Development of a barley head loss susceptibility index for Southern Australia

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Abstract

Across southern Australia, a major reason for reduced harvestable yields in barley is head loss. Head loss arises when a break in the peduncle causes the head to fall to the ground. The extent of head loss in barley is variable, changing from year to year depending on environmental conditions. Management factors for head loss include cultivar selection and pre-emptive sprays of plant growth regulators at flag leaf emergence, however, the best management option for head loss reduction is timely harvest. To aid with timely harvest, we suggest the development and adoption of a new barley head loss susceptibility index, which would provide growers with a warning system for potential head loss events. Head loss forecasting models have previously been based on temperature, humidity, and wind speed, to provide damage potentials. Our susceptibility index is based on the Fire Danger Index (FDI) which accounts for environmental factors as well as the dryness of the landscape or the ripeness of the crop in a head loss index. The FDI categories are reported up to 4 days in advance by the Bureau of Meteorology (BoM) and are easily accessible by growers. The development of a barley head loss susceptibility index will provide growers with greater information about conditions in which head loss might occur and allow decisions around harvest to be made in order to limit yield reductions associated with head loss.

Keywords

Modelling, Environment, Yield, Management, Grain

Introduction

Head loss in barley is characterised by the breaking of the peduncle which causes the head to drop to the ground and not be able to be harvested. In SA in 2016, isolated paddocks of barley on the Eyre Peninsula experienced yield losses of up to 50% due to strong hot winds that induced head loss in the nearly ripened crop (Crop and Pasture report 2016). Cultivar genetics plays a role in head loss susceptibility due to variation in peduncle strength and architecture. Applications of plant growth regulators (PGRs) can be utilised during stem elongation to help strengthen the peduncle to lower the risk of breakage. However, weather conditions around crop maturity have a greater role in determining whether a head loss event will occur and its severity. The magnitude of these events is often dependent on the year and location. Grower management is limited to cultivar selection, preventative PGR applications and timely harvest occurs with good harvest techniques. Mills (1972) proposed a forecasting model for barley head loss potential for the Yorke Peninsula. The basis of this model was the interaction between temperature and humidity creating a dry environment within the plant, and then wind speed causing the breakage of the peduncle. Weather forecasts were then utilised to categorise future weather events as to their head loss potential. In this study we aim to utilise the more common Fire Danger Index (FDI), which is currently issued up to four days in advance across southern Australia, as a head loss susceptibility index.

Methods

Field trials

In 2019 and 2020 field trials were conducted at three locations across SA, with a range of barley cultivars (Table 1) sown in the traditional May timings (Table 2). Cultivars were selected based on broadly representative plant architectures and their head loss susceptibilities (Table 1). All experiments were arranged in a split-plot design (whole plot: treatment, sub-plot: cultivar) with three replicates. At flag leaf emergence (GS 37 (Zadok 1974)) Moddus® Evo (Trinexapac-ethyl) was applied at the standard rate of 400 mL/ha across some plots whilst the controls were left untreated. Nutrients, weeds, pests and diseases were managed so as to not limit yield.

Table 1. Barley cultivars used in field trials with their year of release and reasons for selection.

Cultivar	Year of Release	Selection basis
Compass	2015	Tall fan shaped head, susceptible to lodging
RGT Planet	2017	Tall, good head retention
Schooner	1983	Tall, susceptible to head loss
Spartacus CL	2016	Dwarf, upright plant structure

Harvest index (HI) cuts of 0.45 m^2 were taken from each plot at physiological maturity and used to determine number of stems and heads per square metre. From physiological maturity, the number of detached heads on the ground was counted every fortnight for a 6-week period. An area of 0.68 m^2 was assessed in 3 different locations within each plot. Results were analysed using split plot ANOVA with

Genstat 20th edition. A weather station at each site was used to record temperature, humidity, wind speed and direction as well as gust strength at 15-minute intervals. Bureau of Meteorology (BoM) climatic data for the nearest site was also obtained at 30-minute intervals (Table 2).

Table 2. Location of field trial experiments, including growing season rainfall (GSR) and closest BoM station for climatic and rainfall data.

Region	Site	Year	Location	Sowing Date	Average GSR (mm)	GSR (mm)	BoM station (station no.)
Murray Mallee	Cooke Plains	2019	-35.3588 °S, 139.698 °E	17 May	275.1	271.2	Pallamana Aerodrome (024584)
		2020	-35.3520 °S, 139.6667 °E	12 May		299.1	*Cooke Plains (025502)
Mid North	Riverton	2019	-34.2168 °S, 138.7347 °E	16 May	397.7	266.8	Roseworthy (023122)
		2020	-34.2113 °S, 138.7401 °E	19 May		387.6	*Riverton (023314)
Yorke Peninsula	Minlaton	2019	-34.7888 °S, 137.5610 °E	7 May	269.3	228.0	Minlaton Aero (022031)
	Brentwood	2020	-34.8429 °S, 137.4962 °E	12 May		259.2	

*Closest BoM station recording rainfall data, climatic data not measured at station.

Fire Danger Index and APSIM

The FDI is based on a formula utilising temperature T (°C), humidity RH (%), wind speed v (km h^{-1}) and drought factor DF which gives an indication of how dry the landscape is as shown in Eq. (1) (Dowdy 2017). At each location the 15-minute interval weather data was utilised to calculate when the FDI was maximised each day between September and December. The 30-minute interval BoM data was used to determine the historic long term FDI between September and December yearly. The drought factor was calculated based on crop maturity from the trials and The Agricultural Production Systems sIMulator (APSIM) outputs.

$$FDI = \exp(0.0338T - 0.0345RH + 0.0234v + 0.243147) \times DF^{0.987} \quad (1)$$

APSIM version 7.10 was used to characterise the best sowing date for barley at each location where yield is maximised over a 50-year period, utilising the optimum flowering period method described by Flohr et al. (2017). Using the optimum sowing date, further simulations were run to equate growth stage progression with drought factor to be fed into Eq. 1.

Results

From our field trials, even at physiological maturity, some varieties had already experienced head loss (Figure 1a). Compass and Schooner exhibited the highest amounts of head loss at harvest, with the PGR treatment significantly reducing the number compared to the untreated control. RGT Planet and Spartacus showed limited head loss and no difference was identified between untreated control and PGR treatment. A delay in harvest of up to 4 weeks led to head loss in all cultivars with the PGR treatment significantly preventative effect, except Spartacus CL (Figure 1b and 1c). Despite this, the PGR treatment alone did not prevent completely prevent head loss.

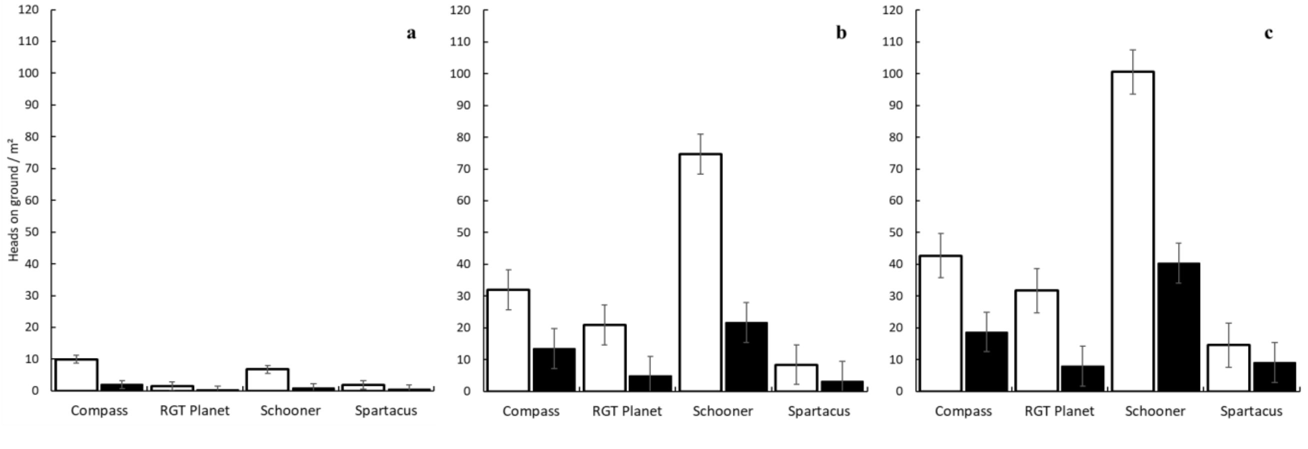

Figure 1. The number of heads on the ground per m^2 for Compass, RGT Planet, Schooner, and Spartacus CL at harvest ripe (a), 2 (b) and 4 (c) weeks later for the 2 years of field trials at 3 locations. Unfilled columns represent the untreated controls while the filled columns are PGR treated plants. Error bars show LSD (p<0.001).

Figure 2 shows the calculated daily FDI for Cooke Plans between November 1st and December 6th of 2019 from data collected at the on-site weather station. The relative amount of head loss is also displayed for the same period for untreated plots of Compass, RGT Planet, Schooner, and Spartacus. On the 13th of November, after the first major head loss event, there were already several heads on the ground for Compass (5.83 heads m^{-2}) and Schooner (2.11 heads m^{-2}) plots but not in RGT Planet or Spartacus CL. By the 29th of November, Compass and Schooner had lost significantly more heads than Spartacus CL as well as RGT Planet which was starting to lose heads. Compass and Schooner had 19.8 and 26.1 heads m^{-2} on the ground, respectively compared to only 4.4 for RGT Planet and 0.5 for Spartacus CL. Head loss steadied for all varieties between the 29th of November and the 4th of December.

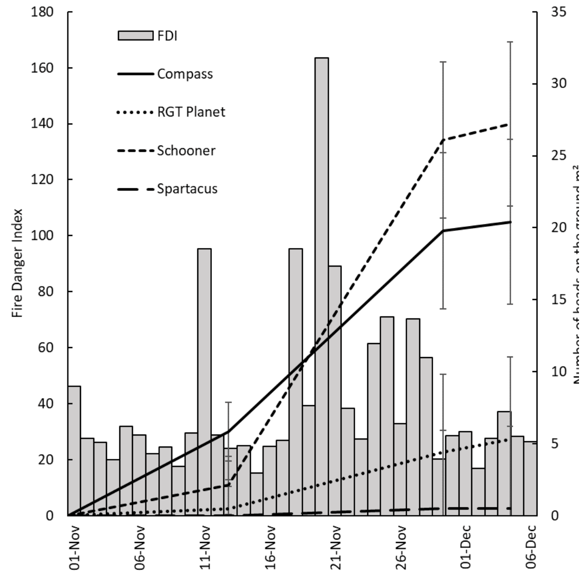

Figure 2. Comparison of daily FDI (columns) and number of heads on the ground per square metre on four occasions at Cooke Plains in 2019 for untreated Compass (solid line), RGT Planet (dotted line), Schooner (small dashes), and Spartacus (large dashes) plots. Error bars show LSD (p<0.001).

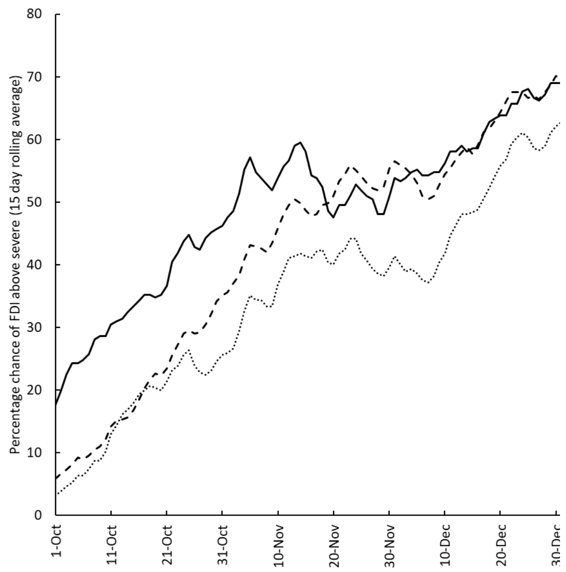

Figure 3. Percentage chance of a single day exceeding a severe category in the FDI calculated on a 15 day rolling average between October and December for Murray Mallee (solid line, BoM data 2006-2019), Mid North (dashed line, BoM data 1997-2019), and the Yorke Peninsula (dotted line, BoM data 2001-2019).

Discussion

RGT Planet and Spartacus CL are cultivars that are more tolerant to head loss while Compass and Schooner are more susceptible (Shackley et al 2021). At the point of physiological maturity head loss was limited to only a few heads per square metre in the susceptible cultivars (Figure 1). However, if harvest was delayed by even two weeks, then there was a loss of heads across all cultivars with the severity varying based on cultivar susceptibility from 21.6 heads m^{-2} (Schooner) to 3.1 heads m^{-2} (Spartacus CL). Four weeks of delaying harvest further increased the number of heads lost to an average of 47.4 heads m^{-2}. The application of a PGR did not prevent head loss but in most cases head loss was significantly less in PGR plots than the untreated control. The PGR did not have a significant effect on Spartacus CL likely due to this cultivar being less susceptible to head loss compared to other cultivars. The best management practice for limiting head loss is harvesting in a timely manner once the crop is ripe. Cultivar selection and PGRs can be beneficial if a timely harvest cannot be guaranteed. The use of a warning system for potential head loss weather events would allow growers to make more informed decisions about harvest timing.

Forecasting models for head loss in barley have been previously suggested by Mills (1972) for the Yorke Peninsula. These models were based on temperature, humidity, and wind speed. The first calculated maximum likely damage rate, in heads per hour, with the second converted this to percentage damage likely in a day with a correlation between sunshine hours and head loss. This conversion is due to anecdotal evidence suggesting head loss is greater in sunny conditions than in overcast conditions. Mills (1972) commented that use of the model was limited by having only three damage categories, while other forecasting models, like FDI, had six categories. Furthermore, it was suggested future development of the model should focus on a regression equation where predictors are not given equal weightings.

Our proposal is that the FDI can be utilised as a forecast warning system for potential head loss events. FDI is categorised into six warning levels based on how quickly a fire will spread and difficultly of suppression or containment of the fire (NSW Fire Service 2017). The FDI categories and corresponding ranges are listed in Table 3. When we compared daily FDI at Cooke Plains in 2019 and heads lost, days classified as severe and above on the FDI scale appears to be associated with head loss events. Prior to the 13th of November there was one severe FDI event, while the other days were classified as either high or very high. Between the 13th and 29th of November, there were six severe and one catastrophic FDI event where head loss increased in all cultivars. While after the 29th there were no FDI events above very high and head loss was limited. We propose that FDI days categorised as severe and above are highly likely to be associated with head loss events in ripe and susceptible barley crops (Table 3). Days categorised as very high have a small chance of being head loss events if the crop is already past physiological maturity. High and low-moderate days are unlikely to be associated with head loss events.

Table 3. FDI categories and corresponding index ranges when calculated with Eq. (1) (NSW RFS 2017) also corresponding likelihood of head loss event.

FDI Category	Index range	L
Low-Moderate	0-12	
High	12-25	
Very High	25-50	Small p
Severe	50-75	
Extreme	75-100	
Catastrophic	100+	

The chance of the FDI for a single day being severe or higher exceeds 50% from mid-October for the Murray Mallee, mid-November for the Mid North, and mid-December for the Yorke Peninsula (Figure 3). The FDI slowly increases over time as the crop matures and dries out, which in turn increases the drought factor and environmental conditions become more conducive to a high FDI category. The FDI equation matches with suggestions by Mills (1972) as each environmental factor has a different weighting and it is equated to the ripeness of the crop. The FDI is released and updated daily by the BoM and is forecasted 4 days in advance (Country Fire Authority 2021), providing a warning system for potential head loss events as well as categories relating to severity.

Conclusion

Barley head loss is a major yield loss risk across southern Australia with the most reliable management tool is to avoid a delayed harvest. The FDI categories are a potential forecast warning system that could be utilised as a barley head loss susceptibility index that would predict potential events four days in advance across southern Australia. It has been demonstrated that days categorised as severe and above are likely to be associated with head loss events once the barley crop has reached maturity. Utilising these categories as a susceptibility index will allow for growers to make more informed decisions at harvest to lower the risk of yield loss from barley head loss events at the end of the season.

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