Response of barley varieties to delays in harvest date

Jeremy Curry[1], Blakely Paynter[2] and Andrea Hills[1]
Department of Agriculture and Food Western Australia, [1]Esperance and [2]Northam

Key messages

- Delayed harvest can:
  - increase the lodging risk resulting in a slower harvest,
  - reduce grain yield (largely through head loss),
  - decease hectolitre weight (through grain swelling),
  - decrease screenings (through grain swelling),
  - increase or decrease grain brightness (depending on the level and timing of harvest rainfall),
  - decrease grain hardness thereby increasing grain breakage during pearling for shochu manufacture,
  - increase pre-harvest sprouting risk, therefore shortening the optimal storage duration,
  - influence the sensitivity of the grain to water during steeping in the malt house, and
  - increase the rate of germination.
- For growers, varietal differences in response to harvest delays were only observed for lodging, head loss and grain brightness with varieties responding similarly for the grain receival traits hectolitre weight, screenings and grain protein concentration.

Aims

Adverse weather conditions can cause significant delays at harvest, resulting in the crop standing in the field for longer than is ideal. These crucial delays affect not only grain yield, but grain quality traits important for meeting malt barley receival standards (Bolland 1984; Gardner *et al*. 2013; Walters and Craig 2013; Murray 2014). End use traits such as pre-harvest sprouting, dormancy, water sensitivity and grain hardness can also be influenced by harvest timing. In some cases delays in harvest can be beneficial, such as bleaching of the discoloured grain due to sunshine, but the negative impacts from delayed harvest usually outweigh the positives.

This study assessed the effect that delays in harvest date might have upon the grain yield and grain quality of a range of upcoming and existing malt or food barley varieties. Such information can be used by growers in decisions relating to harvest prioritisation. It can also be helpful for end-users in determining which varieties to use when and how.

Method

A total of 19 malt (or under malt accreditation) and food barley varieties were evaluated across six trials at three locations (Gibson, Northam and Katanning) between 2009 and 2011. Only 12 varieties were evaluated in any one year at two locations. The varieties were evaluated for their response to delays in harvest date, with three replicates being harvested at the earliest opportunity after physiological maturity (loss of green from peduncle) and then subsequently another three replicates at three weeks intervals at three, six or nine weeks later. Trials were sown as a split plot cyclic design with harvest (4 dates, H1, H2, H3 and H4) as the main plots and variety (12 varieties) as the subplots.

Seven varieties (Bass, Baudin, Buloke, Flagship, Flinders (except 09ED05), Hamelin and Vlamingh) were common to all six trials. Hindmarsh (2009 and 2010 trials) and La Trobe (2011 trials) have been combined for this analysis due to their similar agronomic characteristics to form the eighth common variety. Only data on those eight varieties is presented in this paper.

An NPK compound fertiliser was banded below the seed and the trials were top-dressed at sowing (in front of the seeder) with an additional NPK compound fertiliser to supply a total of 50 kg N/ha, 38 kg P/ha and 41 kg K/ha to each of the sites. A plant density of 150 plants/m^2 was targeted by adjusting the seeding rate (kg/ha) for each variety based on kernel weight and germination percentage. All trials were established into canola stubble.

Table 1: Rainfall (mm) in the three weeks prior to the first harvest (H1) and between each of the subsequent harvests in the six trials.

Site Year Location	**09GS03** 2009 Katanning	**09ED05** 2009 Gibson	**10NO10** 2010 Northam	**10ED21** 2010 Gibson	**11NO25** 2011 Northam	**11ED19** 2011 Gibson
3 weeks preceding H1 (mm)	34	8	3	40	55	84
between H1 and H2 (mm)	0	22	7	15	25	56
between H2 and H3 (mm)	0	1	0	2	24	51
between H3 and H4 (mm)	1	4	26	25	12	41
Total rainfall (mm)	**35**	**35**	**35**	**82**	**116**	**232**

Measurements taken included plant establishment (plants/m^2), plant height (cm, base of ear), lodging score (9-0) close to each harvest date, grain yield (t/ha), head loss (t/ha) if present, kernel weight (mg, db), hectolitre weight (kg/hL), screenings (% < 2.5 mm), grain protein concentration (%, db) grain brightness (Minolta 'L*'), grain hardness (SKCS, NIR), pre-harvest sprouting (PHS) (RVA viscosity, SN), germination percentage (in 4ml and 8ml of water, 72 hours), water sensitivity (72 hours), germination index (0-10) and germination homogeneity (0-100).

A restricted ANOVA was completed using the common eight varieties. Data was analysed using Genstat (VSN International 2013) with a block structure of colrep/harvest/variety and a treatment structure of harvest*variety.

Results

Table 2: Analysis of variance for main effects (harvest date and variety) and their interactions for each site. Significance: *** = p<0.001, ** = p<0.01, * = p<0.05 and n.s. = not significant.

Trait	Harvest						Variety						Harvest x Variety					
Site	09GS03	09ED05	10NO10	10ED21	11NO25	11ED19	09GS03	09ED05	10NO10	10ED21	11NO25	11ED19	09GS03	09ED05	10NO10	10ED21	11NO25	11ED19
Plant counts	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	***	n.s.	***	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Plant height	n.s.	n.s.	n.s.	n.s.	*	n.s.	***	***	***	**	***	***	n.s.	n.s.	n.s.	***	n.s.	n.s.
Lodging score	***	n.s.	**	***	***	***	***	***	***	***	***	***	n.s.	n.s.	***	n.s.	*	*
Head loss	n.s.	***	n.s.	***	n.s.	***	n.s.	***	n.s.	***	n.s.	**	n.s.	**	n.s.	*	n.s.	*
Grain yield	***	***	n.s.	**	**	***	***	***	*	n.s.	***	***	n.s.	n.s.	n.s.	n.s.	***	n.s.
Kernel weight	n.s.	n.s.	n.s.	***	n.s.	***	***	***	***	***	***	***	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Hectolitre weight	**	***	***	**	***	***	***	***	**	***	***	***	n.s.	*	n.s.	n.s.	n.s.	***
Screenings	n.s.	n.s.	*	**	**	***	***	***	***	***	***	***	n.s.	n.s.	n.s.	n.s.	n.s.	*
Grain protein	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	***	*	***	n.s.	***	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grain brightness	***	***	***	**	*	***	***	***	***	***	***	***	*	n.s.	n.s.	*	*	***
Grain hardness	**	***	***	***	***	***	***	***	***	***	***	***	n.s.	n.s.	n.s.	n.s.	*	**
Pre-harvest sprouting	*	n.s.	***	***	***	***	***	***	***	***	***	***	n.s.	n.s.	**	***	***	***
Germination	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Water sensitivity	n.s.	***	***	**	***	***	***	*	***	**	***	***	n.s.	**	***	n.s.	***	***
Germination index	**	***	***	**	***	***	***	***	***	***	***	***	n.s.	***	*	n.s.	***	***
Germination homogeneity	n.s.	n.s.	*	*	**	n.s.	*	n.s.	n.s.	***	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.

Site and variety

Growing season rainfall (May-Oct) ranged from 188 mm to 360 mm at each site (data not shown). Grain yield (at H1) ranged from 2.77 t/ha (Northam 2010) to 4.93 t/ha (Gibson 2010). Harvest rainfall (3 weeks preceding H1 to H4) ranged from 35 mm (Katanning 2009, Gibson 2009 and Northam 2010) to 232 mm (Gibson 2011) (Table 1). Grain quality at the first harvest date was within the GIWA Barley Malt 1 limits for hectolitre weight (≥ 64 kg/hL), screenings (≤ 20%, except Katanning 2009 and Northam 2010), grain protein concentration (9.5-12.5%, except Northam 2010 and Esperance 2011) and grain brightness (≥ 56 'L*') in all trials (data not presented). High screenings (site average >35%) were present at Katanning 2009 and Northam 2010 and high grain protein present at Northam 2010 (12.7%) and Esperance 2011 (13.0%) (data not shown).

Varieties differed in their plant height, lodging score, grain yield (except Gibson 2010), head loss (only at Gibson sites) and all measures of grain quality except grain protein at Katanning 2009 and Northam 2011, plus germination homogeneity at Gibson 2009 and 2011 and Northam 2010 and 2011 (Table 2). Hindmarsh / La Trobe (4.50 t/ha) had the highest grain yield at H1 averaged across trials, with Baudin the lowest (3.70 t/ha). Baudin had the average lowest kernel weight (36 mg), with Buloke and Flagship (42 mg) the highest at H1. Average hectolitre weight at H1 ranged from 72.3 kg/hL (Baudin) to 74.9 kg/hL (Bass); screenings ranged from 14% (Hindmarsh/La Trobe and Vlamingh) to 32% (Baudin), grain protein concentration varied from 10.7% (Buloke) to 11.7% (Flagship); while Baudin had the brightest grain brightness (59.8 'L*') and Buloke and Hamelin (58.4 'L*') the lowest (data not shown).

Harvest date

Delays in harvest date consistently (in at least 80% of trials) influenced lodging score, grain yield, hectolitre weight, grain brightness, grain hardness, pre-harvest sprouting, germination, water sensitivity and germination index (Table 2). To a lesser extent, screenings were also affected (two out of every three trials). Delaying harvest (from three, six and up to nine weeks after the earliest opportunity) had the following impact:

1. No effect on plant height (data not shown),
2. Increased lodging risk (largest drop from initial three week delay from H1 to H2) (Figure 1a),

3. Decreased grain yield (Figure 1b). Changes between H1 and H2 were largely due to differences in the harvest grain moisture. Reductions in grain yield between H2 and H4 at the three Gibson sites were largely due to head loss (Figure 1c) whilst there was no yield reduction at the non-Gibson sites between H2 and H4,
4. No change in kernel weight (Figure 1d),
5. Reduced hectolitre weight presumably due to changes in kernel shape (grain swelling) as there were no changes in kernel weight (Figure 1e),
6. Reduced screenings associated with the swelling of the grain that also influenced hectolitre weight (Figure 1f),
7. No change in grain protein concentration (data not shown),
8. Increased and decreased grain brightness dependent on location and season (Figure 1g),
9. Decreased grain hardness, especially between H1 and H2 (Figure 1h),
10. Increased pre-harvest sprouting risk, but only at sites with more than 80 mm rainfall in the period three weeks prior to H1 until H4 (Figure 1i),
11. Increased germination in 4 ml of water, especially from H1 to H2 (Figure 1j),
12. Peak water sensitivity occuring at either three or nine weeks after H1, dependent on site (Figure 1k),
13. Increased germination index (rate of germination) (Figure 1l), and
14. No change in germination homogeneity (variance of germination) (data not shown).

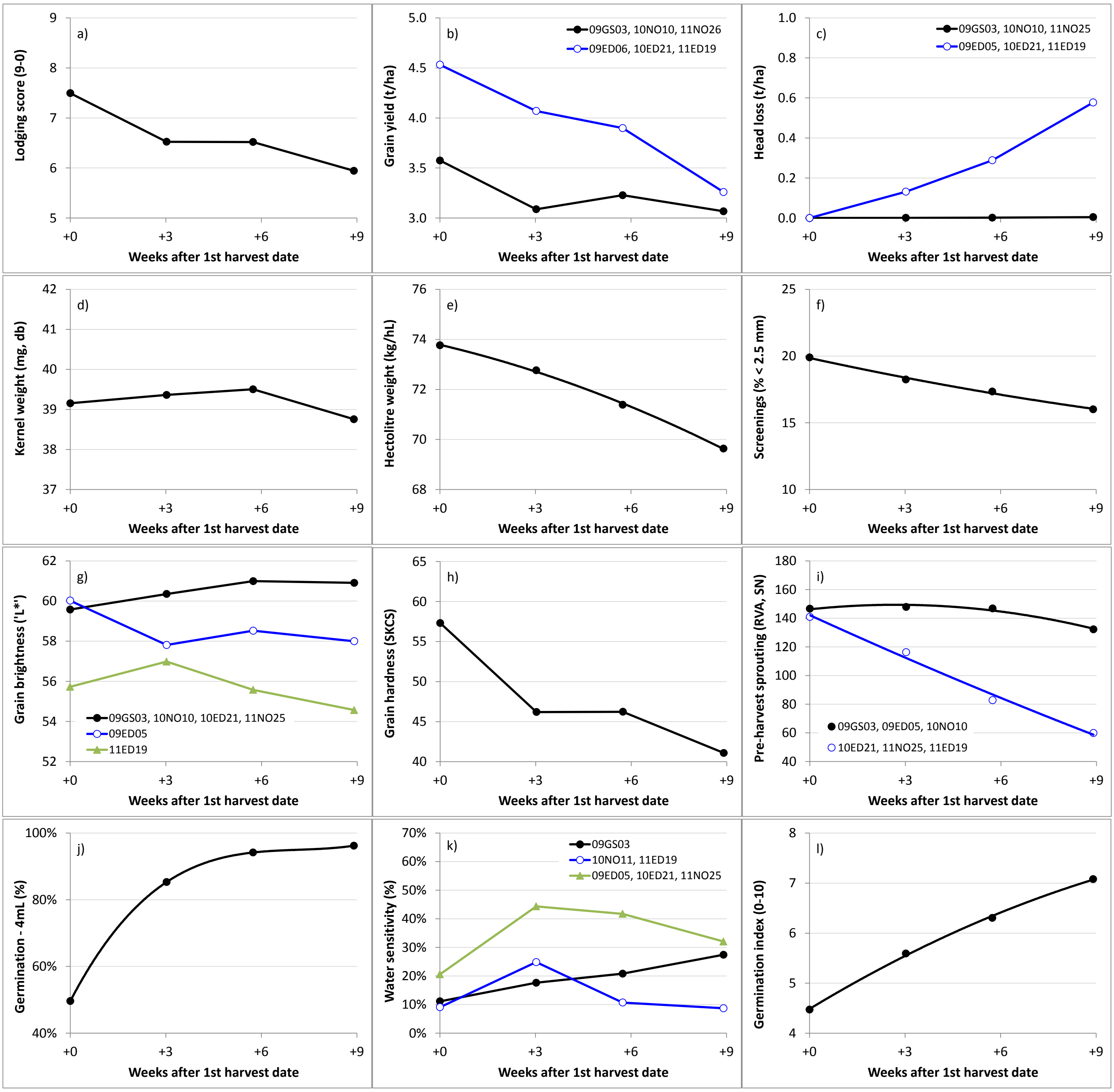

Figure 1. Average varietal response to delays in harvest, a) lodging score, b) grain yield, c) head loss, d) kernel weight, e) hectolitre weight, f) screenings, g) grain brightness, h) grain hardness, i) pre-harvest sprouting, j) germination – 4ml, k) water sensitivity and l) germination index. All graphs represent the means of the six trials unless shown otherwise.

Harvest date by variety interactions

Varieties responded similarly to delays in harvest date except for lodging risk, head loss, grain brightness, pre-harvest sprouting, germination, water sensitivity and germination index (Table 2). Lodging risk interactions were observed at only three sites (Northam 2010 and 2011, Gibson 2011), whilst head loss interactions were only observed at the Gibson sites (2009, 2010 and 2011). For the grain quality and germination related traits, interactions were observed in at least two out of every three trials.

Straw strength of Bass and Hindmarsh / La Trobe was slightly more sensitive to delayed harvest than the six other varieties assessed (Figure 2a). These differences were more noticeable at the sites with an interaction between harvest and variety (10NO25, 11NO25 and 11ED19; data not shown). Buloke, Flagship and Hamelin had poor strength at H1 and the decline in their straw strength was similar to the decline in Baudin, Flinders and Vlamingh as harvest was delayed. Buloke, Flagship and Hamelin consistently had the poorest straw strength at H4.

For head loss, Baudin had the lowest head loss risk of the varieties tested and Hindmarsh / La Trobe the highest risk (Figure 2b). Bass, Buloke, Flagship, Flinders, Hamelin and Vlamingh had a similar risk, averaged across the three sites where head loss was present (Gibson 2009, 2010 and 2011) .

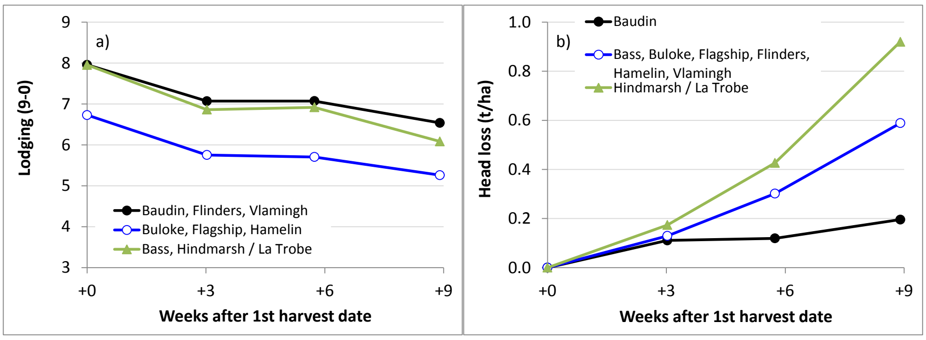

Figure 2. Change in a) straw strength averaged over all six sites and b) head loss at the Gibson sites (2009. 2010 and 2011) for different groups of varieties.

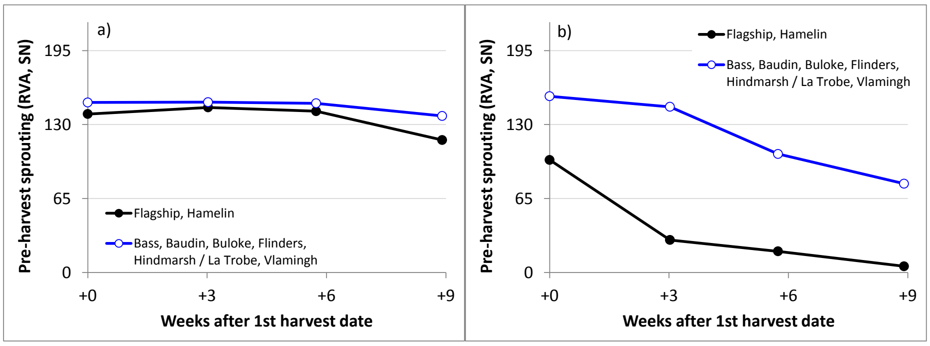

Figure 3. Change in starch viscosity (RVA) with delays in harvest date for a) Gibson 2009 and 2010, Northam 2010 (less than 40 mm rainfall from three weeks preceding H1 until H4, and b) Gibson 2010 and 2011, Northam 2011 (greater than 80 mm rainfall from three weeks preceding H1 until H4. Grain is considered sound if the RVA (SN) value is greater than 130.

The harvest by variety interactions for grain brightness were not always consistent across sites. The data suggests, however, that grain brightness in Bass, Baudin and Flinders reacts slightly differently to the other five varieties with delays in harvest date (data not shown). At sites where grain brightness improved with delayed harvest (Katanning 2009, Northam 2010 and 2011, Gibson 2010), the bleaching or whitening effect in Bass, Baudin, and Flinders was slightly less than for Buloke, Flagship Hamelin, Hindmarsh / La Trobe and Vlamingh. At sites where grain brightness decreased with delayed harvest (Gibson 2009 and 2011), Bass, Baudin and Flinders appeared to weather (dis-colour) slightly more than Buloke, Flagship, Hamelin, Hindmarsh / La Trobe and Vlamingh.

Harvest delay influenced grain “soundness”. Grain is considered “sound” if it has an RVA value above 130 (Izydorczyk 2005). Baudin is considered to be a variety with a low risk of PHS (as measured by RVA), whilst Flagship and Hamelin are considered a high risk (Paynter *et al*. 2004). In environments where there was more than 80 mm over the harvest period the high risk varieties (Flagship and Hamelin) were ‘un-sound” (RVA below 130) at all harvest dates, whereas the varieties with a low risk (Bass, Baudin, Buloke, Flinders, Hindmarsh / La Trobe) and Vlamingh) were not “un-sound” til after H2 (Figure 3). Amongst the low risk group, Buloke was at a slightly higher risk of producing ‘un-sound’ grain at H2 rather than H3. In the environments with less than 40 mm over the harvest period the high risk varieties became “un-sound” at H4, whilst the low risk varieties were “sound” at all harvest dates. The PHS (using RVA) measure is used to determine when grain should be processed and is an alternative to the falling number test used in wheat. Once grain becomes “un-sound” it should be processed (ie. malted) shortly after harvest to realise its inherent quality. Barley samples with initially low RVA values show a propensity to lose viability and exhibit a low germination after exposure and/or storage at poor conditions (Izydorczyk 2005). Timely harvest is therefore recommended for high risk varieties to reduce the risk of delivering “sprouted” grain (low falling number). Timely harvest is also recommended in high rainfall at harvest risk environments to ensure that the grain available for export is “sound”. Varietal differences in sprouting risk will become important to Western Australian barley growers if falling number is introduced into the GIWA Barley standards. GTA Barley standards include falling number.

The two high pre-germination risk varieties (Flagship and Hamelin) differed from the other six varieties in their germination characteristics for percent germination at 72 hours, sensitivity to germinating in 8 ml of water rather than 4 ml of water and their rate of germination (Figure 4). Flagship and Hamelin had a higher germination at H1, slightly higher at H2 and similar thereafter; their level of water sensitivity was un-affected by harvest date; and their germination index increased less than the other varieties with delays in harvest date. In the low risk pre-germination group, the varieties could be broken into two groups based on their germination at 72 hours and water sensitivity. Bass, Flinders, Hindmarsh and La Trobe had a higher rate of germination at H1 and H2 and a lower water sensitivity at H3 and H4 compared to Baudin, Buloke and Vlamingh. Both groups however had similar rate of germination with delays in harvest date.

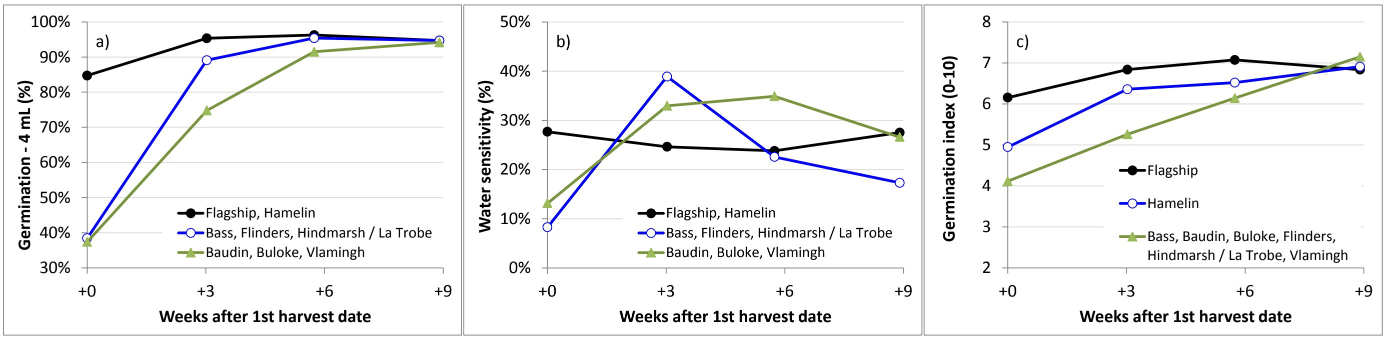

Figure 4. Varietal differences in a) germination, b) water sensitivity and c) germination index with delays in harvest date averaged across all six sites.

Conclusion

In all barley growing regions, there is always a chance of harvest being interrupted by rainfall. This trial series showed that for the varieties assessed, rainfall and delays in harvest can lead to increased lodging risk, losses of grain yield, reduced hectolitre weight, a possible increase or decrease in grain brightness (dependent on the amount and distribution of rainfall at harvest), decreased grain hardness and increased pre-germination risk. In the growers favour is the likely decrease in screenings, with no change to be expected in grain protein concentration. For maltsters, delayed harvest can impact when the grain they have purchased needs to be processed, the level and rate of germination to be expected, as well as the steeping program to be used.

Gardner *et al*. (2013), Walters and Craig (2013) and Murray (2014) similarly observed decreases in hectolitre weight, decreases in screenings and a small or no change in grain protein with delays in harvest date in New South Wales and Victoria. Bolland (1984), in a study on delayed harvest on the south coast of Western Australia, found decreases in hectolitre weight to be only small and generally not significant. Whilst we observed no effect of harvest date on kernel weight in two thirds of our trials, Gardner *et al*. (2013) did observe a decrease in their study whilst Bolland (1984) reported small but generally non-significant decreases in kernel weight. Neither Walters and Craig (2013) nor Murray (2104) reported their kernel weights.

Delays in harvest date did not impact on most of the grain quality traits assessed at receival (hectolitre weight, screenings and grain protein) of one variety more than another (Table 2). There was some evidence, however, that Bass, Baudin and Flinders may weather or bleach slightly differently to the other varieties evaluated. Walters and Craig (2013) similarly observed no harvest by variety interaction for hectolitre weight, screenings and grain protein, but did not measure grain brightness as it is not a receival trait on the east coast in the GTA Barley standards.

Much of the difference between varieties that is important to growers was associated with their straw strength and risk of head loss (Table 2 and Figure 2). To minimise the risk associated with harvest delays, especially on the south coast, growers should consider sowing only manageable areas of susceptible varieties or look to swath susceptible varieties. Baudin was the only variety that you could allow a delay in harvest date by more than six weeks in all sites with minimal loss in yield or quality.

Varieties with a high risk of pre-harvest spouting reacted differently for germination related traits to delayed harvest than those with a low risk (Figures 3 and 4). Whilst those effects on grain quality did not influence the ‘receivability’ of the barley, they could influence what an end user (ie. maltster) might do with the grain.

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Key words

Barley, harvest date, sprouting, germination, grain quality

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