GERMINATION OF WEED SEEDS IN THE GLASSHOUSE

Man has selected crop seeds to produce a high percentage germination immediately after sowing. In contrast, natural selection over a range of ecological niches has resulted in a variety of strategies in germination behaviour among weeds. The result is that weeds are highly competitive to the farmer's crops but sometimes difficult to germinate in the more uniform conditions of a glasshouse!

Knowledge of the main types of seed behaviour, and a consideration of the ecology of a plant species can provide useful clues about how to get its seed to germinate. The next section lists some of the more clearly defined seed strategies that occur in weed species. After this is a section that describes some effective treatments to deal with these strategies. The final section lists certain weeds with specific treatments which are known to stimulate their germination.

WEED GERMINATION STRATEGIES

SMALL SEEDED OPPORTUNISTS

This group includes many arable weeds and ruderals The plant produces a large number of small seeds which are often adapted for long distance dispersal, particularly by wind. Their small energy reserves are insufficient to enable the seedling to grow in competition with established plants. Thus many of these species have evolved germination requirements which ensure that the seed germinates only in open sites. Such sites are characterised by warm sunny days and cool nights. If established plants are present they reduce the amount of red light which reaches the soil surface and reduce the day/night temperature fluctuations. Thus the seeds of many opportunist species require (red) light and fluctuating temperatures for germination. This strategy is common in members of the family Asteraceae (Compositae) such as *Senecio, Lactuca* and *Matricaria* and in small seeded grasses such as *Poa* and *Agrostis.*

These species should be surface sown, with diurnal light and temperature fluctuation.

LARGE SEEDED COMPETITORS

The opposite strategy to that of the 'opportunists' is the concentration of reproductive resources in a small number of large seeds. These seeds have adequate energy to permit the seedling to emerge from a buried seed and to establish itself in competition with other plants. The seed coat is often thick, which reduces the risk of predation, and may require scarification.

Seeds of these species germinate best when covered by soil or when placed in the dark. They may need scarification to erode an impermeable seed coat.

WINTER AVOIDERS

A deeply dormant seed which germinates only after it has experienced an adequate cold period is an adaptation to severe winter conditions. This permits the species to overwinter as a relatively resistant seed in conditions which would kill the vegetative stage. The temperate species of *Polygonum* typify this strategy.

Stratification is necessary for seed of many species that demonstrate winter avoidance.

DROUGHT AVOIDERS

Plants adapted to environments with a pronounced dry period often have a seed coat that is initially impermeable to water. They only germinate after a relatively long period of soil moisture (during which the hydrophobic component of the seed coat is degraded). Many species of the family Fabaceae (Leguminoseae) such as *Vicia* and *Cassia* are examples of this strategy.

Scarification is necessary for seed of species that have impermeable seed coats.

WINTER ANNUALS

Winter annuals germinate in autumn and grow over the winter. In nature their seed lies in or on the soil during the warm conditions of late summer. It is stimulated to germinate by the lower night temperatures of autumn. If a seed batch of a winter annual such as *Alopecurus myosuroides* or *Bromus* species appears dormant, moistening the seed to 12-15% and incubating at 30C for 2-4 weeks (an artificial summer) frequently alleviates the dormancy. Germination is initiated by sowing in a 10/20C temperature regime.

THERMOPHILES

A strategy which prevents seeds germinating too early in the spring before the danger of night frosts has passed is a requirement for warm soil temperatures for germination to take place. Species of *Xanthium* and *Amaranthus* tend to germinate only at temperatures above 20C.

Many warm temperate and frost susceptible species germinate best at temperatures over 20 C.

RISK SPREADERS

Some populations and species produce seeds that are physiologically diverse. A proportion of seeds germinates readily, other seeds from the same plant require a greater stimulus to initiate germination. This results in an extended period over which the population of seeds germinate. This avoids the ‘all eggs in one basket’ risk of instantaneous germination but is unhelpful to the experimenter who needs a population of similarly sized seedlings.

Stratification can be helpful in synchronising the germination of many temperate annuals. Another method is seed priming (page 5 below). For an experimenter needing a supply of near-identical seedlings, the simplest approach is to sow a large quantity of seed so that sufficient seedlings are available from the first flush of germination.

POST-HARVEST DORMANCY

Premature germination, either while on the mother plant or during adverse climatic conditions, perhaps the hot dry conditions of late summer when the seeds of many species are shed, would be disadvantageaous. Thus the seeds of many plants retain a post-harvest dormancy, the length of which varies between species and between different seed batches of the same species. This dormancy declines naturally with time after harvest. Typical examples are *Viola arvensis* and *Echinochloa crus-galli,* some populations of which have well documented post harvest dormancies that can last for anything between three and twelve months. Even some batches of normally non-dormant species such as *Alopecurus myosuroides* and *Veronica persica* occasionally can have an extended post-harvest dormancy.

Simple post harvest dormancy is alleviated by storing the dry seed for an adequate time at room temperature. Storage of the seed at 12% noisture content for a few weeks at 30C can accelerate the decline of post-harvest dormancy in some species.

Herbiseed normally stores seed that is known to have a significant time-dependent post-harvest dormancy for one year before distributing it to our customers.

SEEDS FROM BERRIES

A seed which germinated in the moist environment of the berry in which it matured might be digested by the bird which ate the berry. Thus seeds of plants such as *Solanum spp.* tend to contain inhibitors that prevent premature germination. These inhibitors may decline with time, may be leached out by substantial rainfall, or be removed by the digestive processes of the animal which eats the berry. Herbiseed leaches seeds from berries in cold water before drying and storing them.

Seeds from berries may need substantial leaching with water or acid to permit germination.

ENDOGENOUS TIME CLOCKS

An endogenous time clock occurs in some populations of *Galium aparine.* In seed of this species a short period of post-harvest dormancy is succeeded by several months of non dormancy before a second period of dormancy commences. Cycling between dormancy and non dormancy can continue for several years. These cycles are believed to prevent the seed germinating in summer when conditions are not conducive to establishment in this species.

Cyclical dormancy can be avoided by placing the seed in a deep-freezer at –14C when it is non dormant. The endogenous rhythm is stopped during the period the seed is deep-frozen.

SUMMARYOF SEED STRATEGIES

The descriptions of seed germination strategies outlined above understate their complexity. Several known strategies may be combined in the same seed, for instance *Solanum nigrum* contains a soluble inhibitor and its germination is thermophyllic. Seed from isolated populations or from the extremes of the geographical range may show significantly different behaviour to that of the main population of the species. Conditions experienced by the mother plant during seed production also affect seed behaviour. Variation can occur in the depth of dormancy of individual seeds within the same batch such as in *Chenopodium album.* Different batches of the same seed population may react differently to the same treatment. Nevertheless, for the researcher who receives seed of a species that is new to him, a consideration of the field ecology, particularly of potential need for avoidance of adverse conditions, of the population from which that seed was obtained will be a useful start in determining how to germinate it.

TREATMENTS TO PROMOTE GERMINATION

SHELF STORAGE

Herbiseed aims to store seed from species that are likely to show extended post harvest dormancy for at least one year before dispatching it to our customers. This is achieved with the seed dried to 10% moisture in a thermally insulated store at 30% relative humidity.

COLD STORAGE

Seed which undergoes cyclical dormancy can be deep frozen at -14C to -18C when in its non-dormant phase. When it is taken out of the freezer it will still be non-dormant. If it is intended to store seed frozen for over one year, ensure that its moisture content is not more than 8% and seal the container to prevent the seed absorbing moisture in the freezer.

There is some evidence that storage of dry seed in a refrigerator at a temperature of 1-5C reduces dormancy in certain species.

STRATIFICATION

Sometimes called 'vernalisation', stratification subjects moist seed to cold conditions, thereby fulfilling the cold requirement of winter avoiding species. One method is as follows:

1 Mix the seed with twice its volume of <u>coarse</u> sand or vermiculite.
2 Wet the mixture thoroughly.
3 Drain for three hours but do not allow to dry out.
4 Place in a thin plastic bag or unsealed container.
5 Ideally leave for several days at room temperature and keep moist.
6 Place in a refrigerator at between -4C and 4C.
7 Periodically replace moisture lost by evaporation.
8 Sub-sample seed at monthly intervals and test for germination at 10/15C.

An alternative is to sow the seeds in normal growing medium and put the sown containers outdoors in autumn (protected from birds, mice and molluscs) or into a cold room at any time of year. After an adequate period remove them from the cold and place in the glasshouse to germinate. Pre-sowing seed trays and putting them into a cold room for a week or two is effective in promoting the germination of many temperate weeds. However, many species of Umbeliferae will only germinate after experiencing a full winter outdoors.

SCARIFICATION

Seeds which have an impermeable seed coat require the coat to be made permeable by physical scratching or treatment with solvents or acids. Scarification with sandpaper is the simplest and safest method to use on small quantities of seed. The method is as follows:

1 Place a piece of coarse sandpaper over the bottom of a small tray.
2 Place a single layer of seed on the sandpaper.
3 Rub the seed with another piece of sandpaper or a sanding block.

4 Stop when the seed is thoroughly scratched but before >10% of the seed coats break.
5 Test for efficacy by putting a sample of the seed in warm water overnight. It should imbibe visibly, if does not, drain, surface dry and scarify it further. Do not pre-imbibe the main batch of scarified seed before sowing, too rapid imbibition damages the seed.

HOT WATER TREATMENT

Seed of plants adapted to arid conditions can sometimes be stimulated to germinate by hot water treatment. Effective treatments vary from 24-hour soaking in water at 60C (*Sorghum halepense*) to a few seconds immersion in near-boiling water (*Abutilon theophrasti*). Optimum treatments need to be found by experiment if seed of Mediterranean or arid climate species fails to respond to scarification.

SEED PRIMING

Seeds are able to initiate the early stages of germination at a lower availability of water than is required for emergence of the radicle. They can be held in a primed state for several weeks before sufficient water is made available to stimulate radicle emergence. This provides an opportunity to synchronise the otherwise extended germination of ‘Risk Spreading’ seed batches. However the technology of priming is rather delicate. One method is to determine the moisture content of the seed batch by oven drying a sample, then adding sufficient water evenly to all of the seeds to bring them up to 25-35% moisture and keep them well aerated at 20-25C. An alternative is to put them into a saturated solution of polyethylene glycol, molecular weight 500 and continuously stir them at 15-25C. The optimum conditions for any species requires to be discovered by experiment on that species. Thus **priming is only of practical value to an organisation carrying out a long series of experiments on the same species.**

OTHER TREATMENTS

In general, the treatments outlined above are effective in promoting the germination of the weeds usually used in glasshouse tests. Further techniques are available, including giberellic acid, cytokinins, ethylene, red/far-red light and inorganic cations. **Concentrated sulphuric acid** can, **with care,** be useful in making permiable the hard seed coat of certain Fabaceae and Malvaceae seeds. **Potassium nitrate** is an effective germination stimulant in a wide range of species, particularly Avena, Raphanus and Galium. Although the optimum nitrate treatment can be batch-specific, soaking for 24 hours in concentrations of 1%-3% are often effective.

PRACTICAL RECOMMENDATIONS

While several weed species have special requirements for alleviating seed dormancy mechanisms, many temperate species have similar requirements that permit them to germinate in a single glasshouse regime that has been described as follows:

'The best general purpose seed germinating regime….for most small-seeded temperate weed species would be a combination of alternating temperatures of 25/5C applied in 12h/12h cycles in an 8h photoperiod in which the light is provided at an illuminance of approximately 260 lux from white or warm white fluorescent tubes and the germination medium is 10^{-2}M KnO_3. If necessary the seeds should previously be stratified under aerobic conditions at 1-3C for about 4 weeks.'

(Roberts E.H. & Murdoch A.J. 1989, 'Differences in seed germination between laboratory and field environments and consequences for the field evaluation of pre-emergence herbicides' Aspects of applied biology, 21 1989, 95-106)

It is less possible to generalise on germination conditions for larger seeded temperate weeds, but burial of the seed to a depth equal to 1-2 times its diameter in the same ambient conditions as those for small seeded weeds will suit many species. Nevertheless, a valid generalisation is that fluctuating conditions of light and temperature are more conducive of germination in many species than conditions with no diurnal fluctuation.

ALL SMALL SEEDED (<2mm) TEMPERATE WEEDS

Surface sow or cover with no more than 2mm. of soil. Light is necessary, with light/dark periodicity and temperature fluctuations over the range 10-25C is an advantage for some species. Surface sowing requires constant attention to ensure that the soil surface does not dry out, even temporarily.

ALL SMALL SEEDED TROPICAL ANNUALS

Surface sow in the light at 20-25C. Ensure that the soil surface does not dry out even temporarily.

SEEDS LARGER THAN 2mm DIAMETER

Cover seed with a layer of soil equal to the diameter of the seed. Fluctuating temperatures (5-15 C) can be advantageous with cool temperate species. Warm climate species normally germinate well in temperatures between 20C and 30C. Alternating light and dark periods are likely to give better results than constant light.

PRE-TREATMENTS

To some extent, the pre-treatments which alleviate dormancy can be generalised across groups of weeds related either taxonomically or by germination ecology. Thus many legumes require scarification, the decline of post-harvest dormancy in many grasses is alleviated by storage at 25-35C. Similarly, species which behave as winter annuals, normally germinating in autumn, germinate best if previously conditioned with 15% seed moisture content at 25-30C. Species which are strictly spring germinators often require a period (up to 3 months, in spite of the quotation above) of fully moist cold stratification.

Finally, for a large number of species (and populations, biotypes and seed batches) which are variable in their germination behaviour and otherwise unpredictable or difficult, a pragmatic approach for laboratory and glasshouse purposes is to sow up a large number of pots or trays of each species, water well and keep in a cold room for several weeks. Bring an appropriate number out into a warm environment as needed.

SPECIFIC TREATMENTS

Abutilon theophrasti: Place seed in a tea strainer or sieve. Pour boiling water over it for 5-10 seconds. Allow to drain and sow 3mm. deep. Germinate at 20-25C.

***Ambrosia species*:** Post harvest dormancy can persist for several months. Soak for 24 hours in 2-3 changes of warm water. Sow 5mm deep and germinate at 15-25C in the light. Some seed batches respond to a cold period before germination.

Avena fatua: Most populations have post harvest dormancy which lasts up to three years. This can be alleviated by removing the seed from the caryopsis or by physically damaging the caryopsis. Stratification and potassium nitrate treatment are partially effective on some batches. Sow 10mm. deep and germinate at 5-15C.

Herbiseed supplies seed of a dormant population which has been stored for 3 years to allow the dormancy to decline.

Herbiseed can also supply seed of a genetically non-dormant population which germinates rapidly and in a field trial is less likely to leave ungerminated seed in the field to germinate in the following seasons and contaminate following crops.

Bilderdykia [Polygonum] convolvulus: Stratify for three weeks, germinate at 10-20 C. Some batches may germinate without stratification.

Cassia species: Scarify strongly, soak overnight and repeat scarification if the seed does not imbibe. Sow 5mm. deep and germinate at 20-25C.

Chenopodium album: Individual seeds tend to germinate gradually over several weeks. This can be accelerated by removing the involucre from the seed and stratifying for 2 weeks at 1-5 C. Herbiseed supplies seed from which the involucre has already been removed. Sow 2mm. deep and germinate at 10-25C in the light. Germination can be synchronised by sowing the seed, watering it, then placing it in a cold room at 5-10C for a few weeks before bringing it into the warm to germinate.

Cyperus iria: Surface sow, firm soil well and germinate in the light, at 20C ensuring that the soil surface never dries out.

***Datura species**:* Soak seed in several changes of warm water for 24 hours. Sow 5mm. deep and germinate at 15-25C.

Fumaria officinalis: This species displays much batch to batch variation in germination. Light scarification plus up to three months stratification can be effective on batches that do not germinate readily. Sow 3mm. deep and germinate with temperature cycling between 5 C and 15 C.

***Galeopsis tetrahit*:** Scarify, then stratify for 8 weeks. Sow 3mm. deep and germinate at 5-15C.

***Galium aparine*:** Sow 10mm deep, germinate in temperatures fluctuating from 10-20C, ensuring that the soil is watered to over field capacity at least once per day. Pre-soaking overnight in 3% potassium nitrate solution can be effective.

This species is particularly difficult to germinate in summer. Where it is required for year-round glasshouse screening, seed which has been stored in a refrigerator can be sown in pots or seed trays that are watered, then held for two weeks in a cold room at 5-10C for germination to occur before moving them to the greenhouse.

Great variability occurs between seed batches. Where this species is to be tested throughout the year it is advantageous to stock several batches of seed. Change to the batch giving the best germination as required. Alternatively deep freeze a sub sample at a time when it is germinating well. Batches with shallow dormancy can be germinated after stratification or potassium nitrate soaking. See also Herbiseed Brief Weed Guide No.5.

Herbiseed stock a population which originated in a German potato field that appears to germinate much later in the spring than most populations of the species. This is the population to use for spring sown field trials and glasshouse experiments in summer.

Geranium: Scarify, then sow 3mm deep. *Geranium pratense* (and some other temperate wild species of *Geranium*) are stimulated by stratification.

Imperata cylindrica: Surface sow on free draining soil and keep very moist, preferably in a mist propagator. Keep at 25C. Seedling establishment is slow.

Ipomoea species: Scarify seed and wash briefly with water. Sow 2-5mm. deep depending on seed size and germinate at 25C.

Juncus bufonius: Surface sow, firm well into the soil surface and keep the soil very wet, preferably under a mist propagator. Germinate at 10-15C in diffuse light.

***Kochia scoparia**:* Rub seed and blow away as much extraneous material as possible (Herbiseed seed is already rubbed and winnowed). Soak seed in warm water for 24 hours, surface sow in diffuse light and germinate at 20-25C.

Polygonum aviculare: Remove papery husk around seed (seed provided by Herbiseed has already had the husk removed). Stratify for 6 weeks. Sow 2mm. deep and germinate at 5-20C.

Polygonum lapathifolium, Polygonum persicaria: As for ***Polygonum aviculare**,* but some batches germinate without stratification.

Ranunculus spp. The embryo of several species of *Ranunculus* is immature when the seed is shed, and develops only after the seed encounters conditions suitable for germination. Thus germination occurs several weeks to months after sowing. This is true of *R. repens, R. acris* and *R. arvensis*. If relatively rapid germination is required use *R. muricatus*, which normally emerges within two weeks of sowing.

Raphanus raphanistrum: Seed is enclosed in an indehiscent seedpod. Break seedpods into 1-2 seeded sections (already done in seed from Herbiseed). Soak in 2-3 changes of warm water or 2% potassium nitrate solution for 24 hours. Sow 5mm. deep and germinate at 15C.

Salsola Kali: Wear gloves to rub and blow away as much as possible of the spiny extraneous material (this has already been done in seed from Herbiseed). Sow 2mm. deep and germinate at 25C in the light.

Sesbania exaltata: Scarify, then soak in running warm water for at least 24 hours until the water runs clear. Sow 5mm. deep and germinate at 25C

Sida species*:* Rub seed and blow away as much of the husk as possible (This has already been done in seed from Herbiseed). Soak 24 hours in warm water. Sow 2mm. deep and germinate at 25C in the light.

Sinapis arvensis: Large differences occur between different seed batches of this species. Some are deeply dormant. Stratification for 2-3 weeks is often helpful. Sow 3mm. deep and germinate at temperatures cycling between 5 and 20 C.

Solanum nigrum: Leach out soluble inhibitor by soaking in cold water for two weeks (this has already been done in seed sourced from Herbiseed). Sow 2mm. deep, germinate at 15-20C in the light. Do not allow soil surface to dry out.

Sorghum halepense: Remove caryopses (already completed in Herbiseed seed). Soak seed for 24 hours in running water at 30C or in a well stirred water bath. Sow 3mm. deep and germinate at 25C in the light.

Veronica hederifolia: Some batches have a post harvest dormancy which is alleviated by stratification for up to 6 weeks. Herbiseed has recently obtained a population which appears not to have any dormancy. Sow 5mm. deep and germinate at 5-20C.

Viola arvensis: Post harvest dormancy in this species may last up to a year. It can be alleviated to some extent by stratification. Seed sourced from Herbiseed has been shelf stored for at least one year and is non-dormant. Sow 2mm deep and germinate at temperatures ideally fluctuating between 10 C and 20 C.

Xanthium species: Scarify the fruits or cut off the two terminal spines to facillitate water entry and gaseous diffusion. (This has already been done in seed from Herbiseed). Cover with 10-20mm. of soil and germinate at 30C. Soak the soil well immediately after sowing and at least once per day until the seedlings emerge. Soaking the fruits in stirred or aerated water at 35-40 C for 24 hours before sowing can accelerate germination of this thermophillic species.

CONCLUDING REMARKS

The first consideration of an experimentalist faced with the problem of germinating a species new to him (or a familiar species presenting a new problem) is to ask ‘what are the conditions that the seed of this species experiences in the field between shedding from the parent plant and germinating at its appointed season’. Consideration of the answer to this question provides clues as to which conditions may be involved in alleviating dormancy and promoting germination.

From a practical point of view, it is always easiest to ensure that the seed sample is as free of non-seed material as possible (extraneous organic material tends to stimulate fungal growth) and sow it according to the general recommendations at the start of this section on page 5. It is well worth bearing in mind that a great many weed species germinate more readily in soil than in more uniform substrates, particularly filter paper with its poor substrate to seed contact. Furthermore, in many weed species, fluctuating temperatures tend to result in a higher percentage germination than constant temperatures.

A pragmatic solution to the complex interactions between seed batch, test conditions and time is to stock several batches of the same species, changing batch if one batch begins to germinate inadequately. Similarly, as soon as a germination problem arises, send Herbiseed an e-mail describing the species and the conditions in which you are attempting to germinate it. We will try to suggest practical methods of overcoming the problem.

REFERENCE

The following reference has summaries and further references to techniques for germinating many weed species: 'Andersen's guide to practical methods of propagating weeds and other plants' by Douglas B. Buhler and Melinda L. Hoffman. ISBN 1-891276-10-7, Allen Press, USA.

HERBISEED technical staff are always willing to advise our customers on ways of improving seed germination and seedling establishment. Various staff members have long experience in glasshouse screening of agrochemicals, field trials and habitat creation. We are eager to help with any germination or establishment problem and can be contacted as follows:

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