Sorghum ID

Genomics-informed sorghum improvement

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GENOMICS INFORMED SORGHUM IMPROVEMENT

Better yield, better quality, better resilience

- Genomics and key breeding traits
- New breeding technologies
  - CRISPR/Cas9 genome editing
- Focus on end-use quality
- Yield and yield components
- Future crop design

It's a major staple for >500 million

And through an animal intermediary

You can make these ….

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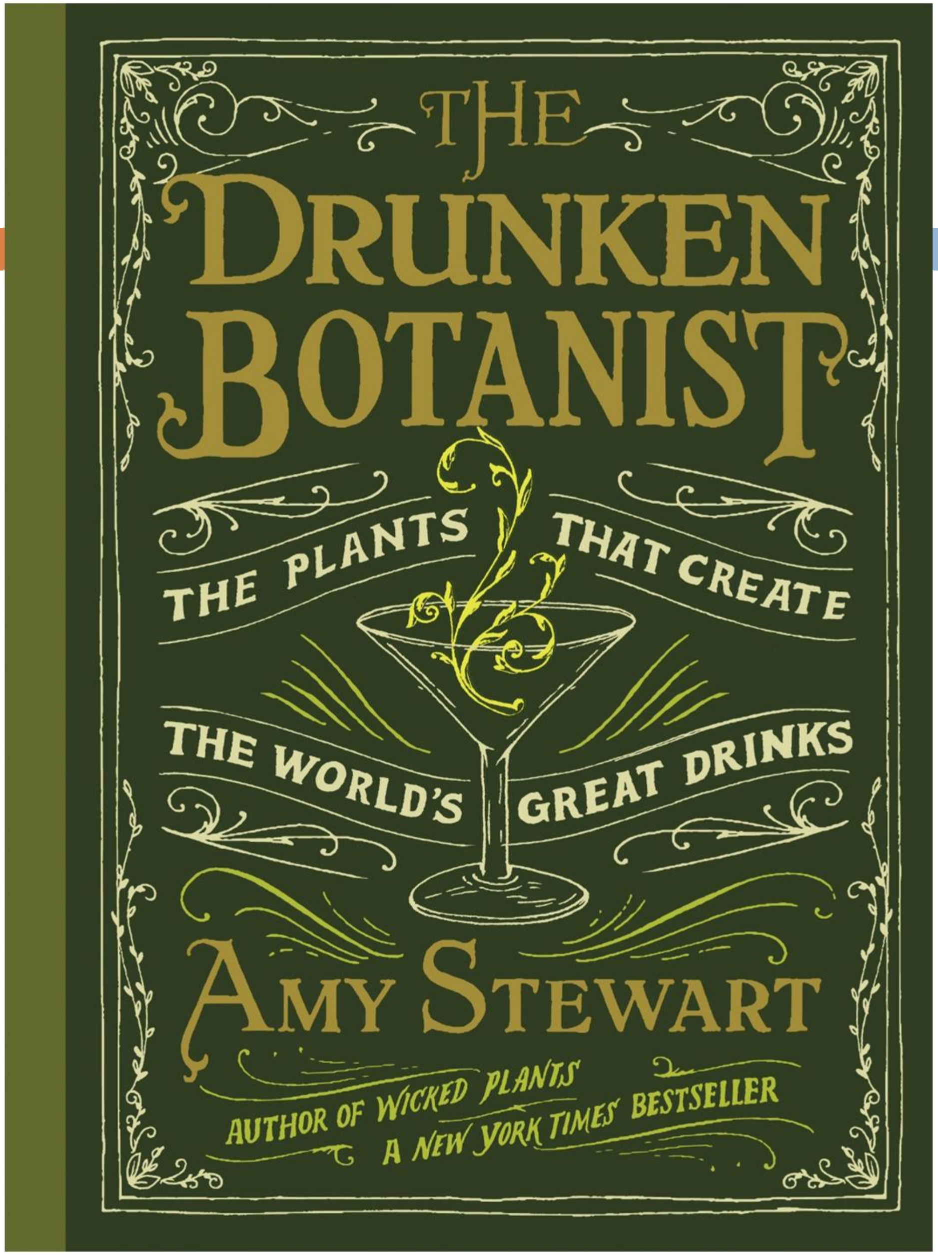
And you can make bio-ethanol and beer from sorghum

So what’s not to like?



- "If we had a way to accurately tally the world's vast and complex drinking practices, sorghum is clearly one of the world's most imbibed plants."

(Stewart, 2013)

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Sorghum: least digestible cereal for monogastrics (humans, pigs etc)

- low starch and protein digestibility
- high starch gelatinization temperature (important for processing and digestibility)
- protein:starch matrix is protease resistant
  - Cysteine-rich leads to S-S bonding
- Small/variable grain size

Whatever the quality – birds love it!

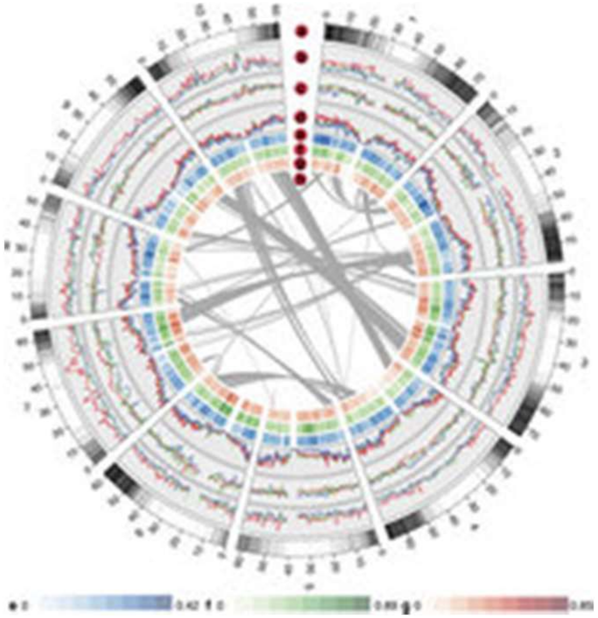
Exploiting genetic diversity

- Association genetics for improving a trait of importance
- GWAS in 400 diverse sorghums

- **Sorghum starch digestibility**

Association with digestibility

- Across the panel, 1 genomic region appeared to confer improved digestibility
- Near the distal end of the short arm of chromosome 6
- A candidate gene was located here – **pullulanase** – a starch debranching enzyme



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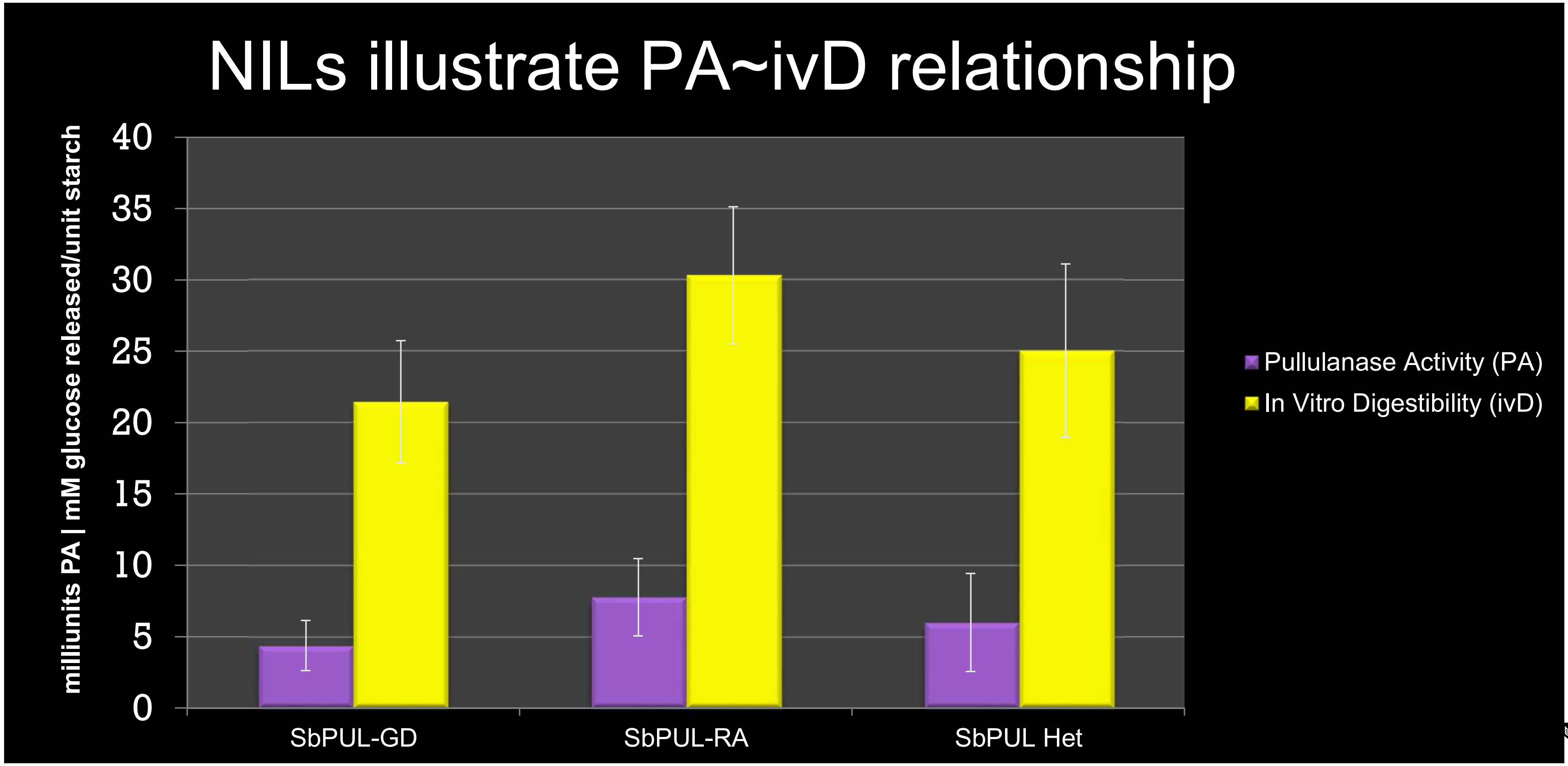
↑ Pul activity → ↑ digestibility


NILs illustrate PA~ivD relationship

Gilding, Frere et al, 2013

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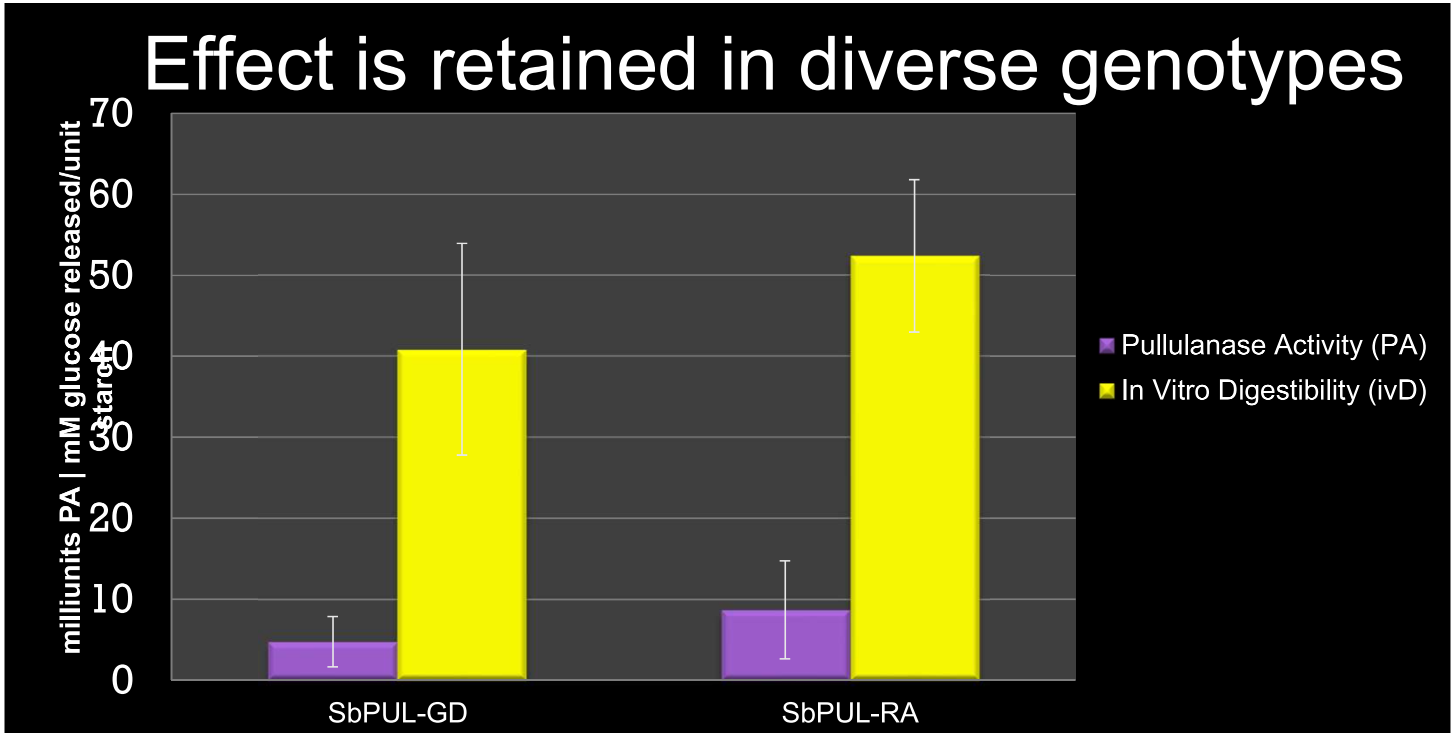
Association holds up in another population



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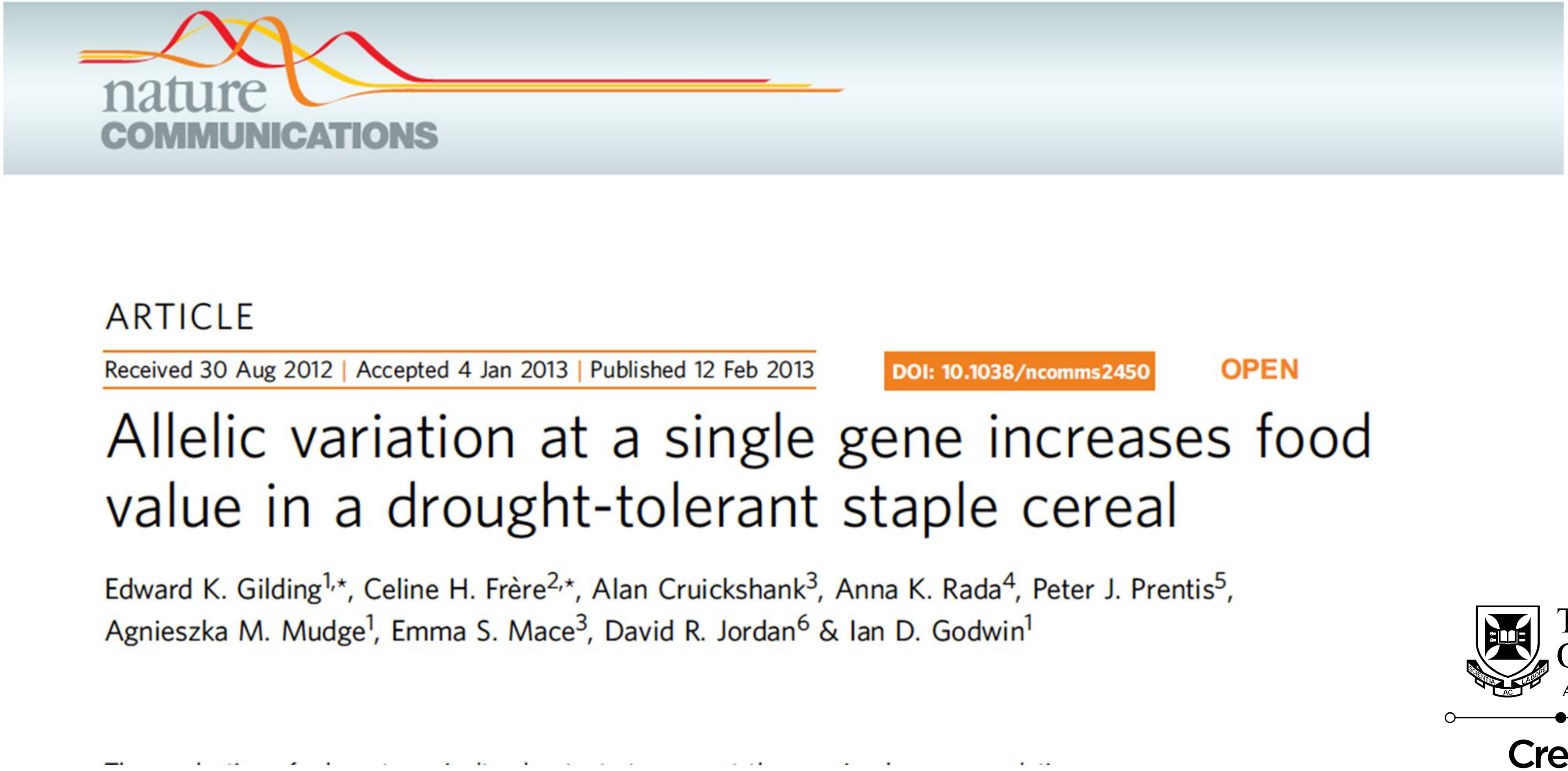
108 inbreds or landraces from Ethiopia

Starch debranching – changes starch structure



nature COMMUNICATIONS

ARTICLE

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OPEN

Allelic variation at a single gene increases food value in a drought-tolerant staple cereal

Edward K. Gilding[1,*], Celine H. Frère[2,*], Alan Cruickshank[3], Anna K. Rada[4], Peter J. Prentis[5], Agnieszka M. Mudge[1], Emma S. Mace[3], David R. Jordan[6] & Ian D. Godwin[1]

Pullulanase sorghum lines

- NILs grown in field trials under bird-netting
- Replicated poultry feeding trials in progress at Sydney University

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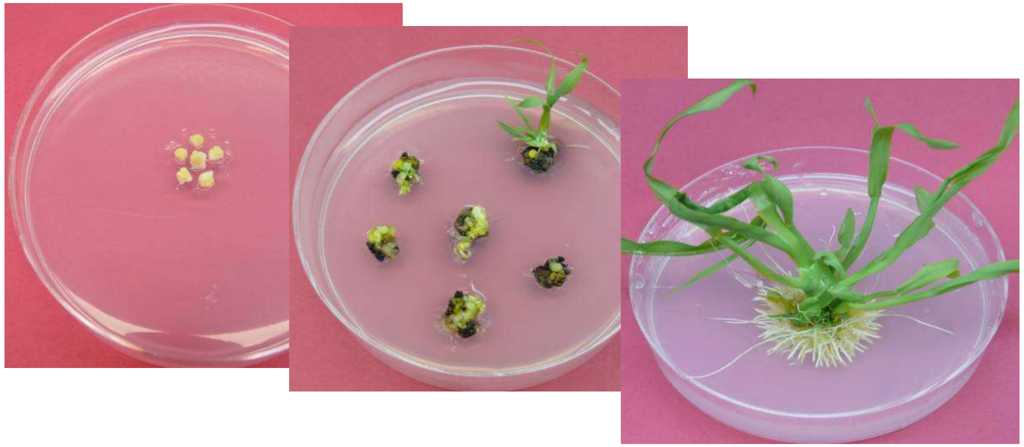
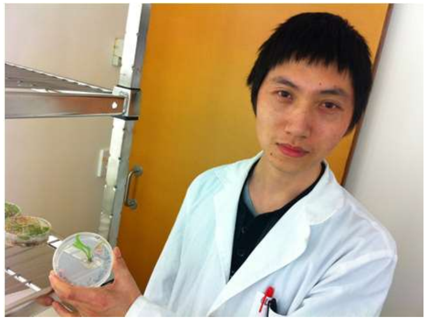
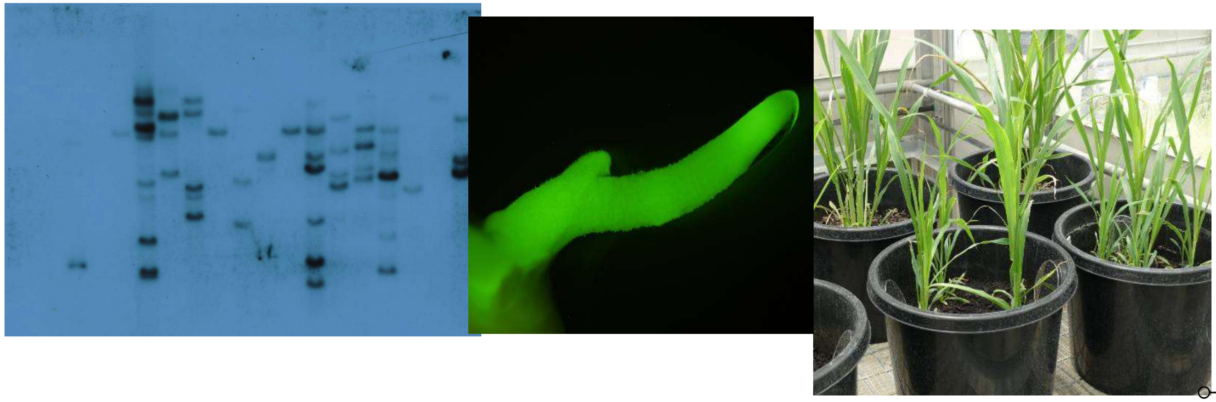
Genomics can inform Transgenic and Editing approaches

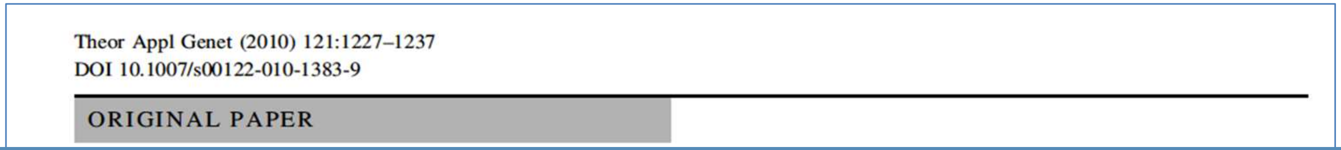




Guoquan Liu
20-25% efficiency
Liu and Godwin, 2012, Plant Cell Rep.

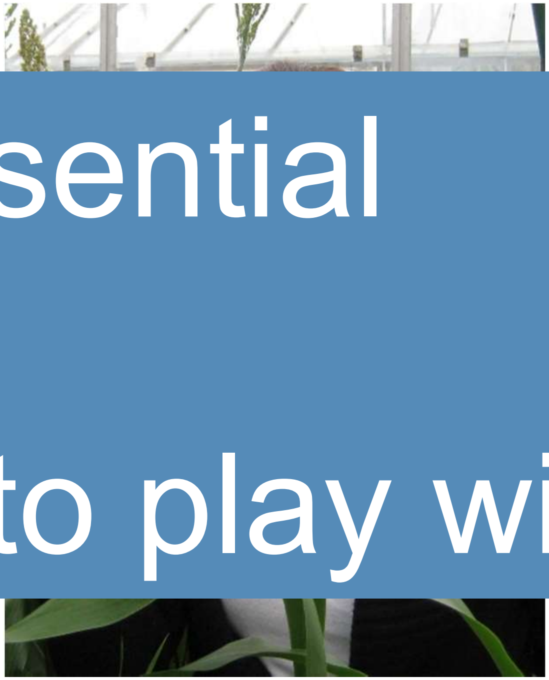


Natural β-kafirin **null mutants**



Theor Appl Genet (2010) 121:1227–1237
DOI 10.1007/s00122-010-1383-9

ORIGINAL PAPER



β-kafirin is not essential

That makes it a target to play with!

- Higher protein
- Higher digestibility
- *Ogi* porridge in West Africa

Transgenics and genome editing

Approaches to improve grain quality

BIGGER GRAIN and MORE DIGESTIBLE PROTEIN

1. Overexpress a synthetic β-kafirin (Liu et al JCS 2018)
2. Change the way proteins fold (RNAi-foldase)
3. Manipulate G-proteins associated with grain size

G protein gamma-subunits

1. Overexpression
2. RNAi silencing
3. Overexpression of truncated genes

- ❖ RNAi silencing (~50-70% downregulation) from independent transgenic events
  - ❖ GGC1 (GS3)– mean 7% increase in seed size
    - Same as the QTL in NAM
  - ❖ GGC2 – mean 7% increase in seed size
  - ❖ GGC3 (DEP1) – mean 9% increase in seed size

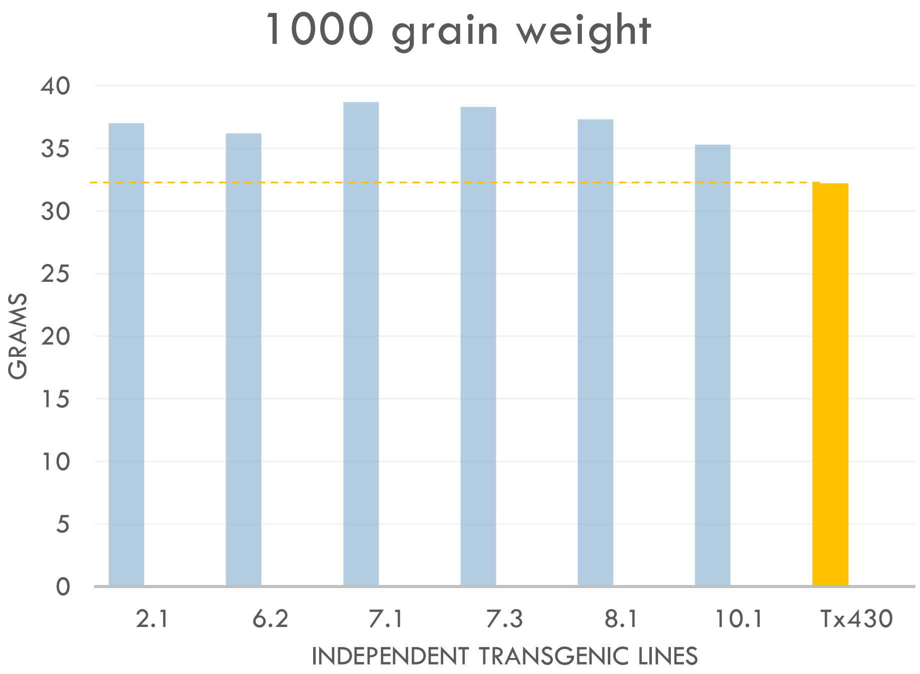
Grain size characteristics

10 seeds

RNAi GGC1 (GS3)
No reduction in grain number
9-12% increase in TKW

“Foldase RNAi lines: larger grain, higher protein

Tx430 Foldase RNAi 8.1



Field trials summer 2018

- Inbred lines

In grain fill in SE Queensland

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Gene editing in sorghum – our progress

Brown Midrib sorghum – lignin biosynthesis (rice U6 promoter)

Sorghum albinism

(rice v sorghum U6/U3 promoters)

Latest: beta-kafirin knockouts – higher protein content

Gatton campus and Research Farm 80 km from Brisbane

27 transgenic lines – 5 genes manipulated 2018

UQ + NuSeed + Qld Dept of Agriculture and Fisheries collaboration

Aims: Larger Grain or More Grain or Higher Protein?

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Some transgenic lines RNAi-GGC1 and GGC3

GGC1

GGC3

Tx430 control

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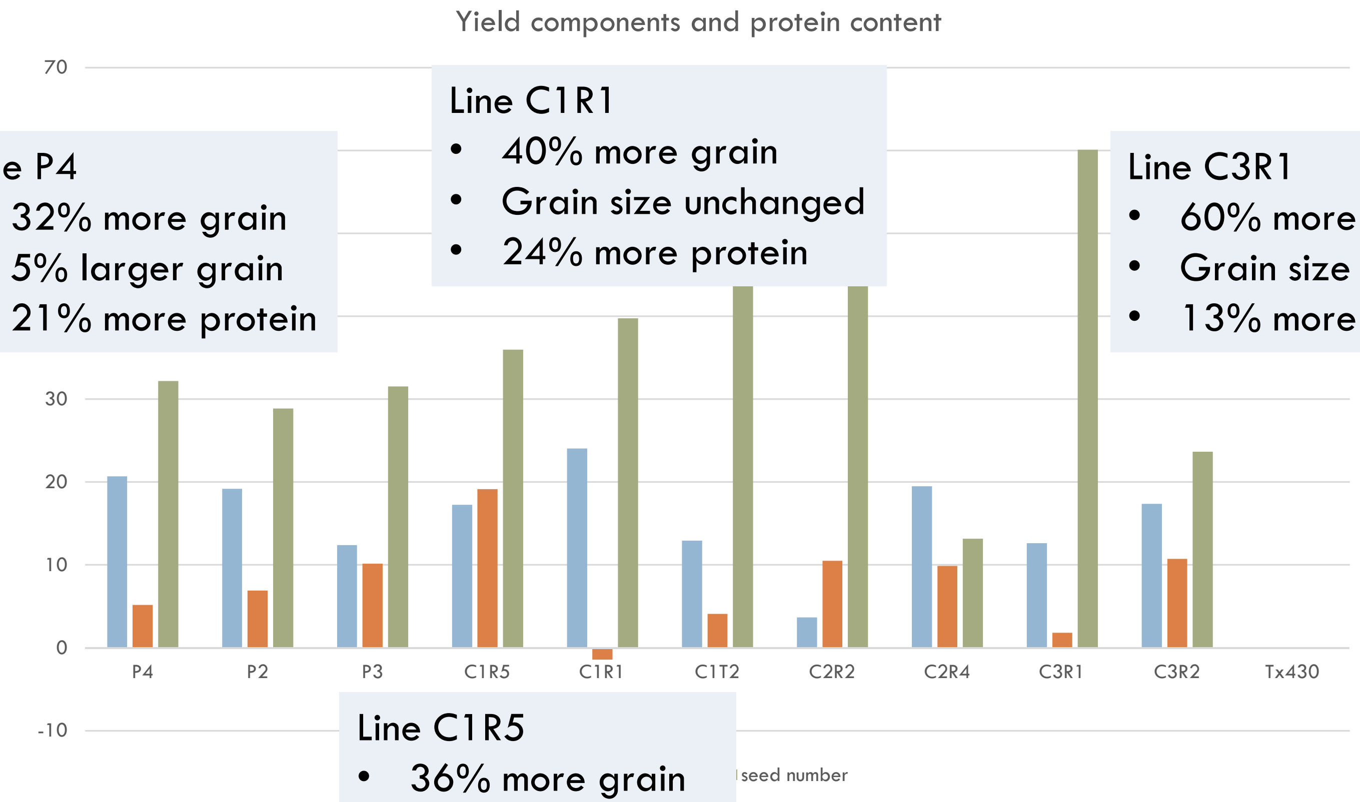
Transgenic Lines – RNAi-foldase

	P2	P4	Tx430 control
Plant height	125 cm	146 cm	119 cm

Higher Protein + all the good yield stuff!



Line P4

- 32% more grain
- 5% larger grain
- 21% more protein

Line C1R1

- 40% more grain
- Grain size unchanged
- 24% more protein

Line C3R1

- 60% more grain
- Grain size unchanged
- 13% more protein

Line C1R5

- 36% more grain
- 19% larger grain
- 17% more protein

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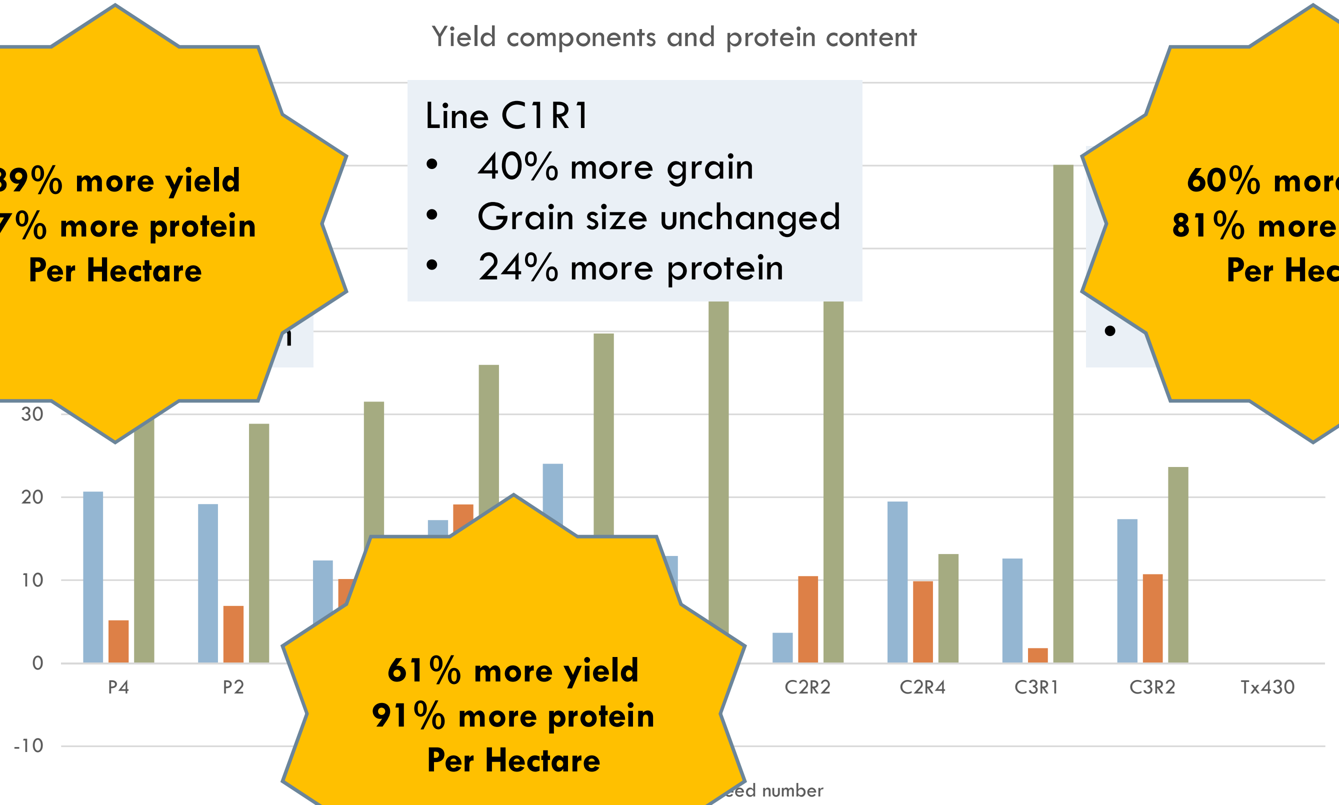
More protein per grain, more protein per hectare



Line C1R1
- 40% more grain
- Grain size unchanged
- 24% more protein

39% more yield
67% more protein
Per Hectare

60% more yield
81% more protein
Per Hectare

61% more yield
91% more protein
Per Hectare

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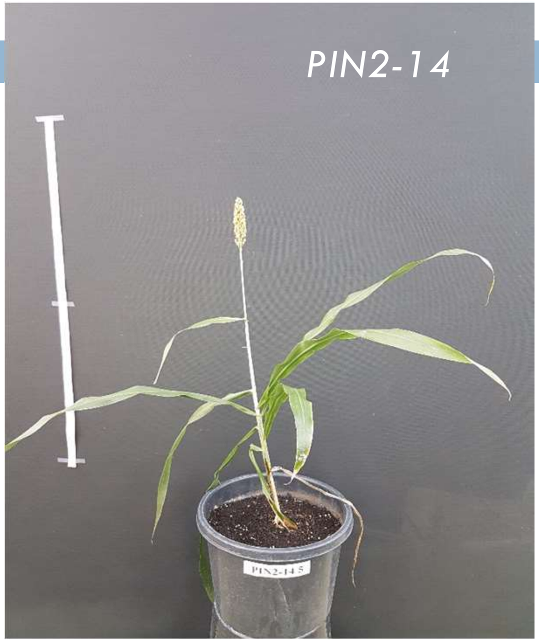
PIN gene expression and plant architecture

1. *PIN* genes
2. Plasticity
3. Pleiotropy



Small canopy

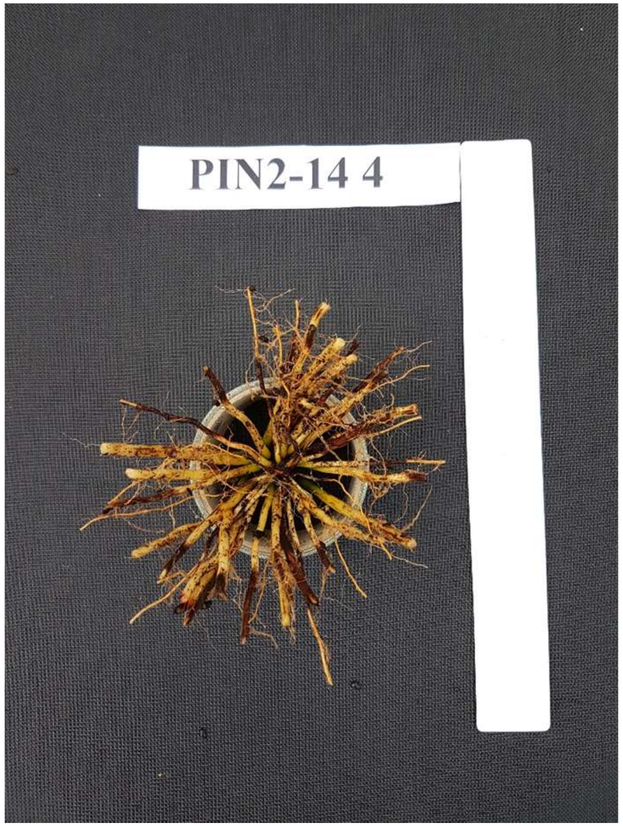
↓ expression

Large canopy

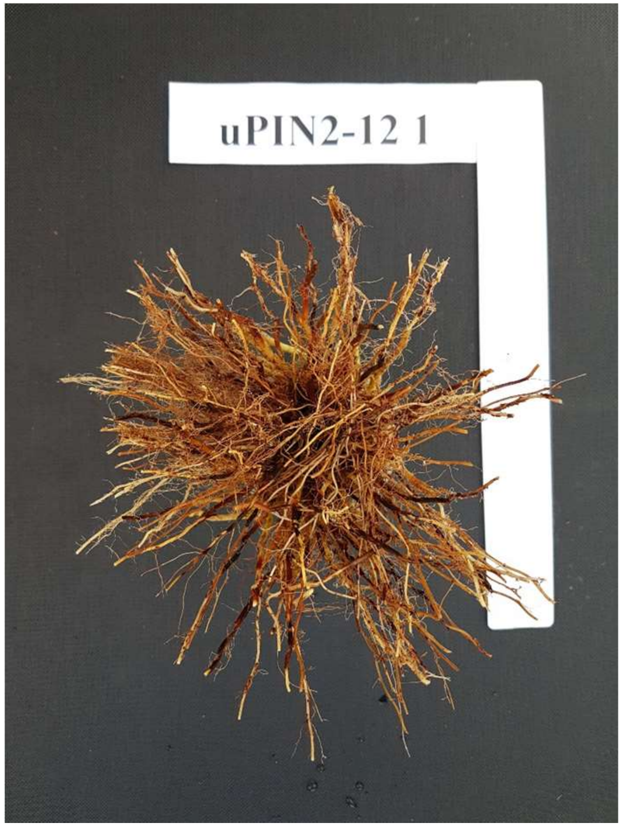
↑ expression

Andy Borrell, Guoquan Liu, Albert Wong

PIN genes confer 'nodal root number' plasticity in sorghum



Small root number



Large root number

Genomics + GM/editing + physiology ⇨ better sorghum

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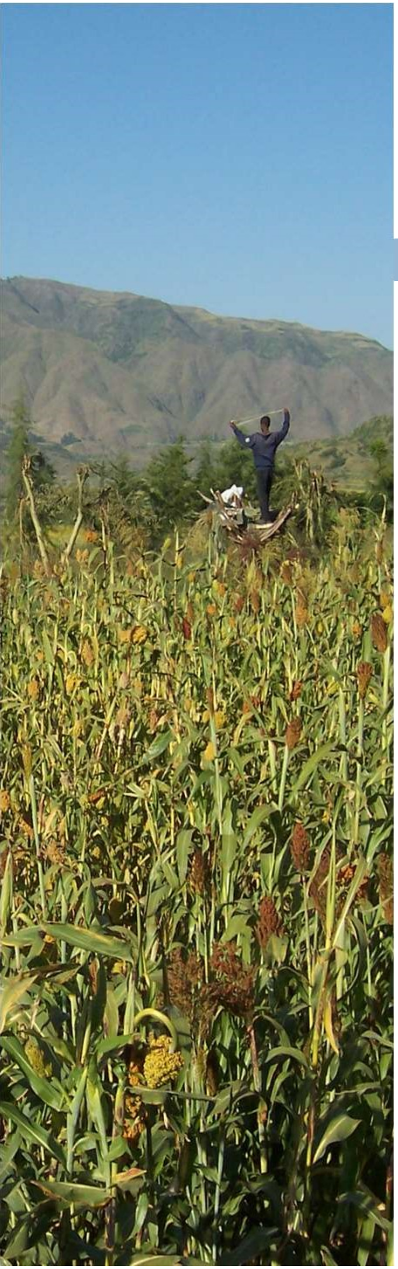

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GRDC
Grains Research & Development Corporation

nuseed

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中國科學院
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ADVANTA
Seed International