Performance evaluation of two-row and six-row forage barley mixtures.

The production of high-yielding and high-quality forage has been a big challenge for Alberta livestock producers because of severe drought conditions across multiple regions of the province since 2021. Water stress and associated crop and pasture failures leave many growers producing insufficient quantities of forage for livestock operations. The shortage of available forage indicates that producers may need to adopt new strategies to get the most yield possible when water is limited due to drought conditions. Perennial forages (grasses or legumes) create a good basis for livestock farming systems, but many perennial forages go dormant as a survival mechanism under drier conditions (Taleb et al., 2023). Annual forages are known to use water more efficiently than perennial forages and could be utilized as additional livestock feed during times of limited rainfall and perennial pasture shortage. Barley is one of the most widely grown annual forage crops in western Canada because it is highly adaptable to diverse growing conditions. It is more water use efficient than other small grains, making it a valuable annual forage crop during moisture-stressed periods. In 2023, approximately 157,000 hectares of silage barley was harvested, with the total estimated production of 2.3 million tonnes in Alberta (Wong, 2024). Anecdotal accounts from cattle producers in Northeastern Alberta have indicated that higher forage yields may be obtained when growing two-row and six-row barley mixtures. However, there have been no assessments performed in an applied research settings to endorse this claim in Northeastern Alberta. A field study conducted by Gill et al. (2013) in the Peace region of Alberta revealed that two-row barley are superior to six-row barley in terms of forage yield and nutritional quality. Therefore, we hypothesized that mixing and planting a suitable ratio of phenotypically contrasting barley varieties would increase forage biomass and improve the overall nutritional profile of a blend. To test this hypothesis, four new barley varieties in the Lakeland region of Alberta, each representing a unique combination of spike type, two-row or six-row, were utilized in a field trial with the following principal objectives:

Objectives:

- To determine the performance of two-row and six-row barely pure stands as well as their binary mixtures in three seeding ratios (1:1, 1:3, and 3:1) for forage dry matter (DM) yield.
- To determine the performance of two-row and six-row barely pure stands as well as their binary mixtures in three seeding ratios (1:1, 1:3, and 3:1) for forage nutritional quality.
- To determine if further research is warranted as this project is a one-year proof of concept project.

Materials and Methods:

The trial was carried out from May 15, 2024, to Aug 02, 2024, at the LARA research farm (54° 18'N, 110° 37'W; NE 25-61-5-W4) in Fort Kent, Alberta. Prior to seeding, soil samples were taken to a depth of 0-6 and 6-12 inches to determine the nutrient level at Element Lab, Edmonton. For weed control, a pre-seed burnoff was carried out with one spray of glyphosate (540g ai/L). The treatments were comprised of 2 two-row (AB Maximizer and AAC Lariat) and 2 six-row (AB Tofield and AB Standswell) varieties in pure stands as well as in twelve possible binary mixtures of 1:1, 1:3, and 3:1 seedling ratio (Table 1 & 2). CDC Austenson was seeded as a check variety. Seeding rate (g/plot) was calculated using the formula: 1000 kernel weight*(desired plants/m2/1000) *plot area m2*(100/germination%) *1.05. The factor 1.05 was used during calculations to take care of seedling mortality. Desired plant density was set to 300 plants/m2 for all plots.

Table 1. Varieties chosen for barley mixture ratios

Two-Row	Seeding Rate (lb/acre)	Six-Row	Seeding Rate (lb/acre)
AB Maximizer	149	AB Tofield	134
AAC Lariat	149	AB Standswell	111

Table 2. Treatment list

Treatment	% Two-Row Inclusion	% Six-Row Inclusion
AAC Lariat	100	0
AB Maximizer	100	0
AB Standswell	0	100
AB Tofield	0	100
AAC Lariat-AB Standswell 1:1	50	50
AAC Lariat-AB Standswell 1:3	25	75
AAC Lariat-AB Standswell 3:1	75	25
AAC Lariat-AB Tofield 1:1	50	50
AAC Lariat-AB Tofield 1:3	25	75
AAC Lariat-AB Tofield 3:1	75	25
AB Maximizer-AB Standswell 1:1	50	50
AB Maximizer-AB Standswell 1:3	25	75
AB Maximizer-AB Standswell 3:1	75	25
AB Maximizer-AB Tofield 1:1	50	50
AB Maximizer-AB Tofield 1:3	25	75
AB Maximizer-AB Tofield 3:1	75	25

The experiment was planted in a randomized complete block design (RCBD) with four replications of 17 treatments. LARA Fabro five row seeder was used for seeding with 9" row spacing. Plots were seeded to a depth of 1-1.5" depending on soil conditions and available moisture. As per soil test, the recommend rate of fertilizers (84:43:14 lbs NPK ac-1) was side banded during seeding. In crop spraying of 0.4L/ac of Buctril M was carried out on June 09, 2024. Hand weeding occurred throughout the growing season to maintain the experimental area weed free. The net plot size was 6.9 m2 (1.15 m by 6 m). Harvesting was done when barley grains were at soft dough stage. Individual plots were harvested with LARA Alfalfa-Omega self-propelled forage harvester. The total precipitation accumulated during the growing season was 147.9 mm. For each treatment plot, ~ 400 g of chopped forage (sub-sample) was frozen immediately and sent to A & L Canada Laboratories Inc. for quality analysis. A second sub-sample of ~ 250 g of freshly harvested material was taken from each plot and dried to a constant weight for dry matter calculations. The data for forage DM yield and each of the quality parameters were subjected to analysis of variance

(ANOVA) and means were subsequently compared by the least significant difference (LSD) test at ≤0.05 probability level using the agricolae (version 1.3-7) package of the R (4.3.2) software.

Figure 1-1. A representative picture showing different project related activities e.g., seeding (Top left), height measurements (Top right), and harvesting (Bottom).

Results and Discussion:

The present study showed that mixtures ought to be more advantageous to farmers than corresponding pure stands when considering forage DM yield as % of check, CDC Austenson (Figure 2). On average, CDC Austenson produced 3.40 t ac-1 of forage DM yield in this trial. We found significant differences among treatments when considering forage DM yield and different quality parameters including crude protein (CP), calcium (Ca), magnesium (Mg), and zinc (Zn) (Table 4, 5 & 6). The average forage DM yield ranged from 2.44 t ac-1 to 3.70 t ac-1 for the mixtures, with AB Maximizer and AB Standswell sown in 1:3 seeding ratio the lowest yielding mixture and AB Maximizer and AB Tofield grown in 3:1 seeding ratio the highest yielding mixture. Among the varieties seeded in monocultures, the highest forage DM yield was produced by AB Maximizer (3.44 t ac-1) followed by AAC Lariat (3.31 t ac-1) and AB Tofield (2.70 t ac-1). AB Standswell produced the lowest forage DM yield (2.07 t ac-1) in pure stands. A total of two mixtures; AB Maximizer and AB Tofield at seeding ratio of 3:1 and AAC Lariat and AB Tofield at seeding ratio of 3:1 yielded 9 and 7% higher than the check variety, respectively (Figure 3). AB Maximizer was the only variety grown in pure stands, which yielded 1% higher than the check variety. Varieties such as AAC Lariat, AB Tofield and AB Standswell yielded 3, 21, and 39% lower than the check variety, respectively, when seeded as monocrops (Table 4).

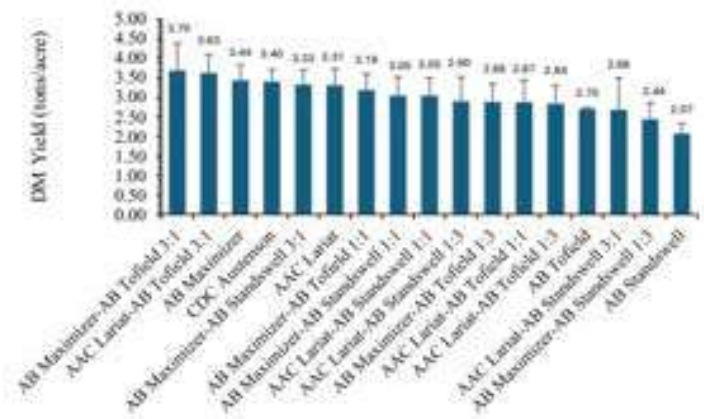

Figure 2. Forage dry matter (DM) yield for variety mixtures and monocultures.

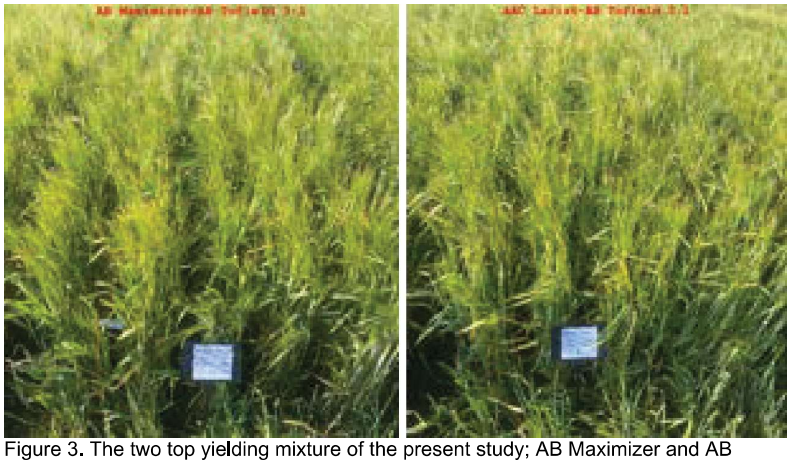

Figure 3. The two top yielding mixture of the present study; AB Maximizer and AB Tofield at seeding ratio of 3:1 (Left) and AAC Lariat and AB Tofield at seeding ratio of 3:1 (Right).

As a general rule of thumb, dietary CP level of 7-9-11% should be maintained to meet the nutrient requirements of beef cows during mid gestation, late gestation and lactation. Of the 12 mixtures tested in this study, 11 had CP content (> 11%) adequate to meet the nutrient requirements for beef cattle after calving. Only CP content (9.67%) of mixture with AAC Lariat and AB Standswell in 3:1 seeding ratio was not sufficient to meet the requirements for beef cattle until post calving. Total digestible nutrients (TDN), which is the easiest method to estimate the amount of energy in the feed follows 55-60-65 rule, where beef cows' mid pregnancy, late pregnancy, and post calving require 55, 60 and 65%, respectively. Our results revealed that all mixtures contain ≥ 65% of TDN and

would meet the energy demands of lactating beef cattle. The maximum TDN (68.71%) was recorded in AB Maximizer and AB Tofield while in 1:3 binary mixture. The lowest TDN (64.97%) came from mixture with AAC Lariat and AB Standswell at seeding ratio of 1:1 (Table 4). Overall, mixtures had adequate Ca (0.27-0.43%), Mg (0.23-0.29%), Na (0.14-0.3%), P (0.20-0.22%), and K (1.04-1.16%) to meet the requirements by beef cows during gestation and nursing calves. However, it is important to note that none of the mixtures had enough Cu (10 ppm) to meet the requirements by different categories of beef cattle (Table 6). Therefore, free choice mineral supplementation, particularly of Cu, would be needed in diets when any of these mixtures are fed to beef cattle.

Table 4. Forage dry matter (DM) yield, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), and total detergent fiber (TDN) for all cropping treatments.

Treatment	DM Yield (% of Check)		CP (% DM)		NDF (% DM)		ADF (% DM)		TDN (% DM)	
AB Maximizer-AB Tofield 3:1	109	a	12.81	abcd	45.68	abcd	27.44	abcd	67.53	abcd
AAC Lariat-AB Tofield 3:1	107	a	11.97	bcd	47.19	abcd	27.79	abcd	67.26	abcd
AB Maximizer	101	ab	13.52	ab	38.81	d	23.97	d	70.23	a
Check	100	abc	13.32	abc	40.17	cd	24.79	cd	69.59	ab
AB Maximizer-AB Standswell 3:1	98	abc	12.47	abcd	43.52	abcd	26.31	abcd	68.40	abcd
AAC Lariat	97	abc	11.25	de	45.99	abcd	25.67	bcd	68.81	abc
AB Maximizer-AB Tofield 1:1	94	abc	11.38	cde	47.78	abc	28.87	abc	66.96	abcd
AAC Lariat-AB Standswell 1:1	90	abcd	11.52	cde	50.38	ab	30.73	a	64.97	d
AB Maximizer-AB Standswell 1:1	90	abcd	11.46	cde	47.08	abcd	28.00	abcd	67.09	abcd
AAC Lariat-AB Standswell 1:3	85	bcd	11.76	ab	41.52	cd	27.08	abcd	67.80	abcd
AB Maximizer-AB Tofield 1:3	85	bcd	12.19	abcd	42.26	bcd	25.92	abcd	68.71	abcd
AAC Lariat-AB Tofield 1:1	84	bcd	11.74	bcde	46.09	abcd	27.05	abcd	67.83	abcd
AAC Lariat-AB Tofield 1:3	84	bcd	11.99	bcd	46.03	abcd	28.74	abc	66.51	bcd
AB Tofield	79	cde	11.73	bcde	48.39	abc	29.84	ab	65.66	cd
AAC Lariat-AB Standswell 3:1	79	cde	9.67	e	52.43	a	30.12	ab	65.44	cd
AB Maximizer-AB Standswell 1:3	72	de	12.96	abcd	43.49	abcd	27.35	abcd	67.58	abcd
AB Standswell	61	e	14.07	a	40.21	cd	26.75	abcd	68.06	abcd
Pr (>F)	0.00128 ***		0.0215*		0.172		0.304		0.343	

Note : Significance Codes : 0 '***' 0.001 '**' 0.01 '*' 0.05 '.'

Table 5. Forage calcium (Ca), phosphorous (P), potassium (K), magnesium (Mg), and sodium (Na) content for all cropping treatments.

Treatment	Ca (% DM)		P (% DM)		K (% DM)		Mg (% DM)		Na (% DM)	
AB Maximizer-AB Tofield 3:1	0.33	cdef	0.21	ab	1.16	a	0.27	abcd	0.25	abcd
AAC Lariat-AB Tofield 3:1	0.39	abc	0.20	ab	1.05	abc	0.26	abcde	0.21	bcde
AB Maximizer	0.27	ef	0.23	a	1.00	c	0.23	de	0.20	cde
Check	0.27	ef	0.20	ab	1.04	bc	0.24	de	0.26	abcd
AB Maximizer-AB Standswell 3:1	0.27	f	0.20	ab	1.05	abc	0.23	e	0.25	abcd
AAC Lariat	0.33	cdef	0.22	ab	1.00	c	0.24	cde	0.18	de
AB Maximizer-AB Tofield 1:1	0.28	ef	0.20	ab	1.06	abc	0.25	abcde	0.25	abcd
AAC Lariat-AB Standswell 1:1	0.43	a	0.20	ab	1.12	ab	0.29	a	0.26	abcd
AB Maximizer-AB Standswell 1:1	0.30	def	0.22	ab	1.05	abc	0.25	bcde	0.21	cde
AAC Lariat-AB Standswell 1:3	0.39	abc	0.21	ab	1.04	bc	0.26	abcde	0.30	ab
AB Maximizer-AB Tofield 1:3	0.28	ef	0.21	ab	1.08	abc	0.24	cde	0.20	cde
AAC Lariat-AB Tofield 1:1	0.39	abc	0.22	ab	1.13	ab	0.28	abcd	0.24	abcde
AAC Lariat-AB Tofield 1:3	0.41	ab	0.22	ab	1.11	abc	0.28	abc	0.23	abcde
AB Tofield	0.41	ab	0.21	ab	1.14	a	0.28	ab	0.25	abcd
AAC Lariat-AB Standswell 3:1	0.39	abc	0.20	ab	1.09	abc	0.26	abcde	0.14	e
AB Maximizer-AB Standswell 1:3	0.34	bcde	0.20	ab	1.10	abc	0.25	abcde	0.27	abc
AB Standswell	0.37	abcd	0.19	b	1.00	bc	0.28	abcd	0.32	a
Pr (>F)	5.78e-05***		0.777		0.136		0.0607.		0.0624.	

Note : Significance Codes : 0 '***' 0.001 '**' 0.01 '*' 0.05 '.'

Table 6. Forage copper (Cu), zinc (Zn), iron (Fe), and manganese (Mn) content for all cropping treatments.

Treatment	Cu (ppm)		Zn (ppm)		Fe (ppm)		Mn (ppm)	
AB Maximizer-AB Tofield 3:1	3.64	ab	26.10	efg	106.49	a	29.19	abc
AAC Lariat-AB Tofield 3:1	3.40	ab	28.54	cdef	106.42	a	32.14	abc
AB Maximizer	3.45	ab	24.10	g	89.66	abc	27.56	bc
Check	3.30	ab	25.15	fg	87.20	abc	29.56	abc
AB Maximizer-AB Standswell 3:1	3.41	ab	24.39	g	91.20	abc	26.53	c
AAC Lariat	3.27	ab	26.87	defg	82.29	bc	28.08	abc
AB Maximizer-AB Tofield 1:1	3.34	ab	28.28	cdef	87.50	abc	29.71	abc
AAC Lariat-AB Standswell 1:1	3.48	ab	29.81	bcd	84.10	abc	31.78	abc
AB Maximizer-AB Standswell 1:1	3.74	ab	27.11	defg	90.29	abc	28.41	abc
AAC Lariat-AB Standswell 1:3	3.12	b	31.70	abc	86.29	abc	30.57	abc
AB Maximizer-AB Tofield 1:3	3.84	a	32.40	ab	99.31	ab	29.15	abc
AAC Lariat-AB Tofield 1:1	3.56	ab	29.77	bcde	68.52	c	30.66	abc
AAC Lariat-AB Tofield 1:3	3.41	ab	32.31	ab	96.33	ab	33.17	abc
AB Tofield	3.27	ab	35.27	a	98.33	ab	36.36	a
AAC Lariat-AB Standswell 3:1	3.30	ab	27.62	defg	88.32	abc	35.81	ab
AB Maximizer-AB Standswell 1:3	3.50	ab	28.35	cdef	82.16	bc	30.78	abc
AB Standswell	3.37	ab	32.3	ab	89.51	abc	29.99	abc
Pr (>F)	0.863		5.24e-07***		0.364		0.643	

Note: Significance Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.'; ppm: parts per million.

We also performed a direct comparison of two-row and six-row varieties utilized in this study (Table 7, 8 & 9). Overall, two-row varieties yielded (3.38 t ac-1) higher than six-row varieties (2.83 t ac-1). Similarly, the average TDN content (69.57%) of two-row varieties was also higher than six-row varieties (66.86%). Though not significantly different, the average CP content of six-row varieties (12.90%) was slightly higher than two-row varieties (12.39%). This study corroborates the findings of Gill et al. (2013) who seeded 12 barley varieties (6 two-row and 6 six-row) from 2009 to 2011 in the peace region of Alberta and noticed that most two-row barley varieties are superior to six-row barley varieties in terms of forage DM yield and nutritive value. Thus, we may also conclude that two-row varieties which showed the highest yield and quality potential in present study, might be responsible for compensation observed within the mixtures. The first two top yielding mixtures had two-row and six-row varieties at seeding ratio of 3:1, suggesting that 3:1 mixture of a high yielding two-row variety and a low-yielding six-row variety could increase the overall forage DM yield and nutritional quality and offer a diet that is able to meet the nutritional requirements for different classes of beef cattle.

Table 7. Mean dry matter (DM) yield, crude protein (CP), neutral detergent fiber (NDF), acid detergent fibre (ADF), and total detergent fibre (TDN) for two-row and six-row varieties used in the present study.

Type	DM Yield (tons/ac)		CP (% DM)		ADF (% DM)		NDF (% DM)		TDN (% DM)	
Check	3.40	a	13.32	a	24.80	b	40.17	a	69.59	a
Two-Row	3.38	a	12.39	a	24.82	b	42.40	a	69.57	a
Six-Row	2.83	b	12.90	a	28.30	a	44.30	a	66.86	ab
Pr (>F)	0.000126***		0.66		0.094.		0.61		0.0945.	

Note: Significance Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.'.

Table 8. Mean calcium (Ca), phosphorous (P), potassium (K), magnesium (Mg), and sodium (Na) content for two-row and six-row varieties used in the present study.

Type	Ca (%DM)		P (% DM)		K (% DM)		Mg (% DM)		Na (% DM)	
Check	0.27	b	0.20	a	1.04	ab	0.24	b	0.26	ab
Two-Row	0.30	b	0.22	a	1.00	b	0.24	b	0.19	b
Six-Row	0.39	a	0.20	a	1.09	a	0.28	a	0.29	a
Pr (>F)	0.00269**		0.158		0.121		0.0151*		0.0191*	

Note: Significance Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.'.

Table 9. Mean copper (Cu), zinc (Zn), iron (Fe), and manganese (Mn) content for two-row and six-row varieties used in the present study.

Type	Cu (ppm)		Zn (ppm)		Fe (ppm)		Mn (ppm)	
Check	3.30	a	25.15	b	87.20	a	29.56	ab
Two-Row	3.36	a	25.49	b	85.98	a	27.82	b
Six-Row	3.32	a	33.57	a	93.92	a	32.72	a
Pr (>F)	0.981		3.92e-06***		0.463		0.0755	

Note: Significance Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.'; ppm: parts per million.

As our study is conducted in only one type of environment during a single growing season, the strength to produce any broad conclusions is limited. Further research is needed to explore how variety selection, seeding ratios, and experimentation under diverse environmental conditions will affect the ability of these mixtures to stabilize forage productivity and quality over time.

Momna Farzand and Brian Kennedy speaking about new barley varieties used in this trial at LARA summer field tour in Fort Kent, Alberta, on July 25, 2024.

Thank you for your support on this project: