Seasonal and genetic differences in the phenology (duration to awn emergence) of barley when sown in late April through to early July

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Key messages

- The actual date a barley cultivar will flower varies significantly from year to year due to the impact of seasonal weather differences, predominantly in temperature and differences in its phenological development pattern based on its basic vegetative phase (BVP), daylength sensitivity (DLS) and vernalisation requirement (VRN).
- Tools such as APSIM, Yield Prophet and FlowerPower aim to predict flowering date and can be used by growers and consultants to compare different cultivars. The phenology data in this study is targeted to develop a barley module of FlowerPower.
- In this study awn emergence (Z49) was used as the measure of flowering date in barley as it is very difficult to accurately determine flowering in barley, unlike in wheat.
- The relative maturity of barley cultivars with a late May planting has little relationship to the relative maturity of the same barley cultivars with late April or early July planting.

Background and aims

Development or time to flower in barley is controlled by temperature and daylength. Barley is known as a 'long day' plant, as its development is often inhibited under shorter days (daylength less than 16 h). Cultivars grown in Western Australia differ in their response to sowing date because of differences in the duration of their basic vegetative phase and their daylength length sensitivity.

Basic vegetative period (BVP) is the minimum number of leaves formed on the mainstem when a plant has had its vernalisation response satisfied and is grown in a daylength above 16 h. BVP modifies the plant's response to temperature and daylength. As our daylength never exceeds 16 h in the south west of Western Australia, we measure the BVP of barley cultivars by growing them with supplementary lighting.

Daylength sensitivity (DLS) is a measure of the sensitivity of a cultivar to daylength and reflects the responsiveness of a cultivar to a change in sowing date. DLS is the difference in duration to flowering between plants grown with and without supplementary lighting. DLS insensitive cultivars will form the same number of leaves on the mainstem, regardless of sowing date. The final leaf number on DLS sensitive cultivars, however, will differ due to sowing date.

Vernalisation response (VRN) is a measure of the responsiveness of a cultivar to a certain number of 'cold' hours needed to initiate its development. All barley cultivars currently grown in Western Australia are spring types and as such have little or no vernalisation requirement, although cultivars such as Ulandra have a mild vernalisation requirement.

Stirling was a dominant barley cultivar in Western Australia for over 20 years. One of the reasons for this was its good agronomic adaptation to most locations and sowing dates due to a phenology based on a short BVP and a high DLS. It has however been demonstrated that varieties with medium BVP and moderate DLS or with long BVP and mild DLS are better suited to earlier sowing opportunities than Stirling (Young and Elliott 1994). Varieties with short BVP and high or very high DLS are however adapted to both early and late sowing dates.

There is a lot of interest in early sowing (before 05 May) but there is very little data to support decisions on which barley cultivar to sow. An understanding of the duration to flowering is useful in determining the risks of frost and heat stress as well how different cultivars respond to early sowing versus later sowing. As the actual flowering date in barley is difficult to measure the duration to awn emergence (Z49) is often used as a surrogate measurement.

The aim of this paper is to

(1) show the seasonal variation in duration to Z49 in barley sown at Northam over the six-year period 2009-2014 for 15 barley cultivars sown over four times of sowing from late April to early July, and

(2) provide information on the relative differences in days to Z49 with respect to three control cultivars Baudin, Buloke and Stirling at those four sowing dates.

Method

Hand sown hill plots (10 seeds per hill) were established at Northam from 2009-2014 (Table 1). Hills were sown at a spacing of 50 cm. In each year 30 cultivars were sown at four times of sowing (TOS) over three replicates with a block structure of TOS/rep/cultivar and a treatment structure of cultivar/TOS. This paper only presents data for the 15 cultivars common to the six-years of trials. As Compass, Fathom, Granger, La Trobe and Scope CL were not sown before 2011 they are not included in this analysis. Supplementary irrigation was used where necessary to help establish the crop. No supplementary lighting was used. At two weeks after sowing the number of plants emerged in each hill plot was counted. In spring, the number of stems at awn emergence (Z49, 1 cm of awn emerged) was recorded three times per week until the number of stems at Z49 was equal to the number of plants emerged. When that occurred that hill plot was deemed to have reached Z49. Duration to Z49 was related to daily weather data collected from the DAFWA weather station located at the Northam Office. Thermal time or growing day degrees (GDD) was calculated as the average of the daily minimum and maximum temperatures above a threshold of 0°C. In 2012 there were emergence problems with TOS4, so this data was not included in this analysis.

Table 1. Date of seeding (TOS) of barley phenology trials at Northam from 2009-2014.

Year	Trial ID	TOS1	TOS2	TOS3	TOS4
2009	09NO01	28 Apr	22 May	12 Jun	03 Jul
2010	10NO11	30 Apr	24 May	16 Jun	06 Jul
2011	11NO26	27 Apr	24 May	15 Jun	04 Jul
2012	12NO35	26 Apr	24 May	14 Jun	-
2013	13NO47	24 Apr	24 May	14 Jun	05 Jul
2014	14NO47	24 Apr	22 May	12 Jun	03 Jul

Results

There was significant variation in the duration to awn emergence (Z49) between cultivars ($p<0.001$), due to time of sowing ($p<0.001$) and an interaction between cultivars in how they responded to delays in sowing date ($p<0.001$) over the six-year period of 2009-2014 at Northam (Figures 1 and 2). Figure 1 shows the average days after sowing to Z49 for six of the 15 cultivars over the four times of sowing and the duration to Z49 relative to Stirling barley. Figure 2 has boxplots (minimum, 1st quartile, median, average, 3rd quartile and maximum) describing the different flowering patterns of all 15 cultivars for the actual date (day of year) of achieving Z49 and the thermal time (GDD) required to reach Z49 at each of the four times of sowing. The variation in date to Z49 decreased as seeding was delayed, whereas the variation in date to Z49 when measured by thermal time was similar across the four times of sowing.

Across the six-years of data the earliest and latest flowering cultivars reached Z49 on average between these dates:

- late April (24-30 April) sown – 27 July to 18 Aug (92-114 days or 1,105-1,339 GDD after sowing),
- late May (22-24 May) sown – 23 Aug to 08 Sept (92-108 days or 997-1,183 GDD after sowing),
- mid (12-16 June) June sown – 08 Sept to 22 Sept (87-100 days or 914-1,100 GDD after sowing), and
- early (03-06 July) July sown – 22 Sept to 04 Oct (80-92 days or 900-1,066 GDD after sowing).

Mundah was always the first cultivar to reach Z49 whilst Oxford was generally the last cultivar to reach Z49 (except with late April where Baudin and Lockyer were later to flower than Oxford) (Figures 1 and 2).

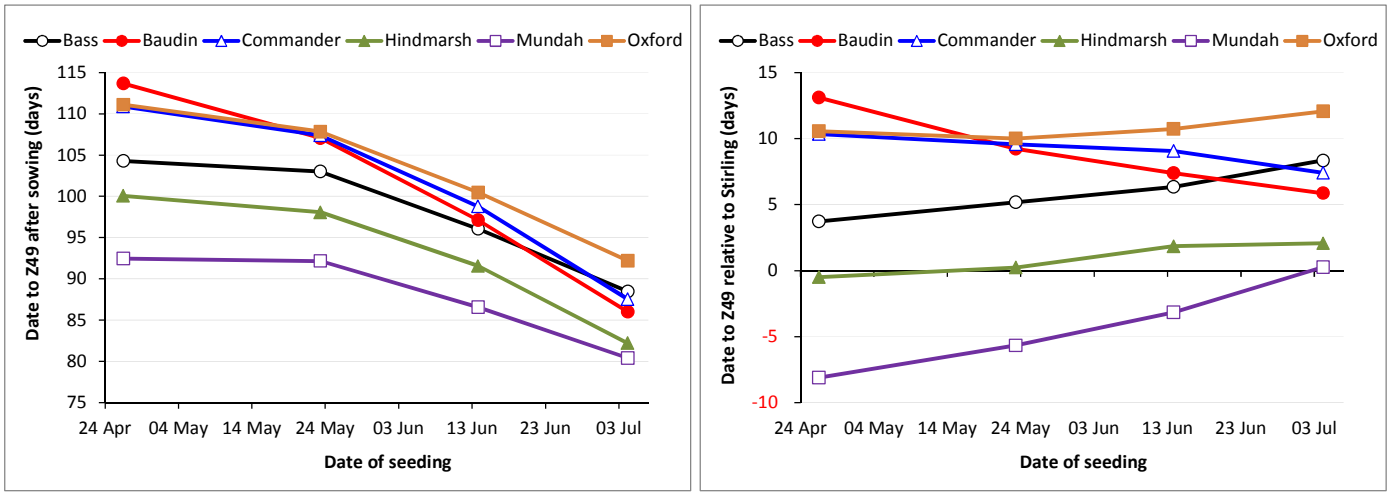

Figure 1. (L) average days to Z49 after sowing and (R) date to Z49 relative to Stirling for six cultivars of barley sown at Northam over the six-year period 2009-2014 as seeding was delayed from late April to early July.

Conclusion

In the annual Barley Cultivar Sowing Guide (ie. Bulletin 4860, agric.wa.gov.au/barley/2015-barley-cultivar-guide-available-growers) cultivars are grouped for their maturity based on their relative phenology with a late May sowing. They are classed into four categories – very early, early, medium and late spring. This categorisation of cultivars is however not relevant for sowing events that occur in late April, mid June and early July due to the strong interaction between daylength and temperature on the phenological development of barley. Barley cultivars respond very differently to delays in seeding date (Figures 1 and 2, Table 2) and it is important to understand how each cultivar changes with date of seeding and not use the generic maturity classification to define likely response to a selected sowing date.

Some of the newer longer season cultivars like Bass and Flinders have very different phenological development patterns to similar longer season cultivars which we collectively class as medium (ie. Buloke) or late spring cultivars (ie. Baudin and Gairdner). With late April sowing Bass, for example, flowers much closer to Stirling (+2 to +5 days) than it does to Baudin (-10 to -8 days) (Figures 1 and 2, Table 2). As seeding was delayed the differences between Bass and Baudin were reduced until early July when Bass was slightly later to flower than Baudin (+1 to +3 days).

Hindmarsh, which has been widely adopted in Western Australia, flowers at a similar to Stirling, another cultivar that was previously very popular in Western Australia. Hindmarsh however is similar to slightly earlier (-2 to +1 days) than Stirling with late April planting but by early July is actually slightly later to flower than Stirling (+2 to +3 days).

Knowledge of these subtle differences in phenology can be very useful when planning seeding programs. When looking for a cultivar to sow in late April, the longest season cultivars tested over the six-year period from 2009-2014 were Baudin, Gairdner and Lockyer. One of the reasons that cultivars like Baudin have been so successful is their ability to reduce their duration to flowering as seeding is delayed. With late April planting at Northam Baudin was +12 to +14 days later to flower than Stirling, but by early July it was only +5 to +7 days later to flower. Gairdner was +10 to +13 days later to flower with late April and +9 to +11 days later to flower with early July. Relative to each other Baudin was 0 to +3 days later to Z49 than Gairdner with late April planting and -3 to -5 days earlier with early July planting, suggesting quite different development patterns. The reason for their differences is because Baudin has a short BVP and a very high DLS, whereas Gairdner has a medium – long BVP and a medium DLS.

The reason for measuring phenology accurately in small plots trials, even with the apparent variation that exists from season to season, is so we can put it to use in tools such as APSIM (apsim.info/), Yield Prophet (yieldprophet.com.au/yp/wfLogin.aspx) and FlowerPower (agric.wa.gov.au/frost/flower-power). These tools allow us to predict flowering date for a wider range of environments than assessed in this study. Using additional data we have collected from Katanning and Esperance, the phenology data collected in this DAFWA-GRDC project DAW00224 and the previous project DAW00190 is targeted for developing a barley module of FlowerPower. The target release date for the barley module of FlowerPower is by seeding in 2017. APSIM and Yield Prophet are able to simulate barley phenology but they are still being validated for the Western Australian environment. It is important to understand that FlowerPower is a statistical model and not a simulation model like APSIM and Yield Prophet. By accurately characterising cultivars, growers and consultants will be able to make reasonably accurate cultivar comparisons for their specific location, but not with a 100% guarantee.

As phenology data for Compass, Fathom, Granger, La Trobe and Scope CL has only been collected since 2011 (except Compass since 2012) they have not been included in this analysis. Observations to date suggest that Fathom flowers between Stirling and Buloke, Granger is similar to Buloke, La Trobe mimics Hindmarsh and Scope CL mimics Buloke across a range of times of sowing. Even though Compass is derived from Commander it appears to be between 2 to 7 days earlier to Z49 with late April to late May planting.

References

Young KJ and Elliott GA (1994). An evaluation of barley accessions for adaptation to the cereal growing regions of Western Australia, based on time to ear emergence. *Australian Journal of Agricultural Research* **45**: 75-92.

Key words

Phenology, flowering, awn emergence, Z49, time of sowing, barley

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Table 2 – Days to Z49 relative to either Baudin, Buloke or Stirling when sown in late April, late May, mid June or early July at Northam over the six-year period 2009-2014. Parentheses highlight the actual range in sowing dates for each time of sowing across the six-years of experiments.

Days to Z49 relative to Baudin

	late April	late May	mid June	early July
Cultivar	(24-30 April)	(22-24 May)	(12-16 June)	(03-06 July)
Bass	-10 to -8	-5 to -3	-2 to 0	+1 to +3
Baudin	-	-	-	-
Buloke	-4 to 0	-3 to -1	+1 to +3	+1 to +3
Commander	-5 to -1	-1 to +2	+1 to +2	0 to +3
Fleet	-11 to -7	-5 to -3	-2 to 0	-3 to -1
Flinders	-8 to -4	-2 to +1	+1 to +3	+4 to +7
Gairdner	-3 to 0	-1 to +1	-1 to +1	+3 to +5
Hindmarsh	-16 to -12	-10 to -8	-7 to -5	-5 to -3
Lockyer	-2 to +2	0 to +2	+1 to +3	+1 to +3
Mundah	-23 to -19	-17 to -13	-12 to -9	-8 to -3
Oxford	-5 to 0	0 to +2	+3 to +4	+5 to +7
Roe	-17 to -13	-13 to -9	-8 to -6	-6 to -3
Stirling	-14 to -12	-10 to -8	-9 to -6	-7 to -5
Vlamingh	-5 to -3	-4 to -2	0 to +1	0 to +3
Wimmera	-10 to -6	-4 to -1	+1 to +2	+2 to +5

Days to Z49 relative to Buloke

	late April	late May	mid June	early July
Cultivar	(24-30 April)	(22-24 May)	(12-16 June)	(03-06 July)
Bass	-9 to -5	-3 to -2	-3 to -2	0 to +1
Baudin	0 to +4	+1 to +3	-3 to -1	-3 to -1
Buloke	-	-	-	-
Commander	-2 to +1	0 to +4	-1 to +1	-2 to +1
Fleet	-8 to -5	-4 to -1	-5 to -2	-5 to -4
Flinders	-3 to -2	0 to +2	-1 to +3	+1 to +4
Gairdner	-1 to +3	0 to +2	-3 to 0	+1 to +3
Hindmarsh	-12 to -10	-8 to -6	-8 to -6	-7 to -5
Lockyer	+2 to +4	+2 to +4	-1 to +1	-1 to +1
Mundah	-21 to -17	-15 to -12	-14 to -11	-10 to -6
Oxford	-2 to +1	+2 to +3	0 to +3	+3 to +5
Roe	-15 to -11	-11 to -7	-10 to -8	-8 to -5
Stirling	-12 to -9	-8 to -7	-10 to -8	-9 to -7
Vlamingh	-2 to -1	-2 to 0	-2 to 0	-2 to 0
Wimmera	-5 to -4	-2 to +1	-2 to +1	-1 to +2

Days to Z49 relative to Stirling

	late April	late May	mid June	early July
Cultivar	(24-30 April)	(22-24 May)	(12-16 June)	(03-06 July)
Bass	+2 to +5	+4 to +6	+5 to +8	+8 to +9
Baudin	+12 to +14	+8 to +10	+6 to +9	+5 to +7
Buloke	+9 to +12	+7 to +8	+8 to +10	+7 to +9
Commander	+9 to +12	+8 to +11	+8 to +10	+6 to +9
Fleet	+3 to +6	+4 to +7	+4 to +8	+3 to +4
Flinders	+6 to +10	+7 to +10	+8 to +11	+10 to +11
Gairdner	+10 to +13	+8 to +10	+6 to +9	+9 to +11
Hindmarsh	-2 to +1	-1 to +1	+1 to +2	+2 to +3
Lockyer	+12 to +15	+9 to +12	+8 to +11	+7 to +8
Mundah	-9 to -7	-7 to -4	-4 to -2	-1 to +2
Oxford	+8 to +13	+9 to +11	+9 to +12	+11 to +13
Roe	-4 to 0	-4 to 0	0 to +1	+1 to +2
Stirling	-	-	-	-
Vlamingh	+8 to +10	+6 to +8	+7 to +9	+7 to +7
Wimmera	+5 to +7	+6 to +8	+7 to +10	+7 to +10

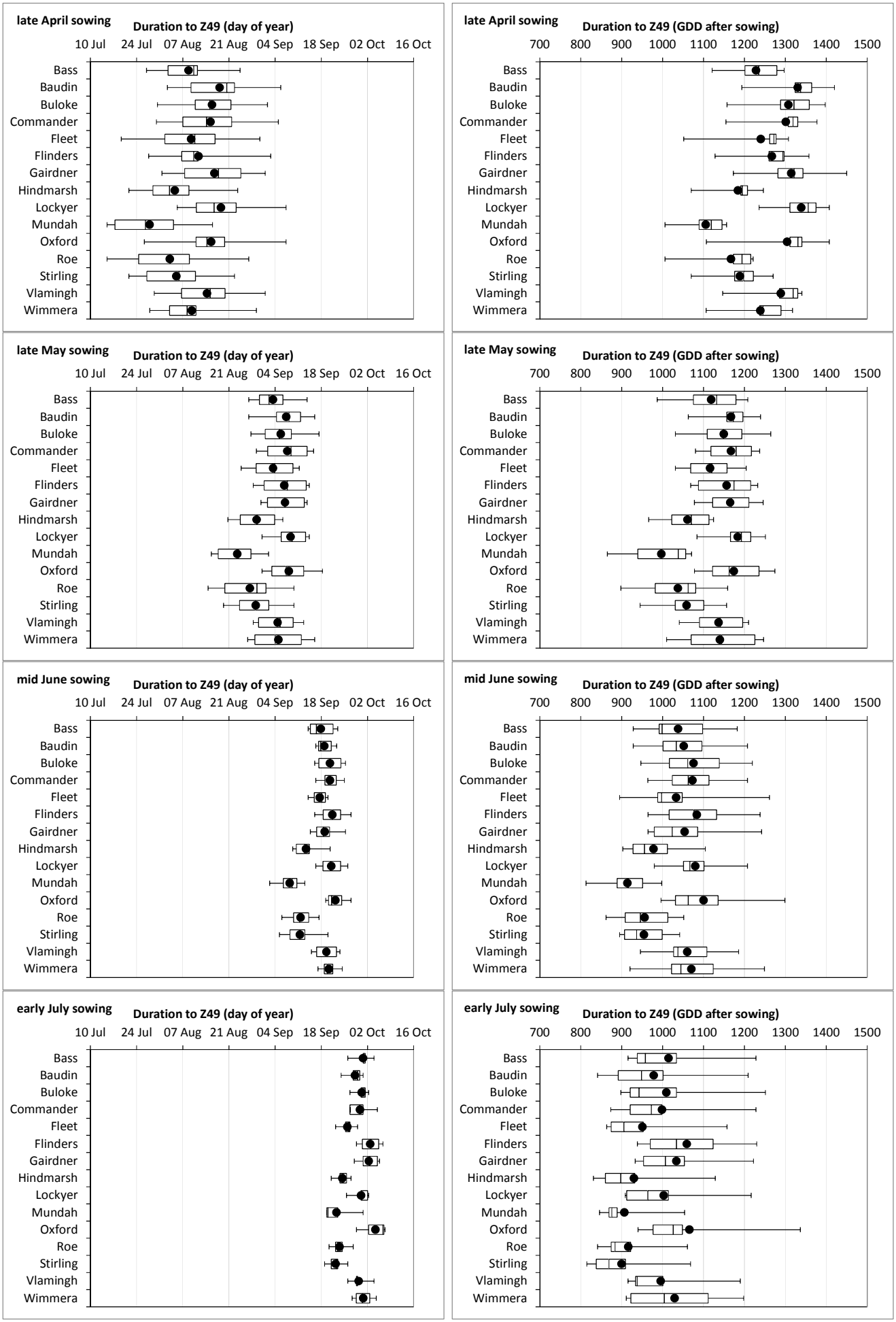

Figure 2. Boxplots of duration to awn emergence (day of year and GDD after sowing) for 15 cultivars of barley sown at Northam at four times of sowing over a six-year period 2009-2014. Solid dots are average duration.