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Optimising management strategies to reduce losses from fusarium crown rot in Australian Prime Hard and durum wheats

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Key findings

- Yield loss from Fusarium crown rot (FCR) across all entries averaged 15.1% (0.74 t/ha) under dryland conditions, but was only 6.4% (0.35 t/ha) when moisture stress was reduced during grain filling within the rainfall simulation treatment (supplementary irrigation).
- High residual soil nitrogen (N) levels, accumulated from mineralisation under extended drought conditions, limited N management interactions in 2020 at each site.
- Fusarium crown rot infection caused significant reductions in grain protein (GP) concentrations, between 0.3% and 0.6% units in some varieties, mainly under dryland conditions.
- The combined effect of FCR infection on reducing yield and grain protein led to reductions in grain N removal rates in all varieties of between 10% and 24% (14–30 kg N/ha) under dryland conditions and 4–10% (8–16 kg N/ha) under rainfall simulation.
- Variety selection is one of the key management strategies growers can use to maximise yield and grain quality in the presence of FCR infection.

Introduction

In northern NSW, bread and durum wheat provide the opportunity to produce a high quality, high protein grain (Australian Prime Hard (APH) or Australian Durum Wheat (ADR)), which attracts a price premium. However, this generally requires higher levels of N input to attain the 13–14% protein grade requirement. This relies on applying artificial N, commonly urea, and represents around 30–40% of input costs. Crop production in northern NSW is characterised by summer dominant rainfall and high water holding capacity vertosol soils, especially when moving from the higher rainfall in the eastern areas to drier areas in the west.

Growers that adopt conservation agriculture (CA) practices, such as no-till with stubble retention to optimise stored soil water, have revolutionised crop production and crop reliability, particularly in north-western NSW.

Unfortunately, there is always a compromise. With the adoption of CA, there has been an increased incidence of the stubble-borne pathogen *Fusarium pseudograminearum*, which causes FCR disease (Simpfendorfer et al. 2019). Fusarium crown rot is a basal infection in winter cereals that restricts water flow from the roots to the heads under moisture and/or temperature stress during grain-fill (Figure 1). This results in the formation of the distinctive 'whiteheads' that are associated with yield loss and reduced grain size, which in turn increases screening levels at harvest (Alahmad et al. 2018) (Figure 2). Increasing rates of N application (urea) at sowing can increase this incidence and the yield and quality losses associated with FCR (Simpfendorfer 2020).

Figure 1 Basal browning from FCR in Hellfire[Ⓟ] wheat, 2021.

Consequently, producing APH and ADR wheat in northern NSW under dryland conditions has an inherently high risk given the level of climatic variability within and between seasons. This balance between risk versus reward is frustrating for growers when harvested grain fails to meet quality specifications in terms of low protein and high screenings (>5%).

Quantitative data on the percentage of grain receivals meeting APH or ADR in northern NSW is not freely available. National Variety Trial (NVT) analysis from 2014–2018 indicates only 25% are achieving APH and 49% ADR. This is supported by estimates from GrainCorp (pers. comm.). The majority of farmers are struggling to get the balance right as maximum yield might not necessarily equate to optimum nitrogen use efficiency (NUE), water-use efficiency (WUE) or profitability.

Research is required to optimise management of dryland durum/APH wheat crops to ensure maximum quality grain profitability under varying scenarios of:

- starting soil water
- variety choice
- risk of FCR
- nitrogen management
- yield potential (in-crop rainfall).

The project findings will underpin an improved matrix of decision support options (pre-crop and in-crop), to minimise the risk and maximise the profitability of producing premium APH and ADR wheat more reliably in northern NSW.

Figure 2 Whiteheads in wheat from fusarium crown rot; image by CSIRO.

Experiment design

Location

Three replicated field experiments were conducted in northern NSW in 2020; all sites had supplementary irrigation capacity to implement rainfall simulation treatments:

- Liverpool Plains Research Station, Breeza: Latitude 31°10'505"S, Longitude 150°25'296"E
- Australian Cotton Research Institute, Narrabri: Latitude 30°12'198"S, Longitude 149°35'589"E
- NSW DPI lease block, Piallamore: Latitude 31°10'1165"S, Longitude 151°03'351"E.

Treatments

- Fully factorial design, three replicates, blocked for in-crop simulated rainfall treatments, randomised design within blocks (288 plots/field site).
- Varieties:
    - three APH bread wheat varieties (LongReach Lancer$^{\phi}$, LongReach Hellfire$^{\phi}$ and Suntop$^{\phi}$)
    - three durum varieties (DBA Lillaroi$^{\phi}$, DBA Aurora$^{\phi}$ and DBA Jandaroi$^{\phi}$).
- Two levels of FCR infection:
    - nil
    - 1.5 g/m row of inoculum applied at sowing to create a moderate level of disease.
- Two target yield potentials:
    - decile 5 (D5) of 5.0 t/ha
    - decile 9 (D9) of 8.0 t/ha seasons.
- Two N application strategies: N budgeted application rates to achieve D5 or D9 yield potential:
    - 100% applied at sowing
    - split 50:50 between sowing and an in-crop application at GS39.
- Two rainfall scenarios:

Crop protection

- in season rainfall
- a simulated higher rainfall with 75 mm of supplementary irrigation at GS39 and GS61.

Measurements

A range of detailed measurements were collected at each site and each plot including:

- segmented soil water and nutrition testing (including N) at 0–30 cm, 30–60 cm, 60–90 cm and 90–120 cm depths at sowing and harvest
- plant emergence counts: 3–4 weeks after sowing
- soil water use: throughout the season using neutron probes (0–120 cm)
- agronomic evaluation: NUE, WUE, biomass accumulation/tiller and head number at physiological maturity, grain yield and harvest index
- pathology assessment: incidence and severity of FCR infection at harvest, based on visually rating the extent of browning in tiller bases and recovery of the causal fungus on laboratory media
- grain quality evaluation: screenings (<2.0 mm), grain protein concentration, 1000 grain weight, test weight, moisture and falling number
- grain N removal (kg/ha), calculated as yield × protein × 1.75.

Results

The predicted, wetter than average La Nina conditions throughout 2020 did not eventuate. Rainfall at Narrabri was 24% lower, Breeza 10% lower and Piallamore 21% lower than the long-term average (LTA) for these locations during the growing season (Table 1).

High residual N levels at the three sites (204 kgN/ha Narrabri, 129 kgN/ha Breeza and 196 kgN/ha Piallamore at 0–120 cm) limited the effect of the N management treatments in 2020, with no significant difference in yield or screening levels evident in the across site analysis. The N management strategy slightly increased grain protein levels from 14.9% in the D5 to 15.2% in the D9 treatment.

FCR infection had significant effects on grain yield, screenings, grain protein and grain N removal. This differed by variety and seasonal conditions (Table 2).

Rainfall simulation in 2020 (75 mm of supplementary irrigation at GS39 and GS61) established the benefit versus cost of varying production strategies if the predicted La Nina conditions had occurred compared with the lower, actual rainfall in winter and early spring (dryland) 2020, both in the presence and absence of FCR infection.

Table 1 Seasonal rainfall (mm) at experiment sites in 2020 and long-term average (LTA) (data from nearest BOM site).

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Narrabri	43.6	218.4	114.8	52.6	18.0	27.4	38.0	26.0	28.6	108.8	2.0
LTA	72.8	59.9	50.6	34.5	38.7	39.3	38.2	32.0	32.9	48.4	51.0
Breeza	63.4	156.6	79.4	43.3	54.8	31.4	44.6	28.9	26.2	120.4	5.6
LTA	84.6	69.3	42.9	35.4	44.2	41.9	43.7	34.6	42.6	52.3	64.6
Piallamore	57.8	146.6	59.4	52.2	45.4	39.6	48.4	38.4	26.8	141.2	6.8
LTA	92.2	69.7	50.4	39.2	47.9	49.1	52.7	48.2	53.4	64.8	79.1

FCR infection effects on yield

- Yield loss from FCR was highest for the dryland treatment (averaged 18.9% at Narrabri, 18.4% at Piallamore and 8.3% at Breeza).
- The rainfall simulation treatment reduced the extent of yield loss from FCR, averaging 3.8% at Piallamore, 6.4% at Breeza and 7.6% at Narrabri.

All further data is discussed in the context of an across site analysis of the three field experiments conducted in 2020.

Yield loss was higher under dryland conditions, ranging from 6.8% (0.32 t/ha) in the APH bread wheat LongReach Hellfire⁽ᵖ⁾ up to 21.8% (0.88 t/ha) for the durum DBA Jandaroi⁽ᵖ⁾ (Table 2).

Yield loss was considerably reduced in the rainfall simulation treatment and ranged from not significant for DBA Aurora⁽ᵖ⁾, up to 9.5% (0.41 t/ha) for the durum DBA Jandaroi⁽ᵖ⁾ (Table 2).

Yield loss calculations can hide actual yield values. The rainfall simulation treatment provided a yield benefit of between 0.28 t/ha (DBA Jandaroi⁽ᵖ⁾) to 1.51 t/ha (Suntop⁽ᵖ⁾) over the dryland treatment in the absence of FCR infection. This benefit was even higher in the presence of FCR infection and ranged from 0.70 t/ha (DBA Lillaroi⁽ᵖ⁾) up to 1.78 t/ha (DBA Aurora⁽ᵖ⁾). LongReach Lancer⁽ᵖ⁾ and Suntop⁽ᵖ⁾ were 0.56 t/ha to 1.69 t/ha higher yielding than the other varieties in the presence of FCR infection under dryland conditions.

Under rainfall simulation, Suntop⁽ᵖ⁾ remained the highest yielding variety in the presence of FCR infection providing a benefit of between 0.55 t/ha to 2.64 t/ha over the other varieties (Table 2).

Table 2 Effect of fusarium crown rot infection on yield, screenings, grain protein and grain nitrogen removal in durum and bread wheat varieties under two seasonal conditions (average three sites in northern NSW in 2020).

Season	Variety	Yield (t/ha)		Screening (%)		Protein (%)		Grain N removal (kg/ha)	
		Minus FCR	Plus FCR	Minus FCR	Plus FCR	Minus FCR	Plus FCR	Minus FCR	Plus FCR
Dryland	DBA Aurora	4.94	3.94	4.5	5.3	14.8	14.5	141	111
	DBA Lillaroi	4.49	3.89	3.1	3.7	16.6	16.0	142	119
	Jandaroi	4.06	3.18	2.1	3.7	16.8	16.3	130	100
	LongReach Hellfire	4.63	4.31	4.7	4.5	15.9	15.4	143	129
	LongReach Lancer	5.72	4.82	3.7	4.3	14.0	13.9	155	131
	Suntop	5.58	4.87	5.1	5.6	13.2	13.2	144	125
Rainfall simulation	DBA Aurora	5.84	5.72	3.7	4.0	15.1	14.7	173	165
	DBA Lillaroi	5.06	4.59	3.4	3.4	16.7	16.6	166	150
	Jandaroi	4.35	3.93	2.1	2.3	16.9	17.1	145	132
	LongReach Hellfire	5.32	5.07	3.9	4.1	15.6	15.2	166	153
	LongReach Lancer	6.37	6.02	3.6	3.7	13.9	13.8	176	166
	Suntop	7.08	6.57	3.7	3.9	12.6	12.6	177	165
l.s.d. ($P = 0.05$)		0.258		0.43		0.29		6.8	

Effects of FCR infection on grain quality

- Fusarium crown rot infection increased screening levels by 0.5 (Suntop⁽ᵖ⁾) to 1.6% units (DBA Jandaroi⁽ᵖ⁾) under dryland conditions, apart from LongReach Hellfire⁽ᵖ⁾.
- Under simulated rainfall, FCR did not significantly increase screening levels in any of the varieties (Table 2).
- Only DBA Aurora⁽ᵖ⁾ (+ FCR) and Suntop⁽ᵖ⁾ (± FCR infection) had screening levels above the minimum receival standard of >5% under dryland conditions.
- Except for LongReach Hellfire⁽ᵖ⁾, FCR infection increased screening levels in all entries by from 0.5 (Suntop⁽ᵖ⁾) to 1.6% units (Jandaroi⁽ᵖ⁾) under dryland conditions only (Table 2).
- Neither LongReach Lancer⁽ᵖ⁾ and Suntop⁽ᵖ⁾ had reduced grain protein under dryland conditions.
- In DBA Aurora⁽ᵖ⁾ and LongReach Hellfire⁽ᵖ⁾, fusarium crown rot infection reduced grain protein concentrations by 0.4% under simulated rainfall (Table 2).

Effects of FCR infection on grain N removal

- Fusarium crown rot infection reduced grain N removal in all varieties for dryland and simulated rainfall treatments.

- FCR infection significantly reduced grain N removal. In LongReach Hellfire$^{\Phi}$, this was 10% (14 kg N/ha) and up to 24% (30 kg N/ha) in DBA Jandaroi$^{\Phi}$ under dryland conditions (Table 2).
- The effect of FCR infection was reduced under simulated rainfall and ranged from 4% (8 kg N/ha) for DBA Aurora$^{\Phi}$ up to 10% (16 N kg/ha) in DBA Lillaroi$^{\Phi}$ (Table 2).

Conclusions

Although varietal selection is one of the key management strategies to maximise yield in the presence of FCR infection, it must not come at the cost of yield potential in the absence of this disease. LongReach Hellfire$^{\Phi}$ for example, despite exhibiting the lowest yield loss from FCR infection (6.8%) under dryland conditions was still 0.51 t/ha to 0.56 t/ha lower yielding than LongReach Lancer$^{\Phi}$ and Suntop$^{\Phi}$ respectively. Similarly, although Suntop$^{\Phi}$ was generally the highest yielding APH variety, LongReach Lancer$^{\Phi}$ had superior grain quality with lower screenings and higher grain protein concentrations. Our results also underlined the susceptibility of durum varieties in the presence of FCR, particularly under dryland conditions.

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