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GROWING WEEDS FROM SEEDS AND OTHER PROPAGULES FOR EXPERIMENTAL PURPOSES

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SUMMARY

Literature on weed seed germination is reviewed with especial reference to the species grown at WRO. This information, together with practical experience gained at the institute, is presented in concise form for easy reference by those wishing to germinate and grow weeds from seeds etc. for experimental purposes. The various ways of breaking innate and induced dormancy in seeds are explained, and practical advice on the collection, storage, testing and sowing of seeds presented. Available information on the treatment of a large number of species is given in an alphabetical list. Some of the information has been directly obtained from "Germination and Establishment of Weeds for Experimental Purposes" by Robert N. Anderson 1968, although in many instances the methods have been verified. For information about species not included in this report consult the General Bibliography on page 21.

INTRODUCTION

There is a vast literature relating to weed seed dormancy, dating back a century or more, some of a general nature and some very precise treatises concerning certain species or groups of related species. Not all of the answers to questions concerning dormancy in seeds are yet known, although in practice it is usually possible to find a suitable method for a given species. For the person whose main interest is the growing plant, seed germination can be an obstacle; this paper is intended as a work of reference to help overcome this obstacle by recommending the best methods of encouraging germination, when wishing to grow weeds in pots or other containers. Perennial weeds have not been included, as they rarely need to be propagated from seed.

The factors preventing many mature and viable seeds from germinating under such conditions, collectively known as dormancy, are many and varied, but can be divided into three main classes (Harper, 1957), of which the first two are the most important.

1) Innate dormancy is a property of the ripe seed as it leaves the parent plant. This means that some at least of the seeds have an inbuilt mechanism which will prevent them from germinating, however favourable the conditions, until certain other conditions have been met. These factors include the following

a) A period of after-ripening.
b) A period of chilling (3-5 ^{o}C).
c) Reduction of the seed coat's mechanical strength and/or permeability to water and/or gaseous exchange by bacterial, fungal or mechanical means.

d) Change in the phytochrome pigment in the seed brought about by the action of light or lack of light.

Any one or a combination of more than one of these factors may be necessary to trigger germination in seeds of particular species. A few species produce seeds which, although apparently ripe, are in fact not fully developed, and these seeds (e.g. Heracleum sphondylium) (Robinson, R.W. 1954) need a further period of after-ripening, preferably at a fairly low temperature (5-10°C) before they will germinate. Stellaria media, among others, requires several weeks at 20-30°C to complete its after-ripening process (Baskin & Baskin, 1976). Many species of weeds (e.g. Polygonum aviculare (Courtney, 1968) and Odontites verna (Chancellor, 1973) have seeds which will only germinate after a period of low-temperature storage. The strength of the seed-coat is also a factor in the germination of several species (Timson, 1965). The weakening or removal of this restriction, which can be artificially carried out in several ways, may not only reduce the pressure required by the radicle to escape from the confines of the seed-coat, but may also induce a chemical reaction to injury within the seed itself that stimulates germination (Black, 1959).

2) Induced dormancy is brought about by the interaction of the seed with its environment after leaving the parent plant. Factors such as desiccation, high temperature or other unfavourable conditions may cause the seed to become dormant. This secondary dormancy (Crocker, 1916) may cause complications which are not removed simply by removing the unfavourable conditions.

3) Enforced dormancy is similar to induced dormancy, but removal of the limiting conditions allows germination to proceed.

These various forms of dormancy give a better chance of survival in the field. Many weeds shed their seeds over several months, and have long germination periods (Fryer and Makepeace, 1977). This not only causes seeds to ripen during successive months but also ensures that the parent plants grow under varying day-length conditions and hence give rise to seeds of varying types and dormancies (Barton, 1961). The degree of dormancy is also affected in Avena fatua by the position of the seeds in the panicle; the lowest and largest seeds in the spikelet tend to germinate earlier (Johnson, 1935). Xanthium canadense has two sizes of seed in the same pod, one in each of the upper and lower lobes; the large lower seed is non-dormant, the small upper one dormant (Crocker, 1906). In Anthemis cotula the small seeds germinate before the large (Ilnicki & Johnson, 1959). A few species, especially in the genera Malva, Ononis, Lathyrus, Trifolium, Atriplex and Chenopodium, have two types of seed, hard and soft-coated, of which the soft-coated brown seeds germinate before the hard-coated black ones. Salisbury (1961) classifies many species into groups according to their seasons of germination. It would appear that some seeds have an inbuilt chemical clock that reacts to daylength, temperature, humidity etc. to trigger germination (Barton, 1961). Thus when trying to germinate seeds out of their usual season, the experimenter must bear this in mind, and add such artificial treatments as can best be judged to stimulate germination.

REVIEW OF MATERIALS AND METHODS

a) Seed collection

Whenever possible only mature seed that is ready for dispersal should be collected. There is often a good correlation between germination patterns and pre-harvest climate (Von Abrams and Hand, 1956). Consequently, batches of seeds gathered at various times differ in their dormancy. Galium aparine is particularly prone to this type of variation. Seeds of some species may be non-dormant if sown when immature, but if left to ripen on the plant become dormant e.g. Datura stramonium (Gill, 1938); others will germinate if ripened on the plant but become dormant if dried further in store. The selection of non-dormant, or less dormant strains of seed is a practical possibility to be borne in mind when collecting seeds. Once selected out, the new strain has to be grown specifically for stock.

b) Seed cleaning

The presence of husks (pales) and remnants of the calyx can sometimes cause dormancy. This may be due either to impedance of moisture and gaseous exchange, or to inhibitory substances present in these organs. Their presence also makes handling and counting more difficult, and tends to disguise flat or empty seeds, so it is advisable to clean all seed as soon as possible after collection.

Cleaning small quantities of seed is best done by a combination of rubbing, sieving and winnowing. Some husks or other debris can be sharp so gloves should be worn, or the seeds stirred in a mortar with the pestle covered in thin foam-plastic sheeting. Dust and light husks can be blown away by careful use of an electric fan, which is preferable to blowing by mouth. Eye and nose protection of some kind is also desirable. Another useful accessory is a set of small sieves, ranging in mesh-size from $\frac{1}{2}$-2 mm. It should be noted, however, that grading of seed by size is not always necessary or advisable, depending on the objective of the experimental work. However, if plenty of seed is available this can be done, each grade being tested and recorded separately in germination records.

c) Seed storage

There is much evidence that many weed seeds can lie dormant in the ground for decades and still be capable of germinating when conditions permit. Storage under room conditions is different, and very few species can be stored reliably for more than 8 years (Brenchley 1920) unless the temperature, humidity and oxygen levels are carefully controlled.

Thorough drying at normal air temperatures is advisable prior to storage for all except aquatic plant seeds, which are best stored in water at temperatures below that in which they normally grow. It is advisable to dress seed before storage with a fungicidal dust, using the minimum quantity recommended by the manufacturers for small seeds. This involves shaking the seeds with the dust in a bottle or plastic bag for a few minutes. Shiny seeds do not hold the dust satisfactorily; in this case it is possible to shake the seeds first with a very small (3 ml/500 gm seed) amount of liquid paraffin or 6% Gum Arabic solution (Jeffs 1973) to make the seedcoats tacky before adding the fungicide. Do not store seeds that have been dressed with mercurial seed dressings

for long periods, or dress them when they have a high moisture content, as germination can be quickly impaired. If such poisonous dressings are used, for example on cereals, care must be taken in handling, because of the toxicity of mercury, and because these organo-mercury compounds are subject to the Poison Rules.

Seeds should be stored in envelopes or cotton bags rather than in plastic bags or glass jars, and kept in closed tins in a cool dry room. If moisture is likely to pose a threat of moulds, silica gel bags can be placed in the tins, to be inspected and dried at intervals. The use of tins rather than other containers will guard against mice, which are attracted by seeds.

d) Seed treatments

The following treatments are recommended for breaking dormancy. An alphabetical list begins on page 9 and the accompanying key shows which treatment to apply to each species.

1) Stratification

Seeds of many weeds growing in temperate regions require a period of moist, low-temperature storage before they will germinate readily; this may vary from a week to six months. As the word stratification implies, the seeds are placed between strata or layers of moist but aerated material such as sand, gravel, peat, paper or cotton wool. For convenience the seeds may be kept separate from the packing material by placing them in cotton or paper bags. Alternatively, a grade of sand or gravel may be used from which the seeds may be easily separated by sieving. The whole needs to be contained in a plastic bag or glass jar, moistened with distilled water, and kept in a refrigerator at around 3-5°C. For some species a period of warm-stratification followed by another period of cold stratification is required, but cold stratification alone is generally sufficient (Anderson, 1968). Germination sometimes occurs during the stratification process, in which case remove the germinated seeds and plant immediately. A few species, e.g. Polygonum aviculare, can be cold treated actually under water, i.e. in a bottle of distilled water (Henson, 1969), but the present author prefers aerated stratification.

2) Pre-chilling

This is similar to stratification except that the seeds are sown, before chilling, in the pot or dish in which they are to be germinated. This may be convenient if only a small number of seeds are to be treated for a short period.

3) Heat treatment

Bulbils of Oxalis latifolia, for example, are stimulated to germinate by a period of cold treatment followed by a short period of high temperature immediately before sowing (see alphabetical list). An accurately controlled oven is essential for this purpose.

4) Mechanical treatments

Mechanical scarification of the seeds may sometimes be necessary to allow penetration of water and exchange of gases through the seed coat. Rubbing the seeds between sheets of sandpaper is a simple although drastic method of scarifying, and great care should be taken not to rub to excess. The entire seed coat may be removed from each seed individually in some circumstances, although it is a slow and laborious process. As an alternative cutting the seed coat with a razor-blade must be undertaken with great care, away from the embryo, while pricking with a mounted needle is possibly the easiest and most effective method of individual seed treatment. In all instances a magnifying glass is required.

5) Acid treatments

Acid acts in the same way as mechanical scarification, reducing the impermeability of the seed coat. Concentrated sulphuric acid is usually used, or it may be diluted to 75%. For a full account see Mirov & Kraebel (1939). Seeds should be thoroughly dry before treatment, and covered with at least twice their volume of acid in a heat-resistant glass container. Eye protection should be worn. Stir occasionally, pour off the acid after the correct period of time, and wash with large amounts of cold water. Sodium bicarbonate may also be used to neutralize the acid after the first rinse, and then washing should continue for 1-2 hours.

6) Chemical stimulants

Some dormant seeds can be stimulated to germinate by chemicals, the four most useful being:-

i) Nitrates, normally employed as a 0.2% solution KNO_3.
ii) Gibberellic acid, usually from 100 ppm-500 ppm.
iii) Thiourea as 1-2% solution.
iv) Kinetin at 50-100 ppm.

Others include Indoleacetic-acid (IAA) 100 ppm; BA (6-benzylamino-purine) 50 ppm; 2,4-D; ethylene etc.

The seeds should be placed in the recommended solution, or on paper saturated with it, at room temperature until fully imbibed, and should then be rinsed and surface-dried before sowing. The time required for imbibition will depend on the permeability of the seed-coat to water, varying from 2 hours to 3 days. The use of the wrong chemical may easily do more harm than using no chemical at all, so the recommendations for each species should be strictly observed. While GA may be one of the best chemicals for inducing germination of many seeds, it also has a subsequent effect upon the growth of the plants, causing elongation of the internodes to a marked degree, and this should be borne in mind when its use is considered. For further information on chemical seed stimulation see the following references.

Ethylene Abeles, F.B., 1973
Egley, G.H. & Dale, J.E., 1969

Nitrates — Toole, E.H., Hendricks, S.B., Borthwick, H.A.& Toole, V.K., 1956

Kinetin — Chancellor, R.J. & Parker, C., 1972

Thiourea — Yamada, I., 1954

Gibberellic acid — Chancellor, R.J. et al, 1972
Corns, W.G., 1960 a
Corns, W.G., 1960 b
Delouche, J.C., 1958
Green, J.G. et al, 1957
Toole, V.K. et al, 1961

A recent advance in seed treatments with GA involves the imbibition of perfectly dry seeds with GA_3 dissolved in redistilled acetone for 24 hours (Millborrow, 1963). The seeds are then dried under vacuum to remove all acetone before germination in the normal way.

e) Seed testing

It is advisable to maintain a record of the percentage viability of each batch of seed stored, tests being carried out at least annually. The following are extracts from the International Rules for Seed Testing (Seed Science & Technology 1976).

"The ultimate object of testing for germination is to gain information with respect to the planting value of the seed, and to provide results which can be used to compare the value of different seed lots."

Seeds are arranged in replicates of 100, 50 or 25 from a total sample of 400 pure and well mixed seeds, spaced uniformly on moist substrate of paper, soil or sand so the seedlings will not touch each other. They are maintained at a favourable moisture level, under suitable conditions of temperature and light until germination is complete. Special dormancy breaking treatments may be used if fresh seed does not germinate.

f) Sowing

Weed seeds can be germinated in, or on soil, sand, filter paper or paper blotters etc. kept moist but not flooded (Anderson 1968). Aquatic plant seeds are better germinated in water, and both Guppy (1897) and Morinaga (1926) found that weeds of several non-aquatic species will germinate under water. Gardner (1921) also used water for some non-aquatic species. Most weed seeds will germinate readily on paper, especially if this is moistened with a 0.2% KNO_3 solution. Galium aparine and possibly a few other species germinate more reliably in the presence of soil. If seeds that have been germinated on paper, etc. are to be kept growing it is of course necessary to transfer them either to soil or other compost or to a liquid culture solution. If soil is used, either alone or mixed with other materials such as peat and sand, it is desirable to sterilize the soil partially by heating it to 85°C for half-an-hour in order to kill insects and indigenous weed seeds. Next remove any large lumps by passing the materials through a 3/8" sieve. For very small seeds the compost which will be

used to cover them should be sieved even finer. The addition of nutrients, especially phosphates, is desirable as the latter are mainly absorbed while the plants are small. Super phosphate (18% P_2O_5) should be added at 1 gm to each kg of compost, which should be sufficient until the plants reach the 2-3 leaf stage. The plant should then be transferred to a larger volume of richer compost. If this cannot be done, more fertilizer will need to be added to the compost before sowing, or liquid feeding done later. However, fertilizer rates of more than 2 gm/kg are liable to damage young seedlings of many species, in particular the small-seeded kinds, especially if watering is done from below, as this tends to bring salts to the soil surface. As the seedlings grow they will require the other major elements nitrogen and potash; these are incorporated into the compost by adding a 'base' fertilizer such as John Innes Base fertilizer or one of the longer lasting resin-coated mixtures available. Recommended rates vary with the material, but in all cases the larger the plant, the greater the amount of fertilizer added per volume of compost.

When sowing seeds in soil, unless they specifically require light in order to germinate, cover them with a depth of soil commensurate with their diameter; generally speaking not more than five times the diameter of the seed will give the best results. Too little soil may not give the seed sufficient anchorage to enable the radicle to push down into the soil below, resulting in the seed being lifted out of the soil with the possibility of drying-out and damage.

The pH value of the soil is not usually critical (Ellenberg 1950) although values of between pH 6-7 should be aimed at (Justice & Reele 1954). Relatively few species of plant seeds will fail to germinate entirely because of this factor, although the natural habitat of the species should always be kept in mind when growing any plant, and adjustments made for species peculiar to extreme habitats. The pH value of any compost depends on that of its constituents, soils varying in acidity or alkalinity, while peat is usually acid, and sand can be alkaline to neutral. Adjustment of low pH can be most easily done by adding finely ground calcium carbonate or magnesium carbonate. High pH values are more difficult to adjust, but the addition of flowers of sulphur or ammonium sulphate to the compost will lower its pH, as will watering with 0.4% Choline phosphate solution. Proprietary soil-less composts based on peat normally have the pH value already adjusted, and can be obtained neutral or acid in reaction.

Soil composts in particular must be freely drained to avoid stagnation, so the containers must have holes in the base and not be placed on a smooth surface which could obstruct drainage. It is preferable to soak the compost thoroughly an hour before sowing the seeds, in which case no further water will be required for several days if evaporation is restricted by covering with glass or plastic. If seeds must be sown in unwatered compost, then water must be applied in a manner which will not disturb the seeds; applied too quickly the seeds may float to the surface or be washed to one side of the container. An alternative method is to water from below by capillarity, tipping away any remaining water from the lower vessel after the water has reached the compost surface.

g) Temperature

Whereas many weed seeds will germinate in a constant temperature, the majority will do better under alternating high-low temperature conditions, and more than a few actually require these alternations in order to germinate at all. Warington (1936) states "It may be inferred that many of the commonly occurring weed seeds are of the type for which alternations in temperature are required for good germination". Kolk (1947) found that varying temperatures between 5°C and 22 °C favoured the germination of most of the species he was studying as compared with constant temperatures of 20-22°C. Aim at 8 hours at the higher temperature, followed by 16 hours at the lower.

h) Light

Many species of weeds have a light requirement for germination. Kinzel (1929) found that out of 964 species examined, germination of 672 was favoured by light, whereas that of 258 was inhibited by light. However, non-dormant seed, or seed that has been stimulated to germinate, e.g. by pricking, does not have a light-requirement (Cumming & Hay 1958). Light and temperature can inter-react in several ways. In some instances seeds which germinate readily in the dark at alternating temperatures require light if held at a constant temperature. Not only this, but seeds that require light if germinated at a high temperature may germinate in the dark at lower temperatures; lettuce is a case in point (Borthwick, Hendricks, Toole & Toole 1954).

The response to light is determined by its wavelength, duration and intensity of exposure, and the temperature of the seed before, during and after exposure (Anderson 1968). For further information see also the following reports and reviews:-

Borthwick, 1965; Evenari, 1956; Evenari, 1961 a and b;
Gardner, 1921; Hendricks et al, 1961; Karssen, 1970;
Toole et al, 1955; Wareing et al, 1961; Wesson & Wareing, 1967.

Some generalizations are, however, possible concerning response to light. Light is only effective after seeds have imbibed water. Red light is more effective than other wavelengths, but far-red illumination acts in opposition to red, and if far-red light immediately follows red light treatment the phytochrome pigment that effects germination is converted back to the inactive form and the seeds will not germinate. Fluorescent tubes emit considerable red, but little far-red light, whereas incandescent bulbs and the sun emit both wavelengths. Considerable latitude in both time and intensity of exposure to light is allowable, in fact little is as yet known about the limits, and it is probable that very short periods are sufficient in many cases to trigger a response. In practice, light-requiring seeds are sown on or near the surface, with a little quartz sand sprinkled over them, to anchor them until the radicles are established. It is imperative to keep the surface moist while seedlings are germinating, and if pots are covered with glass or plastic to maintain humidity it is also essential to shade from the sun, or overheating and scorching can quickly occur.

SPECIES LIST	YEARS OF VIABILITY AT ROOM TEMP (APPROX)	ALTERNATING OR CONSTANT TEMP C OR A	OPTIMUM GERMINATION TEMPERATURES	DORMANT SEED REQUIRES DARKNESS OR LIGHT D OR L	NOTES AND POSSIBLE TREATMENTS FOR SEEDS SEE KEY P. 16	LITERATURE REF NO PP 17-21
Allium vineale (Bulbils)	1-2	A	20	D	B D	47
Alopecurus myosuroides. Huds.	6-8	A	10-25	L	B I O S T	
Amaranthus retroflexus L.	5	C	35	L	B V	3
Amrbosia artemesifolia L.		A	20-30	L	B L N	
Anagallis arvensis L.		C	12-20	L	L	
Anthemis arvensis L.		C	13	L	B	
Anthemis cotula L.		A	10-20	L & D	N	34
Artemisia vulgaris L.		C	25	L	J	
Atriplex patula L.		A	20-30	L	X	
Avena fatua L.	10	A	15-20	D	B N O P	12 15 17 28 36
Avena ludoviciana Dur.	10	C	5-10	D	B N	
Bromus spp.	3-5	A	5-15	L	B D H	
Capsella bursa-pastoris (L) Medic	5	A	20-30	D	B I N O S T	15 41 65
Cardaria draba (L) Desv.	3	A	20-30	L	A R	
Cerastium glomeratum. Thuill.					A	

RECOMMENDATIONS FOR INDIVIDUAL SPECIES

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Cerastium holosteoides Fr.	4	A	20-30	D	B H O	62
Chenopodium album L.	8	A	15-20	D	C F N O T	12 15 39 64 65
Chenopodium polyspermum L.	8	A	20-30	D	C	
Chrysanthemum segetum L.	3	A	15-25	L	B D F	63
Cirsium arvense (L) Scop.	2	A	20-30	D	A H	41
Convolvulus arvensis L.	7	A	20-30	D	Z	
Cyperus esculentus (tubers)		C	35	D	E K	
Datura stramonium L.	3	A	20-30	D	C F N	26
Digitaria sanguinalis (L) Scop.		A	25-30	L	B J N V	
Echinochloa colonum (L) Link.	3	A	20-30	L	B	
Echinochloa crus-galli (L) Beauv.	8	A	25-30	L	B N	
Eleusine indica (L) Gaertn.		A	20-35	L	A N O	
Erysimum cheiranthoides L.	5	A	20-30	L	O	
Euphorbia exigua L.		A	2-20	D	A F O	2
Euphorbia helioscopia L.		C	20	D	A F O	

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Festuca arundinacea. Schreb.		A	10-20	L	J O	
Fumaria officinalis L.	5	C	7		M	
Galinsoga parviflora. Cav.		A	22-30	L	B	
Galeopsis tetrahit L.		A	5-15	D	R	12
Galium aparine L.	3	C	12	D	A O S	
Geranium molle L.	2-5	A	10-25		A	
Geranium pusillum L.	8	C	7			
Gnaphalium uliginosum L.		C	35	L		
Heracleum sphondylium L.	1	A	10-20	D	L	53
Holcus lanatus L.	5	A	15-20	L	A	
Juncus bufonius L.		C	5	L	L	29
Juncus inflexus L.	7	A	10-15	L	L	
Lamium amplexicaule L.		A	10-20	D	B F	
Lapsana communis L.	4	A	20-30	D	A	

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Lepidium campestre (L) R. Br.		A	15-25	L	B I O	56
Matricaria spp.	5	A	20-30	L	A D	
Medicago lupulina L.	4	C	20		D I N	
Mercurialis annua L.		C	20-35			
Montia perfoliata (Willd) Howell		C	10			
Myosotis arvensis (L) Hill.	5	A	12-20	L	A	
Odontites verna (Bell) Dum.	1	A	5-15	D	I	10
Oxalis corniculata L.		C	15		A	
Oxalis latifolia H.B.K. (Bulbils)	1	A	20-30		G J	
Papaver rhoeas L.	5	A	7-13	D	C K N	42
Plantago lanceolata L.	6	A	20-30	L	A L O Q	18 49 64
Plantago major L.	2-3	A	25-30	L	B L N	12 15 18 49
Poa annua L.	5-7	A	5-20	L	O	
Polygonum aviculare L.	7	A	10-20	D	C M (Q & X)	14 32 63

RECOMMENDATIONS FOR INDIVIDUAL SPECIES

SPECIES LIST	YEARS OF VIABILITY AT ROOM TEMP (APPROX)	ALTERNATING OR CONSTANT TEMP C OR A	OPTIMUM GERMINATION TEMPERATURES	DORMANT SEED REQUIRES DARKNESS OR LIGHT D OR L	NOTES AND POSSIBLE TREATMENTS FOR SEEDS SEE KEY P. 16	LITERATURE REF NO PP 17-21
Polygonum convolvulus L.	5	A	20-30	D	B D M (Q & Y)	32 55
Polygonum hydropiper L.		A	15-35	D	C M	
Polygonum persicaria L.	2-3	A	25-35	D	C (H & O) or (X & Q)	12 32 63
Portulaca oleracea L.	5	A	30-40	L	J T U	65
Ranunculus spp.	5	A	5-15	L	J	31
Raphanus raphanistrum L.	5	C	20	D	(I & O)	
Rumex acetosella L.	3	A	20-30	L	D K O W	
Rumex crispus L.	5	A	20-30	L	A N W	9 22 26 63
Rumex obtusifolius L.	8	A	20-30	L	B N P W	9 26
Senecio jacobaea L.	1-2	A	20-30	D	A	31 63
Senecio vulgaris L.	1-2	A	10-25	D	O	63
Sherardia arvensis L.		C	13			
Silene noctiflora L.		A	20-35	L	A	
Silene vulgaris. Garke.	5-8	A	10-25	L	D	
Sinapis arvensis L.	7	A	7-15	D	B F H N O R S V	12 24 41 63

SPECIES LIST	YEARS OF VIABILITY AT ROOM TEMP (APPROX)	ALTERNATING OR CONSTANT TEMP C OR A	OPTIMUM GERMINATION TEMPERATURES	DORMANT SEED REQUIRES DARKNESS OR LIGHT D OR L	NOTES AND POSSIBLE TREATMENTS FOR SEEDS SEE KEY P. 16	LITERATURE REF NO PP 17-21
Solanum nigrum L.	7	A	20-30	D	B J	
Sonchus asper (L) Hill.		A	30-35	D		63
Sonchus oleraceus L.	6	A	20-30		A	
Sorghum halepense (L) Pers.		A	25-40	D	B D I V	
Spergula arvensis L.		A	20-25	L	T	65
Stellaria media (L) Cyrillo	3-4	A	13-20	D	B D K O S	4 12 41 63
Taraxacum officinale. Weber	1	A	10-20		A	
Thalspi arvense L.	2-3	A	20-30	L	B N O R X	11 13 15 41
Trifolium dubium. Sibth.		C	10		M N	
Tripleurospermum maritimum (L) K.	2-5	A	20-25	L	A D O	63
Ulex europaeus L.				D	W	
Urtica urens L.		C	25	D	B	
Veronica agrestis L.		A	10-25		A L	
Veronica arvensis L.	3-4	A	15-30	D	A L	

RECOMMENDATIONS FOR INDIVIDUAL SPECIES

RECOMMENDATIONS FOR INDIVIDUAL SPECIES

SPECIES LIST	YEARS OF VIABILITY AT ROOM TEMP (APPROX)	ALTERNATING OR CONSTANT TEMP C OR A	OPTIMUM GERMINATION TEMPERATURES	DORMANT SEED REQUIRES DARKNESS OR LIGHT D OR L	NOTES AND POSSIBLE TREATMENTS FOR SEEDS SEE KEY P. 16	LITERATURE REF NO PP 17-21
Veronica hederaefolia L.		C	2-5		O S	
Veronica persica Poir.	3-4	A	15-25	D	A L O	63
Vicia spp.	4	C	20	D	C N R T	
Viola arvensis Murr.			13			
Xanthium spp.	5	A	25-35	L	F	15 61

KEY TO NOTES AND POSSIBLE TREATMENTS FOR SEEDS

A Fresh seed has little or no dormancy initially, but this may develop in store.

B Fresh seed has initial dormancy 2-6 months duration.

C Fresh seed has initial dormancy over 12 months duration.

D Store at room temperature (20-23^{o}C).

E Wash seed 1 hour in cold running water before sowing.

F Wash seed 3 days in regular changes of cold water before sowing.

G 4 hours at 45^{o}C immediately prior to sowing.

H Stratify seed in moist conditions for 1 week.

I Stratify seed in moist conditions for 2 weeks.

J Stratify seed in moist conditions for 3-4 weeks.

K Stratify seed in moist conditions for 1-2 months.

L Stratify seed in moist conditions for 2-4 months.

M Stratify seed in moist conditions for 4-6 months.

N Prick or remove seed coat, or scarify with fine sandpaper.

O Soak seed 1-2 days in 0.2% solution KNO_3.

P Imbibe seed in 100 ppm sol. Gibberellic Acid.

Q Imbibe seed in 300 ppm sol. Gibberellic Acid.

R Imbibe seed in 500 ppm sol. Gibberellic Acid.

S Sow in soil, or soil extract solution on paper.

T Soak seeds for 24 hours in 1-2% Thiourea sol.

U Soak seeds in Conc. H_2SO_4 for 1 minute; wash 1-2 hours in running water.

V Soak seeds in Conc. H_2SO_4 for 2-3 minutes; wash 1-2 hours in running water.

W Soak seeds in Conc. H_2SO_4 for 5-10 minutes; wash 1-2 hours in running water.

X Soak seeds in Conc. H_2SO_4 for 10-15 minutes; wash 1-2 hours in running water.

Y Soak seeds in Conc. H_2SO_4 for 20 minutes; wash 1-2 hours in running water.

Z Soak seeds in Conc. H_2SO_4 for 60 minutes; wash 1-2 hours in running water.

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ABBREVIATIONS

ångström	Å	freezing point	f.p.
Abstract	Abs.	from summary	F.s.
acid equivalent*	a.e.	gallon	gal
acre	ac	gallons per hour	gal/h
active ingredient*	a.i.	gallons per acre	gal/ac
approximately equal to*	≃	gas liquid chromatography	GLC
aqueous concentrate	a.c.	gramme	g
bibliography	bibl.	hectare	ha
boiling point	b.p.	hectokilogram	hkg
bushel	bu	high volume	HV
centigrade	C	horse power	hp
centimetre*	cm	hour	h
concentrated	concd	hundredweight*	cwt
concentration	concn	hydrogen ion concentration*	pH
concentration x time product	ct	inch	in.
concentration required to kill 50% test animals	LC50	infra red	i.r.
cubic centimetre*	cm^3	kilogramme	kg
cubic foot*	ft^3	kilo ($x10^3$)	k
cubic inch*	in^3	less than	<
cubic metre*	m^3	litre	l.
cubic yard*	yd^3	low volume	LV
cultivar(s)	cv.	maximum	max.
curie*	Ci	median lethal dose	LD50
degree Celsius*	^oC	medium volume	MV
degree centigrade	^oC	melting point	m.p.
degree Fahrenheit*	^oF	metre	m
diameter	diam.	micro ($x10^{-6}$)	µ
diameter at breast height	d.b.h.	microgramme*	µg
divided by*	÷ or /	micrometre (micron)*	µm (or µ)
dry matter	d.m.	micron (micrometre)*†	µm (or µ)
emulsifiable concentrate	e.c.	miles per hour*	mile/h
equal to*	=	milli ($x10^{-3}$)	m
fluid	fl.	milliequivalent*	m.equiv.
foot	ft	milligramme	mg
		millilitre	ml

† The name micrometre is preferred to micron and µm is preferred to µ.

millimetre*	mm
millimicro* (nano: $x10^{-9}$)	n or mμ
minimum	min.
minus	-
minute	min
molar concentration*	M (small cap)
molecule, molecular	mol.
more than	>
multiplied by*	x
normal concentration*	N (small cap)
not dated	n.d.
oil miscible concentrate	o.m.c. (tables only)
organic matter	o.m.
ounce	oz
ounces per gallon	oz/gal
page	p.
pages	pp.
parts per million	ppm
parts per million by volume	ppmv
parts per million by weight	ppmw
percent(age)	%
pico (micromicro: $x10^{-12}$)	p or μμ
pint	pint
pints per acre	pints/ac
plus or minus*	±
post-emergence	post-em
pound	lb
pound per acre*	lb/ac
pounds per minute	lb/min
pound per square inch*	lb/in^2
powder for dry application	p. (tables only)
power take off	p.t.o.
precipitate (noun)	ppt.
pre-emergence	pre-em.
quart	quart
relative humidity	r.h.
revolution per minute*	rev/min
second	s
soluble concentrate	s.c.
soluble powder	s.p.
solution	soln
species (singular)	sp.
species (plural)	spp.
specific gravity	sp. gr.
square foot*	ft^2
square inch	in^2
square metre*	m^2
square root of*	$\sqrt{}$
sub-species*	ssp.
summary	s.
temperature	temp.
ton	ton
tonne	t
ultra-low volume	ULV
ultra violet	u.v.
vapour density	v.d.
vapour pressure	v.p.
varietas	var.
volt	V
volume	vol.
volume per volume	v/v
water soluble powder	w.s.p. (tables only)
watt	W
weight	wt
weight per volume*	w/v
weight per weight*	w/w
wettable powder	w.p.
yard	yd
yards per minute	yd/min

* Those marked * should normally be used in the text as well as in tables etc.

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