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Germination responses of seven bedding plant species to environmental conditions and gibberellic acid

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Summary

The germination responses of seven bedding plant species to a range of temperatures and water potentials, both with and without light are described. The species were; *Primula acaulis*, *Impatiens wallerana*, *Salvia splendens*, *Verbena X hybrida*, *Petunia X hybrida*, *Tagetes patula* and *Tagetes erecta*. In the light all species except *Primula* exhibited maximum percentage germination over the range 10–25 °C. In *Primula* the optimum temperature range was 15–20 °C. Mean germination time was greatly affected by temperature in all except *Tagetes* species which germinated in less than 5 days over the range 5–30 °C. The other species showed optima at 20–30 °C except *Primula* which showed an optimum at 20 °C. Germination of both *Primula* and *Impatiens* was enhanced in the presence of light. In general mean germination time increased and percentage germination decreased with decreasing water potential of the germination medium. The effects of gibberellic acid ($GA_{4/7}$) and benzyladenine (BA) alone and in combination were tested on all but *Tagetes* species. $GA_{4/7}$ fully overcame the light requirement for germination in *Primula* and improved germination of *Impatiens* in the dark. *Impatiens* germination was further enhanced by combining $GA_{4/7}$ with BA. These plant growth regulators had no beneficial effect on the other species tested.

Introduction

Commercial pressures on the pot and bedding plant industry have created the need to adopt cellular tray systems for plant raising however, for many species poor seed quality makes direct seeding uneconomic. This poor seed quality is often due to seed retaining the characteristics typical of wild species such as, dormancy, a wide range of seed maturity at harvest, and a limited temperature range over which seeds can germinate rapidly. Much of this variation in seed quality is therefore physiologically determined and may be improved by seed technology and by optimising germination conditions. As part of a programme of work to test this possibility and develop practical seed treatments, the germination responses of seed from seven species were studied in a range of environments. Most growers have facilities with a limited range of options for environmental control for germination and in addition, there is a need to produce plants from many species, cultivars and seed lots at the same time. One purpose of this study was therefore to determine whether robust general recommendations for the most suitable environmental conditions during germination could be made which would apply to a number of species. Six of the bedding plants (*Primula*, *Impatiens*, *Salvia*, *Verbena* and African and French marigolds) used in this study were identified in a UK grower survey as having major seedling establishment problems in practice. The seventh, *Petunia*, was identified as having few establishment problems and was therefore included for reference. The species and cultivars used in this study are commonly used in the UK.

In a review of temperature and light requirements for germination of ornamental species, the germination of some *Primula*, *Impatiens*, *Salvia* and *Petunia* species was shown to be enhanced by exposure to light and *Verbena* germination was enhanced in the absence of light (Cathey, 1969). Gibberellic acid (GA) can help to relieve the light requirement for germination of *Primula* species (Thompson, 1970; Miller and Holcomb, 1982) and *Impatiens* species (Jouret, 1977; Simmonds, 1980). GA has also been shown to relieve dormancy in several other flower species (Alderson, 1987) although the effect can vary according to seed structure and the nature of the block to germination (Atwater and Vivrette, 1987). These effects of GA can be enhanced by combination with cytokinins, for example, in celery (Thomas *et al.*, 1975; Biddington, Thomas and Dearman, 1980). A further aim of this study was therefore to determine the potential for using GA and benzyladenine to overcome germination problems in the bedding plant species studied here.

Materials and methods

General experimental details

Seven bedding plant species were studied; *Primula acaulis* cv. Improved Biedermeier Strain, *Impatiens wallerana* cv. Dwarf Baby Mixed, *Salvia splendens* cv. Blaze of Fire. *Verbena X hybrida* cv. Olympia Mixed, *Petunia X hybrida* cv. Red Star, *Tagetes patula* (French marigold) cv. Spanish Brocade and *Tagetes erecta* (African marigold) cv. Inca Orange. In all experiments germination (radicle visible) was recorded on replicates of 50 seeds placed on filter paper moistened with distilled water or test solution in sealed transparent polystyrene boxes. In treatments where germination response in the dark was measured seeds were placed into germination boxes under green light then wrapped in aluminium foil to exclude light. Germination counts were made daily initially and then at longer time intervals on seeds kept in the light (*c.* 100–170 μmol m^{-2} s^{-1}). When germination in the light was complete a single germination count was made on seeds kept in the dark. Percentage germination data were angularly transformed and spreads in time to germination (Orchard, 1977) were log transformed before all measured parameters were subjected to analyses of variance.

Effects of environment

In two separate series of experiments seeds of all seven species were subjected to a range of environmental conditions. In both experiments two replicates of each treatment were kept in the light and in the dark. In the first experiment seeds were placed into growth cabinets at seven temperatures, at 5 ± 1 °C intervals between 5 and 35 °C. In the second experiment seeds were placed on solutions at four water potentials (distilled water, –0.1, –0.2 and –0.5 MPa) at each of three temperatures (10, 20 and 30 °C). The concentration of polyethylene glycol (6000) used for each water potential was determined after Michel and Kaufmann (1973).

Effects of gibberellic acid and benzyladenine

The effects of gibberellic acid and benzyladenine (N-6-benzylaminopurine, BA) both individually and in combination on the germination response of seeds was examined in five of the bedding plants studied: *Primula, Impatiens, Salvia, Verbena* and *Petunia*. A mixture of gibberellins A_4 and A_7 ($GA_{4,7}$) was dissolved in 0.013 M phosphate buffer at pH 6.3 and used at concentrations between 10^{-3} and 10^{-5} M. BA, also dissolved in buffer at pH 6.3, was used at concentrations of 10^{-4} and 10^{-5} M. When combined, $GA_{4,7}$ was 10^{-4} and BA 10^{-5} M. All chemical treatments were replicated three times and placed at a range of temperatures between 15 and 30 °C.

As there was no effect of light on the germination response of *Salvia, Verbena* and *Petunia* in the previously described experiments, chemical treatment comparisons were made in the light with control seeds on distilled water and on buffer. For *Primula* and *Impatiens* where seed germination response was affected by light, the treatments and both water and buffer controls placed in the dark were compared to further controls in the light maintained at optimum temperatures (*Primula* 20 °C and *Impatiens* 25 °C).

Results and Discussion

Effects of environment

In all species mean germination time in the light fell to a minimum as temperature increased (Figure 1). This reduction was comparatively small in the *Tagetes* species which germinated rapidly at all temperatures. Mean germination time in *Primula* reached a minimum at 20 °C, but in all other species mean germination time declined to 25 °C and then showed little change or an increase with increasing temperature. Over the range of environments tested, there was a positive linear correlation ($P < 0.01$) between mean germination time and the spread in time to germination: *Primula*, $r^2 = 0.63$; *Impatiens*, $r^2 = 0.70$; *Salvia*, $r^2 = 0.54$; *Verbena*, $r^2 = 0.72$; *Petunia*, $r^2 = 0.73$; *Tagetes patula*, $r^2 = 0.53$; *Tagetes erecta*, $r^2 = 0.84$. Therefore, for brevity, data are not presented for the spreads in time to germination.

In the light there was little difference in percentage germination over a wide range of temperatures in all species (Figures 2 and 3), but germination was reduced at 5 and 35 °C in most cases. *Primula* seeds showed a more limited optimum range of temperatures between 15 and 20 °C and little germination above 30 °C. *Impatiens* seeds did not germinate at 5 or 35 °C. In *Tagetes patula*, there was no effect of light at any temperature, but in all other species percentage germination was reduced in the absence of light at the extremes of the temperature range tested (data not shown). There was no effect of light on germination in the following temperature ranges and species; *Salvia* 10–25 °C, *Verbena* 10–30 °C, *Petunia* 15–30 °C and *Tagetes erecta*

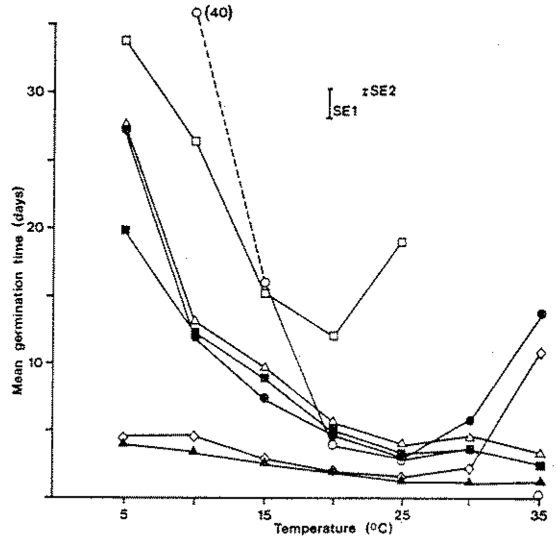

Figure 1. Effects of temperature on mean germination time in the light. S.E.1 = standard error for *Primula* and *Impatiens* (DF = 13), S.E.2 = standard error for other species (DF = 34). □, *Primula*; ○, *Impatiens*; ●, *Salvia*; △, *Verbena*; ■, *Petunia*; ◇, *Tagetes patula*; ▲, *Tagetes erecta*.

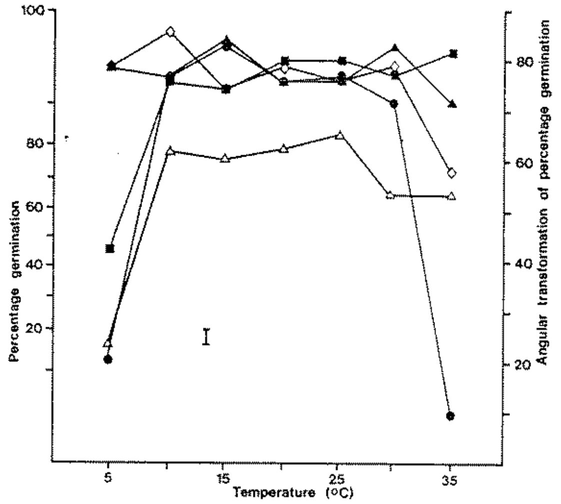

Figure 2. Effects of temperature on percentage germination (angular transformation) in the light. S.E. = standard error with 34 DF. Symbols as for Figure 1.

5–30 °C. Therefore, in these species there would be no effect of light in the range of temperatures commonly used on nurseries. However, a different pattern of germination response to temperature was shown in the light and in the dark by seeds of *Primula* and *Impatiens* (Figure 3). In the absence of light, fewer seeds germinated and there was a more clearly defined optimum temperature.

The germination responses to environmental conditions reported here are broadly in agreement with those of Cathey (1969). Although germination was a little more rapid at 25 °C in some species, in practice all species could be germinated well at 20 °C. The effect of water potential on mean germination (Figure 4) and percentage germination (Figure 5) are therefore shown at 20 °C. In general, mean germination time was least in distilled water and increased with decreasing (more negative) water potential in all species except *Verbena* (Figure 4). With *Verbena* mean germination time was increased by –0.5 MPa only. The same pattern of results was shown at each temperature. There was no significant effect of water potential on percentage germination of *Tagetes* species and *Petunia* at 20 °C. In *Primula* there was a progressive drop in percentage germination with decreasing water potential. With the other species germination was significantly reduced at –0.5 MPa only. At 10 °C the pattern of results was similar but at 30 °C all species gave significantly lower percentage germination at –0.5 MPa compared to other water potentials. Again no germination occurred at 30 °C in *Primula* seed and the effects of light on all species were as reported for the previous experiments.

The rapid germination of a high percentage of seeds from *Tagetes* species in all of the environments tested would suggest that the establishment problems experienced in practice are associated more with the mechanical difficulties of sowing these elongated seeds than with physiological problems. *Tagetes* species were therefore not included in further work.

Effects of GA

Imbibing seeds on plant growth regulator solutions had no significant effect on the germination response of *Verbena* and no beneficial effect on the response of *Petunia*

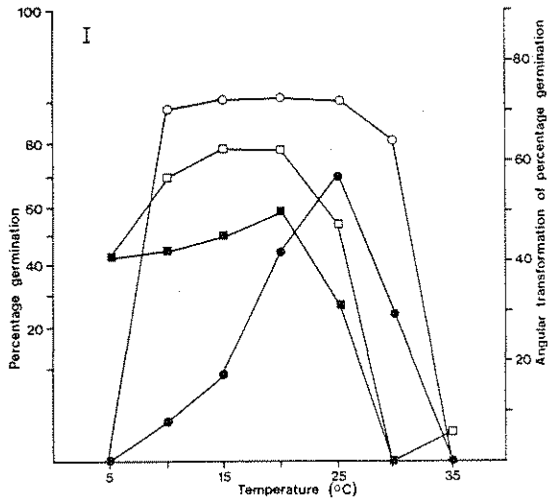

Figure 3. Effects of temperature and light/dark on percentage germination (angular transformation) of *Primula* and *Impatiens*. S.E. = standard error with 13 DF. □■. *Primula*; ○●. *Impatiens*. Open symbols in the light, closed symbols in the dark.

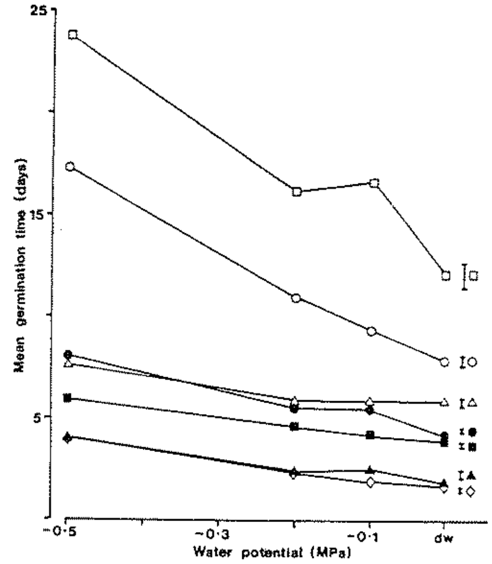

Figure 4. Effects of water potential on mean germination time at 20 °C. S.E. = standard error with 22 DF for *Primula* and *Impatiens*, 11 DF for other species. dw, distilled water. Symbols as for Figure 1.

and *Salvia*. BA delayed germination of *Petunia* and *Salvia* seeds and reduced the percentage germination from 92 to 82% and 90 to 25% respectively in the highest concentration tested (10^{-4} M). However, GA_{4+7} improved the germination of *Primula* and *Impatiens* in the dark (Table 1) although it had no effect on the germination response to temperature in either species. GA_{4+7} completely overcame the light requirement for germination in *Primula* so that percentage germination was not significantly different

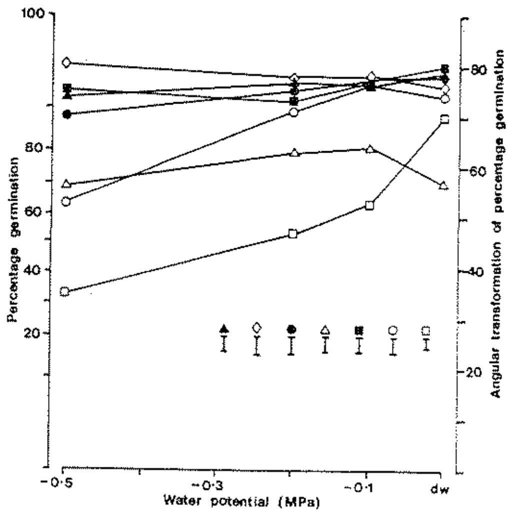

Figure 5. Effects of water potential on percentage germination (angular transformation) at 20 C. S.E. = standard error with 22 DF for *Primula* and *Impatiens*, 11 DF for other species. dw, distilled water. Symbols as for Figure 1.

Table 1. The effect of plant growth regulators on percentage germination (angular transformation) of *Primula* and *Impatiens* seeds in the dark.

Germination solution	Light (+)/ Dark (−)	*Primula*			*Impatiens*		
		15 °C	20 °C	25 °C	15 °C	20 °C	25 °C
Water	+		62.5				75.1
Water	−	44.2	43.5	28.4	2.7	25.3	48.1
Buffer	−	36.8	36.1	23.6	12.4	23.4	39.5
$GA_{4\,7}(10^{-4}M)$	−	56.0	61.2	46.9	16.4	56.4	60.3
$GA_{4\,7}(10^{-4}M)+BA(3\times10^{-5}M)$	−	54.0	51.2	29.7	30.5	59.6	66.2
SE (DF 26)			1.40			2.40	

from that of the control which was kept in the light. *Impatiens* percentage germination in the dark was further improved when $GA_{4\,7}$ was combined with BA, but was still significantly less than in the control kept in the light. The seed response of *Impatiens* to GA was in agreement with that shown by Simmonds (1980). These results indicate the potential benefit to be obtained from developing seed soak treatments with plant growth regulators in these two species.

This germination response data formed the basis of a study (Finch-Savage, Gray and Dickson, 1991), which developed and tested a range of seed treatments to improve germination in these species.

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