Investigating Nitrogen Management in a Perennial Dual-Use Kernza-Alfalfa Intercropping System

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Kernza Intermediate Wheatgrass

Why Kernza?

- Perennial sustainability benefits
- Relatively high grain size and yield
- Consumer quality grain
- High forage biomass

Kernza Shortcomings

- Grain size is ⅓ of wheat
- Grain yield decline over time

Closing the Gap Between Grasslands and Grain Agriculture (Crews, 2017)

Intercropping Kernza with Alfalfa

- ❑ Weed suppression
- ❑ Increased soil N and C in topsoil
- ❑ Refuge for beneficial insects
- ❑ Reduction in pest and disease incidence

- Yield increase
- Higher land use efficiency
- Yield stability over time

Dual-Use Cropping Systems

A dual-use system is one with the intended purpose of both harvesting grain and utilizing vegetative growth as forage for livestock.

- Improved profitability & reduced business risk (McGrath et al., 2021a).
- Bridge for both feed quality and quantity gaps at different times of the season (McGrath et al. 2021b
- Financial risk of Kernza grain production can be reduced by managing the system for high forage yield (Hunter et al., 2020)

Experimental Objectives

Determine whether, compared to monoculture Kernza, a Kernza-alfalfa intercrop can…

- Reduce synthetic N fertilization
- Maintain or improve grain and forage yields
- Maintain or improve forage quality
- Maintain yields and quality over time
- Vary with environment

Experimental Design

4 Locations

- Cornell University (NY)
- University of Wisconsin-Madi (WI)
- University of Minnesota (MN)
- The Land Institute (KS)

2 cropping schemes

- Intercrop: 5.6 kg/ha Kernza, 5.6 kg/ha Alfalfa

3 main data points

- Grain Yield
- Kernza Forage Biomass

3 harvests annually for 2 years

- Spring pre-elongation
- Summer (~r

5 Nitrogen (urea) rates

- 0 kg/ha
- 40 kg/ha
- 80 kg/ha
- 120 kg/

Alfalfa Variety

- Shockwave BR (Fall Dormancy 4)

Results

Grain Yield

N= Nitrogen Rate E= Environment C= Cropping System

Harvest	N	E	C	N:E	N:C	E:C	N:E:C
Year 1	**	****	** **	**	**	*	*
Year 2	***	***		***	***	*	*

* P≤0.05 **, P≤0.01, *** P≤0.001

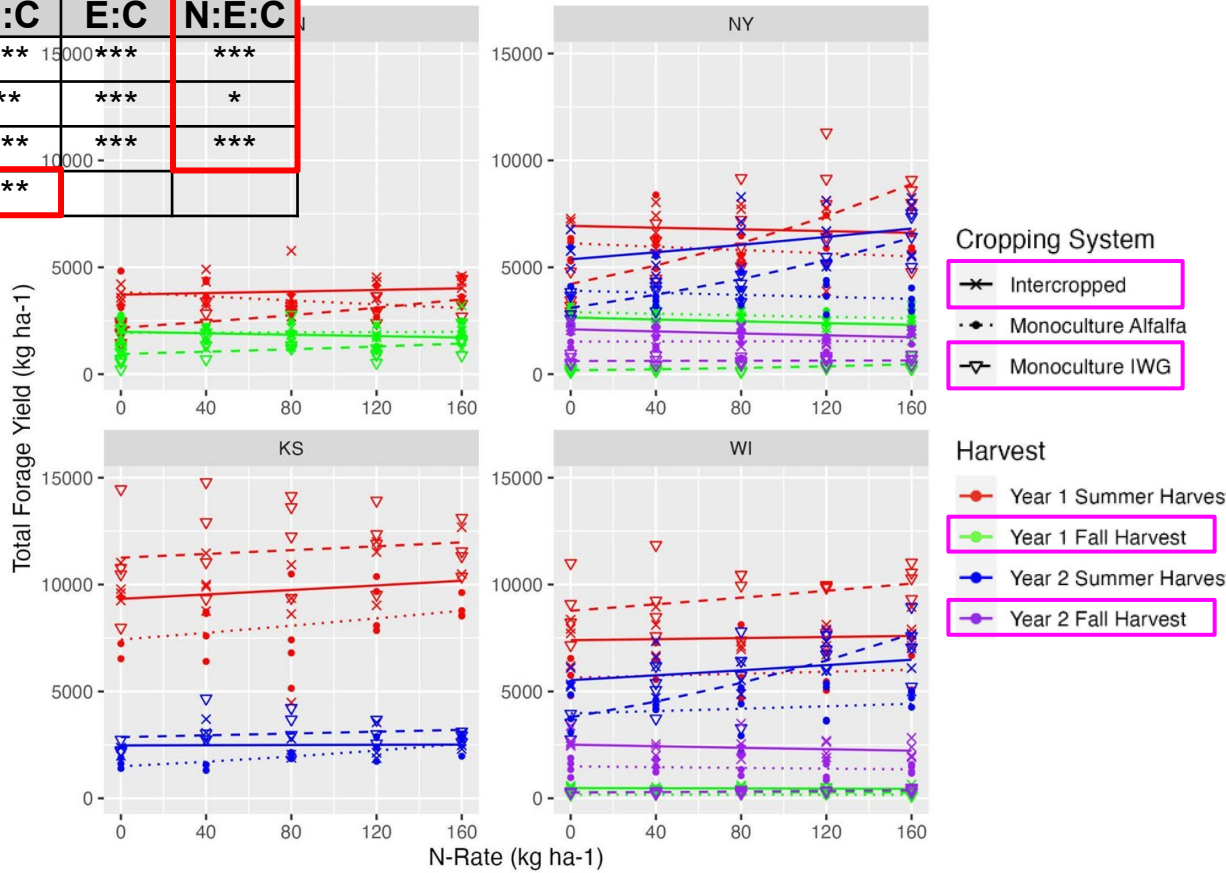
- Variable response to N rate by site and cropping system
- If no differences between cropping systems, then no grain yield penalty per area in intercrop, despite half seeding rate

Total Forage Yield

N= Nitrogen Rate E= Environment C= Cropping System

Harvest	N	E	C	N:E	N:C	E:C	N:E:C	N:C	E:C	N:E:C
Year 1 Summer	***	***	***	***	***	***	***	***	***	***
Year 1 Fall		***	***	***	**	***	*	**	***	*
Year 2 Summer	***	***	***	***	***	***	***	***	***	***
Year 2 Fall		*	***	*	***	***		***		

- If no response to N rate in intercrop, then opportunity to reduce N inputs and costs
- Fall Intercrop total forage yield > monoculture Kernza
- Year 1 total forage > Year 2



Land Equivalent Ratio

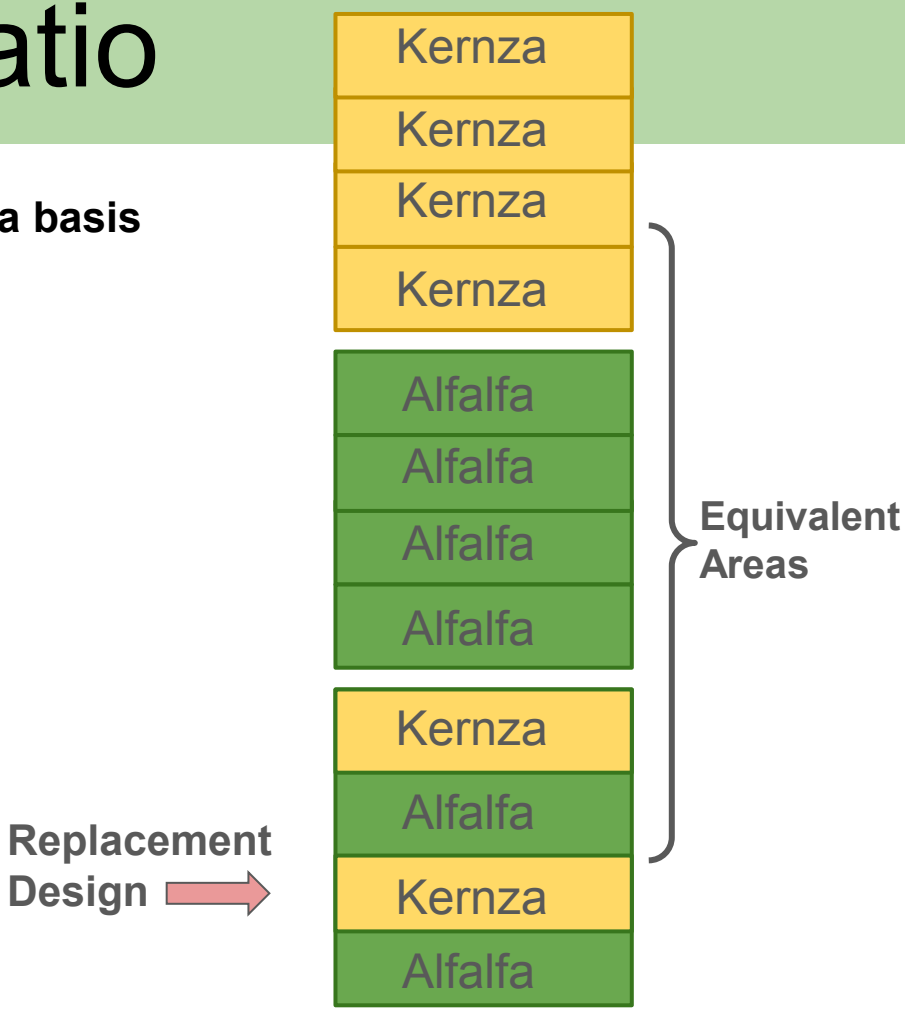
Indicates intercrop yield advantage on a per-area basis

$$\text{Kernza Partial LER} = \frac{\text{Kernza yield intercrop}}{\text{Kernza yield monoculture}}$$

$$\text{Alfalfa Partial LER} = \frac{\text{Alfalfa yield intercrop}}{\text{Alfalfa yield monoculture}}$$

LER= Kernza PLER + Alfalfa PLER

LER>1 = Yield advantage in intercrop

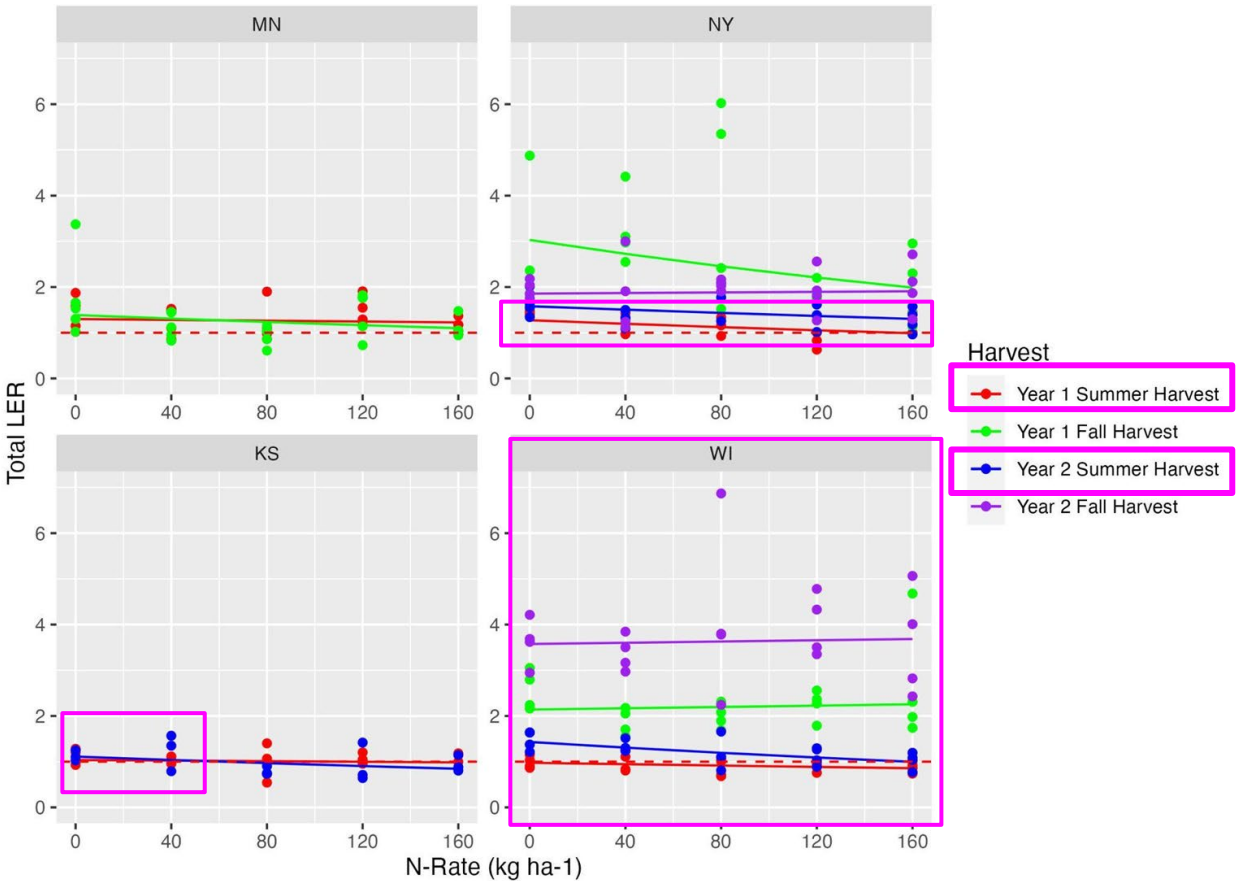


LER

N= Nitrogen Rate E= Environment

Harvest	N	E	N:E
Year 1 Summer			
Year 1 Fall		***	
Year 2 Summer	**	*	
Year 2 Fall		***	

- At higher N rates, intercrop yield advantage less likely
- Intercrop confers yield advantage except at high N rate in summer harvests
- Year 2 LER can be greater than Year 1

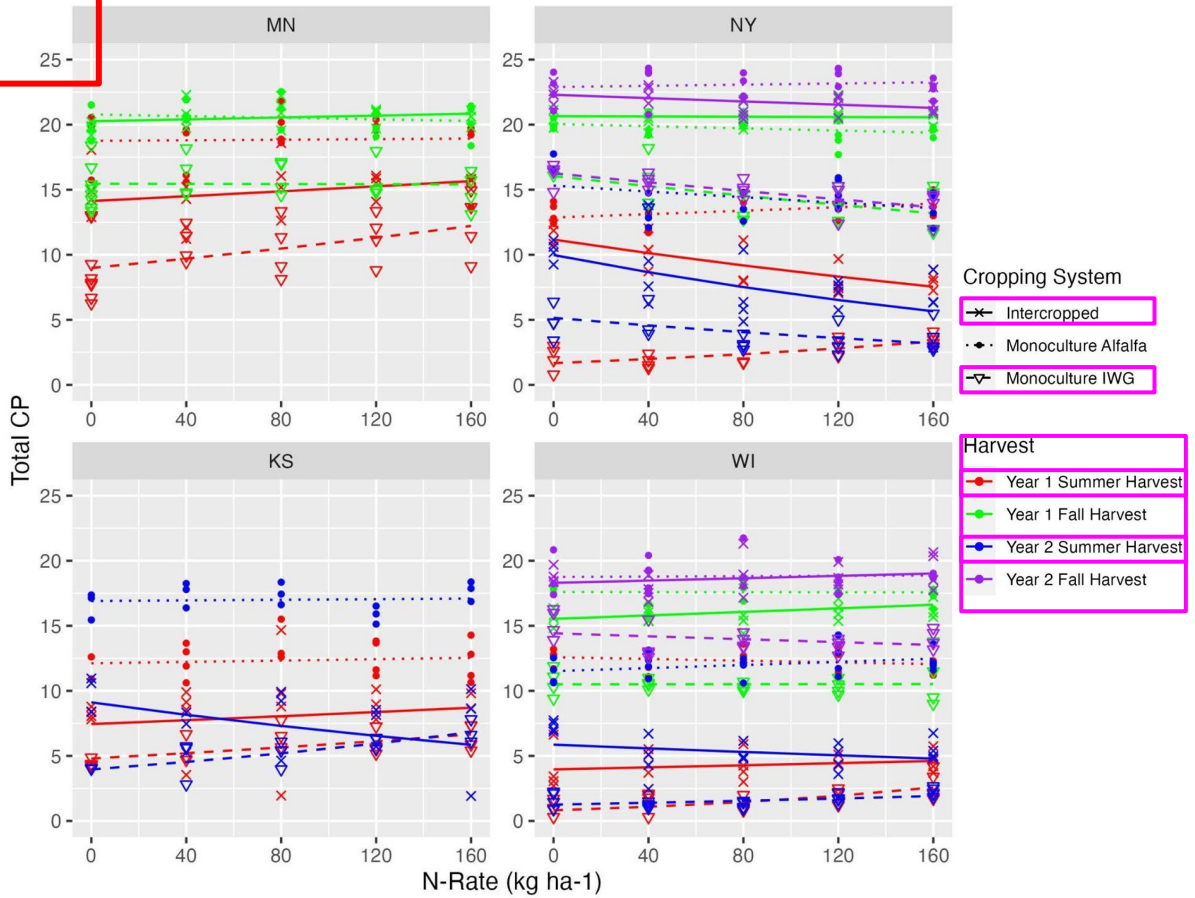


Crude Protein (CP)

N= Nitrogen Rate, E= Environment, C= Cropping System

Harvest	N	E	C	N:E	N:C	E:C	N:E:C
Year 1 Summer	***	***	***	***	***	***	***
Year 1 Fall		***	***	*	*	**	
Year 2 Summer		***	***	***	**		
Year 2 Fall	*	***	***	***	***	**	
Year 2 Fall	*	***		***	**	**	**

- Intercrop CP generally did not respond to N
- Intercrop CP > monoculture Kernza CP
- Fall CP > Summer CP



Conclusions

At some locations, a farmer focused on Kernza grain yield may benefit from a dual-use Kernza-alfalfa intercropping system through….

- Higher forage biomass of higher quality in the fall
- Reduced synthetic N needs
- No significant change in grain yield at half the seeding rate of monoculture

There is more work to be done!

- Third year of results
- Alfalfa variety breeding for intercrop with Kernza (underway)
- Seeding rates in intercrop
- Economic analysis of system

Acknowledgements

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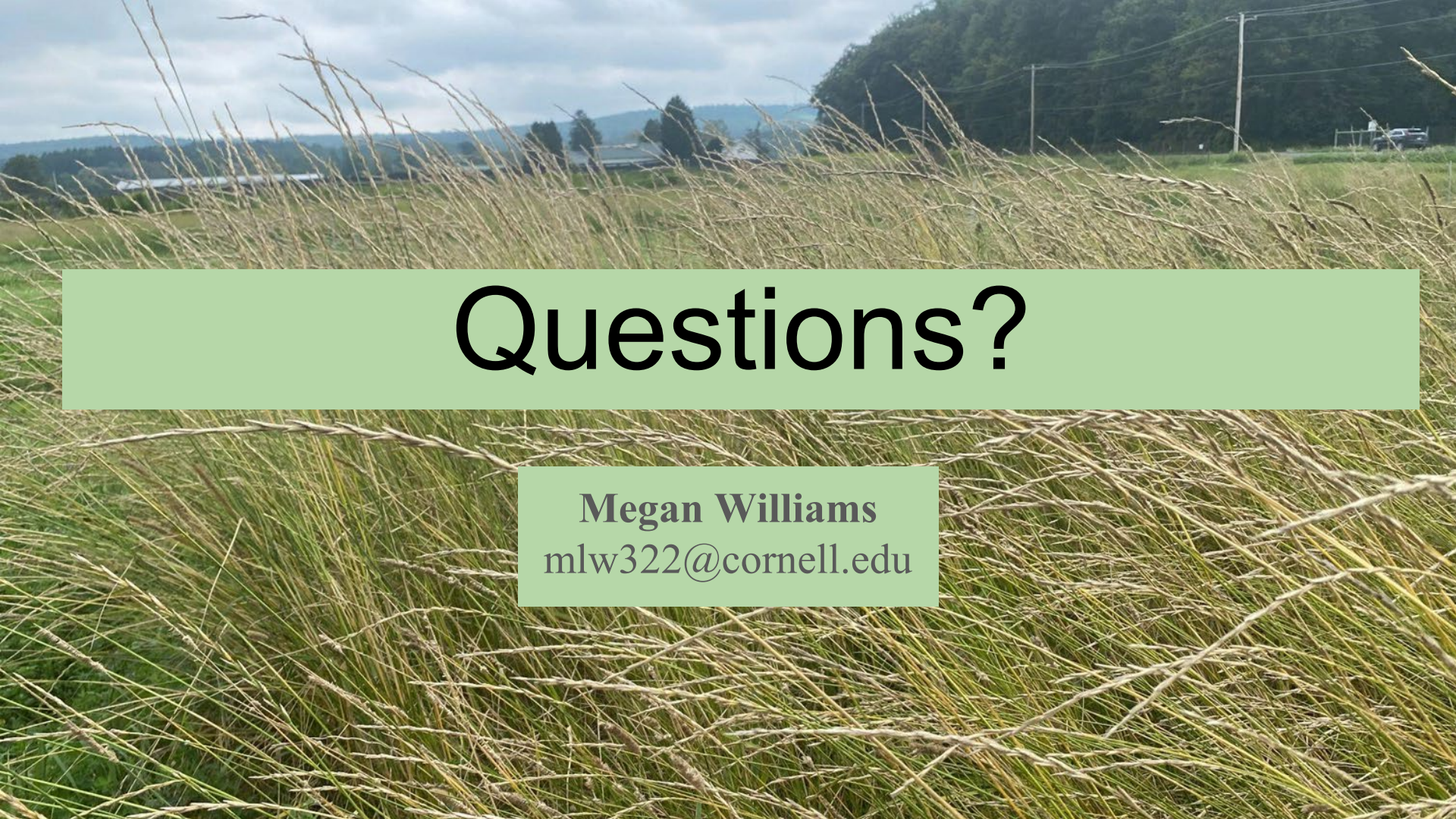

Questions?

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KS weird planting scheme

Weeds

< Perennial weeds for perennial crops

Leguminous weeds may confound N effect results >

Lodging May Affect Grain Yields

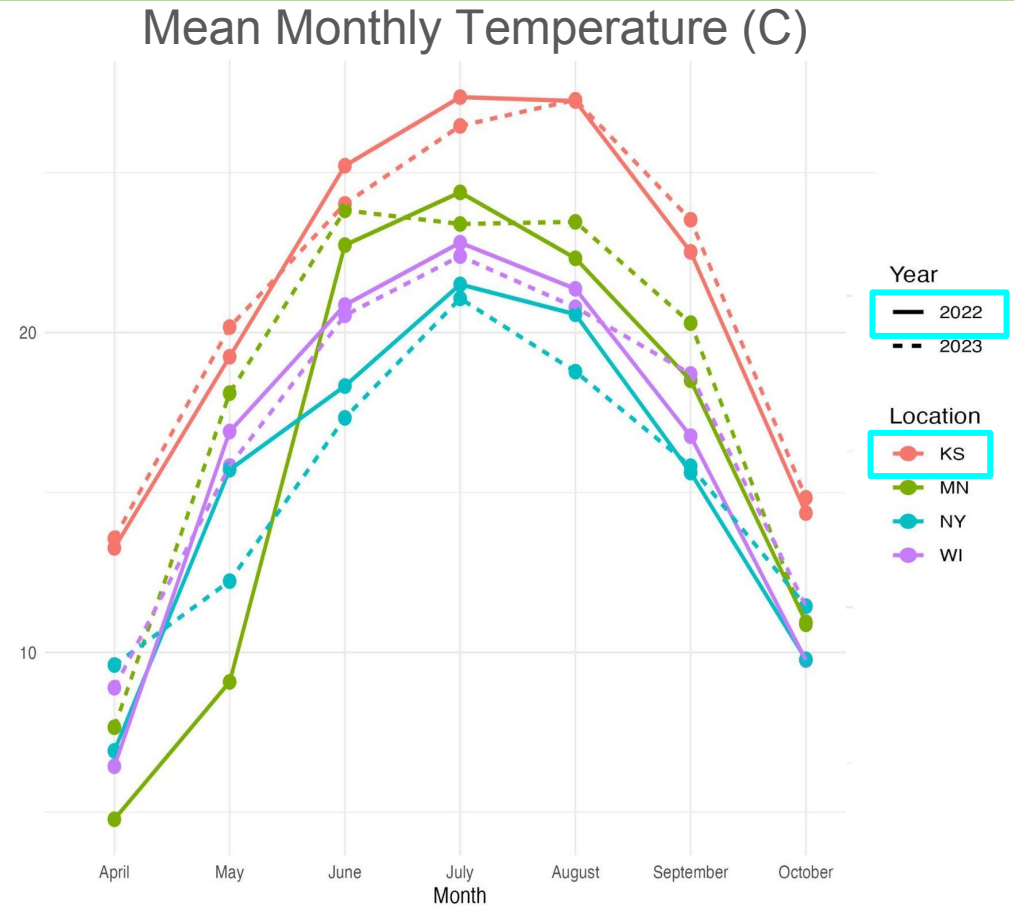
Monoculture

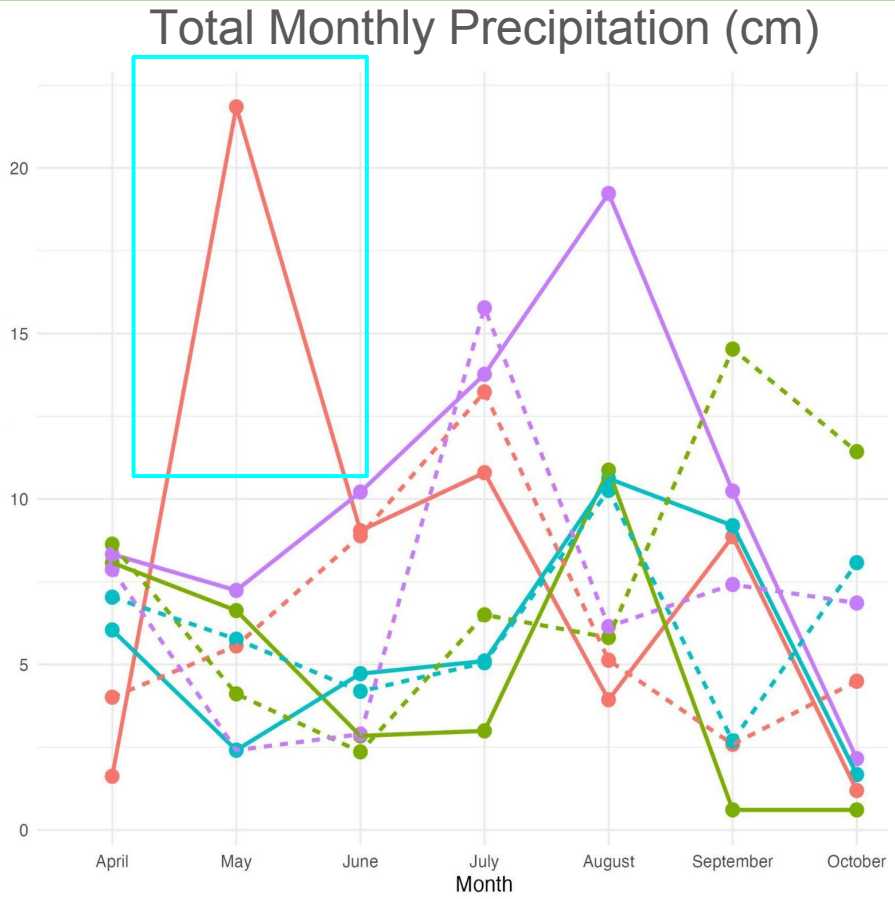
Intercropped

40 kg N ha^{-1}

160 kg N ha^{-1}

Weather by Site





USDA Hay Quality Designation Guidelines

Alfalfa Guidelines (domestic livestock use and not more than 10% grass)

Quality	ADF	NDF	RFV	TDN-100%	TDN-90%	CP
Supreme	<27	<34	>185	>62	>55.9	>22
Premium	27-29	34-36	170-185	60.5-62	54.5-55.9	20-22
Good	29-32	36-40	150-170	58-60	52.5-54.5	18–20
Fair	32-35	40-44	130-150	56-58	50.5-52.5	16-18
Utility	>35	>44	<130	<56	<50.5	<16

Grass Hay Guidelines

Quality	Crude Protein %
Premium	Over 13
Good	9-13
Fair	5-9
Utility	Under 5

Fall monoculture kernza

Summer monoculture kernza

Summer Intercrop

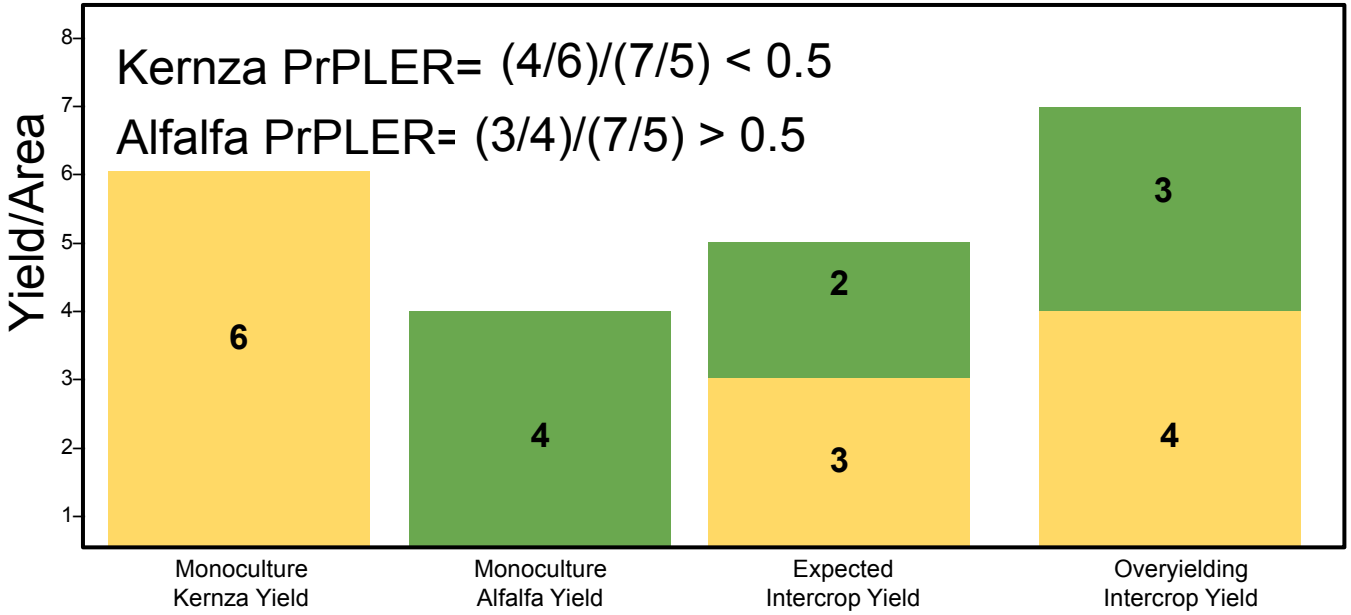
Summer Alfalfa Monoculture

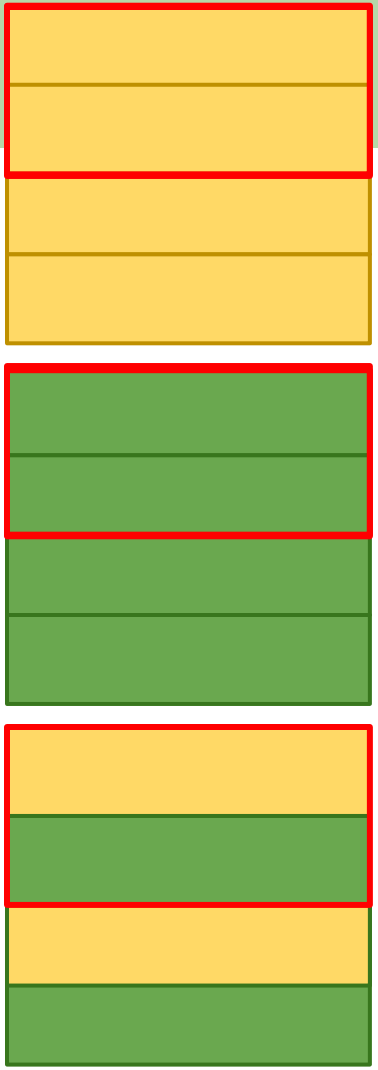
Fall Intercrop

Fall Monoculture Alfalfa

Land Equivalent Ratio (LER)

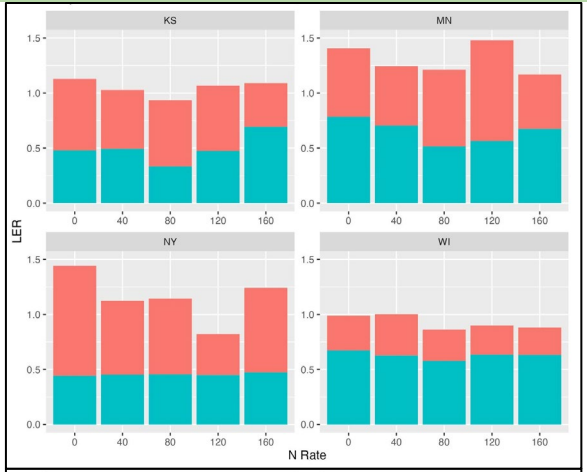
- Replacement Design
- Partial Land Equivalent Ratio (PLER)
- Total Land Equivalent Ratio (TLER)
- Proportional Partial Land Equivalent Ratio (PrPLER)
  - PrPLER= PLER/TLER



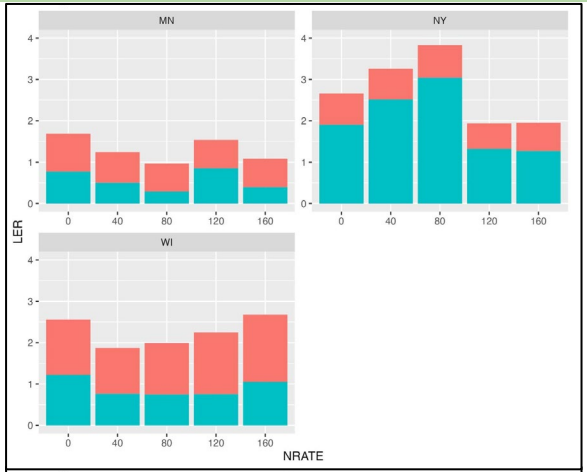


Nitrogen Rate Study: PrPLER

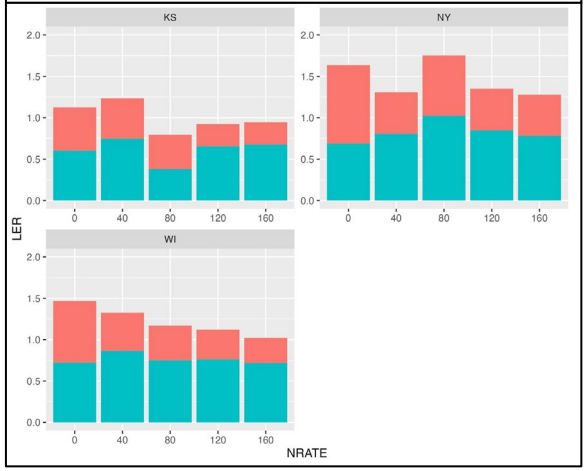
Year 1 Summer



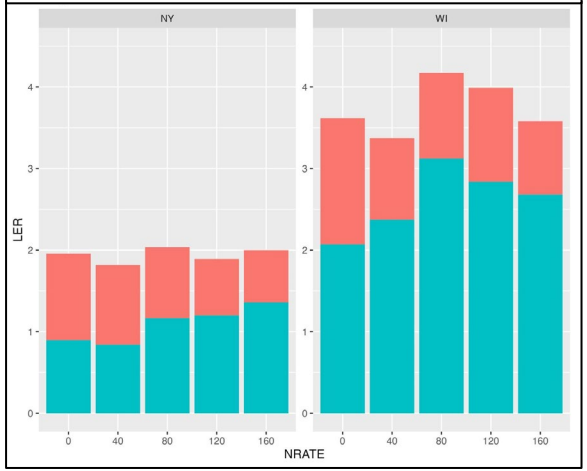
Year 1 Fall



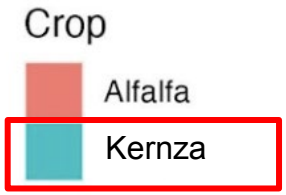
Year 2 Summer



Year 2 Fall



Kernza tended to contribute more to yield advantage in intercrop than alfalfa



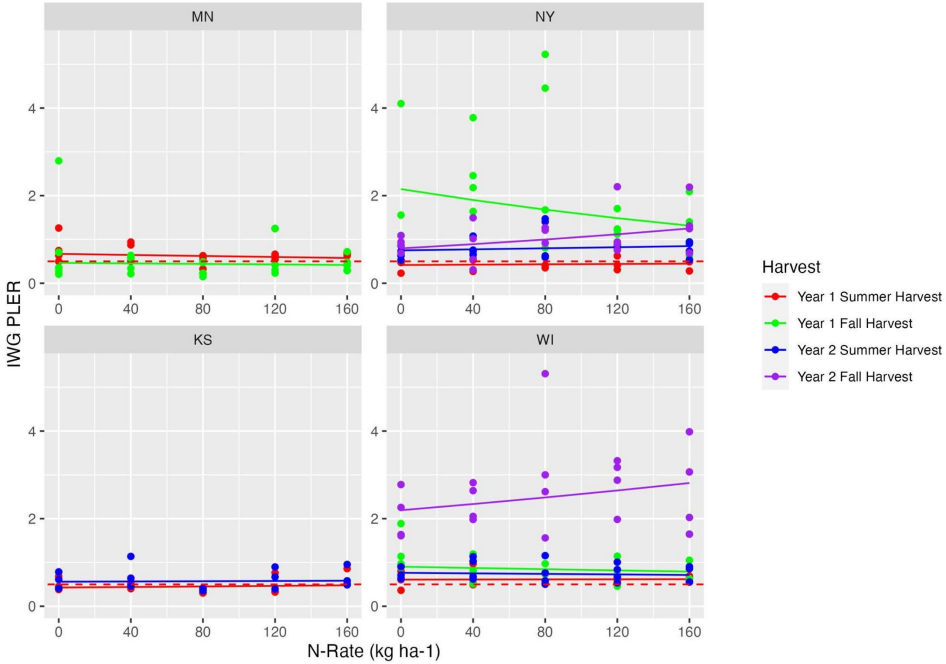
Nitrogen Rate Study: Partial LER

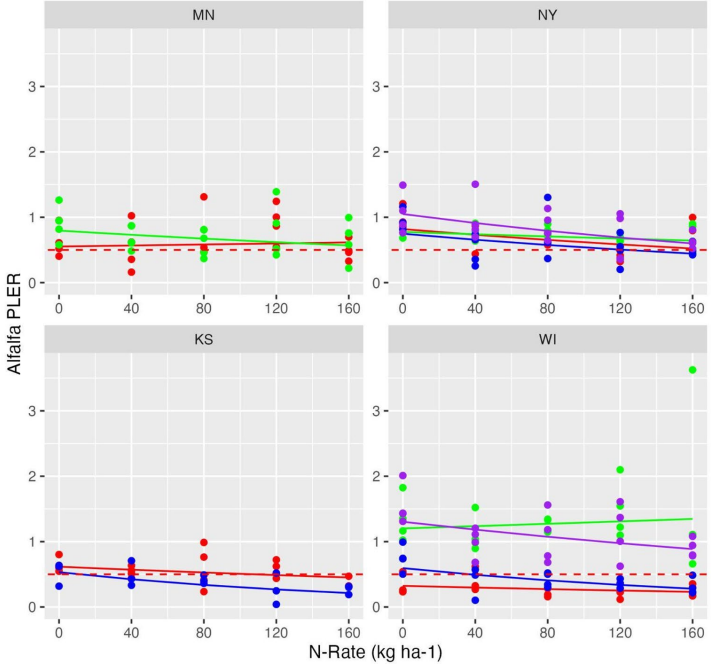
Kernza

Harvest	N	E	N:E
Year 1 Summer		*	
Year 1 Fall		***	
Year 2 Summer			
Year 2 Fall	*	***	

Alfalfa

Harvest	N	E	N:E
Year 1 Summer		**	
Year 1 Fall		*	
Year 2 Summer	***		
Year 2 Fall	***		

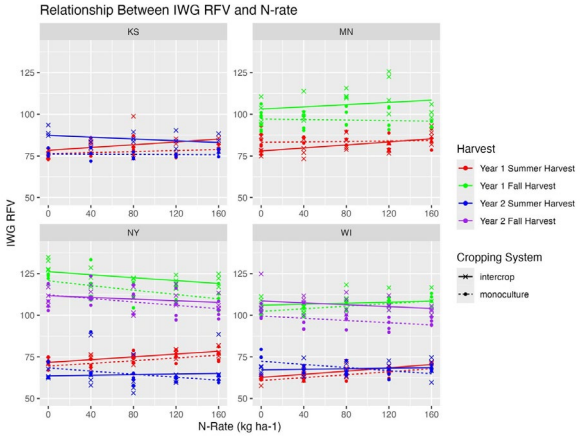




Nitrogen Rate Study: Relative Feed Value (RFV) by species

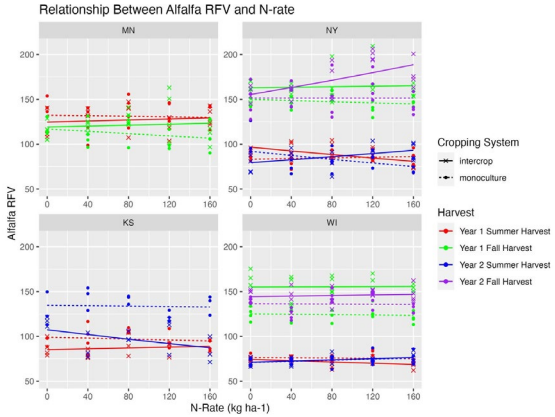
Kernza

Harvest	N	E	C	N:E	N:C	E:C	N:E:C
Year 1 Summer	***	***				*	
Year 1 Fall		***	**	**			
Year 2 Summer	*	***				***	
Year 2 Fall	**	**	*			*	



Alfalfa

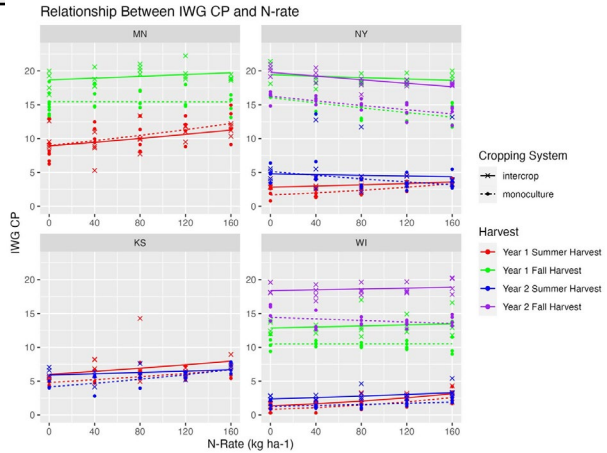
Harvest	N	E	C	N:E	N:C	E:C	N:E:C
Year 1 Summer		***				***	*
Year 1 Fall		***	***			*	
Year 2 Summer		***					
Year 2 Fall					*		



Nitrogen Rate Study: Crude Protein (CP) by species

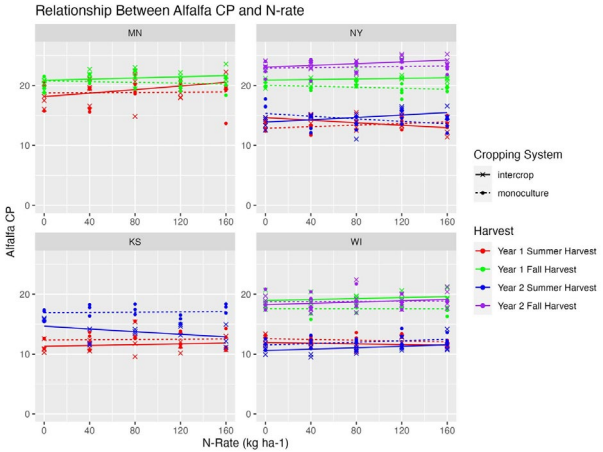
Kernza

Harvest	N	E	C	N:E	N:C	E:C	N:E:C
Year 1 Summer	***	***	***	***		*	
Year 1 Fall		***	***	*			
Year 2 Summer		***	**	**		*	
Year 2 Fall	***	***	***	***	*		



Alfalfa

Harvest	N	E	C	N:E	N:C	E:C	N:E:C
Year 1 Summer		***				**	*
Year 1 Fall		***	**		*		
Year 2 Summer		*					
Year 2 Fall		**					



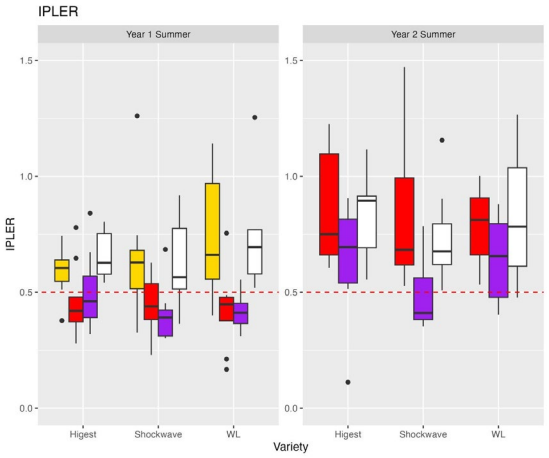
Variety Study: Partial LER

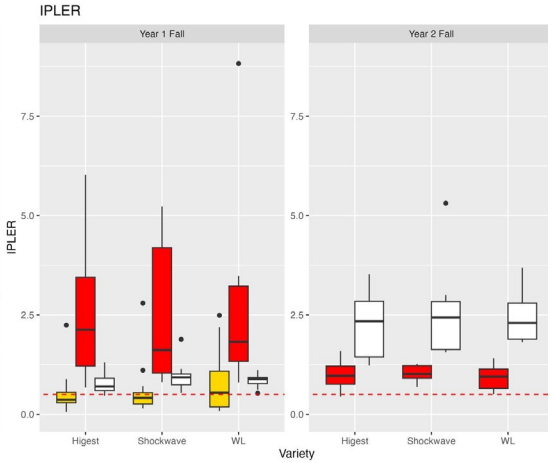
Kernza

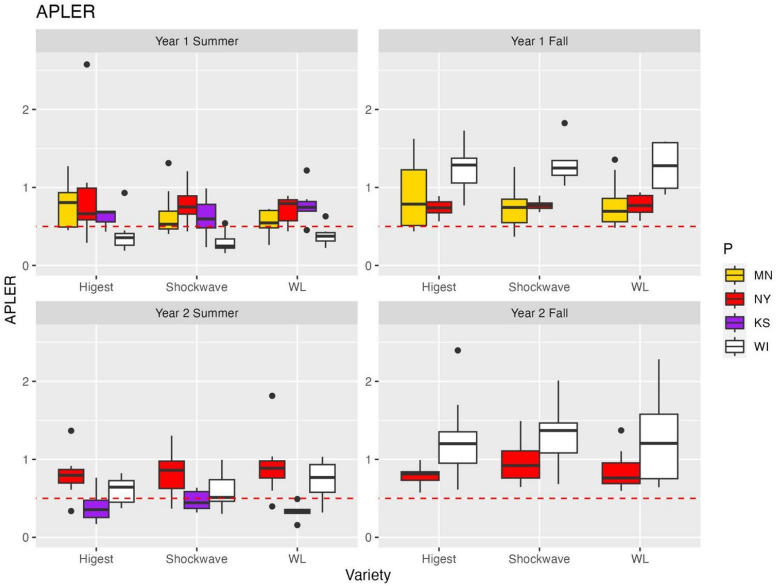
Model	G	E	G:E
Year 1 Summer		*	
Year 1 Fall		***	
Year 2 Summer			
Year 2 Fall		***	

Alfalfa

Model	G	E	G:E
Year 1 Summer		***	
Year 1 Fall		***	
Year 2 Summer		**	
Year 2 Fall		**	



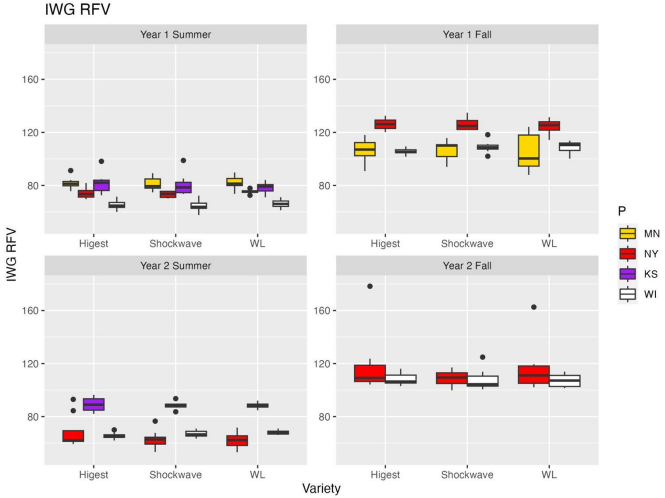




Variety Study: Relative Feed Value (RFV) by species

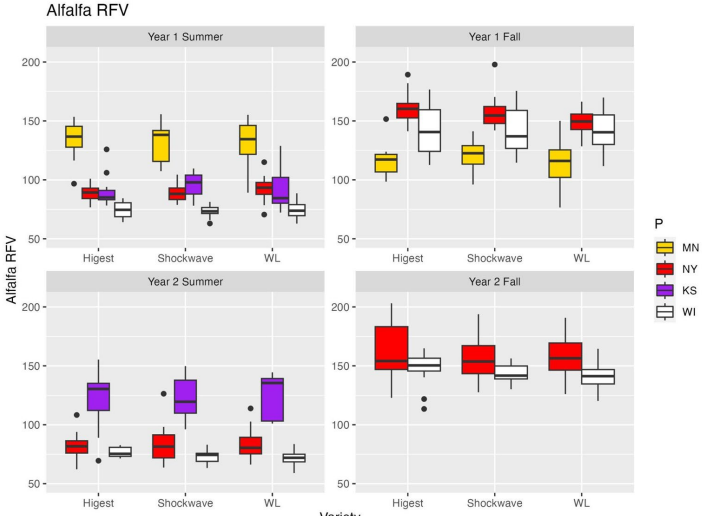
Kernza

Model	G	E	G:E
Year 1 Summer		***	
Year 1 Fall		***	
Year 2 Summer		***	
Year 2 Fall			



Alfalfa

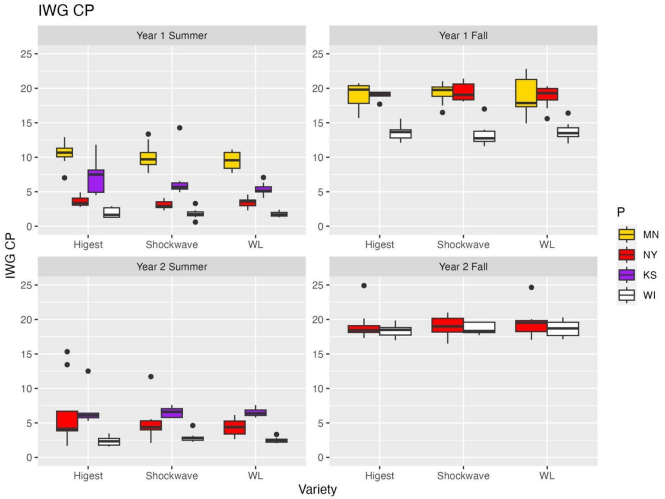
Model	G	E	C	G:E	G:C	E:C	G:E:C
Year 1 Summer		***	***			**	
Year 1 Fall		***	***			***	
Year 2 Summer		***	***			***	
Year 2 Fall		*	*				



Variety Study: Crude Protein (CP) by species

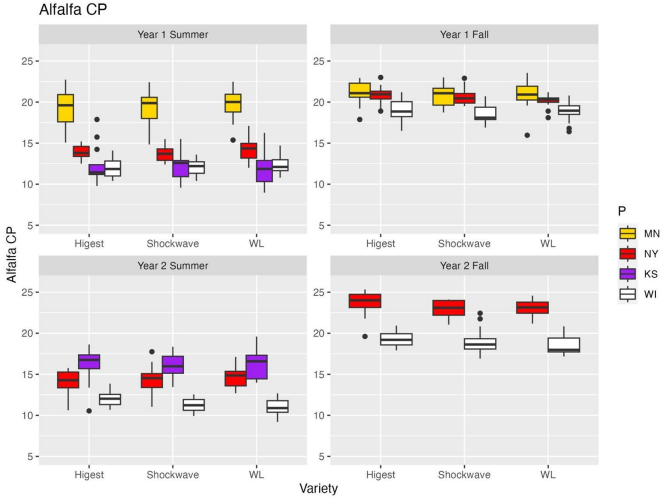
Kernza

Model	G	E	G:E
Year 1 Summer		***	
Year 1 Fall		***	
Year 2 Summer		***	
Year 2 Fall			



Alfalfa

Model	G	E	C	G:E	G:C	E:C	G:E:C
Year 1 Summer		***	*			***	
Year 1 Fall		***	***			**	
Year 2 Summer		***	***			**	
Year 2 Fall		***					



Grain dehulled weight adjustment

Analysis program: *ilastik*

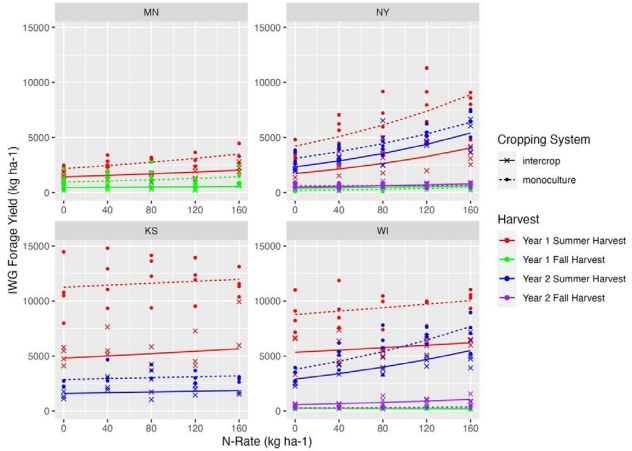
Estimated dehulled sample weight = (0.905045351733363* *imaged sample weight)*-((1.10627799960595E-05)* *hull fraction * hull area)*+((4.10249606987368E-06)**naked seed fraction * naked seed area)*-((2.01262650442053E-05)* *Spikelet fraction * spikelet area)*

Adjusted plot grain yield= *(estimated dehulled sample weight/ sample weight)*(plot grain yield weight)*

Nitrogen Rate Study: Forage yield by species

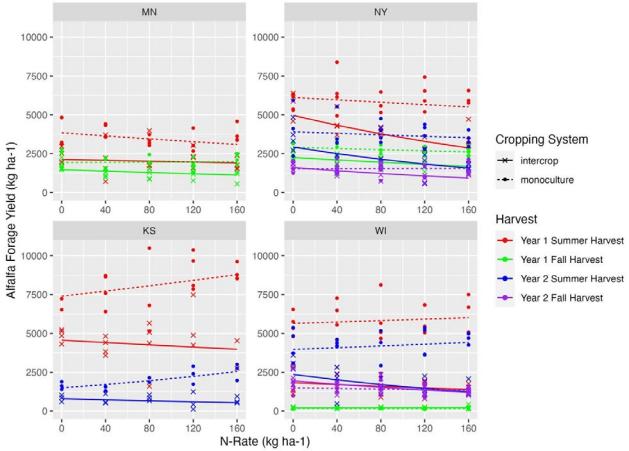
Kernza

Harvest	N	E	C	N:E	N:C	E:C	N:E:C
Year 1 Summer	***	***	***	***		**	
Year 1 Fall	**	***		**		***	
Year 2 Summer	***	***	***	***			
Year 2 Fall	***	**	**		*	***	



Alfalfa

Harvest	N	E	C	N:E	N:C	E:C	N:E:C
Year 1 Summer	*	***	***			***	
Year 1 Fall		***				*	
Year 2 Summer		***	***		***		
Year 2 Fall	**				**		



Nitrogen Effect on Forage Yields

0 kg N ha-1

40 kg N ha-1

80 kg N ha-1

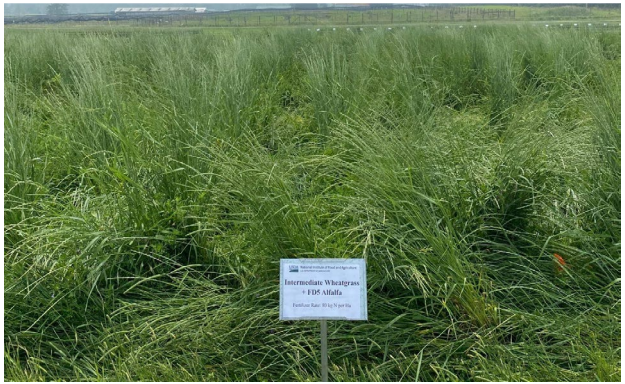
120 kg N ha-1

160 kg N ha-1

Intercropped alfalfa varieties across N rates

Shockwave BR 80 kg N ha-1

WL365HQ 0 kg N ha-1

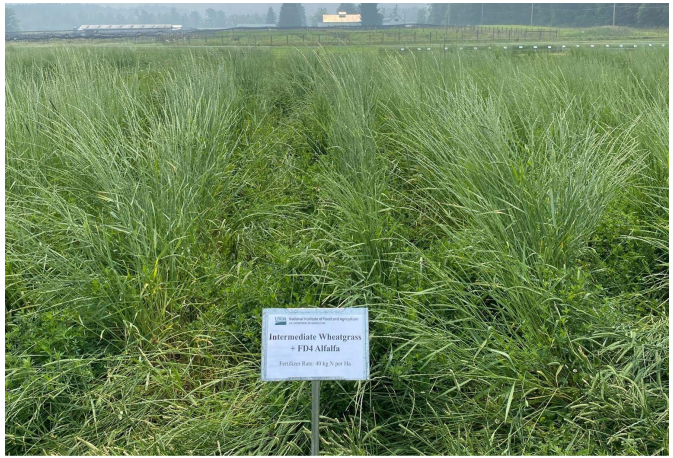


WL365HQ 80 kg N ha-1

Higest 0 kg N ha-1

Higest 80 kg N ha-1

Intercrop across N rates (year 2)



40 kg N ha-1

80 kg N ha-1

120 kg N ha-1

160 kg N ha-1

Monoculture Kernza across N rates

0 kg N ha-1

40 kg N ha-1

80 kg N ha-1

120 kg N ha-1

160 kg N ha-1

Monoculture vs Intercrop Kernza at 160 kg N ha-1

Farmer trouble harvesting grain due to lodging…. ?

Monoculture

Intercropped

Monoculture vs Intercrop Kernza at 120 kg N ha-1

Monoculture

Intercropped

Monoculture vs Intercrop Kernza at 80 kg N ha-1

Monoculture

Intercropped

Monoculture vs Intercrop Kernza at 40 kg N ha-1

Monoculture

Intercropped