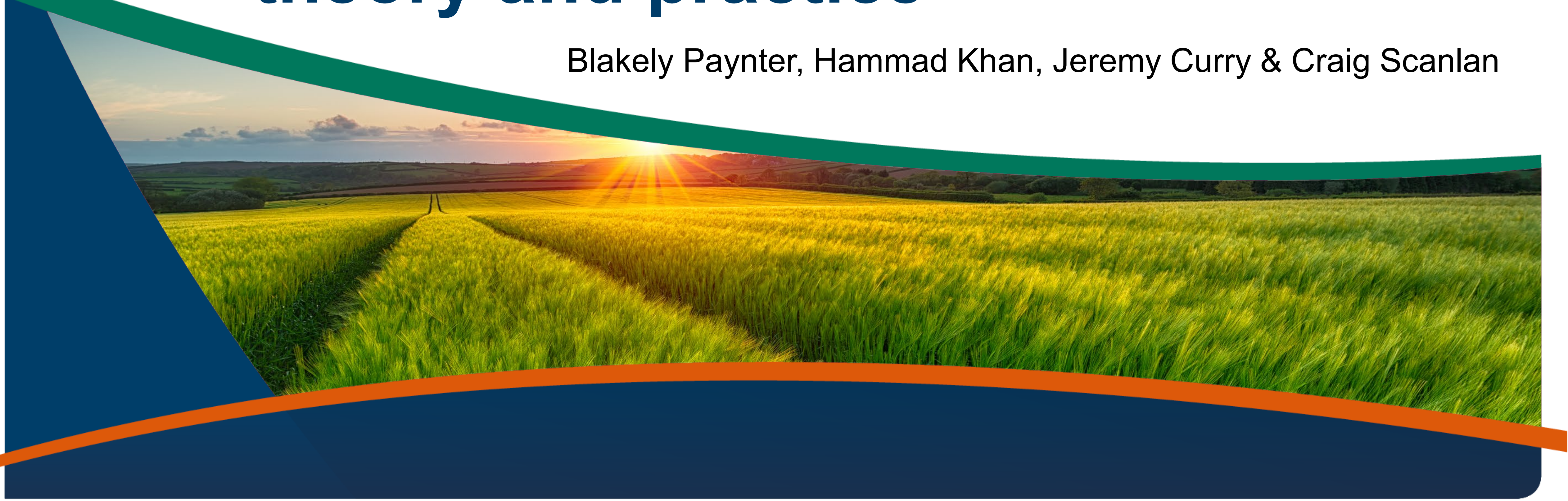
Department of
Primary Industries and Regional Development

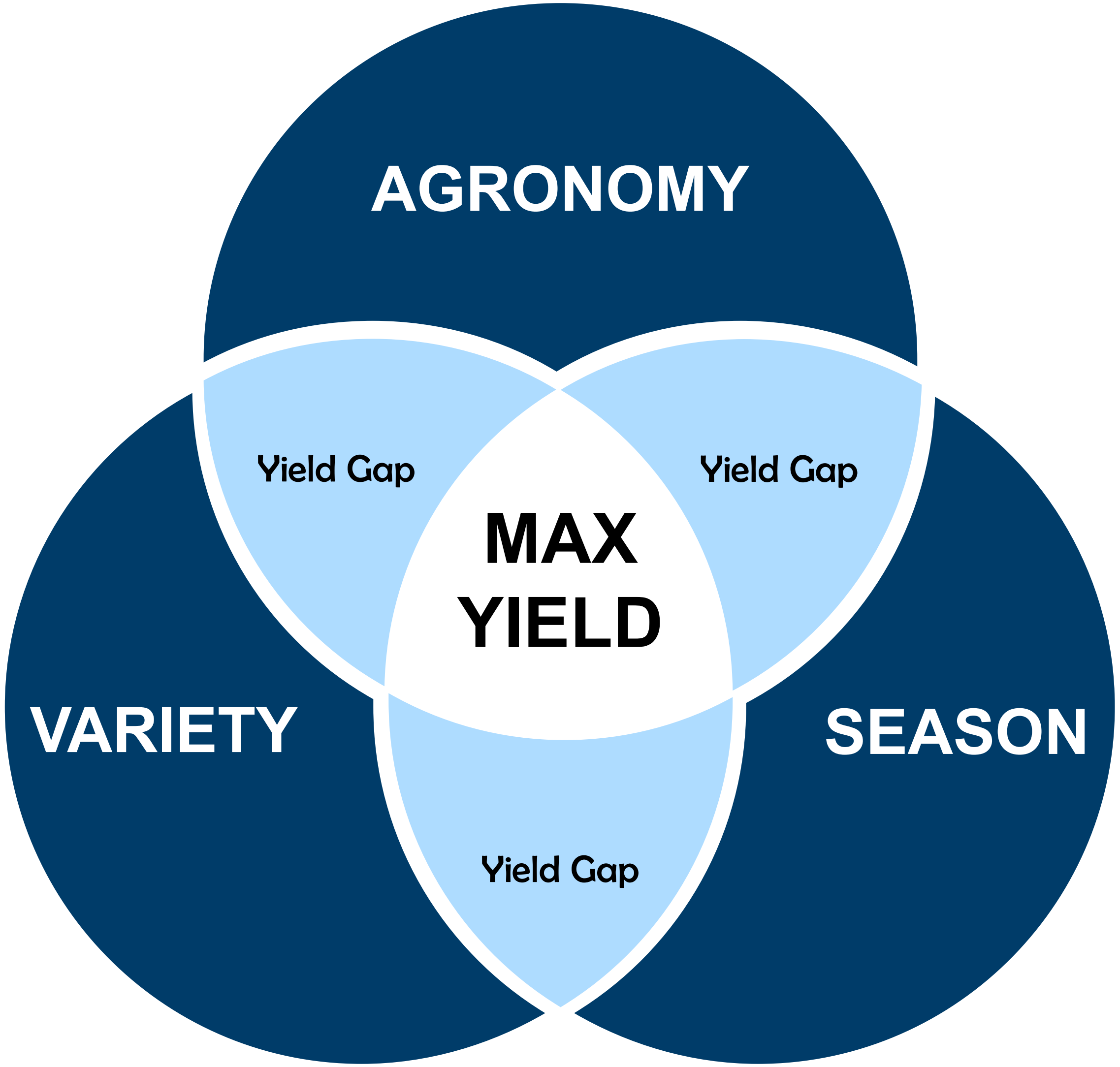
GOVERNMENT OF WESTERN AUSTRALIA

Opportunities to Improve Barley Yield – theory and practice

Blakely Paynter, Hammad Khan, Jeremy Curry & Craig Scanlan



Driving grain yield improvement



Interaction of G x E x M

G: Optimise variety

+

E: Overcome season

+

M: Oversee agronomy

source: Blakely Paynter – DPIRD

Key Messages – maximising barley grain yield

- **Sowing date:** mid-April to mid-May is the target sowing window, with an appropriate maturity variety to manage risk
- **Plant density:** low to medium rainfall – 130-170 plants/m^2
  medium to high rainfall – 180-220 plants/m^2
- **Grain protein:** ≥11.5% grain protein crops are closer to max N yield
- **N decisions:** bigger N response in crops sown before mid-May
- **Regulation:** Moddus Evo® may be needed to protect grain yield
- **Variety:** check out DPIRD 2022 Crop Sowing Guide
- **Soil bucket:** remove constraint by amendment and amelioration
- **Competition:** minimise the weed burden before planting barley

source: Blakely Paynter, Hammad Khan, Jeremy Curry & Craig Scanlan – DPIRD

Theory
- yield potential
- tune plant growth

Yield improvement

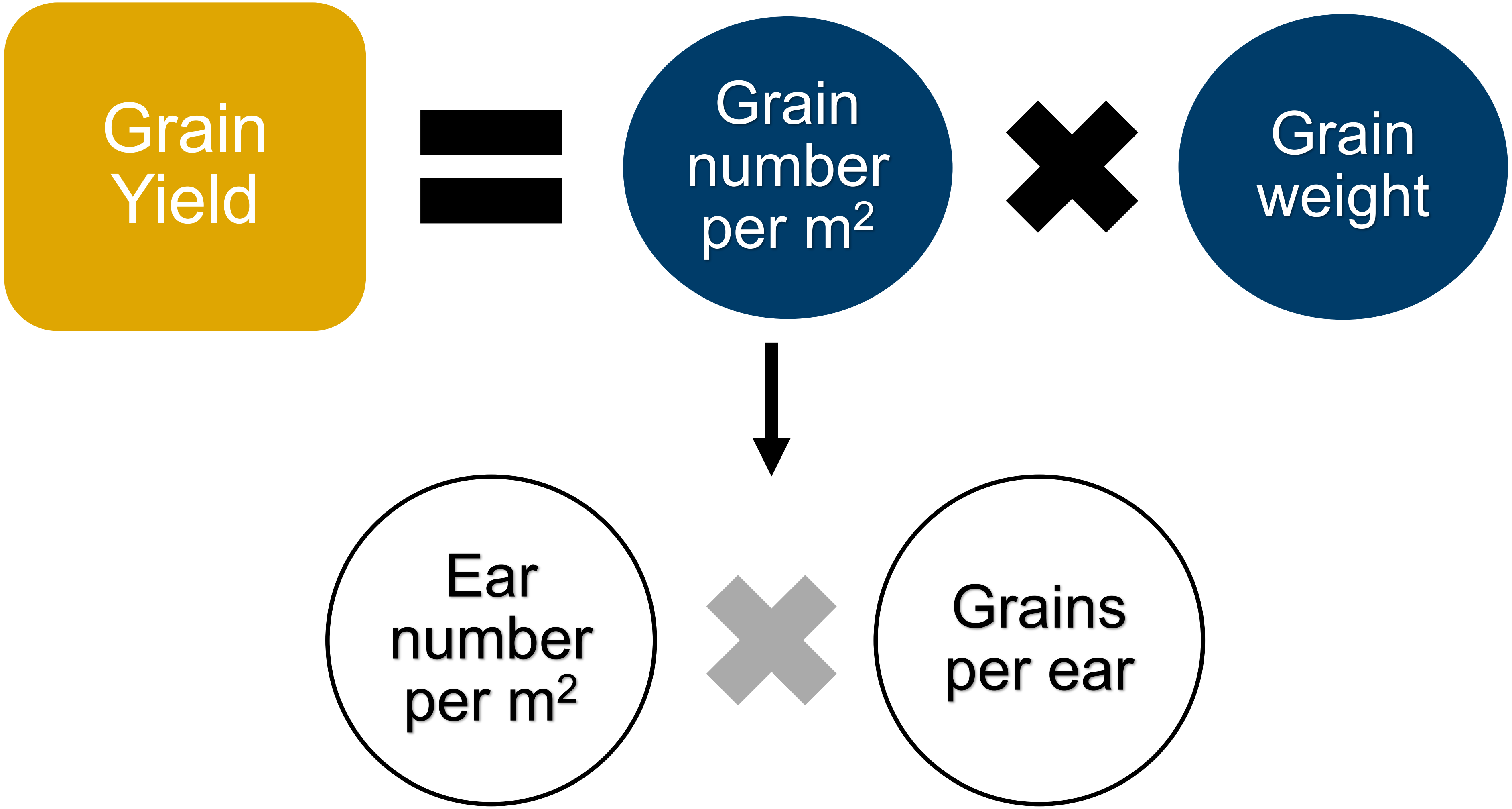
Improving yield potential

- Germplasm/trait diversity
- Breeding involving tools of
  - Genomics
  - Physiology
  - Phenomics

Attain the yield potential

- Soil management
- Weed control
- Pest and disease management
- Abiotic stress tolerance
- Crop management practices
- Growth manipulation using plant growth regulators (PGR)/Novel substances

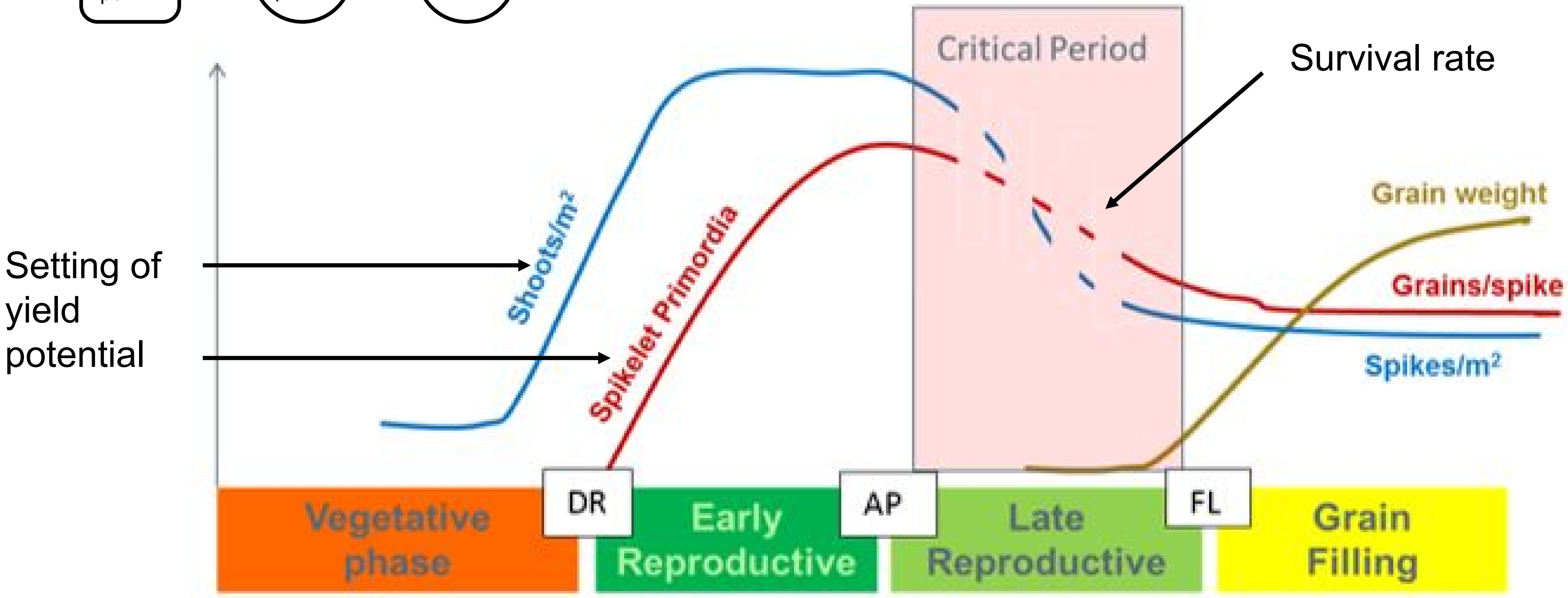
What is grain yield?



source: Hammad Khan – DPIRD

Critical stages for yield development in barley

Grain number per m^2 = Ear number per m^2 × Grains per ear



DR = Double ridge

AP = Awn primordia

FL = flag leaf

source: Porker *et al*. 2017

Yield improvement in numbers

By increasing grains per ear @ 40 mg grain weight

Ears (per m^2)	**Grains** (per ear)	**Yield** (t/ha)	**Yield increase** (t/ha)
600	25	6.00	
600	**27**	6.48	0.48 (8%)

↑ 2 grains per ear
=
↑ 8% yield (0.48 t/ha)

By increasing ear number with no change in grain weight

Ears (per m^2)	**Grains** (per ear)	**Yield** (t/ha)	**Yield increase** (t/ha)
600	25	6.00	
648	25	6.48	0.48 (8%)

↑ 8% tillers (48)
=
↑ 8% yield (0.48 t/ha)

source: Hammad Khan – DPIRD

Yield improvement in numbers

By increasing grain number per ear @ 40 mg grain weight

Tiller/m^2	Yield (t/ha)			
	Grains per ear			
	20	24	28	32
200	1.60	1.92	2.24	2.56
400	3.20	3.84	4.48	5.12
600	4.80	5.76	6.72	7.68
800	6.40	7.68	8.96	10.24
1000	8.00	9.60	11.20	12.80

↑ 2 grains per ear
=
↑ 8% yield (0.48 t/ha)

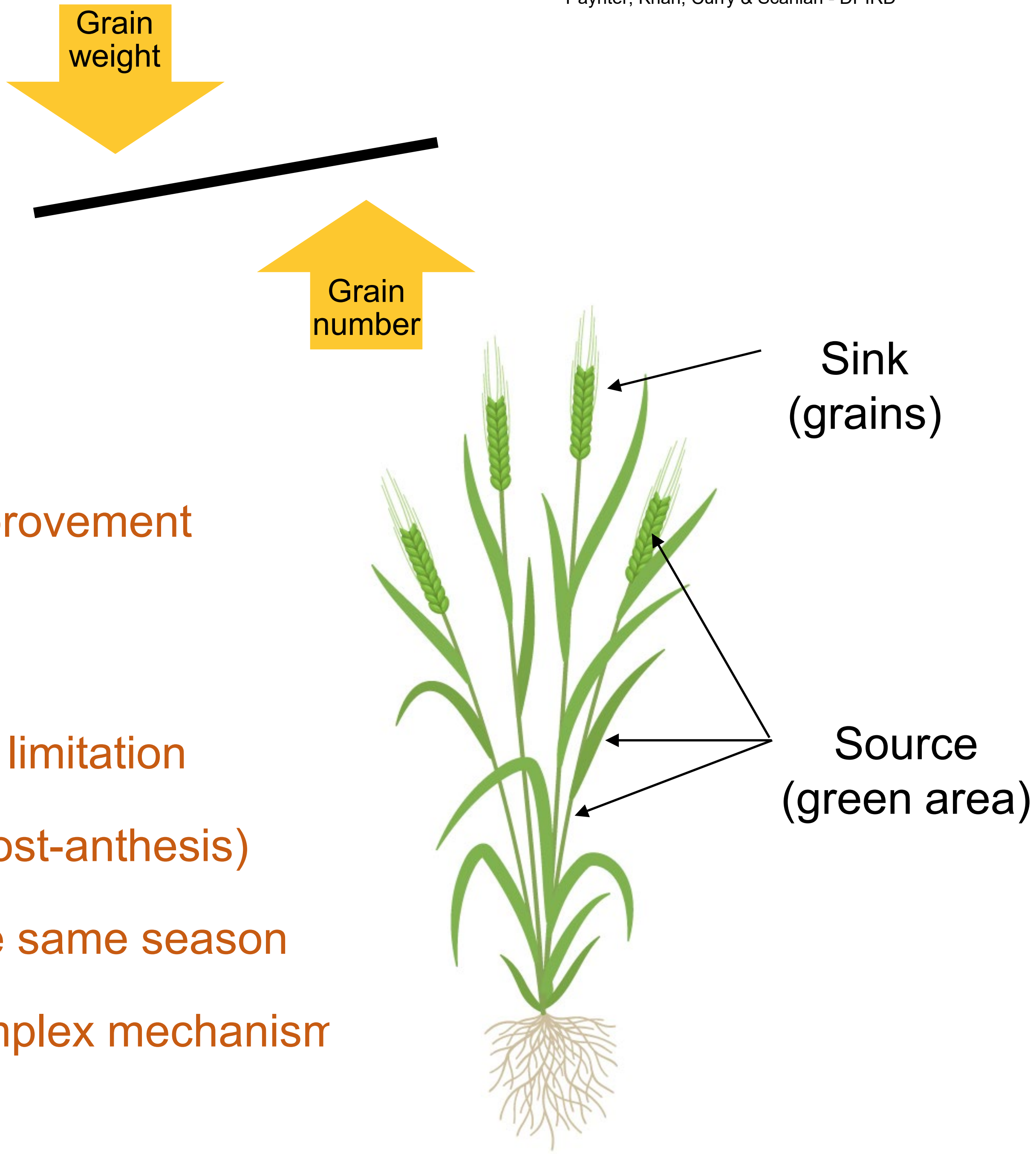
By increasing ear number with no change in grain weight

Tiller/m^2	Yield (t/ha)	Tiller increase	Yield (t/ha)
200	2	20	2.20
400	4	40	4.40
600	6	60	6.60
800	8	80	8.80
1000	10	100	11.00

↑ 8% tillers (48)
=
↑ 8% yield (0.48 t/ha)

source: Hammad Khan – DPIRD

Source:sink balance



High yield potential environments

- Plants set high yield potential (pre-anthesis)
- Source is not a limitation (pre- or post-anthesis)
- Sink (grain number) is the limitation for yield improvement

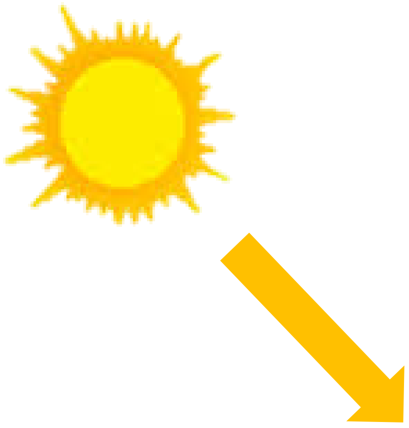
Low yield potential environments

- Plants can set low yield potential – creating sink limitation
- Source is generally limited during grain-filling (post-anthesis)
- Both sink and source limitations can occur in the same season
- Yield improvement require understanding of complex mechanism

source: Hammad Khan – DPIRD

Paynter, Khan, Curry & Scanlan - DPIRD

Physiological traits for improved yield potential



Yield Formation

Light Interception

Radiation Use Efficiency

Harvest Index

Opportunities to improve	Light Interception	Radiation Use Efficiency	Harvest Index
	Good	Good but unexplored	Limited

Identifying yield determinants of spring barley

Aim:

Explore yield formation and the importance of the source:sink balance

Variety	Main yield driver	Other traits
Banks	Tiller number	Short straw, later flowering
Maximus CL	Tiller number	Improved kernel weight, erect leaves
Rosalind	Tiller number	Erect leaves, earlier flowering
RGT Planet	Grain number per ear	Medium height
Beast	Grain weight	Tall height, earlier flowering
Fathom	Grain weight	Medium height, later flowering
Laperouse	Grain weight	Medium height, later flowering
Vlamingh	Grain weight	Erect leaves, later flowering

source: Hammad Khan – DPIRD, 21NO60

Paynter, Khan, Curry & Scanlan - DPIRD

Manipulating source:sink balance

Shaded plants – source limited

Shaded spikes – source limited

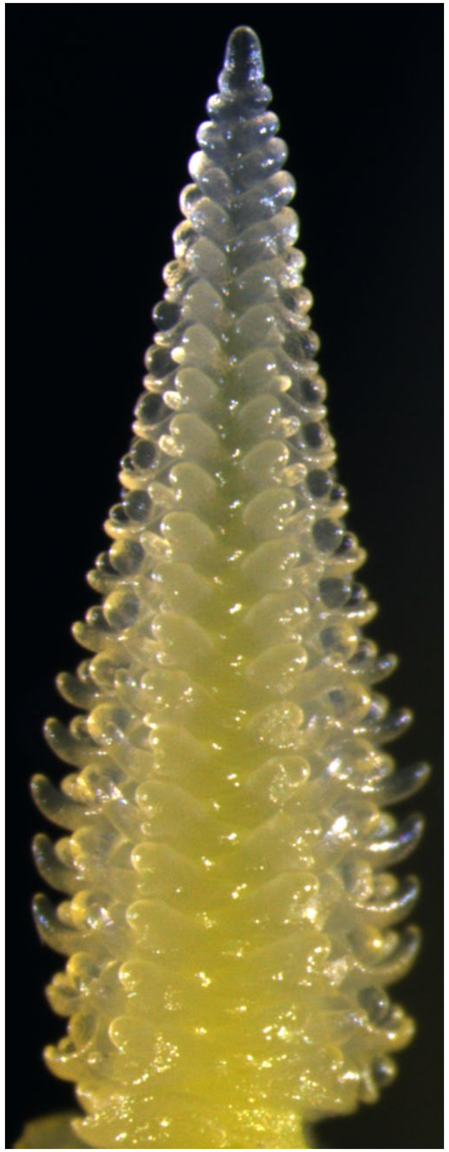
Leaves removed – source limited

De-grained – sink reduced

source: Hammad Khan – DPIRD, 21NO60

Ear primordia number – setting yield potential

Beast = 35
potential grains



RGT Planet = 42
potential grains

source: Hammad Khan – DPIRD, 21NO60

Grain numbers per ear – on the finish line

Beast = 23
actual grains
(lost 34% potential kernels)

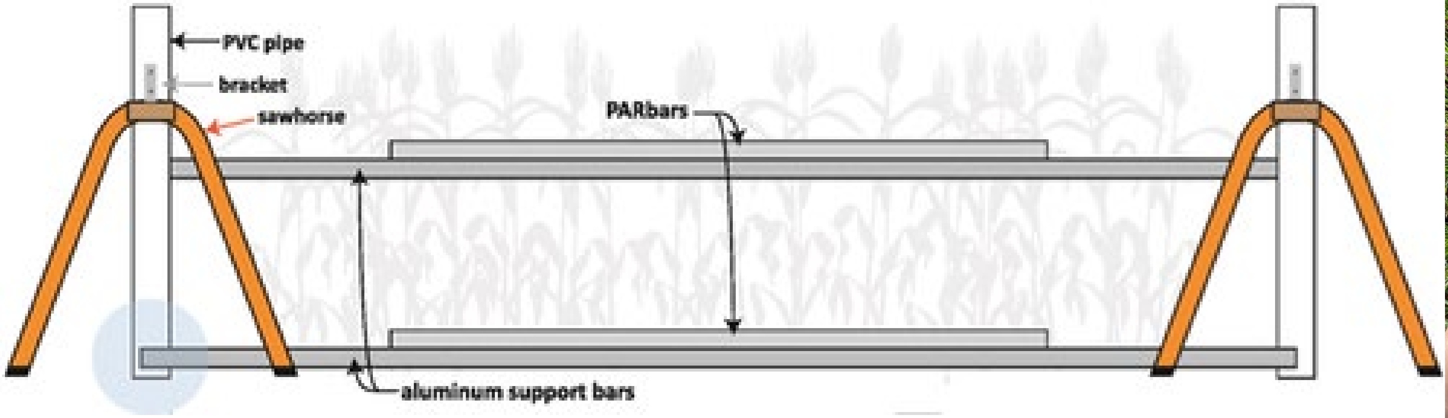
RGT Planet = 29
actual grains
(lost 31% potential kernels)

source: Hammad Khan – DPIRD, 21NO60

Paynter, Khan, Curry & Scanlan - DPIRD

Physiological understanding of the traits

Radiation use efficiency



Photosynthesis

source: Salter *et al*. (2018), PhotosynQ, LICOR

Key Messages – physiology

- **Levers:** most agronomic levers have already been pulled
- **Next yield gain:** likely to come from increasing grain number/m^2
- **Future R&D:** ↑ grain number & improving the sink:source balance

Yield = Grain number per m^2 × Grain weight

	Grain number per m^2	Grain weight
Yield influence →	Major	Minor
Critical growth stage →	Pre-heading	Post-anthesis

source: Hammad Khan – DPIRD

Questions

Manipulating plants using growth regulators

- Traditionally PGRs have only been used for lodging & head loss reduction
- Growth regulators drive every aspect of plant growth, have diverse functions
- Novel regulators with improved field life are being developed & field tested
- We are on the verge of being able to suppress or active the plant
- Targeted use of regulators could influence critical stages like spike primordia
- Synthetic cytokinin regulators (urea-derived compounds) have improved cereal yield by influencing flowering, tillering, seed set & senescence (Nisler *et al*. 2018, 2021)

source: Hammad Khan – DPIRD

Novel urea compounds as regulators

Urea compound 19

- Urea compound 19 is diphenyl urea derived
- Inhibits CKX during early reproduction – ↑ endogenous levels of cytokinin
- Improved barley yield (up to 6.3%) – seed coating/foliar application
- Improved wheat yield (up to 6.0%) – seed coating/foliar application

Urea compound ASES

- ASES urea compound is an anti-senescence agent during the grain-filling stage
- Involves a cytokinin-independent mechanism
- Improved yield in wheat under field conditions

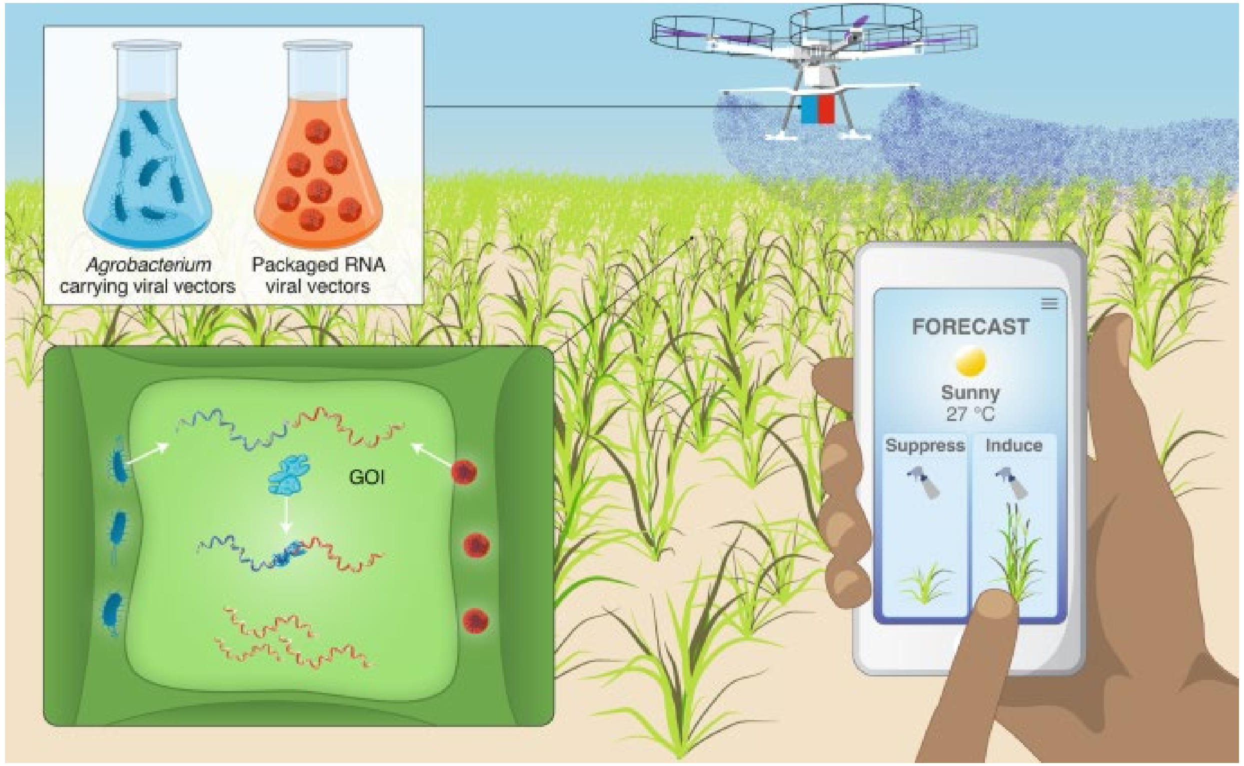
source: Nisler et al. 2018, 2021

RNA viral transfection

Spray packaged RNA viral vector to change gene expression.
Transiently target various regulatory circuits within a plant.

Pros

- Operator-specified alterations of traits
- Transient reprogramming for agronomic performance
- No genetic modification (single generation)
- Industrial scale application (fast, tuneable & versatile)



Cons

- Regulatory issues not defined
- Prior knowledge essential (basic science backed)

Targets

- Time of flowering and vernalisation
- Plant height
- Abiotic/biotic stress tolerance
- Possibly many others but currently only demonstrated in regulatory/hormonal circuits

source: Torti *et al*. (2021); Massel *et al*. (2021)

Key Messages – spray on regulation

- **Regulators:** novel plant regulators in testing in field trials
- **Advantage:** could tune the crop to the season
- **Future R&D:** field application and relevance to WA

NEWSLETTERS
Sign up to read our regular email newsletters

NewScientist

UNLOCK FULL SITE ACCESS

News Podcasts Video Technology Space Physics Health More Shop Courses Events Tours Jobs Sign In Search

Advertisement

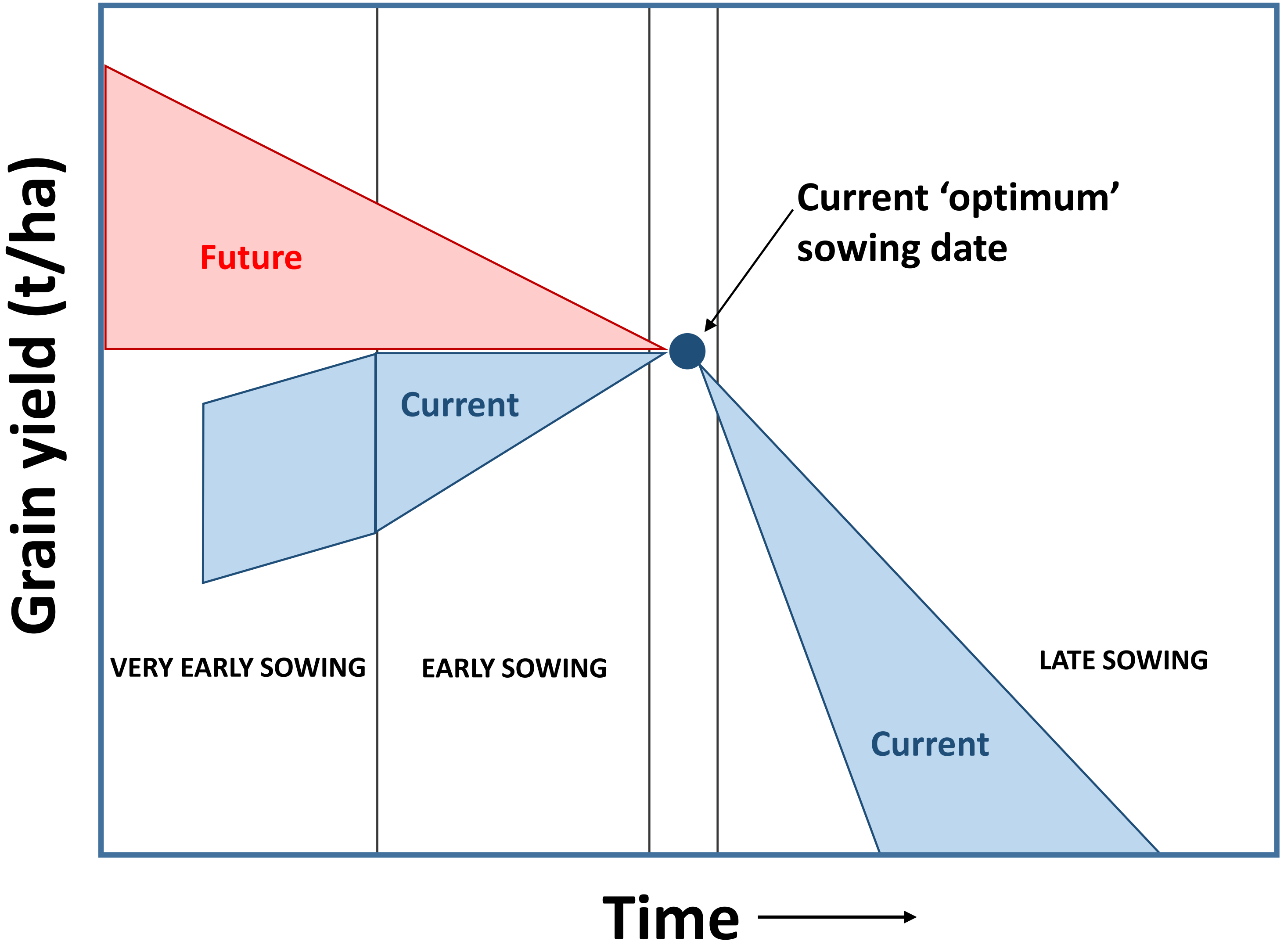
Gene-silencing spray lets us modify plants without changing DNA

source: Hammad Khan – DPIRD


Paynter, Khan, Curry & Scanlan - DPIRD
Questions

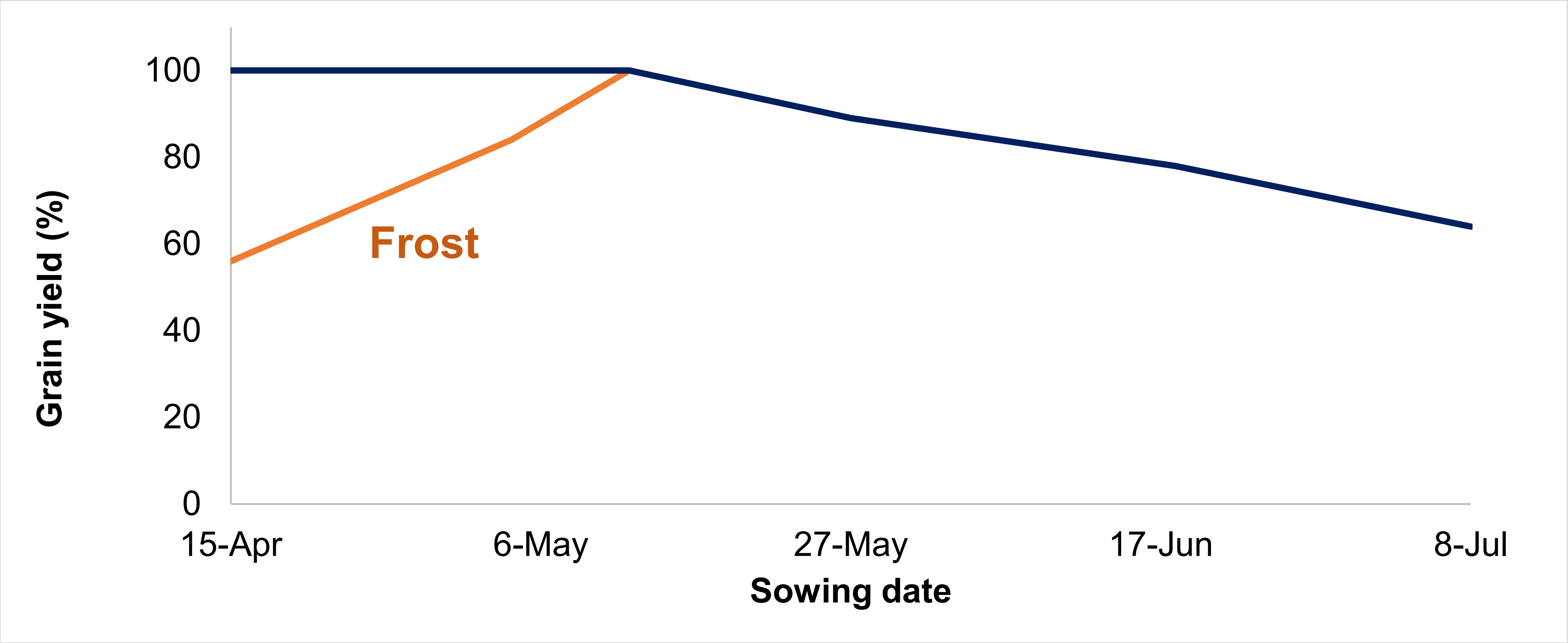
Practice
- timely sowing
- grain protein
- plant density

Timely sowing for grain yield – hypothetical



source: Dion Nicol, Blakely Paynter, Mark Seymour, Marty Harries, Bob French – DPIRD

Timely sowing for grain yield – current varieties



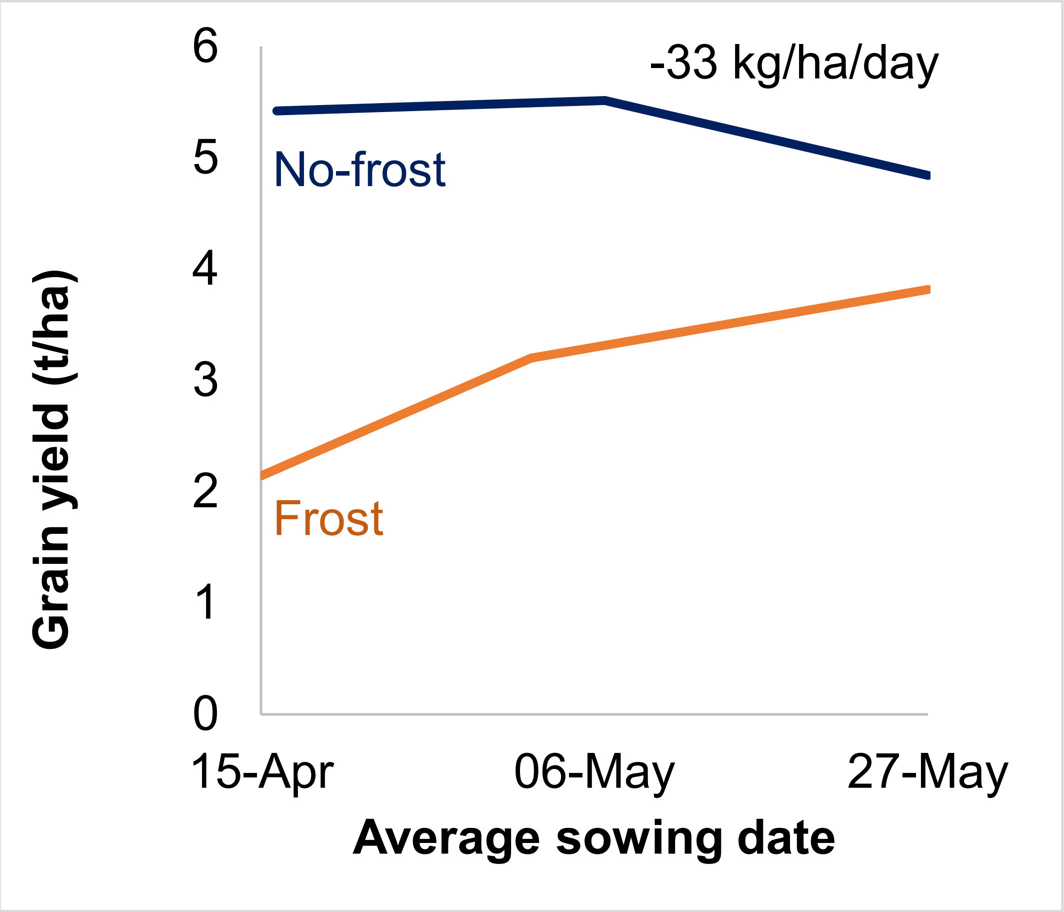
With current spring germplasm, there is a yield plateau from mid-April to mid-May, before declining by up to 1% per day after mid-May

source: Blakely Paynter, Jeremy Curry, Raj Malik, Andrea Hills – DPIRD, data from DPIRD-GRDC projects ‘DAW00148’ (2006-2009), ‘DAW00190’ (2009-2012), and DAW00224’ (2015-2017)

Paynter, Khan, Curry & Scanlan - DPIRD

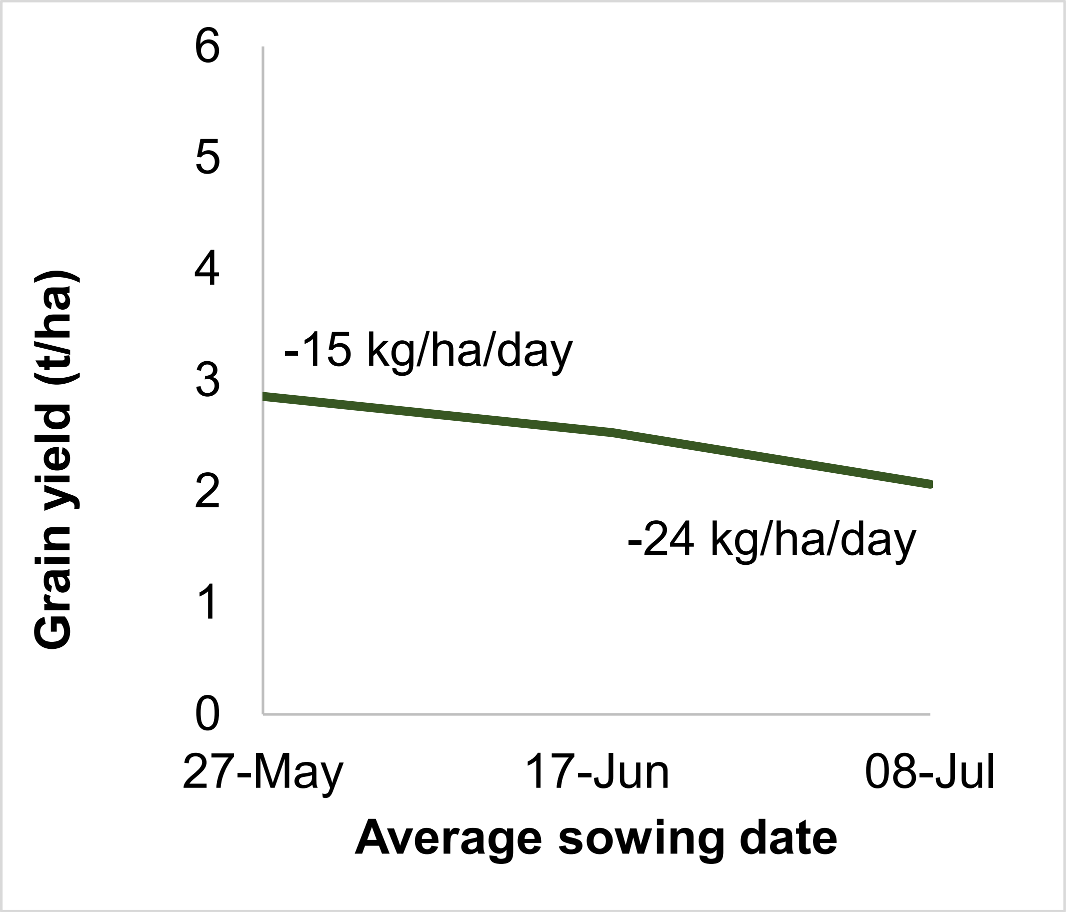
Timely sowing for grain yield – supporting data

6 varieties – 2015 to 2017



Maturity range: Rosalind to Urambie
9 trials

9 varieties – 2006 to 2011

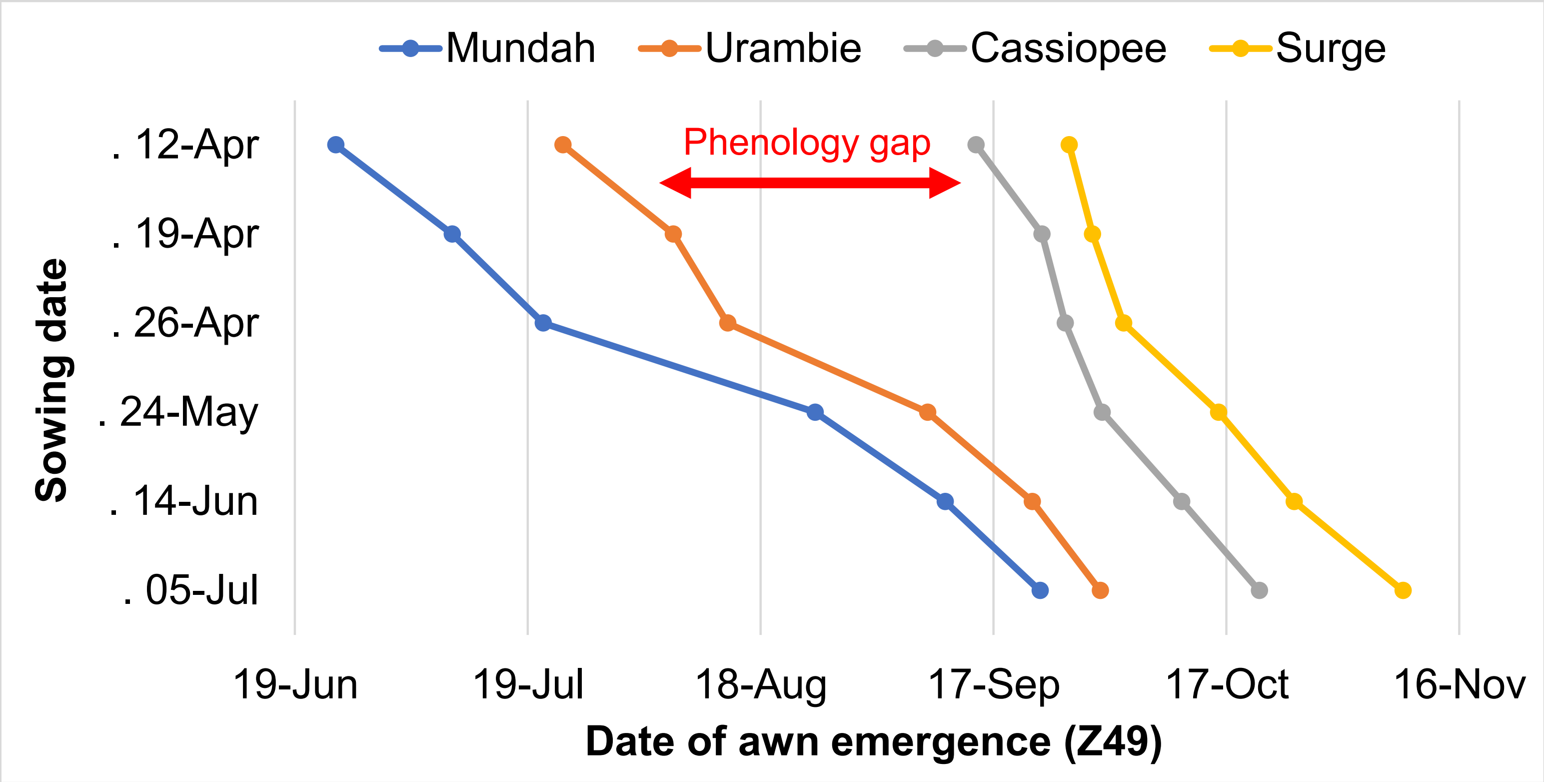


Maturity range: Mundah to Gairdner
31 trials

source: Blakely Paynter, Jeremy Curry, Raj Malik, Andrea Hills – DPIRD, data from DPIRD-GRDC projects ‘DAW00148’ (2006-2009), ‘DAW00190’ (2009-2012), and DAW00224’ (2015-2017)

Paynter, Khan, Curry & Scanlan - DPIRD

Timely sowing for grain yield – the gap



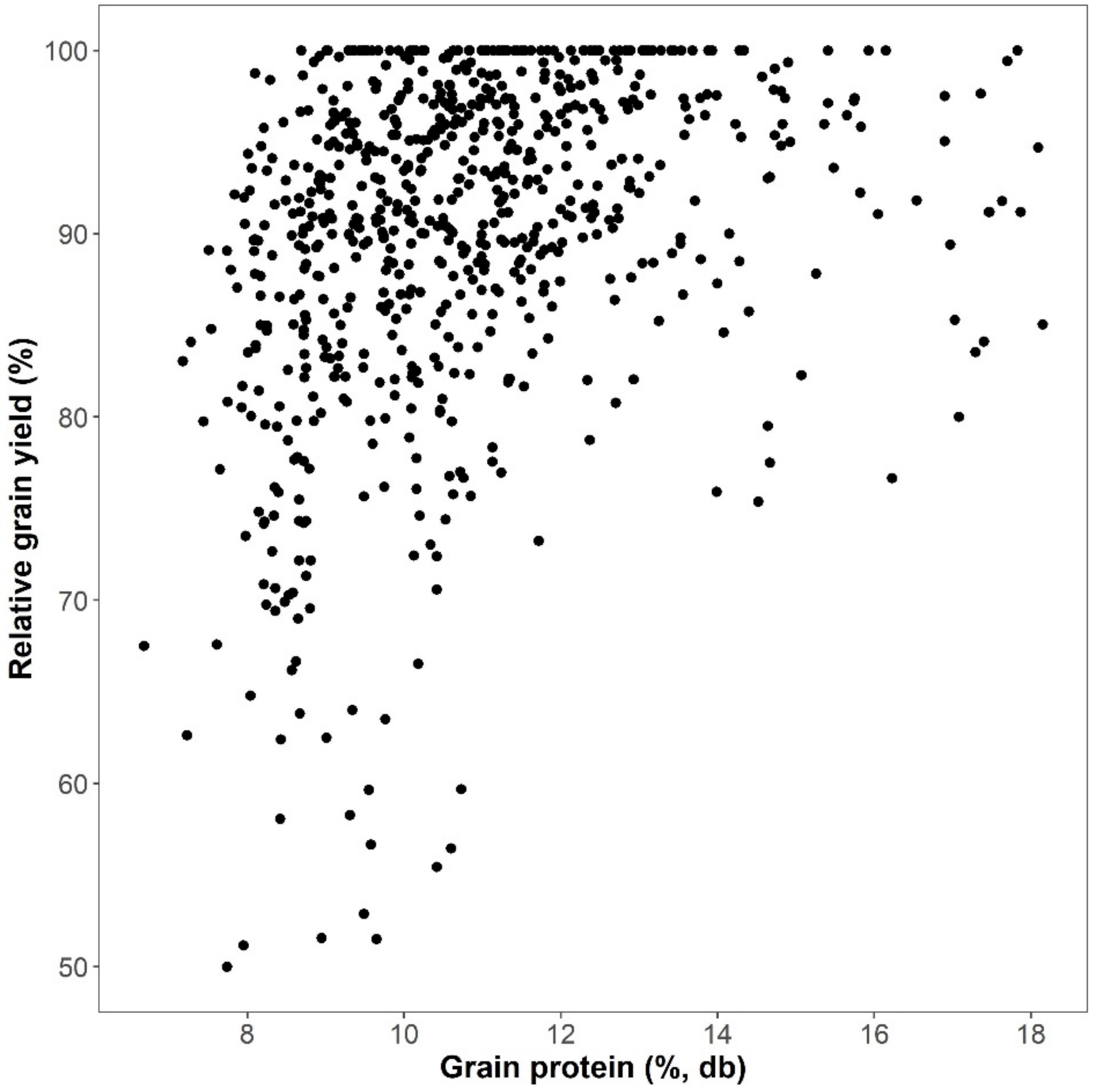
	Date of awn emergence (Z49)		
Sowing date	Spring barley variety spread (days)	**Spring barley to winter barley gap (days)**	Winter barley variety spread (days)
12-Apr	29	**53**	12
19-Apr	29	**48**	7
26-Apr	24	**44**	8
24-May	15	**23**	15
14-Jun	11	**19**	15
05-Jul	8	**21**	19

The gap between spring & winter germplasm is >40 days with April sowing, would varieties that flower in this gap reduce the risk of early sowing & increase yield?

source: Blakely Paynter – DPIRD, data from DPIRD-GRDC project ‘DAW00224’, Northam (2018)


Paynter, Khan, Curry & Scanlan - DPIRD
Questions

Is grain protein a yield indicator?

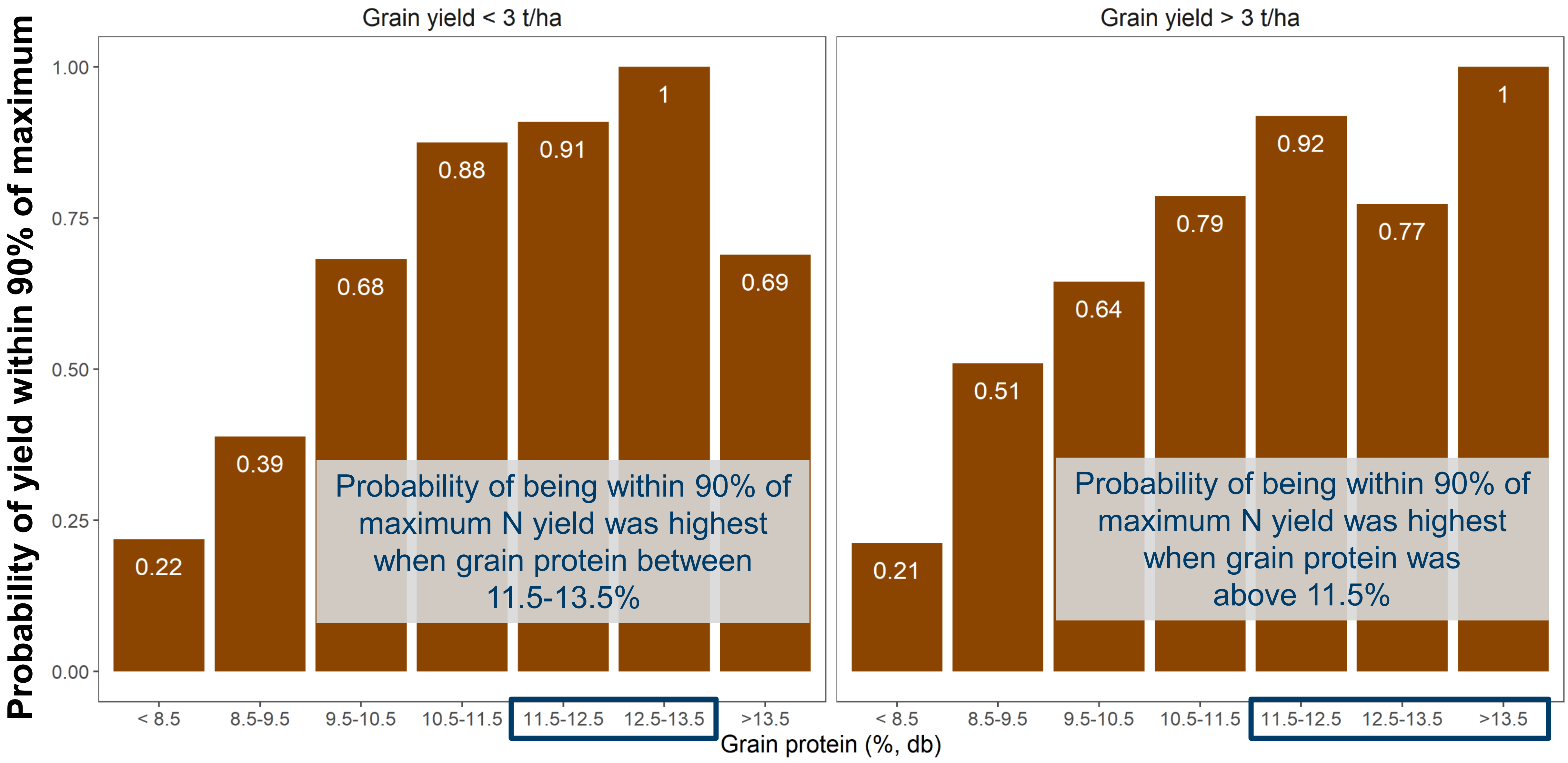


- **Background –** 79 barley trials (2012-2019) with fertiliser N rate as a factor at one or more N timings
- **Rotation –** 95% trials sown onto non-legume stubble (typically canola or barley)
- **Relative yield –** each dot is the mean of a N treatment relative to the highest yield achieved in that trial
- **Analysis –** done through GRDC project 'Increasing profit from N, P and K fertiliser inputs into the evolving cropping sequences in the Western Region (UWA1801-002RTX)'

source: Craig Scanlan – DPIRD, thru DPIRD-UWA-GRDC project 'UWA1801-002RTX' using data from DPIRD-GRDC barley agronomy project 'DAW00224' led by Blakely Paynter – DPIRD

Paynter, Khan, Curry & Scanlan - DPIRD

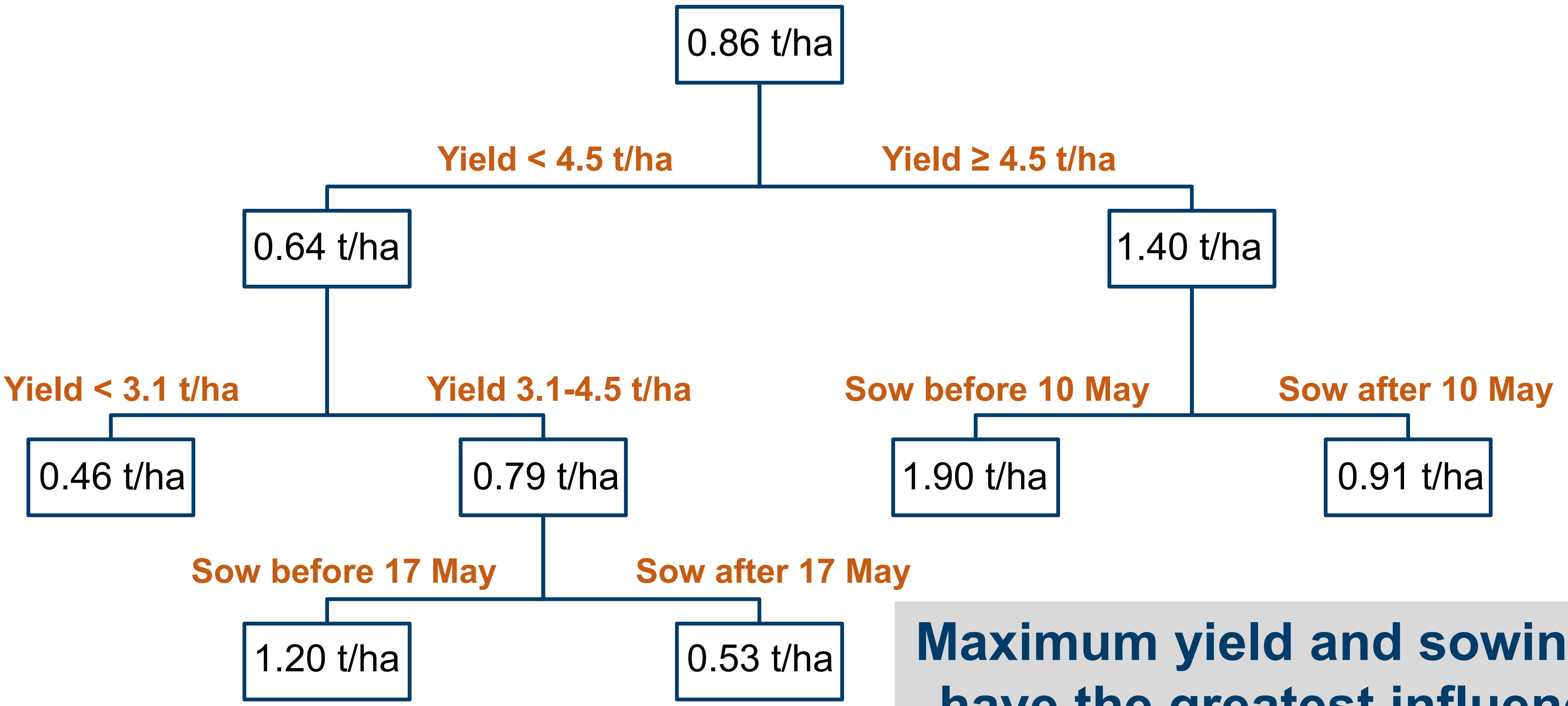
Is grain protein a yield indicator?



source: Craig Scanlan – DPIRD, thru DPIRD-UWA-GRDC project 'UWA1801-002RTX' using data from DPIRD-GRDC barley agronomy project 'DAW00224' led by Blakely Paynter – DPIRD

Paynter, Khan, Curry & Scanlan - DPIRD

What size response to N should be expected?



Maximum yield and sowing date have the greatest influence on the response to applied N

source: Craig Scanlan – DPIRD, thru DPIRD-UWA-GRDC project 'UWA1801-002RTX' using data from DPIRD-GRDC barley agronomy project 'DAW00224' led by Blakely Paynter – DPIRD


Paynter, Khan, Curry & Scanlan - DPIRD
Questions

Target density for maximum yield?

Plant density in lower rainfall

6 varieties

- Banks, Compass, La Trobe, RGT Planet, Scope CL, and Spartacus CL

5 plant densities

- 40, 100, 160, 220, and 280 plants/m^2

3 fertiliser N rates

- 10, 30, and 60 kg N/ha

4 locations in each of 2017 & 2018

- Cadoux, Merredin, Lake Grace, and Grass Patch

Plant density in higher rainfall

6 varieties

- Banks, Bass, Compass, Flinders, La Trobe, and RGT Planet

5 plant densities

- 40, 100, 160, 220, and 280 plants/m^2

3 fertiliser N rates

- 30, 60, and 90 kg N/ha

5 locations in each of 2017 & 2018

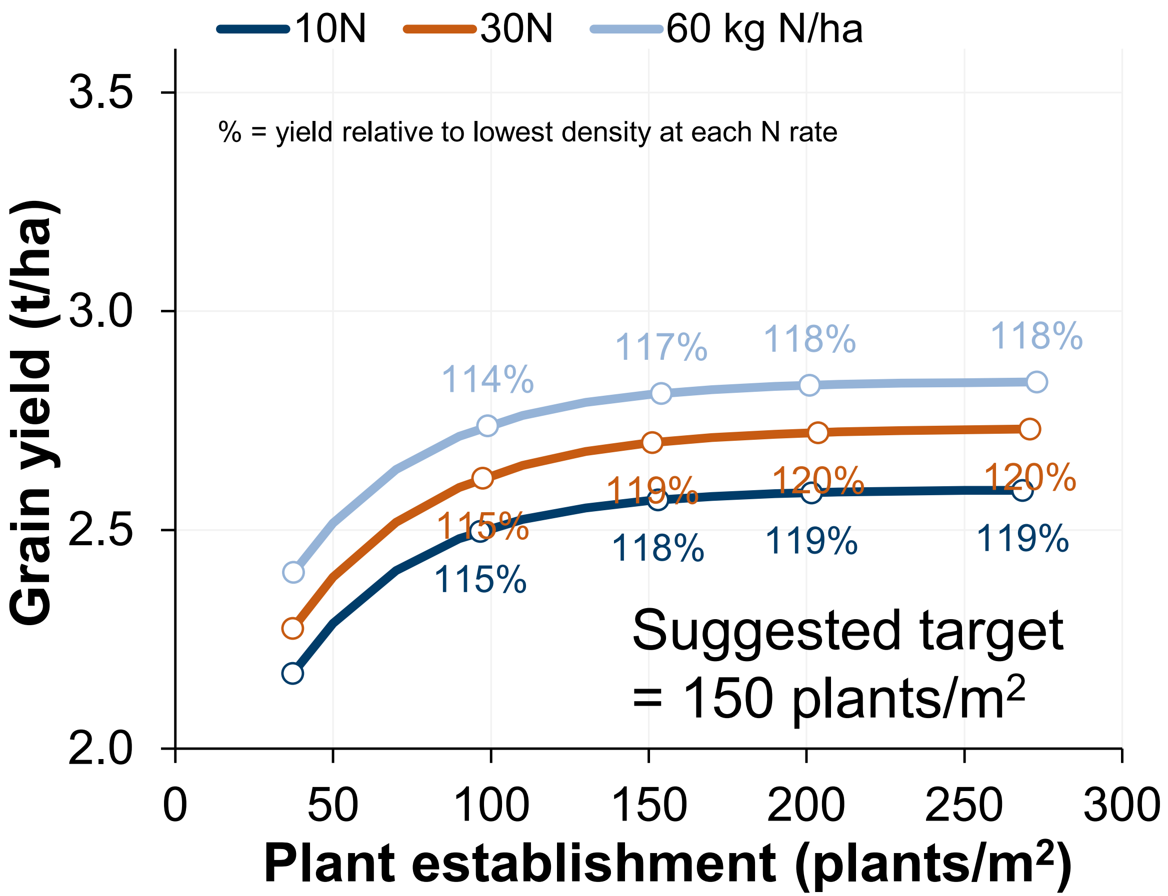
- Yerecoin, Brookton, Kojonup-W, Gnowangerup, and Wittenoom Hills

source: Blakely Paynter, Jeremy Curry, Raj Malik, Karyn Reeves – DPIRD, data from DPIRD-GRDC project 'DAW00224' (2017-2018)

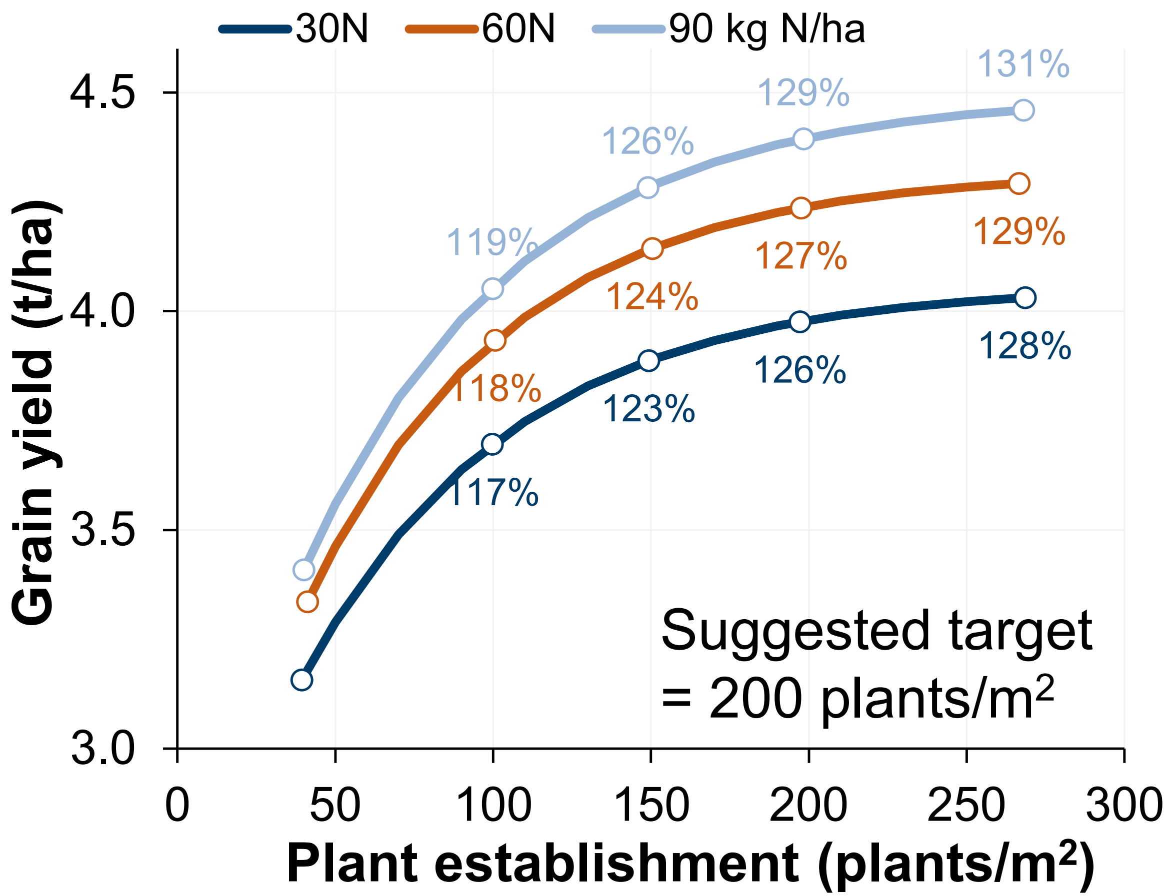
Paynter, Khan, Curry & Scanlan - DPIRD

Target density for maximum yield?

MET analysis in lower rainfall



MET analysis in higher rainfall



to shift from 150 to 200 plants/m^2 is 20-30 kg/ha more seed

source: Blakely Paynter, Jeremy Curry, Raj Malik, Karyn Reeves – DPIRD, data from DPIRD-GRDC project 'DAW00224' (2017-2018)

Paynter, Khan, Curry & Scanlan - DPIRD

Questions

Key Messages – maximising barley grain yield

- **Sowing date:** mid-April to mid-May is the target sowing window, , with an appropriate maturity variety to manage risk
- **Plant density:** low to medium rainfall – 130-170 plants/m^2
  medium to high rainfall – 180-220 plants/m^2
- **Grain protein:** ≥11.5% grain protein crops are closer to max N yield
- **N decisions:** bigger N response in crops sown before mid-May
- **Regulation:** Moddus Evo® may be needed to protect grain yield
- **Variety:** check out DPIRD 2022 Crop Sowing Guide
- **Soil bucket:** remove constraint by amendment and amelioration
- **Competition:** minimise the weed burden before planting barley

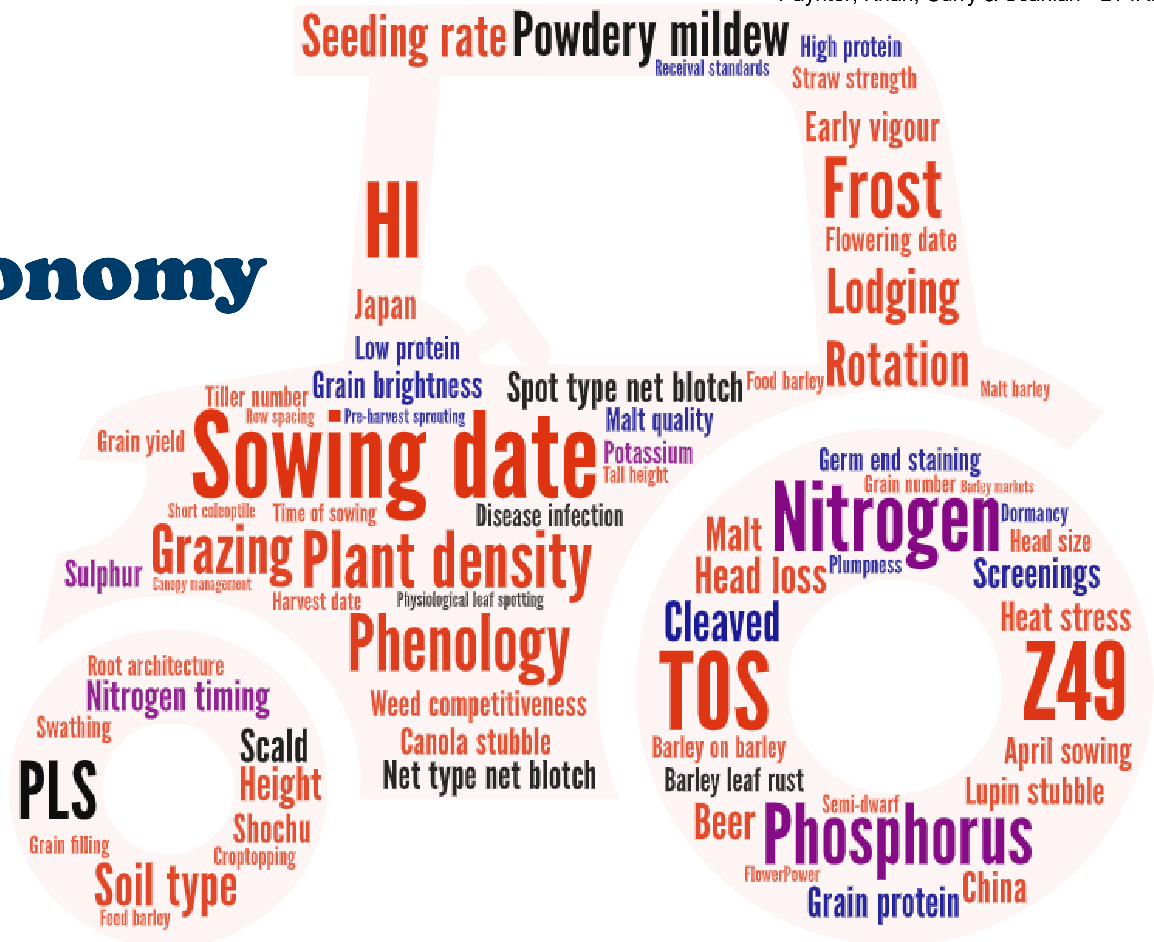
source: Blakely Paynter, Hammad Khan, Jeremy Curry & Craig Scanlan – DPIRD

Paynter, Khan, Curry & Scanlan - DPIRD

Thank you

Varieties

Agronomy



Acknowledgements:

DPIRD Technical – Rhys Flynn, Kate Beilken, Rod Bowey, and many others plus casual staff

DPIRD Field Research