Excess nitrogen also reduces yield in high yielding wheat

Dr Ben Jones

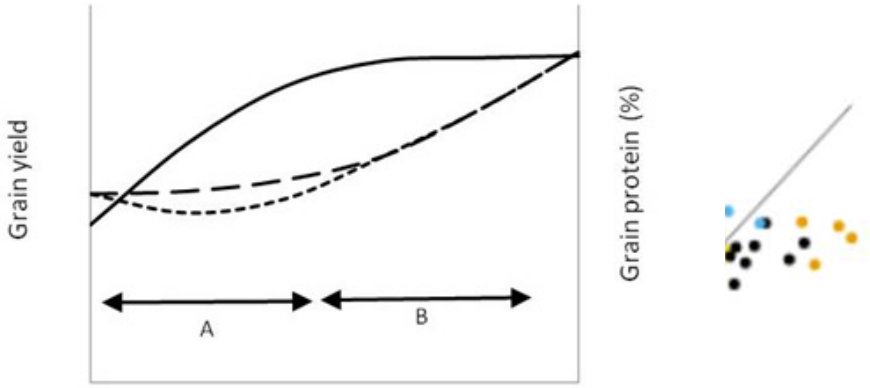
Nick Poole, Darcy Warren, Max Bloomfield, Aaron Vague

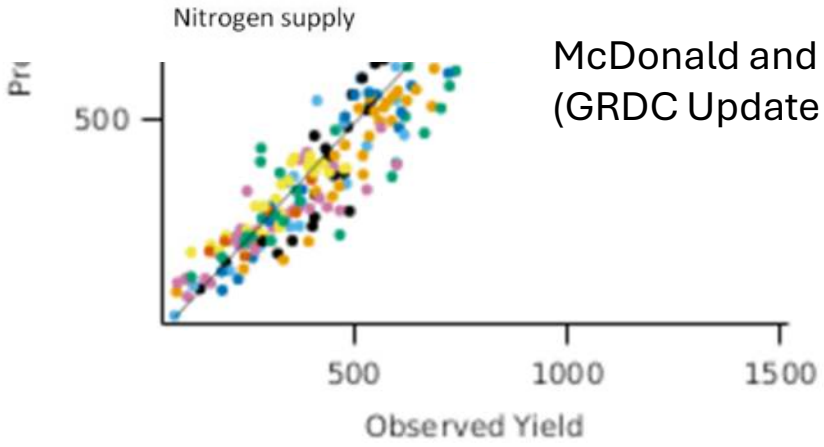
Field Applied Research (FAR) Australia

Background – APSIM NextGen

- FAR Hyper-Yielding 2016-23 experimental data
  - “High input” treatments
  - No/negative yield/minimal protein response

- Importance
  - APSIM (Classic) gets used for a lot
  - Important to understand for N bank





McDonald and Hooper (GRDC Update 2013)

Excess N – water limited

- N -> biomass -> water use
- More spikes, grains
- Reduced water extraction post-anthesis (and in total)
- Less biomass retranslocated to grain
- ~-5 kg grain/kg N
- Small grains and high protein

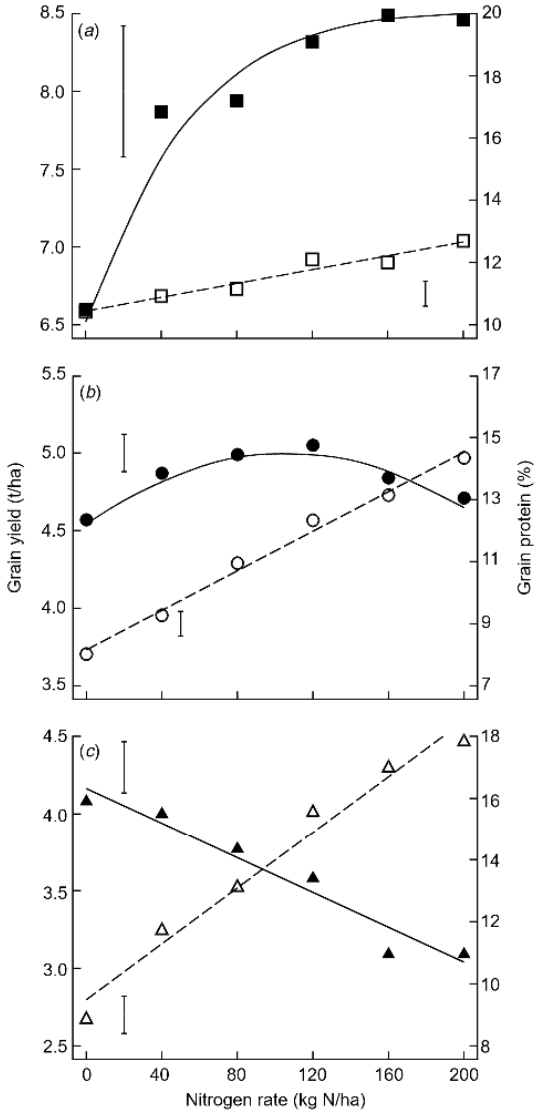
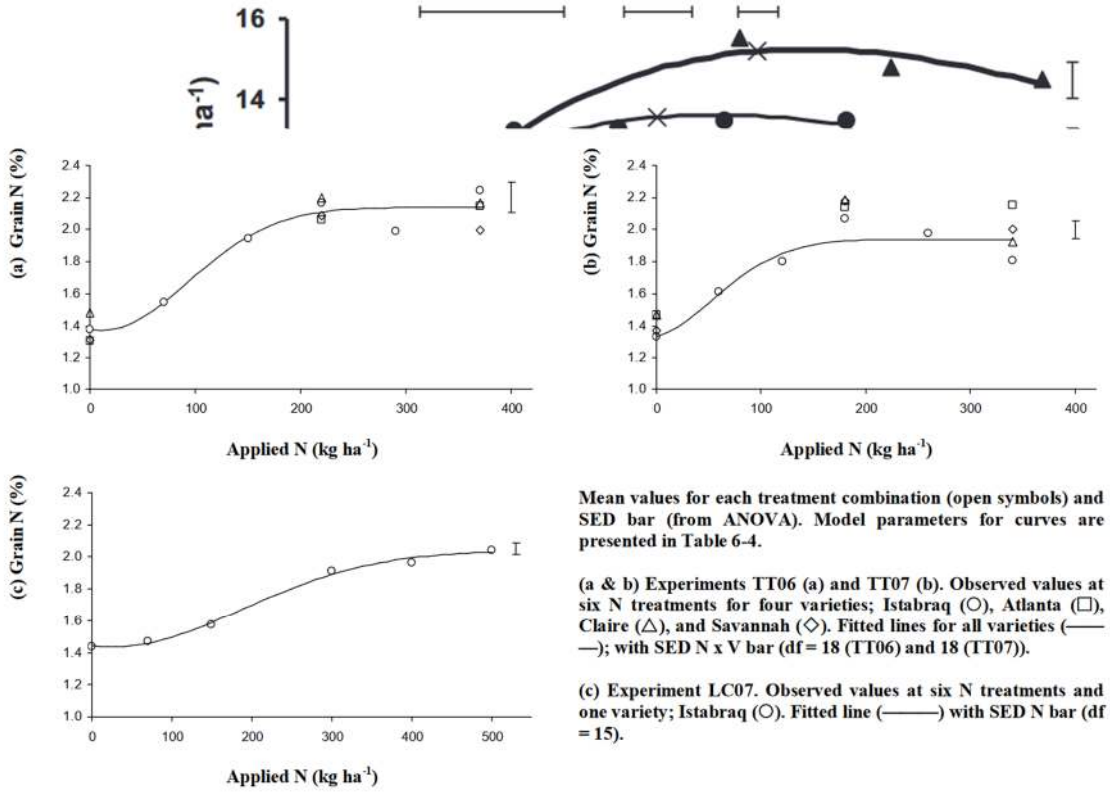


Fig. 2. Responses of grain yield (closed symbols) and protein (open symbols) to N fertiliser applied to wheat at (*a*) Ginninderra, (*b*) Pucawan, and (*c*) Wagga Wagga. Data are at 12% water content, curves are fitted regressions, and the bars indicate the l.s.d. ($P = 0{\cdot}05$).

van Herwaarden et al, Australian Journal of Agricultural Research 49, no. 7 (1998): 1067–82.

Excess N – light limited

- "Reserve N" accumulates an
  poorly remobilised
- Spikes and grains/spike decr
  > optimum
- Grain weight decreases
- ~-5 to -15 kg grain/kg N
- Grain protein stable > opt N



Mean values for each treatment combination (open symbols) and SED bar (from ANOVA). Model parameters for curves are presented in Table 6-4.

(a & b) Experiments TT06 (a) and TT07 (b). Observed values at six N treatments for four varieties; Istabraq (○), Atlanta (□), Claire (△), and Savannah (◇). Fitted lines for all varieties (——); with SED N x V bar (df = 18 (TT06) and 18 (TT07)).

(c) Experiment LC07. Observed values at six N treatments and one variety; Istabraq (○). Fitted line (———) with SED N bar (df = 15).

Figure 6.12 (a, b & c) Effect of applied N and variety on grain N concentration (%) at harvest in TT06, TT07 and LC07.

Pask, et al. Field Crops Research 126 (14 February 2012): 104–18.

Experimentation > optimum

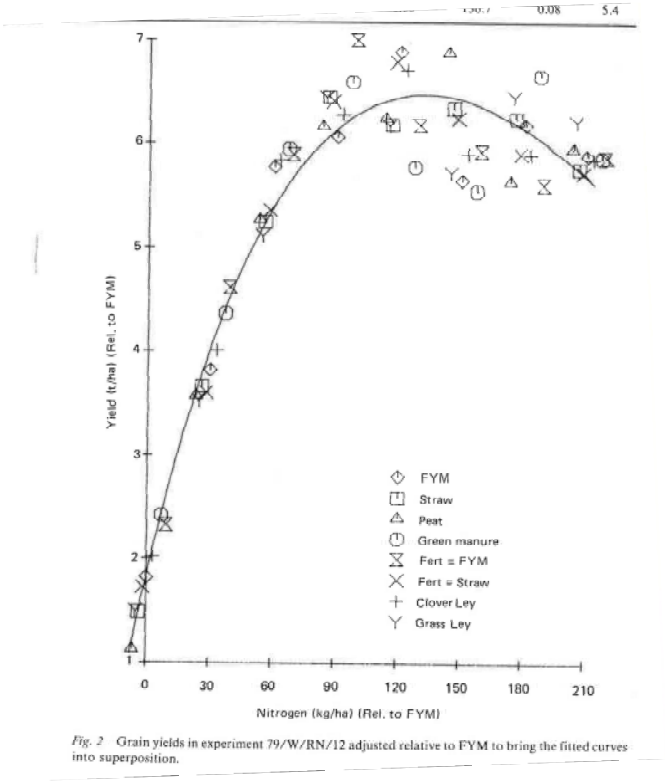
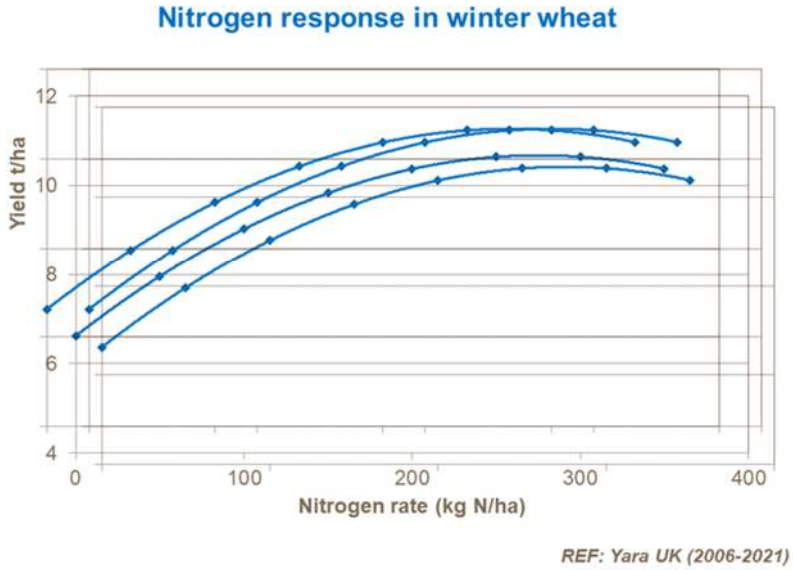


Fig. 2 Grain yields in experiment 79/W/RN/12 adjusted relative to FYM to bring the fitted curves into superposition.



- Issues:
  - Lodging
  - Disease
  - Toxicity

George (1984) 'Design and Interpretation of Nitrogen Response Experiments'

N response experiments 2016-2023

- Fertile sites (chosen for Hyper Yielding Crops)
- High yielding environments
- Winter and slow spring wheats
- Consistent layout (reps are machine passes)
- 35 experiments
- 23 with >2 treatments

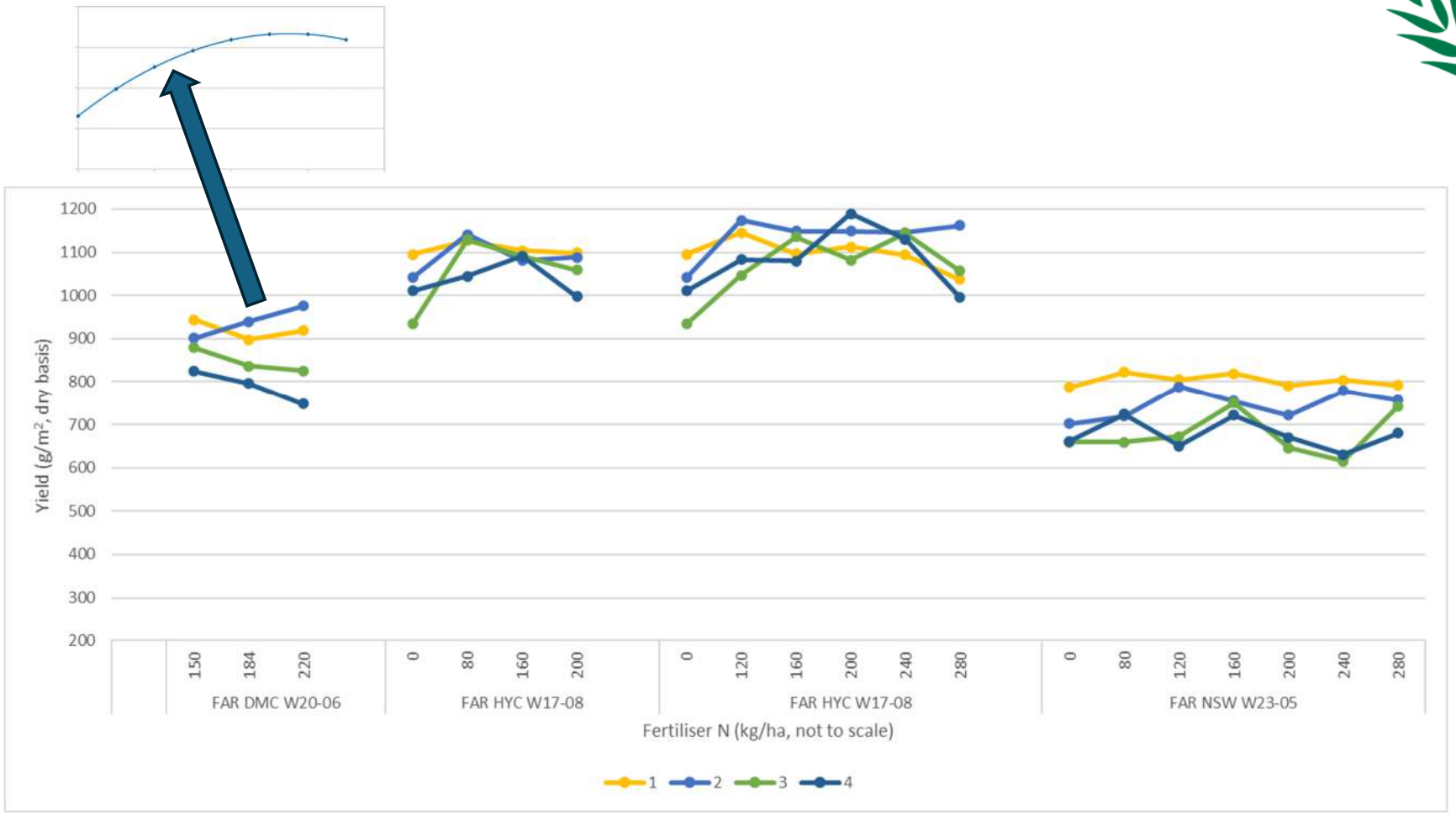
Protocol 8 - Wheat Nitrogen Agronomy trial

Sown: 6 April 2017 **Harvested:** 22 January 2017

Table 1. Grain yield (t/ha), % site mean, protein (%), test weight (kg/hL) and screenings (%).

Nitrogen rate (kg) & timing					Yield	Mean	Protein	Test wt	Screen
GS00	GS22	GS30	GS32	GS39	(t/ha)	(%)	(%)	(kg/HL)	(%)
10	----	----	----	----	11.66 c	92.6	8.7 f	72.8 a	2.3 abc
10	----	80	80	----	12.48 ab	99.1	11.5 ab	71.1 ab	2.5 ab
10	----	100	100	----	12.13 bc	96.3	11.4 abc	70.8 ab	2.3 abc
10	----	----	80	80	12.52 ab	99.4	10.4 de	70.5 ab	2.1 abc
10	----	40	40	40	12.72 ab	101.0	10.8 a-e	72.4 a	1.8 c
10	----	40	60	60	12.75 ab	101.2	10.5 cde	72.1 a	2.3 abc
10	----	40	80	80	12.95 a	102.8	10.8 a-e	72 a	2.6 a
10	----	40	100	100	12.90 a	102.4	10.9 a-e	67.1 b	2.2 abc
10	----	40	120	120	12.15 bc	96.5	11.6 a	70.9 ab	2.1 abc
10	----	40+ 20S	80	80	12.90 a	102.4	10.7 b-e	70.3 ab	2.3 abc
10	----	40	120	74	13.07 a	103.8	11.2 a-d	71.7 a	1.9 bc
10	----	40	40	----	12.69 ab	100.7	10.1 e	70.2 ab	2.5 ab
10	80	----	100	----	12.86 a	102.1	11 a-d	72.8 a	2.2 abc
Mean					12.60	100	10.7	71.1	2.2
LSD 0.05					0.705		0.88	4.15	0.68
P Val					0.010		<0.001	0.405	0.471

NOTE: GS00 N was applied as 100kg MAP/ha

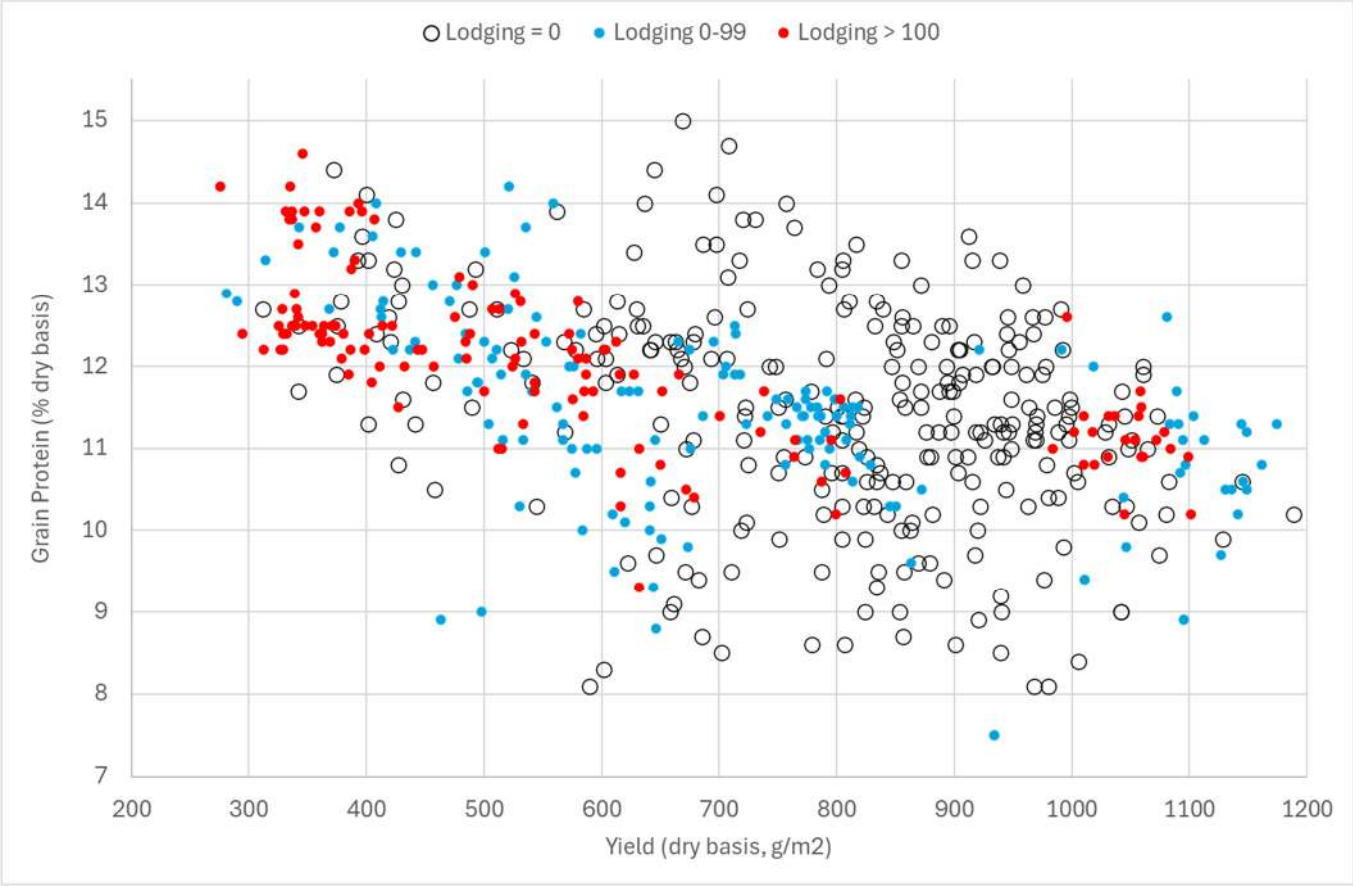

1200
1100
1000
900
800
700
600
500
400
300
200
Yield (g/m², dry basis)
150
184
220
FAR DMC W20-06
0
80
160
200
FAR HYC W17-08
0
120
160
200
240
280
FAR HYC W17-08
0
80
120
160
200
240
280
FAR NSW W23-05
Fertiliser N (kg/ha, not to scale)
1
2
3
4

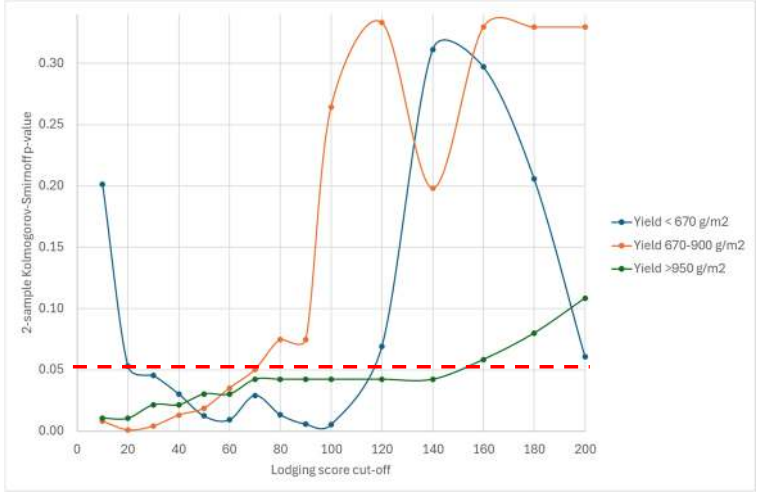
“Valid” experiments

- Lodging - what is the concern?
  - Yield response vs lodging effect
  - Lodging score 0-5 x % plot effected

- Did N have a measureable effect (yield or protein)?
  - 21 of 23 experiments

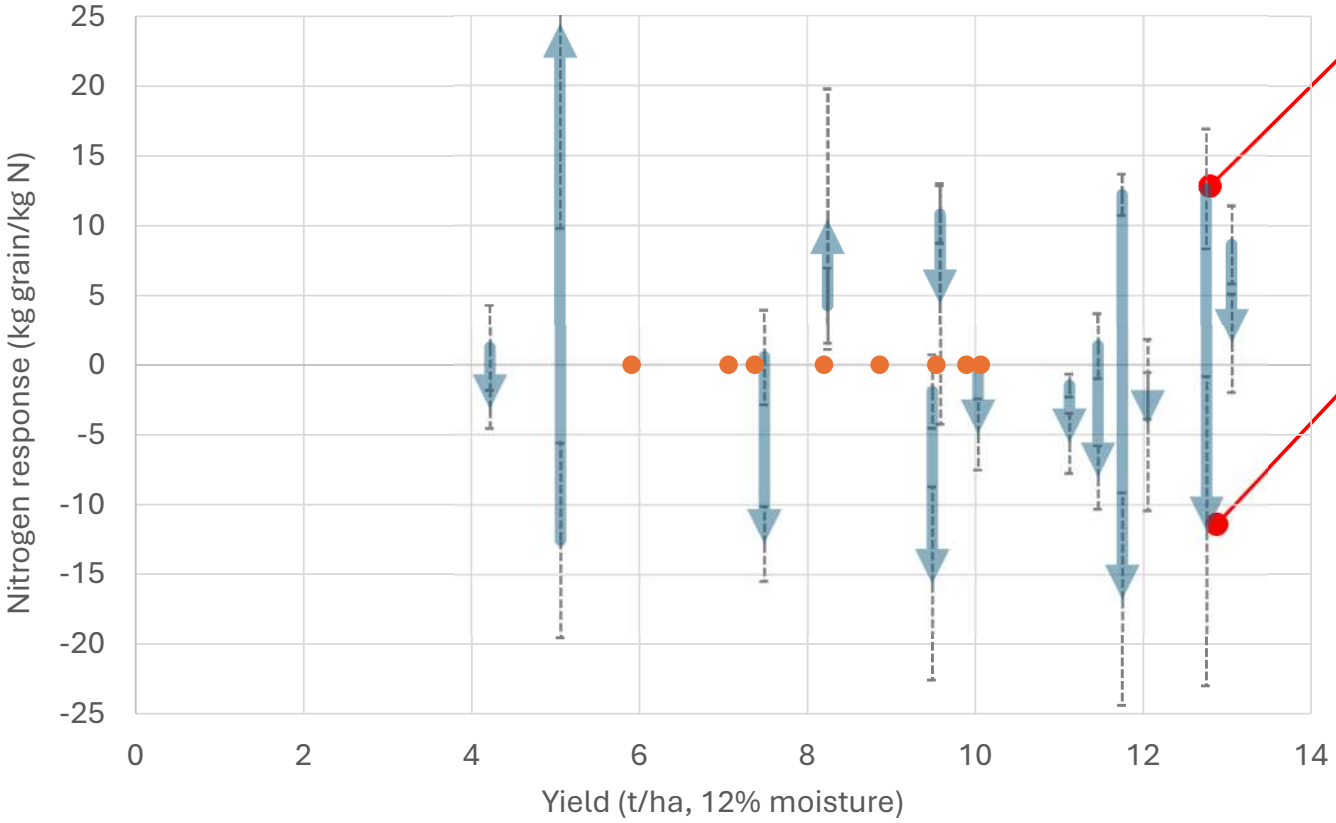
Lodging cutoff analysis

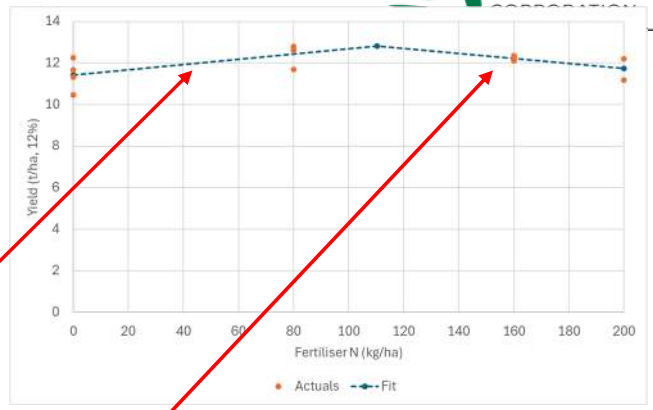




Site fertility

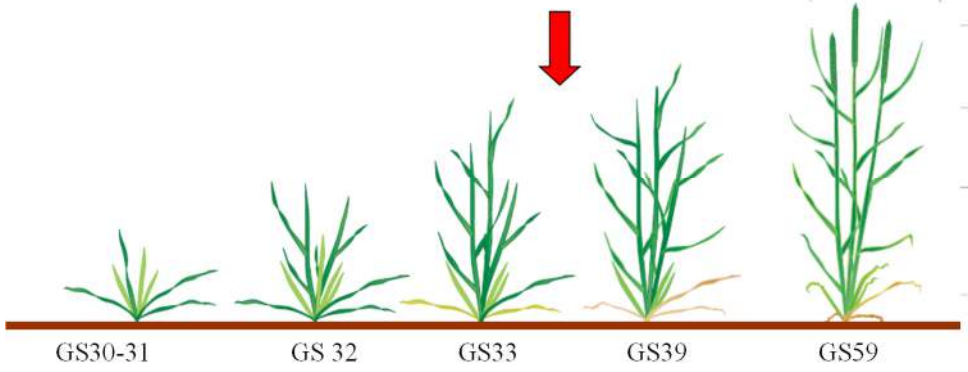
Response vs yield

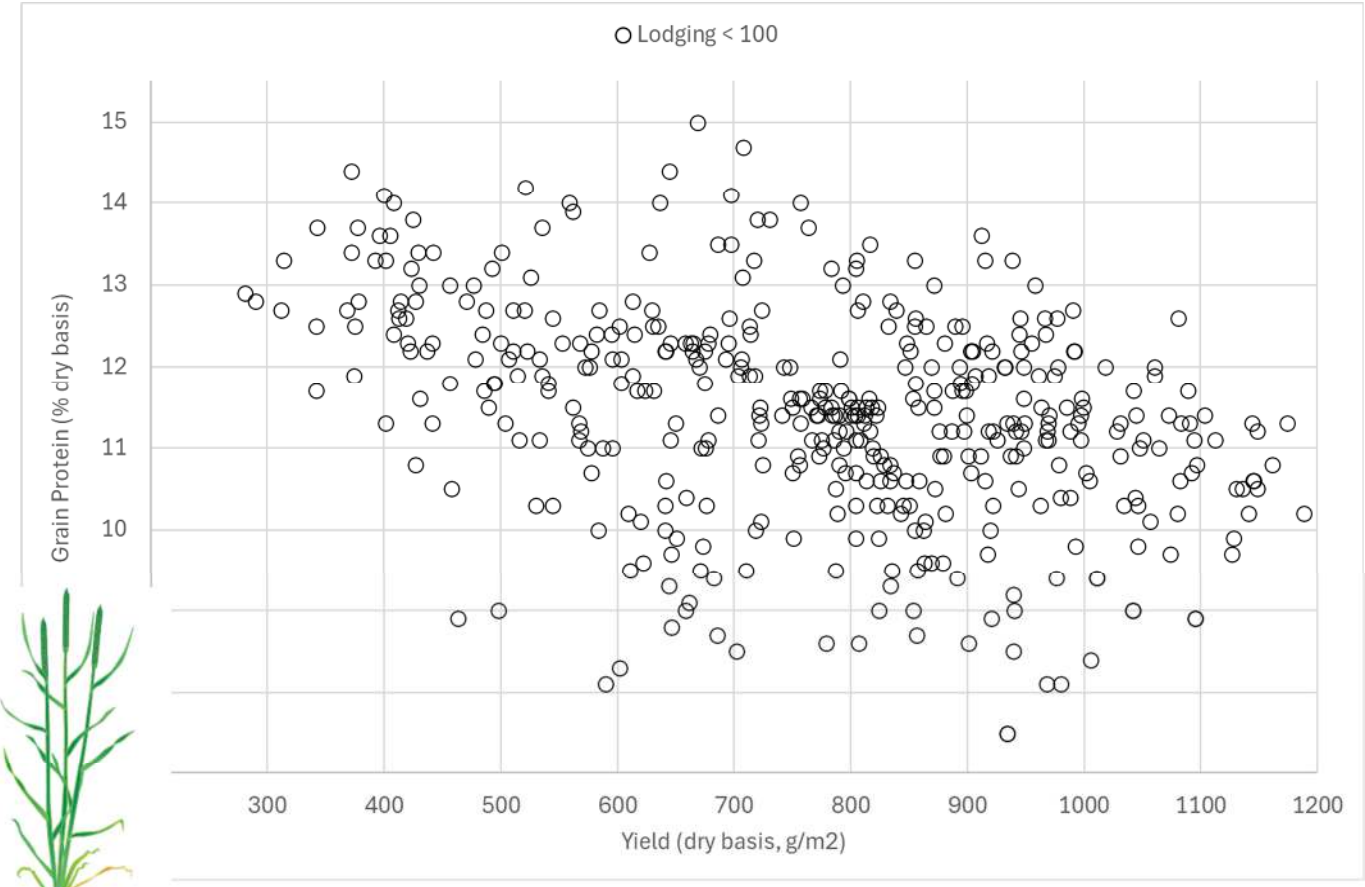




Protein range vs yield?

- N:photosynthesis co-limitation
- Protein synthesis cost 2-2.5 g/g
- ~12-15 kg/kg N





Model for maximum yield

- = -6.86 + 3.14 x PTQ_{SE}
- + 0.0117 TT_{Veg}
- - 3.21 $OC^{0.5}$
- + 0.0127 $N_{0\text{-}60}$
- + 0.0144 N_{Fert}

Yld_{Max}	= -6.86 (±2.93) + 3.14 (±1.91) x PTQ_{SE} + 0.0117 (±0.0028) TT_{Veg} -3.21 (±0.76) $OC^{0.5}$ + 0.0127 (±0.0056) $N_{0\text{-}60}$ + 0.0144 (±0.0047) N_{Fert}

PTQ_SE	+0.74***								
sqOC	-0.48*	-0.49*							
TT_Veg	+0.16	-0.10	+0.36						
N.0.60	+0.06	-0.19	+0.43	+0.14					
NOpt	+0.18	+0.34	+0.04	-0.64**	+0.10				
RF_Fallow	+0.14	+0.30	-0.37	-0.64**	-0.16	+0.46*			
RF_Veg	+0.36	+0.27	+0.30	+0.59**	+0.19	-0.16	-0.05		
RF_SE	-0.04	-0.06	+0.02	-0.05	+0.00	+0.03	+0.45	+0.32	
RF_GF	-0.09	+0.22	-0.17	-0.36	-0.38	+0.25	+0.57*	-0.03	+0.50*
	YMax	PTQ_SE	sqOC	TT_Veg	N.0.60	NOpt	RF_Fallow	RF_Veg	RF_SE

where Yld_{Max} is in t/ha (12% moisture basis), PTQ_{SE} is in MJ/°C, TT_{Veg} is in °C days (>0°C base), $OC^{0.5}$ is in $\%^{0.5}$, and $N_{0\text{-}60}$ and N_{Fert} are in kg N/ha. Adjusted R^2 0.79, $p<0.001$.

Consequences

- In high yielding environments:
  - Downsides of over-application are under-estimated
  - Protein is not a simple indicator of over-application
  - Predictors of N demand in these environments may be different
- Consider options the plant has to deal with extra N
  - when can the plant easily take up more N?
- Models need to include this mechanism

Acknowledgements

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