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FACTORS FAVOURING GERMINATION OF NATIVE AND INTRODUCED PASTURE SPECIES

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Germination may be defined as the process leading to a resumption of development of the plant embryo contained within a seed. Basically it involves an initial uptake of water by all parts of the seed, then a swelling of the plant embryo and finally a renewal of leaf and root growth by the seedling, culminating in the plant's emergence from the soil. This germination process depends on a number of basic requirements-

(i) Water
(ii) temperature
(iii) oxygen
(iv) a lack of seed dormancy (discussed elsewhere)
and sometimes
(v) light

The uptake of water is essential for germination, and being basically a non-biological process, will occur under a wide range of conditions. Seeds have a tremendous ability to absorb water from soil and from the air itself, although for visible germination to occur the soil must feel damp at least. Water uptake from air is directly controlled by the relative humidity and occurs without producing any visible change in the seed's appearance or inducing germination, up until the relative humidity reaches 99% (≡ permanent wilting point of soils). However if seed is stored or lies in the soil under these high humidity conditions for any length of time (eg. 6 months) it will very rapidly lose its viability. The reasons for this are numerous and beyond the scope of this paper.

However the range of moisture contents above the equivalent of 99% relative humidity is the range of interest in this discussion of germination. In soil the availability of water to a seed is affected by a far more complex set of factors than in air and so requires a little explanation before proceeding with this duscussion.

A soil which has been fully wetted and then allowed to drain freely until it reaches moisture equilibrium is said to be at field capacity. This soil moisture is almost as freely available to the seed as pure, free water and thus is considered to be withheld from the seed by a suction force of only 0.1 atmospheres i.e. the seed must expend energy equivalent to at least 0.1 atmospheres if it is to extract water from soil at field capacity. This suction process is called imbibition.

As a soil dries out it contains an increasingly smaller proportion of water which is held in the soil by ever increasing surface forces (i.e. suction). However this water is still available to plants until they visibly wilt, at which time the soil is said to be at its permanent wilting point. The force or suction with which this water is held at this stage is equivalent to about 15 atmospheres pressure, more commonly called 15 bars (1 bar ≡ 1 atmosphere pressure).

As with plants, seeds cannot grow, i.e. germinate, effectively once a soil dries to its permanent wilting point, although they still contain up to 50% moisture by weight. However between the permanent wilting point (15 bars) and field capacity (0.1 bar) germination is very sensitive to the availability of soil moisture. Factors such as plant species, temperature, soil type and osmotic stress (due to salts in the water) can markedly influence moisture uptake and thus affect germination.

Under normal conditions a non-dormant seed will have taken up sufficient water to begin germinating within 5 to 15 hours of first receiving water, depending on the temperature - the higher the average temperature the greater the rate of moisture uptake. There is then another time delay before visible elongation of the embryo occurs and the germination process is irreversibly set in motion. The effect of moisture stress is superimposed on the temperature effect to produce an almost infinite range of times before germination can occur in practice. Moisture stress also affects the final percentage of seeds germinating, with the critical range being 3-5 bars. At levels of moisture stress greater than this, germination is severely curtailed in most species although this can vary as shown in Figure 1.

It is interesting to note that Rhodes grass, which is not very drought tolerant, germinates over a wide range of moisture stress and thus may predispose its seedlings to stress very early in their lives cf. Queensland Bluegrass. Note also that freely available water (0 bars) which simulates flooded conditions, inhibits germination somewhat in native millet. Again the adapted native species in the region was not induced to germinate under high moisture stress conditions.

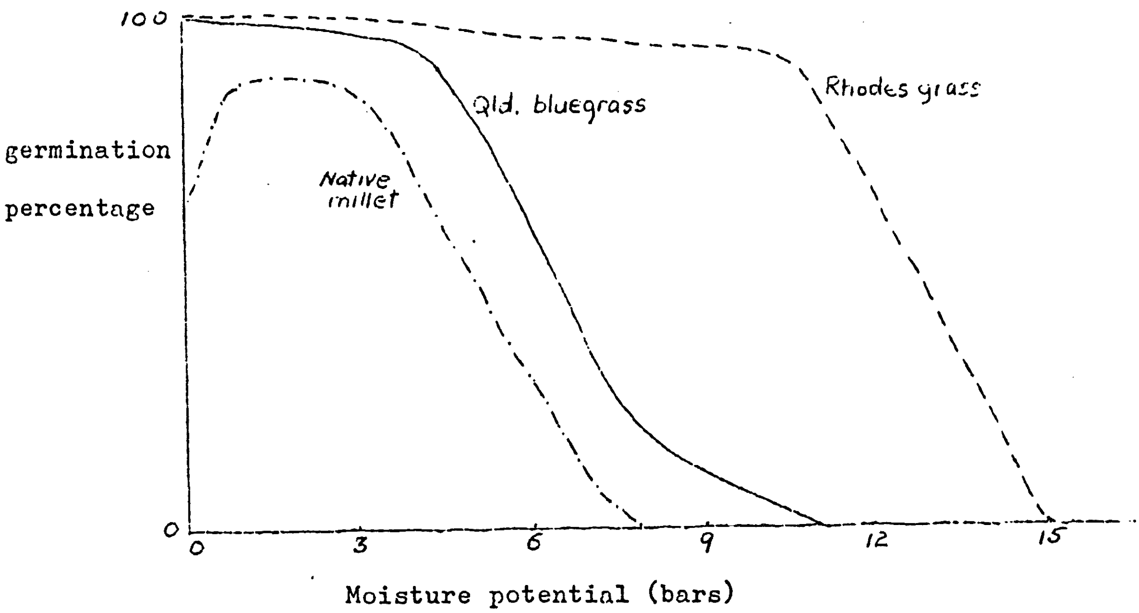

Figure 1. The effect of soil moisture potential on the germination of three grasses.

As an example of how critical soil moisture stress becomes once soil drying begins the following data (Table 1) is presented for mulga soil and very heavy clay soils. Once soil moisture stress reaches about 3 bars, very little extra water has to be removed before permanent wilting point is reached, particularly on the sandier soil. The time period between 0.1 bar (field capacity) and 3 bars depends very much on the distribution of rainfall and the degree of exposure of the soil to sunlight and is often between 2 and 5 days in this region. It is often only a matter of hours between the 3 and 15 bar (permanent wilting point) levels of stress.

The effect of temperature on the time needed before germination can begin is shown schematically in Figure 2. Due to this the range of temperatures over which germination of mulga mitchell grass occurs increases with time since it was first exposed to moisture, as illustrated in Figure 3. The optimum temperature for rapid germination of this species appears to be 24-28°C.

TABLE I

The relationship between soil moisture stress and gravametric soil moisture content of mulga and heavy mitchell grass downs soils.

Moisture Stress (bars)	Percentage water in soil Mulga Soil	Heavy Clay Soil
0.1 (field capacity)	12.5	44
3	6.4	33
5	5.8	31
7.5	5.6	29
10	5.3	28
12	5.1	27
15 (P.W.P.)	5.0	26

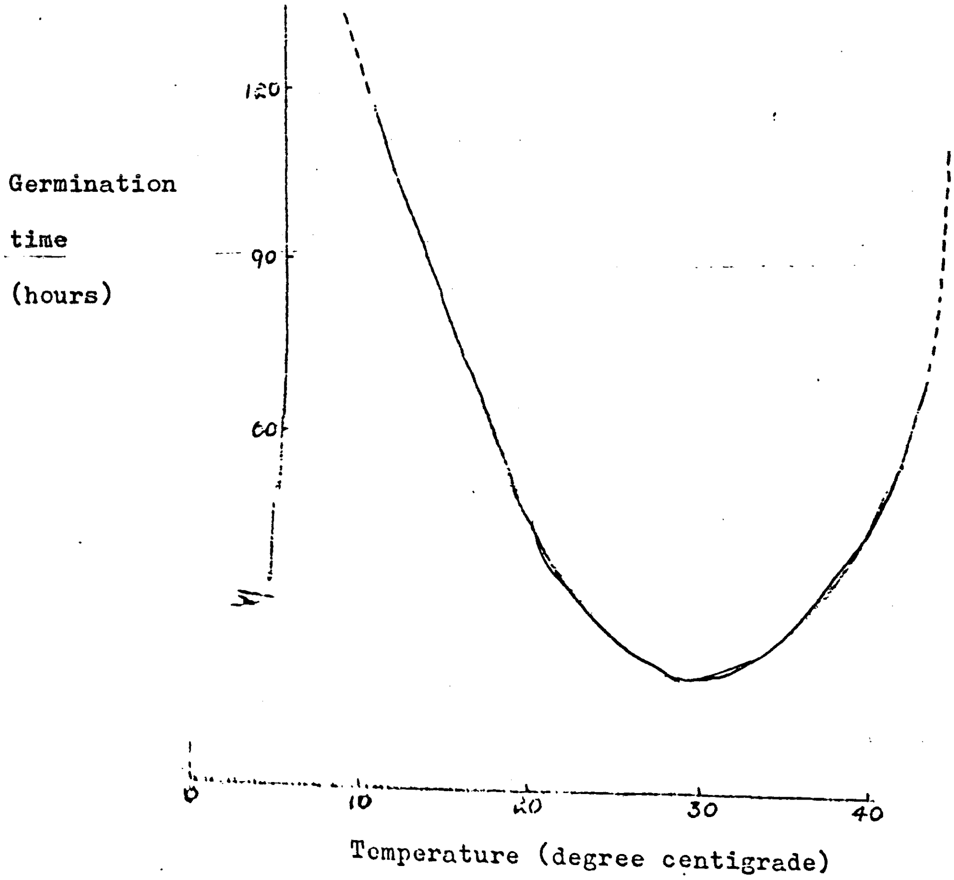

Figure 2. The effect of temperate on the time taken for a seed to germinate.

6

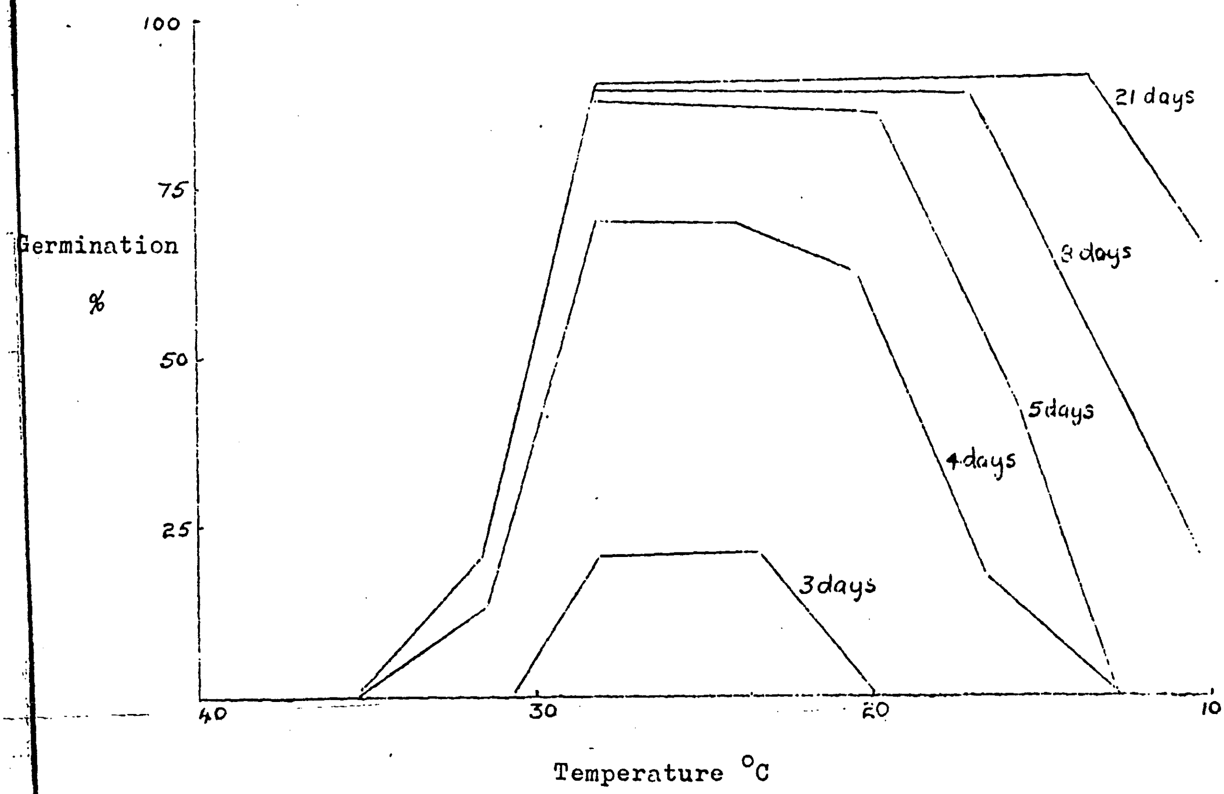

Figure 3. The effect of temperature on the germination of mulga mitchell seed at various times after initial watering.

Below the optimum temperature germination rate is roughly proportional to temperature down to a critical minimium level which is often about 8°C in our grasses. Above the optimum germination is fairly rapidly inhibited. Optimum temperatures usually cover quite a large range of temperatures for most species but is usually 25-32°C for tropical species and 15-25°C for temperate species and winter germinators eg. many wild flowers. Some species have more critical temperature requirements especially if the seed is fresh.

In the field temperature and moisture stress interact to produce a wide range of germination rates which determine very largely the profusion with which seedlings emerge after a particular fall of rain. The ecological implications of this are discussed later.

Oxygen is important for the metabolic processes which occur during germination but only under badly waterlogged or ponded conditons is it a limiting factor. Light is required by some species for germination, particularly if temperatures are not optimal or the seed is very fresh. The mechamism by which light operates is complex but its importance should be recognised as many species which normally colonise bare ground probably require it. On the other hand strong light can prevent seed of mulga oats from germinating.

Under natural conditions only those seeds which are physiologically ready to germinate will emerge after adequate rainfall. Fresh seed typically is dormant (i.e. the seed is good but is prevented from germinating under otherwise suitable conditions by some special feature of the seed itself). This dormancy is usually either controlled by hormones in the embryo itself or by the seed coats around the grain. Seed coat dormancy is common in grasses eg., mitchell grass and Flinders grass, the fresh husks being impermeable to water. Others, like the seed of woolly butt grass, will not germinate until it is at least a year old despite the fact that the grain soon loses its husk. Legumes e.g. mulga, rattle pod (Crotalaria spp.) and darling pea (Swainsona spp.) have a tough waxy coating which prevents water penetration, but once this coating is chipped or split the seeds germinate very easily. Seed coat dormancy is usually broken in the field within 6 months ie. by the next growing season in most species. In some cases a period of moist cold conditions is required to break seed dormancy eg. summer weeds. A typical example of the loss of dormancy with age is shown in Figure 4.

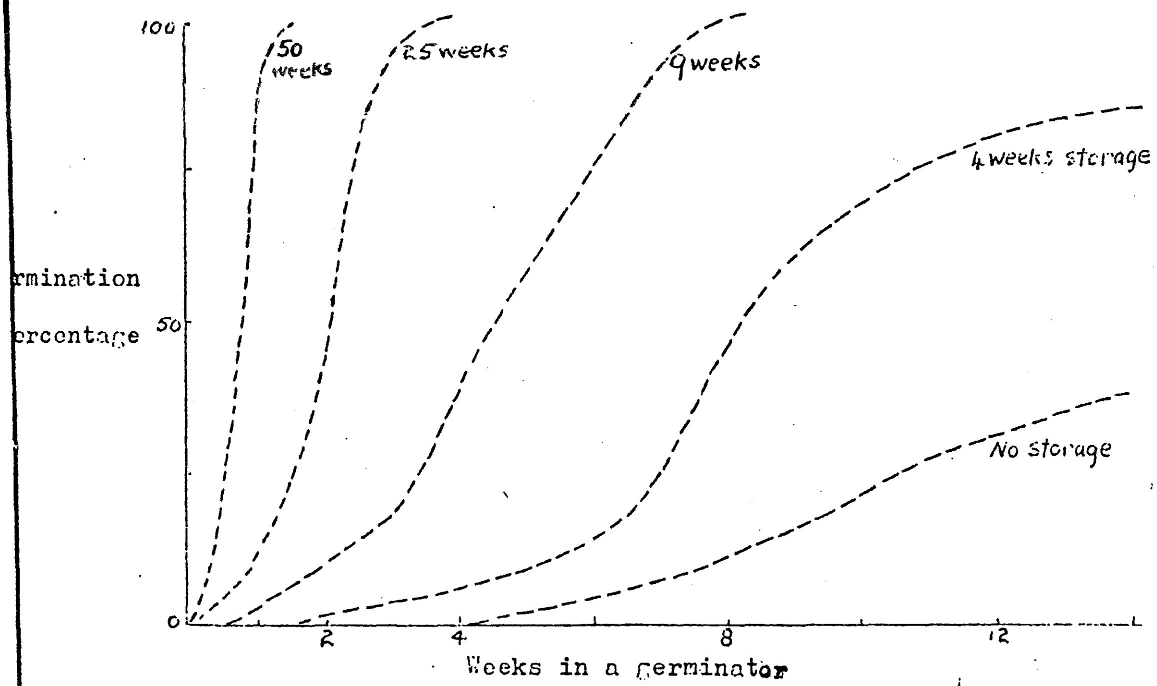

Figure 4. Graphs showing the increasing rapidity of germination of a typical seed sample stored for various periods of time before testing.

Note that fresh seed is not only slow to begin germinating, it also reaches a lower germination level in any given time. Strong sunlight and microorganisms eg. fungi probably play a large part in breaking down seed coat dormancy in the field.

Good contact between the seed and the soil is vital if a seed is to germinate as rapidly as possible. A seed lying on the soil surface may be absorbing moisture from the soil but it is also evaporating imbibed moisture into the air at the same time. Thus the nett rate of imbibition is the difference of these two rates and may easily be negative under sunny or windy conditions. Thus burial of seed is very important for reliable germination, whether the seed is deliberately sown or forms part of the natural soil load. Pasture trash and litter generally can also be very effective in covering seed although excessive amounts may be detrimental in the long run. Sticks and the base of other living vegetation trap both seed and wind blown debris and their importance in increasing the number of favourable germination sites available cannot be emphasied too much. On the otherhand,once a claypan or scald develops they tend to be self perpetuating for this very reason - they prevent seed burial.

Regularly flooded areas are suitable for germination for only a select group of species which are adapted in some special way to this anaerobic environment. Ponding of water is often seen to drastically reduce germination of many crop species and the same applies to many pasture species. However the value of species adapted to this situation eg. Channel millet, Cooper clover and beetle grass should not be overlooked as they may offer some scope for improvement on water spreading schemes.

Bore water, usually fairly high in salts, can also be detrimental to germination as the salts in it effectively reduce, by osmotic effects, the availability of the water to the seed. However in the field this is of scant consequence but may be important in a home garden situation. Saline areas eg. seasonal lakes carry little vegetation because of the high concentration of salts in the soil.

The interaction of temperature and availability of moisture is still the crucial point governing field germination. Most seeds only germinate successfully if they lie within 2 cm of the soil surface and this is the zone most exposed to high temperatures in summer and rapid soil drying in general. In mid summer the combination of very high temperatures and rapid surface soil drying makes this period unfavourable for germination where no other vegetation cover exists. On the other hand in mid winter low temperatures cause a very slow rate of germination and again the surface soil dries out too quickly in our low humidity conditions. Thus, overall, spring and autumn tend to be the times of the year when prolific germination occurs regularly, if adequate rain falls. The temperatures are near optimal still and yet hot drying conditions are not as common.

There are however certain species which have a definite preference for germinating in summer or winter and thus you get the common annual grasses in summer e.g. button and Flinders grass while herbage eg. mulga nettle, wild carrot, lambs tongue etc. comes up in winter. It is not that these species will not germinate at other times of the year, they can. But the farther temperature conditions for germination are from optimum the more critical do other factors such as light, seed age and soil salts become in determining the eventual success or failure of a seed to germinate. The same applies where soil moisture and seed burial may be less than optimal. In exceptionally wet times eg. February 1973 most species will germinate almost anywhere and the final seedling population is determined by factors affecting growth and persistence. Claypans become partially vegetated for the same reason in these times. Special note must be made of a few specific instances where correct management can be implemented to ensure satisfactory germination. Firstly crops should never be sown with the seed in direct contact with nitrogenous fertilizers, especially urea. Upon mixing with the wet soil and microorganisms, toxic amounts of ammonia are released which can kill the imbibed seed. It is best to avoid urea for this purpose and to either band fertilize or broadcast the fertilizer to avoid germination problems.

Secondly, buffel grass seed should always be at least 1 year old before sowing and preferably more; seed fresher than this is dormant and will not germinate readily. Ants quickly harvest buffel seed and by the time the remainder is able to germinate seedbed conditions could have seriously deteriorated.

Conclusions:

For optimum germination, particularly rapid germination, seed should be fully viable (no dormancy), covered by a thin soil layer, and placed in a situation where the mean temperature for 3-4 days is between 25 and 30°C and where the soil remains near field capacity for this period also. In practice in this semi arid environment a certain amount of seed dormancy may be desirable to counteract sowing failures due to post-germination conditions. This idea will be elaborated on in the section on establishment.