red to a cold room or refrigerator at a temperature of 38°F (3°C) or below (but above freezing). The bags should be turned and shaken at least once a week to maintain an even temperature effect and to prevent settling, with a consequent reduction in aeration.

If this procedure is adopted it will be found that chilling times are far less variable than might be anticipated from the available literature and any chilling time for a particular seed lot can be assessed accurately and with confidence.

CLONAL VARIATION IN ROOTING OF SOFTWOOD CUTTINGS OF WOODY PERENNIALS OCCURRING NATURALLY ON DERELICT LAND

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Abstract. The Institute is investigating many aspects of inter- and intra-specific variation in woody plants, including that enabling individuals to grow successfully on derelict and reclaimed land. Clonal stocks are being assembled by rooting cuttings of a wide range of species whose subsequent performances are compared with those of unselected stock in glasshouse experiments and field trials on difficult sites throughout Britain. All four criteria (i) proportion of cuttings which root, (ii) time taken to root, (iii) time of year when rooting is maximal and (iv) survival of rooted plants after potting, have been found to vary considerably both between species and between clones within a species — a feature that influences their possible commercial use. Average rooting of elder: *Sambucus nigra* L. throughout the season exceeded 90% for all clones tested whereas in goat willow: *Salix caprea* L. rooting varied with clone from only 19% to 83% and in silver birch: *Betula pendula* Roth. from 9% to 68%. In silver birch all clones rooted best in July but whereas one clone never dropped below 45% rooting, another gave nil rooting in June.

REVIEW OF LITERATURE

Trees and shrubs propagated commercially are, because they have not been intensively selected, more variable than most agricultural and horticultural crops (11). Excepting a few ornamental cultivars, mostly of exotic origin, there is no equivalent of the true-breeding cultivars of wheat or tomato. Seeds from a single birch tree are likely to produce a varied batch of seedlings, many distinctly different from the mother plant (4). This variation poses considerable problems for tree research, treatment effects often being ill defined unless many replicates are used. Variation can also be problematic for the practising forester and aboriculturist because only a proportion of his

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seedlings will possess the desired qualities to enable them to succeed. This problem is particularly acute on difficult sites such as restored opencast (strip mine) land, wastes from industrial processes, motorway embankments (3,6,8), sites characterized by poor nutrition, inadequate soil aeration, unsatisfactory soil moisture regimes, physical instability and toxicities from several causes. However, despite these difficulties, given time and an adequate supply of seed, colonization occurs naturally with goat willow, sallow (*Salix cinerea* var. *oleifolia* Macreight, Syn.: *S. atrocinerea* Brot.) elder, silver birch, hairy birch (*Betula pubescens* J. F. Ehrh.), being among the first woody plants to establish themselves. Although few quantitative assessments have been made it seems that trees able to establish themselves represent a minute fraction of the total available seed — they could possibly have features fitting them for establishment and survival in adverse conditions (1,5,12). This hypothesis is being tested by clonal propagation and subsequent testing in the field of individual plants collected from many different derelict sites. If some have advantages over the 'unselected' plants currently being used in reclamation work it might be worthwhile to consider their commercial propagation.

Cuttings taken from neighbouring trees of the same species and age often differ greatly in their abilities to root (2,7,9,), differences ascribable to the physiological condition of the cuttings, notably their endogenous auxin concentrations (7,13,15). Clones with large concentrations of endogenous auxin are more likely to root than those with smaller amounts which, as a result, might be expected to be more responsive to exogenous applications of auxins. Irrespective of clone the ability to root fluctuates seasonally. Rooting of *Populus nigra* L. softwood cuttings under mist is directly related to amounts of endogenous auxin (13). The auxin appears to promote rooting by stimulating hydrolytic enzyme activity thus mobilizing starch into soluble sugars which are needed as an energy source for the meristematic activity leading to root production. Rooting is best in spring and late summer when ample stored starch is available, and least successful in mid-season when active shoot growth consumes all available energy supplies. Similar seasonal fluctuations, also related to auxins, were found in sallow. In this instance Vieitez and Pena (15) suggested that the balance between auxins and inhibitory compounds controlled the ability to form roots so determining the seasonal rooting responses.

This report records some of the problems encountered when rooting selected 'tolerant' clones of woody perennials from sites of dereliction.

MATERIALS AND METHODS

Stem cuttings from young containerised plants, collected from spoil tips mostly in Scotland, were taken at intervals of about two weeks from early spring until September. They were dipped in distilled water and then in a commercial rooting powder containing 0.1% 1-napthylacetic acid (NAA) and 2% Captan fungicide. Thereafter cuttings were inserted to a depth of 50 mm in coarse silica sand in plastic trays buried to their rims in a raised shingle bed. Bed temperatures in an unshaded glasshouse were maintained at 24°C ± 3°C. At intervals cuttings, kept moist beneath a misting unit controlled by an electronic leaf, were examined, the "minimum" period to rooting being the period from insertion to the development of vigorous branched roots. At this time rooted cuttings were transferred into 3" plastic pots with sterilized compost consisting of 2 parts coarse sand; 2 parts moss peat; 1 part loam; 6.45 kg of slow release fertilizer (Osmocote 18:11:10) and 3.89 kg John Innes base fertilizer were added to each cubic metre. Potted cuttings were placed on a "weaner" bench which was misted less frequently than during propagation. One week later they were put in an unheated glasshouse where they remained, being potted as required in the above mixture until they were sufficiently established to be put outside in their final 12.5 cm (5") containers.

Many species were rooted in the period 1973-1977 (Table 1). Some rooted relatively easily whereas others — hawthorn (*Crataegus monogyna* Jacq.), mountain ash (*Sorbus aucuparia* L.), and common (European) ash (*Fraxinus excelsior* L.) were generally more difficult. Where attempts were made with only one or two clones, success or failure may have been due to chance selections of good or bad "rooters"; the outcome should not be considered as providing a guide to the response of the species in question.

Among species characteristically colonizing derelict land — goat willow (SC), sallow (SA), hairy birch (BPu), silver birch (BPe), elder (SN) — it was found that rooting ability differed (Table 2). Elder was consistently easy to root, with an average of over 90% of cuttings of all six clones tested rooting whereas percentages varied considerably in species of willow and birch. Only 19% of goat willow clone SC 42 rooted compared with 83% of clone SC 50. Nine percent of silver birch clone BPe 48 rooted compared with 68% of clone BPe 73. Sallow clone SA 90 roots easily as would be expected of plants with a known ability to layer, a character which could be of value in stabilizing mobile reclaimed soils.

Although these average figures give an indication of the overall rooting capability of different species and clones they disguise appreciable seasonal fluctuations (Figure 1.). Birch

Table 1. Tree and shrub species found on sites of dereliction that have been rooted as softwood cuttings.

Species	Comments
Broadleaved plants	
Acer pseudoplatanus	Difficult, few cuttings produced on stock plants.
Alnus glutinosa and *A. incana*	Generally fairly easy but some clones difficult.
Betula pendula	Generally fairly easy from young stock plants but some clones difficult.
Betula pubescens	Markedly easier than *B. pendula* in the clones tried.
Crataegus monogyna	Considerable clonal variation. Vigorous material from young plants required.
Fagus sylvatica	Very difficult.
Fraxinus excelsior	Difficult, few cuttings produced on stock plants.
Malus sylvestris	Only one clone tested, easy.
Prunus avium	Only one clone tested, easy.
Quercus robur	Considerable clonal variation. Growth of rooted cuttings very slow.
Salix caprea	Considerable clonal variation but most are reasonably easy and some very.
Salix atrocinerea	Clones tested easier than *S. caprea*.
Sambucus nigra	Very easy, even from old plants.
Sorbus aucuparia	Fairly difficult, very few cuttings produced on stock plants.
Ulmus glabra	Considerable clonal variation. Many cuttings die after rooting.
Conifers	
Juniperus communis	Easy but slow.
Larix decidua	Very difficult.
Pinus sylvestris	Considerable clonal variation, rooting very slow.

clones rooted maximally at the end of July, with clones BPe 28, BPu 47 and BPu 86 reaching 100%. Whereas the rooting of the latter two hairy birch clones never dropped below 45% and 30% respectively, silver birch clone 28 failed to root in late June and the percentage for clone 48 of the same species never exceeded 20%. In addition to the July peak, earlier but smaller peaks were detected when rooting clone BPe 28 and BPu 86, this secondary peak occurring in early May and early June respectively.

The same pattern of rooting was found in goat willow with peaks in April/May and again in July. Clones SC 29 and SC 51 rooted more readily than clone SC 42.

Cutting production and their subsequent rooting represent the first stages of plant production. Subsequent losses can be severe. In the period from rooting to being put outside (wean-

Table 2. The rooting percentages of softwood cuttings taken from selected clones of 5 species of woody perennials found growing on industrial waste.

Species and Clone	No. of cuttings put into propagation bed	No. of cuttings rooted	Percent rooting
Salix caprea			
SC 29	220	159	72
SC 42	163	31	19
SC 50	193	160	83
SC 51	229	154	67
SC 76	242	145	60
Salix atrocinerea			
SA 12	559	384	69
SA 90	54	49	91
Sambucus nigra			
SN 20	147	141	96
SN 40	79	71	90
SN 49	184	147	80
SN 63	142	140	99
SN 77	145	137	94
SN 89	19	19	100
Betula pendula			
BPe 28	122	70	57
BPe 34	655	122	19
BPe 48	177	16	9
BPe 64	199	81	68
BPe 73	119	81	68
BPe 92	38	6	16
Betula pubescens			
BPu 47	189	134	71
BPu 86	87	48	55

ing) losses tended to be greatest in clones which were difficult to root, e.g. clones SA 12, SC 42, SN 49, BPe 34, BPe 48 (Table 3). There were, however, exceptions, e.g. clones BPu 86 and BPe 92 with high rates of survival although difficult to root and clones SC 51 and BPe 64 where the situation was reversed. Other observations suggested that survival during weaning paralleled differences in rates of rooting with quick rooting clones having high rates of survival (Table 4).

Like rooting percentages, rates of rooting differed seasonally (Figure 2), with fluctuations greater in birch than in willow. In both species early season cuttings rooted quickly regardless of clone, thereafter the rates tended to be slower. However in birch clones BPe 28 and BPu 47 of hairy birch with large rooting percentages rooted rapidly, silver birch clone 48 with a small rooting percentage, rooted slowly. Goat willow clone SC 29 rooting percentages were subject to major seasonal changes, but rates of rooting remained more or less constant. Although

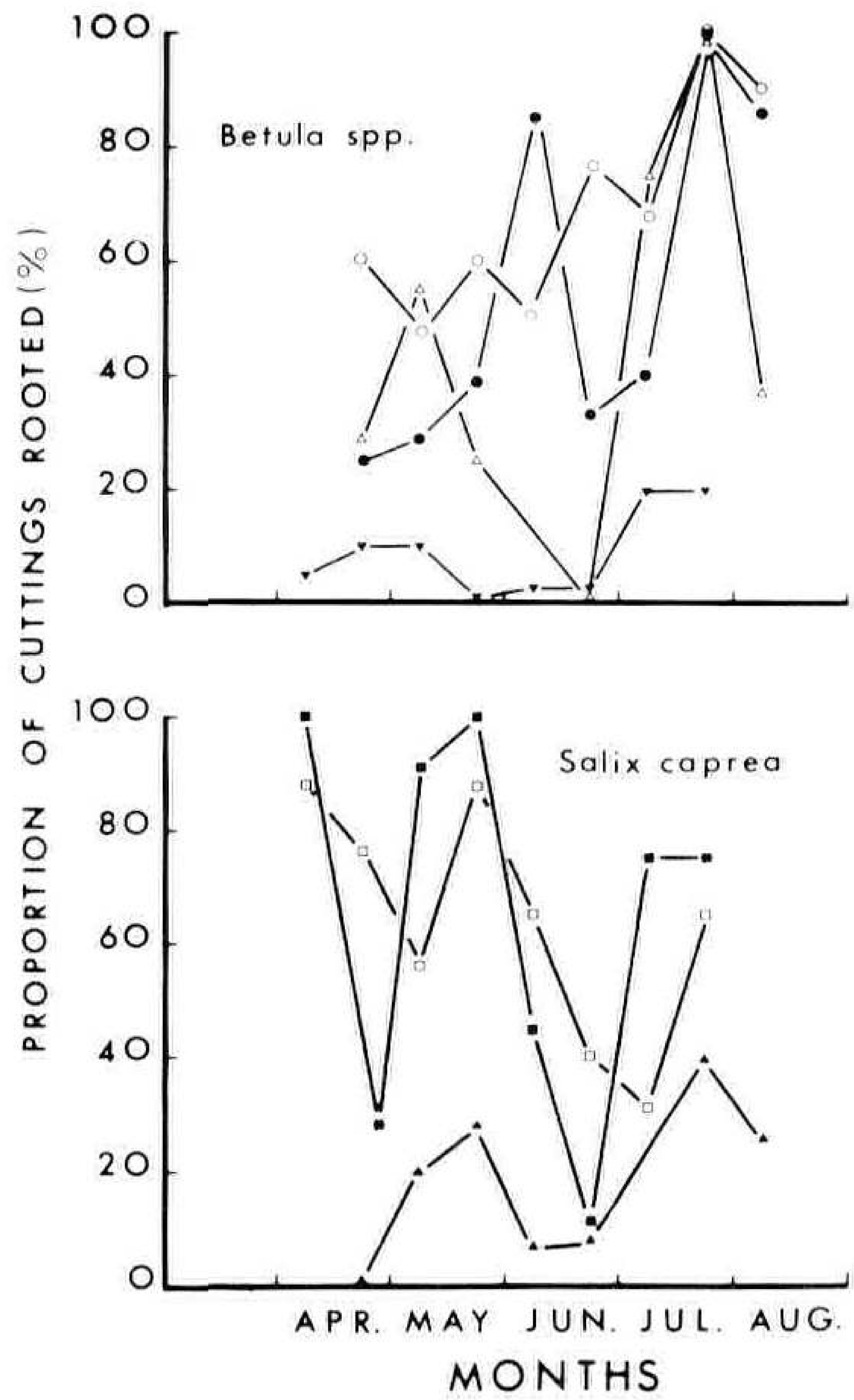

Figure 1. Rooting of cuttings taken at different times of the growing season from selected clones of birch (*Betula pubescens* and *B. pendula*) ○ — ○ BPu 47; ● — ● BPu 86; — BPe 28; ▼ — ▼ BPe 48; and goat willow: (*Salix caprea*) □ — □ SC 29; ▲ — ▲ SC 42; ■ — ■ SC 51.

few cuttings of SC 42 rooted, their rates of rooting were no slower than those of easy to root clone SC 51.

DISCUSSION

Programmes aimed at developing cultivars of woody plants for amenity horticulture and arboriculture, are likely to become involved with the selection of individuals with preferred characteristics, be they of form, foliage colour, flowering habit or, as in the present study, tolerance of infertile and inhospitable sites. So that the suitability of the chosen individuals may be exploited experimentally and, thereafter, commercially, they must be amenable to vegetative propagation — hence the present interest in inherent differences of rooting response. If a clone cannot be rooted it may be difficult or impossible to take advantage of other characteristics.

Using young stock plants, softwood cuttings of a wide range of species have been rooted including some previously regarded as difficult, e.g. sycamore (*Acer pseudoplatanus* L.), common (European) alder (*Alnus incana* (L.) Moench.), European larch (*Larix decidua* Mill), Scots pine (*Pinus sylvestris* L). However, interest was subsequently focussed on producing

Table 3. Rooting Percentages and Survival During Weaning of Softwood Cuttings Taken from Selected Clones of 5 Species of Woody Perennials Found Growing on Industrial Waste.

Species and Clone	No of cuttings put into propagation	No. and percent of cuttings rooted		No. and percent of plants surviving at the end of the period of weaning	
Salix caprea			%		%
SC 29	163	104	(64)	89	(86)
SC 42	133	24	(18)	12	(50)
SC 50	14	10	(71)	8	(80)
SC 51	87	57	(65)	37	(65)
SC 76	242	145	(60)	119	(82)
Salix atrocinerea					
SA 12	446	281	(63)	207	(74)
SA 90	54	49	(91)	47	(96)
Sambucus nigra					
SN 20	60	58	(97)	46	(79)
SN 40	43	39	(91)	38	(97)
SN 49	107	83	(77)	74	(89)
SN 63	79	77	(97)	72	(93)
SN 77	114	108	(95)	100	(92)
SN 89	19	19	(100)	15	(79)
Betula pendula					
BPe 28	58	27	(46)	22	(81)
BPe 34	337	61	(18)	35	(57)
BPe 48	177	16	(9)	3	(19)
BPe 64	129	58	(45)	22	(38)
BPe 73	36	13	(36)	4	(31)
BPe 92	38	6	(16)	5	(83)
Betula pubescens					
BPu47	117	81	(69)	49	(60)
BPu86	87	48	(55)	25	(52)

stocks of a wide range of "tolerant" clones of species which occur commonly as colonizers of bare ground, including coal and other spoil tips. Elder, a much underrated woody perennial for use in difficult situations (10), including those subject to vandalism has, as expected, proved easy to root in the period from April to August. Willows and birches have proved less amenable, rates and numbers of rooting cuttings differing seasonally and from clone to clone. In general, the present results confirm that there are spring and late summer peaks in rooting capacity (13,15). However, the timing of the peaks and troughs differed from clone to clone, possibly reflecting differences in the physiological condition of the respective mother plants, although they were handled similarly.

Regardless of the mechanisms involved, undoubtedly related to endogenous auxin levels, it is essential to know the optimal time to obtain rootable cuttings. Thus clone BPu 86 might have been rejected if only the batch of cuttings inserted in late June had been considered because at this time none rooted. One

Table 4. Periods To Root And Survival During Weaning Of Softwood Cuttings Taken From Selected Clones Of 5 Species Of Woody Perennials Found Growing On Industrial Waste.

Species and Clone		Mean period to rooting (days)	Percent survival of potted plants
Salix caprea			
SC	29	18	86
SC	42	25	48
SC	50	23	75
SC	51	32	65
SC	76	21	82
Salix atrocinerea			
SA	12	20	74
SA	90	17	96
Sambucus nigra			
SN	20	20	79
SN	40	19	96
SN	49	18	98
SN	63	16	94
SN	77	16	93
SN	89	20	79
Betula pendula			
BPe	28	34	83
BPe	34	45	58
BPe	48	48	23
BPe	64	47	38
BPe	73	47	31
BPe	92	31	83
Betula pubescens			
BPu	47	29	60
BPu	86	29	51

month later, however, cuttings from the same mother plants gave 100% success. But, of course, periods of optimum rooting may differ from year to year as a result of climatic fluctuation. In the authors' experience these differences are not likely to seriously affect propagation programmes and may be minimized by varying hormone treatments, bed temperatures, and light regimes. Attempts could also be made to root single node sections in aseptic conditions, a technique which has proved successful with a range of birch clones (14). Aseptic culture is especially suited to investigating the precise conditions required for rooting in differing clones since environmental factors can be changed individually or in combination, a matter not easily achieved in standard propagating houses.

The direct relationship between the time for cuttings to root and their subsequent survival during weaning is of considerable importance in maximizing plant output, possibly reflecting their nutrient status. Applying nutrients in mist has favoured rooting of some species but not of others (16). Partly to minimize the growth of algae, mosses and liverworts on propagation beds, the authors favour foliar feeding of potted cuttings using a

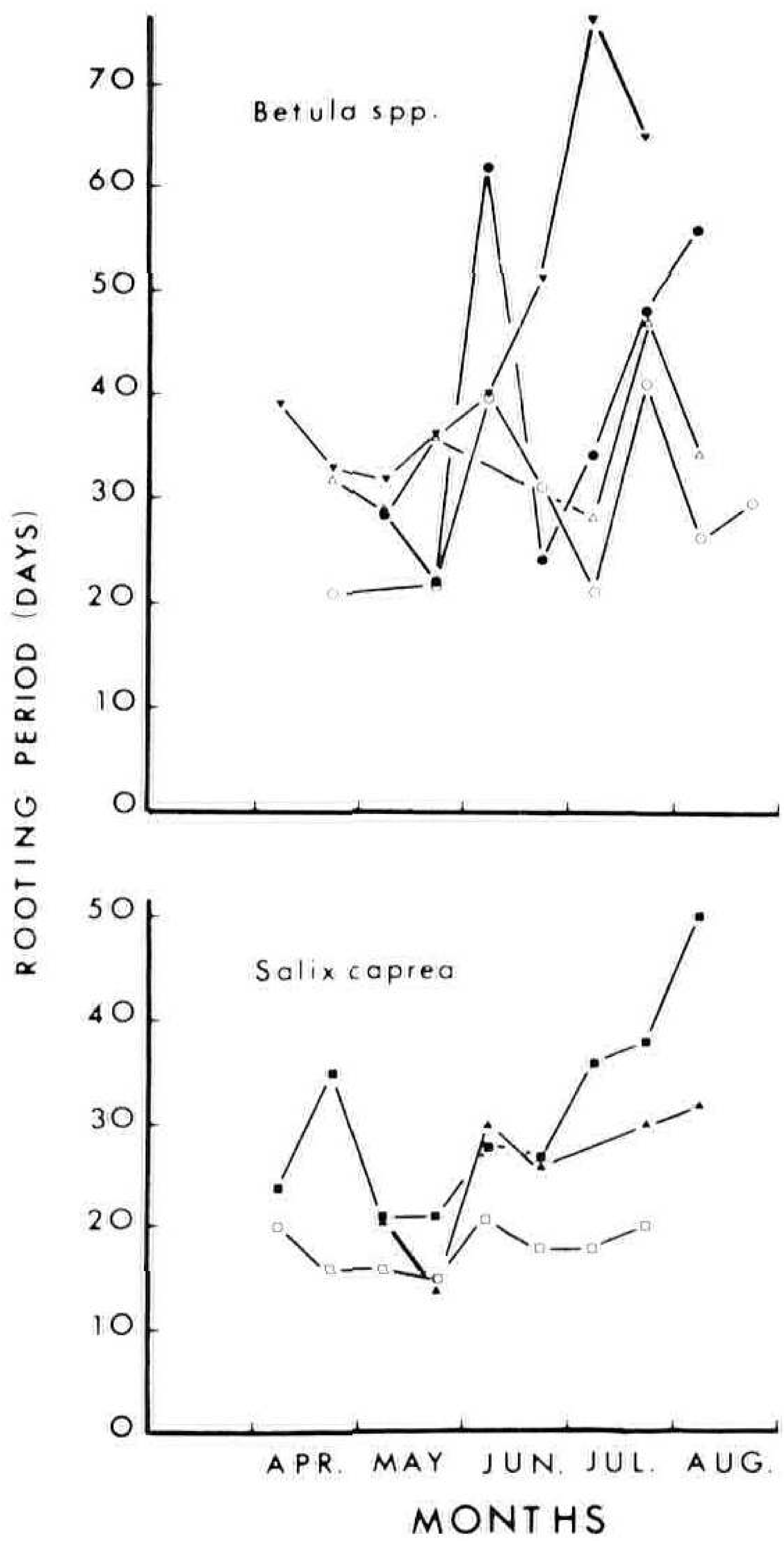

Figure 2. Changes in the minimum period for root development when cuttings were taken at different times of the growing season from birch (*Betula pubescens* and B. *pendula*) ○ — ○ BPu 47; ● — ● BPu 86; — BPe 28; ▼ — ▼ BPe 48, and goat willow: (*Salix caprea*) □ — □ SC 29; ▲ — ▲ SC 42; ■ — ■ SC 51.

pressure sprayer until signs of vigorous new shoot growth are apparent.

Finally, in a paper dealing with the rooting of cuttings it must be emphasized that their quality reflects the management of mother plants which should be kept well fed, free of pests and pathogens, and systematically pruned to encourage the production of numerous strong young shoots.

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THE WORK ON ASSORTMENTS AT THE TREE RESEARCH STATION, BOSKOOP, HOLLAND

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At the Research Station for Arboriculture at Boskoop is a trial ground where research work is being undertaken regularly on nursery stock, for example, collections and trials with new cultivars. Quite a lot of shrubs are brought together here to examine their use in gardens and plantations.

The judging committee of the Royal Boskoop Growers Association criticises plants at shows (for example Flora Nova). These plants may be awarded a prize of a gold or a silver