Management of High Density Pear Orchards

T. Deckers and H. Schoofs

RSF - Royal Research Station of Gorsem*, Sint Truiden, Belgium

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The longevity of a pear orchard in comparison with an apple orchard is much longer. A 10-year-old apple orchard is considered an old orchard with problems of insufficient fruit quality (fruit size and/or fruit color) and should be replaced. A high density pear orchard at the age of 10 years is still a young orchard that comes into optimal productivity for a period of at least 20 years. The higher the plant density, the more difficult it will be to keep the orchard in the productive phase. In this paper we discuss different planting systems for high density pear orchards and the problems of excessive vegetative shoot growth that often occur during an "off" year after frost damage. Crucial in the management of high density pear plantings is the definition of good flower bud quality with a high potential for fruit set.

PLANT MATERIAL

For pear trees planted in high density planting systems the quality of the planting material should be high. It should be a 2-year-old tree with six to eight laterals obtained by pruning back the 1-year-old trees in the fruit tree nursery. There is an important difference in productivity between a 1-year-old feathered tree and a 2-year-old feathered tree during the first year after planting. When a 1-year-old whip is planted, the productivity will be delayed by a period of 2 years during which the frame of the tree has to be developed. For intensive high density pear plantings only 2-year-old trees are recommended. All the laterals should not be kept at the start but should be reduced to the final number wanted in the planting system, e.g., two in the free spindle or four in the V-hedge system. Delaying this reduction in number of laterals to a later date, when the trees are 4 to 5 years old, is risky and can cause a problem of a silver leaf attack. Many times this silver leaf attack is a reaction to a physiological stress situation (heavy pruning cuts) and cannot be related to the fungal attack of *Stereum purpureum.*

HIGH DENSITY PLANTING SYSTEMS FOR PEAR

There are tree planting systems that are very well adapted for high density pear orchards: the V-hedge system, the Tiense hedge system and the free spindle system. A short description of each of these systems is given.

V-Hedge System

In this system we start with 2-year-old pear trees on Quince C rootstock. Four equally developed feathers are chosen and kept as fruiting branches. These branches can be considered as four central leaders on one stem starting at approximately 60 cm (24 inches) above the bud union. The four fruiting branches are not pruned back at planting and are bound on a bamboo stick. At the top of each fruiting branch, the narrow angled shoots are removed in a very early green pinching. In the first year after planting these four central axes are covered with flower buds. Each flower bud can be considered a mixed structure containing the flower bud structure with one or two vegetative buds at the base of the flower bud from where the shoots will start during the second growing season. All the long and strong 1-year-old shoots should be removed at any time. It is clear that the classical flower bud formation on the 2-year-old wood is not important in this pruning system. After 4 years the final height of the trees of about 2.2 m (7.2 ft) is reached and then the prolongation shoot is pruned back into the dormant buds at the base of the shoot. This pruning results in a limited growth reaction of two to three shoots starting from the dormant buds. During the next winter, this pruning can be repeated by pruning back on the lowest growth reaction and by pruning again into the dormant buds. The concept is to keep the vegetative growth on this place

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in the tree and that the apical dominance from these terminal shoots controls the other growth reactions on the same branch. The productivity in this V-hedge system is based on flower buds on short spurs and on bourse shoots on the four central leaders.

The planting distance in the V-hedge system is 3.5 x 1.25 m (11.5 x 4.1 ft) which means 2057 trees/ha (833 trees/acre). The opening of the V is 1.4 m (4.59 ft) at 2 m (6.56 ft) height. There are more intensive V-planting systems with 3.2 x 0.8 m (10.5 x 2.62 ft) planting distance with 3516 trees/ha (1423 trees/acre) and with a more narrow opening of 1.2 m (3.94 ft). Under our climatological circumstances it is difficult to allow sufficient light penetration in these more intensive V-hedges so flower bud formation is more variable in the intensive V-hedge systems. A disadvantage of this V-hedge system is the high amount of labor which is necessary.

Tiense Hedge System

In this system we start with 2-year-old trees on Quince Adams rootstock also with at least four equally developed feathers on one stem. Two feathers are placed at planting in the row direction and attached on a wire. The two other feathers are placed perpendicular to the row direction and should help to bring the trees into early fertility. The central leader is pruned back to about 70 cm (27 inches) above the lowest scaffold branches and the narrow angled growth reactions to that pruning cut are used to form the second level of scaffold branches. This operation is repeated for level three and four of the scaffold branches. Only two scaffold branches are kept on each level and they are bound onto the wire structure. The fruit is hanging predominantly on the short fruiting spurs on these limbs and these structures are renewed by pruning them once they get older. The top of the tree is composed of the last two scaffold branches. The planting distance in this hedge system is 3.5 x 1.75 m (11.5 x 5.7 ft) which means 1632 trees/ha (661 trees/acre).

Free Spindle System

In this system we also start with 2-year-old trees on Quince Adams rootstock with many well-developed feathers. At planting the number of laterals is limited to two feathers in the direction of the row which are chosen with a distance of about 15 cm (5.91 inches) on the central leader. These two laterals are tied to an angle of about 45°. The central leader as well as the two laterals is left unpruned. At the end of the unpruned central leader, competing laterals will develop and they have to be removed in a very early stage at a length of about 10 cm (4 inches).

The many flower buds on the central leader and on the laterals result in early productivity and also in a good start for horizontal branches starting from the bourse shoot. The first growth reaction on these flower buds will be a short bourse shoot of 10 to 15 cm (4-6 inches) ending on a flower bud. The next year this short brindle shoot will develop to a long shoot of more than 50 cm (19.7 inches). And in the third year this long shoot will be covered again with short brindle shoots.

This sequence of short–long–short shoots on the central leader is very important for the free spindle training system. The fruit bearing wood is systematically renewed as much as possible by keeping strong 1-year-old shoots that are covered with flower buds in the second year and will bear fruit during the third year.

When the trees are in a good balance between vegetative and generative growth there will be part of the flower buds on the 2-year-old wood in lateral position. These flower buds are later in phenological development which is an important factor when frost damage occurs. The productivity of the trees in the free spindle system is mainly on the short brindle shoots on the 2-year-old wood and on spurs on the bourse structures. In this training system the fertility of the flower buds on the 2-year-old wood is important. Conservation of some upgrowing new growing shoots leads to differences in branch diameter and indicates the way of natural growth of the fruit tree. These differences in twig diameter are more accentuated during the season by the natural bending tendency of the twigs under the weight of the leaves on the 1-year-old shoots and under the weight of the fruits in terminal position on the fruit bearing twigs.

The planting distance in this system is 3.75 x 1.5 m (12.3 x 4.9 ft) which means 1777 trees/ha (719 trees/acre). An advantage of this system is the relatively low amount of labor needed for training and pruning.

FLOWER BUD QUALITY

There are important differences in flower bud quality on pear trees. The best flower bud quality on pear trees can be found on the terminal flower buds on the short brindle shoots (Table 1).

The highest number of flowers per cluster was found on the flower clusters in terminal position on the 1-year-old wood with more than 10 flowers per cluster. The number of flowers per branch can vary considerably between years when counted on comparable places in the tree. Sometimes the crop load can explain these differences but sometimes there are other determining factors such as climatological factors. For the flower buds on the 1-year-old wood the growth situation on the shoots has an important influence: late regrowth reactions during season can be very negative for flower bud formation on the 1-year-old wood.

The number of flowers per cluster is an important parameter of flower bud quality. The highest number of flowers per cluster can be found on the terminal buds of the short brindle shoots. In some years the number of flowers on this place varies between 10 and 15 flowers per cluster while the flower buds on the 2-year-old wood have only 5 to 7 flowers per bud.

The number of leaves is also an important flower bud quality criterion. Flower buds without leaves have a very low fruit set capacity; they occur on the 1-year-old shoots with late regrowth reactions; there is apparently a competition between this regrowth and the flower bud formation. The presence of a bourse shoot at the base of a flower cluster significantly increases the leaf area of a flower cluster. These leaves around the flowers increase the fruit set capacity of the cluster.

The total weight of a flower bud also can be a good indication for flower bud quality and can be determined on different phenological stages.

Internal flower bud quality criteria also exist. The number of seeds per fruit is

TABLE 1

Flower bud quality on young Conference pear trees.

	# flower clusters/fruiting branch			# flowers/cluster		
	1998	1999	2000	1998	1999	2000
on 2-year-old wood	8.10	4.15	9.63	6.29	4.91	6.05
on 1-year-old wood						
in lateral position	7.05	1.85	1.12	7.25	6.68	3.23
in terminal position	0.95	0.85	0.19	11.99	9.75	5.13

important for the normal fruit development; this number should be ten under normal pollination conditions but is often much lower in reality. For pear cultivars such as Conference a total parthenocarpic fruit set is possible when the seeds are destroyed in an early stage during night frost. Parthenocarpic fruits of Conference are 5 to 10 mm (0.2 to 0.4 inches) smaller in fruit size than standard fruits with seeds of the same pear cultivar. The number and the dimensions of the styles and the anthers are good indications of flower bud quality on pear trees. The number of styles is normally 5 and the number of anthers is normally 20. Flowers with weaker flower bud quality often show a reduced shape of styles and/or anthers. Also the length of the flower stalk is a quality criterion. Flowers with a short stalk have a very low fruit set capacity. Some flower bud quality parameters are not visible such as the longevity of the nucellus. For the pear cultivar Doyenné du Comice this longevity of the nucellus is limited in time and is one of the reasons for the difficult fruit setting of this cultivar (Demayer and Deckers, 1984). Nitrogen can have a positive influence on the longevity of the ovule and can increase the effective pollination period (EPP).

FLOWER BUD POSITION

Not only the internal structure of a flower bud is important but also the position of the flower bud on a fruiting branch. In our fruit set trials high fruit set percentages are often found for the flower buds in terminal position (Table 2). This is known very well by the pear growers and therefore each fruiting branch is pruned back onto a flower bud on the 2-year-old wood or on a brindle with a terminal flower bud.

There are also important differences in fruit set percentages between years on the same phenological stage. For young pear trees the fruit set percentages of the flowers on the 1-year-old wood in lateral position are also good and the fruit quality of these fruits at harvest is sufficient. For older pear trees there is often a risk for insufficient fruit quality of these fruits with a reduced fruit size. The flower buds on the 1-year-old wood in lateral position can be considered a reserve of flower buds with a delay in phenological evolution of about 2 weeks that can be very useful in years with frost problems during bloom.

FLOWER BUD ORIENTATION

The placement of a flower bud on a fruiting branch determines the development. There is a clear superiority of flower buds on the upper side of the fruiting branch in comparison with the flower buds on the underside of the same branch. This preferential development of structures on the upper side by pear trees is not only true for flower buds but is also present for the development of shoots and bourse structures. In this regard it is important to realize that orientation can change during the vegetation period through the weight of the leaves and/or the fruits. With this process of natural bending, there is often an induction of a growth reaction just before the arc on the fruiting branch. This growth reaction can be considered the future fruiting branch but is also an important factor for vegetative growth control on the whole branch. Rom and Barritt (1990) found on apple trees that there was a better fruit quality (fruit weight) for the fruits produced on buds in the upright position. Volz et al. (1992) confirmed that for Granny Smith there is also a difference in fruit quality between fruits in different positions: the fruits on the 2-year-old wood and on the 1-year-old wood in terminal position are comparable in fruit weight while the fruits on the 1-year-old wood in lateral position were significantly lower. They found also differences in mineral composition of the fruits with the best Ca content for the fruits on the 1-year-old wood in terminal position. This could be linked with a significantly higher leaf area per bloom cluster.

For Conference pear trees, the situation is similar with very good fruit size for the fruits on the short brindle shoots in terminal position and for the fruits produced on well-developed 2-year-old branches pruned back into the flower buds.

The differences in development for different orientations are not only present for the flower clusters but also for the shoot development on a fruiting branch. Brunner and Kecskes (1990) described the branching pattern of apple and pear cultivars as epitonic, while the development of the branches above the horizontal is stronger than under the horizontal. These differences in development of the branches are also reflected in differences in branch diameter and indicate the natural

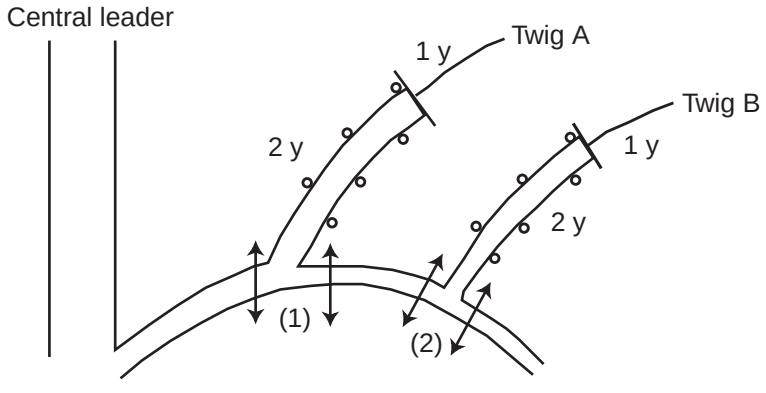
TABLE 2

Fruit set % on young Conference pear trees for flower buds in different positions.

	% fruit set in 1998 after		% fruit set in 1999 after	
	flower drop	June drop	flower drop	June drop
on 2-year-old wood	3.34	0.13	21.51	9.00
on 1-year-old wood				
in lateral position	8.95	2.16	39.70	13.47
in terminal position	11.94	2.24	34.23	11.91

FIGURE 1

Dominant (Twig A) and dominated (Twig B) branches on a fruiting scaffold limb of pear. Twigs A and B are both 2-year-old twigs on an older fruiting limb. On the places (1) and (2) we can see a reduction in branch diameter caused by the presence of Twigs A and B. This reduction in diameter indicates the natural tendency of the branch to grow to Twig A. We consider Twig A the dominant twig. Twig B and all structures farther away from the central leader can be considered dominated structures. Pruning back into the flower buds of the 2-year-old wood during wintertime on Twig A and Twig B will give a totally different growth reaction; the growth reaction will be strongest on Twig A.



growth habits of the tree. These differences in branch diameter should be taken into account during the winter pruning. These branches can be classified as dominant or as dominated structures and the response of the same pruning cut will be totally different when it is made in dominant twig or in dominated branch, even when the branches have the same age (Fig. 1).

EARLY PRODUCTIVITY

For intensive pear orchards early productivity is a must for economical reasons as well as for natural growth control. The first pears should be harvested in the second year after planting with productivity estimated at 3 to 5 kg/tree (6.6 to 11 lb/tree). Gibberellin treatments can help to improve this early productivity on young Conference trees. In Table 3 some results are summarized with different gibberellin treatments applied during full bloom on trees in their second season after planting.

This trial was made on young Conference trees on Quince Adams in the second year after planting. The GA_3 treatment in this trial was made as tablets of 10 g (0.022 lb) each containing 1 g active ingredient per tablet (0.0033 lb). The $GA_{4/7}$ was applied as Regulex, containing 9 g/l $GA_{4/7}$ (0.02 lb). For fruit set improvement, the GA_3 treatment is clearly stronger than the $GA_{4/7}$. The different forms of $GA_{4/7}$ have a comparable positive effect on fruit set. For a fertile pear cultivar like Conference, it is not always necessary to take the strongest fruit set effect. Splitting up the total dose of $GA_{4/7}$ in two treatments, one during full bloom on the 2-year-old wood and one during full bloom on the 1-year-old wood some days later, can be interesting during variable climatological conditions. Also the combination of a low dose of GA_3 and half dose of $GA_{4/7}$ looks promising. On young trees the risk for negative effects on fruit size or on return to bloom is very limited but on adult trees risk should be taken into account.

The global result of these gibberellin applications is different from year to year with sometimes substantial differences but in other years with no differences. The fruit set improvement is only one factor in the whole series of phytotechnical measures that determines the final result.

NUTRITION

Most of the Belgian pear orchards have no possibilities for irrigation or fertigation. Nitrogen and potassium are two important nutritional elements for pear growing in Belgium, nitrogen for an optimal fruit set and potassium for an optimal fruit quality. After the loss of chloormequat (CCC) as growth regulator there is a tendency to reduce nitrogen partially or even completely in Belgian pear growing. This could be negative for the normal fruit set capacity of the flowers which need nitrogen available in the NO_3 form during bloom and immediately afterwards during the process of flower drop and fruitlet drop. Postharvest applications of nitrogen are often used to improve the nitrogen reserve level in the tree and to avoid vegetative growth reactions on the trees. Postharvest nitrogen can be applied by the roots or as a leaf nitrogen application with urea. Part of the nitrogen should always be given some weeks before bloom (20 to 30 kg N/ha; 17.8 to 26.7 lb/acre). This ensures that nitrogen will be available during bloom for optimal fruit set. Early leaf analysis can give useful information on the nitrogen content during the floral and postfloral period.

CONCLUSION

Pear growing in high density plantings is possible with different training systems but there are important differences in labor needed for each system. Planting material for intensive growing should be well-feathered 2-year-old trees with at least 6 feathers. Information on flower bud quality on different structures in the pear tree can help improve the regularity of the yield. The best flower bud quality on pear is found on the terminal flower buds on short brindle shoots. Flower buds in terminal position give higher fruit set percentages than in other positions. Pear trees have an epitonic behavior, which means that the development of flower buds and shoots is better on the upper side of the branches. The use of gibberellins is necessary to guarantee the early productivity of young pear trees. Nitrogen is important for a regular fruit set on young pear trees and should be available during bloom and just after bloom.

TABLE 3

Fruit set improvement on young Conference pear trees with different gibberellin treatments (ns=no significance; *=significance of 95%; **=significance of 99%).

	% fruit set 2 yr wood after		% fruit set 1 yr wood after		
	flower drop	June drop	flower drop	June drop	# pears/tree
1. Untreated	18.4	8.7	25.2	11.5	33.6
2. GA_3 (10 tablets/ha)	35.3 **	25.5 **	32.8 **	19.6 **	44.0 ns
3. $GA_{4/7}$ (1.2 l/ha)	23.7 ns	15.1 ns	23.4 ns	14.7 *	36.4 ns
4. Promalin (0.6 l/ha)	22.2 ns	15.1 *	25.9 ns	14.6 ns	37.1 ns
5. GA_3 (10 tabl.) + $GA_{4/7}$ (0.6 l/ha)	27.1 *	18.1 **	27.8 ns	20.5 **	34.6 ns
6. $GA_{4/7}$ (2 x 0.6 l/ha)	24.9 ns	16.7 *	32.5 **	20.1 **	39.9 ns

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