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Development of bulk priming/plant growth regulator seed treatments and their effect on the seedling establishment of four bedding plant species

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Summary

A range of combinations of osmotic priming/plant growth regulator (PGR)/fungicide treatment protocols in aerated solutions were developed for four bedding plant species. The species were; *Primula acaulis*, *Impatiens wallerana*, *Verbena* × *hybrida* and *Petunia* × *hybrida*. Combination priming treatments reduced mean germination time of all species and increased percentage germination of *Primula* and *Impatiens* seeds in the dark compared with that from untreated controls. In cellular trays, priming reduced seedling emergence time in all species. These benefits were enhanced by the addition of PGRs to the priming solution. PGRs were more effective when added to the priming solution than when applied as a pre-soak. In general, oxygen enrichment of the priming solution reduced seed performance unless PGRs were also present in the solution. The most effective treatment combinations were: *Primula*, oxygen enriched priming with gibberellic acid ($GA_{4/7}$, 10^{-5}M); *Impatiens*, priming with $GA_{4/7}$ (10^{-4}M) and benzyladenine (BA, 10^{-6}M); *Verbena*, priming with $GA_{4/7}$ (10^{-4}M); and *Petunia* priming alone. Seeds of all species were pre-soaked in Iprodione solutions. Osmotic potentials of priming solutions and treatment durations are also specified. Seedling emergence was also recorded in a range of compost temperature and moisture contents. Under near optimal conditions there are worthwhile gains from using seed treatments to increase stands, reduce seedling emergence time and reduce the spread in times to emergence depending on species. However, the results suggest there is only limited potential for bedding plant seed treatments to eliminate the effects of non-optimal environmental conditions likely to be experienced in seedling production practice.

Introduction

Poor seed quality in many bedding plant species results in prolonged seedling emergence and inadequate plant stands. This causes problems during seedling production in commercial practice. Some of the causes of this poor seed quality are thought to be physiological in origin. For example, dormancy, a wide range of maturity at harvest and a limited temperature range over which seeds can germinate rapidly. To address this problem the germination response of bedding plant seeds to environmental conditions and to a range of seed treatments has been investigated (Finch-Savage, Gray and Dickson, 1991a, b). Fungicide treatments, osmotic priming to reduce germination times, and plant growth regulator (PGR) treatments to relieve dormancy were combined into treatment protocols carried out in germination boxes (Finch-Savage, Gray and Dickson, 1991b). In the study reported here, these treatment protocols were

Table 1. Details of treatments and germination test.

	Primula	*Impatiens*	*Verbena*	*Petunia*
Priming in PEG (g kg water^{-1})	342	232	342	342
Nominal osmotic potential of PEG (MPa)	−1.50	−0.75	−1.50	−1.50
Plant growth regulator treatment	$GA_{4/7}(10^{-5}M)$	$GA_{4/7}(10^{-4}M)$ + $BA(10^{-6}M)$	$GA_{4/7}(10^{-4}M)$	
Iprodione in pre-soak (percentage a.i.)	0.3	0.1	0.1	0.3
Germination test	15 °C in light and dark	20 °C in light and dark	15 °C in light	15 °C in light

GA, Gibberellic acid, BA, Benzyladenine.

adapted to systems capable of commercial scale seed treatment (Nienow and Brocklehurst, 1987) and used to determine what part seed technology can play in overcoming the problems of bedding plant seedling establishment. In order to do this the performance of treated seeds was assessed in a range of conditions that could be experienced during seedling production in good commercial practice.

Materials and methods

In a series of experiments, the effects of combinations of priming/plant growth regulator/fungicide seed treatments were compared. Seed treatments were selected in a previous study (Finch-Savage, Gray and Dickson, 1991b) and carried out on four bedding plant species: *Primula acaulis* cv. Improved Biedermeier Strain; *Impatiens wallerana* cv.Dwarf Baby Mixed; *Verbena* × *hybrida* cv. Olympia Mixed; *Petunia* × *hybrida* cv. Red Star.

Seed treatments and germination

All seeds received a 3 h pre-soak in Iprodione (Rovral, 50% a.i. wettable powder). All treated seeds were primed at 15 °C in parallel sided separating columns (50 mm diameter) containing 0.25 l of polyethylene glycol (PEG). The PEG solution was aerated at 0.5 l min^{-1} through a glass tube passing down the centre of the column. The diameter of the tube and the position of its end in the tapering base of the column were selected to give effective bubble distribution in the PEG solution. Treatments to *Primula*, *Impatiens* and *Verbena* seeds included: priming alone; priming following a 48 h soak at 5 °C in a plant growth regulator (PGR) solution; and priming in a solution containing the same concentration of PGR used in soak treatments. Details of these treatments are given in table 1. During priming in each of these combination treatments, solutions were aerated with the ambient gas mixture or a mixture containing 75% oxygen and 25% nitrogen. This gave six treatments that were compared with untreated controls. As PGR treatments were shown to have no significant effects on *Petunia* seeds (Finch-Savage, Gray and Dickson, 1991b), in this species two treatments only were compared with controls. Seeds were collected from each treatment after

7, 10 and 14 days of priming and were then washed under running tap water for 0.5 minutes and rinsed three times in distilled water. After treatment, all seeds were dried in a flow of air at 15 °C and 45 ± 5% rh for 48 h, to an equilibrium moisture content. After drying, seeds were dusted with Iprodione (5 g a.i. kg^{-1}) and seeds from all treatment and duration combinations (*Petunia*, 7, other species, 19) were germinated under the test conditions shown in table 1. For each treatment there were three replicates of 50 seeds. The remaining seeds were sealed in laminated aluminium foil packets and stored at 5 °C for subsequent seedling emergence experiments.

Germination tests were carried out on two layers of absorbent paper (Whatman grade 181) moistened with distilled water in replicate transparent polystyrene boxes (80 × 120 × 20 mm). For germination in the dark, seeds were placed into germination boxes under green light and then wrapped in aluminium foil to exclude light. Germination counts were made on these seeds when germination in the light (100–170 μmol m^{-2} s^{-1}) was complete.

Seedling emergence in cellular trays

From the germination test an optimum priming duration was selected for each of the six treatments. Replicates of all six treatments and an untreated control were sown onto compost in each of eight cellular trays (432, 4 cm^{-3} cells, Plantpack Ltd., UK) and covered with moist medium grade vermiculite. There was a two-cell wide guard row around each of the trays which were arranged as randomised blocks under fluorescent lights (100 μmol m^{-2} s^{-1} at compost level) at 20 °C. Seedling emergence was recorded from the 48 seeds in each replicate.

The compost used was a 75:25 mixture of finely milled and sieved (7 mm) sphagnum peat and sieved non-calcareous grit (1–2 mm) with a pH of 5.8. Under the same conditions of temperature and light that were used in this experiment, early seedling growth from six replicates of 40 *Impatiens* and *Verbena* seeds of each treatment and the untreated control was measured in a slope test (Gray and Steckel, 1983).

The effects of compost temperature and moisture content

The two most effective treatments were selected for *Primula*, *Impatiens* and *Verbena* from the results of seedling emergence in cellular trays. Seedling emergence from freshly prepared and dried seeds of these treatments was compared with that from untreated control seeds at a range of compost moisture contents and temperatures. There were four compost moisture contents (24, 36, 53 and 100% on a dry weight basis) held at three temperatures (15, 20 and 25 °C). Twenty five seeds of the two seed treatments and the control were sown in sealed transparent polystyrene boxes (75 × 135 × 60 mm). There were six replicate boxes at each of the 12 moisture content/temperature combinations. Seeds were sown onto 300 cm^{-3} of compost (as described above) given a uniform pressure of 5.5 g cm^{-2} and then covered by a further 75 cm^{-3} of compost before application of the same pressure. Moisture release curves were constructed in pressure membrane apparatus for compost having the same bulk density (0.59 g cm^{-3}). The moisture contents used corresponded to water potentials of

<–0.005, –0.01, –0.1 and –0.5 MPa. Fully moistened compost had a moisture content of 117%.

Statistical analyses
Germination (radicle visible) and emergence counts were made daily initially and then at longer time intervals. Percentage data were angularly transformed and spreads in time to germination and seedling emergence (Orchard, 1977) were log transformed before all measured parameters were subjected to analyses of variance.

Results and discussion

A number of seed treatment protocols were investigated in a previous study to develop methods of improving seed germination of bedding plant species (Finch-Savage, Gray and Dickson, 1991b). These treatments were carried out on a small scale in germination boxes. The treatment of seeds here on a larger scale in aerated solutions provides the opportunity for further enhancing seed performance by enriching the air supply with oxygen during priming (Bujalski, Nienow and Gray, 1989). Oxygen-enriched atmospheres can help to relieve dormancy (Corbineau, Rudnicki and Come, 1988) and may be of particular benefit during treatment of seeds such as *Verbena* which are thought to suffer oxygen deficiency in an excess of water (Ely, 1979). Oxygen enrichment was therefore included here in treatment protocols. In these protocols, Iprodione was applied as a pre-soak treatment because preliminary experiments had shown a phytotoxic effect of Iprodione added to the priming solutions in all species except *Petunia*. Pre-soaking seeds in Iprodione and then dusting the seeds after priming treatments had no phytotoxic effect.

Seed germination
Priming treatments reduced mean germination time of *Primula*, *Impatiens* and *Petunia* seeds compared to that from untreated seeds (tables 2 and 3). Priming also increased percentage germination of *Primula* and *Impatiens* seeds in the dark, but reduced percentage germination of *Verbena* compared to that from untreated controls. The positive benefit of priming *Primula* seeds in aerated solutions in the absence of PGRs shown here contrasts with the adverse effects of priming on absorbent paper reported in a previous study (Finch-Savage, Gray and Dickson, 1991b). The reasons for this are not known.

With *Primula*, germination in the dark was greatest when $GA_{4/7}$ was added to the priming solution. In all cases the addition of PGRs to the priming solution was more effective than pre-soaking seeds in PGRs. For brevity PGR pre-soaking treatments are therefore not included in the results presented. Oxygen enrichment of the priming solution did not further enhance germination of *Primula*, *Impatiens* or *Petunia* and contrary to expectation adversely affected germination of *Verbena* seeds.

Treatment durations selected for seedling emergence experiments were: *Primula* priming treatments with oxygen enrichment 10 days and without enrichment for 14

Table 2. The effect of priming treatments and treatment duration on mean germination time and percentage germination of *Primula* and *Impatiens* seeds. Angular transformations of percentages are in parentheses.

	Mean germination time (days)				Germination in the light (%)				Germination in the dark (%)			
Days of treatment	0	7	10	14	0	7	10	14	0	7	10	14
Primula												
Untreated	11.8				71(57)				37(38)			
Primed		8.8	7.7	7.3		81(64)	75(60)	79(64)		66(55)	72(58)	79(63)
Primed with PGR		7.1	7.0	5.9		85(67)	81(64)	81(64)		85(67)	83(66)	77(62)
Primed with oxygen enrichment		10.3	9.1	8.4		81(64)	75(60)	81(64)		71(58)	74(60)	73(59)
Primed with PGR and oxygen enrichment		8.2	6.7	6.1		89(70)	83(66)	74(60)		82(65)	88(70)	88(70)
SE (DF_a, 38;$_b$, 78)				0.50_a					$(2.4)_b$			
Impatiens												
Untreated	3.7				96(81)				79(63)			
Primed		2.7	3.0	3.9		97(80)	97(82)	96(79)		96(81)	95(78)	91(73)
Primed with PGR		2.4	2.6	2.9		99(86)	96(79)	92(74)		93(75)	95(77)	88(71)
Primed with oxygen enrichment		2.9	2.8	3.1		94(76)	94(76)	93(75)		91(73)	88(70)	91(72)
Primed with PGR and oxygen enrichment		2.7	2.5	2.7		99(86)	95(78)	91(72)		94(77)	96(79)	93(75)
SE (DF_a,38;$_b$,78)			0.12_a						$(2.5)_b$			

Table 3. The effect of priming treatments and treatment duration on mean germination time and percentage germination of *Verbena* and *Petunia* seeds. Angular transformations of percentages are in parentheses.

	Mean germination time (days)				Germination (%)			
Days of treatment	0	7	10	14	0	7	10	14
Verbena								
Untreated	7.8				60(51)			
Primed		7.9	8.2	6.3		43(41)	45(42)	33(35)
Primed with PGR		6.6	6.1	6.1		51(46)	46(43)	51(45)
Primed with oxygen enrichment		9.5	9.0	7.4		21(27)	29(33)	23(28)
Primed with PGR and oxygen enrichment		8.7	7.6	6.6		36(37)	38(38)	17(24)
SE (DF 38)			0.68				(2.3)	
Petunia								
Untreated	5.2				90(79)			
Primed		2.6	2.7	1.4		93(76)	89(70)	90(72)
Primed with oxygen enrichment		3.1	2.4	2.6		93(75)	95(77)	95(77)
SE (DF 14)			0.12				(3.2)	

days; all *Impatiens* treatments 7 days; all *Verbena* treatments 10 days; and *Petunia* priming with oxygen enrichment 10 days and without enrichment for 7 days. Further treatment for these species was either of no additional benefit or harmful. Slope test results suggest that there is no residual etiolation effect from PGRs at the concentrations used in these treatments in agreement with earlier results from smaller-scale seed treatments (Finch-Savage, Gray and Dickson, 1991b).

Seedling emergence in cellular trays

Experiments have shown improved bedding plant seed germination in composts that have low nitrogen levels, a pH between 5.5 and 5.9 and a suitable mixture of sieved peat and grit (Farthing and Ellis, 1991). A uniform compost conforming to these specifications was mixed for these experiments. Under the conditions of adequate moisture and temperature which should be provided in commerce, priming significantly reduced the mean seedling emergence time of all species in compost-filled cellular trays (figure 1). PGRs added to the priming solution further enhanced the performance of *Verbena* and *Impatiens* seeds. For the untreated seeds and those from the most effective priming treatment, mean seedling emergence times for *Primula* were 19 and 12 days (SE = 0.4, DF = 39) respectively. Corresponding figures for *Impatiens* were 9 and 7 days (SE = 0.1, DF = 49), for *Verbena*, 9 and 6 days (SE = 0.2, DF = 35), and for *Petunia*, 8 and 6 days (SE = 0.1, DF = 21). These reductions in emergence time represent increased turnover and reduced heating costs during seedling production in commercial practice. Percentage seedling emergence of *Primula* was increased by

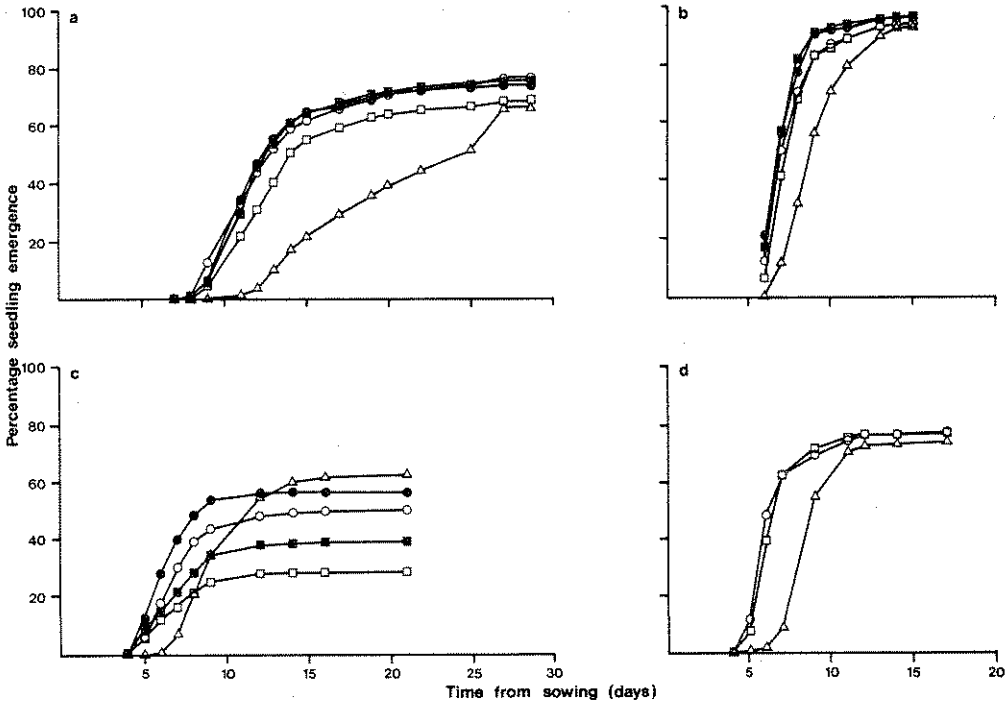

Figure 1. Seedling emergence of a, *Primula*, b, *Impatiens*, c, *Verbena* and d, *Petunia* seeds in cellular trays. △, untreated control; ○, primed; □, primed in oxygen enriched air; ●, primed with PGR; ■, primed with PGR in oxygen enriched air.

priming but was not significantly different to that in the untreated controls in *Impatiens* and *Petunia*. Priming without PGRs significantly reduced final percentage seedling emergence in *Verbena*. The spread in time to seedling emergence was significantly reduced by the most effective priming treatments in *Primula* and *Verbena*. Oxygen enrichment, when not combined with PGRs in the priming solution, reduced and delayed seedling emergence in all species except *Petunia* where there was no positive benefit (data not shown).

The effects of compost temperature and moisture content

It is generally thought that physiological seed treatments can widen the range of environments in which optimum germination and emergence can occur. If true, this could be a major benefit of seed treatments to bedding plant production in practice. This hypothesis was therefore tested here by exposing primed and untreated seeds to a range of compost temperatures and water potentials. The range was limited to conditions that could be experienced in seedling production practice. Different relationships were found with each species (figure 2). There were no significant interactions between seed treatment and environmental treatments with *Primula* and, in general, seed priming reduced mean emergence time and increased percentage emergence. In experiments on *Impatiens* and *Verbena* there were, however, significant seed treatment x compost water potential interactions. Primed seeds showed greater sensitivity to compost moisture than the untreated control seeds. Under the most favourable conditions, priming *Impatiens* reduced mean emergence time and increased percentage emergence com-

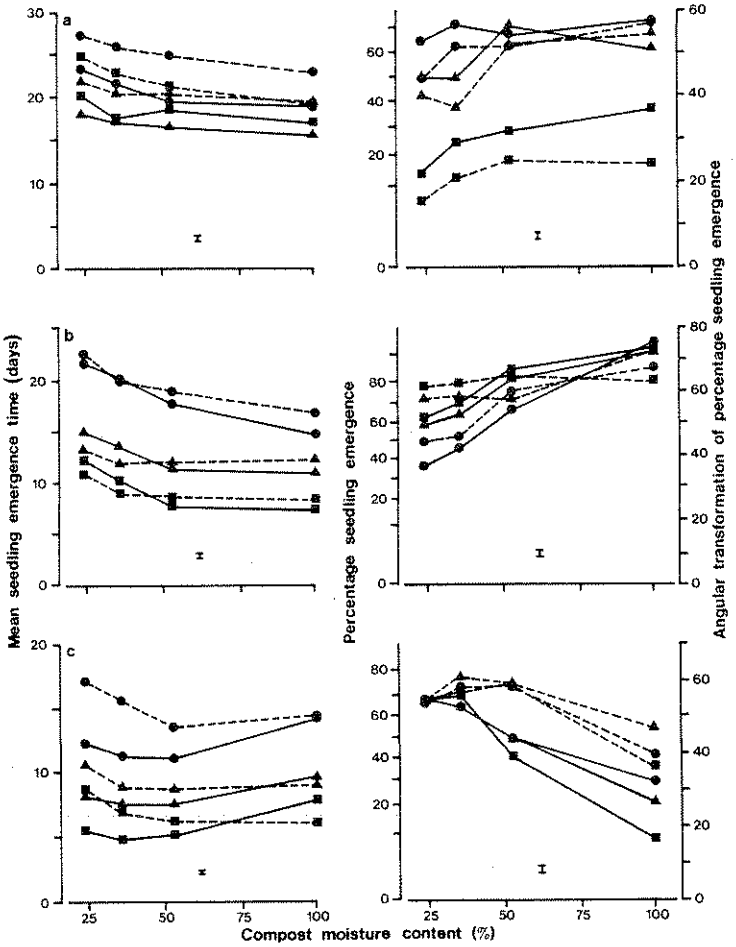

Figure 2. Mean seedling emergence time and percentage seedling emergence (angular transformation) from a, *Primula*, b, *Impatiens* and c, *Verbena* seeds in a range of temperatures and compost moisture contents. ●, 15 °C; ▲, 20 °C; ■, 25 °C; – – – –, untreated control; ———, primed. Priming treatments are for *Primula*; PEG with PGR and oxygen enrichment, *Impatiens* and *Verbena*; PEG with PGR. Vertical bars are standard errors (*Primula* and *Verbena*, 235 DF, *Impatiens*, 115 DF).

pared with that from the untreated control. Under conditions of lower temperature and drier compost the seedling emergence from primed *Impatiens* seeds was reduced and delayed compared with that from the untreated control, this situation was reversed with *Verbena*. Primed *Verbena* seeds had much greater reductions in percentage emergence with increasing compost moisture content than untreated control seeds. This result explains the disappointing performance of primed *Verbena* seeds reported here in cellular trays that were kept moist throughout seedling emergence. The sensitivity of *Verbena* seeds to high compost moistures is also in agreement with results in germination tests (Ely, 1979 and Finch-Savage, Gray and Dickson, 1991b).

Under near-optimal conditions there are worthwhile gains from using seed treatments to increase stands, reduce mean seedling emergence time and reduce the spread in times to emergence depending on the species. However the results reported here suggest that there is only limited potential for bedding plant seed treatments to eliminate the effects of non-optimal environmental conditions likely to be experienced in

seedling production practise.

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