of the redevelopment policy (Bisgrove and Hadley, 2002).

CONCLUSION

In a changing climate where the range of trees and shrubs cultivated will alter, the nursery trade could look to more tender plants and familiar "tried and tested" plants to fulfil the demand by the pubic and private sector for trees and shrubs.

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Use of Long Cuttings to Reduce Propagation Time of Rose and Fruit Rootstocks and Street Trees©

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INTRODUCTION

Difficult-to-root species and cultivars need very precise coordination of plant and culture parameters (Spethmann 1998; 2000). More than 50 factors or conditions that can be altered need to be ranked. The most important ones are effective age stage of the stock plant, sticking date, humidification method, and method of overwintering.

Factors such as substrate mixture or growth hormone have been over estimated. For example, rhododendrons have been rooted in peat but also in pure gravel; difficult-to-root oaks have been rooted in gravel, peat, peat mixtures, or perlite. The success of specific hormone concentrations or formulations varies from year to year. Many species root without any hormone, most other species could be rooted with only one or two concentrations of IBA. For many years we have used only 0.5% IBA and a 3 peat : 1 sand mix (v/v) as a substrate for all species.

The importance of cutting length has very rarely been investigated. The range is mostly 10 to 30 cm, long cuttings of 1 m and more are only associated with *Salix* and *Populus*. Our investigations show that long cuttings (60 to 250 cm) of difficult-to-root species can be rooted successfully. As a result the production time of standard rose rootstocks, fruit trees, and street trees could be shortened and costs saved.

ROSE ROOTSTOCKS

Conventional production of standard roses takes 5 years (Fig. 1). Seedlings of *Rosa* 'Pfänders Canina' are lifted at the end of the 1st year, plants with grade 8- to 12-mm root collar diameter are planted up the following year. In the 2nd and 3rd year, the stems are formed and in the autumn of the 3rd year the stems are lifted. After planting in March of the 4th year, budding of two or three buds usually takes place in July or August. At the end of the 5th year, plants are ready for sale.

The production time can be reduced to 2.5 years (Fig. 1) by the development of a cuttings propagation method using long shoots. The method could also be used for cultivation of tree roses in containers.

Production of Rose Rootstocks by Long Cuttings. Three-years-old seedlings of *R.* 'Pfänders Canina' form several long shoots of 150 to 250 cm length. Our research shows these can be cut in July and struck in 3-L containers after application of 0.5% IBA. The long shoots can be stabilized by chrysanthemum mesh. The substrate we used was a 3 peat : 1 sand (v/v), which had a pH of 4.5. It was fertilised with 2 kg Osmocote 3M per m^3.

Figure 1. Length of production time in tree roses: outdoor production.

	Conventional 5 years	**Cuttings 2.5 years**	**Cuttings 1.5 years**
Mar. **2001**	**Sowing of 'Pfänders'**		
Jul.		**Sticking of long shoots**	**Sticking of long shoots**
Aug.		Planting out	Planting out/budding
	🕷 Y 🚜	🕷 Y	🕷 Y or
Nov.	1+0 lifting		Winter protection
Jan. **2002**			Grafting
Mar.	Planting		
	🕷 Y 🚜	🕷 Y 🚜	🕷 Y 🚜
Jul./Aug	Removal of add'l shoots	Budding	
Oct.		(winter protection)	Lifting
Nov.			**Ready for sale**
Mar. **2003**	🕷 Y 🚜	🕷 Y 🚜	
	Removal of add'l shoots		
Oct.		Lifting	
Nov.	Lifting of stems	**Ready for sale**	
March **2004**	Planting		
	🕷 Y 🚜		
Jul./Aug.	Budding		
Nov.	Winter protection		
2005	🕷 Y 🚜		
Oct.	Lifting/**ready for sale**		

🕷 = pesticides, Y = fertilization, 🚜 = herbicides

The long cuttings were placed in a plastic greenhouse humidified with a high-pressure fog system and by the end of August we recorded 80% to 100% rooted. The rooted stems can be directly planted in the field if sheltered by shade cloth for some weeks, or potted in 5-L containers and grown on either under protection or outside.

Stems are budded in the middle of the following year and at the end of the 3rd year, plants are ready for sale. Total production time is therefore 2.5 years. Whip grafting in the greenhouse in winter was also possible which reduces production time even further, to 18 months.

The quality of the stems is excellent. They are straighter than seedling stems, without a big root base and with only a few new shoots out of the root base. There is little danger of cracking during bending down for winter protection. This procedure is necessary in Central Europe because of the lack of cold tolerance of the budding area.

The method has economical and ecological advantages (Spethmann and Huhn, 2001). Reducing production time reduces production costs while fertiliser, irrigation, and pesticide and herbicide treatments are only needed for 2 years. If the method is used for container standard rose production it enables flowering plants to be offered in summer.

STREET TREES

We have been developing a system for producing street trees by long cuttings since 2000. In July 2000 cuttings of *Quercus robur, Tilia cordata, Ulmus* 'Regal'*, Carpinus betulus,* and *Acer platanoides* with lengths between 61 to 103 cm, were set in a ground bed under the same conditions as mentioned above for standard rose rootstocks. The stock plant ages ranged from 9 to 30 years. The rooting percentages (i.e., rooted and survived the winter until transplanted in spring in the field) achieved were in the range of 74% to 97%, which is high for these trees (Table 1). During the winter the cuttings remained in the rooting bed in an unheated plastic greenhouse.

Table 1. Stock plant age, setting date and rooting percentage of long cuttings 2000 (PR = pruned).

Species	Sock plant age	Setting date	Cuttings set (no.)	Rooting (%)
Acer platanoides	ca. 30	6 Jun. 2000	61	97
Carpinus betulus	ca. 25	15 Jun. 2000	80	85
Pyrus 'Williams Bon Chrétien'	37	12 Jul. 2000	53	57
Quercus robur (early)	9 PR	6 Jun. 2000	65	82
Quercus robur (late)	9 PR	12 Jul. 2000	55	74
Tilia cordata	ca. 30	15 Jun. 2000	93	83
Ulmus 'Regal'	9 PR	15 Jul. 2000	39	74

Table 2. Mean cutting length, height and stem diameter of long cuttings set in 2000.

Species	Mean cutting length (cm)	Height (cm)			Stem Ø (mm) [circumference (cm)]		
		Oct. 01	Oct. 02	Aug. 04	Oct. 01	Oct. 02	Aug.04
Acer platanoides	79	173	338	527	13.2	25.9 (8)	38.8 (12)
Quercus robur (June)	90	137	217		10.5	19 (6)	
Quercus robur (July)	103	113	213		9.5	16.6 (5)	
Tilia cordata (long)	62	85	189			15.9 (5)	
Tilia cordata (short)	21	45	181			15.7 (5)	
Ulmus 'Regal'	61	156	370	596	6.9	32.4 (10)	50.4 (16)

Table 3. Length and rooting percentage of short- and long cuttings of *Acer pseudoplatanus* and *Corylus avellana* 'Contorta' set in 2002 (Fass and Guenther, 2003)

Species	Length class	Mean length (cm)	Range (cm)	Rooting (%)	Cuttings set (no.)
Acer pseudoplatanus	Short	18.8	9-34	82	50
	Long	83.7	66-106	92	50
Corylus avellana 'Contorta'	Short	28.5	10-40	48	25
	Long	56.1	47-70	66	25

Losses after transplanting were low. The shoot growth in the following 2 years until autumn 2002 was very strong in all species. Mean height of *Ulmus* was 3.70 m and *Acer* 3.38 m, of *Quercus* 2.15 m. After a further transplantation in Spring 2003 growth was retarded in 2003; in 2004 strong growth continued, in August 2004 mean height was 5.96 m in *Ulmus*, 5.28 m in *Acer*. Stem diameters were 50.4 mm and 38.8 mm respectively (Table 2) [Spethmann 2003(a); 2003(b)].

We have repeated these propagation trials over several seasons with the same success and extended the work to a wider range of trees including *Acer pseudoplatanus* and some smaller woody plants such as *Corylus avellana* 'Contorta' (Table 3). In both cases the root quality was better when long cuttings were used compared with traditional material (Fig. 2 and 3).

FRUIT TREE ROOTSTOCKS

Most apple, quince/pear, and sweet cherry rootstocks were traditionally propagated by the old extensive method of mound layering. Newly developed dwarfing sweet cherry rootstocks such as 'Gisela' or 'Weiroot', and the dwarfing *Pyrus* Pyrodwarf® semi-dwarf pear rootstock have been propagated only by expensive in-vitro methods. Cuttings propagation is said to be difficult.

Cuttings propagation with conventional small cuttings of *Prunus* 'Gisela' and some *Malus* cultivars was developed some years ago. A problem was that the root

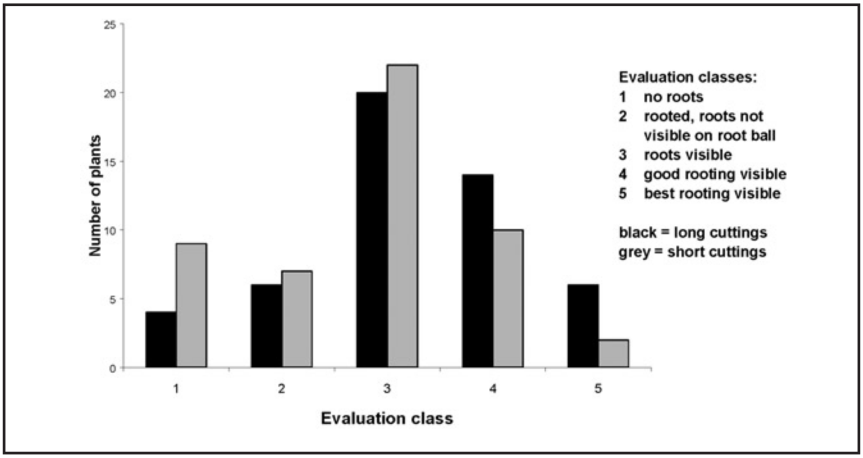

Figure 2. Rooting success of *Acer pseudoplatanus* Oct. 2002 (50 long and 50 short cuttings set July 2002).

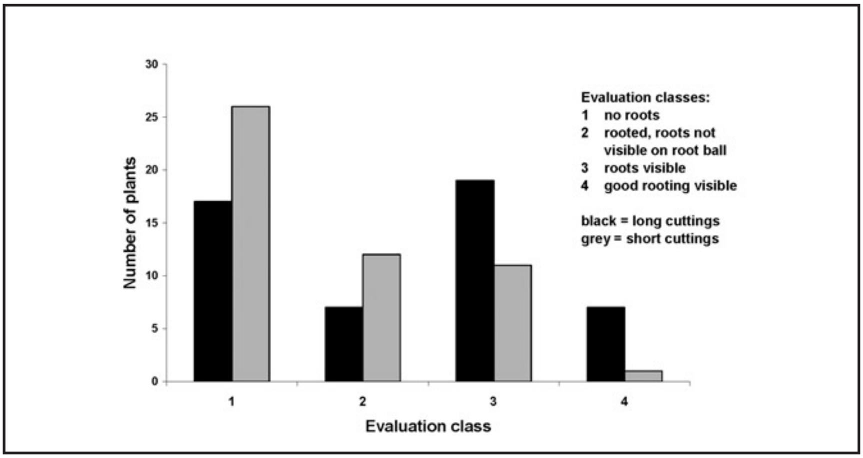

Figure 3. Rooting success of Corylus avellana 'Contorta' Oct. 2002 (50 short and 50 long cuttings set in July 2002).

collar diameter in the following year was often too small for budding (Osterc and Spethmann, 1998; 2001; 2002(a); 2002(b); Osterc, 2000).

Comparison of Long and Traditional-length Cuttings. In mid-July 2003 we struck long (mean length 50-75 cm) and traditional-length (mean length 20 to 25 cm) cuttings of *Malus domestica* M9 dwarfing rootstock, *M.* M27 dwarfing rootstock, P80; *Prunus* 'Gisela'; and *Pyrus* cv., Pyrodwarf® semi-dwarfing pear rootstock. We used IBA 0.5% and 3 peat : 1 sand (v/v) substrate with Osmocote Plus 3-month at 3 kg·m^{-3} and $CaCO_3$ at 2 kg·m^{-3} giving a pH of 4.5. Cuttings were rooted under fog.

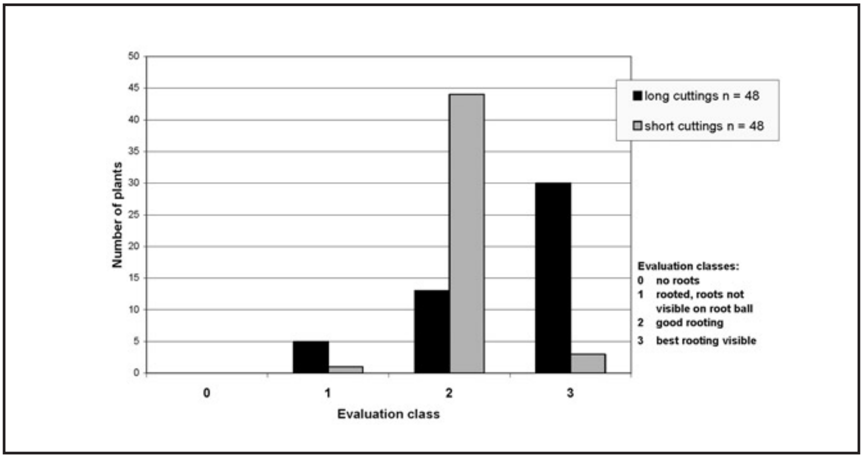

Figure 4. Rooting success of *Prunus* 'Gisela 5' set in July 2003.

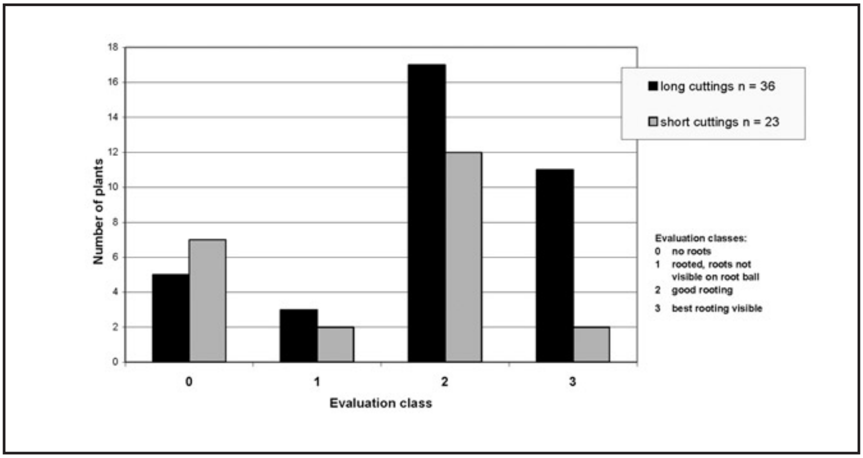

Figure 5. Rooting success of *Malus domestica* 'M 9' set in July 2003.

Mean rooting of the long cuttings ranged from 86% to 100% (Table 4). Rooting quality of the long cuttings was generally better than the smaller ones (Fig. 4 and 5). Half of the plants were transplanted in autumn, the remainder in spring. Due to the mild winter the losses until April 2004 only were between 0% and 4%. After rooting the mean diameter at 0.2 m height of all long cuttings was more than 5 mm, so that all cuttings could be budded in 2004.

FRUIT VARIETIES ON THEIR OWN ROOTS

Traditionally apple, pear, and cherry fruit trees are budded onto rootstocks, by which their growth can be regulated. Dwarfing rootstocks have been used to produce small-crowned trees for many years. Production of fruit trees on their own roots is unusual, because of difficulties in rooting, and because many say that trees on their own roots the will grow too fast.

Propagation of *Pyrus* 'Williams Bon Chrétien'. We did not achieve satisfactory results in our preliminary trials on the use of ordinary small cuttings to propagate *Pyrus* 'Williams Bon Chrétien' (syn. Bartlett). In 2000 we therefore experimented with long cuttings (mean length 80 cm) using the method described above. We used the vertically growing water shoots from the crown area of trees in a 37-year-old pear orchard. Rooting was 57% (Table 1).

Over the winter the cuttings remained in the unheated greenhouse. In March/ April before transplanting we were surprised to see that most of the cuttings started flowering. After transplanting, the plants flowered again in the following spring and in autumn produced some fruits. Cuttings taken in subsequent years showed the same phenomenon. Small cuttings of the same origin do not flower during propagation. Long cuttings of 10-year-old stock plants flower to a smaller degree.

We will be investigating this flowering phenomenon during the next few years. It could be a hormone response to the stress of the rooting environment. Flower induction by climatic stress is well known in many species.

Fruit trees on strong-growing rootstocks only will flower after some years of strong vegetative growth. On dwarfing rootstocks flowering starts earlier. Because of the early flowering of the long cuttings I expected that growth would be retarded too. In Spring 2002, long cuttings set in July 2001 were planted out to compare with plants of the same cultivar on quince A, and plants grown from seed. In October 2003 mean height of the cuttings-grown plants was 1.6 m; those on quince A were 2.0 m, and the seedling plants were 2.4 m. Growth and fruit set will be monitored over next few years.

First investigations to compare long and short cuttings of apple (*M. domestica*) cultivars 'Gala', Fuji', 'Elstar', and 'Jonagold' showed strong clonal differences. 'Fuji' rooted at more than 50% with both short and long cuttings. In 'Elstar' short cuttings rooted better than long (62% and 44% respectively) (Table 5). Best rooting of 'Jonagold' and 'Gala' was only 10%. Rooted cuttings also form flower buds as in pear. Long cuttings of 'Elstar' produced most flower buds with 5 buds per plant. Growth of these cuttings-grown plants will be monitored over next few years.

Table 4. Cutting length, rooting percentage, mean root number of long cuttings of fruit tree root stocks set in July 2003 in containers (Meier 2004).

Rootstocks	Cuttings set (no.)	Mean cutting length (cm)	Range (cm)	Rooting (%)	Mean root (no.)
Malus 'M9'	36	51	36-68	86	7.2
Malus 'M27'	48	48	29-70	90	13.4
Malus 'P80'	48	50	37-69	94	10.8
Prunus 'Gisela 5'	48	79	59-110	100	15.1
Pyrus cv., Pyrodwarf® semi-dwarfing pear rootstock	48	62	42-98	96	7.2

Table 5. Cutting length, rooting percentage, mean root number of long cuttings of apple cvs set in July 2003 in containers (Meier 2004).

Malus domestica cultivars	Cuttings set (no.)	Mean cutting length (cm)	Range (cm)	Rooting (%)	Mean root number
Fuji	50	60	43-83	52	3.9
Jonagold	50	48	36-64	10	2.6
Elstar	48	46	26-61	44	4.1
Gala	48	45	32-62	10	7.0

DISCUSSION

We have been unable to find any published work on long cuttings with which to compare our work. Handbooks such as those of Hartmann et al. (2002) and others always recommend 5- to 20-cm cuttings.

Long cuttings (60 to 250 cm) therefore appear to be a new field of plant production. Successful rooting of long cuttings of rose and fruit rootstocks, street tree species, and *Pyrus* and *Malus* cultivars is possible under fog. Some of the species with which we have been successful, such as *R.* 'Pfänders Canina', *Malus,* and *Pyrus* rootstocks and cultivars, or *C. avellana* 'Contorta', are said to be difficult to propagate from short cuttings.

The good rooting of cuttings from stock plants more than 30 years old (e.g., *Pyrus, Acer platanoides)* was not expected. Usually cuttings from trees more than 10 years old fail or root badly. Water shoots from the crown of 37-year-old *Pyrus* 'Williams Ben Chretien', would be expected to be in the adult stage and so rooting should not be possible.

It could be that dormant buds have remained in the juvenile stage and so the shoots produced are juvenile too. On the other hand these cuttings flower after some months, indicating that they must be already in the adult generative stage. The production or activity of hormones could be changed or the stress during rooting could induce the phase change to the generative stage.

When we compared the young plants produced from short and long cuttings we found that long cuttings produced a better quality root system in all cases. They had higher root number and better branching and resulted in a higher percentage of transplantable rooted cuttings.

In the street trees we looked at, shoot growth was very strong after the first and second transplanting compared with seedling trees. Using long cuttings could therefore reduce production time. On the other hand, shoot growth of *Pyrus* 'Williams Ben Chretien' is initially less for plants from long cuttings than conventional trees on quince A. If growth remains retarded for the life of the plant, and flowering increased, long cuttings could be a totally new, very cheap production method of slow-growing pears on their own roots.

Using long cuttings to produce *R.* 'Pfänders Canina' as rootstocks could reduce the production time for standard roses from 5 to 2 years. The production of flowering container roses for garden centres would be very easy using by direct sticking the long cuttings in containers.

Modern dwarfing rootstocks for cherry and pear fruit trees often are propagated only in vitro which makes these plants very expensive. In 2004 'Gisela' or 'Pyrodwarf' rootstocks cost €1.80 each. Production time and costs can be reduced using long cuttings. For production of conventional rootstocks by mound layering large fields of stock plants with intensive handling, fertiliser, herbicide, insecticide treatments are necessary. After some propagation cycles soil sickness can appear. Rootstocks can be produced in greenhouses by long cuttings and only small plots are then required for stock plants, which can be used over a number of years.

CONCLUSION

Long cuttings as a new method of plant production will reduce the production time and production costs for many trees and shrubs. Reduction of production time results in reduction and saving of pesticide treatments, fertiliser, and irrigation.

Many questions remain, not least of which is why long cuttings root so well. What is the hormonal status within the cuttings? Do they need more or less growth hormone? How many long cuttings could a stock plant produce? We only have 4 to 6 years experience with shoot growth, habit, and flowering. What are the growth, plant habit, and stability of these plants in future years?

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