Integrated use of organic and inorganic fertilizers for forage barley production in Northeastern Alberta.

Barley (Hordeum vulgare L.) is one the most common forage crops in Alberta. It has superior forage quality among small grain cereal species examined (Baron et al., 2000). 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). Although there is a substantial potential to increase barley production, productivity is often limited by soil acidity, nutrient deficiency, and low levels of fertilizers application. In conventional agriculture, synthetic fertilizers are quite extensively used to increase crop yield and improve soil quality; therefore, the input of synthetic or inorganic fertilizers alone constitutes a greater portion of the total variable cost for crop production in Alberta (AAF, 2023). It has been widely realized that injudicious application of synthetic fertilizer, particularly nitrogen, pollutes surface water, ground water and atmosphere through runoff, leaching and volatilization, respectively. Long-term unreasonable synthetic fertilization may also reduce soil organic carbon and total microbial biomass and deteriorate soil quality and crop productivity over time (Tripathi et al., 2020). In contrast to inorganic fertilizers, organic fertilizers improve soil fertility on a sustainable basis through increase in soil organic matter content, water holding capacity and microbial activity (Zhang et al., 2015; Zhou et al., 2022). A long-term study in the cold prairie has shown that manure worked better on improving microbial biomass carbon than chemical fertilizer or no fertilizer treatments (Kiani et al., 2017). Similarly, compost and biochar are both high quality organic fertilizers which have received increasing attention due to their promising effects on plant growth, soil nutrient content, and carbon storage (Ashiq et al., 2020; Hagemann et al., 2018).

However, nutrients derived from organic sources are not immediately available for plant uptake compared to nutrients from synthetic fertilizers. Many research findings have shown that neither inorganic fertilizers nor organic nutrient sources alone bring a sustainable increase in crop yields (Godara et al., 2012; Abid et al., 2020). A balanced and integrated use of organic and mineral fertilizers is a sustainable eco-friendly agricultural approach to maintain soil fertility and improve crop productivity. However, no in-depth study was available to examine the effect of this integrated nutrient management practice on forage barley production in Northeastern Alberta. Therefore, a research trial was carried out to fill this knowledge gap with the following principal objectives:

Objectives:

- To evaluate the impact of soil incorporation of different organic fertilizers such as compost, biochar, cattle manure, and their combination with synthetic fertilizers on forage barley yield.
- To evaluate the impact of soil incorporation of different organic fertilizers such as compost, biochar, cattle manure, and their combination with synthetic fertilizers on forage barley quality.
- To compare the economic feasibility of organic versus inorganic nutrient sources in Northeastern Alberta.

Materials and Methods:

The experiment was planted in a randomized complete block design (RCBD) with four replications of each treatment. Organic fertilizers (Biochar, compost, and manure) were incorporated into the plots manually a day before seeding. Synthetic fertilizers were side banded during seeding. LARA Fabro five row seeder was used for seeding with 9" row spacing. 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 134.8 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.

Table 1. Characteristics of applied organic and inorganic fertilizers

Nutrient Source	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	OC (%)	C:N	DM	Ash (%)
Urea	46	0	0	-	-	-	-	-	-
MAP	11	52	0	-	-	-	-	-	-
Potash	0	0	60	-	-	-	-	-	-
Biochar	1.04	-	-	-	-	83.0	-	32.7	7.8
Compost	1.5	-	-	-	-	16.2	7.1	-	-
Manure	0.9	0.2	1.2	1.1	0.4	19.5	15:1	37.6	-

Note: N: Nitrogen; P: Phosphorus; K: Potassium; Ca: Calcium; Mg: Magnesium; OC: organic carbon C: N: Carbon: Nitrogen; DM: dry matter; MAP: Monoammonium phosphate; -: missing value.

Table 2. Treatment description.

Treatment	Application Rate
Control	No fertilizer
Synthetic fertilizer	84:44:14 lbs/acre NPK
Biochar	1 ton/acre
Compost	2.5 ton/acre
Manure	5 ton/acre
Synthetic fertilizer + biochar at 3:1 ratio	63:33:11 lb/acre NPK + 0.25 ton/acre
Synthetic fertilizer + compost at 3:1 ratio	63:33:11 lb/acre NPK + 0.63 ton/acre
Synthetic fertilizer + manure at 3:1 ratio	63:33:11 lb/acre NPK + 1.25 ton/acre
Synthetic fertilizer + biochar at 1:1 ratio	42:22:7 lb/acre NPK + 0.5 ton/acre
Synthetic fertilizer + compost at 1:1 ratio	42:22:7 lb/acre NPK + 1.25 ton/acre
Synthetic fertilizer + manure at 1:1 ratio	42:22:7 lb/acre NPK + 2.5 ton/acre

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Figure 1-1. A representative picture of trial; captured by Alyssa Krawchuk on July 25, 2024.

Results and Discussion:

The results indicated that plots under the treatments with partial substitution of inorganic fertilizers (NPK) by organic fertilizers such as cattle manure and compost gave better results than plots where inorganic or organic fertilizers were applied alone. The highest forage biomass was obtained from application of 75% of the recommended rate of inorganic fertilizers (63:33:11 lb/acre NPK) + 1.25 ton/acre of cattle manure and lowest forage biomass was obtained from the control (no fertilizer treatment). The highest forage DM yield obtained was 3.45 t ac-1, whereas the lowest was 2.24 t ac-1. Application of 50% of the recommended dose of inorganic fertilizers (42:22:7 lbs/acre NPK) integrated with 1.25 ton/acre of compost, gave the second highest forage production at 3.15 t ac-1. On the other hand, application of full recommended dose of inorganic fertilizers (84:44:14 lbs/acre NPK) gave the third highest forage DM yield in this study at 3.01 t ac-1. All the non- NPK treatments even if they received full rates of manure, compost, and biochar, gave the least forage production (Figure 2).

The average crude protein (CP) content ranged from 10.80 to 13.85% for plots that were amended with organic fertilizers in combination with mineral fertilizers. The highest CP content (13.85%) was recorded in treatment where 75% of the recommended rate of inorganic fertilizers (63:33:11 lb/acre NPK) was applied along with 0.25 ton/acre of biochar. Similarly, total digestible nutrients (TDN) were greater (≥ 65%) in all plots under the treatments where integrated applications of organic and inorganic fertilizers were used.

When comparing treatments with each other, the lowest acid detergent fiber (ADF) and neutral detergent fiber (NDF) concentrations were recorded in plots under the treatments where 25% of recommended dose of inorganic fertilizers was replaced by either 1.25 ton/acre of cattle manure or 0.63 ton/acre of compost (Table 4).

So, we may conclude that the integrated use of inorganic and organic fertilizers (Compost and manure) can not only reduce the input of synthetic fertilizers but also help to maintain high silage barley yield and quality and achieve sustainable agriculture. Since this study is conducted in only one type of environment during a single growing season, further research is needed to produce any broad conclusions

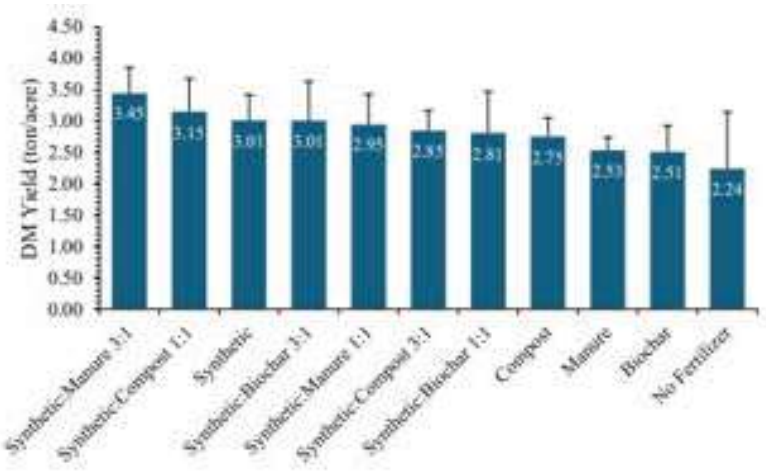

Figure 2. Effects of different fertilizer treatments on forage barley dry matter (DM) yield.

Table 4. Forage crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), and total digestible nutrients (TDN) for all fertilizer treatments.

Treatment	CP (% DM)		ADF (% DM)		NDF (% DM)		TDN (% DM)	
No Fertilizer	11.20	bc	29.70	ab	55.40	ab	65.77	ab
Synthetic Fertilizer	13.68	ab	26.26	b	46.59	ab	68.44	a
Biochar	11.75	abc	30.22	ab	52.18	ab	65.40	b
Compost	12.10	abc	28.55	ab	47.58	ab	66.66	ab
Manure	12.56	abc	30.41	ab	51.44	ab	65.21	b
Synthetic Fertilizer: Biochar 3:1	13.85	a	27.69	ab	45.93	ab	67.33	ab
Synthetic Fertilizer: Biochar 1:1	13.10	ab	27.62	ab	47.60	ab	67.38	ab
Synthetic Fertilizer: Compost 3:1	13.10	abc	26.34	ab	45.24	ab	68.39	a
Synthetic Fertilizer: Compost 1:1	12.20	abc	31.10	a	55.23	a	64.70	b
Synthetic Fertilizer: Manure 3:1	12.81	abc	26.57	ab	45.84	ab	68.20	ab
Synthetic Fertilizer: Manure 1:1	10.80	c	30.60	a	55.02	a	66.48	ab
Pr (>F)	0.204		0.137		0.231		0.161	

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 fertilizer treatments.

Treatment	Ca (% DM)		P (% DM)		K (% DM)		Mg (% DM)		Na (% DM)	
No Fertilizer	0.30	b	0.23	ab	1.50	ab	0.22	ab	0.23	ab
Synthetic Fertilizer	0.28	b	0.26	a	1.51	ab	0.23	ab	0.26	ab
Biochar	0.32	ab	0.24	abc	1.53	ab	0.20	b	0.18	ab
Compost	0.28	b	0.23	abc	1.53	ab	0.20	b	0.19	ab
Manure	0.31	b	0.26	a	1.70	a	0.23	ab	0.12	b
Synthetic Fertilizer: Biochar 3:1	0.37	a	0.24	abc	1.50	abc	0.25	a	0.33	a
Synthetic Fertilizer: Biochar 1:1	0.28	b	0.22	abc	1.22	c	0.22	ab	0.31	a
Synthetic Fertilizer: Compost 3:1	0.33	ab	0.23	abc	1.34	bc	0.25	ab	0.25	ab
Synthetic Fertilizer: Compost 1:1	0.33	ab	0.21	c	1.32	bc	0.22	ab	0.34	a
Synthetic Fertilizer: Manure 3:1	0.29	b	0.22	bc	1.18	c	0.20	ab	0.31	a

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

Treatment	Cu (ppm)		Zn (ppm)		Fe (ppm)		Mn (ppm)	
No Fertilizer	5.52	abc	39.17	a	106.11	ab	24.11	a
Synthetic Fertilizer	4.70	cd	27.85	ab	102.80	ab	28.56	a
Biochar	5.50	abc	25.75	b	108.90	ab	24.31	a
Compost	5.75	ab	25.08	b	108.51	ab	28.49	a
Manure	6.28	a	22.88	b	107.41	ab	24.50	a
Synthetic Fertilizer: Biochar 3:1	4.93	cd	28.10	ab	103.74	ab	28.90	a
Synthetic Fertilizer: Biochar 1:1	4.48	d	24.19	b	90.99	ab	24.51	a
Synthetic Fertilizer: Compost 3:1	4.82	cd	25.57	ab	113.30	a	29.16	a
Synthetic Fertilizer: Compost 1:1	4.97	bcd	26.21	ab	115.10	a	27.88	a
Synthetic Fertilizer: Manure 3:1	4.80	cd	25.29	ab	90.20	ab	24.67	a
Synthetic Fertilizer: Manure 1:1	4.93	cd	24.70	b	84.66	ab	25.28	a
Pr (>F)	0.00872**		0.58		0.488		0.672	

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

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