NDSU NORTH DAKOTA STATE UNIVERSITY

Alfalfa forage yield, nutritive value & cold-stress adaptation in northern U.S. environments

A mixed-model analysis of location, genotype, and genotype × environment effects on NFC and RFQ

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North American Alfalfa Improvement Conference · Session VI: Forage Quality, Sustainability & Ecosystem Services
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Why this matters in the northern U.S.?

Alfalfa combines high forage yield, nutritive value, and multiple ecosystem services, but its adoption in northern regions is constrained by winter injury and poor persistence.

Location	Winter injury	Reference
Alaska	Siberian alfalfa: 17%; A-syn.B: 74%; Rambler: 98%; California Common: 100%	Klebesadel (1993)
Minnesota	Lahontan: 17%; Grimm: 39%; Rambler: 46%; DePuits: 83%	Sheaffer (2023)
North Dakota	Grimm: 60%; Tian Jin: 28%, Miechowsca : 37%	This project

Project objectives:

1

Germplasm resources

Characterize USDA alfalfa accessions for winter hardiness, root architecture, N2 fixation, **forage yield** and **quality**.

2

Field performance

Quantify **forage yield**, **nutritive value**, persistence and root traits in commercial cultivars and accessions.

3

Regional impact

Assess sustainability and translate results into cultivar and management recommendations for northern producers.

Root architecture, N fixation and Objective 3 are underway.

Experimental design (multi-location, 2025)

Locations (6)

- North Dakota: Fargo, Minot.
- Alaska: Palmer, Fairbanks.
- Minnesota: Grand Rapids.
- Missouri: Columbia.

Design: randomized complete block design (RCBD).

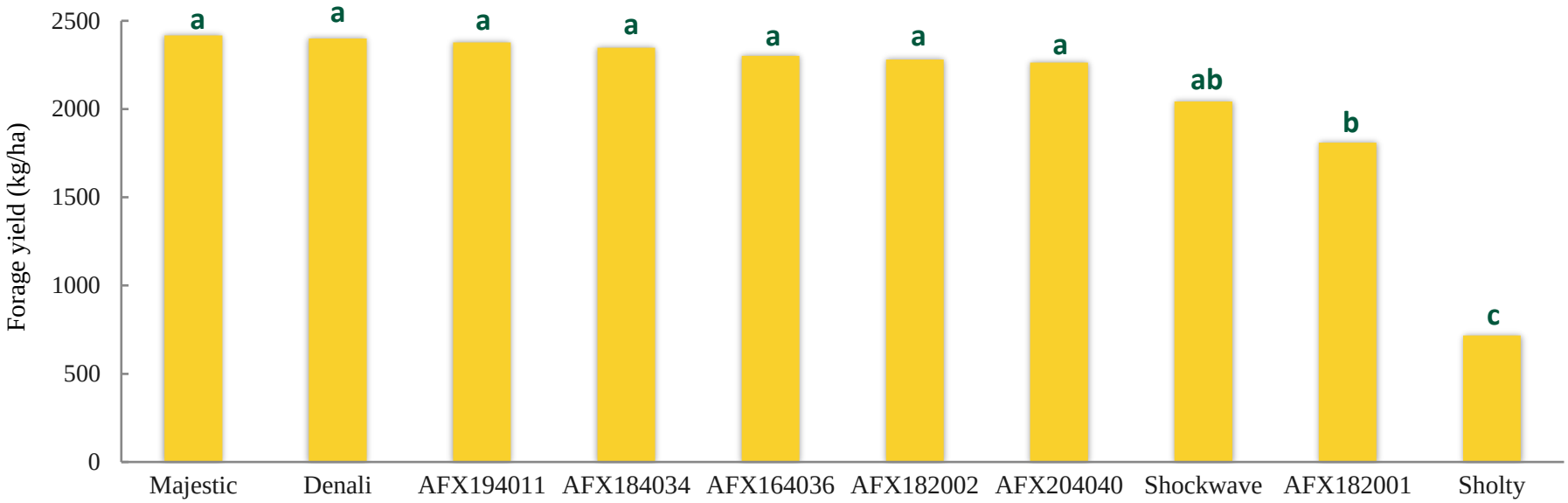
Cultivar trial: 8-10 cultivars/location, 4 replicates
Accession trial: 24 accessions/location, 3 replicates (single 3.3-m rows).

Measured:

- Plant height
- Forage yield
- Total digestible nutrients (TDN), non-fibrous carbohydrates (NFC), and relative forage quality (RFQ).

Harvest: not all sites harvested in 2025 (Minot and Columbia, MO were not harvested).

Results- Cultivar yield in Fargo, ND (2025)

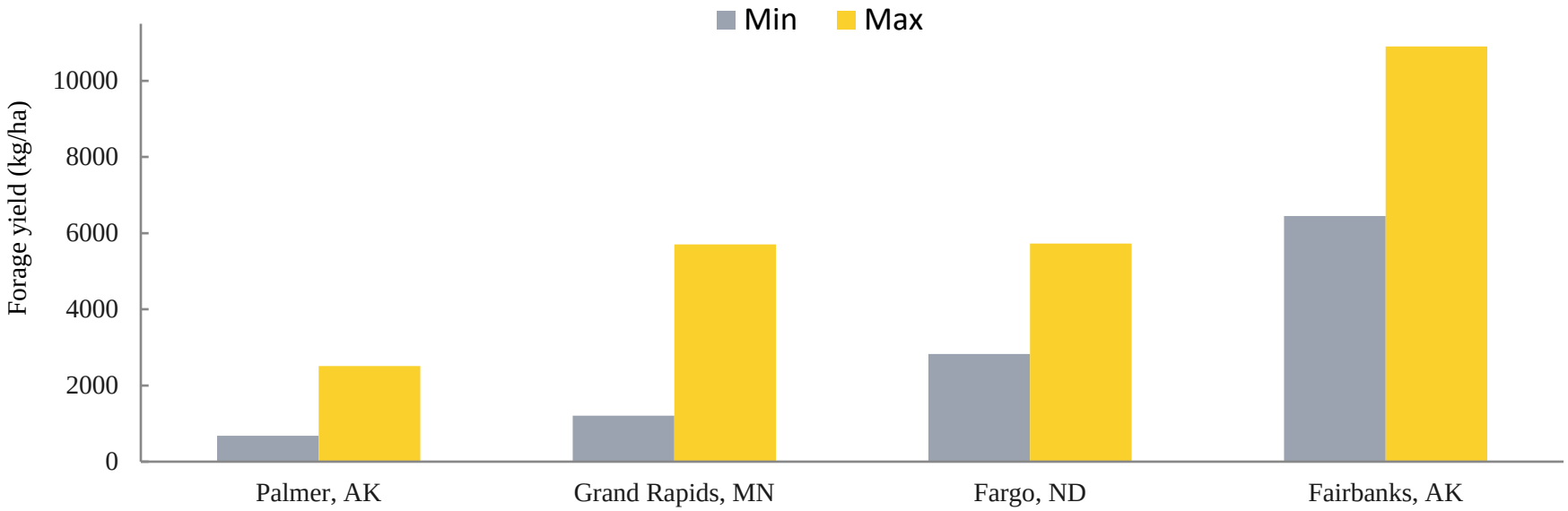


First-cut forage yield of alfalfa cultivars evaluated in Fargo, ND. Bars represent mean, and cultivars sharing the same letter are not significantly different (*P*=0.05).

Key points

- Significant differences among cultivars in establishment year
- Lowest yields: Sholty (*Medicago falcata*) and AFX182001 (*Medicago sativa*)

Forage yield varies strongly by location



Total forage yield of alfalfa cultivars across locations, expressed as the sum of two cuts.

Key points

- Fairbanks showed the highest forage yield (and the widest spread).
- Palmer had the lowest forage yield.

Nutritive value- statistical analysis

MODEL A — Location Random

Goal: To estimate how all the total variance across the locations is driving by genetics vs environment

Trait ~ Cultivar+ (1|Location)
+ (1|Rep:Location)
+ (1|Location:Cultivar)

→ *Value variance components (Location, G×E, Rep, Residual)*

MODEL B — Location Fixed

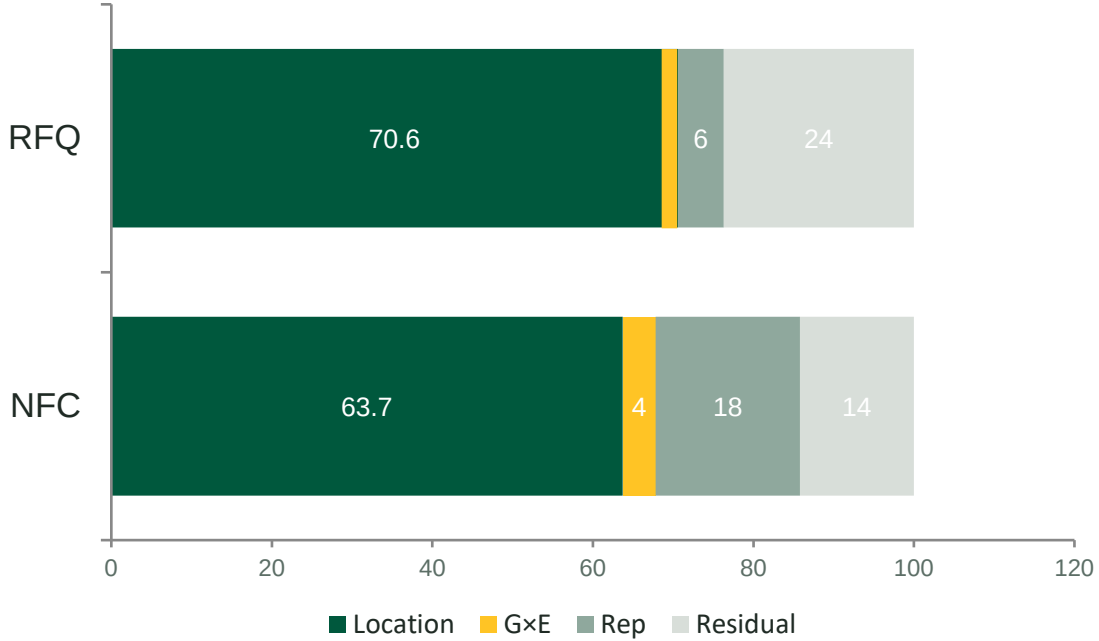
Goal: To statistically compare the specific mean of the 6 tested sites

Trait ~ Location × Cultivar
+ (1|Rep:Location)

→ *F-tests for Location, Genotype, G×E*

Full Variance Decomposition

Variety trial — Model A (location random)



RFQ: Location 70.6% · G×E 0.6% · Rep 5.7% · Residual 23.7%

NFC: Location 63.7% · G×E 4.1% · Rep 18.0% · Residual 14.2%

Location was the dominant, significant effect

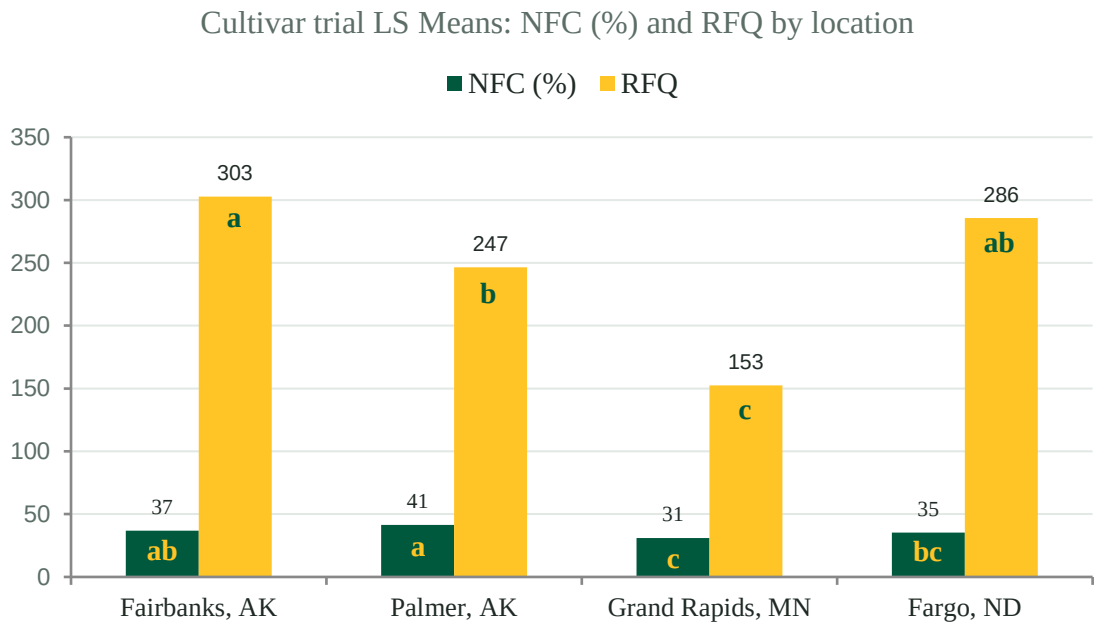
Cultivar trial — Model B (location fixed)

Source	NFC *F*	NFC *P*	RFQ *F*	RFQ *P*
Location	13.96	**0.001 ***	33.65	**0.001 ***
Cultivar	0.89	0.522 ns	2.08	0.055 ns
Location × Cultivar	2.14	**0.008 ***	0.98	0.492 ns

** p<0.05 ns = not significant*

RFQ location effect also significant in the accessions trial ***(F = 4.65, P = 0.036)*** — the pattern replicates across both experiments.

NFC and RFQ were higher in Alaska locations

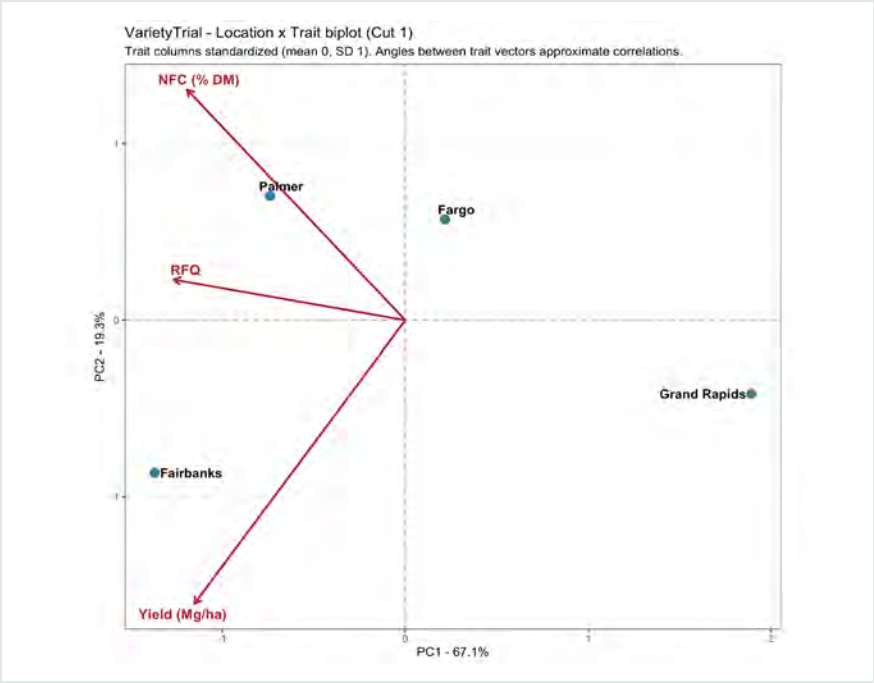


Means followed by different letters are significantly different - Tukey's HSD test (P < 0.05)

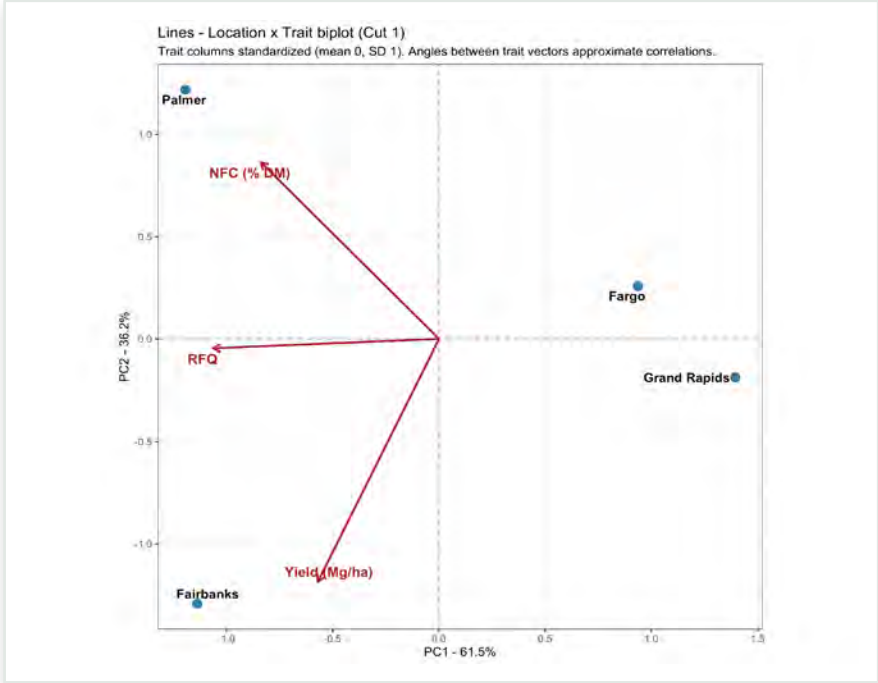
Latitude gradient for

- Fairbanks, AK - 64.8°N
- Palmer, AK - 61.6°N
- Grand Rapids, MN - 47.2°N
- Fargo, ND - 46.9°N

Nutritive value principal components analysis

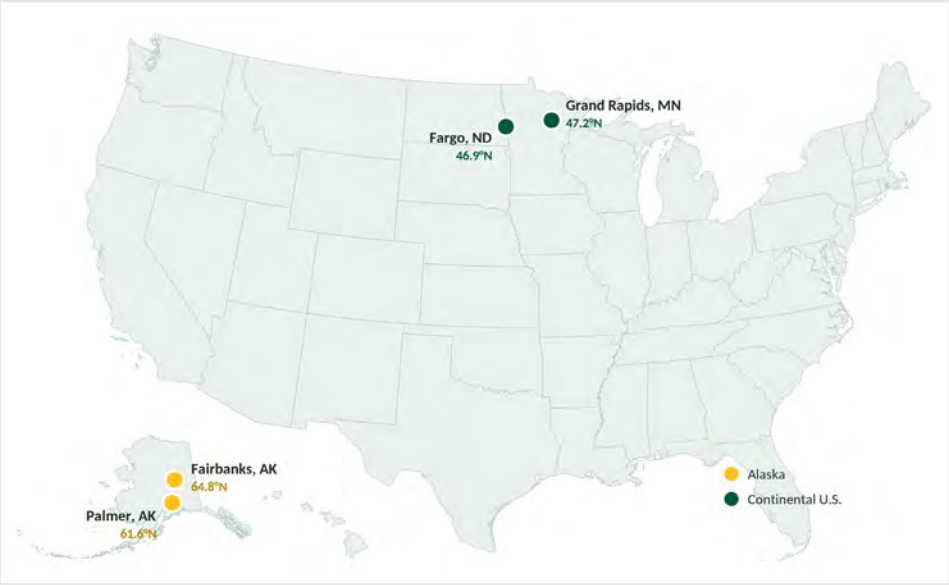


Cultivar Trial (8 cultivars)



Accessions trial (24 accessions)

Discussion



- Non-fibrous carbohydrates (NFC) — sugars, starches, pectins — drive alfalfa digestibility and animal performance
- High-radiation, high-elevation regions of the western U.S. report unusually high NFC (Villalba et al., 2021)
- The northern sites showed a similar response: long photoperiod and cool nights may favor accumulation of non-structural carbohydrates, especially **pectins.**

Conclusions

Alfalfa forage quality was more closely associated with location than with genotype — highest in Alaska.

For breeding and management: where alfalfa is grown may matter more for nutritive quality than which cultivar is planted.

Next: testing whether this pattern holds in mature stands (Second year).

Thank You

Questions are welcome.

Funded by USDA-NIFA-AFRI, project “Northern Exposure: Adaptation of Alfalfa for Challenging Winter Climates” (award 2024-06270), and NDSU Experiment Station Hatch Project 01514.

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