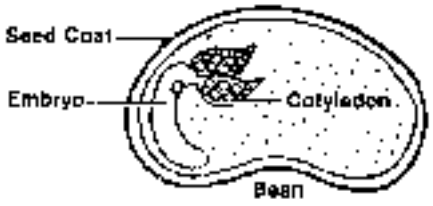
Seed Germination

Late winter is the time of the year to dig out those old seed packets and see if the seed is still good. You may use up a whole packet of beans, carrots or lettuce in one year, but usually there are enough seeds of tomatoes, cucumbers, squash and peppers to last for several years. Just because you have seed left, however, doesn't mean that it is good seed.

Before I launch into a description of how to test the seed, let's talk about seeds a bit. We have all planted seeds, but how much do you really know about them? Learning more about seeds can help improve your success with them.



When you look at a seed you are looking at the seed coat. As people wear coats for protection from foul weather, seed coats perform much the same function. They provide protection against entry of parasites, against mechanical injury and, in some seeds, against unfavorably high or low temperatures.

Inside the seed coat is the embryo, an immature plant with all the parts of the adult plant. A close look shows leaves and a root -- they may be tiny but they are the beginnings of a plant. The seed's embryo leaves are called the "cotyledons." The seed is filled with "endosperm," food that will nourish the embryo during its early stages of development.

Germination is a fascinating process. Seeing a tiny seedling emerge from a dry, wrinkled seed and watching its growth and transformation, is observing the mystery of life unfolding. The first sign of germination is the absorption of water -- lots of water. This

activates an enzyme, respiration increases and plant cells are duplicated. Soon the embryo becomes too large, the seed coat bursts open and the growing plant emerges. The tip of the root is the first thing to emerge and it's first for good reason. It will anchor the seed in place, and allow the embryo to absorb water and nutrients from the surrounding soil.

Some seeds need special treatment or conditions of light, temperature, moisture, etc. to germinate. Seed dormancy is very complex, but it protects that living plant material until conditions are right for it to emerge and grow.

Practical lessons can be learned from the seed:

- Seeds with bigger amounts of endosperm can feed the embryo plant longer, while it works its way toward light. Therefore, big seeds can usually be planted deeper.
- Seeds must absorb water to get germination going. Therefore, presoaking seeds may speed up the process.
- Available water is important to the newly emerged root. Therefore, you should plant seeds a little deeper in the middle of summer, when the top of the soil dries out quickly.

You get the picture; so now let's talk about germination testing. Whether left-over seeds will germinate (sprout) and grow depends on how old they are and how they have been stored. With proper storage conditions, the average useful life of some common vegetable seed is much longer than some others.

1-2 years:	3-4 years:	5-6 years:
corn onions and leeks parsley parsnips peppers	asparagus beans and peas beets cabbage family carrots eggplant squash and pumpkins tomatoes	cucumbers lettuce melons spinach

If you keep your seeds cool and dry, they will last longer, but can you be sure that they are still good? If they are, you can save yourself some money. Before you order your new seed, do a germination test on any seeds more than just one year old. Here's what to do:

1. Put exactly ten seeds on top of a damp, folded paper towel.
2. Put the towel and seeds into a plastic sandwich bag and seal.
3. Label the container with the date and seed variety being tested.
4. Leave at room temperature for a week or so. (Leave parsley, carrot and celery longer; they're slow.)
5. Count the number of seeds that sprout:
    - 10 = 100% or perfect germination
    - 9 = 90% or excellent
    - 8 = 80% or good
    - 6-7 = 60-70% or poor -- sow more thickly
    - 5 or less = 50% or less -- throw the seed out!

GENERAL RULES of SEED SOWING

Seeds need water and oxygen to germinate, so are best started in a light, loose soil that will not compact, get soggy, or crust over. Free flow of water and air are a must. Cover

seed with 2 - 4 times their thickness of soil, unless they require light to germinate. Sow shallowly in cold wet spring, more deeply in warm dry summer. Large seed can be soaked overnight and planted singly. Barely cover small seed, and sprinkle fine seed on the surface and water by misting. Plant flat seed edgewise and winged seed with wing uppermost or broken off. Sowing too thickly wastes seed and weakens the crowded seedlings, but some kinds sprout best if crowded. Lightly tamp soil to insure good contact with the seed, unless heavy. Keep soil moist, not soggy, and do not allow to dry out.

Common causes of failure are soil too heavy, wet or cold, or allowed to dry out, not giving slow seeds long enough to come up, pests eating the seeds or seedlings, and not giving dormant seeds the proper pretreatment. Careful attention to the instructions in the catalog and on the packet will help insure good results. Common causes of seedling loss are damping off due to poor air circulation and overwatering, drying out or burning due to placing in full sun or outdoor conditions too quickly, transplanting shock (best done on a cool, moist day), and predation by insects, slugs and snails at night.

TEMPERATURE

Most seeds germinate best at warm 21 °C (70°F) temperatures. Plants from temperate regions, the arctic, high mountains and high deserts often germinate best at cool temperatures. Plants from winter-rain areas like California, the Mediterranean, Chile, S. Africa and parts of Australia also like cool temperatures. Warm temperatures will often speed germination of these seeds, but lower vigor and survival. Warm desert plants and tropicals like warmth. Temperatures used in the catalog are: Cold 1 - 7 °C (34 - 45°F), Cool 10 - 18 °C (50 - 65°F), Warm 18 - 26 °C (65 - 80°F) and Very Warm 26 - 38 °C (80 - 100°F). When no temperature is given, warm 21 °C (70°F average) is indicated.

TIME UNTIL GERMINATION

Average range of time to germinate is usually given in weeks. A seed that takes 2 - 3 weeks will usually come up fairly evenly; one that takes 1 - 12 weeks will tend to straggle in irregularly. Time varies with temperature, so expect considerable variation. Don't give up too soon—many who have given up and sown another seed in the pot end up with two types of plants in the same pot!

HARDY ANNUALS (HA)

These will stand some frost and can be sown direct to the garden as early as the ground can be worked, March to June. Prepare the soil until a smooth, fine surface is obtained. An attractive annual border can be had by planting in large, irregular drifts.

HALF HARDY ANNUALS (HHA)

These are killed by frost and should be sown in late spring after danger of frost. For early bloom, start early indoors and plant out after danger of frost.

TENDER ANNUALS (TA)

These need warmth and shelter and are best started in pots or flats and planted out in favored spots after the soil has warmed.

BIENNIALS and WINTER ANNUALS

Biennials are sown like half hardy annuals or perennials in spring or fall and planted out in September and October. Winter annuals such as some Californian and desert plants may be grown in summer, but are at their best sown in fall, even if grown in the greenhouse in cold winter areas.

HARDY PERENNIALS (HP)

Many of these germinate readily at warm temperatures, and can be sown direct to the garden or early in the greenhouse or cold frame. If started early, they often bloom the first year. Others germinate best at cool or cold temperatures and the seedlings need cool temperatures. Many have various dormancies and need the pretreatment indicated.

HARDY TREES and SHRUBS

Many will germinate readily if sown in spring. Others need cold or other pretreatment, and some are best sown in fall or winter and covered with a mulch or snow. The addition of some forest soil or litter from below both hardwoods and conifers is often very beneficial, greatly increasing seedling growth due to beneficial mycorrhizal inoculation.

TROPICAL and SUBTROPICAL PLANTS

These often need very warm temperatures. Bottom heat and constant moisture are often beneficial. Some take surprisingly long times to germinate. Many people think all tropical seeds are short-lived and perishable, but many of the longest-lived seeds are tropical, and some even need to be aged dry for a year before they will germinate!

CACTUS SEED

Sow cactus seeds on the surface of a well-drained mix, and barely cover with more soil, a little coarse sand, or some chick-grit. Keep moist by misting until germination begins, then reduce humidity. Keep seedlings in part shade until well-developed and looking like cacti. Pot up when 1/2 - 1" in size. Deno found that 2/3 of the cactus species he studied need GA-3 to sprout, and some need ageing for a couple of years before they would germinate.

AQUATIC PLANTS

We have had the best results with some of these by sowing in pots, pans, or petri dishes, and submerging so that the soil is under 1/4" of water.

FERN SPORES

Spores should be scattered thinly on the surface of a light, sterile, peaty mix which has been watered with clean sterile water about 4 hours before sowing. Cover pot with a pane of glass or enclose in a plastic bag and place out of direct sunlight. A light green film will form on the surface in 1 - 4 weeks or so, up to 6 months for slow species. *Botrychiums* may take up to 8 years, and one *Equisetum* takes 18 years! Small round or heart-shaped prothallia will then form. Begin to mist lightly with distilled water weekly to enable fertilization of the egg cells, until true fronds develop. Transplant sporelings when large enough to handle. Good ferns can usually be had in 8 - 12 months from spores. Ferns are hybridized by sowing 2 kinds of spores together.

SOIL MIXES

Many seeds do well sown direct to ordinary garden soil, but even good soil may be poor in pots or flats. These need a lighter, looser soil. Most commercial mixes are fine, but the addition of some garden soil and compost will often insure adequate beneficial micro-organisms and fungi, A good soil mix can be made at home from 1/3 garden loam, 1/3 peat or compost, and 1/3 gritty sand. Number 1 limestone chick-grit makes a good top dressing for many alpines or slow germinating seed to discourage algae growth. Crushed charcoal also helps.

HARD SHELLED SEED

These have hard impermeable shells and need nicking or scratching the coat to allow water to enter and the seed to germinate. The best results are from the least amount of nicking that will allow water to enter and the seed to swell. Many failures are due to over-nicking and damaging the seed.

Different seeds need varying amounts of nicking. Most do best with lightly rubbing on sandpaper or a file until just the very outer coat is scratched. Often just scratching with a knife-point or scriber works. Others need serious nicking, sometimes with a hacksaw until the white interior shows. Nicking seed one by one can be tedious but is most effective. Larger lots can be rubbed between two boards covered with sandpaper, or shaken or tumbled in a can lined with sandpaper. Then soak the seed overnight and any that don't swell or soften should be re-nicked and soaked again until swollen.

NICK and SOAK means nick first, then soak, and re-nick any hard (unswollen) ones.

SOAK and NICK UNSWOLLEN means the seed is usually only partly hard and many will swell without nicking. Soak first, nick only the hard ones.

OTHER METHODS for large lots include:

Hot Water Soak: The seeds are placed in a cup and not quite boiling (200°F) water is poured on them and allowed to cool and the seeds to swell. At least 4 - 5 times their volume of water is used. Or the seeds are dipped in boiling water for 10 seconds to 3 minutes. Produces erratic results, sometimes killing many of the seeds and increasing fungal attack, but often produces the best results in some species.

Dry Heat: The seeds are baked dry in an oven at 140° to 220°F for 4 - 10 hours, or are microwaved for 30 seconds to 4 minutes. Gives erratic results.

Sulfuric acid or lye soaks work with some seeds.

COLD TREATMENT (Prechill)

Many seeds need a cold moist period before they will sprout. The essentials are moisture, air, cold and time. Dry cold (a packet in the refrigerator) won't work. Often the seed may be sown in fall or winter and allow natural cold and snow to work.

1. Soak seed overnight until swollen or soft (up to four days for large hard nuts). Nick if needed.

2. Mix seed with about 3 times its volume of damp peat moss or vermiculite and place in a plastic bag or pill bottle. Small amounts may be conveniently layered between damp paper towels or coffee filters. Remember, air is essential; avoid sogginess. Label the bag with the name of the seed and date to be removed from cold. Mark your calendar too!

3. Store in the refrigerator (34 - 40°F) for the time specified in the catalog. Four to 12 weeks is usual.

4. Remove the seed and sow. Seed is best kept cool (50°F or so) for a week after sowing, and gradually brought up to warm temperatures. Warming too quickly can be fatal for some seeds.

'Cold germinators' only sprout at cold temperatures, and are most conveniently treated by layering in damp towels and pricked off as they germinate.

If using outdoor treatment, hold pots at above freezing for a few weeks before putting outside.

Snow cover is often highly beneficial.

Dormancy is highly variable. Sometimes a seed collected in the warm lowlands will germinate readily, but the same species collected at a high elevation will need cold. Dormancy even varies between individual plants at the same site, and varies with weather before harvest and conditions of storage after harvest.

OTHER TREATMENTS

DRY STORAGE or AGEING: Many seeds will not germinate when freshly harvested, but are dormant until after a period of dry storage ranging from 1 - 12 months or up to 5 years. The time varies with temperature, humidity and oxygen. We try to supply aged seed whenever necessary. Often this type of dormancy can be broken with GA-3.

WARM MOIST TREATMENT: Many seeds need 1 - 4 months of warm moist treatment, followed by cold treatment to sprout. In some, the root sprouts during the warm period, but the shoot does not sprout until after a cold period (epicotyl dormancy). Called 'two-step' germinators by Deno. Some of these have unformed embryos which must first develop at warm temperatures. Some seeds are '70 - 40' germinators, which need warm moist, then cold moist, and germinate at cold temperatures. Some tropicals which are slow to germinate (many palms and aralias) need prolonged warmth to first develop their embryos. Many seeds are 'multicycle' germinators, needing several cycles of cold and warm periods.

SOAKING, WASHING or LEACHING: Many seeds contain germination inhibitors which in nature prevent the seed from germinating except during the wet season (tropicals) or only after sufficient rain has fallen (desert plants). Soaking the seed in shallow water and changing every day for several days will leach out inhibitors. Heavy daily watering of pots may work. Some have oily coats and need detergent or peroxide soaks.

LIGHT or DARKNESS: Some seeds need light to germinate; others need darkness, and light prevents sprouting. If light is required, sow on the surface; if darkness is needed, cover seed well.

OSCILLATING TEMPERATURES: Some seeds need the daily change from warm to cold that occurs in spring and fall, and they germinate best sown in pots and exposed to outdoor conditions.

OTHER TREATMENTS: Soaking seed in potassium nitrate (KNO_3), hydrogen peroxide, citric acid, sodium hypochlorite (bleach), smoke solution, charred wood leachate, or enzyme solutions have all been used to trigger germination of seeds.

PLASTIC BAG METHOD

Best for very slow to germinate seeds, very tiny dust-like seeds that can't be allowed to dry out, and very slow-growing seedlings. Small clean pots are filled with damp, sterile, soilless mix. Milled sphagnum or a light dusting with powdered charcoal discourage fungi and algae. Seeds are sown and the whole pot is sealed in a plastic bag and placed out of direct sunlight. This creates a mini greenhouse and the soil will not dry out and the seeds are protected from mice, etc. Pots can be left for years with no care other than regular checking for seedlings. As soon as seedlings appear, begin hardening off. Bagged pots may be kept under fluorescent lights without overheating. Don't forget to label!

HARDINESS ZONES

The rating of plants according to the hardiness zones in which they will grow has improved greatly over the last twenty years. They are fine for common, widely grown plants, but for most plants, our knowledge of their ecological limits is incomplete. Too often, the assignment of zones is merely educated guesswork. Many plants will do well far outside their usual ecological range, or seeds collected at the species northernmost limit will be much hardier than usual. Also, a heavy mulch, or planting by a south-facing wall, or other simple tricks can greatly extend a species range in cultivation. So don't rely too much on the zone numbers, or let them prevent you from experimenting!

THE LIMITS OF THE AVERAGE ANNUAL MINIMUM TEMPERATURES FOR EACH ZONE

Zone 1: Below -50°F - to -45.5 °C

Zone 2: -50° to -40°F - to -40 °C

Zone 3: -40° to -30°F - to -34 °C

Zone 4: -30° to -20°F - to -29 °C

Zone 5: -20° to -10°F - to -23 °C

Zone 6: -10° to 0°F - to -17 °C

Zone 7: 0° to 10°F - to 12 °C

Zone 8: 10° to 20°F - to 6.5 °C

Zone 9: 20° to 30°F - to 1 °C

Zone 10: 30° to 40°F to 4 °C

SEED LONGEVITY

Many people have the mistaken idea that seed must be very fresh to grow, and the occasional failure of a packet is blamed on 'old seed'. Properly stored, seed of most species is viable many more years than most people would expect, some giving high germination for decades. Though some species are short-lived, many others are dormant when freshly harvested, and actually need an ageing period of weeks, months, or even years before reaching full germination. "*In several cases, maximum germinability was not attained until after some years of storage*. A longevity study of 36 species of common seeds showed that 14 of the 36 species retained half their viability for *ten years or more of open storage*.

ABOUT DIFFICULT SEEDS

Over millions of years, wild plants have evolved germination strategies which ensure their survival, but which may not be convenient for the home gardener who wants a quick and even stand of plants from a packet of seed. Many seeds sprout irregularly, so that if the first flush of seedlings is killed by adverse weather, insect predation, etc., more will come along to take their place. In adaptation to various environments, some seeds need periods of cold, warmth, darkness or light, fire, etc. Some have seedcoats of varying hardness or impermeability, and others contain chemical germination inhibitors which must be leached from the seed before it can sprout. Some species disperse themselves over wide areas by being eaten by animals, the seed sprouting far from the mother plant, the seedcoat softened by digestive juices. Many seeds have internal clocks, and give much higher germination at certain times of the year, regardless of the treatment given. All seeds wait for the correct time and conditions before sprouting, and the gardener must mimic those conditions to ensure successful germination.