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Training Pear Trees in Semi-high Density Systems with Seedling Rootstocks

D.K. Strydom, Dutoit Group, Ceres, South Africa

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This paper describes a possible approach to the training of pears on pear seedling rootstock at distances of 4.5 x 2.5 m (14.8 x 8.2 feet), 4.5 x 2 m (14.8 x 6.6 feet) and 4 x 1.5 m (13.1 x 4.9 feet). The appropriate distances depend on the quality of the soil, the vigor of the scion variety and whether it is a replant situation. Dates and seasons reported here for South Africa are 6 months off the Northern Hemisphere seasons (January equals July).

Requirements for success of a semi-high density system for pears are :

- Proper soil preparation
- Installing a well-designed irrigation system prior to planting, proper irrigation scheduling and monitoring
- Understanding transplant shock
- Understanding the differences in growth and fruiting habit between apples and pears
- Understanding the differences in growth and fruiting habit between pear varieties
- Planting quality trees
- Having a support system in place in windy areas the day the trees are planted
- The timely use of manipulations suggested to increase tree complexity and growth, i.e., delayed heading, notching, bending, pinching, bud flicking, coldstorage of trees before planting, artificial rest-breaking agents like dormant oil and Dormex
- Minimal pruning
- The use of Chlormequat (Cycocel)

- Scoring or girdling
- Providing sufficient pollinators and understanding the management of bees to optimize pollination
- Using an integrated fertilizer program

SOIL PREPARATION

Every attempt should be made to prepare a medium that will promote initial and sustained growth of the trees. Salty, stony, sandy, poorly drained patches are commonly found in the typical alluvial soils. These limiting factors should be alleviated before the trees are planted. Lack of uniformity of mature blocks is a common problem.

IRRIGATION SYSTEM

Many of the problems associated with variable soils can be overcome by a properly designed irrigation system, employing a scientific scheduling program and proper monitoring of soil moisture in the root zone.

PLANTING QUALITY TREES

Very strict selection of seedlings should take place in the nursery to remove weak seedlings and therefore start with a uniform population. Only well-hardened-off 2-year-old trees (fall budded) should be planted. After the trees are hardened off, the necessary macro- and micronutrients should be foliarly applied to ensure good growth in spring. When the trees are dug, extra care should be taken not to injure the primary buds in the trunk region where the first set of side scaffolds will be developed at 60-110 cm (24-43 inches) above ground level. Make sure that your nurseryman understands the phenomenon of transplant shock.

TRANSPLANT SHOCK

Water movement from the soil to the atmosphere through a tree is a continuum. This continuum is broken when nursery trees are lifted and must be re-established when trees are planted. For re-establishment of the continuum, good root-soil contact is necessary, especially since the root surface area has been reduced during lifting. The soil should be watered in order to make sure that water is readily available. Tree shaking after planting will reduce soil-water contact. Shrinkage of the roots due to water loss of the aerial parts or unavailability of water will impair the restoration of the continuum. Auxin transport to the roots from above ground will also be impaired. Failure to establish a continuum will cause the plants to dry out and the trees will die.

It is also possible that the soil-plant atmosphere is established but that root generation fails. Failure of root generation may be caused by lack of oxygen due to waterlogged compacted soils or low soil temperature. Pear roots start to grow at 7-8˚C (44-46˚F) but the optimum temperature for root growth is 20-25˚C (68-72˚F). Members of the Rosacea family have a high root oxygen requirement and function best at oxygen levels above 10%.

Root growth is much reduced at oxygen levels of 3-5%. Roothair activity is suppressed within 30 minutes after oxygen becomes limiting. Soil oxygen deficiency can result from inadequate aeration due to insufficient pore space for gas exchange in compacted or fine-textured soil or an excess of water in the soil. If the soil-plant atmosphere continuum is established but root generation does not occur, bud development will commence on reserves (carbohydrate, mineral, hormonal) and small leaves will appear. The leaves will start to wilt, dry out and the trees will die.

More often than not, there is partial root generation with very poor initial shoot growth. Later in the growing season, shoot growth will accelerate when soil temperatures increase. At the end of the season, the growth is unsatisfactory and trunk renewal is necessary.

Pear trees which are not properly hardened-off in the nursery will have less reserves than trees which terminated growth before digging. Such trees will suffer more from transplant shock than properly hardened-off trees.

The problem of transplant shock is treated in detail since trunk renewal is often necessary because of poor growth in year 1. Pear trees which are trunk renewed after year 1 often grow very aggressively in year 2, resulting in shoots which are more vegetative and less reproductive. Also success with the establishment of feathered pear nursery trees or "whips" will occur only if the transplant shock problem is fully understood and managed.

PROPER TREE SUPPORT

Make sure the support system is in place the day the trees are planted. Constant rocking of newly planted trees will aggravate transplant shock because the water continuum between the soil and the plant is broken.

BREAKING DORMANCY

Whether feathered trees or whips are planted or whether the trees are headed at planting, it is very important to maximize the number of buds which will start to grow. Putting trees in coldstorage for 2-3 months at 4˚C (39˚F) or applying dormant oil alone or with Dormex will encourage bud

break. When artificial rest-breaking agents are used, the timing and rate of the application and the thoroughness of application of the material are important.

POLLINIZER TREES

Specify the quality of the pollinizer trees. Make sure sufficient pollinizers are planted. For pears it should be at least 11% of trees and spacing should not exceed 15 m (50 feet) between pollinizer trees in every row. Better yet is to plant two varieties (two rows of each alternatively) per block. Assign a full planting space to the pollinizer variety.

SET OF SIDE SCAFFOLDS

It is suggested that the first set of side scaffolds should be between 70 and 110 cm (27 to 43 inches) above the soil on the trunk. This will reduce the opportunity for frost damage, make it easier to apply herbicides and improve water distribution if a mechanical irrigation system is used.

APPLE AND PEAR GROWTH HABITS

To develop a management strategy for pears, it is important to understand the differences in growth and fruiting habits of pears and apples (Table 1). Techniques which are successful for apples are not always useful for pears.

PEAR VARIETY GROWTH HABITS

It is important to understand the differences in the growth and fruiting habits between pear varieties. The following characteristics vary among pear varieties (Source: DuPreez and Strydom):

- Willingness to develop sylleptic shoots
- Willingness to develop proleptic shoots ("blind wood" syndrome)
- Cold ("chilling") requirements
- Willingness to develop flower buds on "1-year-old wood"
- Willingness of "1-year-old wood" to "spur up"
- The degree of basal dominance or lack of basal dominance
- The length of the effective pollination period
- Attractiveness to bees due to differences in the amount of nectar secreted and the sugar concentration in the nectar
- Responsiveness to GA_3 applications to increase parthenocarpic set
- Responsiveness to C.C.C. applications to inhibit vegetative growth, increase fruit set and flower bud formation
- Graft incompatibility when propagated on quince rootstocks
- Susceptibility of *pseudomonas* attack
- Seriousness of transplant shock

TREE TRAINING OPTIONS

Regardless of tree spacings, the important characteristics of the tree—the training of which will be discussed below—are as follows:

- A central leader is present with one set of side scaffolds situated at 70-110 cm (27 to 43 inches) height on the future trunk.
- The first set of side scaffolds preferably should consist of four but not more than six members. On the side scaffolds fruiting units are present.
- The members of the first set of side scaffolds should obey the 3:1 rule, i.e., the preferred ratio of the diameter between central leader and side scaffolds should be 3:1 although, in the case of pears, a 2:1 ratio is also acceptable.
- Above the first set of side scaffolds fruiting branches are present. The fruiting branches should also obey the 3:1 rule. On the fruiting branches, fruiting units are present. Fruiting branches should get progressively weaker toward the terminal part of the central leader.
- Final tree height is a function of row direction. If the orientation is east-west, final tree height should not exceed 80% of row width. If the orientation is north-south, tree height could be 100% of row width.

Planted at the correct density, the final yields of these central leader trees can be very high. There is, as expected, also a strong relationship between planting distance and yield (Table 2).

There are three options available to train the central leader trees described in an earlier paragraph, 1) starting with a headed "whip," 2) starting with an unheaded "whip" and 3) starting with a feathered tree.

Starting With a Headed "Whip"

This "route" is suggested for the average grower. Practice delayed heading, i.e., head the tree at 120 cm (47 inches) at planting time, then apply the artificial rest-breaking agent at the correct rate and timing. When the topmost bud on the headed tree shows substantial growth, the tree is headed again at 110 cm (43 inches). Delayed heading results in more buds breaking (Table 3). When buds below 70 cm (28 inches) on the future trunk start to develop, rub them off to allow investment in new growth in the area between 70 and 110 cm (28 and 43 inches).

If sufficient buds are not breaking, immediately start notching to encourage bud break. The optimum time for notching is 2 weeks after budswell. When the shoots developing from bud

numbers two and three from the top on the future trunk are 10 cm (4 inches) long, start to pinch them to subdue their growth. The presence of the mentioned two shoots encourage epinastic forces and will result in the lower positioned shoots, i.e., future side scaffolds, to develop with wider crotch angles. Bending the laterals at an angle of 70˚ is required during January-February if the growth is very satisfactory. Otherwise wait until the beginning of the next season. At the end of the first growing season, the tree should have a first set of side scaffolds and a central leader which is relatively weak. Always bend shoots based on their length. Remember that, in the case of the pear, bending shoots to a 70˚ angle will dramatically slow down extension growth.

Starting With a Non-headed "Whip"

This option is suggested if good quality nursery trees, more than 1.6 m (5 feet, 3 inches) in length, are available, if the grower understands transplant shock and if the support system is in place the day the trees are planted. It is an option only if the grower is prepared to go to closer spacings.

Use artificial rest-breaking agents as suggested before. At the first signs of strong bud movement (bud swell), apply a "ring" with a pocket knife at 110 cm (43 inches) above ground level. Cut a complete circle through the phloem (bark) onto the xylem (wood).

The purpose of the "ring" is a temporary break in the communication between the topmost buds and the buds immediately below the ring. Applying the ring will result in the region below the ring having faster development than the buds in the terminal portion of the unheaded whip. Rub off all buds developing below 70 cm (28 inches) on the future trunk. Remove, by "bud flicking," the buds greater than 10 cm (4 inches) below the terminal bud on the unheaded tree. Shoots from these buds normally are too strong and their early removal will result in better development of the laterals below the point where the "ring" was made as well as the growth from the terminal bud and other lateral buds above the ring.

The future side scaffolds on this tree should develop between 70 cm and 110 cm (28 and 43 inches) from ground level. If sufficient buds do not "break" in this area, use notching to force the desired total of six laterals (future scaffolds) to develop. Pinch at an early stage very strong laterals which develop higher than 110 cm (43 inches) on the future central leader. Future side scaffolds on the central leader should be bent at an angle of 70˚ from the vertical if they are very strong. If weak, they could be positioned only at the start of the second growing season.

At the end of the first growing season the tree, which started as a whip, should have four to six future side scaffolds and a number of future fruiting branches higher up on the central leader. There should be a distinct pyramid shape.

Starting With Feathered Trees

Pear varieties vary strongly in their feathering capacity and the option to plant feathered trees will thus depend on the variety. Remove all "feathers" above 110 cm (43 inches) with a "Dutch cut" and below 70 cm (28 inches) with a clean cut when the trees are planted. Remove all remaining feathers not obeying the 1:2 rule with a "Dutch cut." Apply the artificial rest-breaking agent at the proper timing and concentration. Head the future leader 40 cm (16 inches) above the first set of side scaffolds. If sufficient feathers are not present after removal of the unsuitable feathers, all the remaining feathers should be removed with a "Dutch cut" and a ring applied as described previously. During the growing season very few manipulations will be required if properly feathered trees are planted.

NUTRITION AND IRRIGATION YEAR 1

Irrigate intelligently at the start of root generation in spring to minimize transplant shock. Do not over irrigate. When the new shoots are about 10 to 20 cm (4 to 8 inches) long, apply the first nitrogen in a circle with a diameter of 60 cm (24 inches) around each tree. Spread the fertilizer evenly over this area. Repeat five to six times at monthly intervals. Split apply N on sandy soils.

At the same time, start with foliar applications of nitrogen (urea spray grade) and the necessary micronutrients. Repeat at monthly intervals for 4 to 5 months.

FIRST WINTER PRUNING

If the trees grew well, very little pruning should take place the winter after the first growing season.

In the case of the headed trees, remove the laterals on the future trunk which developed from bud numbers two and three with a clean cut. Then remove with a clean cut laterals not obeying the 2:1 rule and limit the members of the first set of side scaffolds to not more than six and preferably four. If the future side scaffolds are too weak, head the central leader 40 cm (16 inches) above the first set of side scaffolds.

If trees were unheaded at planting, remove very strong laterals above the first set of side scaffolds with a "Dutch cut."

SECOND GROWING SEASON

Trees Which Were Headed at Planting

At strong budswell, "bud-flick" the central leader over a distance of 10 cm (4 inches) from the terminal bud, leaving the terminal bud on the central leader intact. Follow the same practice on future side scaffolds over a distance of 8 cm (3 inches). The purpose of the removal of these buds is to improve lateral bud development lower down on the future central leader or side scaffolds. Future side scaffolds should be bent at 70˚ if this was not done the previous January-February. Rub off any buds developing below the first set of side scaffolds. If sufficient laterals do not develop above the first set of side scaffolds, use notching to force buds where required. On future side scaffolds, pull off unwanted upright shoots when they are 10-12 cm (4 to 5 inches) long. Do not allow any investment in unwanted growth by employing either shoot pulling or pinching.

Trees Which Were Not Headed at Planting

"Bud flick" the central leader and the future side scaffolds as described above. Notch buds on the central leader if additional laterals are required. Pull shoots developing in unwanted positions. If necessary, bend laterals above the first set of side scaffolds which are too strong.

If sufficient correct inputs were made during the first two growing seasons, very little winter pruning should be required after two growing seasons.

If the trees grew well, they should start to fill their allotted space, girdling and the use of chlormequat (Cycocel) should be considered.

Scoring or Girdling

Scoring or girdling is a technique often used to control vigor, improve fruit set and increase return bloom in pear trees. Many growers and researchers have had a great deal of practical experience with scoring or girdling. There is some disagreement on which timing has the greatest effect on the different goals but the following information seems to be the consensus of opinion.

The optimum time to score is 2 weeks prior to full bloom to control tree growth, 2 weeks after full bloom to improve fruit set in the current season and 1 to 5 weeks after full bloom to improve return bloom.

The most common technique used is to make two opposing "C" shaped grooves around the leader about 25-30 mm ($1/10^{th}$ of an inch) apart. The two grooves each reach about three-fourths of the circumference of the trunk. The cuts must be deep enough to reach the xylem and wide enough to prevent the wound from healing too soon. A hacksaw blade can be used for scoring older trees.

Chlormequat (Cycocel, C.C.C.)

The use of chlormequat (Cycocel) on pears during the early part of the growing season to reduce shoot growth, to improve flower bud formation and to improve fruit set is well documented. Recent work in Holland showed that the optimum time for the first application of Cycocel in spring to reduce shoot growth is when the new bourse shoots have 5 to 8 leaves showing. Repeat applications during the growing season are often required to reduce the growth. The rate of application is 2-3 liters per hectare and the total amount applied per season should not exceed 6 liters per hectare. The safety period for use of Cycocel is 3 months. Recently it was also established that a postharvest application of Cycocel will increase the strength of the fruit buds and improve fruit set the next growing season. The recommended rate is 2 liters Cycocel in 1,500 to 2,000 liters water per hectare. In Europe pear growers endeavor to further improve fruit bud quality with high dosage foliar applications of urea (20-40 kg urea/ha/treatment). My information is that, in Europe, Cycocel will be allowed to be used only until the year 2000. It will be considered for use beyond this date only if new residue analyses are submitted to the authorities by the manufacturers.

PARTHENOCARPIC FRUIT SET

In Europe, gibberellin treatments to Conference, Durondeau and Comice are often used to stimulate parthenocarpic fruit set when frost damage occurs during bloom. GA_3 or GA_{4+7} treatments are used. In the case of young Conference blocks, gibberellin treatments have been compared in fruit set trials by Belgium workers. Many pear growers combine a half dose of GA_{4+7} (0.6 liters/ha) or Promalin (0.3 liters/ha) with a low dose of GA_3 (2-3 g/ha).

ROOT PRUNING

In the absence of a dwarfing rootstock, another tool to reduce tree vigor is root pruning. In Holland a combination of Cycocel and root pruning is used under very vigorous conditions. Experience in Holland showed that pear roots should be cut closer to the trunk than is customary for apples. The best time to root prune was found to be shortly before full bloom. A small fruit problem is sometimes experienced following root pruning of pears.

Table 1. Differences in growth and fruiting habits between apples and pears (Source: DuPreez and Strydom).

Apples	Pears
For most part, basal dominant.	Base weak, leaders very strong.
Come into production relatively early.	Come into production relatively late.
More responsive to Promalin applications to force proleptic and sylleptic shoot development.	Less responsive to Promalin application to force proleptic and sylleptic shoot development.
When shoots are flattened, the reduction in growth is not strong.	When shoots are flattened, the reduction in growth is very strong.
Red standard mutations normally have the same vigor as original variety.	Red mutations inclined to show less vigor than original variety.
Transplant shock a relatively small problem.	Transplant shock a severe problem.
Many dwarfing rootstocks are available. These dwarfing rootstocks have a wide adaptability.	Few dwarfing rootstocks with a wide adaptability are available.
Suffer more from the specific replant disease.	Suffer less from the specific replant disease.
Once established, tolerate very wet soils worse than pears.	Once established, tolerate very wet soils better than apples.
More prone to wood rotting organisms of the framework.	Less prone to wood rotting organisms of the framework, but trees deteriorate fast after infection.
More prone to *phytophthora* attack.	Less prone to *phytophthora*.
Less prone to *pseudomonas* attack.	More prone to *pseudomonas* damage to buds/flowers.
Prone to woolly aphid attack.	Less prone to woolly aphid attack.
Respond well to N and K fertilization and urea spray.	Poor response to N and especially K fertilization and urea sprays.
Cannot tolerate very sandy or clay soils.	Can tolerate a wide range of soils from sandy to clay.
Buds not easily damaged during lifting in the nursery.	Buds easily damaged during handling in the nursery.
Flowers relatively attractive to bees.	Flowers relatively unattractive to bees.

Relatively few problems with flowers of individual varieties having a short effective pollination period.	A number of varieties show the problem of a short effective pollination period.
The "king flower" (the flower opening first in the cluster and occupying the dominant position) sets the easiest and develops into best fruit.	Not a definite "king flower" recognizable and the flower opening first does not necessarily give rise to the best fruit.
High yields when in full production (more than 60 tons/ha) are easy to obtain.	Not so easy to obtain very high yields. Yields of 50 tons/ha are considered to be very high.
Fruit damage caused by high winds relatively unknown.	Fruit damage caused by high winds can be severe.
Mechanism of red color development in fruit is relatively well understood.	Mechanism of red color development in fruit is relatively poorly understood.
Light is more important for color development. Ambient temperatures 2 weeks before harvest also play an important role.	Light plays the more important role with regard to red color development of fruit.
The ripening behavior of fruit is predictable and it is relatively easy to "manage" the ripening behavior of fruit.	The ripening behavior of fruit is less predictable and it is relatively difficult to "manage" the ripening behavior of fruit.
Less prone to shoot:fruit competition with regard to fruit set.	More prone to fruit:shoot competition with regard to fruit set.
Less responsive to in-bloom sprays of boron with regard to fruit set.	Respond positively to boron sprays in bloom with regard to fruit set.
Cultar widely used as growth retardant.	Cycocel widely used as growth retardant.
Not very responsive to GA_3 to increase set.	Some varieties very responsive to GA_3 to increase set.
Many reliable chemical thinning programs are available.	Very few reliable chemical thinning programs are available.
Varieties are very willing to produce flowers on 1-year-old wood.	Many varieties do not produce flowers on 1-year-old wood.

Table 2. Production of central leader Packham's Triumph trees on BP_1 rootstock at different planting distances (t/ha). The semi-commercial trial was planted in 1983 in South Africa.

		Production (t/ha), years 6 to 10				
Planting distance (m)	Trees/ha	6	7	8	9	10
4.5 x 2.5	889	9	6	36	36	120
4.5 x 1.75	1270	12	9	46	37	75
3.5 x 1.75	1633	9	10	37	76	79
3.5 x 1.50	1905	16	26	45	47	100
3.5 x 1.25 x 1.25	3368	20	25	86	81	118
3.5 x 1.25 x 0.75	5614	64	70	114	112	160

Table 3. The influence of different treatments on bud break of newly planted Beurre Bosc trees.

Treatment	Number of laterals per 100 cm (39 inches) of trunk length
Winter heading (7/23)	5.6
Delayed heading (9/18)	10.0
Delayed heading (10/7)	12.2
Delayed heading (9/18) plus Promalin 500 ppm	10.7
Delayed heading (9/18) plus notching	10.9