Are Slow Release Nitrogen Fertilizers a Best Management Practice?

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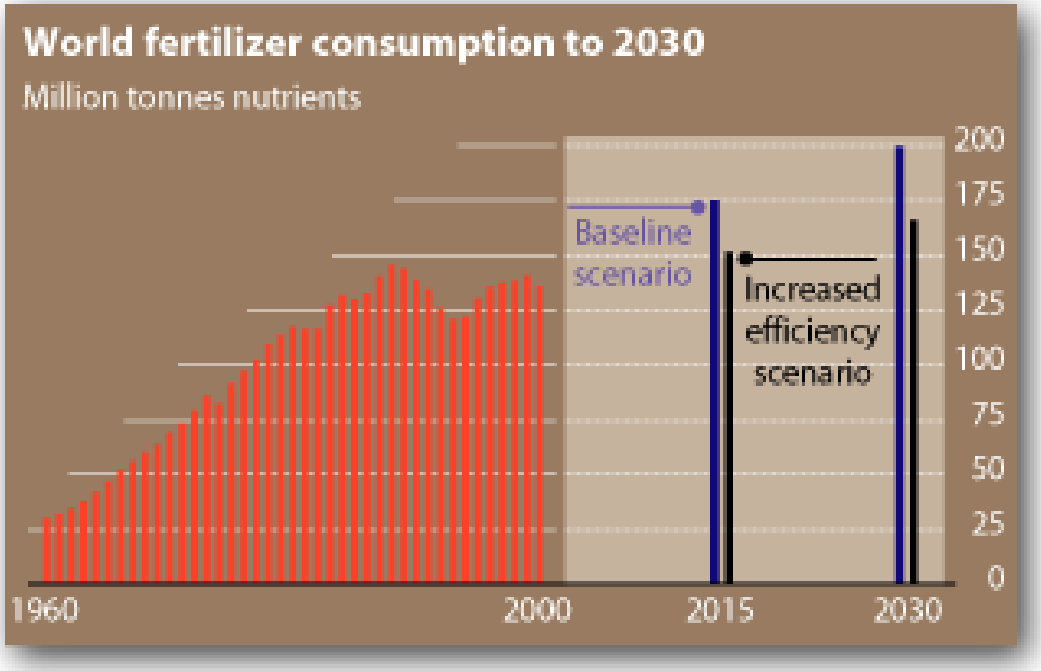
Deanna L. Osmond, Sheri Cahill, Dan Israel, Randy Weisz, and Carl Crozier

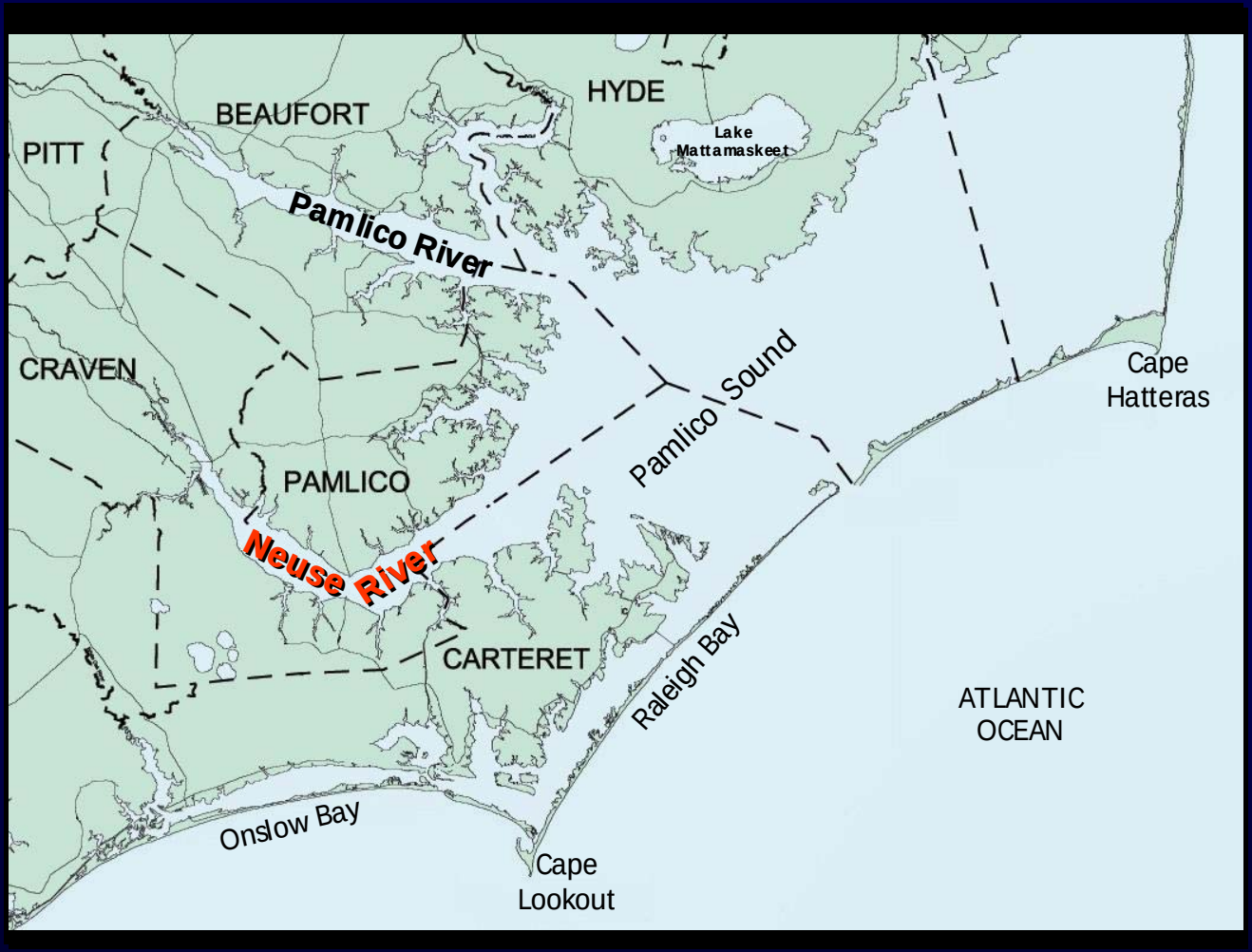
NC State
Soil Science Department

Nutrients and Water Quality Problems



http://www.fertilizer.org/ifa/statistics/indicators/ind_cn_world.asp

Nutrient Sensitive Waters in North Carolina



Fertilizer Prices

Year	Fertilizer Types				
	An. NH_3	N Soln	Urea	NH_4NO_3	N SO_4
2003	373	161	261	243	195
2004	379	178	276	263	205
2005	416	215	332	292	244
2006	521	232	362	366	266
2007	523	277	453	382	288

http://www.ers.usda.gov/Data/FertilizerUse/

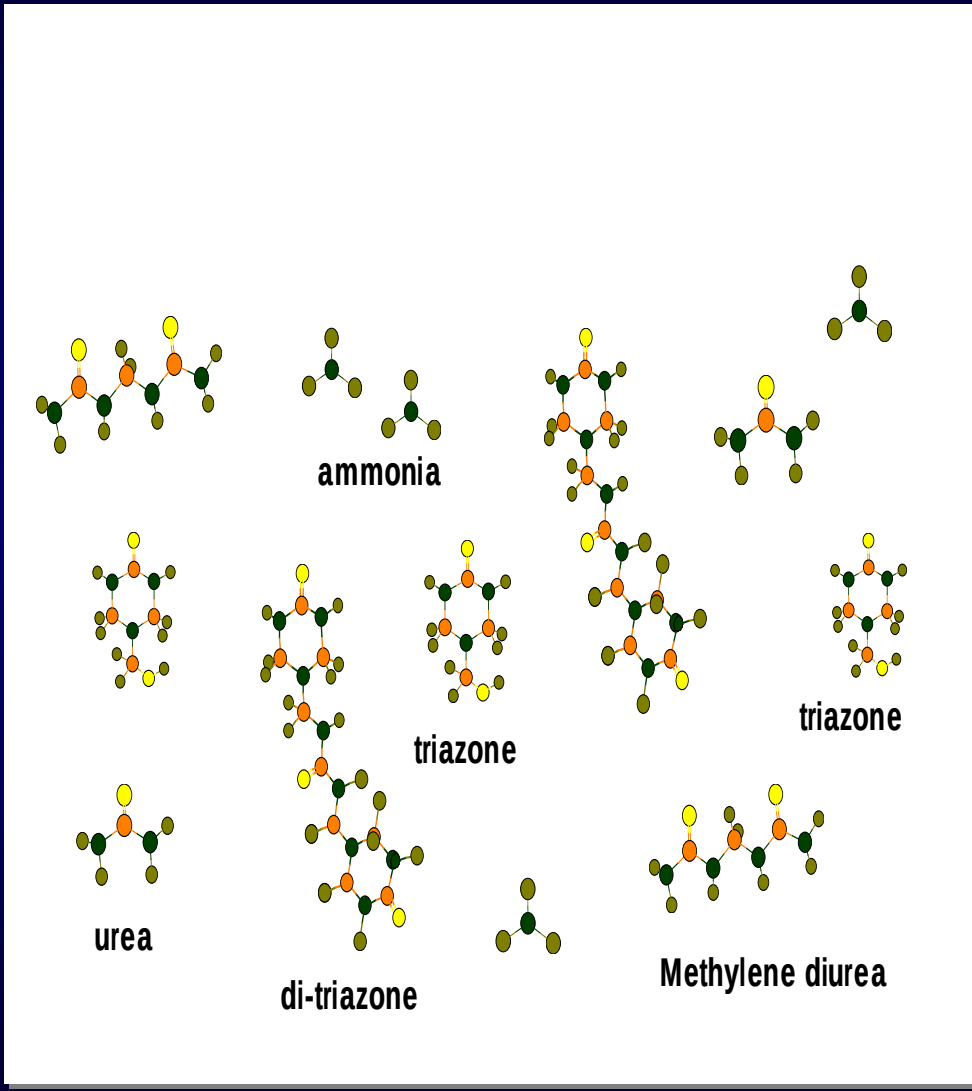
Objectives

- Determine yield response curve
  - Six N rates
  - Two crops (wheat and corn)
  - Two soil types (sandy and mineral-organic)
  - Two fertilizer types
- Compare nitrogen use efficiency (NUE) values
- Investigate soil N concentrations and release patterns for each N fertilizer

Materials and Methods

Urea Formaldehyde Polymer (UFP)

- Slow-release N fertilizer
- Clear, colorless, water-soluble liquid containing 30% N
- Free formaldehyde 0.1%
- Free ammonia 0.5%
- Nitrogen is released within 60-90 days
- Slow release N through microbial breakdown of mono- di- and tri-substitute ureas and cyclic urea molecules



Urea-Ammonium Nitrate (UAN)

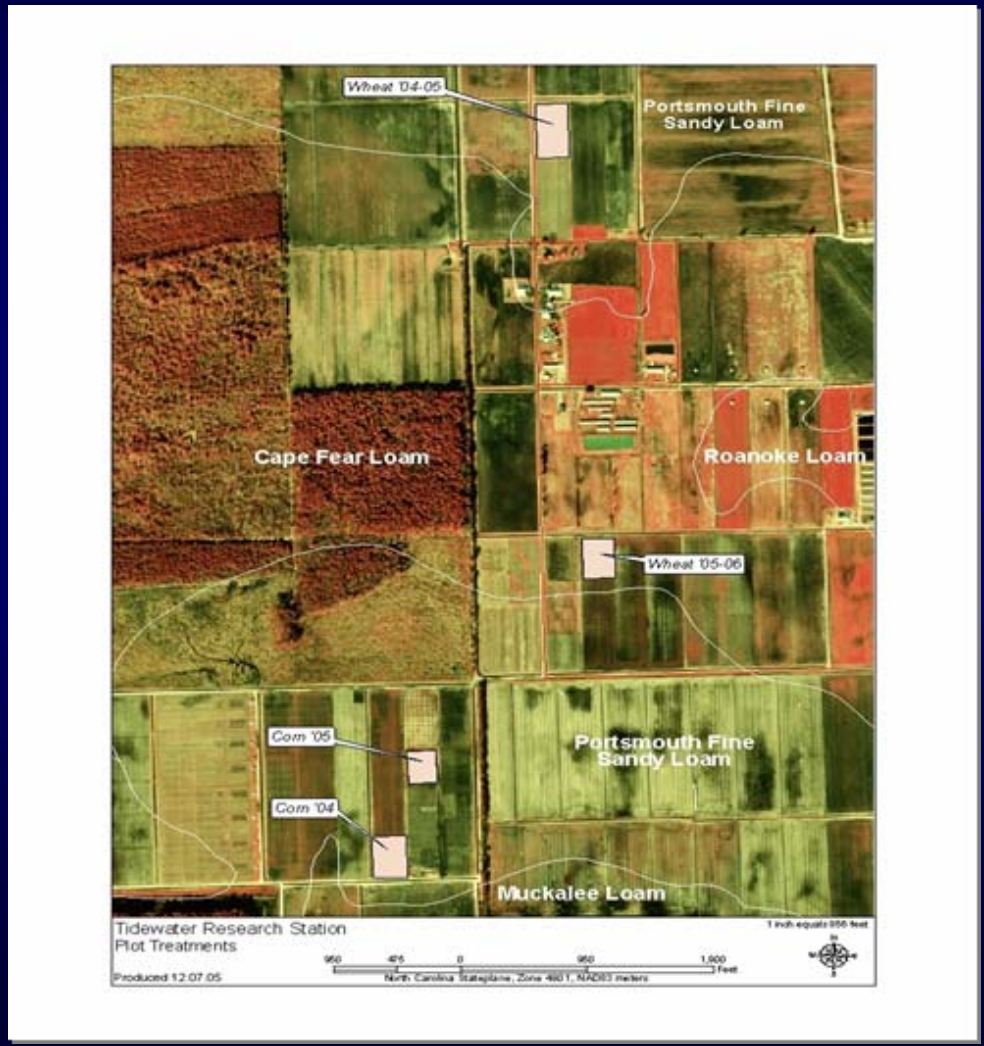
- Traditional N fertilizer for farmers in North Carolina
  - High concentration of N
  - Low manufacturing and transportation costs
  - Relatively easy to handle
  - Readily available
- Colorless, water-soluble liquid containing 30% N
- Manufactured from dissolved ammonium nitrate and urea in water

Site Locations

- Sandhills Research Station
  - Candor (Sandy, siliceous, thermic Grossarenic Kandiudult)
- Soil was irrigated as needed to avoid drought stress

Site Locations

- Tidewater Research Station
  - Portsmouth (Fine-loamy over sandy or sandy-skeletal, mixed, semiactive, thermic Typic Umbraquult)
  - Cape Fear (Fine, mixed, semiactive, thermic Typic Umbraquult)



Experimental Design

- Randomized complete block design with four replications

- N Rates
  - Wheat = 0, 50, 78, 106, 134, 162, and 190 kg N ha^{-1}
  - Maize = 0, 39, 78, 118, 157, 196, and 235 kg N ha^{-1}

- N Timing
  - Wheat = split application for both N sources
  - Maize = UFP at planting and split UAN

Incubation Study

- Soil samples collected from each station to determine the effects of time on mineralization of N in UFP and UAN.
- Fertilizer applied at maximum N rate + control
- Incubated for up to twelve weeks at relatively constant moisture and temperature (25°C)

Apparent Nitrogen Use Efficiency (NUE)

$$\frac{\textit{N above-ground fertilized} - \textit{N above-ground control}}{\textit{Amount of N fertilizer applied}}$$

Results and Discussion

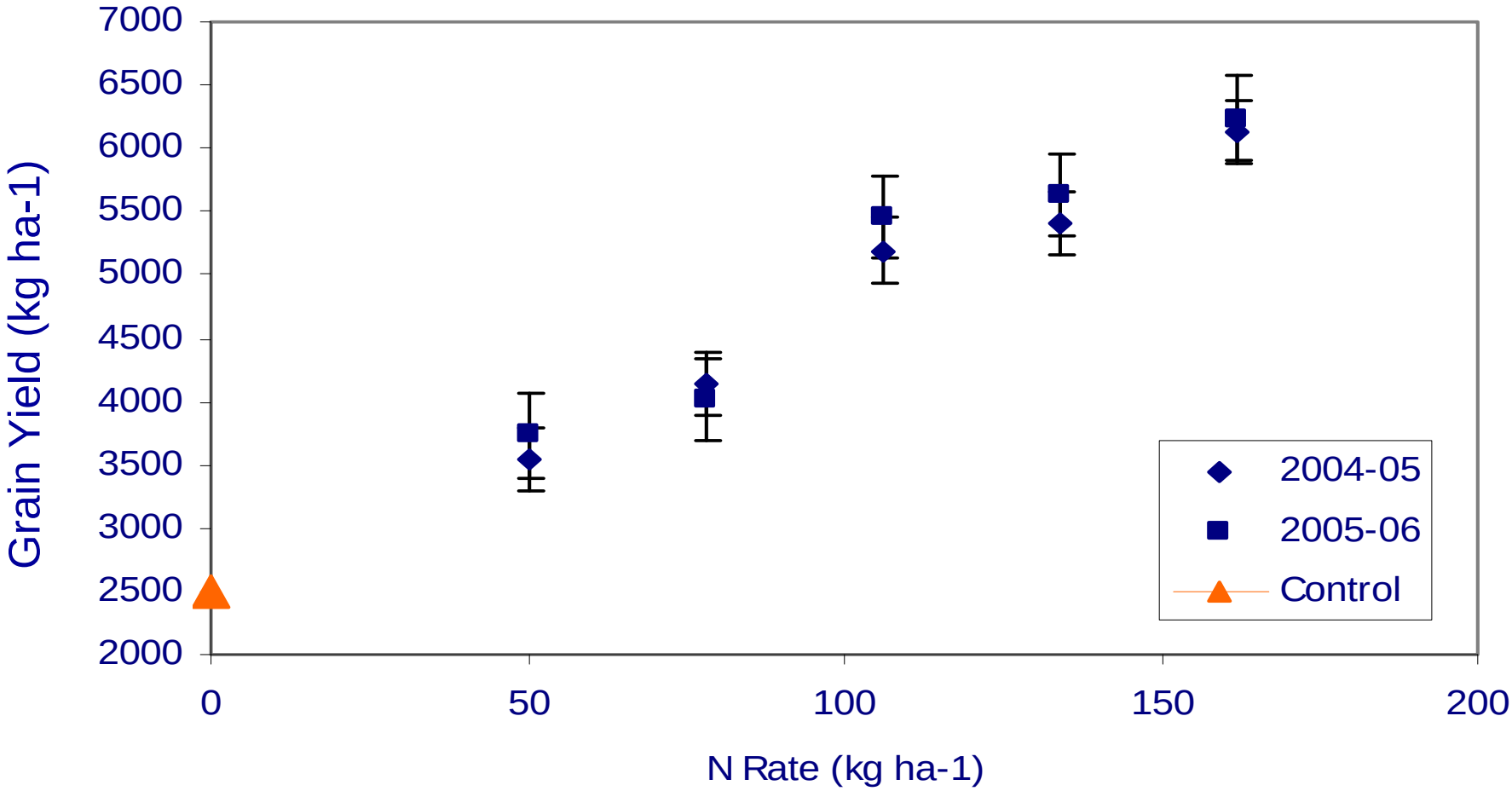
Wheat

Wheat Model Effects

Site	Crop Measurement	Year	N Source	N Rate
Sandhills	NUE	NS	*	NS
	Straw yield	*	*	*
	Grain yield	*	*	*
	%N grain	NS	NS	*
	%N straw	*	*	*
Tidewater	NUE	NS	NS	NS
	Straw yield	*	NS	*
	Grain yield	NS	NS	*
	%N grain	*	NS	*
	%N straw	*	NS	*

Note: NS = $p>0.05$, * = $p<0.05$

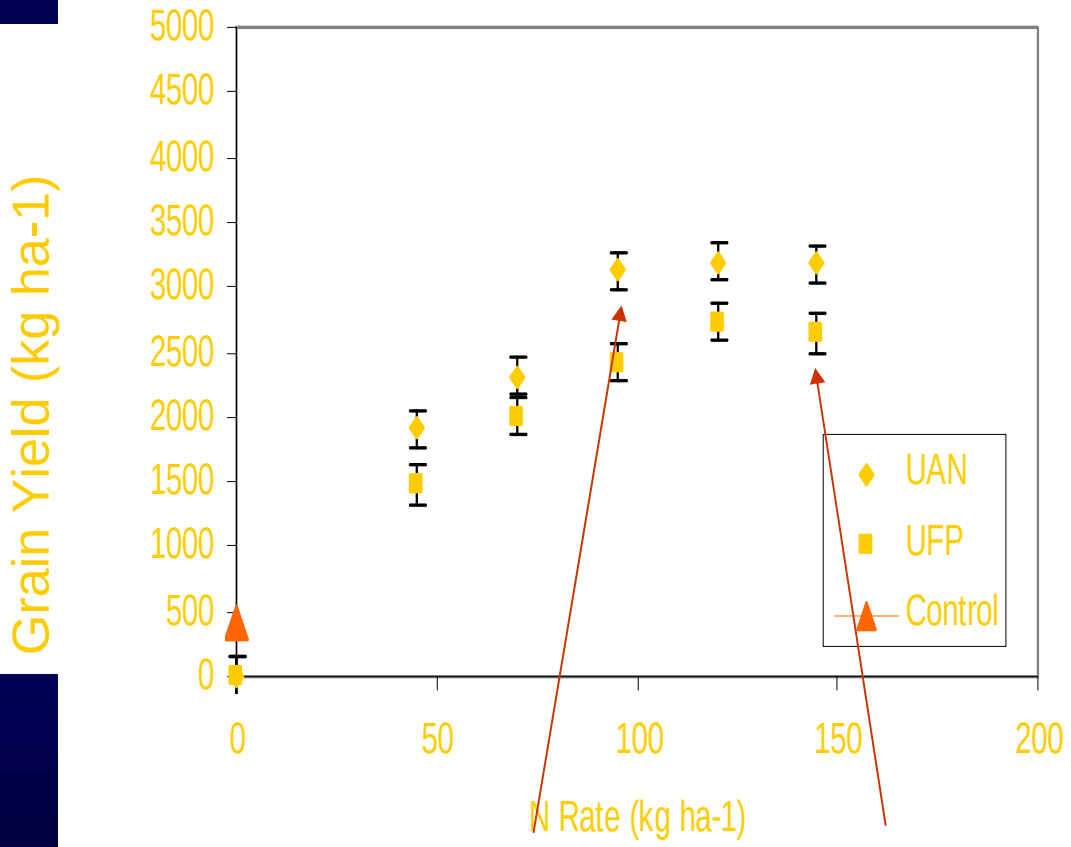
Tidewater Wheat Grain Yield



162 kg N ha-1, maximum yield

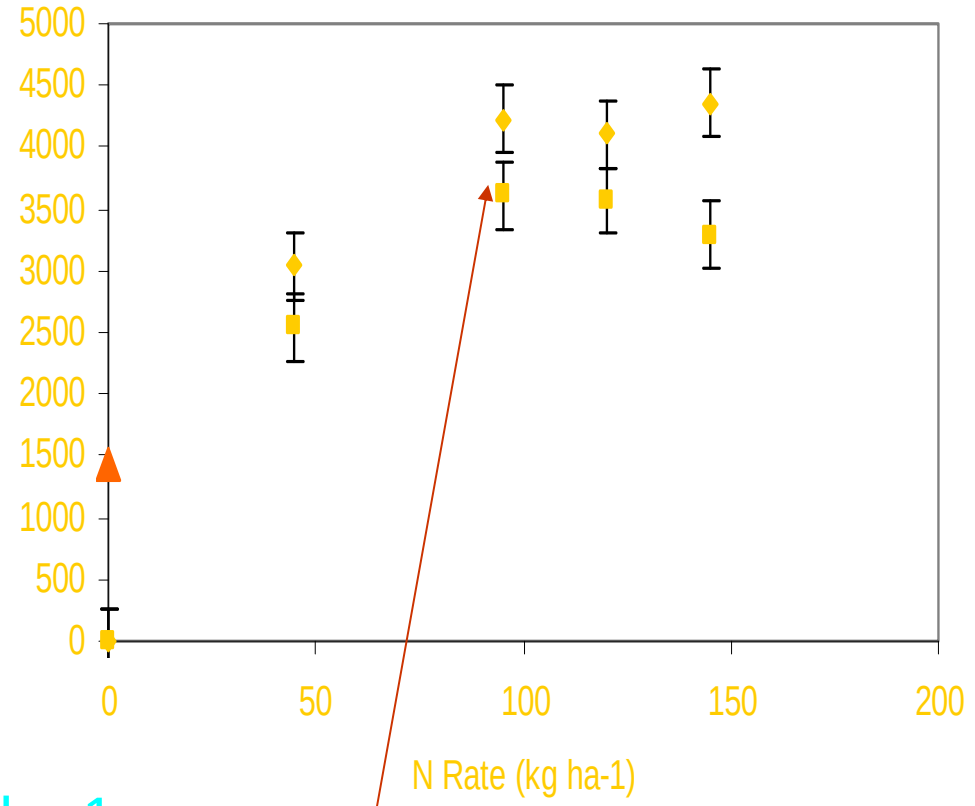
Sandhills Wheat Grain Yield

2004-05



Maximum yield : UAN 95, UFP 120 kg N ha-1

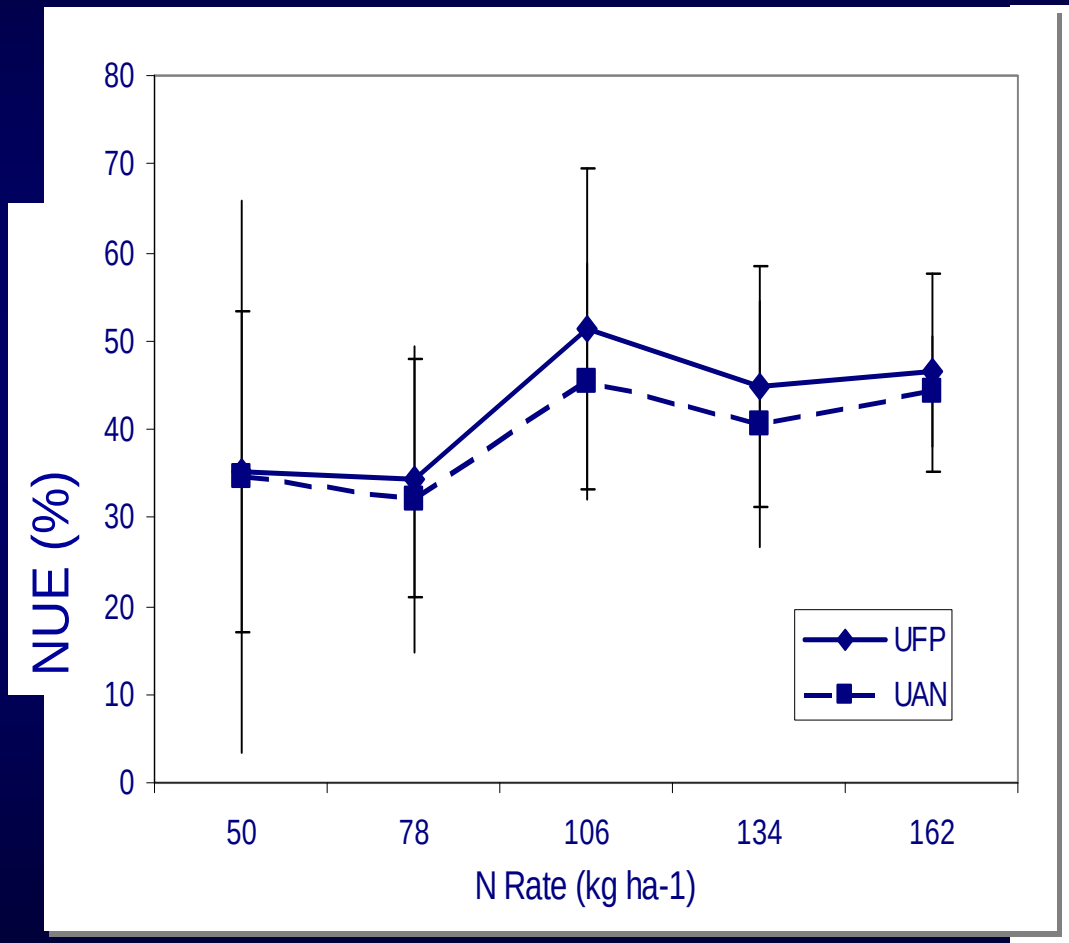
2005-06



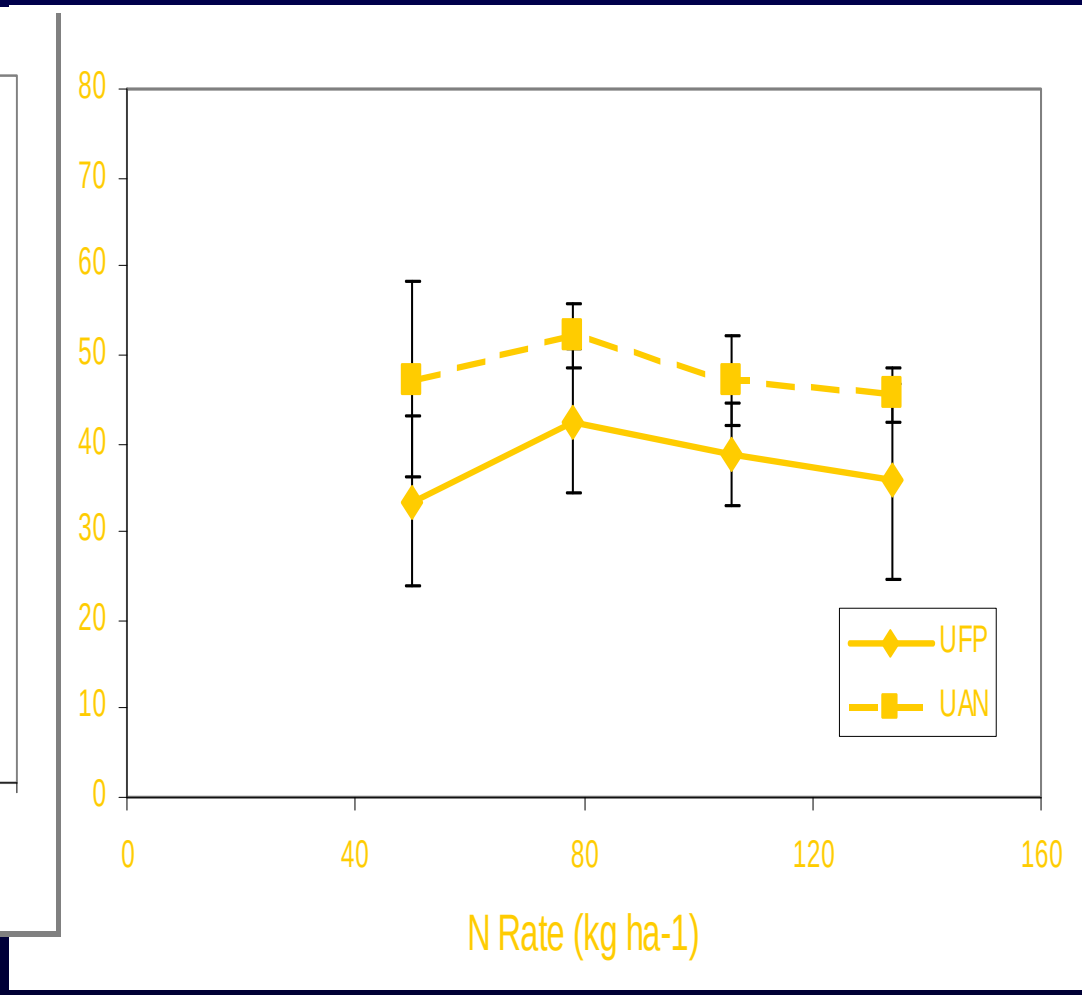
Maximum yield: 95 kg N ha-1 both sources

Wheat NUE

Tidewater: No source difference



Sandhills: UAN outperformed UFP



Wheat Results

- Maximum grain yields were obtained at 162 kg N ha-1 at Tidewater and 95-120 kg N ha-1 at Sandhills
  - N sources were only different at Sandhills (UAN higher yields)

- NUE had no rate differences

Results and Discussion

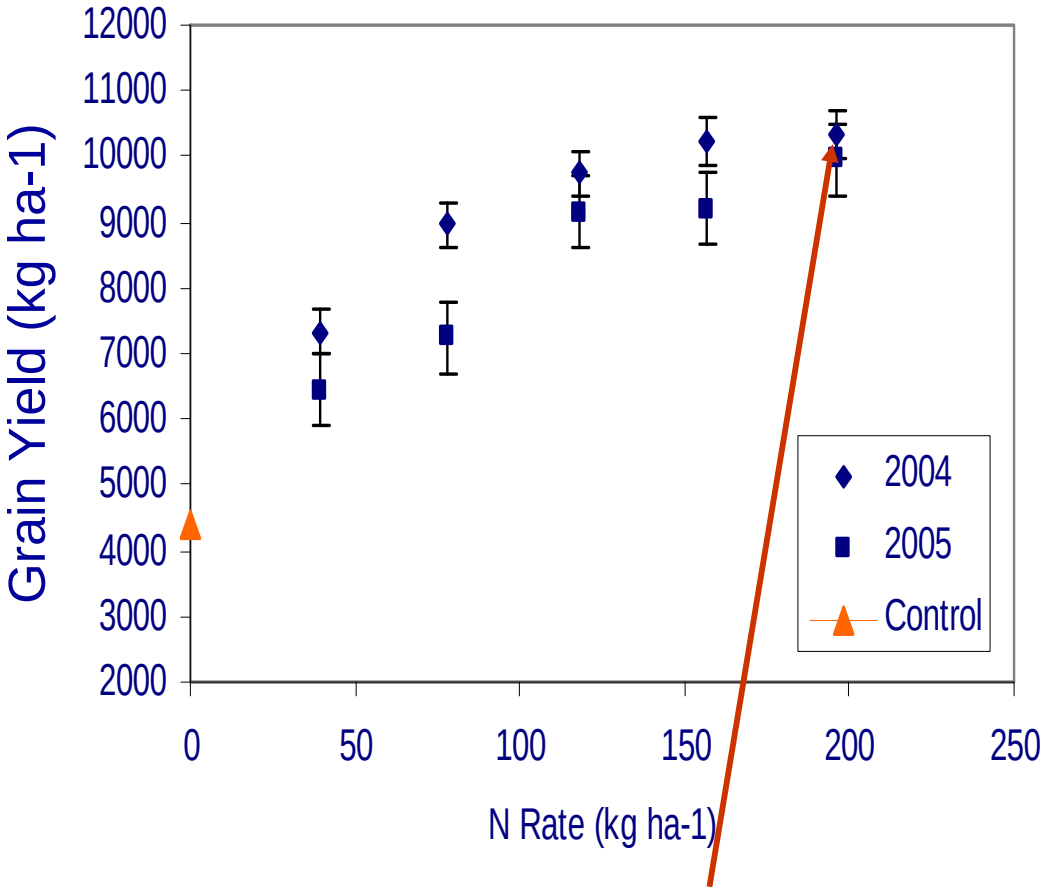
Maize

Maize Model Effects

	Crop Measurements	Year	N Source	N Rate
Sandhills	NUE	*	*	NS
	Stover yield	*	*	*
	Grain yield	NS	*	*
	%N grain	NS	*	*
	%N stover	*	NS	NS
Tidewater	NUE	NS	NS	NS
	Stover yield	*	NS	NS
	Grain yield	*	NS	*
	%N grain	*	NS	*
	%N stover	*	NS	*

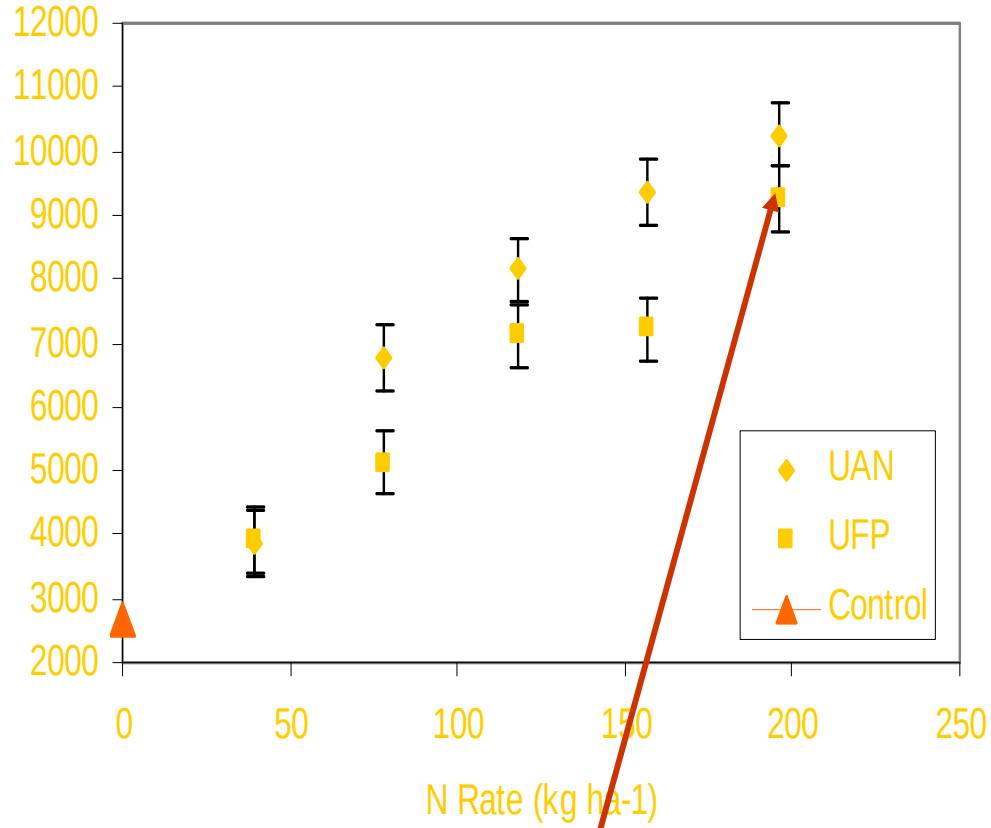
Maize Grain Yield

Tidewater



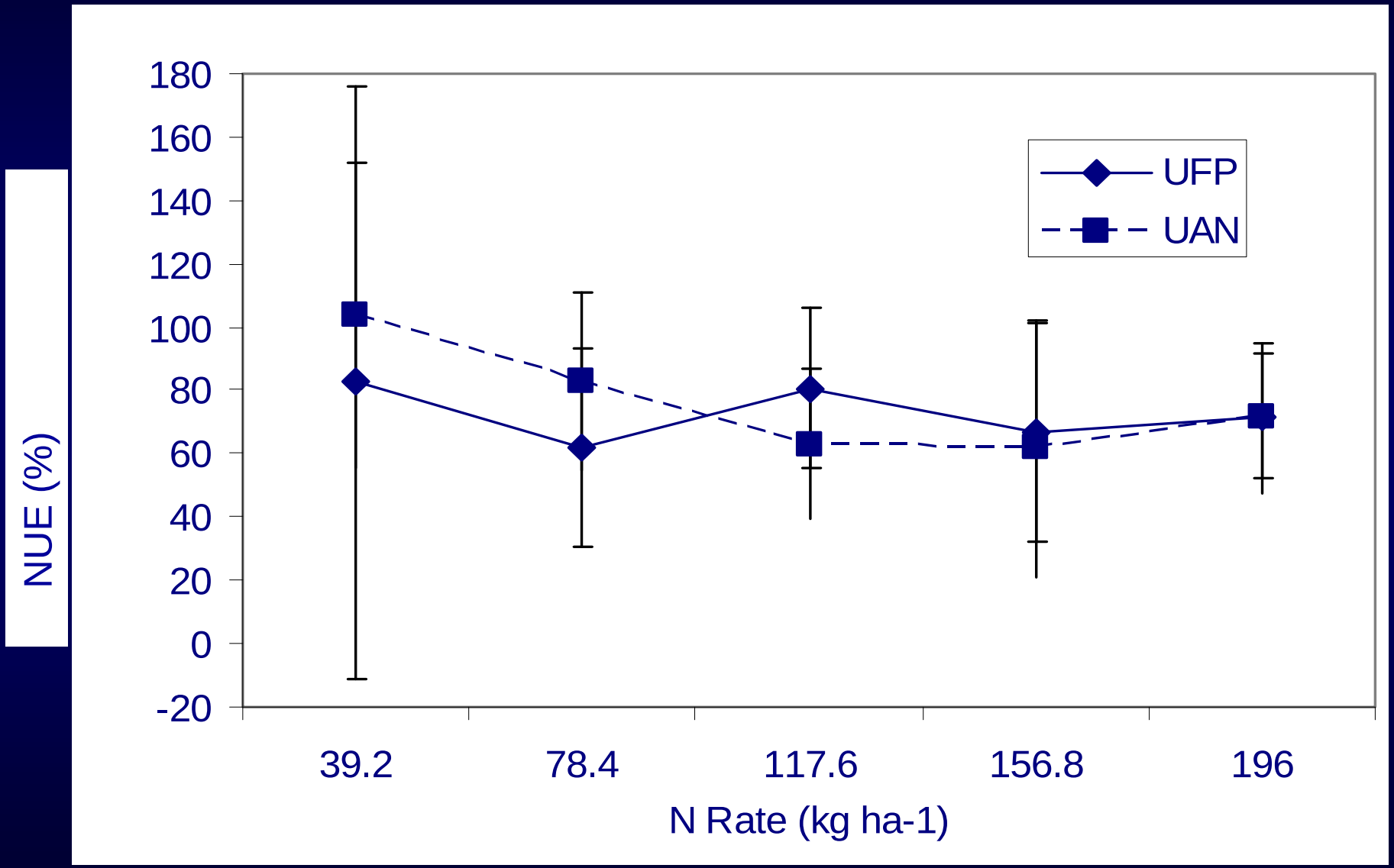
196 kg N ha-1 highest yield both years

Sandhills



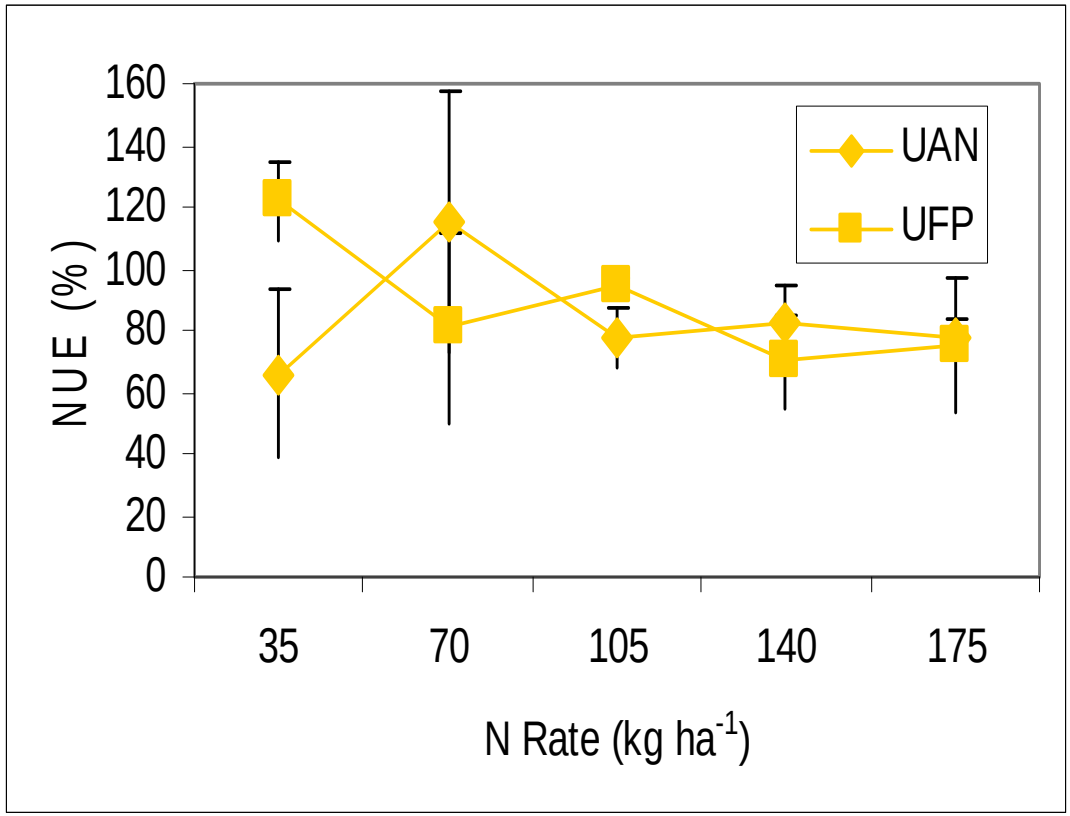
196 kg N ha-1 highest yield for both sources

Tidewater Maize NUE

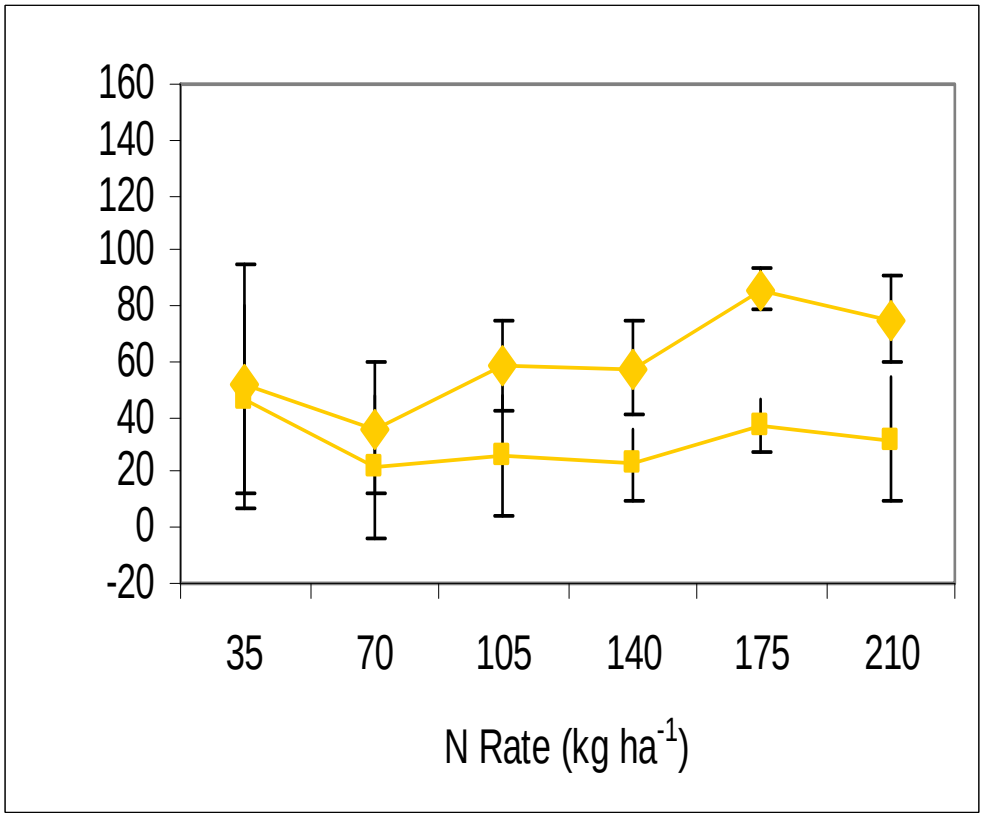


Sandhills Maize NUE

2004



2005



Maize Results

- Maximum grain yield was at 196 kg N ha^{-1} for both sites
  - N sources were only different at Sandhills (UAN higher yields)
- NUE had no rate differences
  - Sources only different one year at Sandhills (UAN higher NUEs)
  - More variability and higher NUE at Tidewater

Results and Discussion

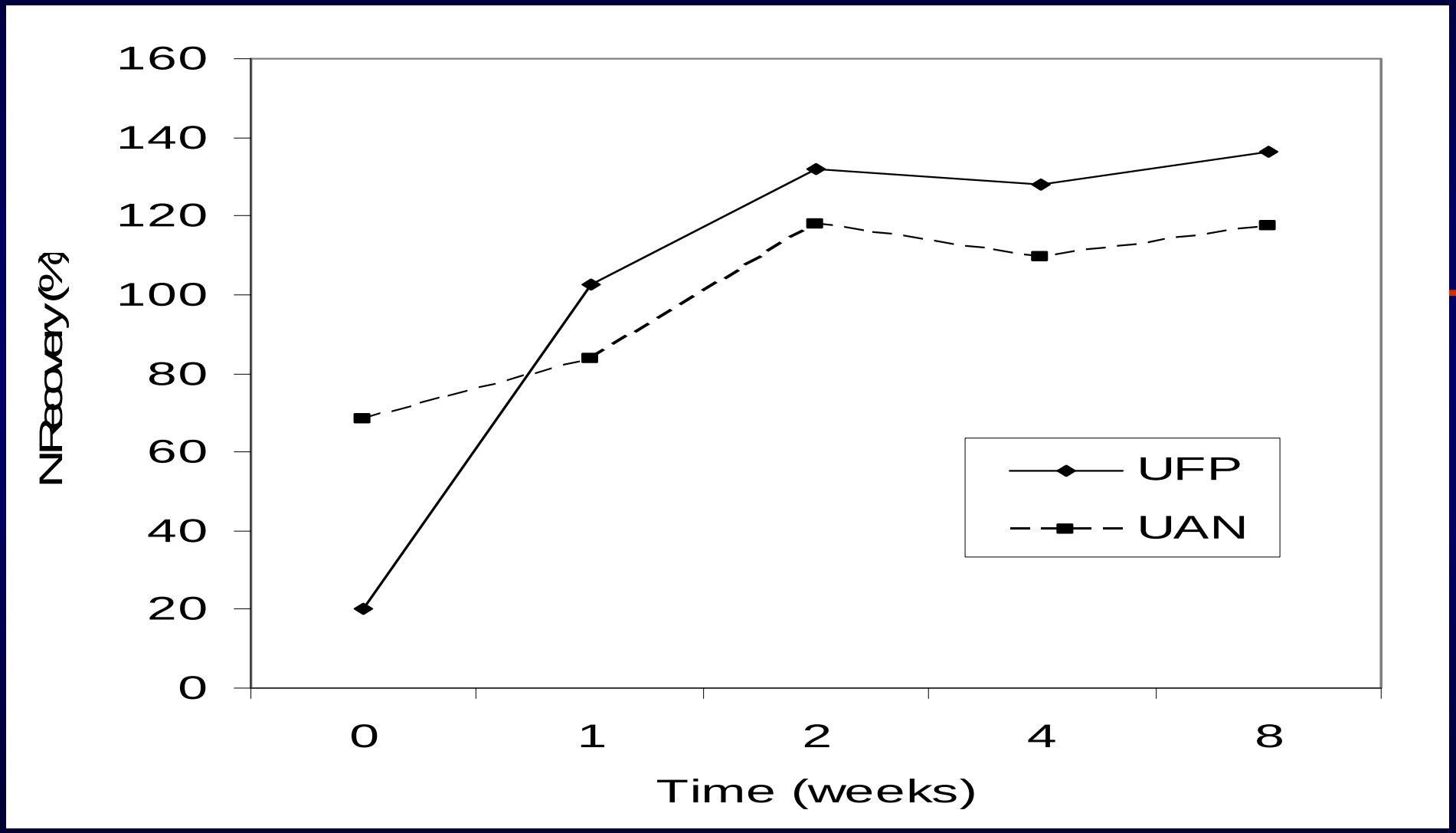
Incubation Study

Incubation Model Effects

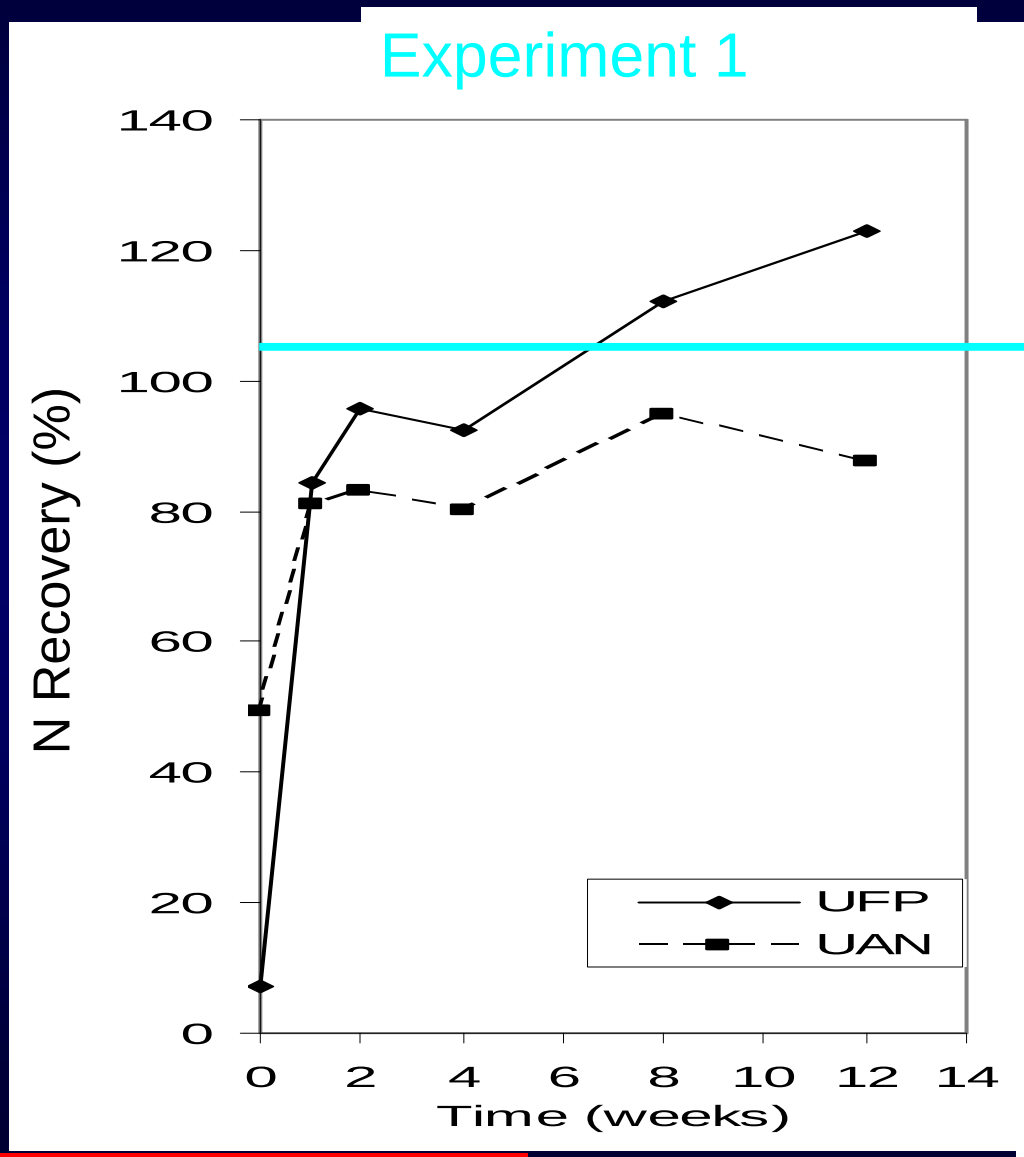
		Experiment	Rep	N Source	N Source x experiment	Weeks	Weeks x experiment	N Source x Weeks
Candor	NO_3^-	NS	NS	NS	NS	*	*	*
	NH_4^+	*	*	NS	NS	*	*	*
	N Recovery	*	NS	NS	NS	*	*	*
Portsmouth	NO_3^-	NS	NS	NS	NS	*	*	*
	NH_4^+	*	NS	NS	NS	*	*	*
	N Recovery	NS	*	NS	NS	*	*	*

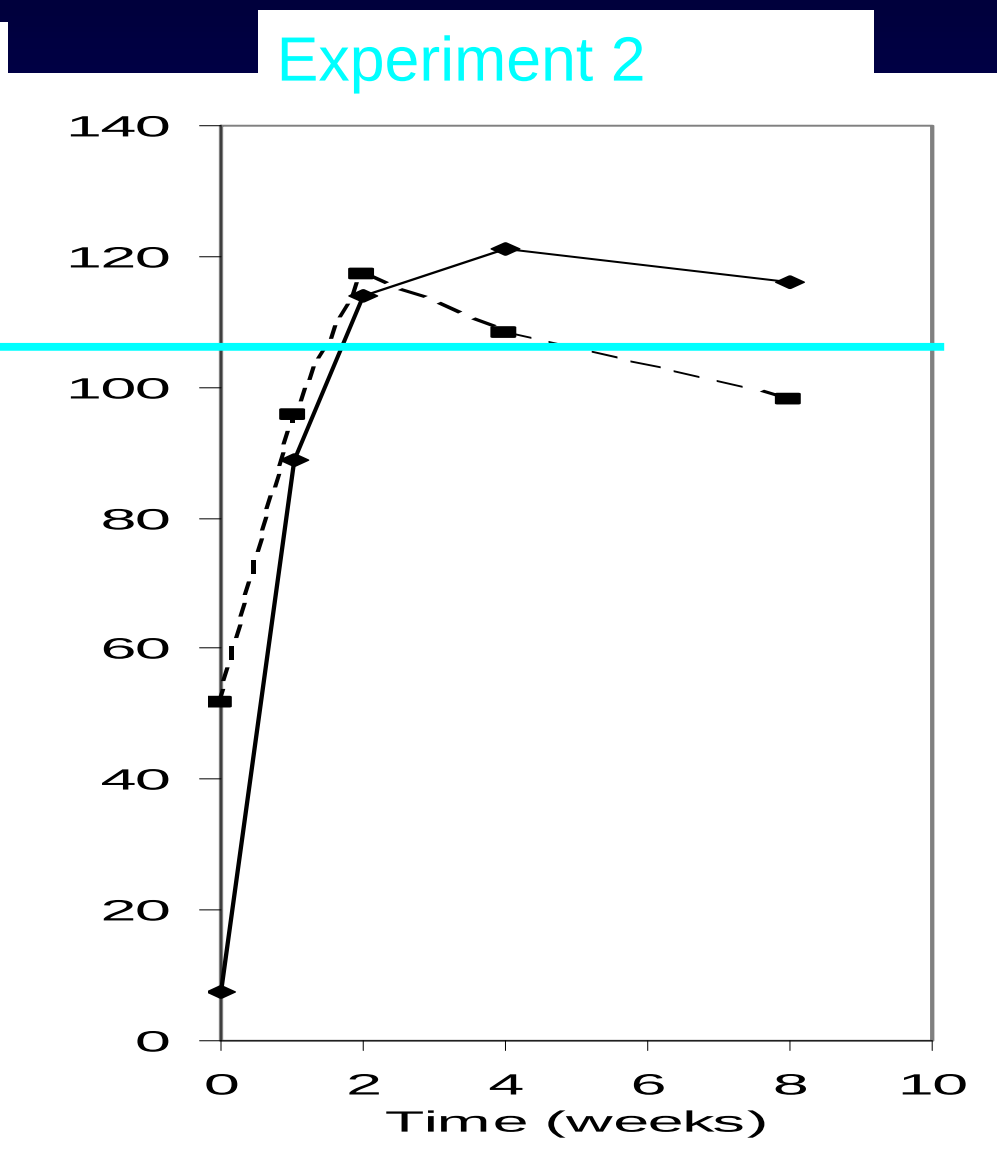
Note : NS = $p>0.05$, * = $p<0.05$.

Portsmouth Total N Recovery



Candor Total N Recovery





Incubation Results

- UFP released by week 2 in both experiments on both soil types.
  - Other studies on similar soils in NC using N inhibitors show a fast mineralization rate due to climate and microbial activity
- Greater than 100% recovery
  - UFP content 27-33%
  - Microsites
  - N Priming

Conclusions

- Objective: Determine N responsive curves
- Conclusion: No consistent significant yield differences between the N sources for either crop.
  - Tidewater 165 kg N ha-1 wheat, 196 kg N ha-1 maize
  - Sandhills 95-120 kg N ha-1 wheat, 196 kg N ha-1 maize

- Objective: Compare NUE values for each N fertilizer
- Conclusion: No consistent NUE differences between the N sources for either crop.

- Objective: Investigate release of N fertilizers
- Conclusion: Incubation study results demonstrated total release of NH_4 in ~ 2 weeks for UFP.
- *Overall:*
  - *Rates of fertilizer comparable*
  - *Fertilizer form did not effect yield*
  - *Cost of UFP is substantially greater than UAN*

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Questions

Particle Size Data

Crop/Year	Field ID	Sand	Silt	Clay	USDA
Sandhills Research Station		**%**	**%**	**%**	**Class.**
Corn/2004	A5	90.99	6.73	2.28	sand
Corn/2005	D4	90.49	7.23	2.28	sand
Wheat/2004-05	6B	90.98	7.35	1.67	sand
Wheat/2005-06	D2A4	90.99	7.87	1.14	sand
Tidewater Research Station					
Corn/2004	N3	64.07	21.02	14.91	sandy loam
Corn/2005	N2	40.47	33.56	25.97	loam
Wheat/2004-05	E3	60.73	24.72	14.55	sandy loam
Wheat/2005-06	H4	42.54	32.09	25.37	loam

Sandhills Climate Data

Month	Irrigation Water (mm)	Rain Water (mm)	Total (mm)	5-year average rainfall (mm)	Average Air Temperature (C)	5-year Average Air Temperature (C)	Month	Irrigation Water (mm)	Rain Water (mm)	Total (mm)	5-year average rainfall (mm)	Average Air Temperature (C)	5-year Average Air Temperature (C)
2004 Maize							**2004-05 Wheat**						
April	-	33.5	33.5	58.0	16.6	16.3	October	-	142.0	142.0	77.8	17.1	16.1
May	38.1	62.0	100.1	84.3	22.7	20.3	November	-	48.0	48.0	55.3	12.5	12.4
June	94.0	58.4	152.4	76.5	23.7	23.8	December	-	36.3	36.3	54.8	6.4	6.0
July	53.3	104.9	158.2	83.7	25.3	25.3	January	-	60.7	60.7	64.0	6.7	4.7
August	-	148.3	148.3	124.2	23.6	25.3	February	-	73.2	73.2	58.1	7.3	7.2
							March	-	83.6	83.6	91.7	9.4	11.7
							April	-	63.8	63.8	48.1	15.4	16.2
							May	-	43.9	43.9	88.4	18.2	20.8
Total			592.5				**Total**			551.5			
2005 Maize							**2005-06 Wheat**						
April	-	63.8	63.8	48.0	15.4	16.2	October	-	85.9	85.9	61.0	17.0	16.4
May	12.7	43.9	56.6	88.0	18.2	20.8	November	-	77.0	77.0	54.5	12.3	12.2
June	58.4	125.7	184.1	77.0	23.8	23.9	December	-	99.6	99.6	54.7	4.9	5.7
July	101.6	126.5	228.1	95.0	26.1	25.1	January	-	52.1	52.1	53.7	8.9	5.2
August	-	50.3	50.3	139.0	25.9	24.7	February	-	28.4	28.4	61.8	6.7	7.0
							March	-	41.4	41.4	99.6	10.2	10.9
							April	12.7	71.9	84.6	50.5	17.8	16.4
							May	-	67.8	67.8	91.7	19.1	20.0
Total			582.9				**Total**			536.8			

Tidewater Climate Data

Month	Precipitation (mm)	5-year average rainfall (mm)	Average Air Temperature (C)	5-year average air temperature (C)	Month	Precipitation (mm)	5-year average rainfall (mm)	Average Air Temperature (C)	5-year average air temperature (C)
Maize 2004					**2004-05 Wheat**				
April	66.3	91.4	16.7	23.5	October	136.7	79.2	17.1	23.7
May	85.1	127.2	23.6	27.1	November	65.3	74.4	12.4	19.5
June	231.4	109.7	25.3	30.8	December	49.5	84.8	6.5	13.1
July	101.9	149.4	27.2	31.6	January	65.0	78.1	6.0	11.6
August	180.6	168.4	24.4	31.5	February	54.6	83.4	6.4	14.5
					March	84.3	106.8	8.5	18.8
					April	59.7	96.3	14.8	22.0
					May	117.9	128.0	17.8	26.5
Total	665.3				**Total**	633.0			
Maize 2005					**2005-06 Wheat**				
April	59.7	96.3	14.8	22.0	October	252.7	72.5	17.3	22.4
May	117.9	128.0	17.8	26.5	November	64.5	76.1	12.4	17.8
June	104.9	141.0	23.8	30.0	December	103.6	86.9	5.4	11.5
July	0.0	154.1	26.4	30.4	January	80.0	69.1	8.9	10.4
August	200.7	174.5	25.7	29.9	February	22.1	86.1	6.2	12.5
					March	40.9	105.8	9.4	16.4
					April	60.5	80.9	16.3	20.5
					May	189.2	123.1	18.9	24.3
Total	483.2				**Total**	813.5			

Wheat Model Effects

Site	Crop parameter	UAN	UFP
Tidewater 2004-05	Grain yield	4813a†	4950a
Tidewater 2005-06	Grain yield	5304a	5200a
Sandhills 2004-05	Grain yield	2744a	2254b
Sandhills 2005-06	Grain yield	3930a	3253b
Tidewater 2004-05	Straw yield	3936a	3844a
Tidewater 2005-06	Straw yield	1460a	1356a
Sandhills 2004-05	Straw yield	1671a	1278b
Sandhills 2005-06	Straw yield	1402a	1072b
Tidewater 2004-05*	%N Straw	0.27a	0.27a
Tidewater 2005-06*	%N Straw	0.32a	0.34a
Sandhills 2004-05	%N Straw	0.37a	0.62b
Sandhills 2005-06	%N Straw	0.49a	0.52a
Tidewater 2004-05*	%N Grain	1.42a	1.45a
Tidewater 2005-06*	%N Grain	1.71a	1.77b
Sandhills 2004-05	%N Grain	1.68a	1.78b
Sandhills 2005-06	%N Grain	1.83a	1.81a
Tidewater 2004-05*	NUE	36.75a	40.40a
Tidewater 2005-06*	NUE	44.40a	46.02a
Sandhills 2004-05*	NUE	41.95a	35.55b
Sandhills 2005-06*	NUE	47.95a	35.83b

Maize Model Effects

Site	Crop parameter	UAN	UFP
Tidewater 2004	Grain yield	9314a†	9321a
Tidewater 2005	Grain yield	8715a	8681a
Sandhills 2004*	Grain yield	8385a	8314a
Sandhills 2005*	Grain yield	8558a	6216b
Tidewater 2004	Stover yield	6517a	6680a
Tidewater 2005	Stover yield	7885a	8605a
Sandhills 2004	Stover yield	7043a	8098b
Sandhills 2005	Stover yield	4982a	5188a
Tidewater 2004	%N grain	1.05a	1.09a
Tidewater 2005	%N grain	1.24a	1.21a
Sandhills 2004*	%N grain	1.06a	0.99b
Sandhills 2005*	%N grain	1.11a	1.03b
Tidewater 2004	%N stover	0.63a	0.63a
Tidewater 2005	%N stover	0.74a	0.71a
Sandhills 2004	%N stover	0.55a	0.54a
Sandhills 2005	%N stover	0.48a	0.39b
Tidewater 2004*	NUE	63.61a	60.95a
Tidewater 2005*	NUE	90.08a	78.27b
Sandhills 2004	NUE	83.82a	88.34a
Sandhills 2005	NUE	60.83a	31.01b

Maize %N In Biomass

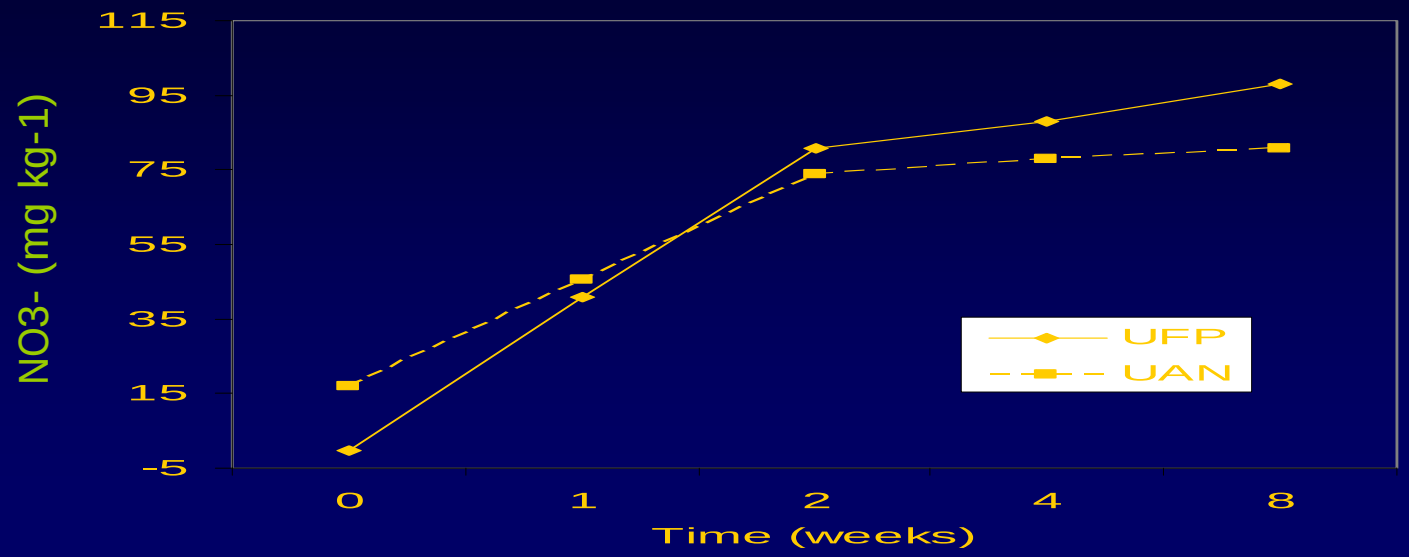
Grain

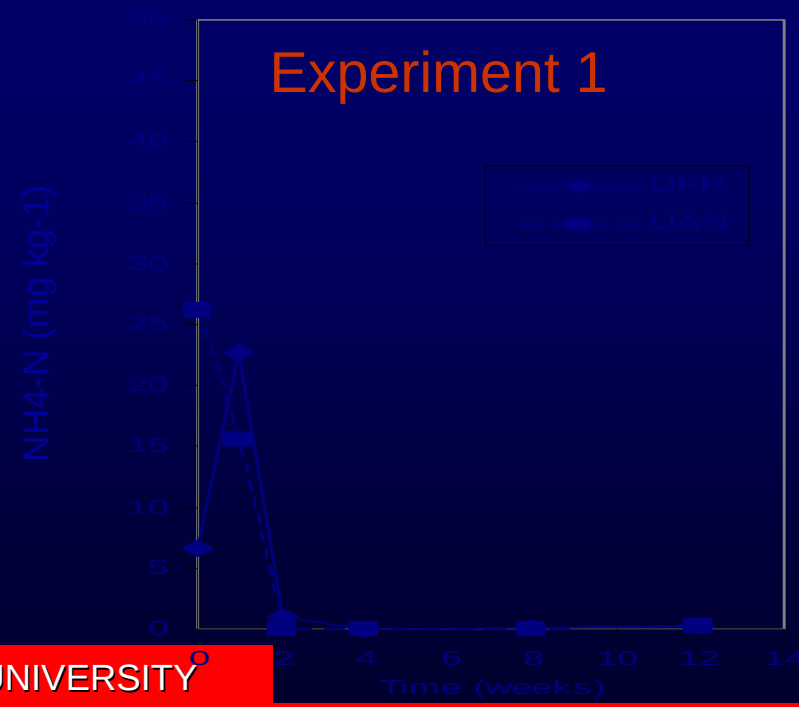
	N Rate (kg ha^{-1})					
Site	39	78	118	157	196	235
Tidewater 2004	0.94a†	0.99a	1.09b	1.14b,c	1.20c	-
Tidewater 2005	1.10a	1.14a	1.23b	1.23b	1.31c	-
Sandhills 2004*	0.82a	0.92b	1.04c	1.10c	1.25d	-
Sandhills 2005*	0.98a	0.97a	1.01a	1.11b	1.16b,c	1.20c

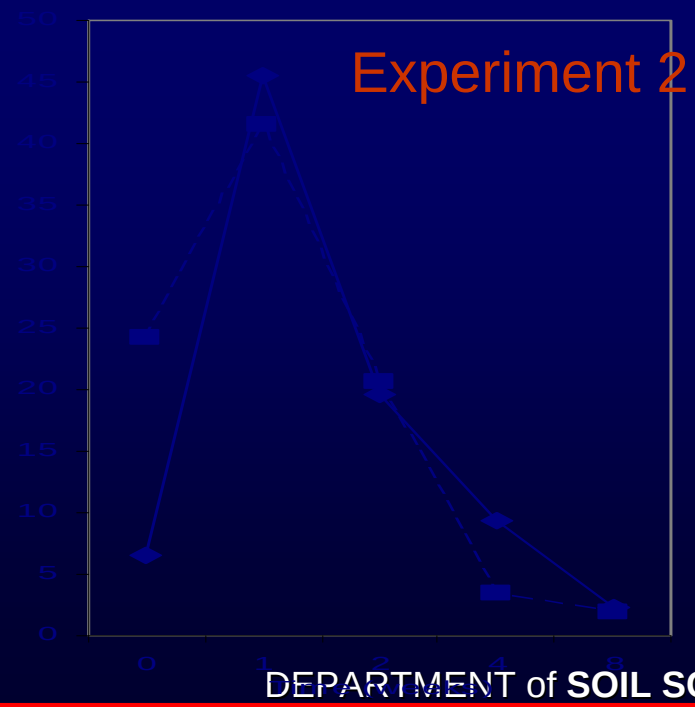
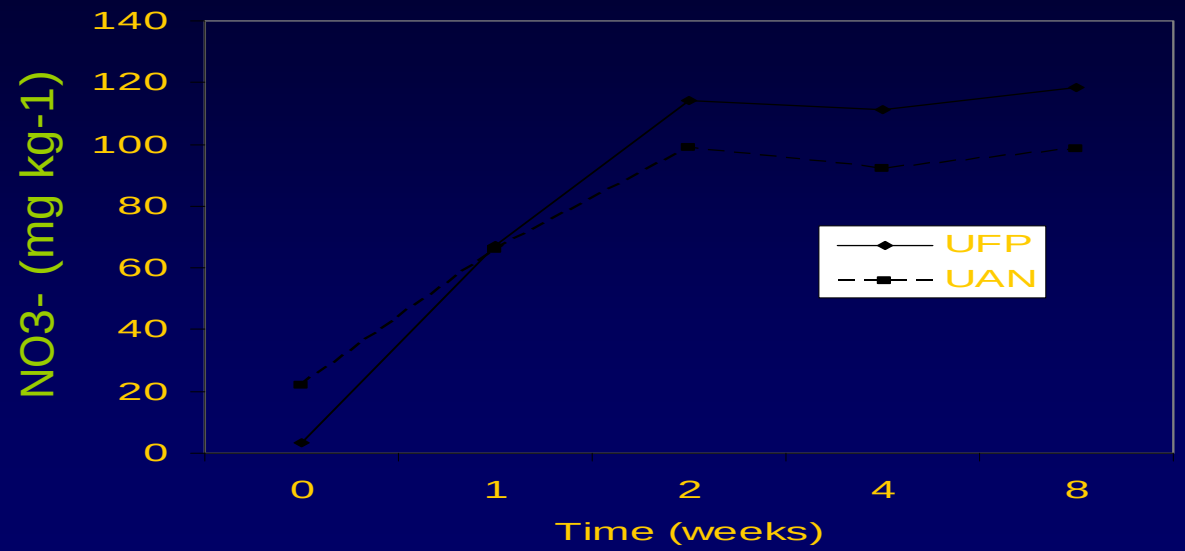
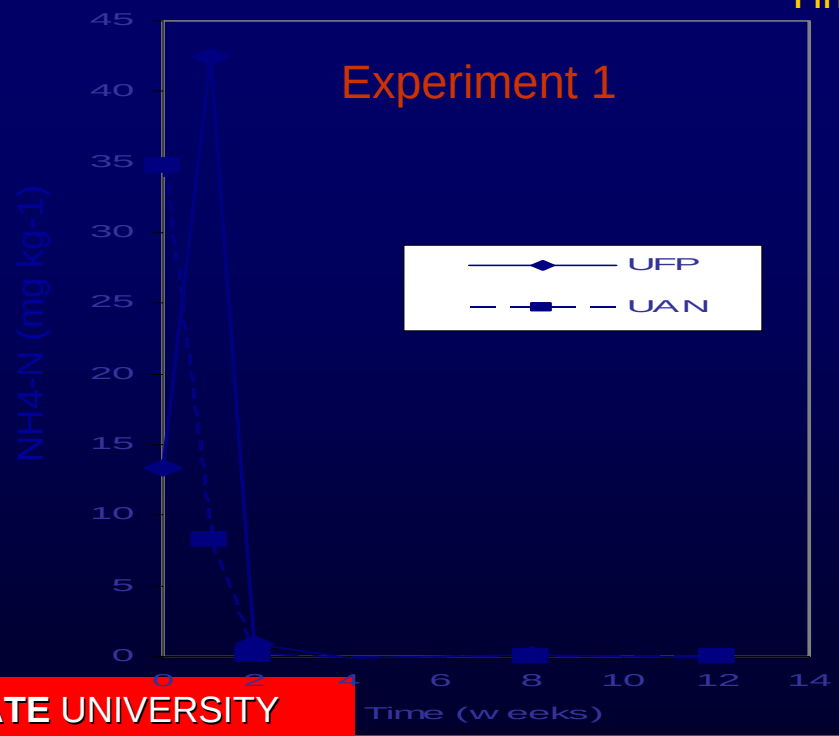
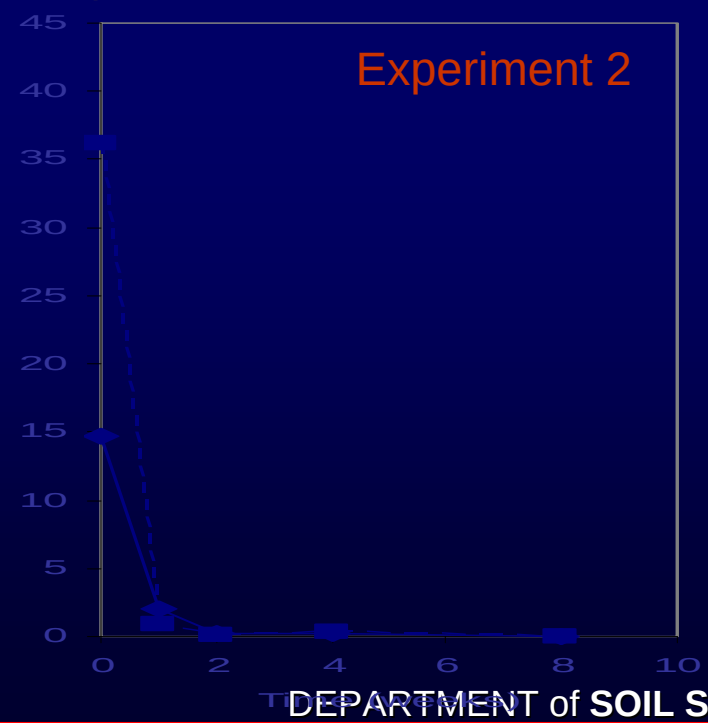
Stover

	N Rate (kg ha^{-1})					
Site	39	78	118	157	196	235
Tidewater 2004	0.55a†	0.61a	0.64a	0.58a	0.77a	-
Tidewater 2005	0.57a	0.62a,b	0.74b	0.81b	0.77b	0.81b
Sandhills 2004	0.50a	0.49a	0.55a	0.59a	0.61a	-
Sandhills 2005	0.35a	0.36a,b	0.41b,c	0.45c,d	0.50d,e	0.55e

Candor Incubation Results







Portsmouth Incubation