Advances in the measurement, characterisation & classification of crop development

Dr Corinne Celestina

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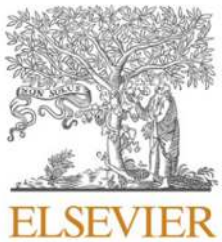

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Scales of development for wheat and barley specific to either single culms or a population of culms

Corinne Celestina [a,*,1], James Hunt [a,1], Hamish Brown [b], Neil Huth [c], Mariana Andreucci [d], Zvi Hochman [e,1], Maxwell Bloomfield [a,2], Kenton Porker [f,2], Melissa McCallum [f], Felicity Harris [g,3], Mary Matthews [g], Ben Biddulph [h], Ghazwan Al Yaseri [h], Dion Nicol [i], Jessica Hyles [j], Enli Wang [j], Bangyou Zheng [e], Zhigan Zhao [j], Michele Kohout [k]

[a] *Department of Animal Plant and Soil Sciences, La Trobe University, Bundoora, Victoria 3086, Australia*
[b] *The New Zealand Institute for Plant and Food Research Limited, Christchurch 8140, New Zealand*
[c] *CSIRO Agriculture and Food, Toowoomba, Queensland 4350, Australia*
[d] *Department of Agricultural Sciences, Lincoln University, Lincoln 7647, New Zealand*
[e] *CSIRO Agriculture and Food, St. Lucia, Queensland 4067, Australia*
[f] *Agronomy Group, Crop Sciences Research Division, South Australia Research and Development Institute, Urrbrae, South Australia 5064, Australia*
[g] *NSW Department of Primary Industries, Wagga Wagga, New South Wales 2650, Australia*
[h] *Department of Primary Industries and Regional Development, South Perth, Western Australia 6151, Australia*
[i] *Department of Primary Industries and Regional Development, Merredin, Western Australia 6415, Australia*
[j] *CSIRO Agriculture and Food, Black Mountain, Australian Capital Territory 2601, Australia*
[k] *Nature Illustrations, Ferny Creek, Victoria 3786, Australia*

Scales of development for wheat and barley

External morphology (e.g. leaves, tillering, heading, flowering, grain filling)

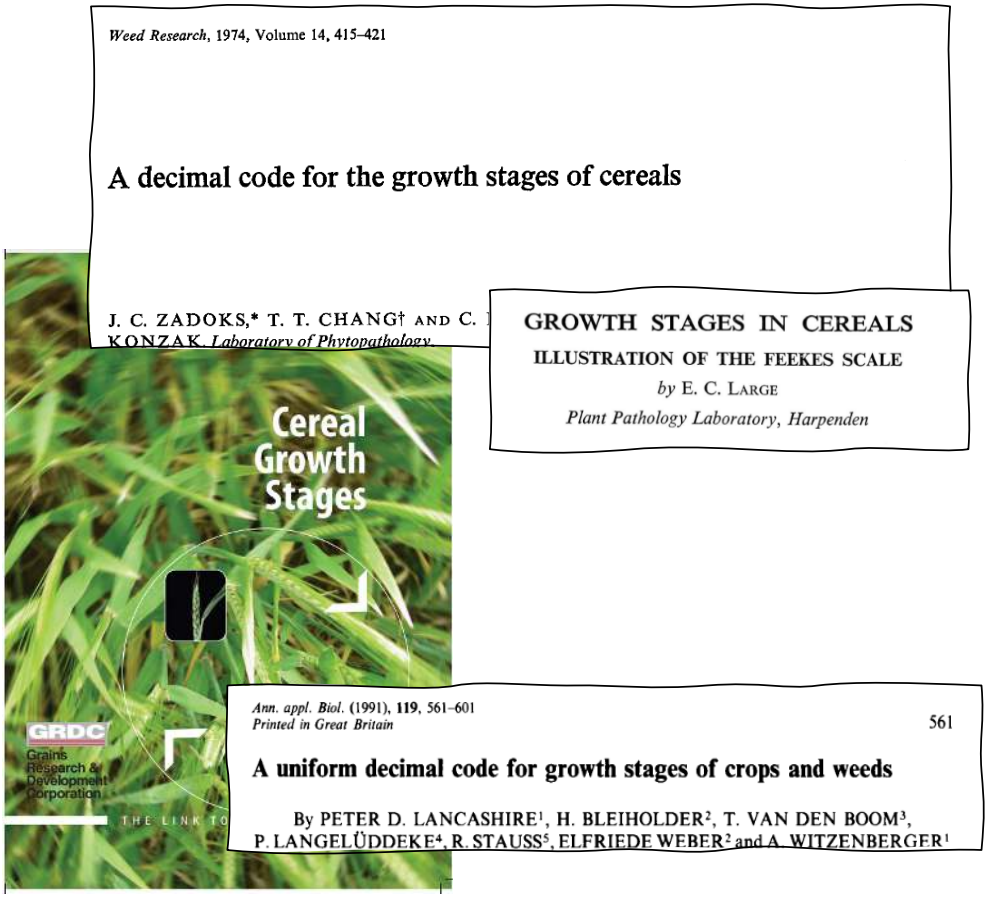
- Feekes scale for cereals (1941)
- Haun's notation system (1973)
- Zadoks decimal code for cereals (1974)
- The universal BBCH scale for crops and weeds (1991)

Internal anatomy (i.e. shoot apex)

- Waddington's scale (1983)
- Gardner's developmental stages (1985)

Limitations of existing scales

- Confusion of growth vs development, phase vs stage



Limitations of existing scales

- Confusion of growth vs development, phase vs stage
- Ambiguous, subjective and qualitative

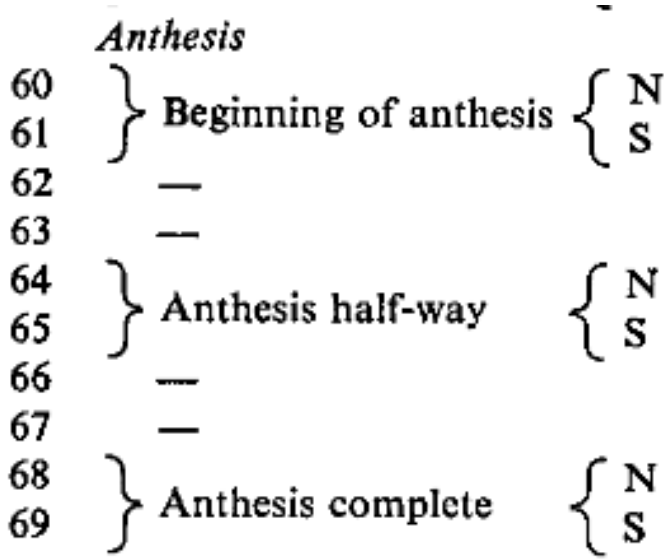
Anthesis

60	Beginning of anthesis
61	
62	—
63	—
64	Anthesis half-way
65	
66	—
67	—
68	Anthesis complete
69	

Zadoks et al (1974) Weed Research 14, 415-421.

Limitations of existing scales

- Confusion of growth vs development, phase vs stage
- Ambiguous, subjective and qualitative
- Don’t apply to both single plants and populations



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- Confusion of growth vs development, phase vs stage
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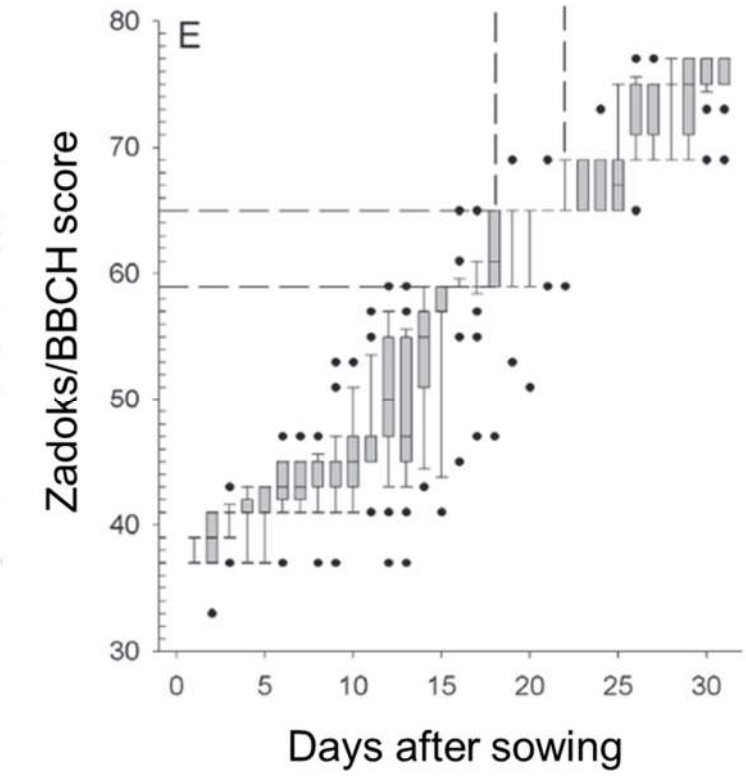
- Don’t apply to both single plants and populations
- Don’t cover entire crop life cycle

Slafer et al 2021. Chapter 3 Wheat. Crop Physiology. P99-163.

Limitations of existing scales

- Confusion of growth vs development, phase vs stage
- Ambiguous, subjective and qualitative
- Don’t apply to both single plants and populations
- Don’t cover entire crop life cycle
- Numerical scores analysed incorrectly



Barber et al (2015) Annals of Applied Biology 166, 355–371.

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- Don’t cover entire crop life cycle
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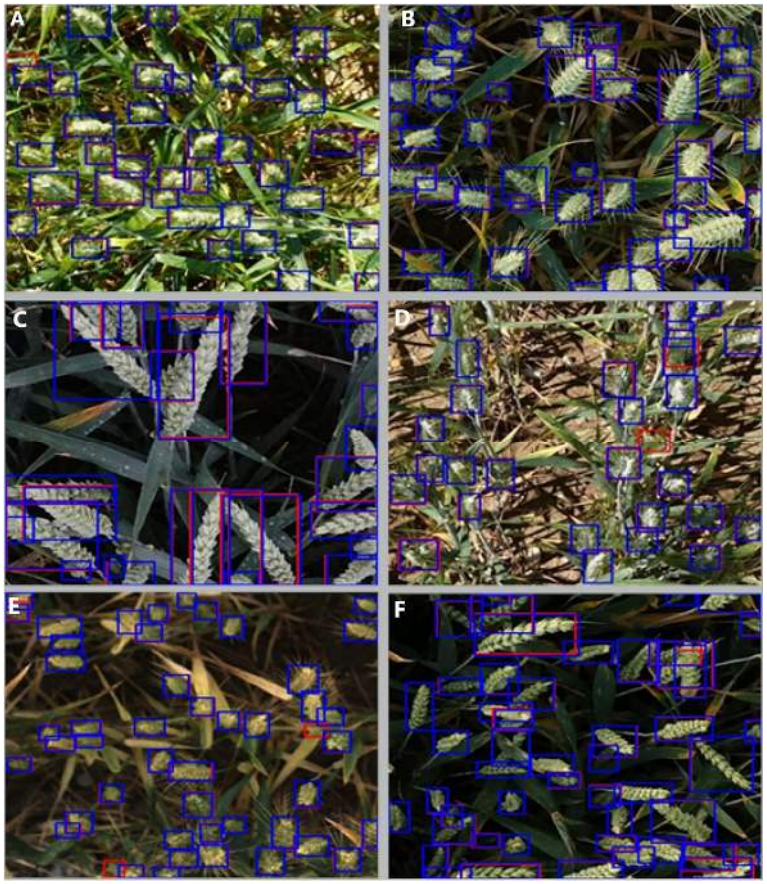
- Not compatible with modern technologies



Okafor et al (2024) Canadian Journal of Remote Sensing 50, a2367479.

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☒ **Repeatable**
Same operator
Same environment

☒ **Reproducible**
Different operator
Different environment

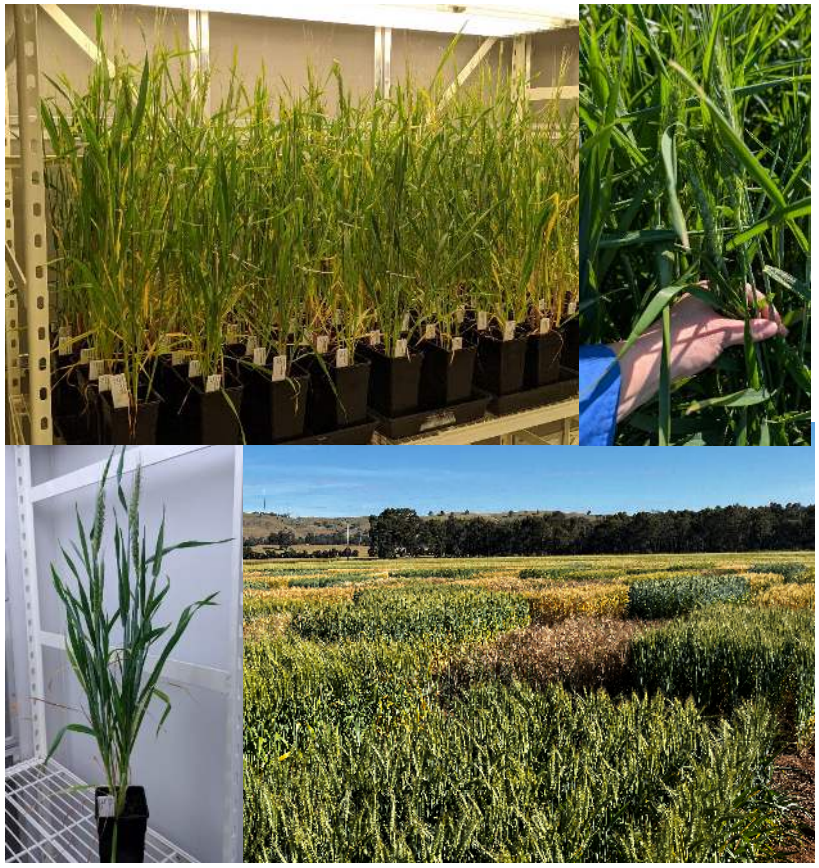
New scales of development for wheat and barley

Single culm development scale (SCDS)

- Primary culm of single plant
- One point in time
- “What stage is my crop today?”

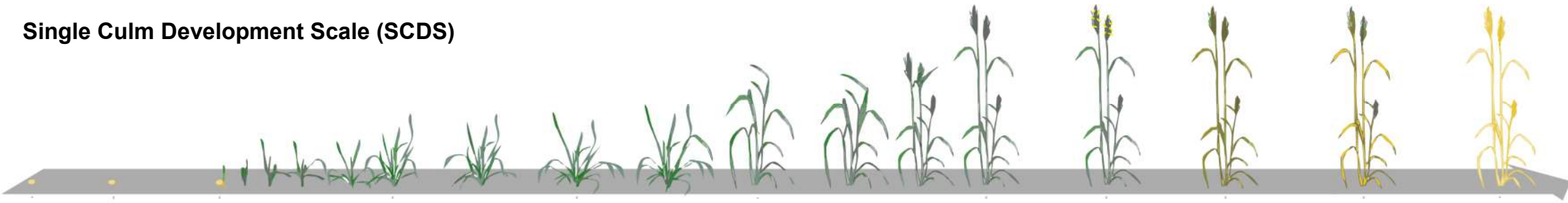
Population of culms development scale (PCDS)

- All culms of all plants
- Multiple observations over time
- “When was [stage]? How long was [phase]?”



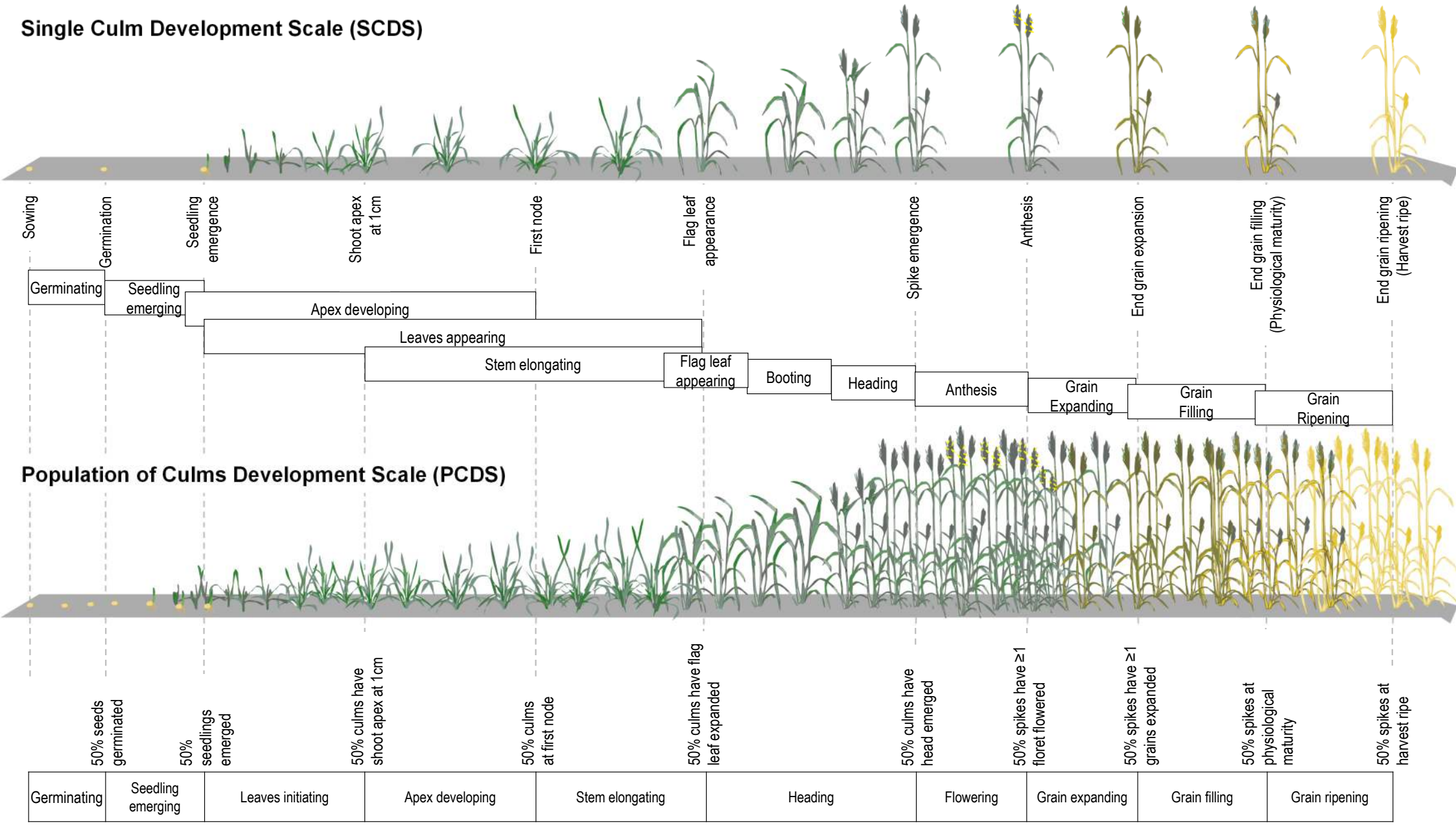
Celestina et al (2023) Eur. J. Agron. 147, 126824.

Single Culm Development Scale (SCDS)



Sowing
Germination
Seedling emergence
Shoot apex at 1cm
First node
Flag leaf appearance
Spike emergence
Anthesis
End grain expansion
End grain filling (Physiological maturity)
End grain ripening (Harvest ripe)

Germinating
Seedling emerging
Apex developing
Leaves appearing
Stem elongating
Flag leaf appearing
Booting
Heading
Anthesis
Grain Expanding
Grain Filling
Grain Ripening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Leaves appearing
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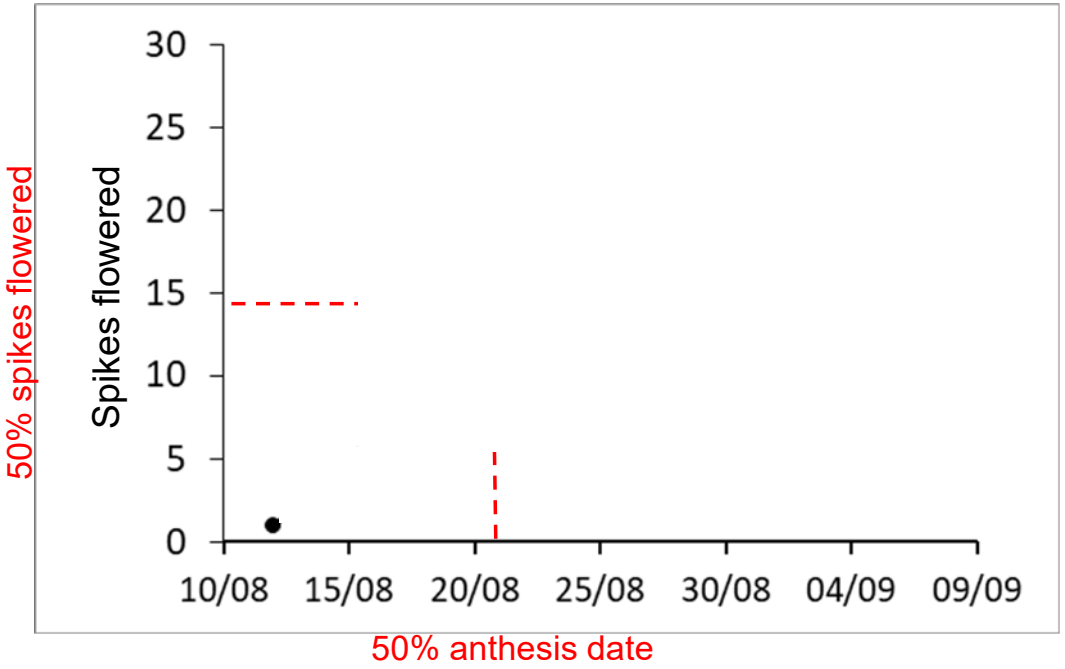
Heading
Anthesis
Grain Expanding
Grain Filling
Grain Ripening
Population of Culms Development Scale (PCDS)
50% seeds germinated
50% seedlings emerged
50% culms have shoot apex at 1cm
50% culms at first node
50% culms have flag leaf expanded
50% culms have head emerged
50% spikes have ≥1 floret flowered
50% spikes have ≥1 grains expanded
50% spikes at physiological maturity
50% spikes at harvest ripe
Germinating
Seedling emerging
Leaves initiating
Apex developing
Stem elongating
Heading
Flowering
Grain expanding
Grain filling
Grain ripening

Single culm development scale (SCDS)

Code	Description	Detailed remarks
Anthesis (A)		
A10	10% anthesis	10% of florets proximal to the rachis on the spike have flowered.
…		
A50	50% anthesis	50% of florets proximal to the rachis on the spike have flowered.
…		
A100	100% anthesis	Anthesis complete. All florets proximal to the rachis on the spike have flowered.

Population of culms development scale (PCDS)



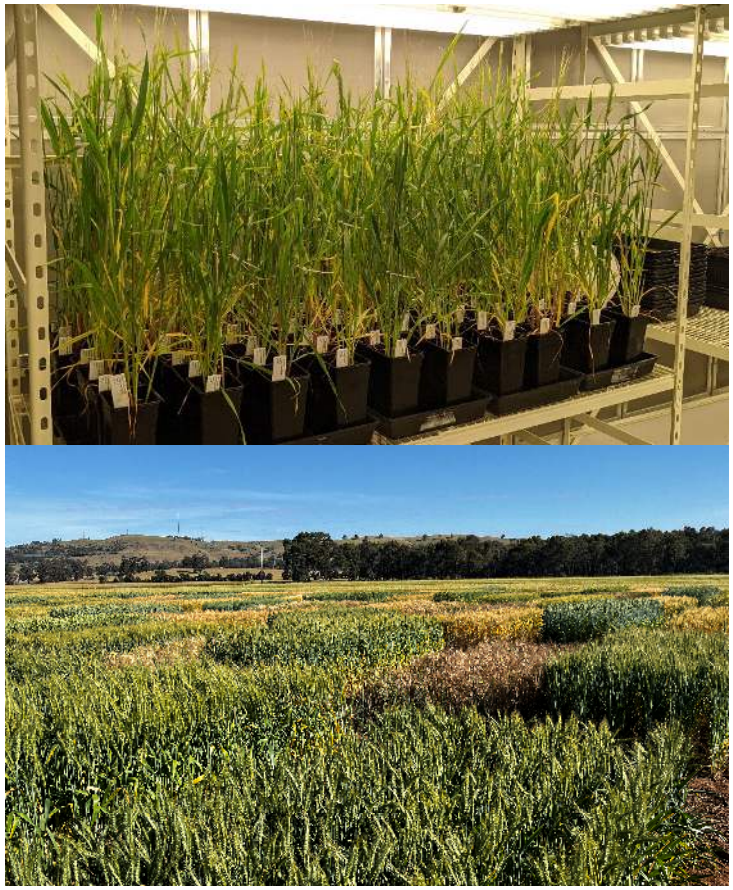
Anthesis = ≥1 florets proximal to the rachis on the spike have flowered

Applications of the new scales

1. Improved simulation of phenology in APSIM-NG

GRDC National Phenology Initiative

- 64 wheat + 32 barley
- Controlled environment experiments for cultivar parameters
  - 2 photoperiod × 2 vernalisation
- Field experiments for validation data
  - 4 sites × 8 times of sowing × 2 years



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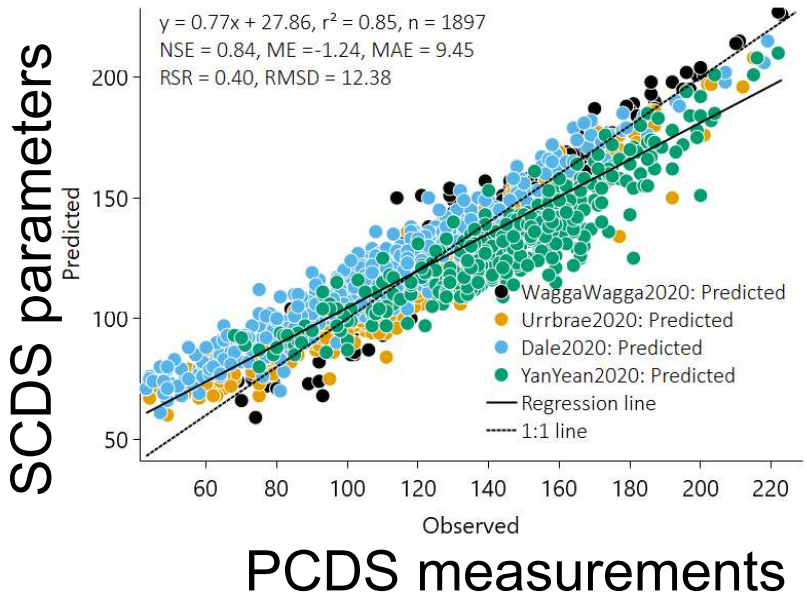

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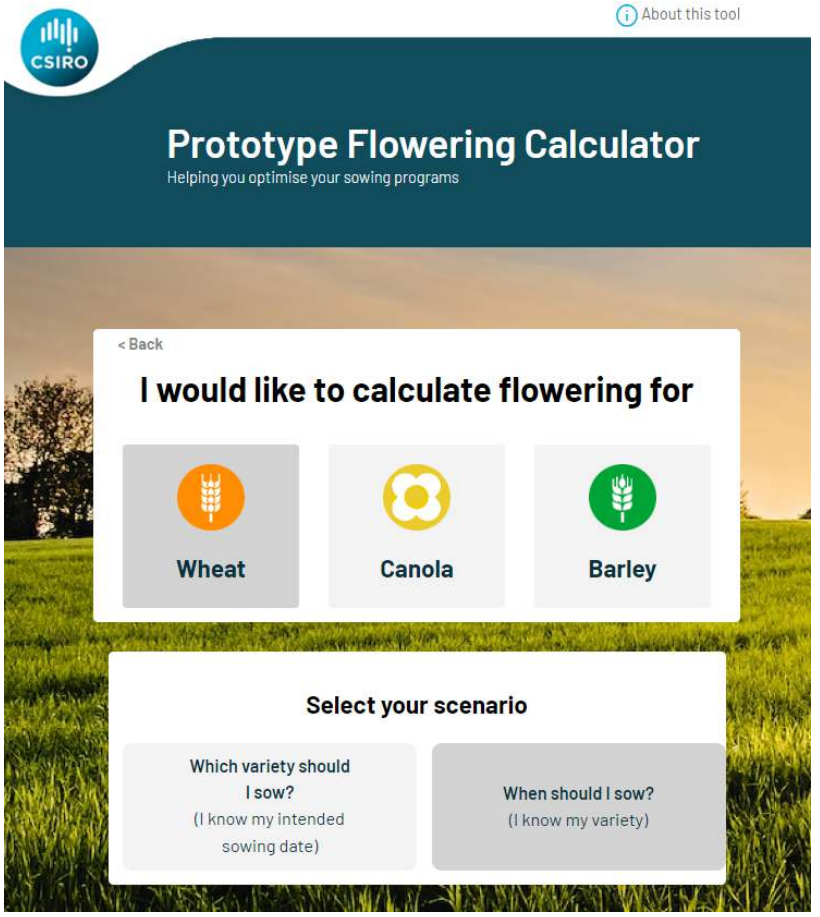
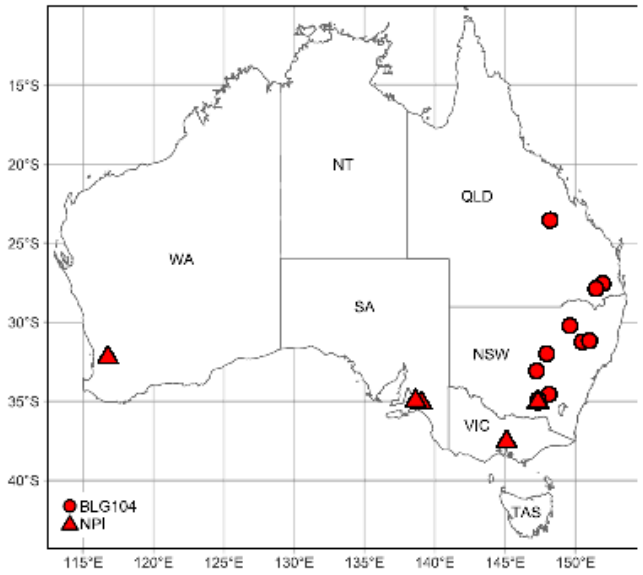


Applications of the new scales

2. New phenology (‘maturity’) classification scheme

- Data from multiple GRDC investments
- National G × E × M field experiments
- 70 wheat + 30 barley



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[c] NSW Department of Primary Industries, Wagga Wagga, New South Wales 2650, Australia
[d] Crop Sciences, Agronomy Program, South Australia Research and Development Institute, Urrbrae, South Australia 5064, Australia
[e] Department of Primary Industries and Regional Development, South Perth, Western Australia 6151, Australia
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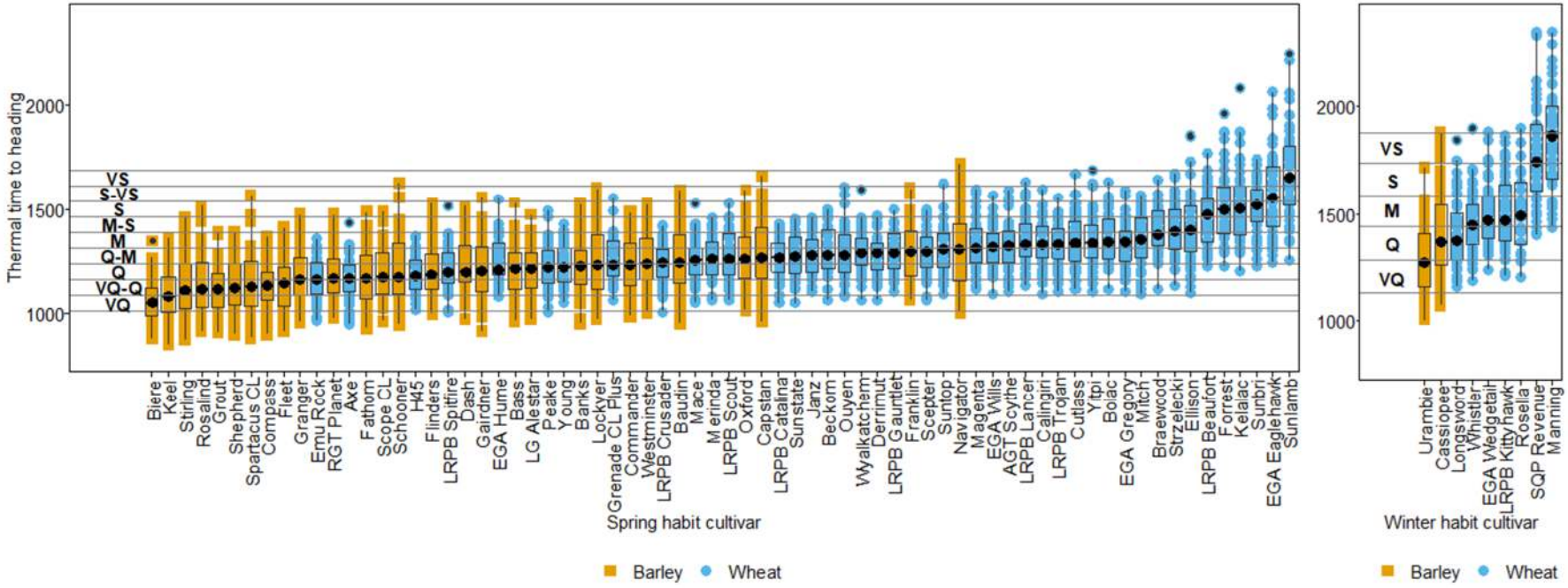

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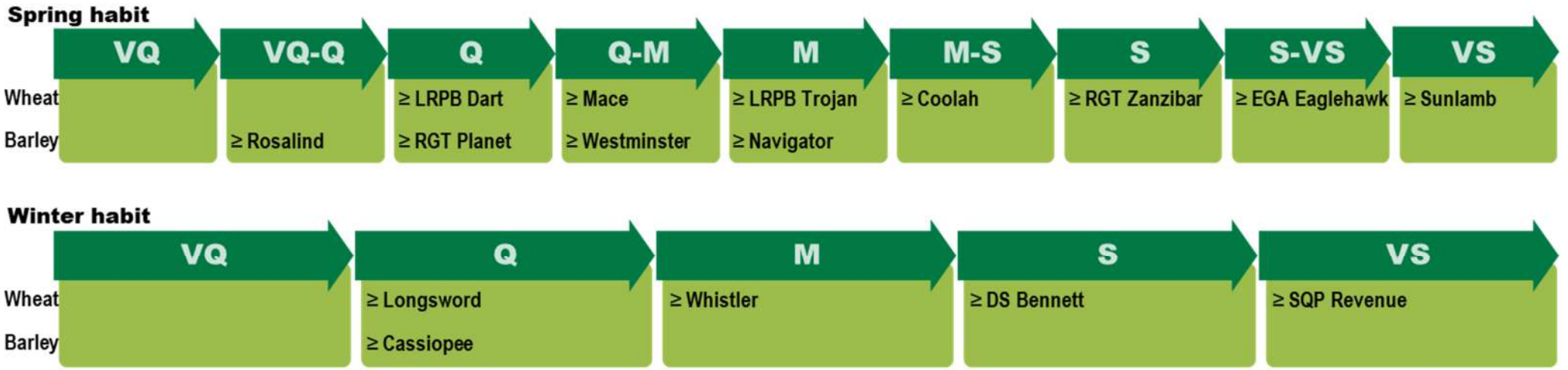

Thank you

Dr Corinne Celestina
corinne.celestina@unimelb.edu.au

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