

Forage and Livestock Research

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

Background:

Barley (*Hordeum vulgare* L.) is one of the most widely grown annual forage crops in Alberta and has better feed quality than oats, wheat, or triticale. Given its major role in cattle feed, producers rely heavily on intensive applications of synthetic fertilizers to increase barley yield and quality. Consequently, the cost of synthetic fertilizers constitutes a large proportion of the total variable cost of forage barley production in Alberta. Moreover, the overuse of synthetic or chemical inputs can pose a serious threat to environmental quality. In addition, injudicious application of synthetic fertilizers does not guarantee long-term productivity on many soils due to rapid soil quality degradation, highlighting the need for more sustainable alternatives.

Compared with inorganic fertilizers, organic fertilizers contribute to a more sustainable improvement in soil fertility; however, nutrients derived from organic sources may not be as readily available to plants. In this context, the combined use of organic and inorganic nutrient sources could be a feasible approach to improving and maintaining soil fertility compared to the use of either source alone. Partial substitution of inorganic fertilizers with organic nutrient sources may also help producers reduce the cost of forage barley production in Alberta. Numerous experimental studies from different regions of the world have shown that replacing up to 50% of inorganic fertilizers with organic amendments such as cattle manure, poultry manure, biochar, and compost can enhance crop yield and quality.

However, no in-depth study has examined the effects of this integrated nutrient management practice on forage barley production in northeastern Alberta. Therefore, the proposed study was conducted to fill this knowledge gap with the following principal objectives.

Objectives:

- i. 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.
- ii. 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.
- iii. To compare the economic feasibility of organic versus inorganic nutrient sources in Northeastern Alberta.

Materials and Methods:

The trial was carried out at the LARA research farm (54° 18'N, 110° 37'W; NE 25-61-5-W4) in Fort Kent, Alberta, during the 2025 growing season. Before seeding, soil samples were taken to a depth of 0-6 and 6-12 inches to determine the nutrient level at Element Lab, Edmonton. AB Maximizer, one of the top-yielding forage barley cultivars in the Lakeland region, was utilized in this trial. Seeding rate (g/plot) was calculated using the formula: $1000 \text{ kernel weight} * (\text{desired plants}/\text{m}^2/1000) * \text{plot area m}^2 * (100/\text{germination}\%) * 1.05$. 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 3c-1. Description of treatments applied in the present study.

Treatment	Application Rate
Control	No fertilizer
Synthetic fertilizer	133:24:13 lbs/acre NPK
Biochar	1 ton/acre
Compost	2.5 ton/acre
Manure	5 ton/acre
Synthetic fertilizer + biochar at 3:1 ratio	100:18:10 lb/acre NPK + 0.25 ton/acre
Synthetic fertilizer + compost at 3:1 ratio	100:18:10 lb/acre NPK + 0.63 ton/acre
Synthetic fertilizer + manure at 3:1 ratio	100:18:10 lb/acre NPK + 1.25 ton/acre
Synthetic fertilizer + biochar at 1:1 ratio	67:12:7 lb/acre NPK + 0.5 ton/acre
Synthetic fertilizer + compost at 1:1 ratio	67:12:7 lb/acre NPK + 1.25 ton/acre
Synthetic fertilizer + manure at 1:1 ratio	67:12:7 lb/acre NPK + 2.5 ton/acre

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. The LARA Fabro five-row seeder was used for seeding with 9" row spacing. 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 the soft dough stage. Individual plots were harvested with the LARA Alfalfa-Omega self-propelled forage harvester. For each treatment plot, ~ 400 g of freshly chopped forage (sub-sample) was dried to a constant weight 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.

Results and Discussion:

The results indicated that the fertilizer treatments had a significant effect on forage DM yield. Among the four top-yielding treatments, three involved biochar applied either alone or in combination with inorganic fertilizer, while one used compost alone, and all outperformed the full recommended dose of synthetic fertilizer (133:24:13 lb ac⁻¹ NPK). The highest forage biomass (4.00 t ac⁻¹) was obtained from 75% of the recommended inorganic fertilizer (100:18:10 lb ac⁻¹ NPK) combined with 0.25 t ac⁻¹ of biochar. Plots treated with the full recommended dose of compost (2.5 t ac⁻¹) produced the second-highest yield (3.8 t ac⁻¹), followed by plots receiving 50% of the recommended inorganic fertilizer (67:12:7 lb ac⁻¹ NPK) + 0.5 t ac⁻¹ of biochar, and plots that received the full recommended dose of biochar (1.0 t ac⁻¹), both yielding 3.62 t ac⁻¹.

The plots receiving full recommended inorganic fertilizer dose produced 3.58 t ac⁻¹ of DM yield. All other treatments, including even the one that received the full recommended dose of manure (5 t ac⁻¹), produced lower yields than these top-performing treatments. As expected, the lowest yield (2.98 t ac⁻¹) was recorded in the control treatment, which received no fertilizer (Fig 3c-1).

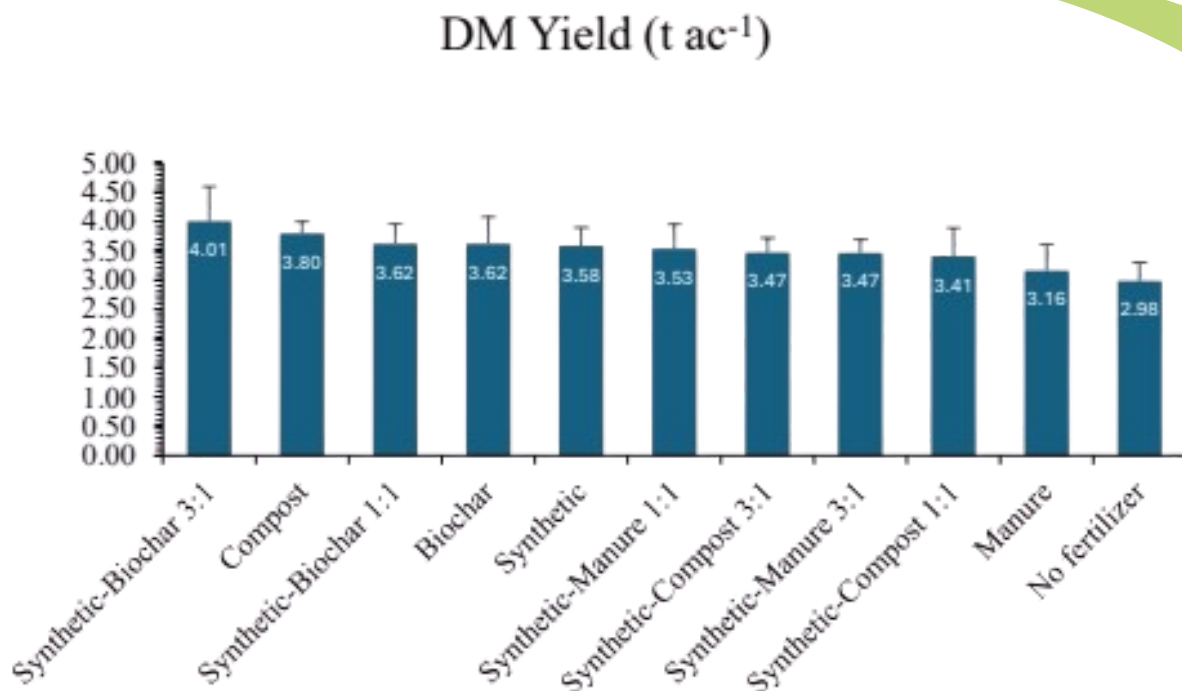


Figure 3c-1. Effects of different fertilizer treatments on forage barley dry matter (DM) yield.

In terms of forage quality, crude protein (CP) levels were also significantly influenced by the fertilizer treatments. Overall, CP content ranged from 10.42% to 11.70% across all treatments, which is sufficient to meet the protein requirements of beef cows during mid-gestation and lactation. For reference, dietary CP levels of 7%, 9%, and 11% are recommended for beef cattle during mid-gestation, late gestation, and lactation, respectively. Total digestible nutrients (TDN), which provide a simple estimate of feed energy, follow the 55-60-65 rule, where beef cows in mid-pregnancy, late pregnancy, and post-calving require 55%, 60%, and 65% TDN, respectively. All treatments produced TDN levels above 65%, indicating they would meet the energy requirements of beef cows after calving. The fiber fraction of forage barley was not significantly affected by the fertilizer treatments, as indicated by ADF and NDF values that ranged from 21.61 to 23.93% and 44.41 to 47.06%, respectively (3c-2). Most treatments also produced adequate amounts of essential macro-minerals, including calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) (Table 3c-3). However, none of the treatments supplied sufficient copper (Cu), zinc (Zn), or manganese (Mn) to fully meet the recommended requirements for beef cattle (Table 3C-4). Copper and zinc concentrations were below the recommended levels of 10 mg kg⁻¹ and 30 mg kg⁻¹, respectively, while manganese concentrations were below 20 mg kg⁻¹ across treatments. These results may indicate a potential risk of micronutrient deficiency, suggesting that free-choice mineral supplementation containing Cu, Zn, and Mn may be required for beef cattle consuming this forage.

Table 3c-2. 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	10.49	b	23.10	a	47.06	a	70.91	a
Synthetic Fertilizer	11.70	a	22.24	a	45.00	a	71.58	a
Biochar	10.53	b	22.58	a	44.45	a	71.31	a
Compost	10.69	b	21.61	a	44.41	a	72.10	a
Manure	10.42	b	22.17	a	44.53	a	71.63	a
Synthetic Fertilizer: Biochar 3:1	11.13	ab	23.62	a	46.30	a	70.50	a
Synthetic Fertilizer: Biochar 1:1	10.56	b	23.93	a	45.72	a	70.26	a
Synthetic Fertilizer: Compost 3:1	10.93	b	22.99	a	45.28	a	70.99	a
Synthetic Fertilizer: Compost 1:1	10.58	b	22.48	a	45.28	a	71.39	a
Synthetic Fertilizer: Manure 3:1	10.84	b	22.61	a	45.27	a	71.29	a
Synthetic Fertilizer: Manure 1:1	10.94	b	23.83	a	46.43	a	70.34	a
Pr (>F)	0.044*		0.662		0.846		0.661	

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

Table 3c-3. 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	0.24	a	0.11	ab	1.11	a	0.18	a	0.25	abcd
Synthetic Fertilizer	0.25	a	0.11	ab	1.20	a	0.17	a	0.25	abcd
Biochar	0.22	a	0.10	b	1.10	a	0.17	a	0.22	d
Compost	0.27	a	0.12	a	1.17	a	0.17	a	0.23	bcd
Manure	0.24	a	0.11	ab	1.15	a	0.18	a	0.23	cd
Synthetic Fertilizer: Biochar 3:1	0.25	a	0.11	ab	1.19	a	0.17	a	0.28	abcd
Synthetic Fertilizer: Biochar 1:1	0.23	a	0.11	ab	1.14	a	0.18	a	0.29	a
Synthetic Fertilizer: Compost 3:1	0.23	a	0.11	ab	1.12	a	0.17	a	0.29	abc
Synthetic Fertilizer: Compost 1:1	0.24	a	0.10	b	1.21	a	0.18	a	0.26	abcd
Synthetic Fertilizer: Manure 3:1	0.24	a	0.11	ab	1.16	a	0.18	a	0.29	abcd
Synthetic Fertilizer: Manure 1:1	0.24	a	0.10	b	1.19	a	0.17	a	0.29	ab
Pr (>F)	0.918		0.617		0.796		0.984		0.182	

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

Table 3c-4. Forage copper (Cu), zinc (Zn), iron (Fe), and manganese (Mn) content for all fertilizer treatments.

Treatment	Cu (mg kg ⁻¹)		Zn (mg kg ⁻¹)		Fe (mg kg ⁻¹)		Mn (mg kg ⁻¹)	
No Fertilizer	3.52	a	15.56	a	104.72	a	12.83	e
Synthetic Fertilizer	2.52	c	16.52	a	94.81	a	18.94	a
Biochar	3.09	abc	14.86	a	97.93	a	13.79	de
Compost	3.26	ab	16.69	a	102.16	a	15.43	bcde
Manure	3.19	ab	15.76	a	115.23	a	14.75	cde
Synthetic Fertilizer: Biochar 3:1	3.24	ab	15.56	a	102.41	a	18.86	a
Synthetic Fertilizer: Biochar 1:1	3.03	abc	15.76	a	114.53	a	16.67	abcd
Synthetic Fertilizer: Compost 3:1	3.19	ab	14.52	a	105.58	a	17.16	abc
Synthetic Fertilizer: Compost 1:1	3.24	ab	15.89	a	104.16	a	17.32	abc
Synthetic Fertilizer: Manure 3:1	2.83	bc	14.89	a	97.83	a	18.00	ab
Synthetic Fertilizer: Manure 1:1	2.89	bc	15.25	a	108.67	a	16.40	abcd
Pr (>F)	0.103		0.953		0.772		0.00445**	

Note: Significance Codes: 0 **** 0.001 *** 0.01 ** 0.05 *; mg kg⁻¹: milligram per kilogram.

In conclusion, replacing 25% of the recommended inorganic fertilizer dose with 0.25 t ac⁻¹ of biochar increased yield by approximately 10% compared to the full recommended inorganic fertilizer dose. However, the economic feasibility of this practice is questionable, as inorganic fertilizer costs around \$100 per acre, whereas replacing 25% of the recommended dose with 0.25 t ac⁻¹ of biochar may cost up to \$475 per acre. Although biochar provides several benefits, including improved nutrient and moisture retention, its high cost makes this substitution economically impractical under the conditions of this study. By contrast, the second-highest yielding treatment, which received the full recommended dose of compost (2.5 t ac⁻¹), surpassed the yield of the full recommended dose of synthetic fertilizer by almost 6%. Applying 2.5 t ac⁻¹ of compost costs approximately \$150 per acre, making it a more cost-effective option. While compost is still more expensive than inorganic fertilizer, it offers additional advantages by improving soil fertility on a sustainable basis.

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