	54.8
240	166.1 a	219.8 a	1 a	1195.7 a	17.4	2.8	95.2	41.5	92.7	56.7
LSD	NS	NS	NS	119.0	NA	NA	NA	NA	NA	NA
V by M interaction	0.003	NS	NS	NS	NA	NA	NA	NA	NA	NA

[1]Background level of N was 44 lb N/ac.

Table 17. Main effects of variety and nitrogen rate on various parameters of barley at Yorkton 2021.

	Emergence (plants/m^2)	**Maturity (Julian days)**	**Lodging (0-9)**	**Yield (kg/ha @13.5%)**	**Protein (%)**	**Thins (>5/64",%)**	**Plumps (>6/64", %)**	**Thousand kernel Weight (g)**	**4ml Energy Germination (%)**	**8ml Water Sensitive Germination (%)**
Variety (V)										
AC Metcalfe	319.1 a	207.2 a	1.55 a	1472.1 a	17.6	1.9	97.4	42.0	11.2	7.4
AAC Synergy	321.3 a	206.7 a	1.75 a	1473.7 a	17.0	2.3	97.0	42.2	14.2	6.2
CDC Bow	323.6 a	206.7 a	1.90 a	1435.4 a	16.5	1.6	97.8	41.8	8.3	6.8
LSD	NS	NS	NS	NS	NA	NA	NA	NA	NA	NA
Nitrogen Rate (Soil + fertilizer) (lb N/ac)										
Background N[1]	297.3 c	206.3 c	1.83 a	1667.5 a	16.8	2.0	97.2	41.8	12.7	6.3
Background N[1]	305.4 bc	206.4 bc	1.67 a	1566.1 a	17.2	1.9	97.4	42.3	11.2	8.2
120	342.2 a	206.8 abc	1.42 a	1350.7 a	16.3	1.9	97.5	41.7	13.2	5.7
180	327.7 ab	207.2 ab	1.92 a	1274.1 a	17.4	1.9	97.6	41.9	8.7	6.0
240	334.1 a	207.5 a	1.83 a	1443.7 a	17.6	2.0	97.5	42.4	10.5	7.8
LSD	24.8	0.8	NS	NS	NA	NA	NA	NA	NA	NA
V by M interaction	NS	NS	NS	NS	NA	NA	NA	NA	NA	NA

[1]Background level of N was 77 lb N/ac.

Table 18. Main effects of variety and nitrogen rate on various parameters of barley at Melfort 2022.

	Emergence (plants/m^2)	Maturity (Julian days)	Lodging (0-9)	Yield (kg/ha @13.5%)	Protein (%)	Thins (>5/64",%)	Plumps (>6/64", %)	Thousand kernel Weight (g)	4ml Energy Germination (%)	8ml Water Sensitive Germination (%)
Variety (V)										
AC Metcalfe	222.9 a	232.4 a	1.6 a	4699.7 b	11.5	4.0	95.0	45.3	99.2	94.0
AAC Synergy	226.7 a	232.6 a	1.5 a	5460.8 a	10.3	1.8	97.3	46.8	99.5	94.4
CDC Bow	223.5 a	233.6 a	1.0 b	5330.4 a	10.6	1.7	98.0	50.4	96.5	89.9
LSD	NS	NS	0.4	357.3	NA	NA	NA	NA	NA	NA
Nitrogen Rate (Soil + fertilizer) (lb N/ac)										
Background N[1]	221.6 a	233.3 ab	1.0 b	3870.1 d	9.9	1.6	97.3	47.7	99.2	93.3
Background N[1]	220.5 a	234.0 a	1.0 b	4204.6 d	10.2	2.1	97.4	46.2	98.5	91.8
120	222.1 a	230.5 c	1.0 b	5050.3 c	10.0	2.4	96.6	48.1	99.0	93.5
180	240.0 a	232.4 b	1.3 b	5981.4 b	11.4	2.7	96.9	46.7	99.5	93.7
240	217.6 a	234.0 a	2.3 a	6711.7 a	12.5	3.7	95.7	48.7	95.8	91.5
LSD	NS	1.42	0.5	461.3	NA	NA	NA	NA	NA	NA
V by M interaction	NS	NS	0.014	NS	NA	NA	NA	NA	NA	NA

[1]Background level of N was 66 lb N/ac.

Table 19. Main effects of variety and nitrogen rate on various parameters of barley at Prince Albert 2022.

	Emergence (plants/m^2)	**Maturity (Julian days)**	**Lodging (0-9)**	**Yield (kg/ha @13.5%)**	**Protein (%)**	**Thins (>5/64",%)**	**Plumps (>6/64", %)**	**Thousand kernel Weight (g)**	**4ml Energy Germination (%)**	**8ml Water Sensitive Germination (%)**
Variety (V)										
AC Metcalfe	322.5 a	234.5 a	2.15 a	4769.3 b	13.1	9.0	86.3	45.8	96.2	79.3
AAC Synergy	170.3 c	235.6 a	1.20 b	6344.3 a	12.1	2.9	95.5	53.4	96.0	87.5
CDC Bow	236.3 b	235.5 a	1.00 b	6192.8 a	11.7	1.9	96.6	53.7	96.9	76.8
LSD	18.4	NS	0.42	270.0	NA	NA	NA	NA	NA	NA
Nitrogen Rate (Soil + fertilizer) (lb N/ac)										
Background N[1]	215.8 b	236.2 a	1.33 a	5812.4 a	11.8	3.6	94.7	51.6	96.0	82.3
Background N[1]	263.5 a	234.8 a	1.33 a	5719.7 a	11.9	4.1	93.3	51.2	95.5	83.5
Background N[1]	247.5 a	234.6 a	1.25 a	5710.9 a	11.6	3.4	94.3	51.4	96.8	80.5
180	247.8 a	234.8 a	1.58 a	5819.8 a	12.7	5.6	90.7	50.4	96.7	78.0
240	240.5 a	235.7 a	1.75 a	5781.3 a	13.4	6.2	91.0	50.3	96.8	81.7
LSD	23.8	NS	NS	NS	NA	NA	NA	NA	NA	NA
V by M interaction	NS	NS	NS	0.011	NA	NA	NA	NA	NA	NA

[1]Background level of N was 138 lb N/ac.

Table 20. Main effects of variety and nitrogen rate on various parameters of barley at Swift Current 2022.

	Emergence (plants/m^2)	**Maturity (Julian days)**	**Lodging (0-9)**	**Yield (kg/ha @13.5%)**	**Protein (%)**	**Thins (>5/64",%)**	**Plumps (>6/64", %)**	**Thousand kernel Weight (g)**	**4ml Energy Germination (%)**	**8ml Water Sensitive Germination (%)**
Variety (V)										
AC Metcalfe	191.6 a	216.3 b	1 a	2513.1 a	16.4	4.9	93.3	42.5	99.2	98.0
AAC Synergy	177.4 a	219.0 a	1 a	2638.8 a	15.3	5.1	93.3	45.3	99.2	98.8
CDC Bow	189.0 a	218.4 a	1 a	2649.2 a	15.0	3.3	94.7	45.0	99.0	98.4
LSD	NS	0.78		NS	NA	NA	NA	NA	NA	NA
Nitrogen Rate (Soil + fertilizer) (lb N/ac)										
Background N[1]	185.1 a	216.9 b	1 a	2644.5 a	14.6	4.4	93.8	44.4	99.2	98.3
Background N[1]	191.7 a	216.8 b	1 a	2706.4 a	14.2	3.6	94.6	44.8	98.3	98.5
Background N[1]	190.7 a	217.5 b	1 a	2619.3 a	15.9	4.8	93.3	44.0	99.7	98.5
180	180.3 a	218.7 a	1 a	2616.2 a	16.5	5.0	93.0	44.0	99.0	98.3
240	182.1 a	219.5 a	1 a	2415.3 b	16.8	4.3	94.0	44.3	99.5	98.3
LSD	NS	1.0	NS	174.1	NA	NA	NA	NA	NA	NA
V by M interaction	NS	NS	NS	NS	NA	NA	NA	NA	NA	NA

[1]Background level of N was 159 lb N/ac.

Table 21. Main effects of variety and nitrogen rate on various parameters of barley at Yorkton 2022.

	Emergence (plants/m^2)	**Maturity (Julian days)**	**Lodging (0-9)**	**Yield (kg/ha @13.5%)**	**Protein (%)**	**Thins (>5/64",%)**	**Plumps (>6/64", %)**	**Thousand kernel Weight (g)**	**4ml Energy Germination (%)**	**8ml Water Sensitive Germination (%)**
Variety (V)										
AC Metcalfe	319.1 a	235.7 a	1.1 a	4941.2 b	11.9	3.9	94.7	44.6	95.1	59.9
AAC Synergy	321.3 a	235.8 a	0.7 b	5521.2 a	11.3	2.2	97.0	48.4	97.7	81.1
CDC Bow	323.6 a	235.8 a	0.2 c	5507.1 a	11.5	2.2	96.7	48.4	90.2	55.9
LSD	NS	NS	0.4	317.0	NA	NA	NA	NA	NA	NA
Nitrogen Rate (Soil + fertilizer) (lb N/ac)										
Background N[1]	297.3 c	236.4 a	0.2 c	4729.5 c	11.2	2.5	96.4	47.3	94.5	65.8
Background N[1]	305.4 bc	235.7 b	0.3 c	4822.7 bc	11.1	2.0	97.2	47.7	93.7	62.7
120	342.2 a	235.7 b	0.2 c	5199.4 b	11.2	2.5	96.0	46.5	93.3	66.3
180	327.7 ab	235.3 b	0.8 b	5880.8 a	11.5	2.7	96.2	47.0	93.8	64.8
240	334.1 a	235.7 b	2.0 a	5983.5 a	12.7	4.0	94.9	47.1	96.3	68.5
LSD	24.8	0.64	0.5	409.2	NA	NA	NA	NA	NA	NA
V by M interaction	NS	0.0001	<0.0001	NS	NA	NA	NA	NA	NA	NA

[1]Background level of N was 104 lb N/ac.

Abstract

12. Abstract/Summary:

From 2020 to 2022, trials were conducted at Melfort, Prince Albert, Swift Current and Yorkton to determine if the most economic rate of N differed between new and old varieties of malt barley. Site-years were divided into high and low yielding groups and analyzed separately. Varieties within the low yielding group did not respond to added N and protein levels for all varieties were too high for malt. However, the protein level for AC Metcalfe was significantly higher compared to the newer varieties implying AC Metcalfe requires less N. For the high yielding group, the yield of AAC Synergy and CDC Bow were more responsive to added N than AC Metcalfe. Grain protein for AC Metcalfe reached 12.5% protein when soil + fertilizer N reached 164 lb/ac. In contrast, 208 lb N/ac were required for AAC Synergy to reach 12.5% protein. Assuming protein levels in excess of 12.5% are not acceptable for malt, 44 lb/ac more N could be applied to AAC Synergy compared to AC Metcalfe. However, depending on the value of N and malt, AAC Synergy may only require 12-30 lb N/ac more than AC Metcalfe to maximize economic returns.

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