Table 2. Germination and infection of zinnia seeds with a constant concentration of $CaCl_2$ $2H_2O$, and with varying temperatures

Temperature, degrees C	$CaCl_2$ $2H_2O$ 1.5M	7 day germination, percent healthy	10 day Infection, percent
Cool water	+	58[1]	23
soak	–	51[1]	19
54	+	57	9
	–	5	3
56	+	54	4
	–	1	not read
58	+	43	2
	–	0	not read
60	+	30	0
	–	0	not read

[1] Many others rotted

Thus from the work so far it appears that satisfactory control of *Alternaria zinniae* can be achieved and germination greatly increased by incorporation of a concentrated salt into the hot water treatment.

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PROPAGATION OF ORNAMENTAL *GREVILLEA*

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Abstract. *Grevillea* species and cultivars were propagated by four different techniques The results were heavily dependent on the condition of the plant material and on the species or cultivar used Cuttings of G. × 'Robyn Gordon' are best taken from wood 10 to 20 cm from the shoot apex, i e not terminal cuttings, and rooted at 29°C without application of IBA Air layering of G robusta and G. banksii was 100% successful in autumn but the latter species gave only 44% success in winter under glasshouse conditions. Scions of G bipinnatifida, G leucopteris and G johnsonii were almost 100% successfully grafted onto seedlings of G 'Ivanhoe' and G × 'White Wings' rootstocks gave 60% success when grafted with G bipinnatifida scions but the other two scion species were not compatible Seed germination in Grevillea is promoted by partial removal of the seedcoat and by storage of seed for 2 months at 12°C and 35% relative humidity

INTRODUCTION

Relatively little scientific research has been completed on propagation techniques of *Grevillea*.

Cuttings of *Grevillea* species and cultivars propagated in the nursery trade have often been rooted by using different treatments. Some species such as *G. rosmarinifolia* produce roots readily without growth regulators or other treatments. In comparison, *G. johnsonii* and G. × 'Robyn Gordon' have been extremely difficult to propagate by cuttings. Taken in February and with the application of growth regulators, only 40% of the cuttings of G. × 'Robyn Gordon' form roots. The time of year when *Grevillea* cuttings are taken seems to be important in determining whether or not cuttings will produce roots. Semi-hardwood cuttings of *Grevillea* seem to give the best results in the nursery trade.

Marsh (3) studied the effect of soil temperature, a growth regulator, and cutting type on *G. biternata*, *G. buxifolia* and *G. laurifolia*. She found all the species reacted differently to the treatments. She recommended that under mist *G. biternata* should have a medium temperature of 28°C, with a 500 ppm IBA application to tip cuttings. Tip or stem cuttings of *G. laurifolia* should have the same medium temperature and IBA application as for *G. biternata*. Stem cuttings of *G. buxifolia* rooted best with medium temperature 28°C and application of 2000 ppm IBA

Tay (5) successfully grafted G. × 'Robyn Gordon' onto *G. robusta* using three types of grafts. She found chip budding and side grafting produced better results than whip and tongue grafting. The "take" of the grafts done in late autumn (April and May) was significantly better than those done earlier (March).

In the past, *Grevillea* spp. and cultivars have been propagated mostly by cuttings and a few by seed. Various methods of propagation must be used to develop and improve *Grevillea*. Some selections, hybrids, or polyploids will have to be propagated by layering or grafting if cuttings do not produce roots readily.

MATERIALS AND METHODS

Rooting of G. × 'Robyn Gordon' cuttings: — Cutting material of G. × 'Robyn Gordon' was collected in plastic bags early in the morning on March 15, 1979, from Swane's Nursery, Dural, N.S.W. Within two hours of collection, semi-hardwood terminal stem cuttings 10 to 12 cm long, with one fully expanded leaf were soaked in a 2% solution of sodium hypochlorite for five minutes

A completely random experimental design was chosen with three levels of indole-3-butyric acid (IBA) at 0, 2000, and 4000 ppm in 50% ethanol quick-dip solution. Each of the four replicates for each hormone level and soil temperature had five cuttings. The basal 1 cm of the cuttings were dipped for 5 seconds. The cuttings were placed with the bottom ⅔ of the stem in 1:1 (v/v) steam sterilized sand: peat mixture. Each replicate was placed in a separate 6-inch pot and watered. A total of 180 cuttings were placed in the glasshouse with 80% shade under conditions of ten-second mist, every ten minutes. The medium temperature was regulated by heating cables in the soil The medium temperature treatments of 25°C, 29°C and 33°C ± 1°C were not replicated. After eight weeks cuttings were removed from the mist bed. Cuttings with one or more roots at least one cm long were considered rooted.

For a second experiment, cutting material of G. × 'Robyn Gordon' was collected and placed in plastic bags early in the morning on June 8, 1979, from Swane's Nursery, Dural. Within two hours of collection, terminal stem cuttings with one fully expanded leaf with the terminal bud removed were cut 10 to 12 cm long. Stem cuttings of older wood taken from the same material as the terminal cuttings were also cut 10 to 12 cm long. The older cuttings consisted of the stem, leaves and the fifth, sixth and seventh axillary buds from the terminal end of the stem. All leaves were trimmed from the older cuttings except for the leaf near the fifth axillary bud. All cuttings were soaked in a 2% solution of sodium hypochlorite for five minutes.

A completely random design was used in this experiment. Four replicates of five cuttings per replicate with and without hormone gave a total of 80 cuttings. A 3% (w/w) concentration of IBA in talc powder (Seradix 2) was applied to the basal 1 cm of half of the terminal and stem cuttings. The bottom ⅔ of all the cuttings were placed in 1:1 (v/v) steam sterilized sand: peat in 6-inch pots under the mist conditions described in the previous experiment. Temperature of the root environment was 29°C ± 1°C; the glasshouse was not shaded. After eight weeks all cuttings were removed and roots examined. Those cuttings with the description of roots given in the previous experiment were considered rooted.

Air layering of G. banksii, G. robusta, G. johnsonii and G. × 'Robyn Gordon: — In the first experiment, six plants each of *G. robusta* and *G. banksii* were grown for one year in a steam sterilized medium which consisted of 1:1:1 (v/v) sand:native peat:sandy loam. The young plants were grown outdoors under 80% shade and watered daily. Soluble complete fertilizer was applied every four months. Two weeks before the layering was done, all the plants were placed in a glasshouse without temperature control.

During May 1980, all 12 young plants were air-layered. Approximately 15 to 20 cm from the end of the shoots, a sharp knife was used to girdle the stems. The girdle was along 2 cm of the stem where two or three leaves had been removed. A slurry of 0.8% IBA in talc powder (Seradix 3) was applied to the stem wound. A handful of clean moist peat moss was placed from 3 cm above to 3 cm below the girdle on the stem. Transparent plastic used to cover the layer was fastened with wire. After 12 weeks, all layers were assessed for rooting and those shoots which had any root more than 2 cm long were removed and potted on.

In a separate experiment, 18 plants each of *G. johnsonii* and *G.* × 'Robyn Gordon' grafted on *G. robusta* plus 18 seedlings of *G. banksii* were grown for one year in the same medium and the same shade conditions as the layers in the previous experiment. Every six months 7 g of Agriform (Sierra Co., Yates, Dist., Sydney) fertilizer (20:4.3:4.1) was applied to all plants. Due to the cool daily temperatures of winter, the plants were grown for two months in a glasshouse with supplemental light before the layering was done. Night temperatures in the glasshouse remained above 10°C and the maximum temperature during the day was 25°C.

In July 1980, one layer on each plant of the three different *Grevillea* was treated according to the method given in the previous layering experiment. All 54 layers were assessed for roots after 12 weeks in the glasshouse.

Grafting of Grevillea: — Under 50% shade conditions, 100 *G. robusta* seedlings were grown for one year in 1.25 litre plastic bags. The medium consisted of 1:1:1 (v/v) sand:peat-:loam, and 4 g of Agriform slow-release fertilizer was added every six months. Two weeks prior to grafting, 60 *G. robusta* seedlings were selected for uniformity and were placed in a glasshouse with no temperature control. On April 25, 1979, semi-hardwood scion material was collected from one plant of *G.* × 'Robyn Gordon' at Sydney University Farms, Camden.

Thirty replicates of each of the two *Grevillea* were grafted using the top cleft graft technique.

The cleft graft was started by a 15 to 20 mm longitudinal cut made in the centre of each *G. robusta* seedling about 10 to 12 cm from the base of each seedling At this height the diameter of the seedling was approximately 4 to 5 mm. Scion material was cut so that the stem diameter matched that of the seedling to align the cambial layers Scion material had two dormant axillary buds with leaves partially removed. The proximal end of the scion was cut to make a wedge. The scion was joined to the distal end of the stock and translucent plastic tape (1 cm wide) wrapped firmly around each graft. Grafting mastic was applied to the surface of the tape and all cut surfaces of the scion All grafts were placed in a glasshouse with 80% shade and high relative humidity. Emerging shoots from the *G. robusta* stocks were removed every four weeks. After 20 weeks, all grafts were examined and the results recorded.

In a second experiment, a 3 x 8 factorial design was employed for grafting 3 scions onto 8 rootstocks. The three species used for scions were *G. bipinnatifida* (glaucous form), *G. leucopteris*, and *G. johnsonii* One-year-old seedlings of *G. robusta* were used as a control in the experiment because all three scion species were known to be compatible with *G. robusta* (Clemens, personal communication). Advanced (2-year) *G. robusta* seedlings were grafted to compare the results with the younger control stock. *G. lavandulacea*, *G. vestita*, *G.* × 'Ivanhoe' and *G.* × 'White Wings' were tested as clonal rootstocks The one and two year *G. robusta* seedlings were grown under conditions described in the previous experiment. *G. lavandulacea*, *G. vestita*, *G.* × 'Ivanhoe' and *G.* × 'White Wings' were grown from cuttings from one year prior to the grafting experiment. All stocks grew vigorously and two weeks prior to grafting were selected and placed under the same glasshouse conditions as in the previous experiment

Semi-hardwood scion material was collected from one plant of each of the three *Grevillea* species grown by Mr. Sid Cadwell, Kandos. On April 21, 1980, scion material of *G bipinnatifida* and *G. leucopteris* was grafted onto the appropriate rootstock. The grafting of *G. johnsonii* was completed on April 22, 1980. Eight replicates of stock-scion combinations were grafted using the cleft graft method described in the previous experiment Since the diameter of the stock and scion varied between species and cultivars, the height at which grafting was done for each combination varied from 20 to 30 cm above soil level. Shoots which suckered from the rootstocks were removed every four weeks. The progress of the experiment was observed and results were recorded at 20 weeks after grafting

Seedling emergence of G. banksii: — Seeds of *G. banksii* were collected from 30 mature plants at the Sydney University Farms, Camden, during February 1979. The seed was air-dried for 15 days at room temperature before the seeds were stored or treated.

The completely random experimental design consisted of 3 x 3 factorial with three periods of storage before planting, and three seed pretreatments applied immediately before the seeds were sown. Seeds of *G. banksii* were planted directly with no storage and after 1 and 2 months storage at 12°C and 35% relative humidity. The three pretreatments were adding 150 ml of boiling water to each replicate of seeds and allowing the seed to soak for 12 hours; soaking the seed in 150 ml of water at 25°C for 3 hours followed by the cutting away of part of the testa, and controls with no pretreatment. Four replicates of 30 seeds each were used for each storage period and seed pretreatment. Seed which had been stored was allowed to equilibrate to ambient conditions for three days before it was planted. Seed was planted in trays of vermiculite at a depth of 3 to 4 cm in a glasshouse with a 12 hour day/night temperature regime of 24°C/19°C. Seed trays were watered every day. The number of seeds which had emerged was recorded after 35 days.

In a second experiment, a completely random 4 x 2 factorial design was used for four period of seed storage and two seed pretreatments. Seeds of *G. banksii* were planted directly with no storage and after 2, 4 and 6 months storage under the conditions described in the previous experiment. Seed was pretreated by soaking it for 3 hours in 150 ml of water (at 25°C) before cuttings away part of the testa. Controls received no pretreatment. Four replicates of 50 seed each were used for each storage period and seed pretreatment. Seed was germinated and data recorded as given in the previous experiment.

RESULTS

Effect of bottom heat and indolebutyric acid on the rooting of Grevillea × *'Robyn Gordon' cuttings:* —

Individual analyses of variance which were performed on the $\sqrt{X + ½}$ transformations of numbers of rooted cuttings within each bottom heat temperature showed that IBA concentration had no effect on rooting. No interaction between IBA concentration and from within each bottom heat temperature was evident, and a chi-square test for homogeneity of variance between temperatures was not significant, allowing data to be pooled.

Bottom heat temperature had a highly significant ($P \leqslant 0.01$) effect on rooting of G × 'Robyn Gordon' cuttings. An estimate of error could not be calculated because of lack of replication of temperature, but temperature data was partitioned into linear and quadratic effects. The quadratic portion showed that cuttings rooted significantly better with a bottom heat temperature of 29°C than at either 25°C or 33°C (Table 1).

Of those cuttings that did not root at 25°C, 56.7% formed callus. At 33°C, 86 7% of cuttings died without rooting.

Table 1 Effect of bottom heat temperature and IBA on number of rooted G. × 'Robyn Gordon' cuttings ($\sqrt{X + ½}$ transformation, treatment means, percent rooted shown in parentheses)

Growth regulator	Bottom heat temperature 25°C	29°C	33°C	Mean
Control (O)	1 35 (30 0)	2 06 (75 0)	0 84 (5 0)	1 41 (36 7)
2000 ppm IBA	0 84 (5 0)	1 93 (65 0)	2 00 (15 0)	1 20 (28 3)
4000 ppm IBA	1 18 (20 0)	1 86 (60 0)	0 84 (5 0)	1 29 (28 3)
Mean	1 12 (18 3)	1 95 (66 7)	0 92 (8 3)	
S E = 0 14				

Effect of wood origin and IBA on rooting of G. × 'Robyn Gordon,' cuttings

The origin of wood used for making cuttings significantly ($P \leqslant 0.01$) influenced how well cuttings rooted (Table 2) the overall rooting of older stem cuttings being 87 5% compared to 62.5% with terminal cuttings. Cuttings of older wood tended to produce larger numbers of longer shoots. Application of IBA had no significant effect on rooting and there was no interaction of IBA level with wood origin. Unrooted cuttings produced callus tissue.

Table 2. Effect of wood and IBA on number of rooted G × 'Robyn Gordon' cuttings ($\sqrt{X + ½}$ transformation, treatment means, percent rooted shown in parentheses)

Growth regulator	Terminal cuttings	Stem cuttings	Mean
Control (0)	1 93 (65 0)	2 23 (90 0)	2 08 (77 5)
0 3% (w/w) IBA	1 86 (60 0)	2 18 (85 0)	2 02 (72.5)
Mean	1 90 (62 5)	2 21 (87 5)	
S E = 0 09			
LSD (0 05) = 0 17			
LSD (0 01) = 0 23			

Air layering of Grevillea

Within 6 weeks of being treated all plants of *G. banksii* had produced abundant roots. All air layers of *G. robusta* also rooted but only after 8 to 12 weeks. When a separate collection of *G. banksii* plants were air layered, only 44% of the plants had formed roots after 12 weeks. In the same experiment 28% of *G.* × 'Robyn Gordon' layers, and no layers of *G. johnsonii* had rooted after the same length of time.

Grafting of Grevillea

In the preliminary experiment using seedling *G. robusta* rootstocks and scions of *G. johnsonii* and *G.* × 'Robyn Gordon', 67% and 60%, respectively, of grafts were successful. Shoots began to emerge from the scions 6 to 8 weeks after grafting, *G. johnsonii* growing with a strong leader, and *G.* × 'Robyn Gordon' with a low, spreading habit.

In the stock-scion factorial experiment, large differences were found between the suitability of the rootstocks and the way in which different scions survived on any one rootstock. This was borne out in a chi-squared analysis which showed that rootstock, and the rootstock by scion interaction were highly significant ($P \leqslant 0.01$). There was no significant effect of scion.

By far the best results were obtained using young seedlings of *G. robusta* onto which all 3 scions could be grafted with 88 to 100% success (Table 3). Shoots grew out from the scions after only 4 to 6 weeks. Advanced seedlings gave less satisfactory results. Of the clonal rootstocks, *G. vestita* showed promise for grafting the 3 scions with a mean success rate of 62.5%.

Table 3. Percentage survival of 3 kinds of *Grevillea* scions grafted onto 6 kinds of *Grevillea* rootstocks

Rootstock	Scion			
	G bipinnatifida	*G. leucopteris*	*G. johnsonii*	*mean*
*G *robusta* (tube)	87.5	100 0	87.5	91 7
*G *robusta* (advanced)	62 5	87.5	75 0	75.0
G *vestita*	50 0	50 0	87 5	62 5
G 'White Wings'	75 0	12 5	0	29.2
G *'Ivanhoe'*	75 0	0	0	25 0
G lavandulacea	0	12 5	0	4 2
mean	58 3	43 8	41 7	

*denotes seedling rootstocks, survival recorded at 20 weeks.

In contrast, the remaining 3 scions gave disappointingly low survival, except for the combinations of *G. bipinnatifida* on G. 'White Wings' and G. 'Ivanhoe' Highest mortalities were observed within 12 weeks of grafting.

Effects of pretreatment and storage on emergence of Grevillea banksii seed

Conflicting results were obtained in the two experiments in which emergence of G. *banksii* seedlings was studied. In the first experiment emergence rates declined after one month's storage and were still worse than the initial rates after 2 months (Figure 1 - above), whereas in the second, storage for 2 months dramatically improved emergence (Figure 1-below)

Both experiments showed that partial removal of the seedcoat was beneficial to emergence, the effect being more marked in the second experiment in which, taken over all storage times, 70% emergence was obtained following treatment, compared to only 18% in controls. The comparison in the first experiment was 36% to 25%, respectively

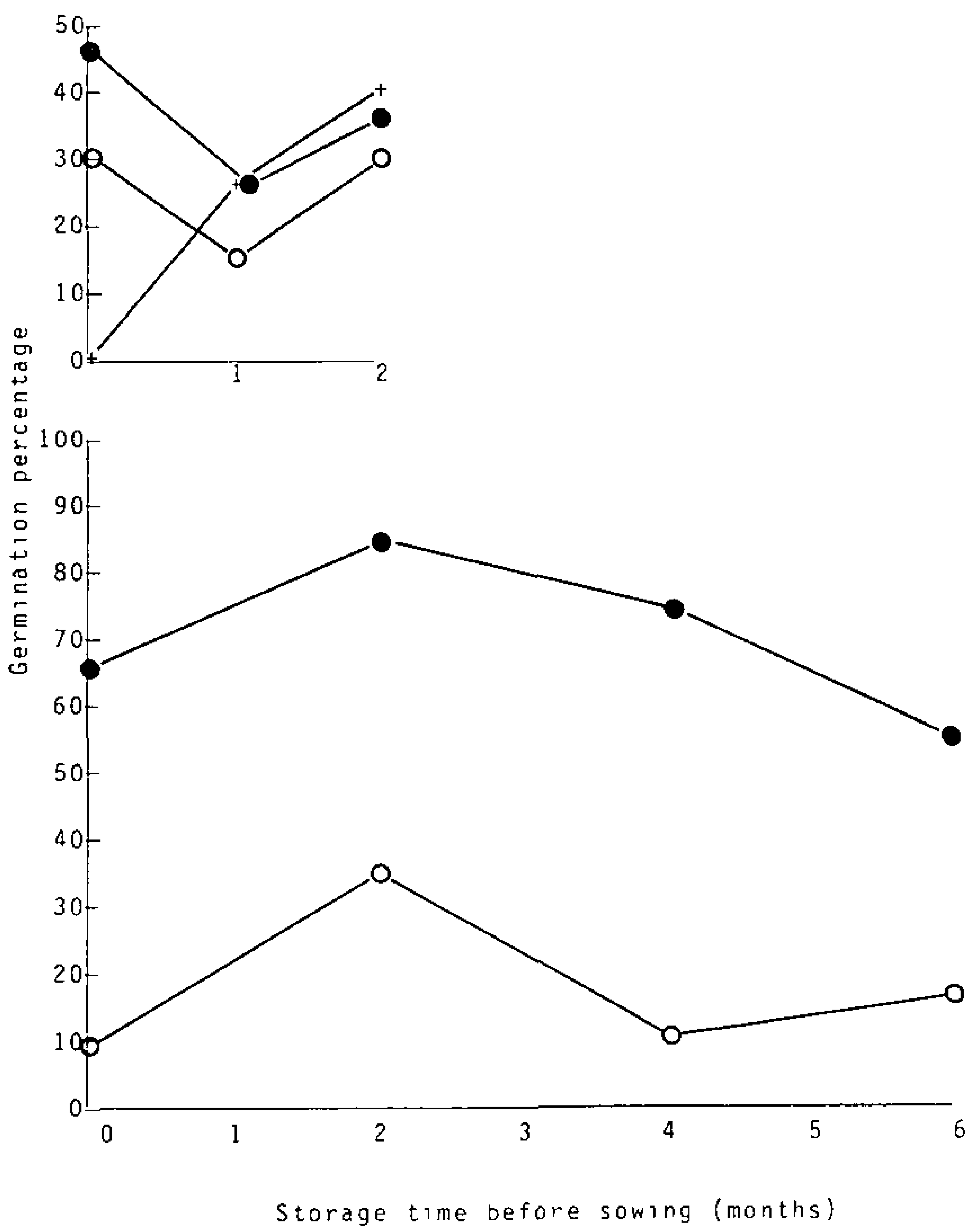

Figure 1. Effect of seed pretreatment and storage on the emergence of G *banksii* seed after 35 days in two separate experiments (see text). O control, no treatment, ● seedcoat cut after cold water soak 3 hours, + boiling water

Analyses of variance performed on the arcsin transformations of the data showed that main effects and interactions were all highly significant. Storage for 2 months following partial seedcoat removal gave significantly ($P \leq 0.01$) better emergence than no storage or 4 months storage. The analysis for the first experiment was complicated by the unusual data for the emergence of seed following boiling water pretreatment. The highest emergence at 2 months was for boiled seed that had failed completely to emerge immediately after treatment (Figure 1-above).

DISCUSSION

The results showed that ornamental *Grevillea* can be propagated in a number of ways. However, not all species respond similarly, e.g. some species could be grafted with 100% success, whereas others did not graft at all on the same rootstock; and the success of a technique for any species will vary depending on the condition of the material.

The rooting of cuttings of G. × 'Robyn Gordon', which was favoured by the use of older wood, was probably influenced by the greater carbohydrate reserves in this material (1). In similar propagation experiments, Marsh (3) found that stem cuttings rooted better than terminal cuttings in G. *buxifolia*, but that the result was reversed when G. *biternata* was used.

The use of IBA has been found to promote rooting in many plants in the *Proteaceae* (4), so it was somewhat surprising that this had no effect on rooting in G. × 'Robyn Gordon'. However, it would have been difficult to improve on the 90% strike obtained with older wood and a bottom heat of 29°C. This cultivar may now be regarded as relatively easy to root provided the correct material is used and collected in autumn.

The effect that growing conditions and the resultant condition of the plant material can have on propagation was highlighted by G. *banksii* in the two air layering experiments. Layering in autumn on partially hardened shoots on plants that had not grown under glasshouse conditions was much more favourable than layering of new shoots forced by favourable glasshouse conditions in mid-winter. It is of interest that G. *robusta* can be successfully air layered, a species so commonly grown from seed Vegetative propagation in this way of mature wood could reduce the time for small silky oak plants to flower after leaving the nursery. The complete failure of G. *johnsonii* to air layer was not surprising in the light of the difficulty usually experienced in rooting cuttings of this species (Clemens, unpublished results).

The results of the grafting experiments suggest that incompatibility between wood of different species and cultivars of *Grevillea* could be a problem in the raising of certain graft combinations. However, some combinations were outstandingly successful, the most significant being the grafting of *G. johnsonsii* onto *G. robusta* or *G. vestita*. This has been used in routine multiplication of *G. johnsonii* plants for further experimental studies (Dupee and Clemens, in prep.). Perhaps the results are of greatest interest in that they allow further long-term trials to be carried out to assess the rootstock effects (if any) on the flowering and development of the scion growth. Cleft grafting proved to be the most successful. Chip budding, side, and whip-and-tongue grafting were used with less success by Tay (5).

As a routine measure, *Grevillea* seed should have a portion of the seedcoat removed before sowing. However, this is a laborious procedure and is probably of greatest value in the propagation by seed of species in short supply or in breeding programmes when the highest possible emergence of viable seed is required. The results are contrary to those of Heslehurst (2) who found that seed treatments inhibited germination in *G. banksii* seed. The recovery of boiled seed after storage is an interesting phenomenon and requires further study.

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