

greenhouse environment. The CO₂ can be supplied as a gas or through the mist system.

In summary, it appears that the last 10 years have indeed been productive in terms of advances in plant propagation. Current research indicates that the next 10 years will also supply us with many more changes.

WITCHES'-BROOM COLLECTION OF CONIFERS AND THEIR PROPAGATION

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Witches'-brooms are dense shrub-like growths that occur as a result of the mutation of buds (Figure 1). They are found mainly on conifers and generally retain their dwarf and dense character when propagated vegetatively (1, 2). The grafting of witches'-broom tissue has been done since 1874 and is the origin of such dwarf evergreens as *Pinus sylvestris* 'Beauvronensis' and *Pinus nigra* 'Hornibrookiana'.



Figure 1. A witches'-broom found on an eastern white pine.

The number of different forms of such dwarf plants is limited by the number of witches'-brooms found. A much larger number of different plant forms can be obtained, however, from the seed of the broom.

Over 20,000 seedlings of *Pinus strobus*, *P. sylvestris*, *P. resinosa*, *P. banksiana*, *P. rigida*, *P. densiflora*, *Picea abies*,

Larix laricina, and *Tsuga canadensis* have been grown at the University of Connecticut since 1964 and have produced many interesting forms that are dwarf, semi-dwarf, weeping, spreading, upright, and prostrate, as well as variegated (4). Table 1 illustrates the wide range of height and width among dwarf seedlings from different witches'-brooms.

Table 1. A comparison of the dimensions (height \times width) of the largest and the smallest witches'-broom seedlings.

Species	Age	Smallest	Largest
	years	H \times W	H \times W
<i>Picea abies</i>			
Witches'-broom No. 1	9	1½ \times 2 ft	2½ \times 4 ft
Witches'-broom No. 2	4	6 \times 5 in	20 \times 16 in
<i>Pinus strobus</i>			
Witches'-broom No. 1	19	11 \times 9 ft	13 \times 11 ft
Witches'-broom No. 2	19	1½ \times 2½ ft	2½ \times 6 ft
<i>Pinus resinosa</i>			
Witches'-broom No. 1	11	2 \times 4½ ft	3 \times 6 ft
Witches'-broom No. 2	12	1½ \times 2 ft	3 \times 3 ft
<i>Tsuga canadensis</i>			
Witches'-broom No. 1	4	9 \times 7 in	27 \times 22 in
Witches'-broom No. 2	12	1 \times 2 ft	7 \times 6½ ft

These seedlings have also exhibited variations in needle color, needle length, stem thickness, branch rigidity, branch density, and branch orientation. This variation offers a wide choice of shapes and sizes of plants from which one may select. Although I have obtained seedlings from many different brooms, I constantly look for additional ones because the progenies from different brooms may differ significantly from one another. In other words, in addition to obtaining variation among a group of seedlings from a single broom whose progeny, on the whole, have a slow rate of development and are extremely dwarf, we also can obtain variation among a population from a second broom whose rates of development are considerably greater. In the latter population, the plants are much larger than those of the former although they retain the dense branching character. Figure 2 illustrates the growth differences among progenies from three different witches'-brooms.

In another example, but with Canadian hemlock, one population had seedlings whose branching habits varied from horizontal to weeping, whereas the progeny from another broom had branching habits that were ascending.

The purpose of this project is to introduce new, interesting forms of dwarf conifers to the nursery industry. As of this date the following plants have been named and scions distributed to cooperating propagators.



Figure 2. Three groups of seed-grown dwarf white pines, all the same age (12 years), which were obtained from three different witches'-brooms.

1. *Pinus strobus* 'Sea Urchin'. A miniature shrub having very short needles $1\frac{1}{4}$ in. long. After 19 years of growth it has developed into a low mound having a height of only $1\frac{1}{2}$ ft and a width of $2\frac{1}{2}$ ft. The foliage has a bluish-green appearance (5). It is propagated by grafting, since rooting of cuttings has not been successful.
2. *P. strobus* 'Green Shadow'. A multi-trunk dwarf shrub with dark green foliage. It has grown $5\frac{1}{2}$ ft tall and $7\frac{1}{2}$ ft wide in 16 years. Its form, shrub-like in its formative stages, becomes more tree-like with age. The needles, which are 3 in long and thicker than the other cultivars, are retained on the plant for 3 years while most white pines retain their needles for only 2 years. This cultivar is relatively easy to root having been rooted successfully in February, March, April, September and November.
3. *P. strobus* 'Blue Shag' (5) is a dwarf shrub but with a faster annual rate of growth than 'Sea Urchin' or 'Green Shadow.' Its bluish-green needles are $2\frac{1}{2}$ in. long. The overall dimensions of the plant after 8 years of growth are 3 ft tall, and $5\frac{1}{2}$ ft wide. Rooting of cuttings has been moderately successful (20%).
4. *P. strobus* 'UConn' (4) is a relatively rapid growing but fully branched tree. It has obtained a height of 10 ft and a diameter of 7 ft in 15 years.
5. *P. resinosa* 'Sand Castle' is a broadly ovate and very dense shrub (Figure 3). It has tufts and short dark green needles and has a growth rate of $3\frac{1}{2}$ to 4 in. per year.

Its dimensions after 10 years are 4 ft tall and 4½ ft wide. It should be grafted. Rooting of cuttings has not been successful.

6. *P. resinosa* 'Thunderhead' is a low vigorous shrub more broad than tall. It has long dark green needles arranged in tufts and has grown 4 ft tall and 5 ft wide in 10 years. It is propagated by grafting. Rooting of cuttings has been difficult (2%).
7. *Tsuga canadensis* 'Florence' is a low and spreading with layered branches; its dimensions, after 12 years, are 1½ ft tall and 4½ ft wide. It is propagated by grafting and has had some success by cuttings (20%).

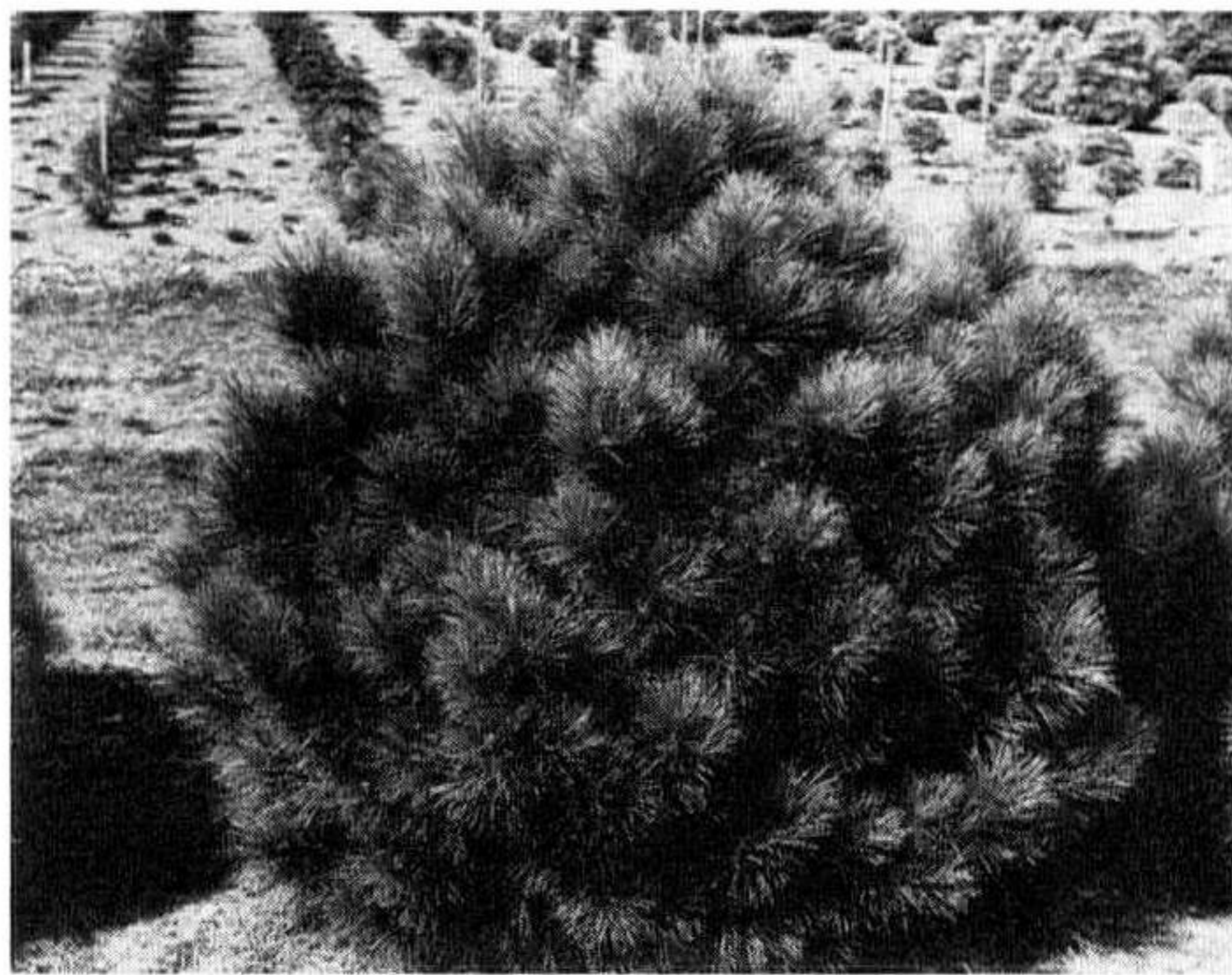


Figure 3. A red pine witches'-broom graft, *P. resinosa* 'Sand Castle'.

In general, among the white pines, rooting of cuttings has been most successful on cuttings taken from young seedlings. Cuttings taken from 4-year-old seedlings rooted 60% while those taken from 5-year-old plants rooted only 29% (3). Among the seedling obtained from various witches'-brooms, those exhibiting the highest rooting percentages were taken from the more rapidly growing forms, while cuttings taken from the very dwarf forms were very difficult to root.

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