

Dormancy in grass weeds

August 2012



Project Report No. 498

Dormancy in grass weeds

by

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This is the final report of a 40 month project (RD-2006-3336) which started in July 2007. The work was funded by a contract for £192,231 from HGCA.

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1. ABSTRACT

Innate or primary dormancy is a natural condition that develops as the seed matures. It prevents premature germination of the seed whilst it is still attached to the plant or just after shedding and allows for dispersal of the seed from the parent plant.

A range of controlled environment and small plot experiments were done between 2007 and 2010 to provide the farming industry with an annual forecast of dormancy in black-grass, Italian ryegrass, barren, meadow, rye and soft brome and to understand the implications of dormancy on emergence patterns. Results from the dormancy testing were released to the press annually in late August. These contained specific management principles so that farmers and agronomists could adjust cultivation method and timing, drilling date and herbicide programmes to accommodate the effect dormancy would have on black-grass emergence.

Seed of black-grass, Italian ryegrass, barren and meadow brome were collected from winter wheat fields in July when 10-30% of seeds had already been shed. Germination tests were done on the seed according to a strict protocol. A population was termed more dormant or as having high dormancy when, given the ideal growing conditions a low percentage of seeds germinated. Conversely, a population was termed less-dormant or with low dormancy when a high percentage of seeds germinated in the test. The dormancy level of black-grass seed was low when June and July had been warm and dry and high when this period was cold and wet. Dormancy in Italian ryegrass, meadow brome and barren brome was unaffected by weather conditions during seed ripening.

In black-grass, emergence of high dormancy seed was delayed when compared to seed of low dormancy. The knowledge of changes in emergence patterns can be used to adapt the management strategies adopted by growers to improve black-grass control. The emergence patterns of Italian ryegrass, meadow brome and barren brome were unaffected by dormancy level; all species emerged rapidly during the autumn.

To reduce the cost of annual dormancy forecasting, nine years of black-grass dormancy results from 367 sites were collated. A weather data for each site was created and a window pane analysis was done. This type of analysis looks for the period of weather that has the greatest effect on dormancy. Black-grass dormancy was affected by both average temperature 20-39 days after flowering, and rainfall 4-12 days after flowering. Only 31% of the variation was accounted for and this indicated that there was a strong level of genetic control in addition to the weather affects. The correlation can be used to give an indication of the level of dormancy expected for the season but some field sampling will be necessary.

2. SUMMARY

2.1. Introduction

The test for assessing dormancy in black-grass was developed in the LINK project 'Improving profitability by using minimum cultivations and exploiting grass weed ecology' (LK0923/HGCA 2469). Innate or primary dormancy is a natural condition that develops as the seed matures. It prevents premature germination of the seed whilst it is still attached to the plant or just after shedding and allows for dispersal of the seed to avoid possible poor growing conditions around and competition from the parent plant. Results from the dormancy tests done in the previous project indicated that temperature had a significant part to play in determining seed dormancy. Warm or hot summers during the period of seed maturation led to reduced dormancy in the seed produced.

This project aimed to continue to provide annual information on black-grass dormancy to the industry and also to extend the dormancy prediction to other difficult to control grass species – Italian rye-grass (*Lolium multiflorum*), barren brome (*Anisantha sterilis*) and meadow brome (*Bromus commutatus*). The objectives were:

1. To provide an annual forecast of black-grass dormancy to the farming industry.
2. To assess and report on dormancy in Italian rye-grass, barren brome and meadow brome.
3. To understand the implications of dormancy on emergence patterns and to allow optimisation of black-grass management.
4. To reduce the cost of providing an annual dormancy forecast.

2.2. Annual dormancy forecasting of black-grass, Italian ryegrass, barren brome, meadow-brome and rye brome (objectives 1 and 2)

2.2.1. Method

Seeds of black-grass (*Alopecurus myosuroides*), Italian rye-grass (*Lolium multiflorum*), barren brome (*Anisantha sterilis*) and meadow brome (*Bromus commutatus*) were collected from winter wheat fields in July 2007, 2008, 2009 and 2010 when about 10-30% of seeds had already been shed.

For all species, germination tests were initiated within seven days of seed collection. Germination was determined by placing 50 seeds in 9 cm Petri-dishes containing three cellulose filter papers (Whatman Number 1) covered by one glass-fibre filter paper (Whatman GF/A) and adding 7 ml KNO₃ (2 g/l in deionised water) per dish. For each sample tested, four replicate dishes were used. They were placed in sealed transparent polythene bags in an incubator with a light (17°C, 14 h) and a dark (11°C, 10 h) phase. The number of seeds that had germinated within two weeks was

recorded and used as a measure of the proportion of non-dormant seeds in the sample. All germination data were corrected before analysis to account for differences between samples in the proportion of seeds containing a caryopsis (a dry one-seeded fruit united with the seed coat). A population was termed more dormant or as having high dormancy when, given the ideal growing conditions outlined above, a low percentage of seeds germinated. Conversely, a population was termed less-dormant or with low dormancy when a high percentage of seeds germinated in the Petri-dish test.

Meteorological records were collated for eleven recording centres across England, representative of the original (2001-2006) seed-sample collection sites. The meteorological parameters used were maximum and minimum daily temperatures (°C) and daily rainfall (mm). For comparative purposes, 30 year means (1975-2004) have been used for all recording centres.

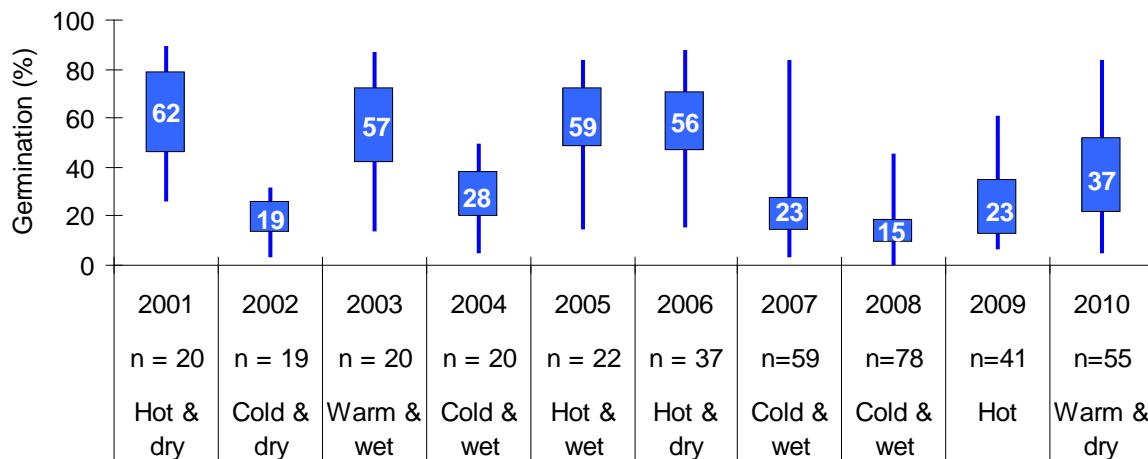
2.2.2. Results

Black-grass

Although the period covered in this study was 2007-2010, the results of the dormancy assessments for 2001 to 2006 data have been included to provide the fullest possible picture of the dormancy levels in black-grass experienced throughout 10 years of study (Summary Figure 1). The last four years have resulted in high levels of dormancy with the highest level experienced in 2008. The original work (2001 to 2006) identified that dormancy levels in the seed were related to weather conditions during maturation of black-grass seed between 15th June and 12th July.

Meteorological records were collated for eleven recording centres across England. For each of the weather stations, the average for the period 15th June to 12th July was calculated and then compared to the 30 year mean (1975-2004). The difference between the weather parameter and the long term mean were classified as follows:

Temperature classification	Difference to 30 year mean (°C)	Rainfall classification	Difference to 30 year mean (mm)
Cold	Equal to or less than 0	Wet	Greater than or equal to 0.1
Warm	Between 0 and 1.4	Dry	Less than -0.1
Hot	Between 1.4 and 2.9		



Summary Figure 1. Dormancy patterns in black-grass 2001-2010 (For each year the graph shows maximum and minimum values, the lower and upper quartiles, the mean (written in) and on the X axis, the number of samples and a categorisation of the weather for the period 15th June to 12th July).

Using this simple method there were strong indicators that dormancy in black-grass was lower in warm, dry years and higher in colder wetter years. However, this method did not correctly describe the level of dormancy measured in 2009 and 2010. The weather during the critical period (15th June to 12th July) followed a similar pattern in 2009 and 2010, being colder than the average for all cold years during the first half of the period and warmer than the average for all the hot years in the second half.

Italian rye-grass

Dormancy in Italian rye-grass was measured in ten or fewer samples per year between 2008 and 2010. There was no a clear indication that dormancy level can easily be linked to weather conditions during the same period as black-grass. Dormancy in Italian rye-grass was always lower than that of black-grass in the same year.

Barren brome

Dormancy levels of barren brome were similar in all years. There was more difference between samples in a single year than between years, for example at Boxworth samples were collected from two fields in a single year and dormancy was found to be 0% in one population and 100% in the other. There seemed to be no link to weather conditions during seed maturation.

Meadow brome

Identification of meadow brome proved to be difficult and was only completed after all samples had been grown on and identified in the following year. There was a wide range of dormancy levels between populations and, as with barren brome, there seemed to be no relationship with the weather during June and July.

Soft brome

Few soft brome samples were collected, dormancy was low in both 2007 and 2008 but varied between populations. It was not possible to link weather conditions during June and July with dormancy level.

Rye brome

Rye brome seems to be more common than first thought and where it occurs it can be a serious problem and difficult to control. Initial dormancy done within seven days of collection was always exceptionally high and not linked to weather during June and July.

2.3. Understanding the implications of dormancy on emergence patterns and allowing optimisation of black-grass management (objective 3)

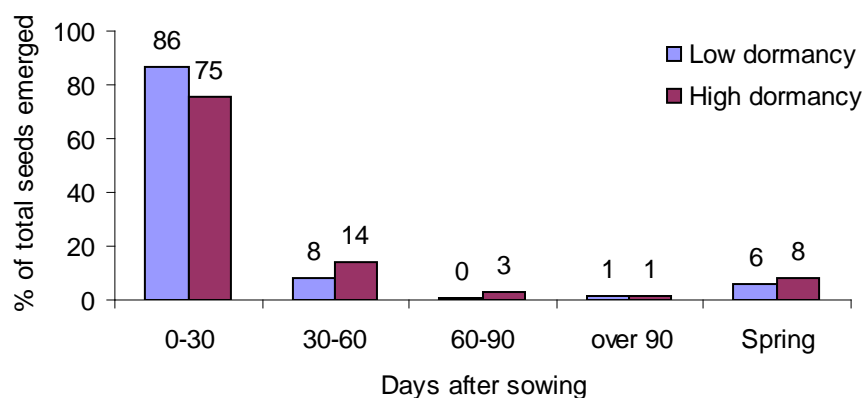
2.3.1. Method

In 2007, 2008 and 2009 seed from black-grass, Italian rye-grass, barren brome, meadow brome, rye brome and soft brome at different dormancy levels were sown into sterilised Kettering loam in containers on 21 September and 21 October and kept outdoors. Seed had been stored at 18°C and 50% relative humidity since collection.

2.3.2. Results

Black-grass

The greatest proportion of black-grass seed emerged during the first 30 days after sowing; this was greater with low dormancy seed (86%) than high dormancy seed (75%) (Summary Figure 2) During the 30-60 and 60-90 day periods more high dormancy seed emerged than low dormancy seed. Spring emergence was greater in high dormancy seed.



Summary Figure 2. Seasonal pattern of emergence for black-grass of different dormancy levels sown in containers (Percentage of total emergence that occurred in each timeframe)

Italian rye-grass, barren brome, meadow brome, rye brome and soft brome

Emergence in all species began approximately 10 days after sowing. In Italian rye-grass there was little difference in the speed of emergence between the seedlots of different dormancy levels in a single season. Emergence was quick and reached a maximum of 65-75% at 14 days after sowing in 2007 and 24 days after sowing in 2008 when the sowing date was delayed until October and soil conditions were colder.

Barren brome emerged 10 days after sowing and was 95% emerged at 20 days. There was a slight indication that the higher dormancy seed emerged more slowly but due to the rapid and almost complete emergence, this should be of little consequence to growers.

Meadow brome emergence began 12 days after sowing and had reached a plateau seven days later, a maximum of 75% of high dormancy seed emerged and 85% of the low dormancy seed.

Rye brome had an initial germination of 0% seven days after collection but this initial dormancy was lost rapidly. Emergence began 12 days after sowing and had reached a plateau in a further seven days. Approximately 20% did not germinate.

Soft brome showed little or no initial dormancy and had emerged 11 days after sowing; emergence was complete at 15 days with 94% emergence.

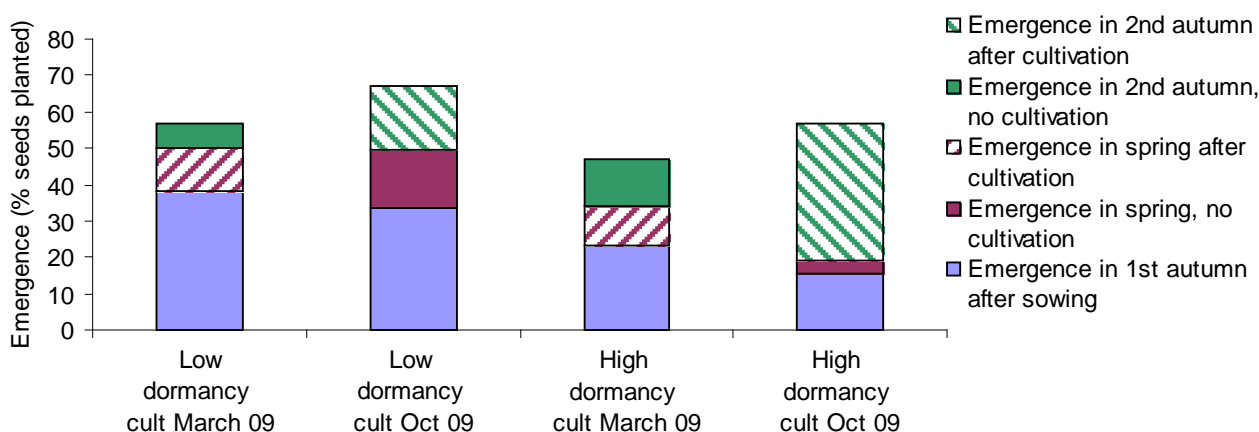
2.4. The effects of spring and autumn cultivation on black-grass seed emergence

2.4.1. Method

Two seedlots of high and low dormancy were sown into pots and the number of emerged plants was counted every 3-7 days. In the early spring (March), the existing plant material was cut at the soil surface and removed and the soil was then mixed to sowing depth (1cm). The number of newly emerged plants counted every 3-7 days. This process was repeated in October 2009.

2.4.2. Results

In the autumn of sowing, emergence was greater in the low dormancy seed than the high dormancy (Summary Figure 3). In the spring a greater amount of low dormancy seed emerged after cultivation. Cultivation in the following autumn encouraged a further flush of black-grass in both the high and low dormancy seed but this was greater in the high dormancy. Over the year a similar amount of the planted seed emerged in all treatments (56%).



Summary Figure 3. The effects of spring and autumn cultivation on the emergence of high and low dormancy black-grass seed.

2.5. Reducing the cost of annual dormancy forecasting

2.5.1. Method

Black-grass samples were collected for germination studies from 2001 to 2010 using the method detailed above. A total of 367 samples were collected and these were used to define a germination dataset containing sample identification, postcode, grid reference, altitude (m) and dormancy (% germination).

A weather dataset for each individual site year combination was created. The flowering date of each sample of black-grass was calculated using the Weed Manager growth model. Sowing date was set at 15th September.

Modelled weather, dormancy level and estimated flowering date were assembled for each sample of black-grass. A windowpane analysis was used to find the period of weather that has the greatest effect on dormancy. The analysis looks for the best correlation of weather variables with black-grass dormancy during the seed maturation period. The windowpane analysis correlated germination with each variate either averaged or summed over different numbers of days. The black-grass flowering date was used for day one of the analysis. The correlation window (windowpane) started from day 1 to 30 days after flowering. The windowpane length varied from 1 to 25 days.

2.5.2. Results

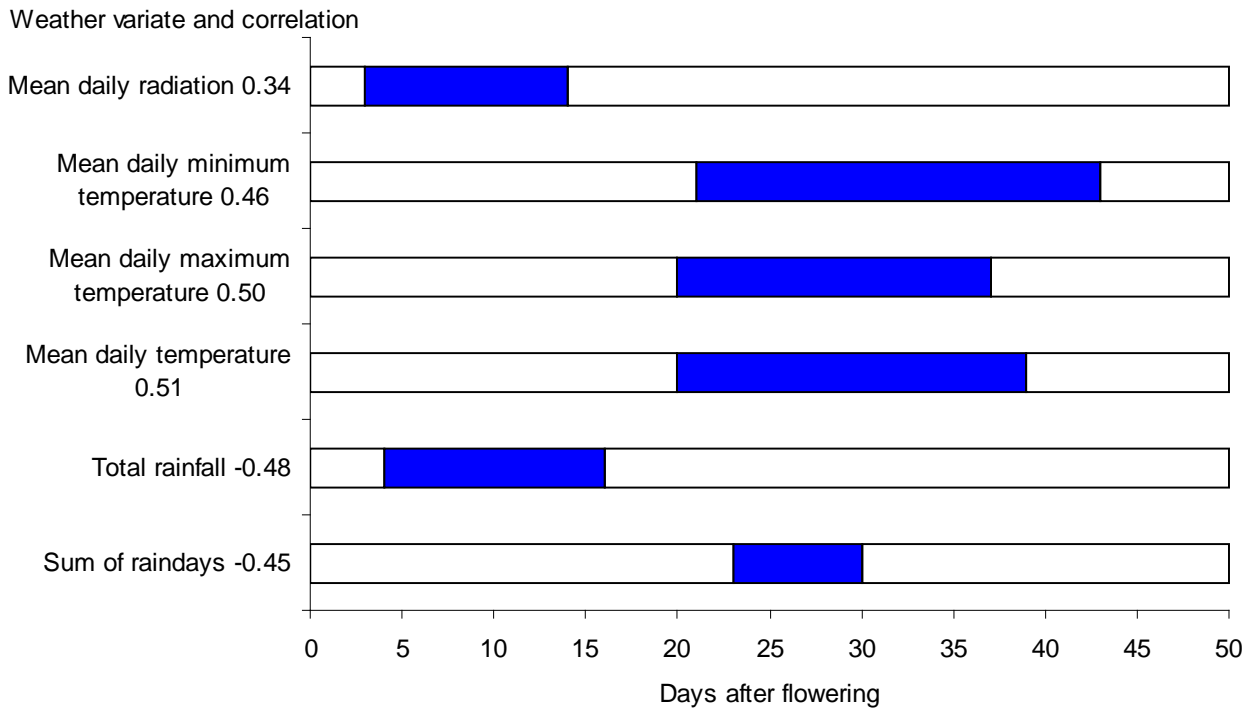
The Weed Manager growth model indicated that flowering date varied between 13th May and 5th June with most black-grass flowering between 20th and 26th May; average 22nd May. Flowering was up to 7 days later later at the northern sites.

Temperature and rainfall data had good correlation with the dormancy level of black-grass. Single periods were indicated for average temperature (11th to 30th June, based on a 22nd May flowering date) total rainfall (24th May to 7th June) and total number of raindays (14th to 21st June). The maximum correlations are summarised in Summary Figure 4.

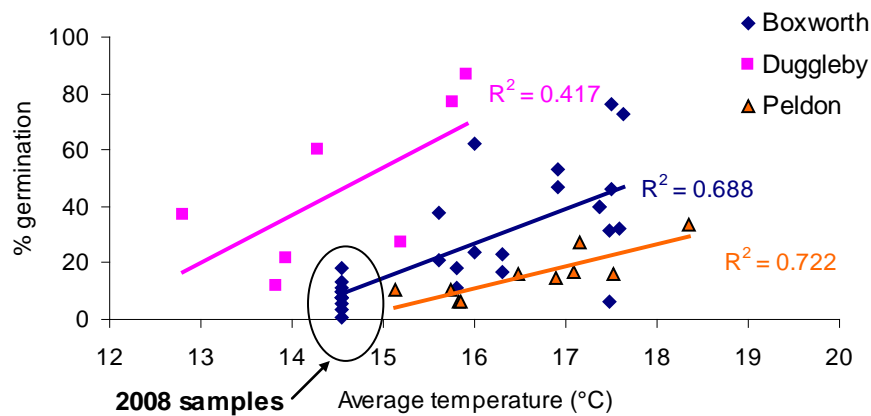
Further analysis was done on the data and average temperature was shown to be the most important factor in determining dormancy although total rainfall and the sum of raindays were important but to a lesser extent

Two thirds (69%) of the variation could not be accounted for by temperature and rainfall variates so other factors such as geographical location or local populations may be important. Three sites were selected for which there was several years' data; Boxworth, Cambs; Duggleby, North Yorkshire; and Peldon, Essex. There was a significant ($p < 0.05$) correlation between average temperature and dormancy at Boxworth and Peldon (Summary Figure 5) but for rainfall the correlations were only significant ($p < 0.001$) at Boxworth (Summary Figure 6). This may be due to localised summer rainfall events and temperature may account for more of the variation. Black-grass populations at each of the sites responded differently, for example at the same temperature at all sites the dormancy level was lower at Duggleby than at Boxworth and Peldon. There was still variation between samples collected at the same site, at Boxworth in 2008 several fields were sampled on the same day and the circled points on both graphs show the variation experienced at

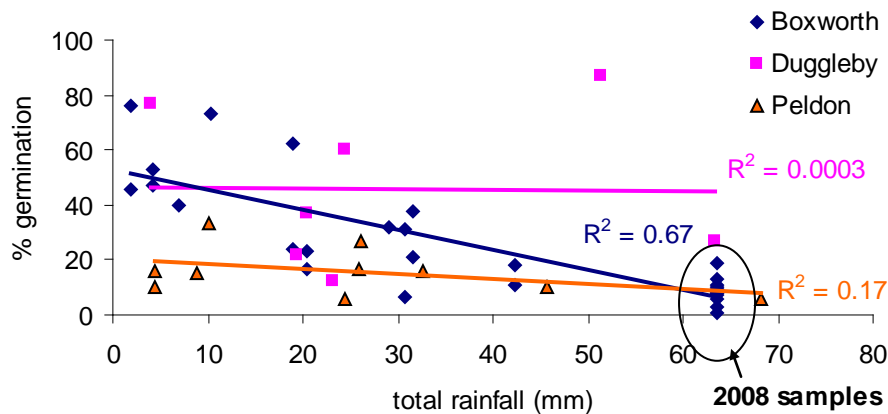
this site within a single season (Summary Figure 5 and Summary Figure 6). Because such large variation occurred within sites and between sites it is not appropriate to describe the relationship with a single multivariate formula as there is an indication of a strong level of genetic control.



Summary Figure 4. Weather periods important to determination of dormancy and the degree of correlation for the period shown



Summary Figure 5. The relationship between average temperature between 20 and 39 days after flowering and dormancy level in black-grass. Multiple samples at Boxworth in 2008 are circled.



Summary Figure 6. The relationship between total rainfall between 2 and 15 days after flowering and dormancy level in black-grass. Multiple samples at Boxworth in 2008 are circled.

2.6. Key messages for levy payers and implications of the work

2.6.1. Annual dormancy forecasting of black-grass, Italian ryegrass, barren brome, meadow-brome and rye brome (objectives 1 and 2)

An annual forecast of dormancy was issued each August containing guidelines on the most suitable crop management and herbicide strategies to best manage black-grass that season. The results indicated that dormancy in black-grass was lower when the weather during the period between 15th June and 12th July was warm and dry and higher in years when this period was colder and wet.

In Italian rye-grass there was no indication that dormancy level and temperature during the period 15th June to 12th July were related. In barren brome there was a greater difference in dormancy level between samples in a single year than between years and no link to weather conditions during seed maturity was observed.

Identification of meadow brome was difficult and it was often confused with rye and soft brome. Dormancy in the brome species was very variable between populations and there was no link to the weather in June and July.

2.6.2. To understand the implications of dormancy on emergence patterns and to allow optimisation of black-grass management (objective 3)

Black-grass

Dormancy in black-grass changes the emergence pattern of the weed. In high dormancy years emergence will be protracted with 90% of seed emerging up to 60 days after drilling. In low

dormancy years 90% of seed will emerge after only 30 days. Knowing the dormancy allows management strategies to be altered (Summary Table 1).

Summary Table 1. Options for management of black-grass in high and low dormancy years

	High dormancy	Low dormancy
Black-grass emergence	More protracted, 90% emergence 60 days after drilling	90% emergence 30 days after drilling
Management strategy		
Pre-harvest glyphosate	No effect	Check and treat if black-grass is emerging in moist conditions
Cultivations	Plough if high populations in previous crop	Non-inversion
Drilling	Early drilling encourages crop competition	Delay drilling for maximum weed emergence
Pre-emergence herbicide	Use a robust mixture with a high residual component	Apply immediately after drilling
Post-emergence herbicide	Could be delayed but add a residual to cover protracted emergence	Apply early when emergence is complete

Italian ryegrass, barren, meadow, rye and soft brome

The majority of Italian rye-grass seed germinates in the autumn and dormancy has little effect on emergence patterns. Emergence of barren, meadow, rye and soft brome is very rapid during the autumn. There was no effect of dormancy level on emergence. Management strategies that encourage rapid weed emergence should be used, delaying drilling until weeds have emerged and been sprayed off with a non-selective herbicide. After drilling, an appropriate robust pre-emergence herbicide should be applied.

2.6.3. To reduce the cost of providing an annual dormancy forecast for black-grass (objective 4)

Analysis of the complete data set showed that the average temperature in the period between 11th and 30th of June was important in the determining the dormancy of black-grass at harvest. The amount of rainfall received between 26th May and 3rd June was also important but both of these parameters together only accounted for 31% of the variation on dormancy level. This correlation can be used to give an indication of the level of dormancy for the season but some field sampling will be necessary to give a more reliable indication of the dormancy for that season.

3. TECHNICAL DETAIL

3.1. Introduction

The LINK project 'Improving profitability by using minimum cultivations and exploiting grass weed ecology' (HGCA project report 381) finished in August 2005 and within this project a test for assessing dormancy level in black-grass (*Alopecurus myosuroides*) was developed (Cook *et al.*, 2006). Innate or primary dormancy is a natural condition that develops as the seed matures. It prevents premature germination of the seed whilst it is still attached to the plant or just after shedding and allows for dispersal of the seed to avoid possible poor growing conditions around and competition from the parent plant. Results from the dormancy tests done in the previous project indicated that temperature had a significant part to play in determining seed dormancy. Warm or hot summers during the period of seed maturation led to reduced dormancy in the seed produced. Soil moisture appeared to be important but had a lesser effect. Seed samples were collected from 20 fields, over a wide geographical area each year and the results were consistent showing that seed dormancy was higher in summer 2002 and 2004 than in 2001, 2003, and 2005 and this related well to weather patterns. The information on the dormancy status of black-grass meant that strategic cultivation and drilling decisions could be made to maximise seed losses pre-drilling by exploiting this weakness of black-grass ecology. The provision of dormancy information in black-grass on an annual basis has provided a valuable service to the arable farmers where black-grass is a problem.

This new project aimed to continue to provide annual information on black-grass dormancy to the industry and also to extend the dormancy prediction to other difficult to control grass species – Italian rye-grass (*Lolium multiflorum*), barren brome (*Anisantha sterilis*) and meadow brome (*Bromus commutatus*). This will help growers to understand what affects dormancy in these species and how their management might be improved in the subsequent crop. Another part of the project was to look at the implications of dormancy on emergence patterns to allow the optimisation of black-grass management and allow better prediction of herbicide strategies. The final part of the project was to use the information from ten years of dormancy testing and to assess whether a dormancy prediction system was possible, based on weather data during seed maturation.

3.1.1. Project aim

To provide annual information on black-grass dormancy to the industry, extend the dormancy prediction to other difficult to control grass species and improve prediction of herbicide strategies.

3.1.2. Objectives

1. To provide an annual forecast of black-grass dormancy to the farming industry.
2. To assess and report on dormancy in Italian rye-grass, barren brome and meadow brome.
3. To understand the implications of dormancy on emergence patterns and to allow optimisation of black-grass management.
4. To reduce the cost of providing an annual dormancy forecast.

3.2. Annual dormancy forecasting of black-grass, Italian ryegrass, barren brome, meadow-brome and rye brome (objectives 1 and 2)

Annual dormancy levels of black-grass have been produced since 2001, the objective was to continue this annual forecasting to the farming industry and to include dormancy levels of Italian rye-grass, barren brome and meadow brome. Every dormancy forecast was accompanied by guidelines on cultivation methods and date of drilling.

3.2.1. Materials and methods

Sample collection

Seeds of black-grass (*Alopecurus myosuroides*), Italian rye-grass (*Lolium multiflorum*), barren brome (*Anisantha sterilis*), meadow brome (*Bromus commutatus*) and rye brome (*Bromus secalinus*) were collected from winter wheat fields in July 2007 to 2010 when about 10-30% of seeds had already been shed. Ripe seed from the grasses were removed from the head by gently rubbing or shaking them over a polythene bag, tray or envelope to detach the ripe seeds. Seed were collected from an area of about 100m by 2-3 tramlines. Collectors were asked to place the seed in a paper envelope provided and leave to dry for 24 hours before sending to ADAS Boxworth.

In the laboratory, before conducting viability and germination tests, samples were cleaned in an air column separator to remove most of the empty seeds and debris. A minimum airflow was used and checks were made to minimise loss of seeds. Viability was estimated by dissecting 50 random seeds per sample and recording the total number of caryopses present. The testing was identical to that used in the SA LINK project 0923 (Cook *et al.*, 2006).

The initial plan was to collect seed from 20 sites but due to the high level of interest from the industry, seed was sent in from farmers, agronomists and agrochemical representatives from a greater number of sites. The numbers of samples collected are detailed in Table 1. In some years less than 20 samples were collected for each species due to availability in the field.

Table 1. Number of samples collected each year.

Species	2007	2008	2009	2010
Black-grass	59	116	43	55
Italian rye-grass	25	8	8	4
Barren brome	17	20	11	10
Meadow brome	15	7	6	8
Soft brome	2	5	0	1
Rye brome	10	7	1	5
Total	128	163	70	83

Species identification

When meadow brome samples were received for assessment of dormancy it became clear that they had not all been identified correctly. From 2008 onwards collectors were asked to submit a head of the grass for more formal identification. Identification proved difficult from the head alone and in autumn 2008 all samples of meadow, rye (*Bromus secalinus*) and soft brome (*Bromus hordeaceus*) were sown into 1 litre pots and placed in a net covered pot-standing area. Throughout the growing season and at heading the samples were formally identified to species using keys (Cope & Gray, 2009; Hubbard, 1992).

Germination tests

For all species, germination tests were initiated within seven days of seed collection and results were corrected to account for differences between samples in the proportion of seeds containing a caryopsis. Germination was determined by placing 50 seeds in 9 cm Petri-dishes containing three cellulose filter papers (Whatman Number 1) covered by one glass-fibre filter paper (Whatman GF/A) and adding 7 ml KNO₃ (2 g/l in deionised water) per dish. For each sample tested, four replicate dishes were used. They were placed in sealed transparent polythene bags in an incubator with a light (17°C, 14 h) and a dark (11°C, 10 h) phase. The number of seeds that had germinated within two weeks were recorded and used as a measure of the proportion of non-dormant seeds in the sample. All germination data were corrected before analysis to account for differences between samples in the proportion of seeds containing a caryopsis. Maximum, minimum, mean, median and upper and lower quartiles of the data were done using GenStat.

A population is termed more dormant or has high dormancy when, given the ideal growing conditions outlined above, a low percentage of seeds germinate. Conversely, a population is less dormant or has low dormancy when a high percentage of seeds germinate in the Petri-dish test.

Weather records

Meteorological records were collated for eleven recording centres across England, representative of the original (2001-2006) seed-sample collection sites. The recording centres, for all years were Rothamsted Research, Harpenden (Hertfordshire); Marham, Norfolk; Morley, Norfolk (2001-2005); Colchester, Essex (2005-2010); Maidenhead, Berks and six ADAS sites; Boxworth (Cambridgeshire), Drayton (Warwickshire), Gleadthorpe (Nottinghamshire), High Mowthorpe (North Yorkshire), Rosemaund (Herefordshire), and Terrington (Norfolk). The meteorological parameters used were maximum and minimum daily temperatures (°C) and daily rainfall (mm). For each of the weather stations the average for the period 15th June to 12th July was calculated and then compared to the 30 year mean (1975-2004).

The difference between the weather parameter and the long term mean were classified as follows:

Temperature classification	Difference to 30 year mean (°C)	Rainfall classification	Difference to 30 year mean (mm)
Cold	Equal to or less than 0	Wet	Greater than or equal to 0.1
Warm	Between 0 and 1.4	Dry	Less than -0.1
Hot	Between 1.4 and 2.9		

3.2.2. Results and discussion

Black-grass

Although the period covered in this study was 2007-2010, data from the dormancy assessments for 2001-2005 (Cook *et al.*, 2006, Cook & Brooke, 2006) have been included to provide the fullest possible picture of the dormancy levels in black-grass experienced throughout 10 years of study (Figure 1). The last four years resulted in high levels of dormancy with the highest level experienced in 2008. Press releases were issued each year and these can be found in the Appendix.

The original work identified that dormancy levels in the seed were related to weather conditions during maturation of black-grass seed between 15th June and 12th July (Swain *et al.*, 2006). Weather data from 2001-2010 is shown in Figure 2.

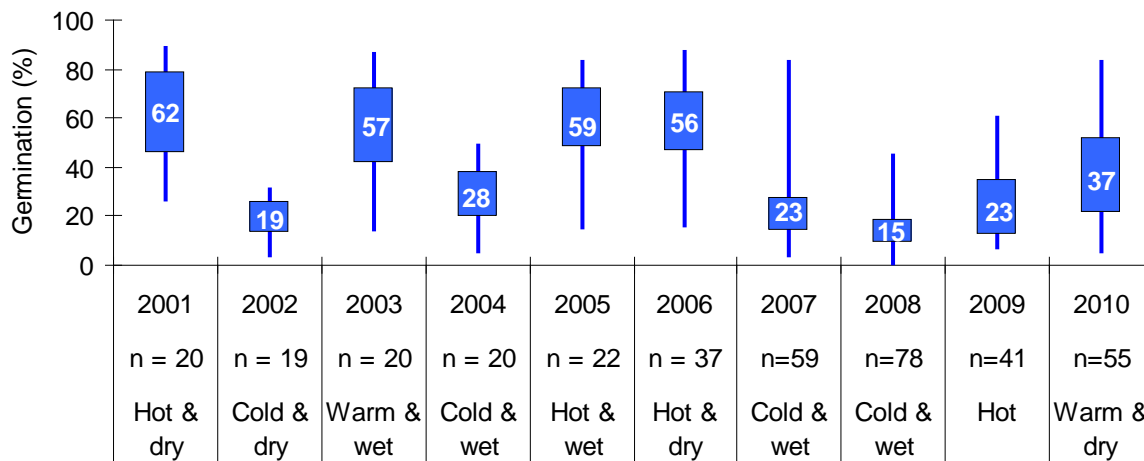


Figure 1. Dormancy patterns in black-grass 2001-2010 (For each year the graph shows maximum and minimum values, the lower and upper quartiles, the mean (written in) and on the X axis the number of samples and a categorisation of the weather for the period 15th June to 12th July).

There were strong indicators that dormancy in black-grass was lower in warm, dry years and higher in colder wetter years. However, the simple method described above did not correctly describe the level of dormancy measured in 2009 and 2010. The weather during the critical period followed a similar pattern in 2009 and 2010, being colder than the average for all cold years during the first half of the period and warmer than the average for all the hot years in the second half (Figure 3).

The current project has taken all of the data from ten years of dormancy work and looked at the factors affecting dormancy in greater detail. This is presented in Section 4.

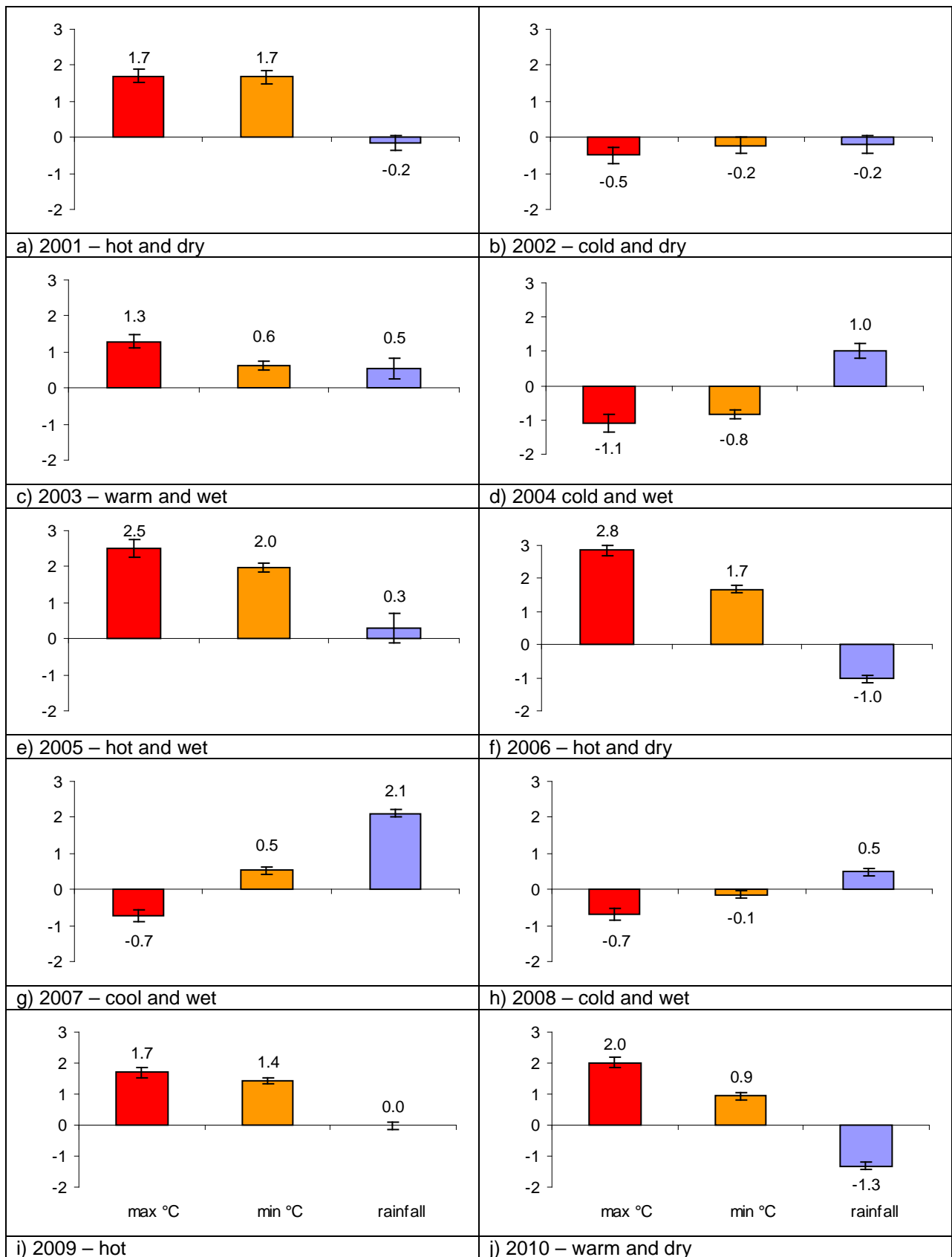


Figure 2. Average weather parameters from ten sites throughout the UK for 4 weeks from 15th June to 12th July, 2001-2010. The y axis shows difference from the long-term mean and the units are dependant on parameter; temperature (°C) and rainfall (mm).

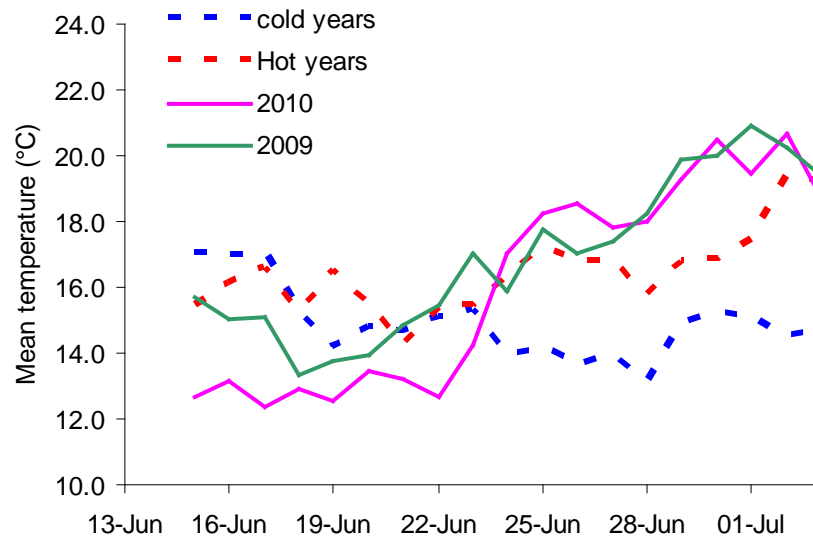


Figure 3. Daily mean temperature for 'hot' years (2001, 2003, 2005 and 2006) and 'cold' years (2002, 2004, 2007 and 2008) compared to 2009 and 2010.

Italian rye-grass

Dormancy in Italian rye-grass was measured in ten or fewer samples per year between 2008 and 2010, there were a greater number of samples analysed during 2007 (Figure 4), data have also been included from 2004 for reference (Cook *et al.*, 2006). There was no clear indication that dormancy level can easily be linked to weather conditions during the same period as black-grass (Figure 4 and Figure 2). Dormancy in Italian rye-grass was always lower than that of black-grass in the same year.

Work done by Alarcón-Reverte (2010) in HGCA project SR18 indicated that higher than average temperatures during seed development and maturation (June and July) resulted in lower seed dormancy. Akpan and Bean (1977) had similar conclusions. The work on rye-grass in this project was done on fewer samples than black-grass and over fewer years and there was no indication of a response to temperature.

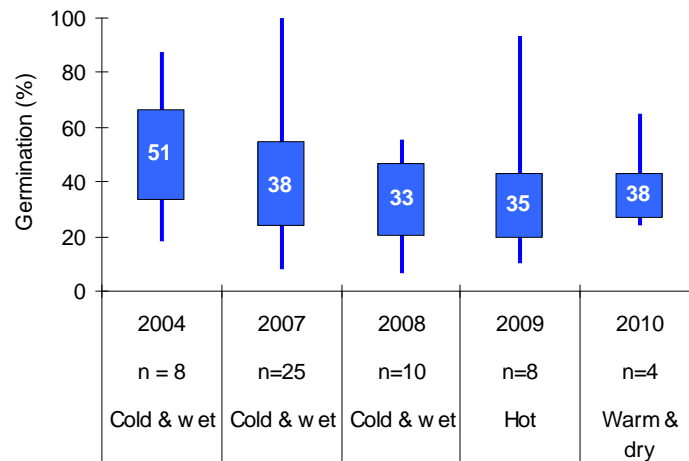


Figure 4. Dormancy patterns in Italian rye-grass, 2004 and 2007-2010 (For each year the graph shows maximum and minimum values), the lower and upper quartiles, and the mean (written in) and a categorisation of the weather for the period 15th June to 12th July).

Barren brome

Dormancy levels of barren brome were similar in all years (Figure 5); data have also been included from 2004 for reference (Cook *et al.*, 2006). There was a greater difference between samples in a single year than between years. For example, at Boxworth, samples were collected from two fields in a single year and dormancy was found to be 0% in one population and 100% in the other. There seemed to be no link to weather conditions during seed maturation.

Froud-Williams (1981) noted that in barren brome, primary dormancy tends to be weak but a few populations had higher dormancy. This was also supported by Peters *et al.*, (2000). Differences in dormancy between populations have been noted previously (Andersson *et al.*, 2002; Peters *et al.*, 2000). Peters *et al* (2000) found that some populations always produced either low or high dormancy and indicated that there was a strong genetic component to dormancy and Boxworth was one of those showing greater dormancy. Green *et al.*, (2001) showed that barren brome exists as numerous separate and genetically different lines, which are maintained by inbreeding but which very occasionally outcross.

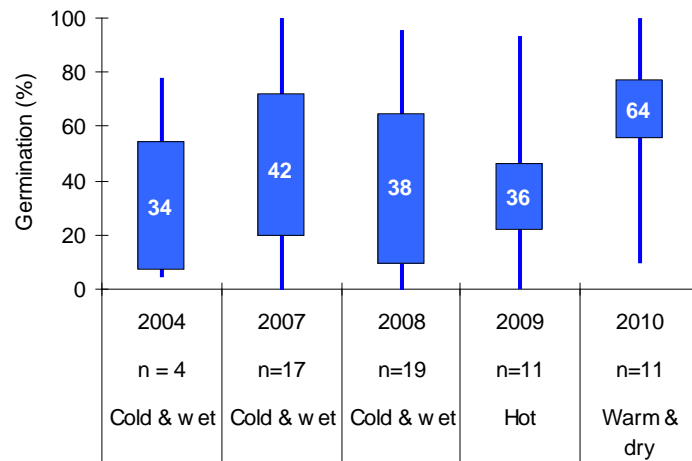


Figure 5. Dormancy patterns in barren brome 2004 and 2007-2010 (For each year the graph shows maximum and minimum values), the lower and upper quartiles, and the mean (written in) and a categorisation of the weather for the period 15th June to 12th July).

Meadow brome

Identification of meadow brome proved to be difficult and was only completed after all samples had been grown on and identified in the following year. There was a wide range of dormancy levels between populations and, as with barren brome, there seemed to be no relationship with the weather during June and July (Figure 6, Figure 2), data have also been included from 2004 for reference (Cook *et al.*, 2006). The variation between samples in a single year was greater than variation between the years. Froud-Williams and Chancellor (1986) and Orson *et al.* (1998) had noted little innate dormancy in this species.

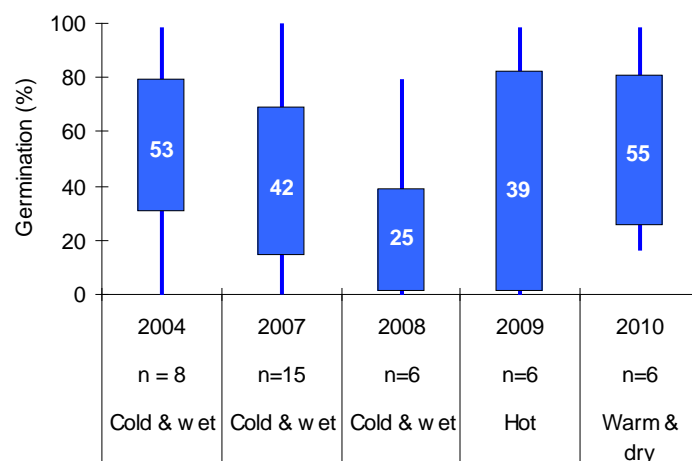


Figure 6. Dormancy patterns in meadow brome 2004 and 2007-2010 (For each year the graph shows maximum and minimum values), the lower and upper quartiles, and the mean (written in) and a categorisation of the weather for the period 15th June to 12th July).

Soft brome

Few soft brome samples were collected, dormancy was low in both 2007 and 2008 but varied between populations (Figure 7). There were no samples collected in 2009 and only one in 2010.

Froud-Williams (1981) and Orson *et al.* (1998) reported that dormancy on soft brome was low and Andersson *et al.*, (2002) and Jain (1982) also reported differences on dormancy between populations.

It was not possible to link weather conditions during June and July with dormancy level in this project but in central and northern California strong correlation with rainstorms was noted by Jain (1982) who suggested a direct adaptive role of seed dormancy to timing of germination in moist conditions. In the UK moisture is not usually limiting.

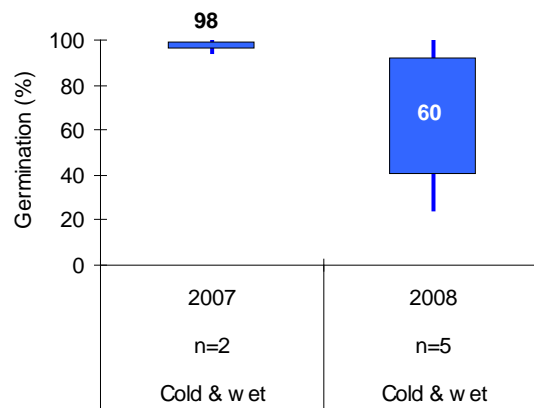


Figure 7. Dormancy patterns in soft brome 2007 and 2008 (For each year the graph shows maximum and minimum values), the lower and upper quartiles, the mean (written in) and a categorisation of the weather for the period 15th June to 12th July).

Rye brome

Rye brome seems to be more common than first thought and where it occurs it can be a serious problem and be difficult to control. Dormancy was always exceptionally high (Figure 8) and not linked to weather during June and July (Figure 2).

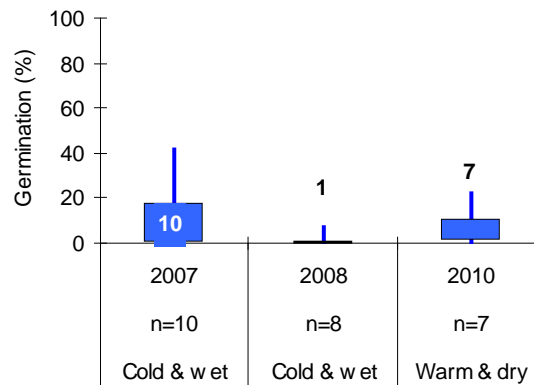


Figure 8. Dormancy patterns in rye brome 2007-2010 (excluding 2009 as only one sample was collected) (For each year the graph shows maximum and minimum values), the lower and upper quartiles, the mean (written in) and a categorisation of the weather for the period 15th June to 12th July).

3.2.3. Summary and key points

- An annual forecast of dormancy was issued each August containing guidelines on the most suitable crop management and herbicide strategies to best manage black-grass that season.
- Results indicated that dormancy in black-grass was lower in warm, dry years and higher in colder wetter years; however this relationship does not explain the dormancy in 2009 and 2010.
- In Italian rye-grass there was no indication that dormancy level and temperature during the period 15th June to 12th July are related.
- In barren brome there was a greater difference in dormancy level between samples in a single year than between years and no link to weather conditions during seed maturity was observed.
- Identification of meadow brome was difficult. There was high variation in dormancy between populations in a single year and there was no relationship with the weather in June and July.
- Few samples of soft brome were received. Dormancy levels were always low and we found no link between dormancy levels and weather during June and July.
- Rye brome was more common than expected and initial dormancy levels were very high. No link between rye brome and weather during June and July was observed.

3.3. Understanding the implications of dormancy on emergence patterns and allowing optimisation of black-grass management (objective 3)

In order to understand the implications of dormancy on emergence patterns, seedlots with a range of dormancy levels were needed. In 2007, seed with a range of dormancy levels was selected from different sites. Selected seedlots from the emergence experiments were grown through to maturity and ripened in two different environments to provide seed of different dormancy levels with the same genetic base for further emergence work.

The information gained from this work was twofold; firstly ripening the seed in two different temperature regimes added to the information pool on the effects of environmental conditions on dormancy level. Secondly the seed from the experiments was used to look at the effects of dormancy level on the speed and extent of seed emergence.

3.3.1. Creating black-grass seedlots of different dormancy levels

Materials and methods

Two seedlots were collected in 2007 from Littleport, Cambridgeshire and Navenby, Lincolnshire. Four replicates of the seedlots were sown in washing up bowls (23.5cm x 30.5 cm x 8 cm) with holes drilled in the bases and 'hydroleca' in the bottom to provide drainage. Each container was filled with sterilised Kettering loam and grit (5:1 mix) and 60 seeds of each seedlot were placed in the container, at least 12mm from the edge. Seeds were covered with fine soil to an even depth of 0.5 cm and lightly watered. The containers were placed on a net covered pot standing area and watered regularly. Any broad-leaved weeds were removed by hand weeding; pests (aphids) and disease (powdery mildew) were controlled using appropriate pesticides if necessary.

The containers were kept through to ear emergence in the pot standing area of the netted cage. At ear emergence the replicates were separated, with replicates one and two being moved to a polytunnel (hot) and replicates three and four remaining in the netted cage outdoors (cold). Seed was collected in summer 2007 from these plants. This seed was then used in the emergence experiments in autumn 2008 detailed in 3.2. After the emergence assessments the plants were grown on in the pot standing area of the netted cage. The replicates were separated into the hot and cold areas from ear emergence through to ripening. This process was repeated in autumn 2009. Table 3 details how the seed from each seedlot was split each year and under what conditions it was ripened.

Table 2. Place of ripening of the two seedlots from 2007-2009

2007	Place of ripening		
	2008	2009	2010
Seedlot 1 Littleport, Cambs	Ripened in the netted cage (cold)	Cold	Cold
			Hot
		Hot	Cold
			Hot
Seedlot 2 Navenby, Lincs	Ripened in the polytunnel (hot)	Cold	Cold
			Hot
		Hot	Cold
			Hot

The maximum and minimum temperature in both the netted cage and the polytunnel were recorded daily using a Tinytalk data recorder.

Seed was collected when an estimated 50% had shed, was air dried, and tested for viability and dormancy as described in 2.1.3. Data were analysed by Anova using GenStat.

Results and discussion

Dormancy levels of black-grass were significantly lower in the polytunnel than netted cage ($p < 0.001$) in all years (Figure 9).

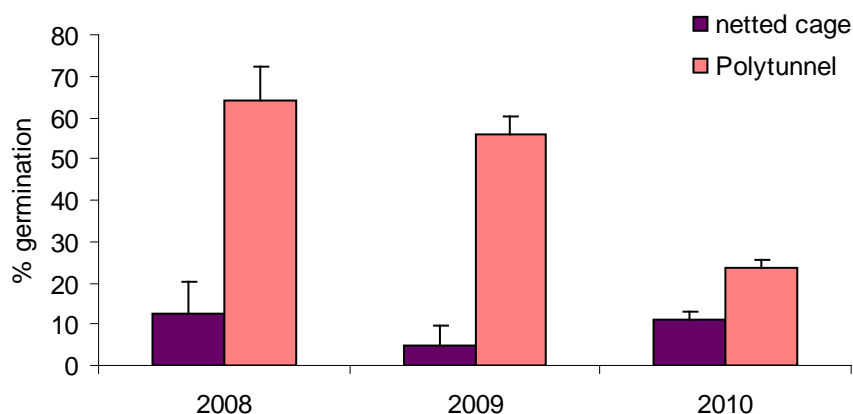


Figure 9. Dormancy level of seed collected between 2007 and 2009 after ripening in the netted cage (cold) or polytunnel (hot) (% germination)

Critical period

The windowpane analysis (See section 4.1.4) suggested that the critical period for temperature begins 20 days after flowering and goes on for 19 days. The critical periods for the three years are detailed in Table 4.

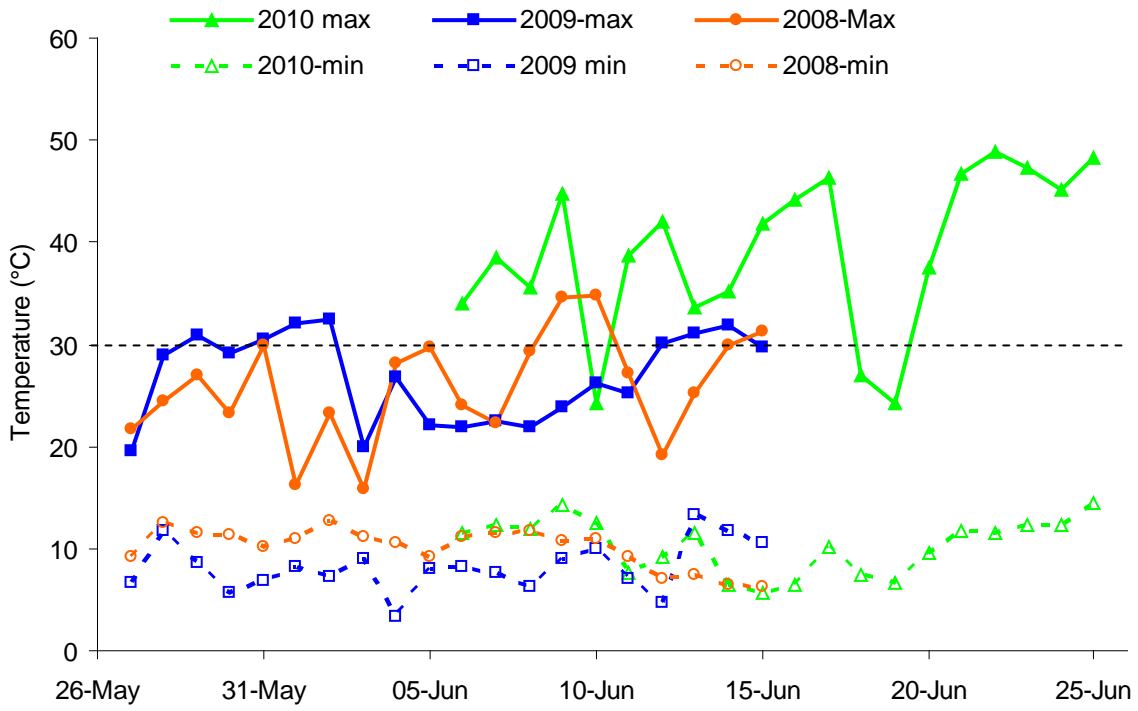
Table 3. Anthesis date and critical period for container grown black-grass.

	Anthesis	Start of critical period	End of critical period
2008	7 th May	27 th May	15 th June
2009	7 th May	27 th May	15 th June
2010	14 th May	6 th June	26 th June

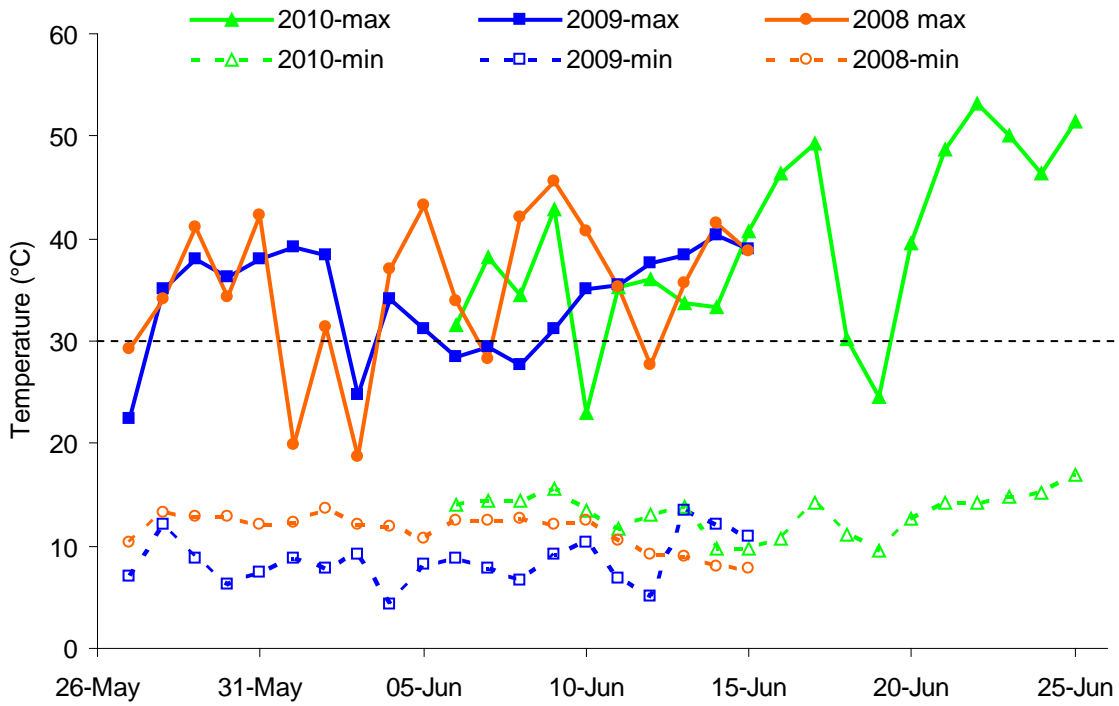
During the critical period maximum temperatures during 2008 and 2009 were significantly higher ($p < 0.001$) in the polytunnel than the netted cage but minimum temperatures were similar in both locations (Figure 10, Table 5). In 2010 temperatures were similar in both environments because the temperature recorder in the netted cage was not placed in the shade as in 2008 and 2009. The field temperatures are lower than both probably due to the pots standing on concrete, which acts as a heat sink, and being located in a more sheltered position.

Table 4. Temperatures during critical period

	Year	Average daily maximum temperature (°C)	Average daily minimum temperature (°C)	Average daily temperature (°C)
Netted cage	2008	25.9	10.1	18.0
	2009	26.8	8.2	17.5
	2010	39.2	10.3	24.7
Netted cage Mean		30.6	9.5	20.1
Polytunnel	2008	35.0	11.4	23.2
	2009	34.0	8.5	21.2
	2010	39.4	13.2	26.3
Polytunnel Mean		36.1	11.0	23.6



a) Netted cage



b) Polytunnel

Figure 10. Maximum and minimum temperatures for the critical periods of 2008-2010 measured in the netted cage and polytunnel (°C).

As indicated in the windowpane analysis (See section 4.1.4) as average temperature rose, dormancy level decreased however, we did not achieve the very low dormancy levels in the polytunnel we would have expected (Figure 11). This may be due to one or more of the following factors:

- The minimum temperature in the polytunnel was the same as the netted cage as there was a degree of temperature buffering from the concrete standing. Also the polytunnel was not insulated enough to prevent similar minimum temperatures being reached.
- The water was slightly limiting in both situations; it wasn't possible to keep the containers at field capacity for the whole 24 hour period.
- There were very high temperatures (>37°C) in the polytunnel in all three years and the netted cage in 2010 (Table 6), this could have prevented the black-grass from developing normally as seen in wheat (Weir *et al.*, 1984).

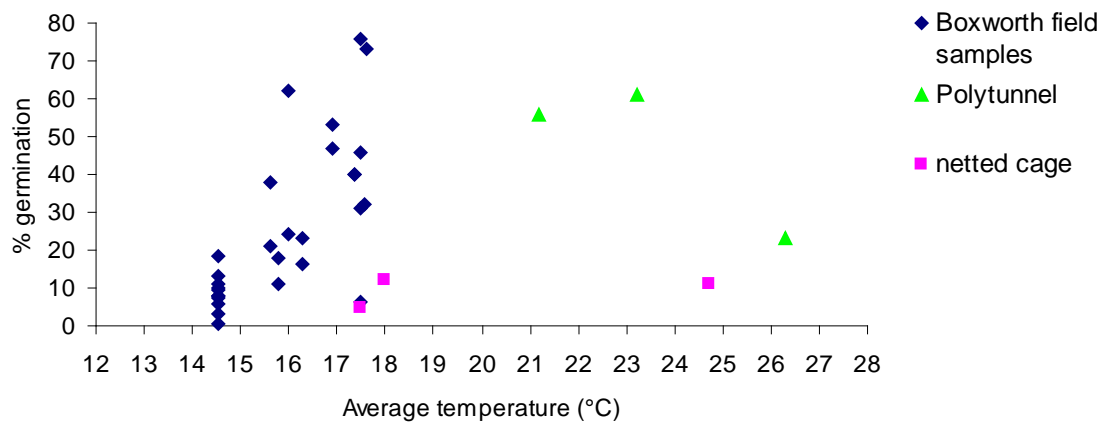


Figure 11. The relationship between average temperature during the critical period and dormancy level in black-grass for samples from the Boxworth field, polytunnel and netted cage

Table 5. Total number of hours above 37°C in the field, netted cage and polytunnel at Boxworth 2007-2010.

Year	Polytunnel	Netted cage	Field
2008	38	0	0
2009	18	0	0
2010	61	54	0

Effect of seedlot and previous ripening

Both seedlots responded similarly to the temperature regimes over the three year period (Figure 12). There was also no relationship between the previous season and current season's dormancy levels. Dormancy level was influenced by weather conditions during the summer of ripening only.

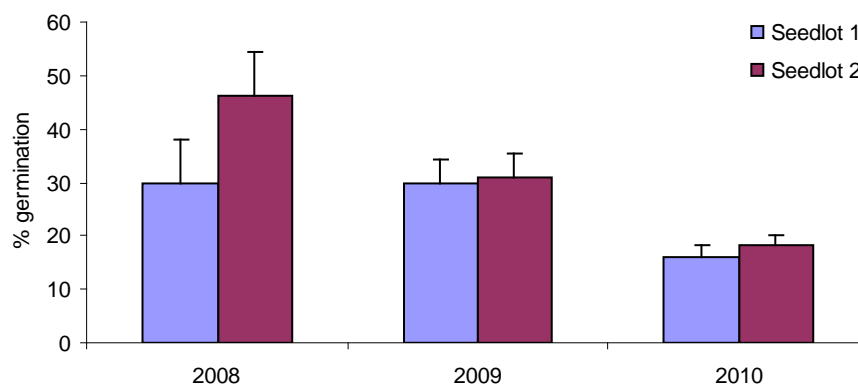


Figure 12. Mean dormancy level of seedlots between 2008 and 2010.

Summary and key points

- Temperature during the critical period, beginning at 20 days after flowering for a period of 19 days, had a significant effect on the development of dormancy.
- Temperature was not the only factor involved, there was probably some effect of water being limiting during ripening
- Dormancy only lasted one season and did not carry over into following year's seed production.

3.3.2. Emergence of black-grass, Italian rye-grass, barren brome, meadow brome, rye brome and soft brome

Materials and methods

In 2007, 2008 and 2009 black-grass seed from the netted cage, polytunnel (as described in section 3.1) plus seed from field sampling of black-grass and field samples of Italian rye-grass, barren brome, meadow brome, rye brome and soft brome at different dormancy levels were sown into containers. Black-grass was sown at two dates, the other species at the early date only (Table 7). There were four replicates. Seed had been stored at 18°C and 50% relative humidity since collection.

Seed was sown in washing up bowls (23.5 cm x 30.5 cm x 8 cm) drilled on the bases and containing 'hydroleca' in the bottom to provide drainage and filled with sterilised Kettering loam and grit (5:1 mix), 60 seeds of each seedlot were placed in the container, at least 12 mm from the edge. Seeds were covered with fine soil to an even depth of 0.5 cm and lightly watered. The containers were placed on a net covered pot standing area and watered regularly. Any broad-leaved weeds were removed by hand weeding; pests (aphids) and disease (powdery mildew) were controlled using appropriate pesticides if necessary.

Table 6. Sowing dates and approximate number of days after seed collection

	Approximate number of days after seed collection	2007	2008	2009
Early sowing	70	21 Sept	21 Sept	24 Sept
Late sowing	100	21 Oct	21 Oct	21 Oct

Plant emergence was counted from sowing through to spring, twice weekly during the first month, weekly up to the 4th month and weekly in the spring.

Dormancy level at sowing

Seed dormancy level was measured within seven days of seed collection and also at the date of the early and late sowing approximately 70 and 100 days after seed collection respectively using the methodology described in 2.1.3.

Comparison of field and container emergence

In 2010, seed of black-grass, barren brome and Italian rye-grass were sown in the field at ADAS Boxworth and into containers at two sowing dates, 21 September and 20 October. 60 seeds were sown into containers using the method above. In the field, seed was scattered onto the soil surface and incorporated to 1 cm deep. Emergence was assessed weekly.

Results and discussion

Black-grass

Changes in dormancy level

Dormancy level decreased through storage (18°C and 50% relative humidity) of black-grass seed. After 100 days low dormancy seed reached a maximum germination level of 83%. High dormancy seed did not lose its dormancy as readily as low dormancy seed and reached a maximum after 100 days of 62% (Figure 13). There was some variation between years; in 2009 dormancy was lost to a greater extent than in 2007 and 2008.

Dormancy level in black-grass seed does decline in a field situation after shedding and this seed will emerge even though emergence is delayed. Storage under warm conditions made dormancy decline faster and to a greater extent than in the field.

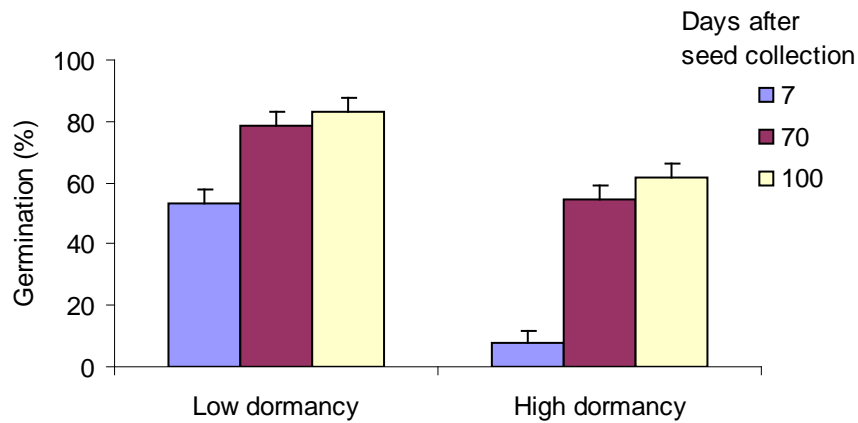
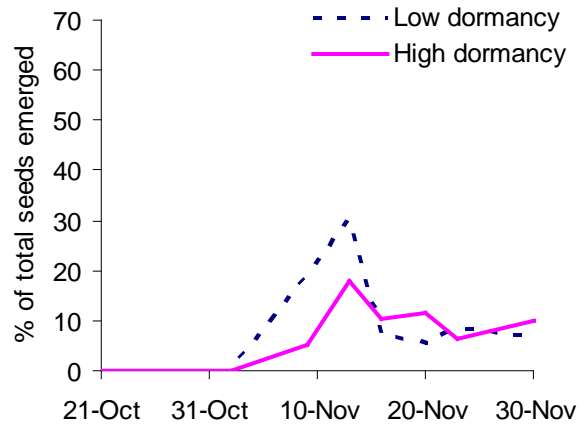
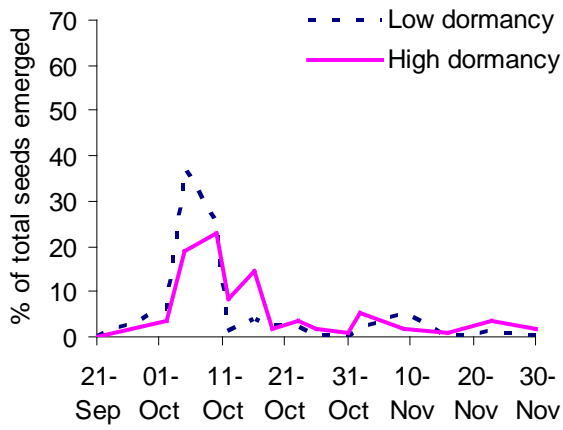


Figure 13. Changes in black-grass dormancy during storage

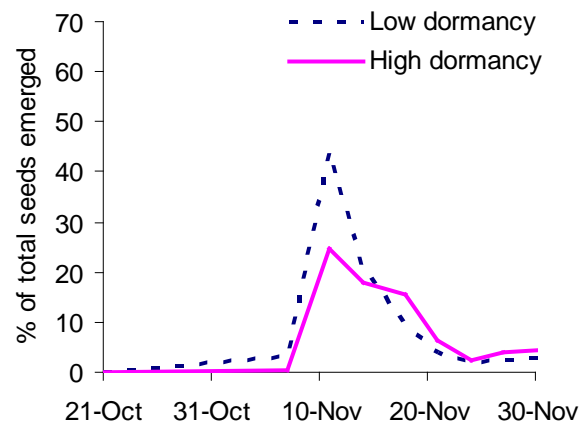
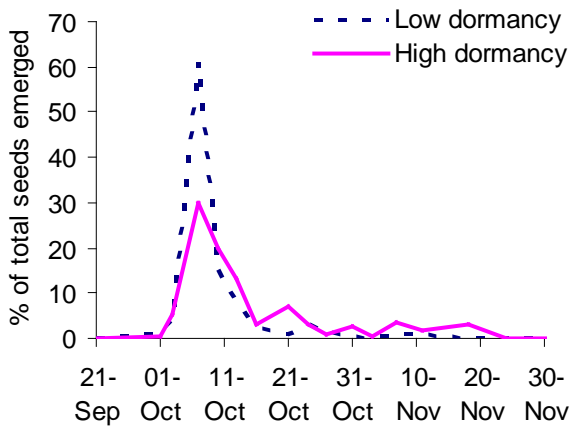
Autumn emergence

Black-grass emergence in containers followed a similar pattern for the three years of the experiment (Figure 14). There was always a peak of emergence at approximately 15 days for early sown seed and 20 days for late sown. It must be remembered that the seed sown had been in storage for 70 days after seed collection and dormancy levels had declined as described above. In a field situation dormancy level would decline slower. Low dormancy seed tended to emerge first and a greater percentage of the seed emerged during the first autumn when compared to high dormancy seed (Figure 14).



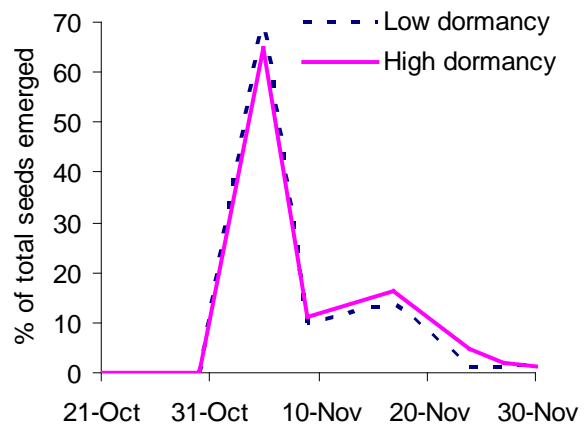
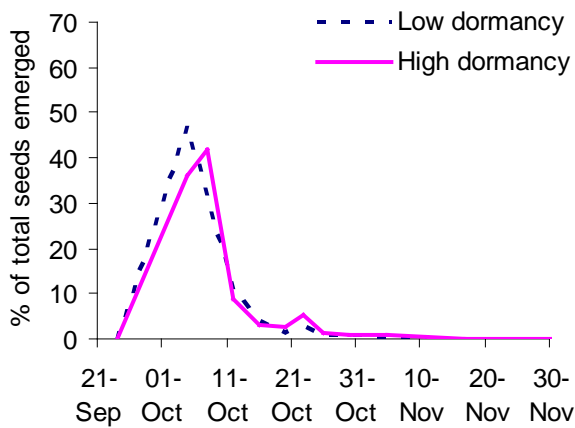
a) 2007 Early sown

Late sown



b) 2008 Early sown

Late sown



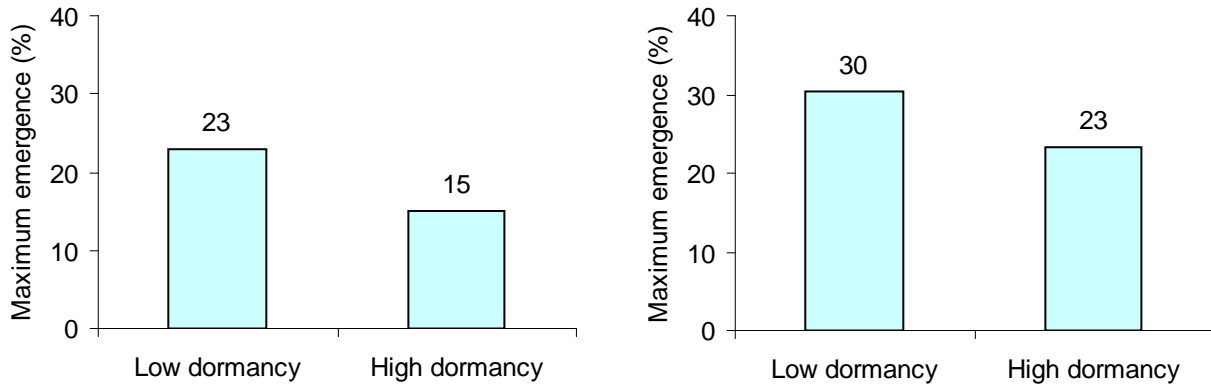
c) 2009 Early sown

Late sown

Figure 14. Emergence of black-grass from September to November (% emergence of total seeds emerged). Early sown = 21 September, Late sown = 21 October

Extent of emergence

Low dormancy seed emerged to a greater extent than high dormancy seed by approximately 8% on average (Figure 15), these differences were significant ($p < 0.001$) in 2008 and 2009. Late sown seed also emerged to a greater extent than early sown ($p < 0.001$) probably linked to the decline in dormancy during storage. The implications on cumulative emergence are discussed later.



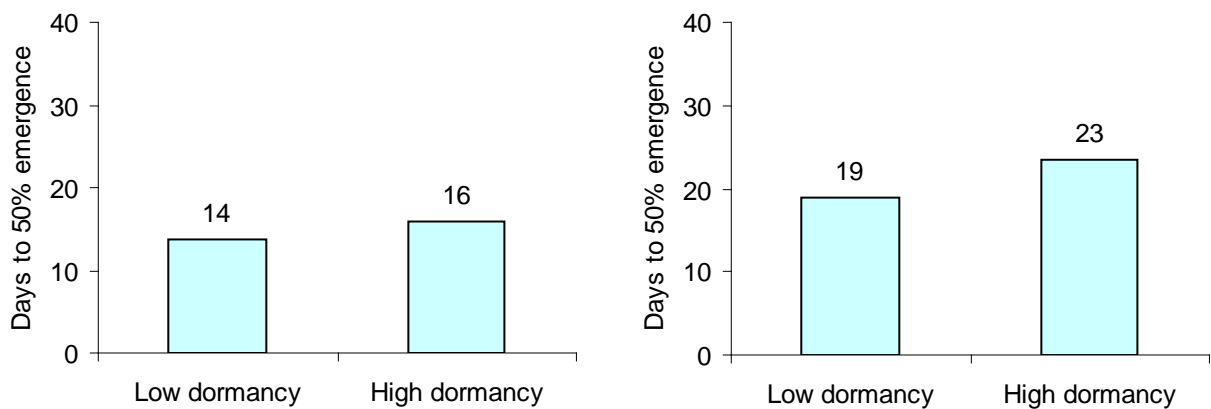
a) early sown

b) late sown

Figure 15. Mean maximum emergence of high and low dormancy black-grass seed (% of 60 seeds sown, mean of 2007-2009). Early sown = 21 September, Late sown = 21 October

Speed of emergence

High dormancy black-grass seed was slower to emerge than low dormancy seed. At the early sowing date the number of days to 50% emergence was 14 days for low dormancy seed and 16 days for high dormancy ($p = 0.042$) (Figure 16a). Delaying sowing of the black-grass by one month delayed the number of days to 50% emergence for low and high dormancy seed by a further five and seven days respectively ($p = 0.021$) (Figure 16b).



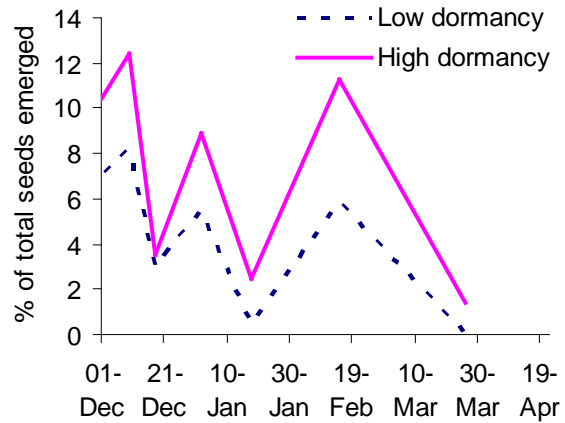
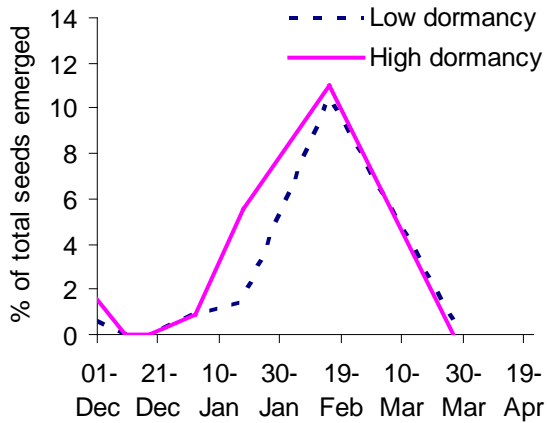
a) early sown

b) late sown

Figure 16. The mean number of days to 50% emergence of black-grass sown in containers at ADAS Boxworth. Early sown = 21 September, Late sown = 21 October

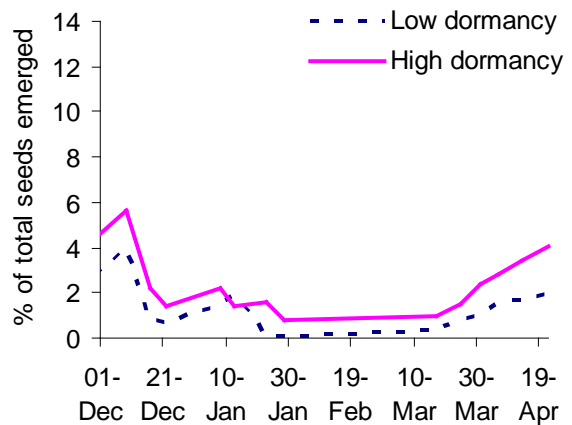
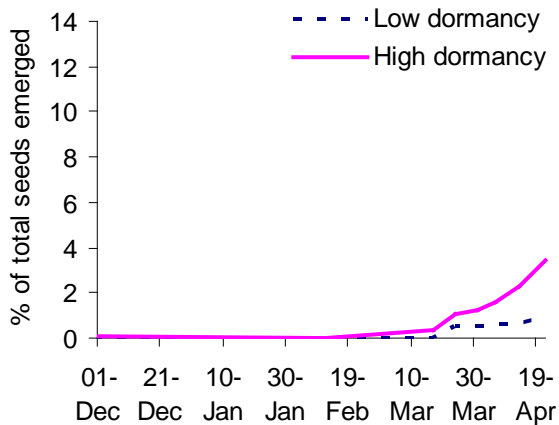
Spring emergence

There was a degree of spring emergence in the containers, even though the soil was not disturbed. This was greater in 2007 than in 2008 and 2009 (Figure 17). More high dormancy seed emerged in the spring than low dormancy seed.



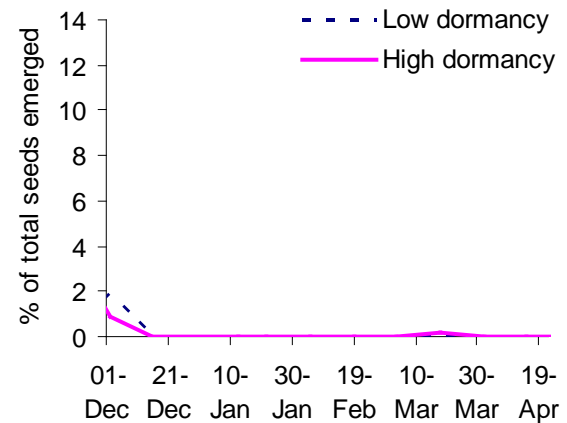
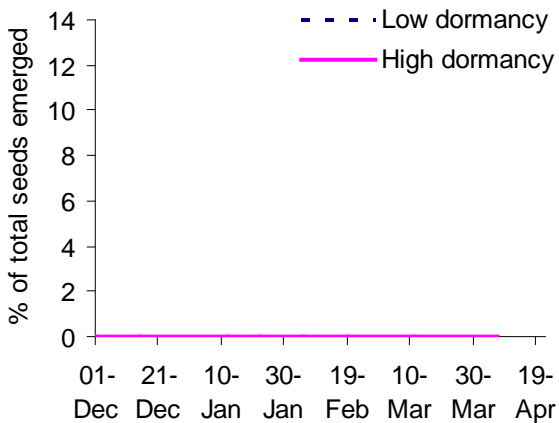
a) 2007 Early sown

Late sown



b) 2008 Early sown

Late sown



c) 2009 Early sown

Late sown

Figure 17. Emergence of black-grass from December to April (% emergence of total seeds emerged). Early sown = 21 September, Late sown = 21 October

Seasonal pattern of emergence

The greatest proportion of black-grass seed emerged during the first 30 days after sowing; this was greater with low dormancy seed (86%) than high dormancy seed (75%) (Figure 18). During the 30-60 and 60-90 day periods more high dormancy seed emerged than low dormancy seed. Spring emergence was also greater in high dormancy seed.

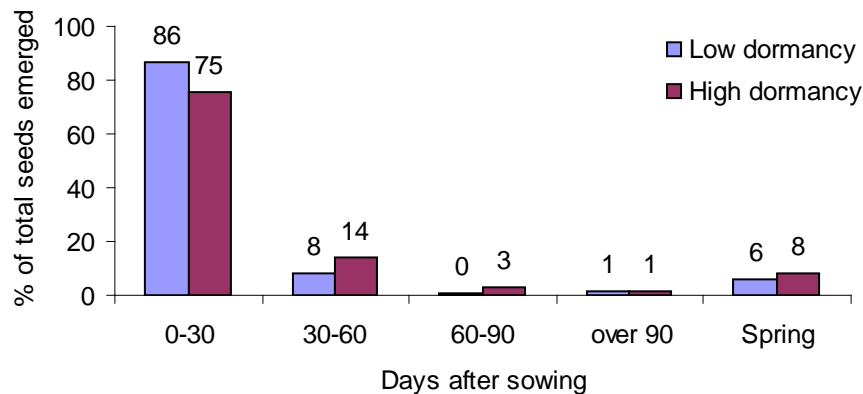
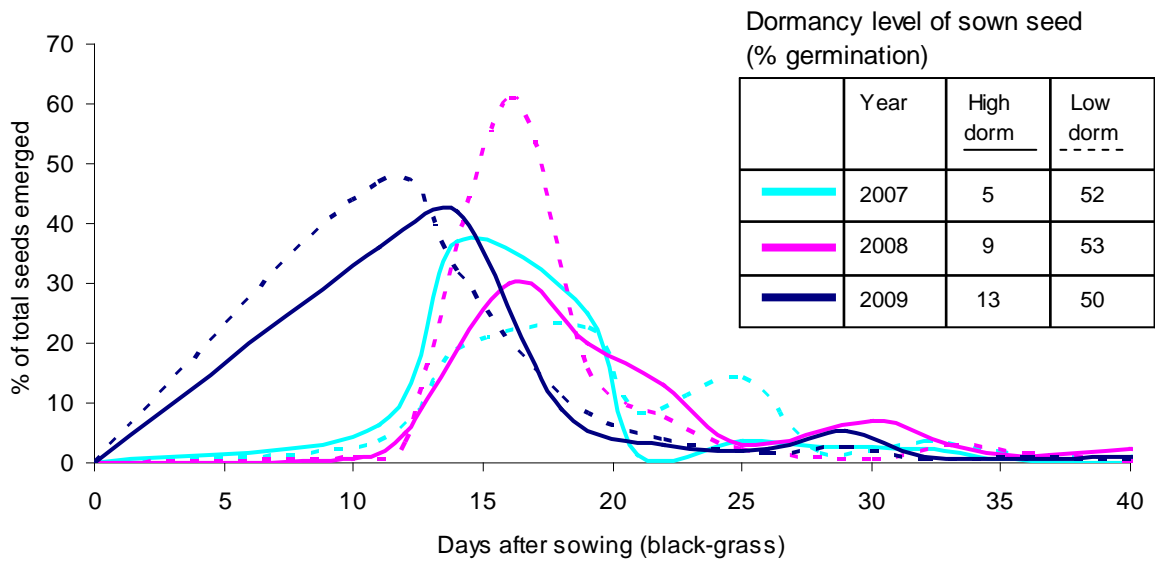


Figure 18. Seasonal pattern of emergence for black-grass of different dormancy levels sown in containers (Percentage of total seeds emerged during each timeframe)

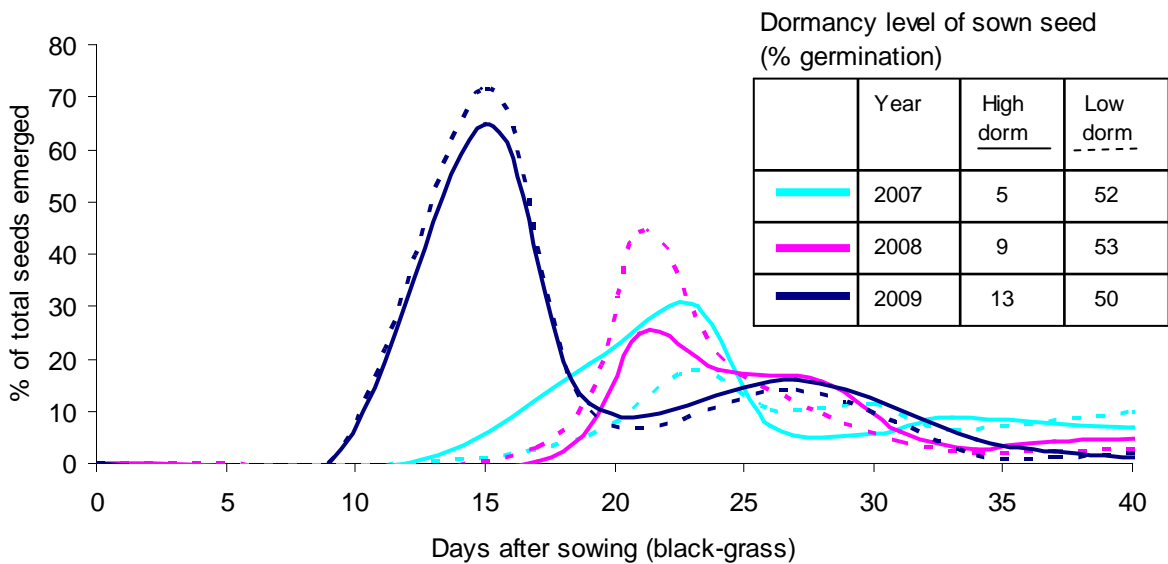
Differences in emergence between years

Speed of emergence was affected by weather conditions during emergence. In 2009 emergence of both high and low dormancy seed was faster than in 2007 and 2008, maximum emergence being three days earlier at the early sowing date and seven days when later sown (Figure 19).

Cumulative emergence is shown in Figure 20. This difference can be accounted for by warmer air temperatures during the autumn period (Figure 21).

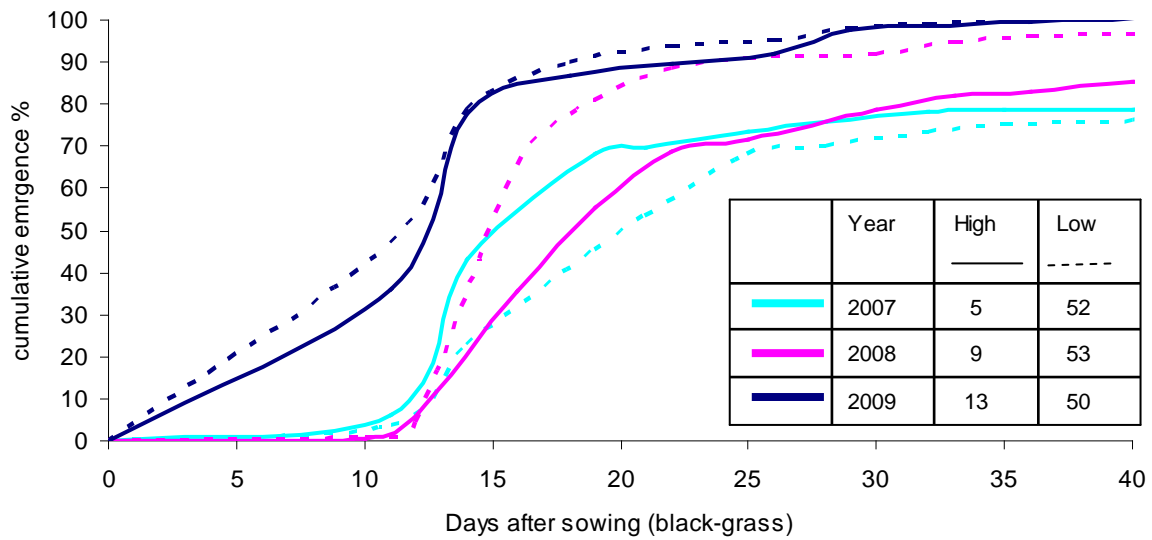


a) early sowing

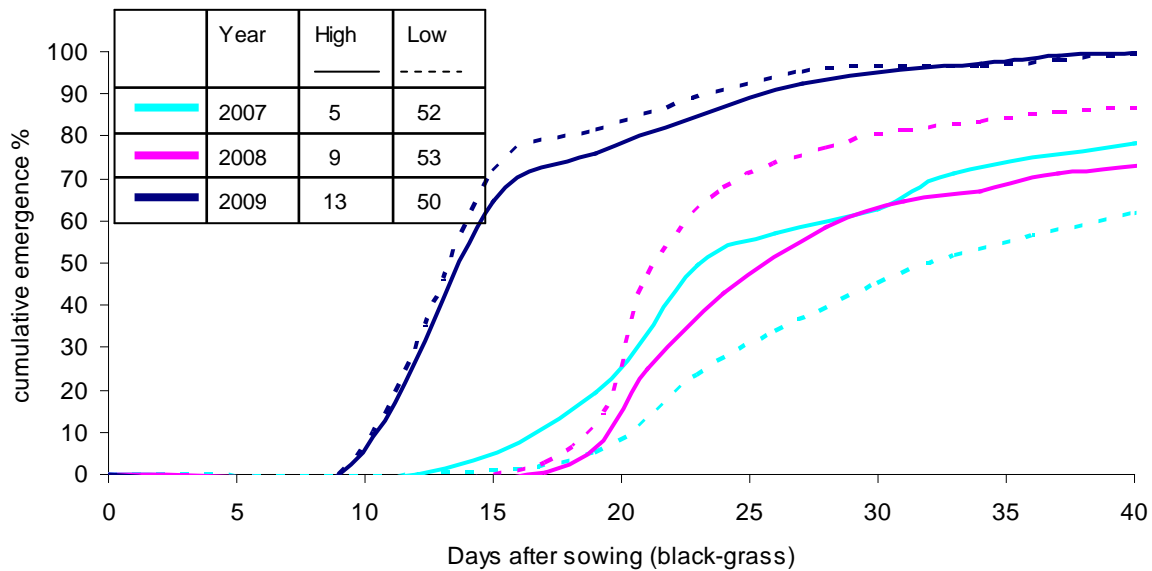


b) late sowing

Figure 19. Comparison of high and low dormancy black-grass emergence during autumn 2007, 2008 and 2009. The figures in the legend indicate the % germination of the high and low dormancy seed that was sown.



a) early sowing



b) late sowing

Figure 20. Cumulative emergence of high and low dormancy black-grass during autumn 2007, 2008 and 2009. The figures in the legend indicate the % germination of the high and low dormancy seed that was sown.

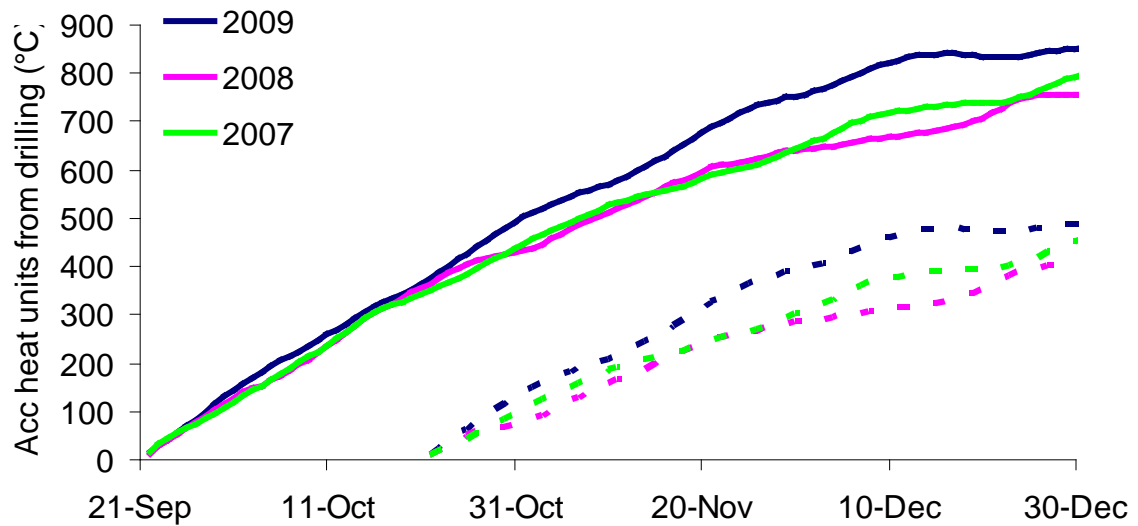
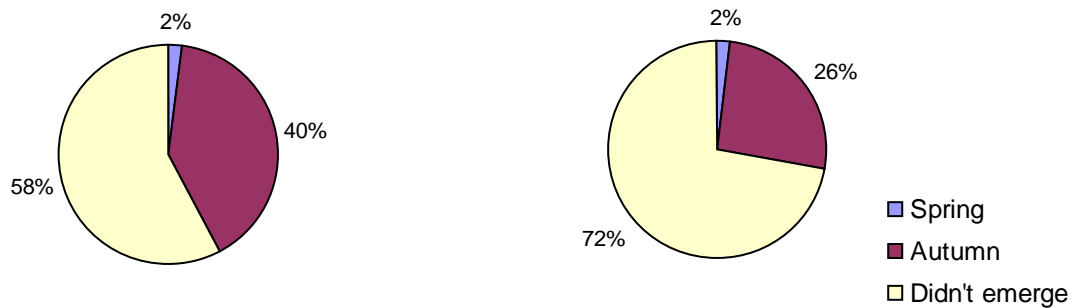


Figure 21. Accumulated day degrees for the early (—) and late (---) sowing dates for 2007 to 2009 (°C above zero)

Seed that didn't emerge

Most seed sown into the containers did not emerge although seed was cleaned and was assessed as viable. More low dormancy seed emerged than high dormancy (Figure 22). Further work gave some indication of what happened to the un-emerged seed (See section 3.4).



a) Low dormancy

b) High dormancy

Figure 22. Emergence of black-grass seed during the first autumn after collection (% emergence of seeds planted)

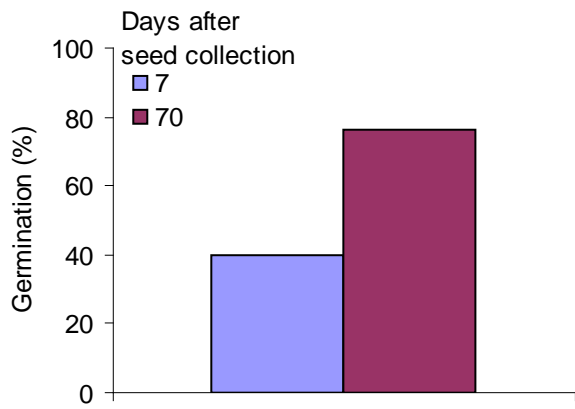
The results show that peak black-grass emergence was restricted to the autumn (September-November) and that emergence was delayed by higher levels of seed dormancy. Warmer temperatures during the autumn increased the amount of seed that germinated and the rate of emergence. Optimum temperatures for germination have been reported between 8°C (Froud-Williams, 1981) and 20°C (Menck, 1968). Higher temperatures during emergence resulted in a higher final percentage emergence (Naylor 1972). Colbach (2002b) showed that germination increased as seed became older which relates to the decrease in dormancy level. The total proportion of seed that germinated was in line with previous work; Colbach (2002a) reported a

range of 38-70%. Spring germination was low; this is discussed in section 3.4.2 in relation to the addition of spring cultivations.

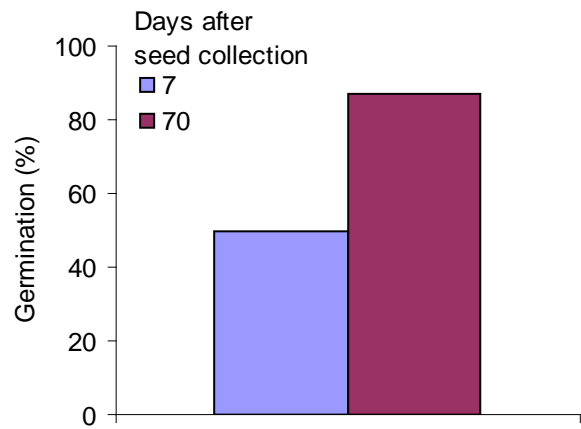
Italian rye-grass, barren, meadow, rye and soft brome.

Dormancy level

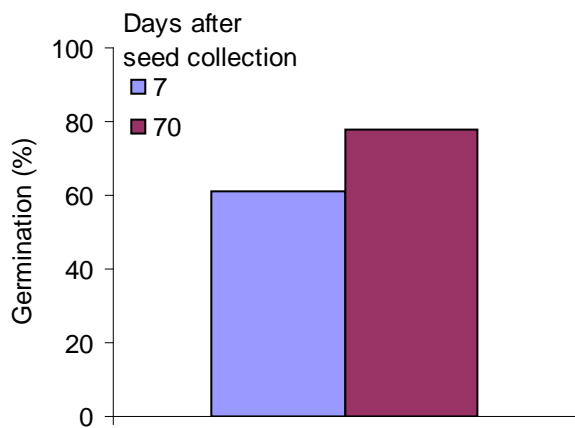
As with black-grass, dormancy levels in Italian rye-grass and the brome grasses decreased with storage (Figure 23). Generally where dormancy was low there was little change in germination level in all species. Rye brome was completely dormant at the first assessment but had lost this almost totally by the early sowing date (Figure 23d). The decline in primary dormancy through storage has also been shown by Peters *et al.*, (2000) in barren brome and by Froud-Williams & Chancellor (1986) in meadow brome.



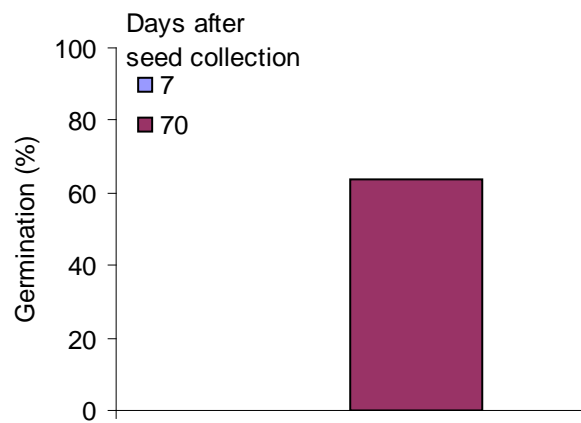
a) Italian rye-grass



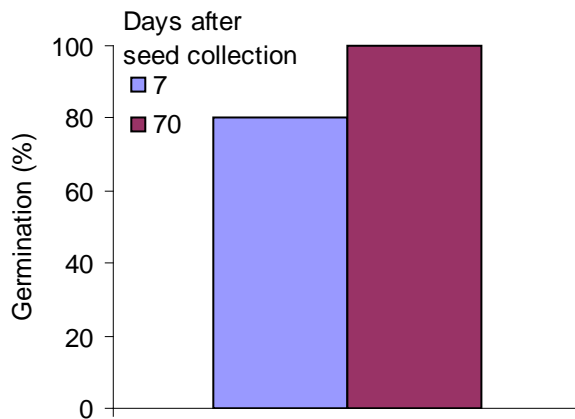
b) Barren brome



c) Meadow brome



d) Rye brome



e) Soft brome

Figure 23. Changes in Italian rye-grass, barren, meadow, rye and soft brome dormancy during storage

Emergence

Emergence in all species began approximately ten days after sowing (Figure 24 a, b, c, d and e).

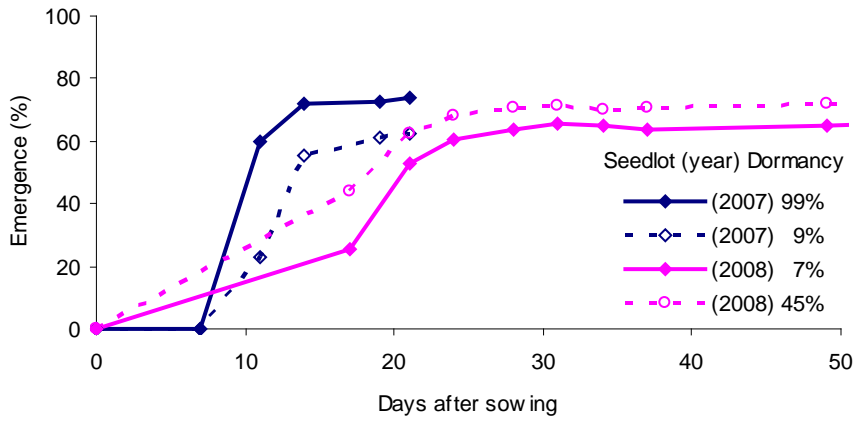
In Italian rye-grass there was little difference in speed of emergence between the seedlots of different dormancy levels in a single season (Figure 24 a). The species emerged quickly and emergence reached a maximum of 65-75% at 14 days, after sowing in 2007 and 24 days after sowing in 2008 when the sowing date was delayed until October and soil conditions were colder. Both Orson (2007) and Alarcón-Reverte (2010) noted that peak emergence of Italian rye-grass occurred within 2-3 weeks of the soil surface becoming moist.

Barren brome emerged ten days after sowing and was 95% emerged at 20 days, there was a slight indication that the higher dormancy seed emerged more slowly but due to the rapid and almost complete emergence this should be of little consequence to growers. This supports previous work by Froud-Williams (1981), Peters *et al.* (2000) and Andersson *et al.* (2002).

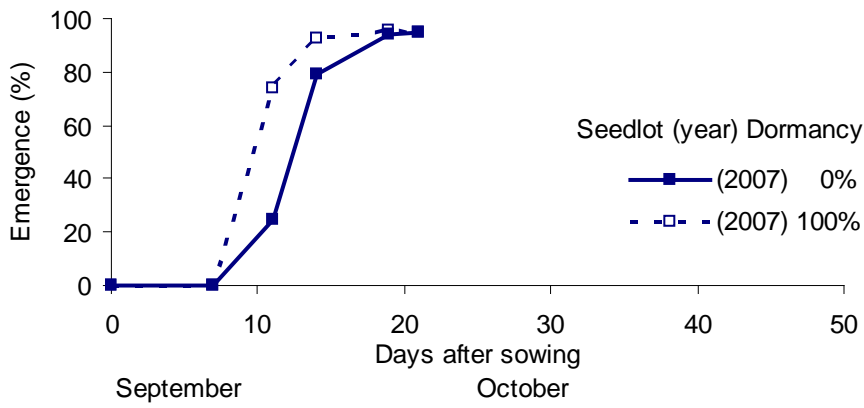
Meadow brome emergence began 12 days after sowing and had reached a plateau seven days later, a maximum of 75% of high dormancy seed emerged and 85% of the lower dormancy seed. This agrees with observations by Froud-Williams and Chancellor (1986) in this species where little seed remained after 14 weeks of burial. Orson *et al.*, (1998) noted that some populations when sown in the dark reached a plateau of emergence leaving a small proportion of seeds to form subsequent populations.

Rye brome had an initial germination of 0% seven days after collection but this initial dormancy was lost rapidly, a result supported by Steinbauer & Grigsby (1957). Emergence began 12 days after sowing and had reached a plateau in a further seven days. Approximately 20% did not germinate.

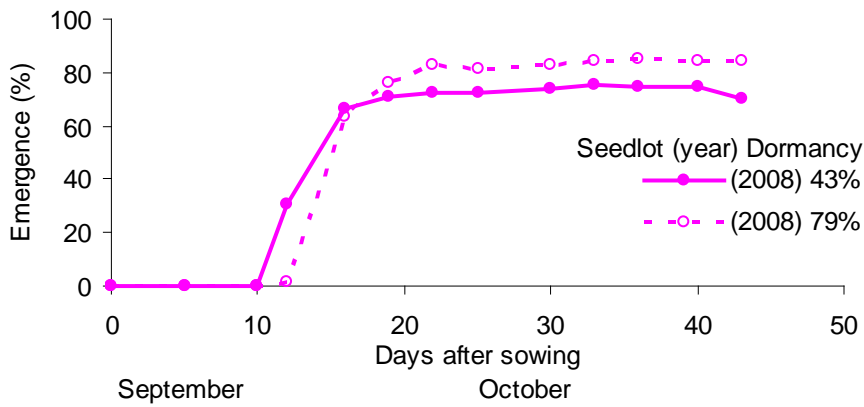
Soft brome showed little or no initial dormancy and had emerged 11 days after sowing; emergence was complete at 15 days with 94% emergence. These results are similar to those reported by Andersson *et al.* (2002) who recorded 87-95% of seeds germinated and a low level of innate dormancy.



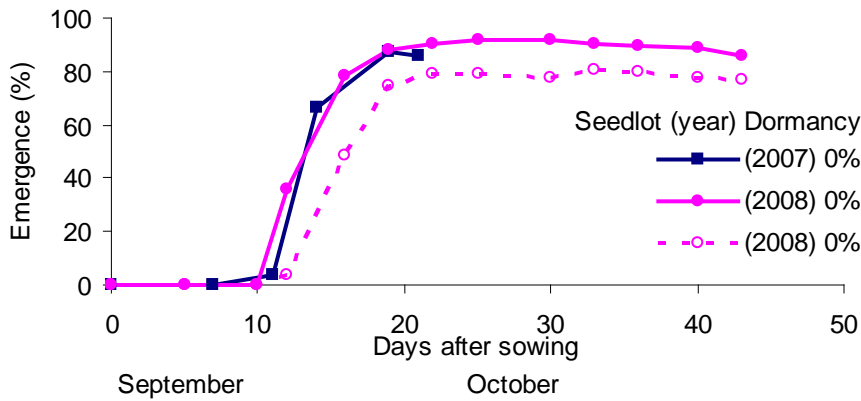
a) Italian rye-grass



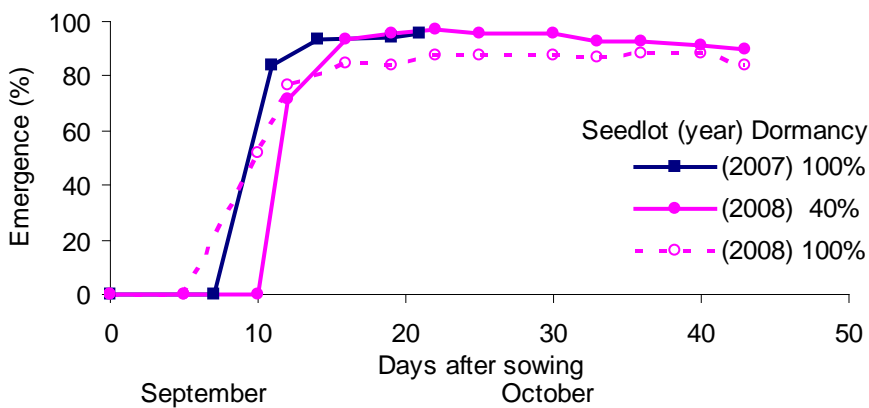
b) Barren brome



c) Meadow brome



d) Rye brome



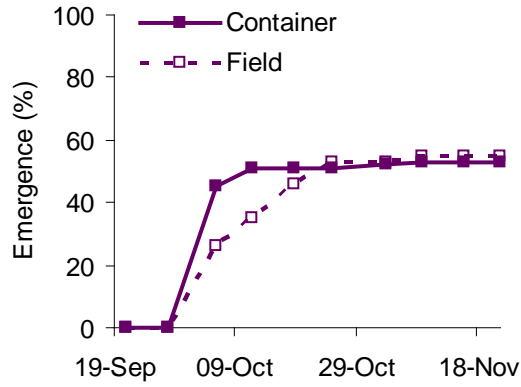
e) Soft brome

Figure 24. Emergence of Italian rye-grass, barren, meadow, rye and soft brome. Legend shows dormancy level (percent germination) as determined through dormancy testing seven days after seed collection.

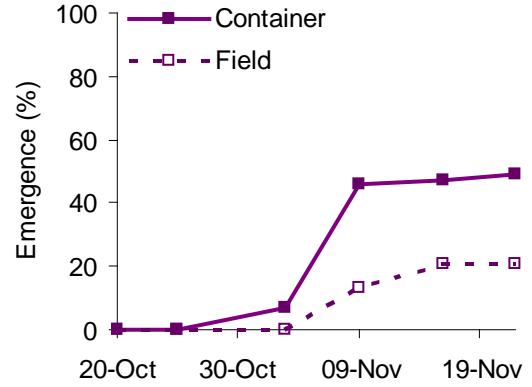
Comparison of field and container emergence

Generally, emergence in the containers was greater than in the field at both sowing dates (Figure 25). The soil in the containers was loam, whereas the field was clay, and was probably warmer, being a small volume and raised above the ground. Black-grass only reached 60% emergence in both the container and the field at the early sowing date, maximum emergence being delayed by two weeks in the field.

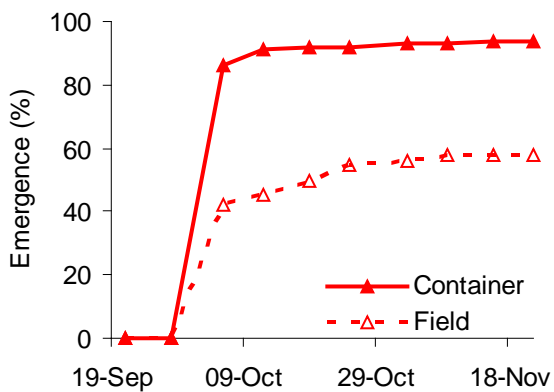
Containers have provided a valuable tool representative of the field effects. Using containers provides an absolute comparison of emergence between seedlots without interference of naturally occurring seeds, although it does not mirror exactly conditions in the field due to differences in soil type and cultivations.



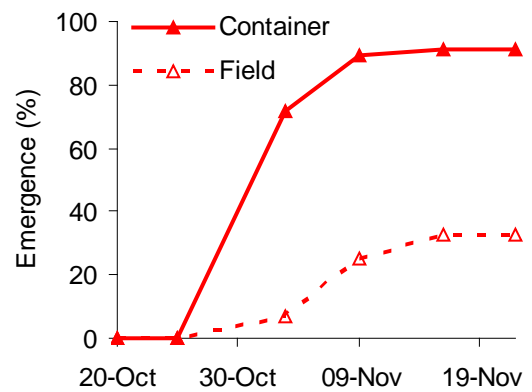
a) Black-grass early sown



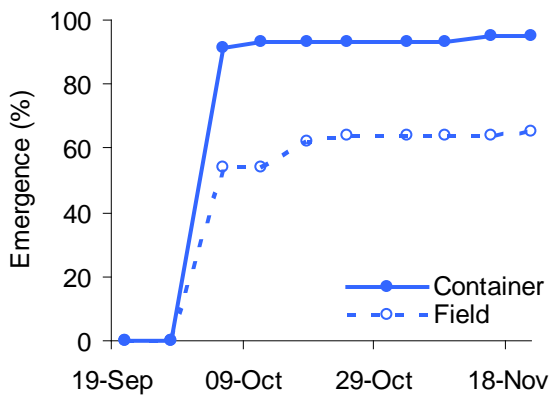
b) Black-grass late sown



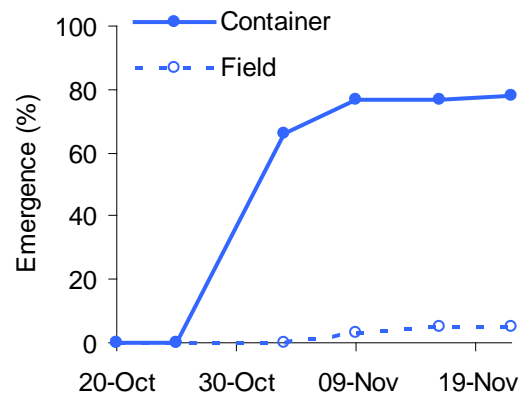
c) Italian rye-grass early sown



d) Italian rye-grass late sown



e) Barren brome early sown



f) Barren brome late sown

Figure 25. Emergence of black-grass, Italian rye-grass and barren brome in the field and in containers (% emergence)

Summary and key points

Black-grass

- In black-grass, low dormancy seed emerged first, emergence peaked at 15 days after sowing, and this peak of emergence was delayed five days with high dormancy seed.
- Eight percent more low dormancy seed emerged in the first autumn compared to high dormancy seed.
- 86% of low dormancy black-grass emerged within 30 days of sowing compared to 75% of high dormancy seed. Emergence of high dormancy seed was more protracted.
- Autumn black-grass emergence was greater in warmer years than in colder years and emergence rate was faster.
- A high proportion of black-grass did not emerge in the first autumn.
- More low dormancy seeds emerged than high dormancy seed.

Italian rye-grass

- There was little difference in emergence between dormancy levels and maximum seed emergence occurs 14-24 days after sowing

Barren brome

- Emergence was very rapid and 95% of seed had emerged after 20 days. Differences in dormancy level should be of little consequence to growers

Meadow brome

- Emergence began 12 days after sowing and had reached a plateau seven days later, a maximum of 75% of high dormancy seed emerged and 85% of the lower dormancy seed

Rye brome

- Initial dormancy was lost rapidly, emergence began 12 days after sowing and reached a plateau in a further seven days, approximately 20% did not germinate

Soft brome

- Soft brome showed little or no initial dormancy and had emerged 11 days after sowing; emergence was complete at 15 days with 94% emergence.

3.3.3. Emergence of surface sown and buried seed

Materials and methods

Two seedlots of high and low dormancy were selected from seed collected in the field during summer 2009 and sown into washing up bowls (23.5 cm x 30.5 cm x 8 cm), into which drainage holes had been drilled, filled with sterilised Kettering loam and grit (5:1 mix), with 'hydroleca' in the bottom of the bowl to aid drainage. Sixty seeds of each seedlot were placed in the container, at least 12 mm from the edge. Seeds were either covered with fine soil to an even depth of 1 cm, or left uncovered. Treatment details are as in Table 8. After sowing, the containers were lightly watered. Containers were placed on a pot standing area inside a netted cage. Any broad-leaved

weeds were removed by hand weeding; pests (aphids) and disease were controlled with pesticides when necessary. Containers were watered regularly and emergence counts were done every 3-7 days.

Table 7. Black-grass- seedlots and germination levels within seven days of seed collection

Treatment Number	Seedlot	Date collected	Site	Germination 7 days after collection (%)	Sowing depth
1	09D42	13 July 2009	Colchester, Essex	60	Surface
2					1 cm
3	09D73	20 July 2009	Rippingale, Lincs	7	Surface
4					1 cm

Results and discussion

Buried seed emerged first with 9% more of the low dormancy seed emerging than the high dormancy seed (Figure 26). First emergence of the surface sown seed was delayed by 5 days, the high dormancy seed emerged first and to a slightly greater extent (5%).

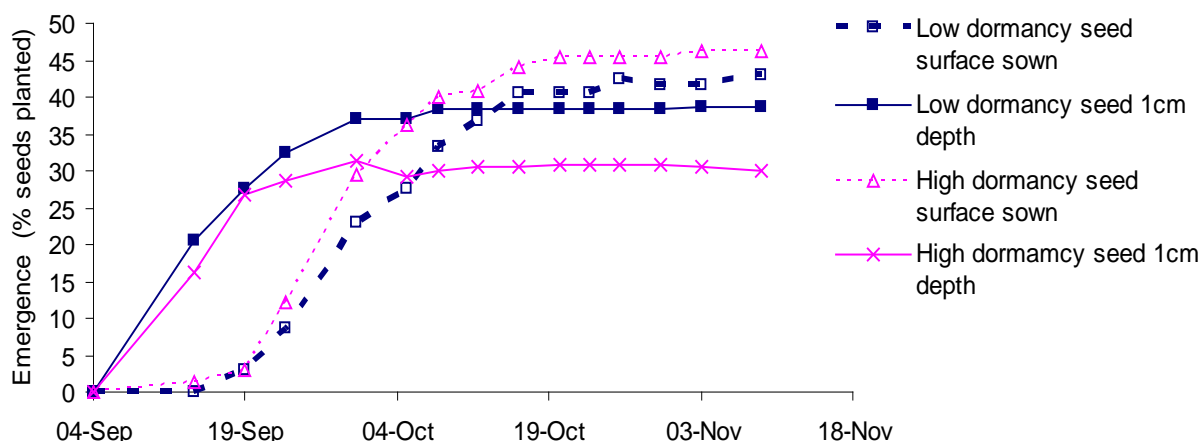


Figure 26. Emergence of black-grass sown on the soil surface or at 1 cm depth

Black-grass seed germinated both on the surface and when buried, but seed on the surface took longer to germinate because seed contact with the soil was insufficient to permit good water absorption (Colbach *et al.*, 2006). Surface-sown seed germinating to a greater extent than buried seed was also noted by Andersson & Åkerblom-Espeby (2008) who attributed this to the greater availability of light breaking dormancy.

Summary and key points

- Emergence of surface sown black-grass seed was delayed by 5 days compared to seed buried at 1cm depth.

3.3.4. The effects of spring and autumn cultivation on black-grass seed emergence

Materials and methods

One litre pots were filled with sterilised Kettering loam and grit (5:1 mix), with 'hydroleca' at the bottom for drainage. Two seedlots of high and low dormancy were selected from field collected seed. Thirty seeds per pot were sprinkled on the soil surface of half the pots and then covered with 1 cm of soil and gently firmed. Treatments are detailed in Table 9; there were six replicates. The pots were placed on the pot standing area covered by a netted cage and watered regularly to keep the soil surface moist. The number of emerged plants was counted every 3-7 days.

Table 8. Treatments

Treatment number	Seedlot	Date collected	Site	Germination 7 days after collection (%)	Soil mixing treatment timing
1	09D113	28 July 2009	Essex	7	March
2					October
3	09D01	8 July 2009	Norfolk	56	March
4					October

In the early spring (March), plants were cut off just above the roots with minimal disturbance to the soil surface in all pots. According to treatment, soil was mixed to sowing depth (1cm) on 11 March 2009 in the appropriate pots and the number of newly emerged plants counted every 3-7 days. In the following autumn (1 October 2009) all plants were cut off at the soil surface, the soil was mixed to sowing depth (1cm) in the appropriate treatments and emerged plants counted as before.

Results and discussion

In the autumn of sowing, emergence was greater in the low dormancy seed than the high dormancy (36% compared to 19%) (Figure 27). In the spring, overall germination was on average 10%, range 3-16%, with a greater amount of low dormancy seed emerging. Cultivation did increase the amount of high dormancy seed emerging. Cultivation in the following autumn encouraged a further flush of black-grass in both the high and low dormancy seed but this was greater in the high dormancy. Over the year a similar amount of the planted seed emerged in all treatments (56%).

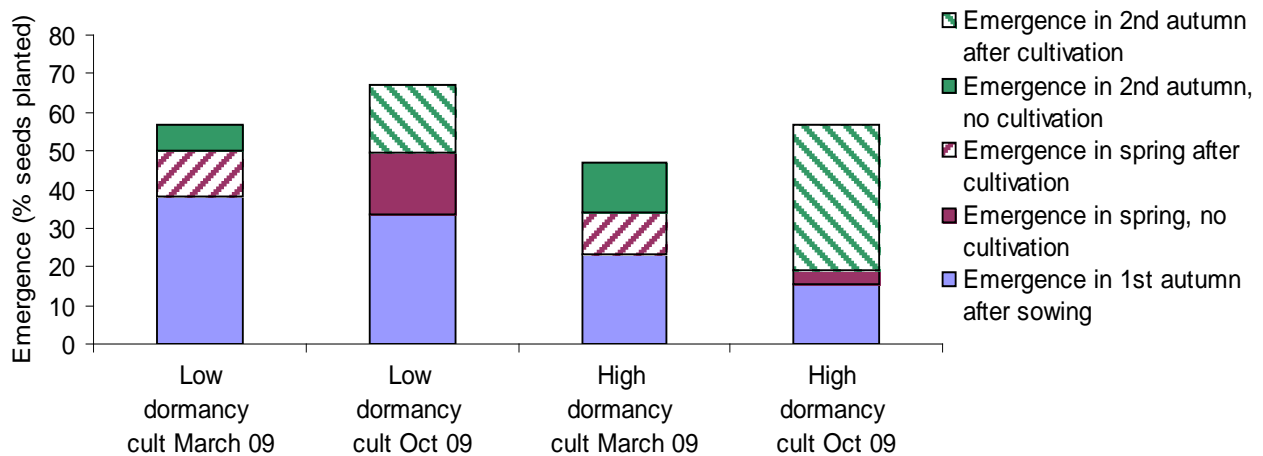


Figure 27. The effects of spring and autumn cultivation on the emergence of high and low dormancy black-grass seed.

The results from this project are in line with previous research, Colbach (2006) noted that after the first flush of emergence a type of secondary dormancy sets in gradually and that cultivation is required to trigger further germination, also reported by Moss (1979). Andersson & Åkerblom-Espeby (2009) attributed the peak of germination to the high light sensitivity in seeds during the autumn, seeds are desensitised during the winter and cultivations in the spring fail to trigger a large germination, the flush in the spring being proportional to the light intensity experienced. Therefore, if a control strategy is based on depletion of the soil seedbank, cultivations need to be done primarily in the autumn.

Summary and key points

- With cultivation more black-grass seed emerged in the autumn than in the spring.
- Cultivation in the spring encouraged emergence but this was lower than in the autumn.
- If a control strategy is based on depletion of the soil seedbank then cultivations need to be done primarily in the autumn.

3.4. Reducing the cost of annual dormancy forecasting (objective 4)

3.4.1. Materials and methods

Germination dataset

Black-grass samples were collected for germination studies from 2001 to 2010 as detailed in 2.1.1. A total of 367 samples were collected and these were used to define a germination dataset containing sample identification, postcode, grid reference, altitude (m) and dormancy (% germination).

Weather dataset

The weather dataset for each individual site year was created in Irriguide. Irriguide is an application created by ADAS (Bailey & Spackman, 1996) to calculate soil moisture deficits (SMD) and help growers calculate the irrigation needs of crops. Part of Irriguide is a weather module (Metmake) which calculates the weather variables using a least squares weighted model from up to five official meteorological stations surrounding a chosen location identified by the grid reference. Height above sea level was also required.

Collectors of each black-grass sample tested for dormancy provided a grid reference for the site from which their sample was collected. Where only a postcode was available this was converted to a grid reference using www.multimap.com. The height above sea level came from the Ordnance Survey map for this grid reference.

The Metmake module of Irriguide was used to output the weather data for the site-crop year, assuming a wheat crop sowing date of 15th September and harvest of 15th August.

It has been shown that the Metmake module output for temperature correlates well with actual temperature readings but the rainfall has a lower correlation. This is because rainfall events are more localised especially during the summer in the UK (Silgram, 2005).

Flowering date

The flowering date of each sample of black-grass was calculated using the Weed Manager growth model (Benjamin *et al.*, 2010). The weather datasets described in 4.1.2 were used to drive this model. Sowing date was set at 15th September.

Windowpane analysis

The windowpane analysis, developed by Coakley *et al.*, (1985, 1988) was used to find the best correlation of weather variables with black-grass dormancy during the maturation period. The previous link project (0923) had identified that temperature during the period 15th June to 12th July was important in determining the dormancy of black-grass seed. This assessment had been done on a limited amount of data and the full data set from 2001 to 2010 has now been used to more accurately define the period of time that influences dormancy in black-grass.

The windowpane analysis looks for a period of weather that has the greatest effect on dormancy. At the start of the analysis the exact starting point and length of the period of the best correlation is not known, so many iterations of different time periods of different durations starting on different days are used. The steps of the process are shown below:

1. Identify the weather variables to explore

2. Start from first day of flowering
3. Start correlation for each weather variable for the first day after flowering
4. For each successive correlation increase the time period by one day e.g. two days after flowering, then three days and so on. Continue until the time period is 25 days
5. Repeat step four starting at the second day after the start of flowering, then the third day after the start of flowering. Continue until the start date is 30 days after flowering.
6. Plot the correlations and for each variable choose the start day and period length with the highest correlation.

A review of literature (Colbach & Durr, 2003; Colbach & Chauvel, 2004; Colbach *et al.*, 2005; Simpson, 1990; Swain *et al.*, 2006) had suggested the following weather variables should be explored:

- Average temperature
- Average radiation
- Total rainfall
- Number of raindays (Chosen to give an indication of the daily dampness of a time period)

Modelled weather, dormancy level and estimated flowering date were assembled for each sample of black-grass.

The black-grass flowering date was used for day 1 of the analysis. The correlation window (windowpane) started from day 1 to 30 days after flowering. The windowpane length varied from 1 to 25 days to cover the time period identified by Cook *et al.*, 2006.

Line graphs of the calculated correlation matrix were used to facilitate identifying the start day and length of periods where maximum correlations of >0.3 or <-0.3 occurred.

3.4.2. Results and discussion

Flowering date

The Weed Manager growth model indicated that flowering date varied between 13th May and 5th June with most black-grass flowering between 20th and 26th May; average 22nd May (Figure 28). Flowering was later at the northern sites.

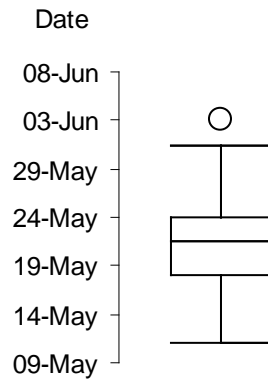


Figure 28. Flowering date. The box plot plots the range of flowering dates for the whole dataset; the centre square denotes the interquartile range. The outer bars denote 95% of the samples. Samples above or below this are shown as circles and are known as outliers.

Windowpane analysis

Figures 29 to 31 show the correlation matrices plotted for the start dates (1 to 30 days after the start of flowering) and different windowpane lengths (1-25 days). These graphs identify the periods where the correlation is less effected by individual variation, and also shows maximum and minimum correlations. The windowpane size is the length of the time period, and the x axis shows the starting day of the period after flowering.

Average temperature and rainfall data had good correlation with the dormancy level of black-grass, and the analysis indicated which time periods effected dormancy to the greatest extent and should be selected for further analysis. For average temperature, the greatest correlation is approximately 0.5 (50% of the variation accounted for), this is for time periods of 19 days in length with start day 20 days after flowering (Figure 29). This period is equivalent to 11th to 30th June, based on a 22nd May flowering date.

For total rainfall, the correlation was greater than for average temperature at -0.48 this is for a time period of 12 days in length starting 4 days after flowering (Figure 30). This period is equivalent to 26th May to 7th June,

The total number of raindays was also important during the period 23 days after the start of flowering for seven days, equivalent to 14th to 21st June (Figure 31).

The maximum correlations are summarised in Figure 32.

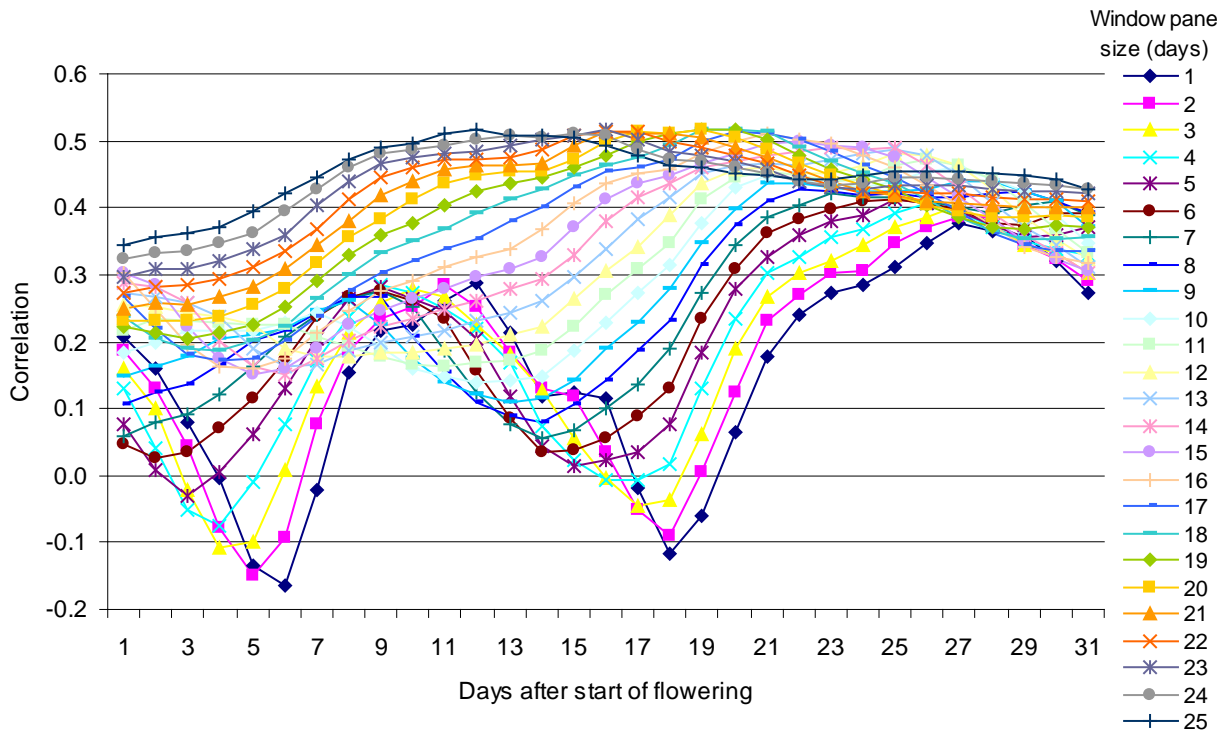


Figure 29. Results of the windowpane analysis for average temperature

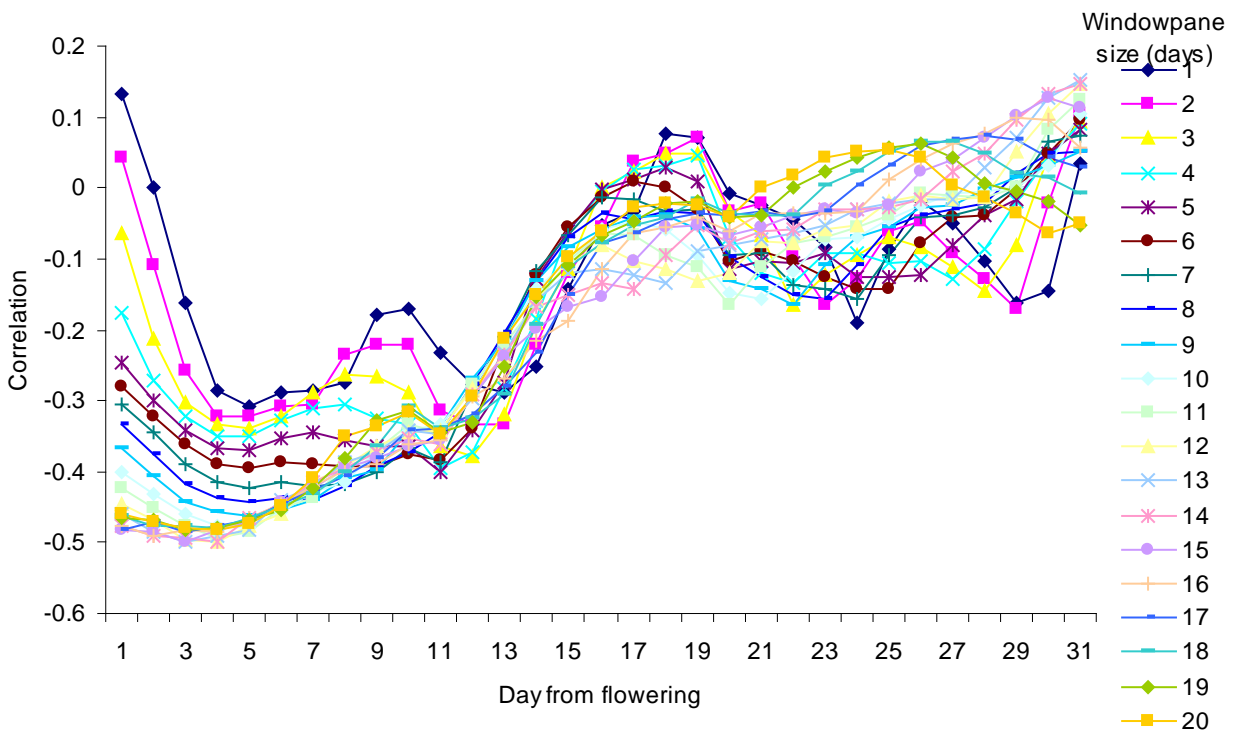


Figure 30. Results of the windowpane analysis for total rainfall

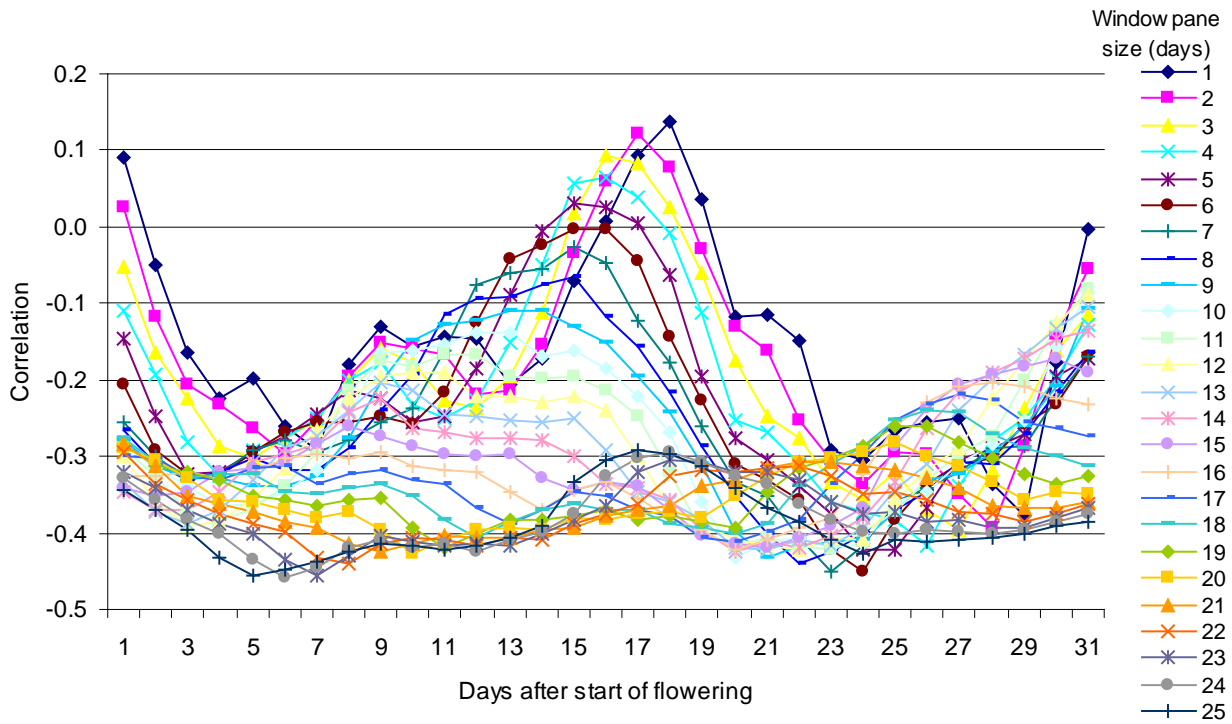


Figure 31. Results of the windowpane analysis for total number of raindays

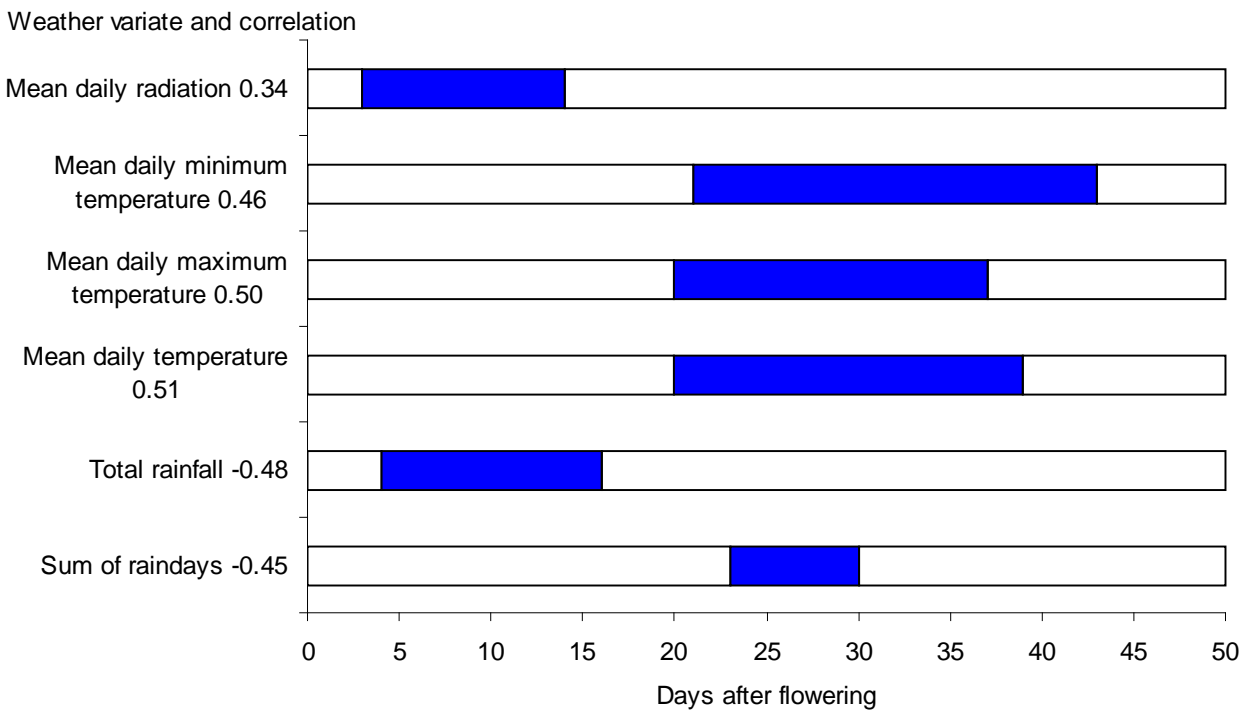


Figure 32. Weather periods important to determination of dormancy. Solid bars represent the duration of the correlation for each weather variate and the numbers indicate the correlation for the period shown.

Each of the windowpanes for temperatures had similar periods and levels of correlation with dormancy level and had high levels of correlation between themselves of $r=0.73$ to 0.96 . For this

reason and since it represents both maximum and minimum temperatures, average temperature was considered the best representative of the temperature variates.

Rainfall seemed to be influential in two periods, total rainfall at the beginning of seed formation and number of rainy days later during ripening. The rainfall variates did not correlate as well either amongst themselves ($r=0.44$ to 0.76) or with the temperature variates ($r=0.54$ to 0.71). This confirms the results from Swain *et al.* (2006) that soil moisture had no consistent effect on seed dormancy.

A multivariate regression was done using these three variates, all of these contributed to dormancy level to a significant level ($p<0.002$). A stepwise regression was done and this highlighted the contribution of each variate. Average temperature was shown to be the most important contributor although total rainfall and the sum of raindays do correlate but to a lesser extent

When the variates were paired and then compared, average temperature and total rainfall added approximately 5% to the correlation to that of the average temperature alone. Therefore rainfall during early seed formation (days 4-16) was an important factor in addition to the average temperature during days 20-37. Adding extra variates such as sunshine did not increase the amount of variation accounted for by just temperature and rainfall factors alone.

Two thirds (69%) of the variation could not be accounted for by these weather variates so other factors such as geographical location or local populations may also be important. In order to explore this we looked at sites that varied geographically and for which we had data over several years; Boxworth (Cambridgeshire), Duggleby (North Yorkshire) and Peldon (Essex). The two variates identified above were plotted against germination (Figure 33 and Figure 34).

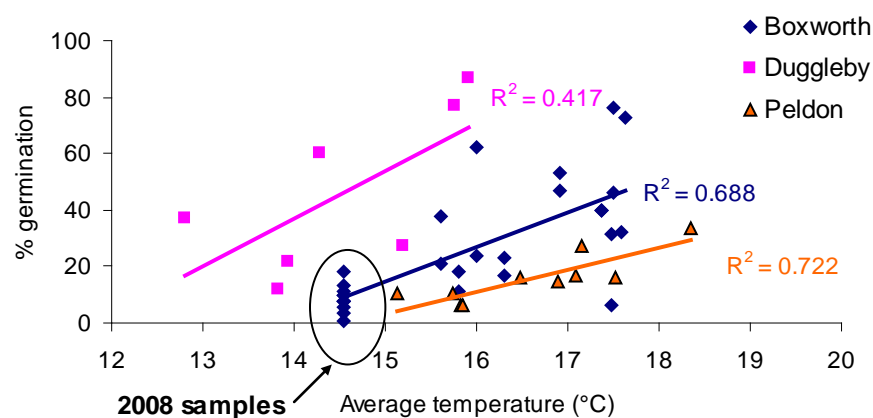


Figure 33. The relationship between average temperature between 20 and 39 days after flowering and dormancy level in black-grass. Multiple samples at Boxworth in 2008 are highlighted.

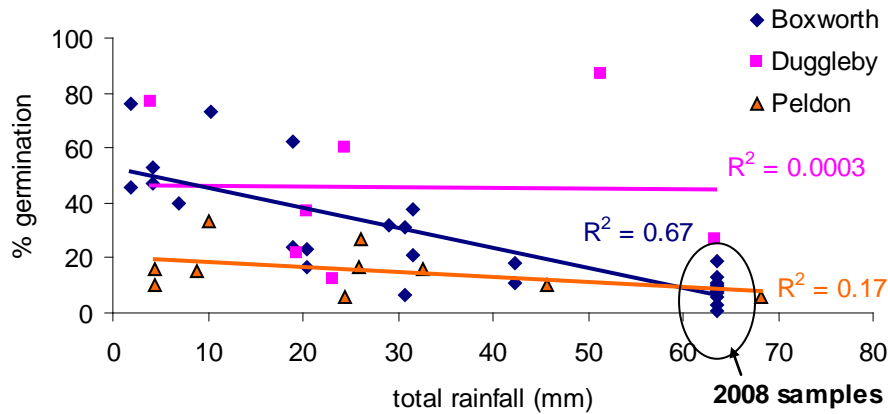


Figure 34. The relationship between total rainfall between 2 and 15 days after flowering and dormancy level in black-grass. Multiple samples at Boxworth in 2008 are highlighted

At Boxworth and Peldon there was significant ($p < 0.05$) correlation between average temperature and dormancy but for rainfall the correlations were significant ($p < 0.001$) only at Boxworth.

At each of the sites the populations responded differently, for example for the same temperature at all sites the dormancy level was lower at Duggleby than at Boxworth and Peldon. It is probable that the inverse relationship is occurring for total rainfall. There was still variation between samples collected at the same site, at Boxworth in 2008 several fields were sampled on the same day and the circled points on both graphs show the variation experience at this site within a single season (Figure 33 and Figure 34). Because such large variation occurs within sites and between sites it is not appropriate to describe the relationship with a single multivariate formula as there is an indication of a strong level of genetic control.

3.4.3. Summary and key points

- Black-grass dormancy was affected by average temperature in the period 20-39 days after flowering. This equates to the period 11th -30th June if flowering date was 22nd May.
- The amount of rainfall during early seed formation was also an important factor, 4-12 days after flowering (26th May to 3rd June) but this relationship was poorer probably due to localised summer rainfall events.
- Only 31% of the variation in dormancy level was accounted for by temperature and rainfall.
- There was variation in dormancy level at the same site which indicated a strong level of genetic control in addition to weather effects.
- Dormancy levels related well to average temperature between 11th and 30th June. At the same temperature dormancy was lower in the north and higher in the south of the UK.
- The correlation can be used to give an indication of the level of dormancy expected for the season but some field sampling will be necessary.

3.5. Key messages for levy payers and implications of the work

3.5.1. Annual dormancy forecasting of black-grass, Italian ryegrass, barren brome, meadow-brome and rye brome (objectives 1 and 2)

An annual forecast of dormancy was issued each August containing guidelines on the most suitable crop management and herbicide strategies to best manage black-grass that season. The results indicated that dormancy in black-grass was lower when the weather during the period between 15th June and 12th July was warm and dry and higher in years when this period was colder and wet.

In Italian rye-grass there was no indication that dormancy level and temperature during the period 15th June to 12th July were related. In barren brome there was a greater difference in dormancy level between samples in a single year than between years and no link to weather conditions during seed maturity was observed.

Identification of meadow brome was difficult and it was often confused with rye and soft brome. Dormancy in the brome species was very variable between populations and there was no link to the weather in June and July.

3.5.2. To understand the implications of dormancy on emergence patterns and to allow optimisation of black-grass management (objective 3)

Black-grass

Dormancy in black-grass changes the emergence pattern of the weed. In high dormancy years emergence will be protracted with 90% of seed emerging up to 60 days after drilling. In low dormancy years 90% of seed will emerge after only 30 days. Knowing the dormancy allows management strategies to be altered (Table 10).

Table 9. Options for management of black-grass in high and low dormancy years

	High dormancy	Low dormancy
Black-grass emergence	More protracted, 90% emergence 60 days after drilling	90% emergence 30 days after drilling
Management strategy		
Pre-harvest glyphosate	No effect	Check and treat if black-grass is emerging in moist conditions
Cultivations	Plough if high populations in previous crop	Non-inversion
Drilling	Early drilling encourages crop competition	Delay drilling for maximum weed emergence
Pre-em herbicide	Use a robust mixture with a high residual component	Apply immediately after drilling
Post-em herbicide	Could be delayed but add a residual to cover protracted emergence	Apply early when emergence is complete

Italian ryegrass, barren, meadow, rye and soft brome.

The majority of Italian rye-grass seed germinates in the autumn and dormancy has little effect on emergence patterns. Emergence of barren, meadow, rye and soft brome is very rapid during the autumn. There was no effect of dormancy level on emergence. Management strategies that encourage rapid weed emergence should be used, delaying drilling until weeds have emerged and been spray off with a non-selective herbicide. After drilling, an appropriate robust pre-emergence herbicide should be applied.

3.5.3. To reduce the cost of providing an annual dormancy forecast for black-grass (objective 4)

Analysis of the complete data set showed that the average temperature in the period between 11th and 30th of June was important in the determining the dormancy of black-grass at harvest. The amount of rainfall received between 26th May and 3rd June was also important but both of these parameters together only accounted for 31% of the variation on dormancy level. This correlation can be used to give an indication of the level of dormancy for the season but some field sampling will be necessary to give a more reliable indication of the dormancy for that season.

3.6. Acknowledgements

The authors would like to thank everyone in ADAS, Rothamsted Research, AICC and farmers who had an input to the experiment and for collecting and sending samples and Dr Stephen Moss. They would also like to thank the project funders, HGCA (Project Number 3336).

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APPENDICES

Annual press releases on grass weed dormancy

2007

Dormancy this autumn is the highest we have ever seen – reliance on a competitive crop and good herbicide choice important

Results from HGCA-funded research have shown that **dormancy in black-grass seed samples this autumn is very high**. Seeds for the project were collected by farmers, ADAS, AIC members, AICC and Rothamsted Research.

Based on 37 geographical samples from 2008 the actual figure was 17% germination. This compares with the results for about 20 samples tested in each of the years 2001 to 2005 as part of a LINK project (LK 0923) and from tests in 2006 and 2007 funded by HGCA. All these years' results are summarised in the table below.

The 2008 result is slightly lower than 2002, 2004 and 2007, these were after cooler and wetter summers. In 2008 the weather has been much cooler than the long-term average with an average number of rain days . In all years samples were collected from across the country and we will be looking more closely at the data to identify if regional variations are occurring, especially in the light of the heavy rainfall and flooding of this summer.

Year	Mean % black-grass seed germinating	Conditions during black-grass seed maturation	Mean Temp °C	Number of raindays
2001	62	Hot , dry	16.9	10.9
2002	22	Cool , damp	15.2	15.1
2003	57	Hot , dry	16.9	10.4
2004	28	Cold , wet	14.7	18.5
2005	59	Hot , dry	17.6	11.5
2006	53	Hot , dry	17.6	10.6
2007	25	Cold , wet	15.3	21.5
2008	17	Cold , damp	15.5	13.8

Mean temperature and number of raindays are the mean of 20 weather stations throughout England for the period 15 June to 12 July.

As in previous years, despite an average high dormancy, a few samples showed lower levels of dormancy indicating that local conditions were still important.

High dormancy is likely to mean a more protracted germination period for black-grass.

What do these results mean?

2008 is similar to 2002, 2004 and 2007; black-grass seeds this year are more dormant and unwilling to germinate even with adequate seedbed moisture. This is unlike 2005 and 2006 where seeds had a lower dormancy and germinated readily when moisture was available.

The prediction this year is that black-grass germination will be protracted even with adequate seedbed moisture.

The following management principles are likely to apply:

- Spray off any black-grass that does emerge before drilling – although this is likely to be less than in a low dormancy year.
- Where there are high black-grass populations consider burying weed problems by ploughing. However, after high levels of control in the current crop avoid ploughing-up more seeds than you bury.
- Early drilling may be appropriate to encourage establishment of a competitive crop.
- Do not be tempted to reduce seed rates where high populations of black-grass are expected.
- Use a robust pre-emergence herbicide with a residual component to cover the protracted period of emergence.
- Post-em sprays need to be timed after most black-grass has emerged and could also need a residual element (this project has a component which aims to characterise emergence patterns better and to provide better guidance on appropriate herbicide strategies. If your seedbed is not cloddy and you do not intend to cultivate within the crop after drilling there is unlikely to be a spring flush of black-grass.

Does high dormancy in the autumn mean a spring germination flush?

This was a hot topic of conversation last year and some herbicide applications were delayed to cover this. As part of the dormancy project large containers of soil were sown in September with a known population of black-grass and emergence monitored through to April. Emergence in these containers was slow and only 20% of seeds germinated. There was no evidence of spring emergence. Spring emergence will only occur when cloddy seedbeds breakdown or where soil is cultivated or moved again in the late winter or spring. At Boxworth we have seen high populations

of spring germinating black-grass in spring crops but none in autumn sown crops where seedbeds were reasonable.

This project was sponsored by HGCA (Project Number 3336). For further information please contact Sarah Cook, ADAS Boxworth (e-mail sarah.cook@adas.co.uk; Tel. 01954 268215).

2008

Dormancy this autumn is the highest we have ever seen – reliance on a competitive crop and good herbicide choice important.

Results from HGCA-funded research have shown that **dormancy in black-grass seed samples this autumn is very high**. Seeds for the project were collected by farmers, ADAS, AIC members, AICC and Rothamsted Research.

Based on 37 geographical samples from 2008 the actual mean figure was 17% germination. This compares with the results for about 20 samples tested in each of the years 2001 to 2005 as part of a LINK project (LK 0923) and from tests in 2006 and 2007 funded by HGCA. All these years' results are summarised in the table below.

The % black-grass seed germinating in 2008 was slightly lower than 2002, 2004 and 2007, these were after cooler and wetter summers. In 2008 the weather has been much cooler than the long-term average with an average number of rain days. In all years samples were collected from across the country.

Year	Mean % black-grass seed germinating	Conditions during black-grass seed maturation
2001	62	Hot , dry
2002	22	Cool , damp
2003	57	Hot , dry
2004	28	Cold , wet
2005	59	Hot , dry
2006	53	Hot , dry
2007	25	Cold , wet
2008	17	Cold , damp

As in previous years, despite an average high dormancy, a few samples showed lower levels of dormancy indicating that local conditions were still important.

High dormancy is likely to mean a more protracted germination period for black-grass.

Does high dormancy in the autumn mean a spring germination flush?

This was a hot topic of conversation last year and some herbicide applications were delayed to cover this. As part of this dormancy project large containers of soil were sown in September with a

known population of black-grass and emergence monitored through to April. Emergence in these containers was slow and only 20% of seeds germinated. There was no evidence of spring emergence. However, spring emergence might occur when cloddy seedbeds breakdown or where soil is cultivated or moved again in the late winter or spring. At ADAS Boxworth we have seen high populations of spring germinating black-grass in spring crops but none in autumn sown crops where seedbeds were reasonable.

Where happened to last autumn's non-germinating black-grass?

If only 20% of black-grass present germinated, a further 64% will have rotted, this means 16% of last year's black-grass is unaccounted for.

What do these dormancy results mean?

The prediction this year is that black-grass germination will be slow even with adequate seedbed moisture.

2008 is similar to 2002, 2004 and 2007. This is unlike 2005 and 2006 where seeds had a lower dormancy and germinated readily when moisture was available.

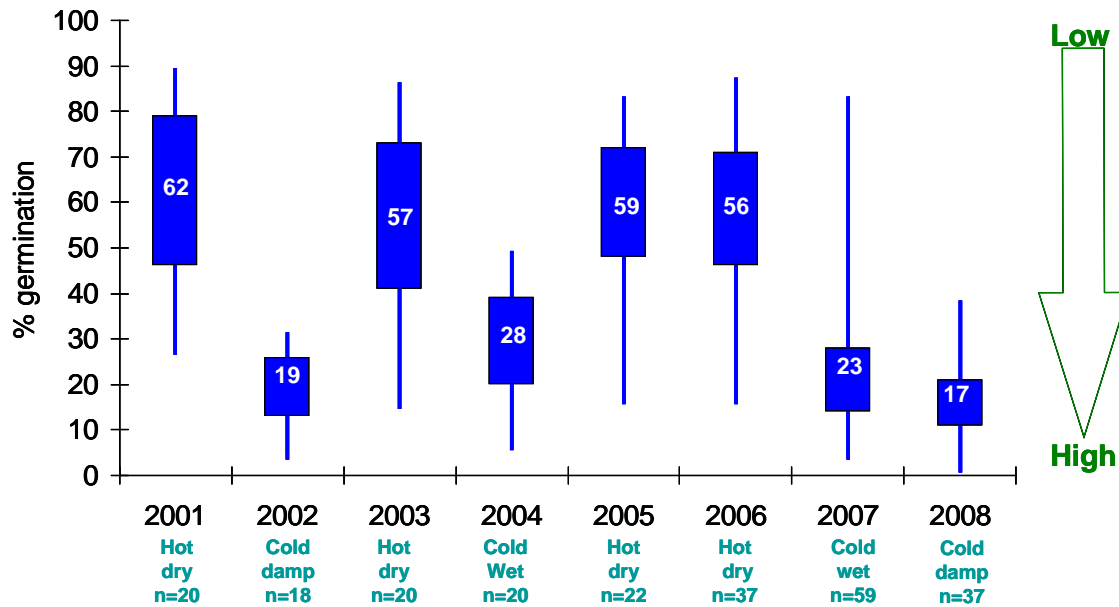
The following management principles are likely to apply:

- Spray off any black-grass that does emerge before drilling – although this is likely to be less than in a low dormancy year.
- Where there are high black-grass populations consider burying weed problems by ploughing. However, after high levels of control in the current crop avoid ploughing-up more seeds than you bury.
- Early drilling may be appropriate to encourage establishment of a competitive crop.
- Avoid cloddy seedbeds
- Do not be tempted to reduce crop seed rates where high populations of black-grass are expected.
- Use a robust pre-emergence herbicide with a residual component to cover the protracted period of emergence.
- Post-emergence sprays could need a residual element to cover some late emergers. Based on last year's monitoring, high dormancy did not, in winter crops, lead to a spring flush of black-grass. It is also worth remembering that late emerging plants are much less competitive, especially in a well established crop. Consider the following important aspects in determining the optimum post-em timing:
- Apply herbicides in conditions most suited to their activity

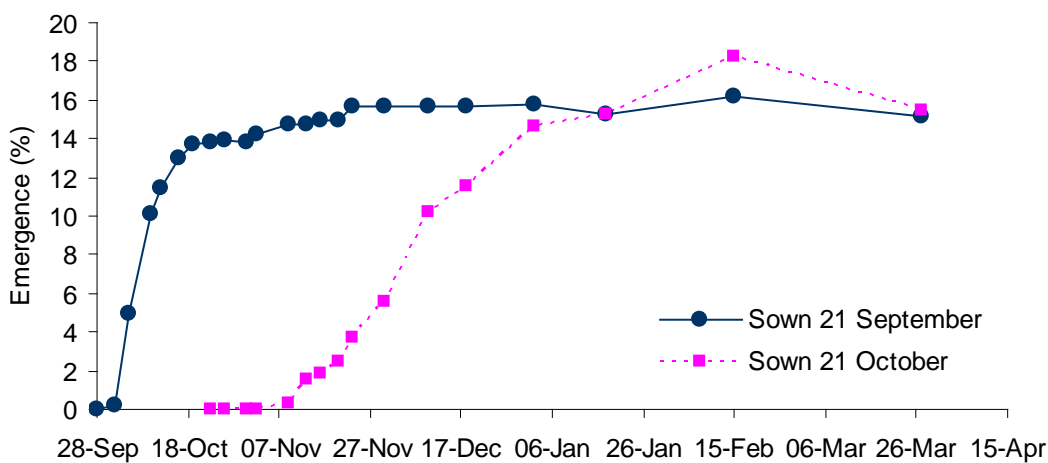
- Small black-grass plants are easier to control. This is especially the case where enhanced metabolism resistance is, or may be, present.

This project was sponsored by HGCA (Project Number 3336). For further information please contact Sarah Cook, ADAS Boxworth (e-mail sarah.cook@adas.co.uk; Tel. 01954 268215).

Appendix 1. Dormancy patterns in black-grass (2001-2008)



Appendix 2. Black-grass emergence patterns (Autumn 2007 – Spring 2008)



Note for editors

1. HGCA project 3336 aims to provide an annual forecast of black-grass dormancy in the years 2007-2010. This new project also has the objective of understanding the implications of dormancy on emergence patterns into the winter and spring and to allow optimisation of black-grass management within following crops. It also extends earlier work to examine

annual dormancy prediction of other difficult to control grass species; Italian rye-grass, barren brome and meadow brome. The work is lead by Dr Sarah Cook of ADAS.

Notes on graph for editors

This is a box plot. For each year the graph shows the most extreme values in the data set (maximum and minimum values), the lower and upper quartiles, and the mean (written in).

The darkened boxes indicate the quartiles, the first quartile of a group of values is where 25% of the values fall at or below this value. The third quartile of a group of values is where 75% of the values fall at or below this value.

5 August 2008

2009

Dormancy this autumn is high again – reliance on a competitive crop and good herbicide choice important.

Results from HGCA-funded research have shown that **dormancy in black-grass seed samples this autumn is high**. Seeds for the project were collected by farmers, ADAS, AIC members, AICC and Rothamsted Research.

Based on 37 geographical samples from 2009 the actual mean figure was 23% germination. This compares with the results for about 20 samples tested in each of the years 2001 to 2005 as part of a LINK project (LK 0923) and from tests in 2006 to 2008 funded by HGCA. In all years samples were collected from across the country. All these years' results are summarised in the table below.

Year	Mean % black-grass seed germinating	Conditions during black-grass seed maturation
2001	62	Hot, dry
2002	19	Cool, damp
2003	57	Hot, dry
2004	28	Cold, wet
2005	59	Hot, dry
2006	56	Hot, dry
2007	23	Cold, wet
2008	15	Cold, damp
2009	23	Average

(See Appendix 1 for figure).

Weather conditions during maturation influence the dormancy level of black-grass, this period generally occurs during the second half of June through to mid July. The weather in 2009, during this period, has been the most variable of all the years we have studied. Generally the weather has been slightly warmer than the long-term average with a lower number of rain days, but there were 50% of stations wetter than average and 50% drier.

As in previous years, despite an average high dormancy, some samples tested showed lower levels of dormancy indicating that local conditions were still important.

High dormancy is likely to mean a more protracted germination period for black-grass.

Does high dormancy in the autumn mean a spring germination flush?

Again this was a hot topic of conversation and some herbicide applications were delayed to cover this. As part of this dormancy project large containers of soil were sown in the autumn with a known population of black-grass and emergence monitored through to April. Over the two years of the project, autumn emergence averaged 29% and a very low level of spring emergence did occur (3%). Spring emergence can also occur when cloddy seedbeds breakdown or where soil is cultivated or moved again in the late winter or spring (See Appendix 2 for figure).

If only 29% emerged where are the un-emerged seeds? Unfortunately we do not know precisely where the 68% un-emerged seeds are or what they will do. However, we would normally expect an 80% seedbank decline in undisturbed soil. If that were the case for every 100 seeds shed last year, 31 may have grown, 54 (80% of 80) may have rotted or been predated and that would leave 14 with the potential to emerge this autumn.

What do these dormancy results mean?

The prediction this year is that black-grass germination will be slow even with adequate seedbed moisture.

The results of 2009 is most similar to 2002, 2004, 2007 and 2008. This is unlike 2005 and 2006 where seeds had a lower dormancy and germinated readily when moisture was available.

The following management principles are likely to apply:

Before drilling

- Spray off any black-grass that does emerge before drilling – although this is likely to be less than in a low dormancy year.
- Where there are high black-grass populations consider burying weed problems by ploughing. However, after high levels of control in the current crop avoid ploughing-up more seeds than you bury.

At drilling

- Aim to get a competitive crop, perhaps by early drilling.
- Avoid cloddy seedbeds to maximise herbicide performance and reduce risk of late emerging black-grass.
- Do not be tempted to reduce crop seed rates where high populations of black-grass are expected.

Herbicide strategies

- Use a robust pre-emergence herbicide with a residual component to cover the protracted period of emergence.
- Post-emergence sprays could need a residual element to cover some late emergers. Based on last years monitoring, high dormancy did not, in winter crops, lead to a spring flush of

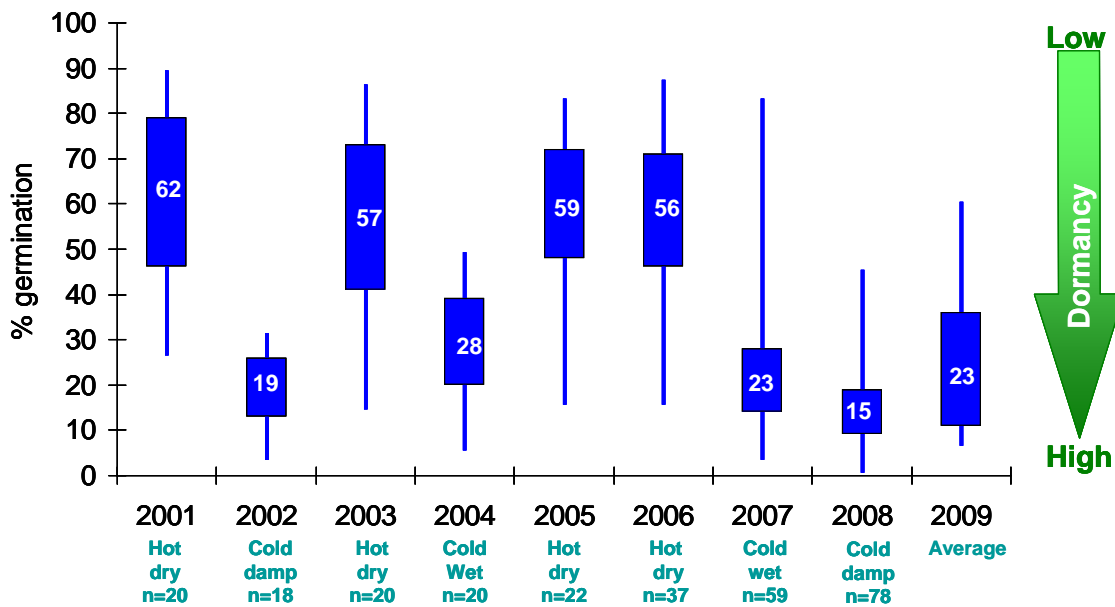
black-grass. It is also worth remembering that late emerging plants are much less competitive, especially in a well established crop.

- Consider the following important aspects in determining the optimum post-em timing:
 - Apply herbicides in conditions most suited to their activity
 - Small black-grass plants are easier to control. This is especially the case where enhanced metabolism resistance is, or may be, present.

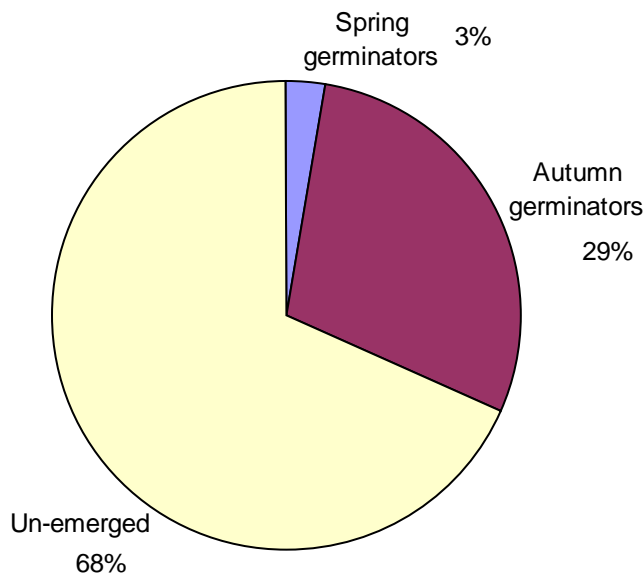
This project was sponsored by HGCA (Project Number 3336). For further information please contact Sarah Cook, ADAS Boxworth (e-mail sarah.cook@adas.co.uk; Tel. 01954 268215).

11 August 2009

Appendix 1. Dormancy patterns in black-grass (2001-2009)



Appendix 2. Black-grass - percentage emergence (2007 and 2008)



Note for editors

1. HGCA project 3336 aims to provide an annual forecast of black-grass dormancy in the years 2007-2010. This new project also has the objective of understanding the implications of dormancy on emergence patterns into the winter and spring and to allow optimisation of black-grass management within following crops. It also extends earlier work to examine annual dormancy prediction of other difficult to control grass species; Italian rye-grass, barren brome and meadow brome. The work is lead by Dr Sarah Cook of ADAS.

Notes on graph for editors

This is a box plot. For each year the graph shows the most extreme values in the data set (maximum and minimum values), the lower and upper quartiles, and the mean (written in).

The darkened boxes indicate the quartiles, the first quartile of a group of values is where 25% of the values fall at or below this value. The third quartile of a group of values is where 75% of the values fall at or below this value.

11 August 2009

2010

2010 is a medium dormancy year

Results from HGCA-funded research have shown that **dormancy in black-grass seed samples this autumn is medium**. Seeds for the project were collected by farmers, ADAS, AIC members, AICC and Rothamsted Research.

Based on 52 geographical samples from 2010 the actual mean figure was 37% germination. This compares with the results for at least 20 samples tested in each of the years 2001 to 2005 as part of a LINK project (LK 0923) and from tests in 2006 to 2009 funded by HGCA. In all years samples were collected from across the country. All these years' results are summarised in the table below.

Year	Mean % black-grass seed germinating	Conditions during black-grass seed maturation
2001	62	Hot, dry
2002	19	Cool, damp
2003	57	Hot, dry
2004	28	Cold, wet
2005	59	Hot, dry
2006	56	Hot, dry
2007	23	Cold, wet
2008	15	Cold, damp
2009	23	Cold then hot
2010	37	Cold then hot

(See Appendix 1 for figure).

Weather conditions during maturation influence the dormancy level of black-grass, this period generally occurs during the second half of June through to early July. The weather in 2010, during this period was cold during the first half and hot at the end, a similar pattern to 2009.

As in previous years some samples tested showed lower levels of dormancy indicating that local conditions were still important, but there were no obvious regional differences.

What do these dormancy results mean?

This is not a result we have seen before and so there is a degree of extrapolation in what we would expect. Based on our understanding the following management principles are likely to apply:

Black-grass emergence

- We do not expect either very rapid or very slow emergence of seed shed this year. It is possible it could be a couple of weeks later than a low dormancy year.
- Seed shed in previous years is likely to emerge early (given that most regions have had recent rain).
- Based on two years monitoring, high dormancy did not, in winter crops, lead to a spring flush of black-grass. Remember that late emerging plants are much less competitive, especially in a well established crop.

Before drilling

- Spray-off any black-grass that does emerge before drilling – there should be some opportunities this year, but ‘a little patience’ may be required. Adequate moisture will also be necessary.
- Where there are high black-grass populations consider burying weed problems by ploughing. However, after high levels of control in the current crop avoid ploughing-up more seeds than you bury.

At drilling

- Aim to get a competitive crop and do not reduce crop seed rates where high populations of black-grass are expected.
- Avoid cloddy seedbeds to maximise herbicide performance and reduce risk of late emerging black-grass.

Herbicide strategies

- A robust **pre-emergence** herbicide, with a residual component, is an essential start for any programme and will help cover the period of emergence.
 - ✓ Aim to apply within a week of drilling to a fine seedbed.
- **Post-emergence** sprays should be applied to small emerged plants in good conditions for activity. There might be a benefit from a residual element, especially if applying early, to control late emergers.
 - ✓ Apply herbicides in conditions most suited to their activity.
 - ✓ Small black-grass plants are easier to control. This is especially the case where enhanced metabolism resistance is, or may be, present.

HGCA guide No. 50 ‘Managing weeds in the arable rotation’ which can be accessed from www.hgca.com/weedmanagement contains more information on managing weeds through a rotation including the latest Weed Resistance Action Group Guidelines.

Table 7: Dormancy and management of black-grass

	High dormancy	Low dormancy
Pre-harvest glyphosate application	No effect.	Check and treat if black-grass is emerging in wet conditions.
Black-grass emergence	More protracted, 90% emergence 60 days after drilling.	90% emergence 30 days after drilling.
Cultivations	Plough – unless low weed populations.	Non-inversion.
Drilling	Early encourages crop competition.	Delay for maximum weed emergence.
Pre-em herbicide	Use robust mixture with a herbicide residual component.	Apply immediately after drilling.
Post-em herbicide	Could be delayed but add a residual if applied early.	Apply early, once most germination is complete.

This project was funded by HGCA (Project Number 3336). For further information please contact James Clarke, ADAS Boxworth (e-mail james.clarke@adas.co.uk; Tel. 01954 268219).

16 August 2010

Dormancy sampling results

Black-grass

Parameter	2007	2008	2009	2010
Number of samples	59	78	41	55
	(% germination or non-dormant)			
Mean	23	15	23	37
Median	19	14	17	32
Minimum	4	1	7	6
Maximum	83	45	60	83
Lower quartile	14	9	12	21
Upper quartile	28	19	35	52
Standard deviation	16.1	9.3	15.0	19.6

Italian rye-grass

Parameter	2007	2008	2009	2010
Number of samples	25	10	8	4
	(% germination or non-dormant)			
Mean	38	33	35	38
Median	28	38	27	31
Minimum	9	7	11	25
Maximum	99	55	93	64
Lower quartile	23	20	19	26
Upper quartile	55	47	43	43
Standard deviation	23.1	17.1	26.8	17.9

Barren brome

Parameter	2007	2008	2009	2010
Number of samples	17	19	11	11
	(% germination or non-dormant)			
Mean	42	38	36	64
Median	32	28	28	75
Minimum	0	0	1	10
Maximum	100	95	93	99
Lower quartile	19	9	21	55
Upper quartile	72	65	46	77
Standard deviation	32.0	31.9	28.0	26.3

Meadow brome

Parameter	2007	2008	2009	2010
Number of samples	15	6	6	6
	(% germination or non-dormant)			
Mean	42	25	39	55
Median	35	16	20	54
Minimum	1	0	0	17
Maximum	99	79	98	98
Lower quartile	14	1	1	25
Upper quartile	69	39	82	81
Standard deviation	34.5	31.5	47.4	34.0

Soft brome

Parameter	2007	2008	2009	2010
Number of samples	2	5	0	1
	(% germination or non-dormant)			
Mean	98	60	-	-
Median	98	47	-	-
Minimum	95	25	-	-
Maximum	100	100	-	-
Lower quartile	96	40	-	-
Upper quartile	99	92	-	-
Standard deviation	3.5	33.5	-	-

Rye brome

Parameter	2007	2008	2009	2010
Number of samples	10	8	1	7
	(% germination or non-dormant)			
Mean	10	1	-	7
Median	1	0	-	1
Minimum	0	0	-	0
Maximum	42	7	-	22
Lower quartile	0	0	-	1
Upper quartile	18	0	-	11
Standard deviation	16.4	2.3	-	9.4