AN EXPERIMENTAL INTRODUCTION OF VASCULAR PLANTS FROM SOUTH GEORGIA TO THE MARITIME ANTARCTIC

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ABSTRACT. Transplants of 23 native and alien vascular species from South Georgia were grown between 1967 and 1973 in local soil and vermiculite on Signy Island, South Orkney Islands. Many of these survived at the most sheltered site and eight species flowered after at least one winter. Seed germination was observed during two summers but seedling establishment was generally low. The results of the introductions are discussed with reference to the possible further colonization of the maritime Antarctic region by vascular plants.

THERE have been several intentional introductions of flowering plants to Antarctic regions and a review of the species tested and their fate has been published by Edwards and Greene (1973), who also described a recent introduction of plants from the Falkland Islands to South Georgia and Signy Island, South Orkney Islands. Although several species were able to maintain themselves vegetatively, it was shown that their reproductive performance was generally reduced and it was suggested that few were likely to become naturalized on either island. At the same time as the Falkland Islands trials were in progress, an experiment with South Georgian species was also carried out on Signy Island as part of an attempt to determine whether the floristic poverty of the Antarctic botanical zone, as defined by Greene (1964), is due to environmental factors or to barriers to dispersal. In view of the differences in reproductive performance noted in native Antarctic bryophytes (Longton, 1970, 1972) and angiosperms (Holtom and Greene, 1967; Greene and Holtom, 1971), it may be questioned whether the South Orkney Islands are the most suitable location for such trials, since the summer climate would appear more severe, at least in terms of sunshine, than localities in the Argentine Islands or Marguerite Bay, 4–6° of latitude farther south. However, the shortness of the growing season is one of the characteristics of the Antarctic terrestrial environment (Greene and Longton, 1970) and the more northerly South Orkney Islands may be presumed to be more favourable in this respect.

MATERIALS AND METHODS

Flowering plants were collected from King Edward Point, Bore Valley and Husvik on South Georgia in early December 1967, and planted out on Signy Island on 23 and 24 December 1967, after being kept at *c.* 0° C during 4 days transport by sea. A second collection of material was made from Cumberland East Bay on 18 November 1968 and this was kept at air temperature before being planted at Signy Island between 2 and 4 December 1968.

A proportion of each species was transplanted into vermiculite contained in pots which were watered twice weekly with a modified Hoagland's nutrient solution (see Callaghan and Lewis, 1971); the remainder were planted in an area of natural soil. The latter received no artificial watering, since long periods without precipitation are uncommon on the South Orkney Islands. An attempt was made to transplant each species into a habitat of similar moisture and light regimes to that from which each was collected on South Georgia. The two soil and two vermiculite sites were those described by Edwards and Greene (1973), being close to the shore on low-altitude north-facing slopes which also supported populations of the two native phanerogams, *Colobanthus quitensis* and *Deschampsia antarctica*. In accordance with the recommendations for conservation contained in the Antarctic Treaty, measures were taken to ensure that the imported aliens did not spread beyond the study sites. After potting and re-planting had been carried out, all plant remains were burnt and the imported soil disposed of at sea. The test sites were kept under continual surveillance and seedlings

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growing outside the experimental areas were destroyed. All introduced material was removed in February 1973 and the surviving plants returned to Birmingham.

Vegetative Survival

Transplants made in 1967

Fourteen species were introduced in December 1967 and eight of these failed to survive the first winter (Table I). The three species of fern soon died, while throughout the first summer the condition of *Juncus scheuchzerioides*, *Festuca contracta* and *Uncinia meridensis* deteriorated slowly. A few new leaves were produced by *F. contracta* but these failed to survive for long. In contrast, the turnover of leaves in both species of *Acaena* was extremely rapid and several new leaves were noted each time the plants were scored but these became moribund and began to decay with the next frost. *Ranunculus biternatus* also proved very susceptible to frosts and these transplants were gradually dominated by *Callitriche antarctica*, which was intermixed with *R. biternatus*, as the buttercup died.

The *Callitriche antarctica*, which was introduced unmixed with other species, survived the summer in good condition but it appeared to have died completely during the winter (Table I). However, in the middle of the following summer new sparse shoots, apparently the result of seed germination, became visible beneath the old dead leaves. Neither this growth nor the green shoots which were produced again the following February was able to survive winter conditions and the transplants failed to produce any new growth after their third winter. Apart from *Callitriche antarctica*, four other species remained alive on Signy Island after two winters, although none had particularly vigorous growth. *Colobanthus subulatus* showed little change during the first summer but gradually leaves in the upper parts of the cushions turned pale and only shoots around the bases remained healthy. A few moribund cushions survived through their third summer but all died during the 1970 winter. Plants of *Phleum alpinum* were also quite successful at first. The high-altitude phenotypes in vermiculite showed increases in the number of healthy leaves and tillers each summer but died after 2 years. The surviving plants of *Rostkovia magellanica* also died in the spring of 1969–70, having produced little new growth since their introduction. However, two plants of this species, which had appeared dead in April 1968, each developed a new leaf 9 months later and one produced a deformed flower.

Poa flabellata was the most successful of all the South Georgian species introduced at this time. An increase in leaf and tiller numbers was noted on most plants during the first two summers and, even after surviving two winters, most of the plants appeared in reasonable condition. However, the number of healthy plants declined dramatically during the 1969–70 summer so that at the end of the third summer only one plant remained alive. This plant was still growing in March 1972, $4\frac{1}{2}$ years after being introduced, when it was destroyed.

Transplants made in 1968

Of the material introduced to Signy Island in December 1968, only 11 of the 21 species had died out completely by February 1973, $4\frac{1}{2}$ years after their introduction (Table II). *Montia fontana*, *Callitriche antarctica*, *Ranunculus biternatus*, *Hymenophyllum falklandicum* and *Poa pratensis* all failed to survive their first winter. *Festuca contracta* and *Uncinia meridensis* gradually died during their second summer without producing much new growth, although the number of leaves on two *Festuca* plants in native soil increased from 58 to 83 and from 25 to 66 between December 1969 and March 1970.

Several species established more successfully at the second transplant sites than at those used in 1967, especially those in native soil. Single plants of *Acaena magellanica* and *A. tenera* survived four winters. One plant of the former species with five main shoots produced 16 new leaves between mid-January and mid-February 1969, yet in the same 35 day period it lost

TABLE II. VEGETATIVE SURVIVAL OF SOUTH GEORGIAN VASCULAR SPECIES TRANSPLANTED ON SIGNY ISLAND IN DECEMBER 1968

Species	*Number of plants tested in December 1968* Vermiculite / Soil	*Percentage apparent vegetative survival*								
		Feb. 1969	*Apr. 1969*	*Dec. 1969*	*Feb. 1970*	*Apr. 1970*	*Nov. 1970*	*Mar. 1971*	*Feb. 1972*	*Feb. 1973*
Acaena magellanica (Lam.) Vahl.	0	–	–	–	–	–	–	–	–	–
	4	100	100	75	75	75	25	25	25	25
Acaena tenera Alboff.	0	–	–	–	–	–	–	–	–	–
	2	100	100	100	100	100	100	50	50	50
Achillea millefolium L.†	0	–	–	–	–	–	–	–	–	–
	1	100	100	100	100	100	100	100	100	100
Callitriche antarctica Engelm.	0	–	–	–	–	–	–	–	–	–
	3	100	100	0	0	0	0	0	0	0
Colobanthus quitensis (Kunth) Bartl.	2	100	100	100	100	100	100	100	50	*
	5	100	100	100	100	100	100	80	80	*
Colobanthus subulatus (D'Urv.) Hook. f.	0	–	–	–	–	–	–	–	–	–
	10	100	100	100	100	80	70	70	60	10
Deschampsia antarctica Desv.	2	100	100	100	100	100	100	100	50	*
	6	100	100	100	100	100	100	83	83	*
Festuca contracta T. Kirk	5	100	100	0	0	0	0	0	0	0
	5	100	100	60	60	60	0	0	0	0
Hymenophyllum falklandicum Baker	0	–	–	–	–	–	–	–	–	–
	1	100	100	0	0	0	0	0	0	0
Juncus scheuchzerioides Gaud.	4	100	100	0	0	0	0	0	0	0
	1	100	100	100	100	100	100	100	100	0
Montia fontana L.	0	–	–	–	–	–	–	–	–	–
	1	100	100	0	0	0	0	0	0	0
Phleum alpinum L.	5	100	100	80	80	80	20	20	20	0
	5	100	100	80	80	80	80	80	80	60
Poa annua L.†	2	100	100	0	50	50	50	100	*	*
	0	–	–	–	–	–	–	–	–	–
Poa flabellata (Lam.) Hook. f.	5	100	100	100	100	100	60	60	20	*
	5	100	100	100	100	100	40	40	40	*
Poa pratensis L.†	0	–	–	–	–	–	–	–	–	–
	1	100	100	0	0	0	0	0	0	0
Polystichum mohrioides (Bory) Pr.	0	–	–	–	–	–	–	–	–	–
	5	80	80	0	20	20	0	20	0	0
Ranunculus biternatus Sm.	0	–	–	–	–	–	–	–	–	–
	1	100	100	0	0	0	0	0	0	0
Ranunculus repens L.†	0	–	–	–	–	–	–	–	–	–
	1	100	100	100	100	100	100	100	100	100
Rostkovia magellanica (Lam.) Hook. f.	5	100	100	100	100	100	40	40	0	0
	3	100	100	100	100	100	66	33	33	0
Trifolium repens L.†	0	–	–	–	–	–	–	–	–	–
	1	100	100	0	0	0	0	0	0	0
Uncinia meridensis Steyermark	0	–	–	–	–	–	–	–	–	–
	5	100	100	40	0	0	0	0	0	0

*Plants were removed following the previous examination.
All remaining plants were destroyed after scoring in February 1973.
†Species which are aliens on South Georgia.

TABLE I. VEGETATIVE SURVIVAL OF SOUTH GEORGIAN VASCULAR SPECIES TRANSPLANTED ON SIGNY ISLAND IN DECEMBER 1967

Species	*Number of plants tested in December 1967* *Vermiculite* / *Soil*	*Percentage apparent vegetative survival*											
		Feb. 1968	*Apr. 1968*	*Nov. 1968*	*Feb. 1969*	*Apr. 1969*	*Sep. 1969*	*Dec. 1969*	*Feb. 1970*	*Apr. 1970*	*Nov. 1970*	*Mar. 1971*	*Mar. 1972*
Acaena magellanica (Lam.) Vahl	5	100	100	0	0	0	0	0	0	0	0	0	0
	5	100	40	0	0	0	0	0	0	0	0	0	0
Acaena tenera Alboff	5	100	100	0	0	0	0	0	0	0	0	0	0
	5	100	80	0	0	0	0	0	0	0	0	0	0
Blechnum penna-marina (Poir.) Kuhn.	5	80	40	0	0	0	0	0	0	0	0	0	0
	5	40	0	0	0	0	0	0	0	0	0	0	0
Callitriche antarctica Engelm.	5	100	100	0	40	40	0	0	0	0	0	0	0
	5	100	100	0	100	100	0	0	80	80	0	0	0
Colobanthus subulatus (D'Urv.) Hook. f.	5	100	100	100	100	100	20	20	0	0	0	0	0
	5	100	100	80	80	60	20	20	20	20	0	0	0
Cystopteris fragilis (L.) Bernh.	5	60	0	0	0	0	0	0	0	0	0	0	0
	5	80	20	0	0	0	0	0	0	0	0	0	0
Festuca contracta T. Kirk	5	100	80	20	20	0	0	0	0	0	0	0	0
	5	100	100	0	0	0	0	0	0	0	0	0	0
Juncus scheuchzerioides Gaud.	5	100	80	0	0	0	0	0	0	0	0	0	0
	5	100	60	0	0	0	0	0	0	0	0	0	0
Phleum alpinum L.	5	100	80	80	60	60	40	20	0	0	0	0	0
	5	100	100	0	0	0	0	0	0	0	0	0	0
Poa flabellata (Lam.) Hook. f.	5	100	100	100	100	100	100	40	20	20	20	20	20
	5	100	100	100	100	100	60	60	0	0	0	0	0
Polystichum mohrioides (Bory) Pr.	5	100	100	0	0	0	0	0	0	0	0	0	0
	5	100	100	0	0	0	0	0	0	0	0	0	0
Ranunculus literatus Sm.	5	100	60	0	0	0	0	0	0	0	0	0	0
	5	100	60	0	0	0	0	0	0	0	0	0	0
Rostkovia magellanica (Lam.) Hook. f.	5	100	80	60	60	60	40	0	0	0	0	0	0
	5	100	80	60	60	60	20	0	0	0	0	0	0
Uncinia meridensis Steyermark	5	100	100	0	0	0	0	0	0	0	0	0	0
	4	100	75	0	0	0	0	0	0	0	0	0	0

All plants were removed and destroyed after the final examination.

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more than 30 leaves due to frost damage. *Polystichum mohrioides* was more successful at the 1968 introduction site in natural soil, one rhizome producing new fronds for two summers after dying back each winter (Table II). *Juncus scheuchzerioides* produced new growth each summer with most of the leaves slighly red at the tips. *Rostkovia magellanica* likewise survived longer after the second introduction, although only plants in soil produced an increase in leaf number in their second summer.

As might have been expected, *Deschampsia antarctica* and *Colobanthus quitensis*, both of which are native to Signy Island, withstood transplantation without apparent ill effect and each retained its South Georgian phenotype. A large amount of *C. subulatus* was transplanted but only two cushions were reasonably healthy in March 1971 after three summers on Signy Island. *Achillea millefolium* and *Ranunculus repens*, restricted naturalized aliens to South Georgia (Walton and Smith, 1973), proved capable of surviving on Signy Island and, although experiencing a reduction in leaf number each winter, they increased in overall size each year. The most widespread adventive species on South Georgia, *Poa annua*, also appeared to thrive at the more southerly station. Plants were in a healthy condition in October 1969 after wintering but reduced from over 100 leaves per plant, during the next month, to fewer than ten leaves remaining green. The plants which flourished in the next two summers resulted mainly from seed germination, which was particularly abundant during the mild 1970–71 season.

Two other successful grasses were *Poa flabellata* and *Phleum alpinum*. The latter grew better in soil than in nutrient-treated vermiculite and the plants surviving in February 1973 were in good condition. Plants of *Poa flabellata* remained healthy for the first two summers but several died during the ensuing winter so that only 50 per cent of the total transplants were alive in March 1971. In the previous introduction in 1967, most plants of this species had succumbed after two growing seasons in their new environment, possibly the result of a depletion of reserves in plants not sufficiently established.

Reproductive Success

Twelve of the South Georgian angiosperms possessed inflorescences, and two ferns, *Cystopteris fragilis* and *Polystichum mohrioides*, had sori when transplanted on Signy Island (Table III). The flowers and sori present on the 1967 transplants developed little during the summer; for example, inflorescences of *Festuca contracta* which were partly emerged from their sheaths at the time of planting, had fully emerged by April 1968 but appeared dead and did not contain full-sized seed. One plant of this grass, which was initially vegetative, later produced a single inflorescence and several further inflorescences developed on plants that were already in flower. New inflorescences also developed on *Phleum alpinum* during 1967–68 and the flowering spikes already present became more fully exserted.

All material of *Callitriche antarctica* and *Colobanthus subulatus* appeared vegetative when planted but flowers developed on both species in January 1968 while *C. subulatus* also produced flowers in the following season. One plant of *Rostkovia magellanica* which appeared moribund during the first season re-commenced growth after the winter and developed a flower in January 1969. Although the peduncle failed to elongate, the capsule grew to 6 mm. long by April. The following September the capsule had swollen to 7 mm. by 3 mm. and contained shrivelled brown seeds 0·4 mm. in length.

In terms of reproductive performance, as with vegetative survival, the second introduction of plants was more successful than the first. Although the results during the first summer were almost identical to those outlined previously, eight species became fertile after wintering on Signy Island. *Festuca contracta* and *Phleum alpinum* were already in flower when transplanted and the inflorescences of the former species elongated slightly during the first summer, while plants of *Phleum* produced several more inflorescences. *Poa annua* was also flowering

when planted and the two plants of this species produced a further 15 and 19 inflorescences, respectively, during the first season. *Colobanthus subulatus* and *C. quitensis* were initially vegetative when re-planted but both flowered in February. *Callitriche antarctica*, a plant which had flowered when introduced in 1967, remained infertile.

Colobanthus quitensis, *C. subulatus* and *Deschampsia antarctica* all produced flowers during the first three seasons after transplanting but with diminishing vigour. Both *C. quitensis* and *D. antarctica* flowered in soil and in vermiculite but inflorescences of the grass never fully emerged or expanded and pearlwort flowers failed to become elevated above the leaves or to open and expose seeds, the developmental stages usually reached by these species on South Georgia (Edwards, 1974). The number of plants of *C. subulatus* which flowered decreased each summer as the vegetative vigour of the plants declined.

Some of the species which are naturalized aliens on South Georgia (Walton and Smith, 1973) produced flowers after wintering on Signy Island, even though they were vegetative during the summer in which they were transplanted. A capitulum was observed on *Achillea millefolium* in December 1969 but the florets failed to open and in March 1970 no trace remained. In December 1969, nine flowers, two of which were partly open exposing healthy stamens, were present on the single plant of *Ranunculus repens*. At the beginning of February 1970 there were three fully open flowers, two moribund flowers and 19 flower buds but no fruits were apparent at the end of the summer. After a second winter the plant of *R. repens* produced another flower bud but again there were no floral or fruit remains in March 1971.

One plant of *Polystichum mohrioides* produced two fertile fronds during its second summer but no prothalli or sporelings were observed for any of the pteridophytes introduced.

None of the plants of *Poa flabellata* in the second introduction was flowering when re-planted but one plant of approximately 50 tillers produced an inflorescence in 1969–70 and again in 1971–72. These had become apparent in January each season and had almost fully emerged from the inflorescence sheath by March. On South Georgia, floral initiation in *P. flabellata* occurs in January of the year prior to the season in which it becomes externally visible (Smith and Walton, 1975), so that it is possible that the inflorescence formed in 1969–70 was initiated on South Georgia but this would appear most unlikely in the case of the floral shoot produced in 1971–72. In contrast to South Georgia, where *Poa annua* exists as a perennial (Walton and Smith, 1973), the species behaved as an annual on Signy Island, setting fertile seed in the first summer. During 1969–70 the plants were not sufficiently vigorous to produce inflorescences but succeeded in doing so the following more favourable summer, again producing apparently fertile seed.

The only species to flower consistently on Signy Island was the grass *Phleum alpinum* (Table III). All but two plants developed inflorescences in the first season but subsequently flowering spikes were produced by only two plants. A single plant produced one inflorescence in 1969–70 and in 1970–71 developed two flowering spikes, each 2·5 cm. in length, while a smaller spike, 1 cm. long, was produced by another plant. One of these spikes was found detached later in the season, presumably the result of activities of cape pigeons (*Daption capensis*) which have been shown to distribute native *Deschampsia antarctica* in this way (Edwards, 1972). The more fertile plant produced a single inflorescence in 1971–72 and again in 1972–73 before it was finally uprooted when the trials were terminated.

Seedling Establishment

Seed germination under the prevailing climatic conditions was observed in two of the species introduced in 1967 and in six of the species transplanted in 1968. A record of the abundance of seedlings produced and their fate was maintained whilst performing monthly scoring of the parent plants.

In December 1967, four of the *Poa flabellata* clumps which were transplanted on Signy

TABLE III. THE REPRODUCTIVE SUCCESS OF SOUTH GEORGIAN VASCULAR SPECIES TRANSPLANTED ON SIGNY ISLAND IN 1967 AND 1968

Species	*Introductions in 1967*					*Introductions in 1968*						
	Plants fertile when introduced		*New flowers or sori produced*			*Plants fertile when introduced*		*New flowers or sori produced*				
	Failed to develop further	*Developed further*	*1967–68*	*1968–69*	*1969–70*	*Failed to develop further*	*Developed further*	*1968–69*	*1969–70*	*1970–71*	*1971–72*	*1972–73*
Acaena magellanica	+	–	–	–	–	–	–	–	–	–	–	–
Achillea millefolium	*	*	*	*	*	–	–	–	+	–	–	–
Callitriche antarctica	–	–	+	–	–	–	–	–	–	–	–	–
Colobanthus quitensis	*	*	*	*	*	–	–	+	+	+	–	?
Colobanthus subulatus	–	–	+	+	–	–	–	+	+	+	–	–
Cystopteris fragilis	+	–	–	–	–	*	*	*	*	*	*	*
Deschampsia antarctica	*	*	*	*	*	–	+	+	+	+	–	?
Festuca contracta	–	+	+	–	–	–	+	+	–	–	–	–
Phleum alpinum	–	+	+	–	–	–	+	+	+	+	+	+
Poa annua	*	*	*	*	*	–	+	+	–	+	?	?
Poa flabellata	–	+	–	–	–	–	–	–	+	–	+	?
Polystichum mohrioides	+	–	–	–	–	+	–	–	+	–	–	–
Ranunculus repens	*	*	*	*	*	–	–	–	+	–	–	–
Rostkovia magellanica	+	–	–	+	–	+	–	–	–	–	–	–

+ Development of flowers or sori.
– Failure of flowers or sori to develop.
* Species not tested.
? Plant previously removed; uncertainty exists as to whether flowers would have been formed.
All plants were removed or destroyed at the end of the experiments in 1973. Species listed in Tables I and II but not included above existed in a vegetative state only.

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Island each bore a single inflorescence. Samples taken in March 1968 showed that soft white seeds were present and, although these did not appear mature, the inflorescences were removed. However, the following season several seedlings developed around the bases of the transplants, notably those which had been flowering. The seedlings remained prostrate and did not approach an erect growth form until the leaves were 12 cm. in length. By the end of the summer most of the seedlings which had germinated in soil and in vermiculite in January had reached the three-leaf stage but some were larger than this and consisted of two or three tillers. One plant germinated in November 1968 in soil sheltered by the black polythene pots containing vermiculite and, before the onset of winter, it had developed 62 leaves and approximately a dozen tillers. This plant failed to survive for a second season, however, in common with most of the other *P. flabellata* seedlings which had a low overwintering success rate (Table IV).

TABLE IV. THE SUCCESS OF SELF-ESTABLISHED *Poa flabellata* SEEDLINGS DURING ONE YEAR ON SIGNY ISLAND

Date	*In soil*				*In vermiculite*			
	Number of seedlings		*Mean number of green leaves*		*Number of seedlings*		*Mean number of green leaves*	
13 January 1969	20		1·0		41		1·7	
14 February 1969	n.r.		n.r.		58		2·6	
11 April 1969	78		3·0		60		3·6	
			Winter					
23 September 1969	5		1·7		27		2·5	
17 November 1969	1		1·0		7		2·8	
3 January 1970	1	*10*	3·0	*1·0*	2		8·0	
4 February 1970	1	*47*	4·0	*1·5*	2	*11*	21·0	*1·2*
13 March 1970	0		0·0		2		31·0	

n.r. Not recorded.
Italicized values refer to newly germinated seedlings.

Of the 140 self-established seedlings present in March 1969 only three remained alive a year later. Seedlings of *P. flabellata* again developed in 1969–70 but these were fewer in number and none survived the winter. It is thought that all of these seedlings arose from the seed formed in the inflorescences which were on the plants transported from South Georgia in 1967, since there was no indication that the inflorescences produced on Signy Island developed fertile seed.

Of the other species introduced in 1967, seed germination was observed only in *Callitriche antarctica*. In both 1968–69 and 1969–70, seedlings developed amongst most transplants of this species, although in greatest abundance in those in soil. It is not certain whether these were the product of seed formed on South Georgia or from the flowers developed on Signy Island during the first summer, but the former is strongly suspected from the relative abundance of the flowers and seedlings present and from their distribution.

Seed germination under the conditions prevailing on Signy Island was again observed amongst material introduced in December 1968. Seedlings of *Acaena* spp. were recorded in February 1970 amongst transplants of *Festuca contracta*, *Phleum alpinum*, *Acaena tenera* and *A. magellanica*. It was thought that five of the seven seedlings were *A. tenera* but none

developed beyond the one-leaf stage and all died during the winter. Seeds of *Deschampsia antarctica* and the two species of *Colobanthus* germinated during January 1970 in both soil and vermiculite, surrounding the introduced plants of these species, but again it seems unlikely that the seedlings survived the winter (personal communication from R. Webb).

Seedlings of *Poa annua* appeared amongst several of the transplanted species during 1969–70 and three transplants of *C. quitensis* and one of *D. antarctica* became partly overgrown one season as a result. Approximately 24 other seedlings of *P. annua* became established in native soil *c.* 5 m. from the study site in March 1970 but none of these seedlings appeared to survive the 1970 winter. Fresh germination occurred during the mild 1970–71 summer when some of the seedlings developed sufficiently to produce inflorescences by the end of the season (Table III). In view of its reproductive success and its ability to colonize rapidly open communities, at least on South Georgia (Greene, 1964), all plants of *P. annua* in and around the transplant sites were collected and burnt in 1971 and 1972 (personal communication from T. N. Hooker) to safeguard the native communities.

Discussion

It would appear that the transplanting of 23 South Georgian vascular species to Signy Island has been the most successful introduction of plants into the Antarctic to date. Fourteen species have proved capable of surviving for at least 1 year in native soil while several of these have been able to produce flowers under the climatic conditions prevailing on Signy Island. In some cases the initiation of floral primordia seems certain to have occurred in the Antarctic. Seedlings of eight species became naturally established on Signy Island during the summer months, but without exception their overwintering mortality was high. However, a few seedlings of *Poa annua* and *P. flabellata* survived for $1\frac{1}{2}$ years and these accomplished rapid growth during each short austral summer, inflorescences being produced by some of the more advanced plants of *Poa annua*.

The difference in performance of the species in soil and in vermiculite was not as pronounced as in species from the Falkland Islands (Edwards and Greene, 1973); again this suggests that the native soils in the vicinity of the flowering plant community at Factory Cove, Signy Island, are not lacking in nutrients. The more successful second introduction of plants clearly indicates the extreme importance of the degree of shelter afforded by the transplant site in determining the survival of the plants. Although the 1967 sites were set up as close as possible to one of the native angiosperm communities, observations by V. W. Spaull (personal communication) during the winter of 1968 suggested that variations in local topography caused the sites to be rather exposed and wind-swept and not representative of conditions experienced by the native vascular flora on Signy Island. In 1968 an attempt was made to place the new transplant sites in a more sheltered situation and observations during the 1969 winter suggest that this was achieved, the soil site being so deeply covered with snow for most of the winter that it did not become snow-free until mid-December 1969, 2 months after the other transplant sites had become exposed and *c.* 4 weeks after the native grass sward had cleared. The importance of such snow cover during the early spring was demonstrated at the vermiculite site established in 1968 where several species, which appeared in reasonably healthy condition at the beginning of November 1969, deteriorated markedly during the 6 weeks following the removal of the protective snow layer.

As has been pointed out by Edwards and Greene (1973), there are many factors besides that of a more severe alien climate militating against the success of plants introduced in the manner of the present experiment. Not the least of these is the undesirable check to growth imposed on adult plants by their removal, transport and re-planting in the middle of the spring period of physiological activity, and the problems of their subsequent re-establishment. Not every individual transplant would be expected to survive under such conditions and in the

present experiment the performance of *Deschampsia antarctica* and *Colobanthus quitensis*, which occur naturally on Signy Island, shows this to be true. Nevertheless, successful re-establishment at the 1968 soil site must have been achieved by several of the introduced species in view of the fact that even woody perennials of the genus *Acaena* maintained themselves for several years at the site. The two groups of plants from South Georgia which proved most capable of vegetative survival in the more severe climate of the maritime Antarctic were the graminoid species native to that island and some of the persistent aliens introduced by the whalers.

The present introduction of plants also demonstrated the capabilities of seed of certain species to germinate under maritime Antarctic conditions and the ability of the resultant seedlings to survive. It is suggested that this may be of importance since, although much of the maritime Antarctic is permanent snow or bare rock, seeds derived from southern continents or sub-Antarctic islands, if transported on the feet or feathers of birds (Falla, 1960), would most likely arrive at fairly rich organic soils near to nest sites, where seedling establishment might be feasible if germination were possible. The most likely avian species responsible would appear to be the cape pigeon (*Daption capensis*) and snow petrel (*Pagadroma nivea*) which nest on ledges and in clefts above many grass swards on Signy Island, but Wilson's petrels (*Oceanites oceanites*) and dove prions (*Pachyptila desolata*) also nest in burrows at flowering plant sites. Larger species, such as the southern black-backed gull (*Larus dominicanus*), may also be involved since this is implicated in distributing *Deschampsia antarctica* around the Argentine Islands (Corner, 1971).

Because the overwintering capabilities of young plants of all species was low, it is suggested that, although many of the South Georgian species were able to flower and produce seedlings, the chances of any establishment being other than transient are slight. Apart from the species already present on the South Orkney Islands, *Deschampsia antarctica* and *Colobanthus quitensis*, the flowering plants most likely to complete their life cycle and also to survive vegetatively were *Poa annua* and *P. flabellata*. Seedling growth in these two species was comparatively rapid and a few individual seedlings were able to re-commence growth successfully after wintering. They were also able to spread slightly into native communities, the most widely dispersed being a seedling of *Poa flabellata* which was growing *c.* 250 m. from the site of introduction on the slope behind the research station at Factory Cove in 1972–73 (personal communication from T. N. Hooker). In this context, it is interesting to note that the only alien species to have been introduced accidentally by Man into the Antarctic in recent years are the two species of meadow grass, *Poa annua* and *P. pratensis* (Longton, 1966). The transplant trials described above suggest that any future colonization of Antarctic regions by flowering plants would probably be by fast-growing species tolerant of frequent frosts and periodic light snow cover during the short growing season, such as *Poa* spp., whose widespread distribution in Tierra del Fuego, the Falkland Islands and South Georgia could result in time in their natural dispersal to sites on the Antarctic Peninsula or offlying islands.

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