Stubble trouble: mapping Fusarium crown rot survival under different cereal stubble management scenarios

Toni Petronaitis[1, 2*], Clayton Forknall[3], Steven Simpfendorfer[1] and David Backhouse[2]

[1] NSW Department of Primary Industries, Tamworth, NSW, Email: toni.petronaitis@dpi.nsw.gov.au
[2] University of New England, Armidale, NSW
[3] Department of Agriculture and Fisheries, Leslie Research Facility, Toowoomba, Qld

Abstract
The adoption of stripper-front headers, light tillage and rotations with shorter-stature break crops is increasing in northern New South Wales cropping systems. The effect of these practices on survival of Fusarium crown rot inoculum in cereal stubble is unknown but may impact future disease risks. Field experiments at Narrabri and Breeza in NSW examined whether reducing the harvest-height of a cereal crop infected with Fusarium crown rot (*Fusarium pseudograminearum, Fp*) limits post-harvest pathogen colonisation. Pathogen survival was assessed within standing cereal stubble during a chickpea break crop in 2020. *Fp* was recovered higher within stems in tall and medium harvest-height treatments in May 2020 compared to harvest levels in 2019. This confirms that wet fallow conditions allow *Fp* to saprophytically colonise cereal stubble and shortening harvest-heights could limit this inoculum production. Performance and disease levels in a successive wheat crop is required to verify potential benefits of this practise.

Keywords
Disease management, crop rotation, Kelly-chain, stubble-borne disease, durum wheat

Introduction
Despite continuous research and the development of crop protection strategies, the impacts of Fusarium crown rot (FCR), caused by the fungus *Fusarium pseudograminearum* (*Fp*), have increased in Australia over the past four decades. This increase has been associated with the adoption of conservation-agriculture practices such as cereal stubble retention, which help to offset the risk of low in-crop rainfall but promote the carry-over of *Fp* inoculum to successive cereal crops (Simpfendorfer et al. 2019). Despite the yield penalties associated with FCR, the benefits of cereal stubble retention on soil structure, moisture and fertility in the northern grains region (northern New South Wales and Queensland) are considered a necessity. Finding ways to limit the negative effects of disease whilst retaining cereal stubble is therefore essential.

Although disease management strategies such as inter-row sowing can reduce the impact of FCR on production systems, cereal cropping practises are continually evolving. Adoption of higher harvest-heights (i.e. stripper-fronts), light tillage (i.e. Kelly-chaining) and rotations with shorter stature break crops (e.g. chickpea, *Cicer arietinum*) are becoming common in the northern grains region. Stripper front harvesting systems improve harvest efficiency through the rapid “stripping” of heads during harvest but also increases retained stubble biomass by increasing standing stubble height i.e., ~50-60 cm compared to ~30 cm with combine harvester. It is unknown how such an increase in vertical cereal stubble will affect the survival and/or growth of *Fp*.

Fp is capable of surviving in post-harvest cereal stubble for ~3 years (Summerell and Burgess 1988) and can also continue to colonise (i.e. grow) in post-harvest cereal stubble (Petronaitis et al. 2020) by a process known as saprophytic colonisation. Additional cereal stubble remaining from stripper front-harvests may increase saprophytic colonisation, as there is more cereal stubble to vertically colonise, compared to the extent of growth possible in stubble remaining from conventional or shorter harvest-heights. This has the potential to increase inoculum levels and inoculum dispersal. Thus, we hypothesised that the lowering of the harvest-height of a cereal crop infected with *Fp* can restrict saprophytic colonisation of standing cereal stubble after harvest. If true, reducing or modifying harvest-heights of cereals infected with FCR could be beneficial for preventing further increases in *Fp* inoculum levels during fallow or non-host periods.

Methods

Site preparation (2019-20)

Field experiments were conducted at Breeza and Narrabri in northern New South Wales, spanning both the 2019 and 2020 winter crop growing seasons. Cereal stubble (from durum wheat) with extensive *Fp* colonisation was established at both sites in 2019 and a range of harvest-height (low, medium or high) and harvest-trash (trash returned to plot or trash removed off plot) treatments were imposed at harvest in 2019. Harvest-heights were unique to each site due to differences in final crop height. Stubble height measurements were conducted after harvest to derive the mean observed stubble height for each treatment (Figure 1). Prior to sowing in 2020, an additional stubble management treatment (Kelly-chain) was imposed on a selection of plots. This treatment was applied in combination with the harvest-height treatments, to plots that had previously had trash retained. A chickpea break crop (PBA Seamer) was subsequently sown across both field experiments in 2020.

Chickpea growth and yield (2020)

Chickpea plant populations (plants/m^2) were counted in each plot 30 days after planting. Lowest pod heights were measured on two random plants per plot prior to harvest as the distance from ground level to lowest pod. Grain yield was determined from machine harvested grain samples taken from 2 × 10 m plots.

Soil moisture profiling (2019-20)

Soil moisture content (SMC) was measured in November 2019, May 2020 and November 2020. One 1.2 metre soil core was sampled per plot and cut into 0-30 cm, 30-60 cm, 60-90 cm and 90-120 cm segments. The wet weight and dry (dried for 48 hours at 105 ºC) weight of each soil segment was measured to calculate gravimetric SMC.

Recovery of pathogens in standing-stubble using agar culturing (2019-20)

Thirty plants were collected at random across each plot in November 2019 and May 2020. Plants were separated into individual tillers and twenty tillers were then selected randomly for culturing. Starting at the stem base (crown), a 1.5 cm segment was removed from the tiller every 5 cm along the entire tiller length. Stem portions were surface sterilised (5 mL sodium hypochlorite solution, 45 mL deionised water, 50 mL >98% ethanol) for 1 minute then washed with sterile water. Samples were dried overnight and plated on 1/4 strength Potato Dextrose Agar (PDA) + novobiocin (10 g PDA, 15 g technical agar plus 0.1 g novobiocin/L water) and incubated under alternating ultra-violet light (12 h light/12 h dark) for 7 days at 25 °C. Pathogen incidence was recorded as the number of segments producing typical *Fp* colonies based on morphology.

Experimental design and analysis

The nine stubble management treatments (factorial combination of harvest-height and harvest-trash, plus Kelly-chain treatments), were randomly assigned to plots in each experiment according to a randomised block design, with three replicate blocks. The response variables, length of maximum colonisation and SMC, were analysed across sampling times, for each experiment separately using a linear mixed model framework, whereby treatments, sampling time and their interaction were fit as fixed effects while structural terms were fit as random. Response variables related to chickpea crop performance were analysed separately for each experiment. All models were fit using the ASReml-R package in the R statistical computing environment.

Results

Saprophytic colonisation of cereal stubble by Fp was restricted in shorter stubble

The maximum colonisation height of *Fp* in the post-harvest cereal stubble increased significantly over the 2019-20 fallow in the medium and tall stubble at both sites ($P < 0.001$, Figure 1). However, *Fp* height did not change in the short stubble because the fungus had already reached the observed (cut) height at harvest in 2019. At Breeza, maximum colonisation height increased significantly in medium (+11.1 cm) and tall (+22.2 cm) stubble over the fallow period (Figure 1). Similarly, at Narrabri, *Fp* progressed significantly in medium (+15.2 cm) and tall (+21.4 cm) stubble (Figure 1). Maximum colonisation of short stubble at Breeza in November 2019 was significantly lower than medium and tall stubble, but this was possibly a reflection of the shorter stubble treatment imposed (stubble was sampled after harvest), given that maximum colonisation at the Narrabri site was more uniform (Figure 1). Maximum colonisation measurement above the mean observed height (e.g. Breeza in May 2020), was due to variation in individual tiller lengths within a harvest-height treatment (Figure 1). There was no effect of cereal trash treatment (retained, removed or Kelly-chained) on maximum colonisation at each time point for both sites ($P > 0.1$).

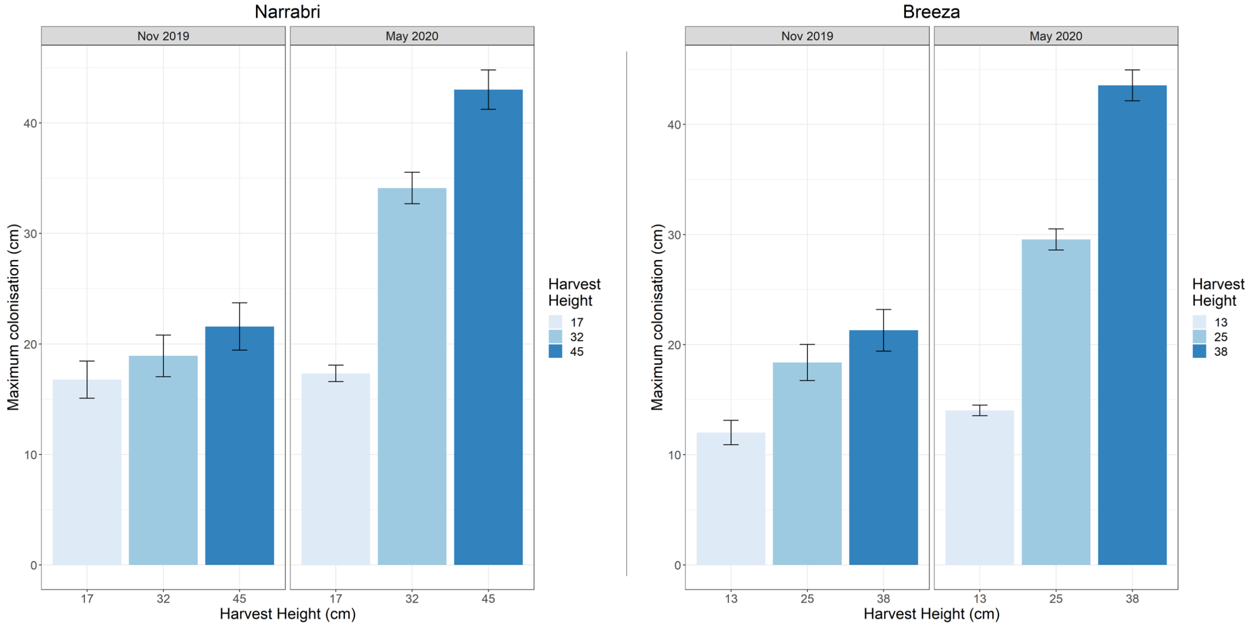

Figure 1. Maximum vertical colonisation by *F. pseudograminearum* in cereal stubble of different heights (mean observed height, in cm) over a summer fallow period at Breeza and Narrabri in NSW. Error bars represent the approximate back-transformed standard error of the mean.

These results demonstrate that *Fp* will continue to saprophytically colonise the cut cereal stubble and supports the hypothesis that lower cereal harvest-heights are effective at preventing the progression *Fp* in infected standing stubble during a summer fallow.

Soil moisture was not compromised by cereal stubble treatments
There were no detrimental effects of the cereal stubble management treatments on soil moisture levels after the 2019 summer fallow (May 2020) and after harvest of the chickpea crop (November 2020) ($P > 0.2$) (data not shown). There was good rainfall at both sites, 324 mm at Narrabri and 439 mm at Breeza (from 01/12/19 to 31/05/20). This significantly increased soil moisture over the fallow period (for depths 0 to 90 cm, $P < 0.03$) and may have evened-out any differences in soil moisture before May 2020. The differential stubble treatments may have had a more profound impact on soil moisture levels if drier conditions had persisted over summer and autumn.

Chickpea crop performance was not affected by cereal stubble treatments
Overall, the cereal stubble treatments did not have any meaningful impact on chickpea performance in these experiments. Chickpea crop performance was not affected by cereal stubble management treatments at Breeza or Narrabri, as there were no differences in yield, and only minor differences in chickpea establishment. There was no interaction between chickpea yield and standing stubble height ($P > 0.96$), trash treatment ($P > 0.19$) or a combination of harvest-height and trash treatments ($P > 0.14$) at both sites (data not shown). At Breeza, the Kelly-chained treatment resulted in slightly higher chickpea establishment (+4 plants per m^2) compared to the trash retained treatment ($P = 0.05$), possibly due to better seed-soil contact when using a disc seeder in Kelly-chained plots. Lowest pod height was not affected by cereal stubble treatments at either site ($P > 0.32$).

Conclusion
Implementing lower harvest-heights in cereal crops affected by FCR could be a useful strategy to limit saprophytic colonisation of *Fp* during fallow and non-host periods. In the present study, the maximum detection of *Fp* within standing cereal stubble at harvest in 2019 was relatively even across the different stubble height treatments. However, by the end of a 6-month summer fallow, the maximum height of *Fp* recovery within standing stubble was equal to, or very close to, the cut height of the cereal stubble at harvest in 2019. This confirms that *Fp* can saprophytically colonise the full length of cereal stubble in the field, given sufficient fallow rainfall.

Restricting movement of *Fp* vertically within standing cereal stubble may provide two-fold benefits. Firstly, it can prevent inoculum build-up within the standing stubble fraction, beyond the inoculum levels present at harvest. Secondly, it may stop the spreading of inoculum during harvest of short-stature crops such as chickpea, when inoculum is present above chickpea harvest-height, improving the efficacy of inoculum avoidance strategies like inter-row sowing. Harvesting cereals above the height of *Fp* colonisation could prevent the non-colonised stubble fraction from becoming saprophytically colonised. This approach could still be used with stripper-fronts by stripping grain, then cutting stubble above colonisation height to restrict saprophytic vertical *Fp* colonisation. The cut fraction could be left between rows as mulch or baled and removed, providing a better option than burning if extensive saprophytic colonisation has occurred during a wet summer fallow – prevention is better than cure!

Cereal harvest-height modification for FCR management appears promising with implications on FCR risk in a subsequent cereal crop to be determined in these field experiments in 2021.

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