# Predicting the mass emergence of *Vulpia bromoides*

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**Summary** *Vulpia bromoides* (L.) Gray (hair grass) is a serious grass weed of New Zealand cereal crops, contaminating seed and reducing yield. Optimal management of this weed may be achieved when the environmental factors that affect its emergence are well understood. Emergence may then be predicted and manipulated through land management techniques, e.g. through the promotion of germination (irrigation) or the prevention of it (soil inversion), thus enabling optimisation of weed control. The hydrothermal time for germination of *V. bromoides* was determined in order to better understand when germination and emergence occurs and how environmental conditions including soil temperature (T) and water potential (Ψ) may influence this. The germination profile of *V. bromoides* was determined on a thermogradient table. Seeds were also incubated under constant factorial combinations of temperature and water potential in order to better understand the water potential required for the germination of this species. The rate of germination of *V. bromoides* was slowest from 5 to 7°C and most rapid from 13 to 32°C. At temperatures of 5 to 15°C *V. bromoides* experienced reduced germination rates at water potentials between –0.75 to –1.00 MPa. At temperatures of 20 and 25°C *V. bromoides* germinated rapidly across all of the water potentials assessed. These results will inform the development of optimised weed management on farm.

**Keywords** Hair grass, hydrothermal time, germination, base temperature.

## INTRODUCTION

Grass weeds such as *Vulpia bromoides* (L.) Gray (hair grass) are a continuing problem in New Zealand cereal crops, especially in the eastern South Island. Reduced tillage systems favour winter annual grasses which, as with *V. bromoides*, have short lived seeds with little innate dormancy (germinate readily). Reduced tillage systems especially favour winter annual grass weeds because seed remains in the top layer of soil (not buried with soil inversion) which favours germination (Melander *et al.* 2013). Reduced tillage though is common practice due to benefits of soil quality and, at least until recently, herbicides successfully controlled most weeds. Cases of herbicide tolerance by *V. bromoides* and herbicide resistance by *Lolium* spp. (Gunnarsson *et al.* 2017) as well as market demands for reduced herbicide use are fuelling investigations into alternative methods of weed management (Melander *et al.* 2013).

Seed germination and seedling emergence is arguably the most important phenological event that influences the success of a weed (Benech-Arnold *et al.* 2000, Forcella *et al.* 2000). As such, weed management strategies often focus on the seeds and seedlings of problem weeds, as this is when they are most easily controlled (Bradford 2002). Soil temperature, soil water, soil air and light quality are the main environmental factors affecting seedling emergence, factors which may be manipulated indirectly through land management techniques which either promote germination (irrigation) or prevent it (soil inversion) (Forcella *et al.* 2000). The ability to predict weed emergence could facilitate the implementation of effective weed management by optimising the timing of weed control (Dastgheib and Poole 2010, García *et al.* 2013).

Seeds germinate across a temperature range that can be defined in terms of three cardinal temperatures, the base ($T_b$), the optimum ($T_o$) and the maximum ($T_m$) (Monks *et al.* 2009). The cardinal temperature range represents species-specific responses to environmental conditions and can be used to predict the time of germination and emergence of weeds (Moot *et al.* 2000a, Alvarado and Bradford 2002).

Water availability is similarly an important factor controlling germination. Changes in soil water content affect the soil water potential and are directly involved in water transport to germinating seeds such that base water potential ($\psi_b$) is also required to predict germination and emergence of weeds (Bloomberg and Watt 2008, Bloomberg *et al.* 2009, Guillemin *et al.* 2013).

To determine the germination emergence period of *V. bromoides* in New Zealand cereal cropping two separate experiments were performed in the laboratory. The first was to determine the temperature profile and the second was to determine the water potential required for germination of this species.

## MATERIALS AND METHODS

**Preparation of seed** Seed was supplied by the Foundation for Arable Research in 2015. The initial seed quality was assessed following the standards set in the International rules for seed testing (ISTA 2015): this included an assessment of purity, germination and seedling health.

The initial seed germination was assessed by germinating four replicates of 50 seeds on steel blue seed germination blotters (Anchor Paper Company, St. Paul, Minnesota) at alternating temperatures of 20°C for 16 hours with no light and 30°C for eight hours with light (ISTA 2015). A seedling was scored as normal when it showed a well-developed healthy primary root, a coleoptile free of splits at the base or less than one-third the coleoptile length if split from the top, and an intact primary leaf emerging through the coleoptile (ISTA 2009).

**Cardinal temperature range** A Grant Temperature Gradient Plate (Grant Instruments Limited, Cambridge, United Kingdom) was used to determine the cardinal temperature range for germination. The temperature gradient plate was set to run a one-way gradient, using a temperature range of 5°C to 35°C. A single layer of K-22 Kimpak® (Anchor Paper Company, St. Paul, Minnesota) that had been soaked in water was placed on the plate surface and two layers of steel blue seed germination blotters, also soaked in water, placed on top. The minimum and maximum temperatures on the plate were verified by measuring the temperature on the germination blotters at each end of the plate with a calibrated thermometer. The plate was located in a laboratory and received natural light.

The plate was split into two blocks. Each block was divided into three sub-blocks and one species randomly assigned to each sub-block. Fifty seeds were placed at even increments up the plate with each increment representing a 1°C change in temperature. Seed germination was assessed twice on the plate to provide data from four blocks in total. Germination on the plate was scored as radicle emergence. Germinated seeds were left on the plate until normal development of the emerging seedling could be seen.

Once germination had slowed on the plate (after 30–40 days) the plate was set to run at 21°C at one end and 24°C at the other, and remaining un-germinated seed allowed to germinate for at least a further 30 days. Any seed that had not germinated on the plate after 30 days was then determined as not-viable.

**Hydrothermal time to germination** Seed were incubated for up to 42 days in constant controlled factorial combinations of temperature; 5, 10, 15, 20, and 25°C and water potentials 0, −0.10, −0.30, −0.50, −0.75 and −1.00 (±0.05 MPa). Solutions with different water potentials were created using polyethylene glycol (PEG) as described by Hardegree and Emmerich (1990). The water potential of the solutions was checked using a VAPRO vapour pressure osmometer at the start of the experiment and again at the end to ensure that the osmotic potential of the solutions did not change significantly due to evaporation during the experiment.

Lidded containers (264 × 238 × 85 mm) were filled with 65 mL of each of the six different solutions. Four pre-soaked Whatman Grade 181 90 mm seed grade filter papers, were placed into the containers on top of cut glass squares (80 × 80 × 3 mm), so that they were touching but not free floating in the solution. Fifty seeds were counted onto the filter paper within these containers. Containers were carefully sealed and placed into the incubators held at the different temperatures.

Seed germination was counted, initially every few hours as germination commenced and peaked, and then as germination slowed these were checked once a day and finally once every two days. Seed were considered to have germinated when the radicle protruded more than 2 mm from the seed coat and were discarded immediately after counting. The containers were left in the incubators for up to six weeks or when all seed within them had germinated.

**Statistical analysis** All germination data was transformed (arcsine square root transformation) prior to analysis. A test for normal distribution (Kolmogorov-Smirnov) was applied to all data after transformation, where $P \geq 0.05$ was considered normal distribution. For data not normalised by the transformation, a non-parametric ANOVA was used to analyse the data, followed by the Bonferroni (Dunn) t-test for multiple comparisons. For germination data that was normally distributed after the arcsine square root transformation when a significant treatment effect was observed, treatment means were compared using the Tukey test.

## RESULTS

**Initial seed quality** The *V. bromoides* seed was contaminated with an *Agrostis* sp., the seed was cleaned and the percentage of normal germination was recorded as 98%. The remaining 2% was made up of either dead or underdeveloped seed.

**Cardinal temperature range** Germination was high, reaching 96–98% between 8–28°C. The seed was able to germinate over the entire temperature range assessed, indicating that the base temperature

of *V. bromoides* is below 5°C. There was no significant difference in germination percentage of *Vulpia* seed between 5°C and 32°C but germination began to decline after 32°C dropping from 80% at 32°C to 60% at 33°C and down to 7% at 35°C. The rate of germination of *V. bromoides* was slowest from 5–12°C and above 32 °C. Faster rates were seen between 13–32°C (Figure 1).

**Hydrothermal time to germination** The lowest water potential (−1.00 MPa) was not able to prevent germination. Germination was significantly slower when exposed to the more severe reductions in water potentials (−0.75 and −1.00 MPa) at the lower temperatures of 5 and 10°C, where the time to 50% germination was unable to be measured as 50% germination was not reached (Figure 2). The study also found that at the higher temperatures of 20 and 25°C, the water potentials tested here were not severe enough to restrict germination. This indicates that the optimal germination temperature range is between 15–25°C (Figure 2).

## DISCUSSION

The base temperature of *V. bromoides* was not determined from this study. The base temperature of the closely related *V. myuros* (L.) C.C. Gmel. was determined by Monks *et al.* (2009) as 3.4°C although Scherner *et al.* (2017) determined 0.6°C. Other studies have also determined that it is not unusual for winter annual grass species to germinate from as low as 0°C (Moot *et al.* 2000b). It is reasonable to suggest that the base temperature of *V. bromoides* would be similar.

Ball (2008) also found that germination of *V. myuros* declined at temperatures above 35°C. Monks *et al.* (2009) found a lower maximum temperature (25°C) at which germination percentage began to decline. In our study, it was not until the temperature increased above 31°C that abnormal seedling development of *V. bromoides*, predominantly stunted or no seedling roots, increased. Abnormal seedlings when observed above 31°C ranged from 2–20% (average 12%). Monks *et al.* (2009) also found a similar decline in germination rate at 30°C. In this study, germination was 60% at

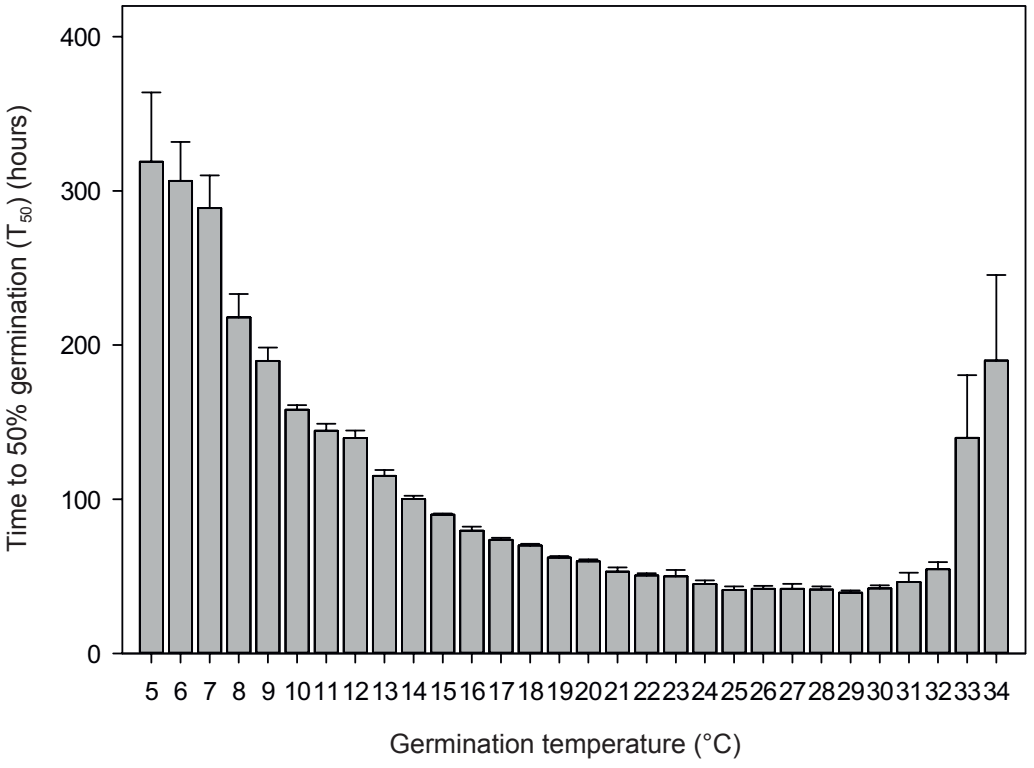


**Figure 1.** Time to 50% germination of *Vulpia bromoides* seed at a range of temperatures from 5°C to 34°C. Bars are the standard error of the mean.

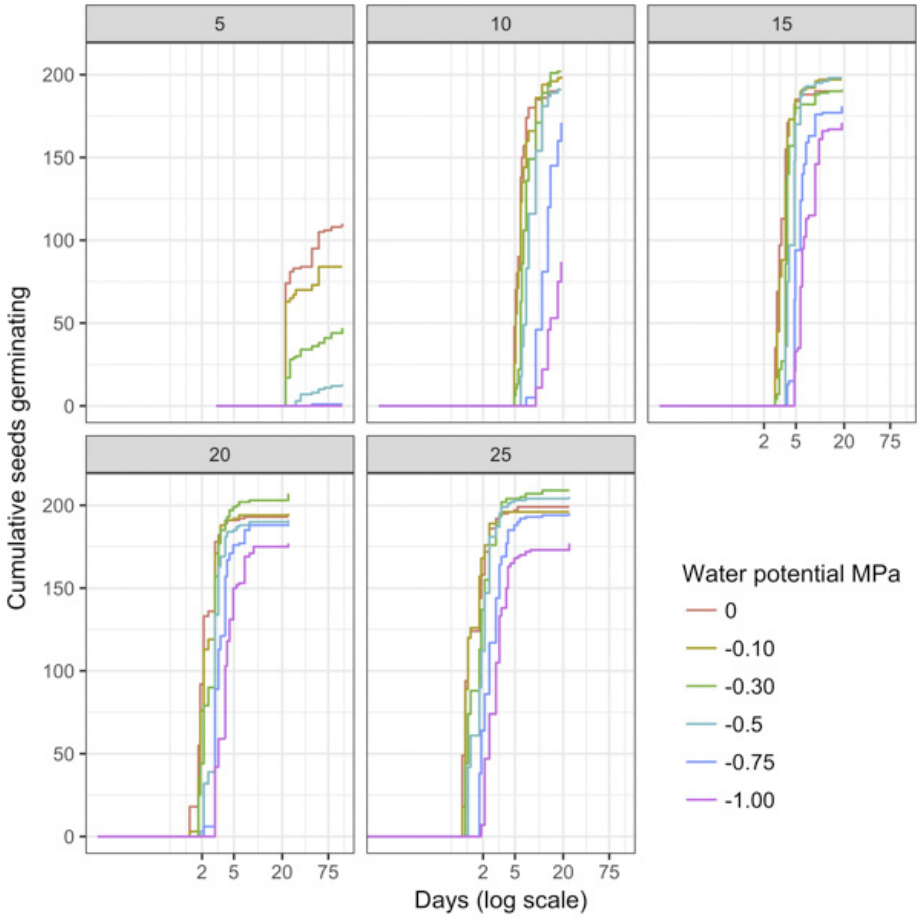


**Figure 2.** Cumulative numbers of *Vulpia bromoides* seed germinating over time (200 were planted) under different temperatures 5, 10, 15, 20 and 25°C (panels) and under exposure to normal or reduced water potentials (legend).

33°C and 33% at 34°C declining to only 7% at 35°C, suggesting that the seed was under stress at these higher temperatures.

Germination of *V. bromoides* occurred at the fastest rate between 13 and 32°C. The hydrothermal time to germination study found that reductions of water potential were not limiting to percentage germination inside this range either. Though this was not always the case; often high or low potentials are very limiting at all temperatures.

Cordeau *et al.* (2018) found that *V. myuros* is capable of tolerating fairly extreme hydric stress. Similarly, *V. bromoides* is able to tolerate reductions in water potential well, with germination possible across all reductions of water potential examined in this study.

Weed seed banks are the primary source of annual weed infestation in most crop production systems and can be depleted through germination, predation, or death. In New Zealand *V. bromoides* will shed seed in mid-summer. Seeds typically remain dormant for up to three months but germinate readily following rainfall during March through to May (Dillon and Forcella 1984, FAR 2008). In Canterbury the average temperature and rainfall during this time is: March – 16°C and 45 mm; April – 13°C and 46 mm; and May – 10°C and 64 mm (NIWA 2018).

Our data show that germination rates are slower in cool and dry conditions (Figure 2). The amount of seed germinated over 100 days at 5°C was less than half that observed at 10°C. Unfortunately this is not enough to prevent hair grass establishment in winter crops. The

soil seed bank is known to be short lived and only a small proportion, 1–7% may survive for three years (FAR 2008). Using the stale seed-bed approach, with good irrigation in early autumn, while temperatures are high and before the winter crop is sown, will be a quickly effective method to deplete the seed bank, given any remaining seed should be short lived. Our study showed that close to 100% *V. bromoides* will germinate between 20–25°C (Figure 1) especially under low hydric stress (Figure 2). Normal 2–3 month delays in seed ripening could reduce the effectiveness of this approach, and give farmers problems later in the season. Therefore monitoring of seed-shed (and preventing seeding) is important for the success of this management strategy.

Other authors suggest that ongoing issues with winter annual grass weeds are best managed by making (temporary) changes from reduced to conventional tillage systems, and by rotating crop species (Melander *et al.* 2013). Growing broad-leaf crops during summer could give farmers access to better chemical control options, and provide better crop to weed competition scenarios.

## ACKNOWLEDGMENTS

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