Relocating Large Trees for Germplasm Conservation in Tree Fruit Breeding Programs

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SUMMARY. **Mature seedling trees of pear (*Pyrus communis* and interspecific hybrids), and fruiting trees of peach and nectarine (*Prunus persica*), apricot (*Prunus armeniaca*), and pear were relocated during the dormant season using tree spades. During the growing season immediately following, some signs of drought stress were noticed but all trees grew well enough that they could be used as a source of budwood for limited propagation purposes. When drip irrigation was supplied, supplemented by overhead irrigation as required, normal growth and production resumed within two growing seasons of the move. Some tree losses (less than 10% of trees moved) were reported from one site where the soil type was Fox sand with very poor water holding capacity. These tree losses were attributed to an inadequate water supply to the root ball, even though the site was irrigated. Our experience has demonstrated the feasibility of relocating relatively large trees, which can be beneficial for germplasm conservation in a tree fruit breeding program. However, it is probably not economically viable to relocate such trees for commercial production.**

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Tree fruit breeding programs typically require considerable areas of land for seedling populations, as well as for growing and maintaining trees of parental material and selections undergoing advanced testing prior to introduction. Individual seedlings that do not meet the selection criteria established for the breeding program are removed, and only a few selections are retained for further evaluations (Bell et al., 1996; Hunter, 1993; Hunter and Layne, 1999). To release land for other uses, including rotation back into seedling orchards, individual selections may be consolidated into a smaller area. To the best of our knowledge, there have been no published reports of the successful transplanting of bearing trees of pear or stone fruits (peach, nectarine, apricot). However, Wood et al. (1990) reported that bearing trees of pecan (*Carya illinoensis*) could be successfully transplanted using a tree spade during the dormant season.

This manuscript describes our experiences in southern Ontario, Canada, where our objectives were to 1) consolidate original seedling trees of pear (mainly *Pyrus communis*, and interspecific hybrids with other *Pyrus* species including *P. ussuriensis*, *P. pyrifolia* and *P. fauriei*), thus releasing land for other uses; 2) conserve germplasm of pear, peach, nectarine, and apricot; and 3) relocate evaluation orchards to other sites in order to meet program requirements.

Materials and methods

In the traditional tree fruit breeding programs formerly located at the Agriculture and Agri-Food Canada (AAFC) Research Centre in Harrow, Ontario, Canada (lat. 42°02′N, long. 82°54′W), seedling populations were generated each year through controlled hybridizations between selected parents (Hunter and Layne, 1999). Following stratification and germination, seedlings were planted out into seedling orchards for evaluation.

Seedling populations of pear were planted out at within-row spacings of 1.2–1.5 m (4–5 ft), and between-row spacings of 4.6–5.2 m (15–17 ft), giving planting densities between 1265 and 1794 trees/ha (512–726 trees/acre). In some cases, pear seedlings were planted in double rows 1.5 m apart, with a 5.2-m alleyway between the double rows, thus giving an effective planting density of 1957 trees/ha (792 trees/acre). Seedling populations of stone fruits (apricot, peach, nectarine) were typically planted 1.5 m apart in rows spaced 4.6 m apart, giving a planting density of 1433 trees/ha (580 trees/acre).

Seedling orchards were grown with minimal inputs of fertilizers and sprays. Because of juvenility in seedling populations, seedling trees were grown for several years prior to the onset of flowering and fruiting. The onset of flowering and fruit production for stone fruits was normally within 3–4 years after planting in seedling orchards, whereas for pear, it was much longer, typically 7–10 years. During this "nonproductive" period, trees were not pruned or trained, and evaluations tended to focus on major pest or disease problems. With the onset of fruiting, evaluations then focused on both fruit and horticultural characteristics.

When selections were made from the seedling populations, trees were propagated, usually by budding or grafting onto a rootstock, grown in the nursery for 1–2 years, and subsequently planted out into evaluation orchards spaced at normal planting distances [for pears, 3.0 m (10 ft) within row × 4.6–4.9 m (15–16 ft) between rows; for stone fruits, 3.0 m within row × 5.2–6.1 m (17–20 ft) between rows] to determine fruiting potential. At planting time, pear trees typically had a trunk diameter of 1.1–1.4 cm (7/16–9/16 inch) while that of stone fruit trees was typically 1.4–1.8 cm (9/16–11/16 inch). Until these orchards came into production, evaluations continued on the original trees in the seedling orchards. Seedlings that did not meet selection criteria were removed, and when the seedling orchard was terminated, the only trees remaining were those where evaluations were continuing. Normally, all trees in stone fruit seedling orchards were removed at the same time, but seedlings of pear selections were retained for a number of years to continue evaluations, to have a source of budwood for propagation, and for use in further breeding.

PEAR SEEDLINGS. Fully dormant seedling trees were moved in Mar. 1995 and Mar. 1996, when the ground was still partially frozen, sufficiently hard to support a large tree spade truck, yet soft enough to allow penetration by the tree spade. A total of 39 pear

seedling trees, 10–30 years old, were moved. Tree heights and trunk calipers were not measured, but typically the older seedling trees were ~4.6–6.1 m in height (estimated from the requirement for a 3-m picking ladder to reach the upper fruiting zone), and trunk diameters were estimated at 15.2–30.5 cm (6–12 inches). A commercial landscape company (Instant Shade, Maidstone, Ontario, Canada) was contracted to move and consolidate trees into a single orchard at the Harrow Research Centre. This orchard site had been in oats (*Avena sativa*) and alfalfa (*Medicago sativa*) during the 1994 and 1995 growing seasons; oats had been harvested and only alfalfa remained at the time of transplanting, so no cultivation or land preparation was required prior to moving and transplanting trees. Trees were moved from seedling orchards within ~1 km (0.6 mile) of the new location. Because of the large size of the trees, a truck-mounted tree spade (model 90B; Big John, Herber Springs, Ark.) was used to dig, transport, and replant the seedling trees into rows spaced 4.6 m between rows and 3.0 m within-rows. After planting, tree height was reduced by ~30%, and some branches and shoots pruned to produce a tree form more typical of a "managed" central leader tree, i.e., one that had been subjected to normal training and pruning practices (Forshey et al., 1992), and to remove some shoots and branches that were broken during the move. Mulch was laid by unrolling large round hay bales down the row to provide ~15.2 cm of mulch in the tree row. During the rest of the transplant year, irrigation was supplied ~weekly through low-rise sprinklers (model 20A; Rain Bird, Vancouver, B.C.) to provide overall wetting of the root zone while minimizing wetting of the foliage. During the summer following transplanting, the between-row alleys were cultivated and seeded to a permanent sod of creeping red fescue (*Festuca rubra*).

Stone fruit (*Prunus*) germplasm. Most of the stone fruit trees that were moved were 2- to 4-year-old budded trees grown on seedling rootstocks of peach cultivar Bailey (for peach and nectarine selections) or apricot cultivar Haggith (for apricot selections). Trees had been planted in a "second test" evaluation orchard, and trained to a central leader system (Forshey et al., 1992). Trunk calipers were typically 7.6–10.2 cm (3–4 inches). These trees had been grown on a Fox sandy loam soil where natural drainage was excellent to excessive (Richards et al., 1949). Because of the sale of this farm, the commercial landscaper, Instant Shade, was contracted to move these trees in Nov. 1995, using a truck-mounted 114.3-cm (45 inches) tree spade (model 45; Big John), and replanting them in a new location at the Harrow Research Centre, where the soil type was a Harrow sandy loam, a naturally well-drained soil (Richards et al., 1949). Because of the relatively short distance [~5 km (3.1 miles)], trees were transported in the truck-mounted tree spade. A total of 78 trees of peach and nectarine and 64 apricot trees were moved, and transplanted into rows 5.5 m (18 ft) wide, with 3.7 m (12 ft) between trees. No land preparation was performed prior to transplanting. In Spring 1996, a trickle irrigation system was installed, with two 2 $L \cdot h^{-1}$ (0.5 gal/h) emitters (model 102; Netafim, Fresno, Calif.) per tree and irrigated as required, usually two to three times weekly during the months of July and August. The between-row alleys were worked and seeded to creeping red fescue permanent sod in Summer 1996.

Pear evaluation orchards. Because of the time involved in getting pear orchards into production, some trees were moved from the Harrow Research Centre to the Niagara region [~350 km (217.5 miles) away], while other trees were moved from the Niagara region to a new location at Delhi, Ont. [~125 km (77.7 miles)].

Trees of several advanced test selections and reference cultivars, planted in second test evaluation orchards at the Harrow Research Centre between 1994 and 1996, started to produce fruits in 1998. These trees were budded onto pear cultivar Bartlett seedling rootstock (standard practice) or pear clonal rootstocks ('Old Home' x 'Farmingdale' clones 51, 69, and 87). The orchard spacing was 3.0 m within row × 4.6 m between rows, and trees were trained to a central leader system (Forshey et al., 1992). The commercial landscaper, Instant Shade, used a backhoe-mounted 101.6-cm-diameter (40 inches) tree spade (Dutchmaster 40E; Dutchman, Brougham, Ont.) to dig the trees, which were then placed in burlap-lined 91.4-cm (36 inches) wire baskets. The digging operation was conducted in mid-November after trees had entered dormancy and leaves had all abscised. Trees were placed on a flatbed trailer (~50 trees per load), and covered with a tarpaulin for transportation. In 1999, a total of 98 trees were moved to the AAFC Research Farm at Jordan Station, Ont. (lat. 43°10′N, long. 79°21′W). The planting site had been clean cultivated in Oct. 1999. Planting holes, ~0.6 m (2 ft) deep, were prepared using a 91.4-cm-diameter tree auger (Danuser Digger model F7; Danuser, Fulton, Mo.), again at a 3.0-m within-row × 4.6-m between-row spacing. Trees were then planted directly into the hole without removing the burlap or wire basket from the root ball (Lumis, 1990). However, the burlap was untied from around the trunk and covered with soil to prevent water loss through wicking. After filling in the planting hole, wheat straw mulch was applied to a depth of ~15.2 cm during the first winter. Broken shoots and limbs were removed following planting, and trees were subsequently pruned during the dormant season to maintain the modified central leader system. This orchard was irrigated as required during subsequent growing seasons through a drip irrigation system [Netafim 18 mm (0.71 inches) pipe with 2.2-$L \cdot h^{-1}$ (0.58 gal/h) in-line emitters spaced 61.0 cm (24 inches) apart (Netafim, Fresno, Calif.)], and a permanent sod cover crop of creeping red fescue was seeded during the summer following transplanting.

In 2001, 18 trees were moved from the Harrow Research Centre to the University of Guelph Victoria Farm at Vineland Station, Ont. (lat. 43°11′N, long. 79°23′W). Procedures were as described for the 98 trees moved in 1999. The planting site was a single row in permanent sod where peach trees had been removed about 1 year earlier, so this row was deep cultivated prior to transplanting the pear trees. As these trees had not been trained or pruned for ~2 years at Harrow, they were pruned heavily after planting to develop an appropriate modified central leader training system. Also, these trees were mulched with a paper biosolids by-product (Ontario Paper, Thorold, Ont.) to a depth of ~15.2 cm. Because the year after transplanting was wetter than normal, irrigation was not required, and no irrigation system has been installed for these trees.

In Nov. 1999, 4-year-old trees of

'Bartlett' pear on 'Bartlett' seedling rootstocks were moved from a well-drained Vineland fine sandy loam (Wicklund and Matthews, 1963) at the AAFC–Jordan Farm, to a site at Delhi, Ont. (lat. 42°52′N long. 80°33′W), where the soil type is a Fox sand with excellent to excessive drainage (Ball-Coelho et al., 1998). A commercial landscaper (Lyon's Creek Tree Farm, Welland, Ont.) used a tractor-mounted 81.3-cm-diameter (32 inches) tree spade (model T32; Caretree, Columbus, Ohio) to dig a total of 110 trees, and place them in 71.1-cm-diameter (28 inches) wire baskets lined with burlap. Trees were transported to the AAFC–Delhi Farm. To prevent wind erosion, the Delhi site had been planted in Spring 1999 with a rye (*Secale cereale*) cover crop, which had been cut in early Fall 1999. Planting holes, ~0.6 m deep, were prepared using the 91.4-cm-diameter Danuser Digger model F7 tree auger; trees were planted as described earlier, and mulched with wheat straw to a depth of 15–20 cm (5.9–7.9 inches). Because these trees were scheduled for experiments into host–pathogen interactions, the orchard was planted at a spacing of 3.0 × 3.0 m. In the following spring, the land was cultivated and seeded to a permanent sod of creeping red fescue. A drip irrigation system was installed with two 4 $L \cdot h^{-1}$ (1.1 gal/h) emitters per tree, and trees were drip irrigated three times weekly throughout the growing season, with additional irrigation being supplied once or twice as required through an overhead gun (model SR100; Nelson Irrigation Corp., Walla Walla, Wash.). A total of 110 trees were moved. Additional wheat straw mulch was applied to a depth of 15–20 cm in Nov. 1999 and Nov. 2000. In Jun. 2001, ~10 cm (3.9 inches) of wood mulch, primarily oak chips, was applied in the tree row.

FERTILIZER APPLICATIONS. In early spring (April) each year, each tree was fertilized with 100–300 g (3.5–10.6 oz) of ammonium nitrate (34N–0P–0K) by banding in the drip line, according to Ontario recommendations [Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), 1996]. For trees moved to the Delhi location, a second application of ammonium nitrate (34N–0P–0K) was made in June each year. A broadcast application of 10N–4.4P–8.3K fertilizer at a rate of 370 $kg \cdot ha^{-1}$ (330.1 lb/acre) was applied each year to orchards with a permanent grass cover crop.

WEED CONTROL. At all sites, weeds in the tree rows were controlled by applications of the herbicides glyphosate (Roundup; Monsanto, St. Louis) and paraquat (Gramoxone; Syngenta, Basel, Switzerland) as recommended for fruit production in Ontario (OMAFRA, 1995).

Results and discussion

With the exception of the Delhi site, all trees were moved successfully, and no tree losses were experienced following planting.

Pear seedlings consolidated into a small area at Harrow showed some signs of drought stress (wilting and flagging of shoot tips, small sized fruit) during the 1995 growing season (i.e., immediately following transplanting), even with supplemental irrigation and a reduction in tree size by pruning. During this first growing season following the move, we did not use the trees for any evaluation purposes, but we were able to collect a limited amount of budwood for further propagation. These symptoms were less apparent during Summer 1996, and we were able to use some of these trees for breeding as well as screening for fire blight (*Erwinia amylovora*) resistance through shoot tip inoculations (Hunter, 1993). Normal growth was resumed by the 1997 growing season, and was maintained until the orchard was finally removed in Fall 2000.

There was no damage to the stone fruit trees (trunks or branches) due to moving. Growth was also good, and budwood for propagation was collected during the growing season immediately following the relocation. Fruit thinning severity in that year was increased slightly relative to normal practices in order to reduce fruit load to levels that did not induce stress on the trees, yet fruit yields in the year immediately following transplanting were essentially normal. All trees survived subsequent winters, and we did not observe any increase in winter injury as compared to trees that had not been moved. This orchard was also removed at the end of the 2000 growing season.

Pear trees moved from Harrow to the Niagara region were allowed to carry some fruits in the year immediately following transplanting in order to verify trueness-to-type. In subsequent years, trees were allowed to carry a normal fruit load for yield data collection, and also were used, as required, as a source of budwood for propagation purposes and as seed parent trees in the breeding program.

At Delhi, tree losses were ~10% in the growing season immediately following transplanting. These losses were attributed primarily to inadequate moisture in the rooting zone, despite irrigation through a drip system, supplemented by overhead irrigation once or twice during the growing season. Because the Fox sand has a very low moisture holding capacity, water moves vertically, with very little horizontal movement. Drip irrigation as applied was unable to provide sufficient water to the root ball to prevent drought stress. The use of microsprinkler irrigation, which provides a larger wetting area at the surface, would have been preferable to ensure adequate moisture in the rooting zone. While pear trees moved from Vineland to Delhi grew slowly for the first 3 years, additional applications of N-fertilizer were beneficial in stimulating vegetative growth. Improved tree performance was attained when tree rows were mulched with wood chips, which facilitated water retention in the rooting zone. However, the relatively poor growth of these trees and limited number of growing points provided a constraint to the planned research into host–pathogen interactions.

This experience in moving mature pear seedling trees as well as established grafted trees demonstrates the feasibility of the operation. Where economics are a major consideration, it may have been better to propagate new trees and establish them in new orchards, rather than move older trees. However, for tree fruits in general, and pears in particular, the time loss involved in establishing production in a new orchard is considerable. Here crop losses were restricted to the growing season immediately following the move, but in subsequent years, trees were capable of producing normal crops, and normal research and production activities were resumed. When the unique genetic nature of seedling trees and advanced test selections is taken into consideration, the benefits resulting from the successful conservation of this germplasm were well worth the expenses associated with moving and transplanting large trees.

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