Economic Evaluation of High Density versus Standard Orchard Configurations; Case Study Using Performance Data for 'Golden Russet Bosc' Pears

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Abstract

Interest in size-controlling rootstocks and high-density plantings has recently increased among U.S. pear growers. A replicated trial was performed in a commercial orchard to evaluate the performance of 'Golden Russet Bosc' on five training systems and nine rootstocks. Trees grafted onto 'Old Home' x 'Farmingdale' (OHxF) 69, 97, 217, 333 and 513, and *P. betulaefolia* rootstocks were planted in May 1993. Seedlings of OHxF 40 and 87 and Quince BA29C/Comice interstem were simultaneously grafted to 'Golden Russet Bosc'. Final height of freestanding trees was approximately 4.5–4.7 m, while the Tatura height was limited to 2.7 m to avoid use of ladders for pruning and harvest. No fruit thinning was performed, as is normal in California. From 1996–2002 (4th–10th leaf) the calculated average per hectare gross returns showed the Tatura trellis and parallel hedgerow to be the best performing training systems and OHxF 69 the best performing rootstock. Tatura trellis/OHxF 69 was the best performing combination. In 2005 (13th leaf), there were no differences among training systems. OHxF 69 and 97 were the highest grossing rootstocks and Tatura trellis/OHxF 69 still the highest grossing combination. Productivity data derived from trial yields was utilized to develop a set of three economic analyses comparing high density plantings to standard spaced plantings. Overall, the high density plantings came into production sooner, showing an estimated profit in year 6 compared to year 9 for the standard planting, and reached 56 tonnes per hectare at full production compared to 45 tonnes for the standard planting, an increase in profit of $10,378 per hectare. Establishment costs were recovered in year 10 for high density systems versus 21 years for the standard spaced planting.

INTRODUCTION

High density pear orchards (1000 – >4000 trees per hectare) are widely present in many Western European countries and are increasingly being adopted in other pear growing regions (Palmer, 2002; Sansavini and Musacchi, 2002). The major reason for this is the prospect of earlier return on establishment investment, but other reasons include: 1) mechanized orchard operations that require closer spacing and smaller trees and 2) more efficient use of land as land values increase (Westwood, 1993). High density orchard systems are most successful if there are productive, vigor-controlling rootstocks available. Unlike apples, there are few rootstocks available for pears that both control vigor and offer economic yields. Quince (*Cydonia oblonga* (L.)) is the most widely utilized rootstock for this purpose, and its use has enabled high density orchards in some parts of

Europe (Johnson et al., 2005).

The situation is quite different in the United States. There are very few high density orchards due to 1) historical availability of inexpensive migrant labor willing to perform orchard operations from ladders, 2) reluctance to replant existing orchards due to declining economic returns, and very importantly, 3) lack of acceptable or suitable size-controlling rootstocks (Elkins et al., 2007). Quince is utilized mainly for ‘Doyenne du Comice’ (‘Comice’), but is incompatible with ‘Bartlett’ (Williams), ‘Anjou’ and ‘Bosc’ (the three major commercial U.S. cultivars) without an interstem. Quince is also very susceptible to fire blight and cold injury. Quince BA29C is considered the best available choice due to its reputed superior vigor compared to Quince A and C (Westwood, 1993).

The clonal ‘Old Home’ × ‘Farmingdale’ series offer an alternative choice. Several selections have recently become more widely available due to their perceived precocity and vigor-controlling characteristics, though data is still limited. Selections 87 and 97 are the most commonly used, and there is increasing interest in OHxF69 (Reil et al., 2007).

The need for size controlling rootstocks, as well as lack of data on available choices led to a replicated trial in a commercial pear orchard to evaluate the performance of ‘Golden Russet® Bosc’ (‘Bosc’) on five training systems and nine rootstocks from 1996–2002 (Elkins and DeJong, 2002). The trial was re-evaluated in 2005 (year 13) in order to ascertain any change in rootstock and/or training system performance. Trial results were then incorporated into three comprehensive cost and return studies to compare high density versus standard planting densities (Elkins et al., 2006a, b, c). Two different propagation systems, standard and sleeping eye (dormant budded) trees, were also compared.

MATERIALS AND METHODS

Two-year-old nursery trees of ‘Bosc’ grafted on clonal ‘Old Home’ × ‘Farmingdale’ (OHxF) 69, 97, 217, 333 and 513, and *P. betulaefolia* were planted in May 1993 on a sandy clay loam soil in Kelseyville, Lake County, California. Ungrafted clonal OHxF40 and 87 and Comice/Quince BA29C trees were planted at the same time as grafted ‘Bosc’ trees were unavailable. The OHxF and ‘Comice’/29C interstem trees were grafted to ‘Bosc’ in June 1993 and fruiting was thus one year behind the other selections. Trial design was a randomized complete block, with nine single-tree scion/rootstock combination replicated five times on each of five different training systems, for a total of 45 training/rootstock combinations. Spacing was 5 x 3 m (797 trees/ha) for the central leader, three-leader, and parallel hedgerow “palmette-type” (grower system) training systems, and 1.5 x 5 m (1,594 trees/ha) for the freestanding perpendicular fan and Tatura trellis systems (DeJong et al., 1994; Elkins and DeJong, 2002; Elkins et al., 2007). The Tatura was formed by heading single trees at planting, rather than double planting. Four systems received delayed heading, pinching of upright and narrow, angled young shoots, selective limb tying, and summer pruning. The parallel hedgerow (grower system) was exclusively dormant pruned by the grower and received intensive limb tying through the season. Final height of free standing trees was approximately 4.5–4.7 m, while Tatura trellis height was limited to 2.7 m to maximize sunlight penetration and avoid use of ladders. Trunk circumference and tree height was measured from 1994–1999. Total yield and fruit number per tree was measured from 1996–2002 (4^{th}–10^{th} leaf) and yield per hectare, yield efficiency and gross economic return calculated (Table 1a). Data were collected again in 2005 (13^{th} leaf) for only those rootstocks showing acceptable size control (OHF 40, 69, 87, Q. BA29C) and OHF 97 as a standard and with the assumption all trees were now at stable full bearing (Table 1b). Results were subject to ANOVA and where significant differences were observe the means compared using Tukey’s HSD ($p=<.05$).

Three alternative establishment and production cost and return analyses were developed for specialty pears: 1) high density planting using sleeping eye (dormant-budded) trees; 2) high density planting using standard (2-year-old grafted) trees; and 3) standard-spaced planting using standard trees (Elkins et al., 2006a, b, c). Study parameters included total planting costs, cultural costs during establishment years, yield and returns, and associated harvest costs. Pest management, irrigation and fertility practices and costs were assumed to be equal. Accumulated net returns above operating costs were calculated for each system. Yields were based on trial results for the best performing combination of trellis system and root stock for the high density systems. Production costs were based on theoretical data from other crops with similar type plantings rather than actual pear farming operations. No specific cultivar was utilized but examples might include 'Bosc', 'Comice', 'Seckel', or 'Red Clapp's Favorite'. High density spacing was 1.7 x 4.7 m for double trees, (1,538 t/ha) and the standard planting 3.3 x 6 m, (532 t/ha). Orchard life was assumed to be 30 years. The studies used a cost of $6.40 U.S. each for standard trees and $2.50 U.S. for sleeping eye trees. High density trees were trained on an Open Tatura trellis system with one tree planted on each side of the trellis row (double trees) and maintained at a 2.7 m height. A bamboo stake was placed by each sleeping eye tree for support.

RESULTS AND DISCUSSION

Data is shown for each training system and rootstock overall. From 1996 through 2002, the average highest grossing training systems were Tatura trellis and parallel hedgerow, OHxF69 the highest grossing rootstock (Table 1a), and Tatura/OHxF69 the highest grossing combination (data not shown). In 2005, there was no difference among training systems; however, OHxF69 and 97 were the highest grossing rootstocks (Table 1b). The highest grossing combination was again Tatura trellis/OHxF69 (data not shown).

Based on these overall results, Tatura trellis/OHxF69 and three leader/OHxF69 trial yield data were chosen to provide the basis for comparative economic analysis. The high density/standard tree system incurred the highest planting costs due to cost of trees ($33,482/ha), followed by high density/sleeping eye ($21,947/ha) and standard density/standard ($13,279/ha) (Table 2). Maximum yields for the standard density plantings were based on industry average and assumed at 45 tonnes/ha, with 36 tonnes fresh fruit and 9 tonnes by-product. Yields for the mature high density orchards were assumed to reach 56 tonnes/ha with 50 tonnes fresh fruit and 6 tonnes processed based on the trial results for the best performing combination of trellis system and rootstock, Tatura trellis/OHxF69 (data not shown). Sleeping eye trees came into bearing more slowly than standard trees and the high density/standard came into bearing earlier than the standard density/standard trees (Fig. 1). Positive net returns were achieved in year 6 for high density/standard trees vs. year 10 for standard/standard trees (Fig. 2). Accumulated net returns above operating costs were positive for the high density/standard trees in year 10, for the high density/sleeping eye trees in year 14, and for the standard density/standard trees in year 21 (Fig. 3).

Although cost of establishing the high density, trellised orchard was 152% higher than for the standard density planting using standard trees, utilizing the combination of Tatura trellis and a compatible, precocious rootstock such as OHxF69 paid for the cost of investment in 10 years, 11 years sooner than for standard planting densities using the same rootstock. Sleeping eye trees, while costing $3.50 less than standard trees, required more replacement trees and intensive training, thus negating the benefit of lower purchase price.

The above results suggested that pear growers could achieve early, high yields and relatively rapid return on investment by utilizing the Tatura trellis/OHxF69 combination. Actual returns will depend on multiple factors, particularly planting site and cultivar choice, which will in turn depend on market demand. Seasonal environmental factors, cultural practices and management decisions will also influence final returns.

Trial data also showed that it is useful to challenge candidate rootstocks on varying training systems to ascertain field performance. Future research and economic analyses should focus on comparing differences in labor (harvest, pruning, etc.), pest management, fertility and irrigation practices and costs. Overall cultural costs should theoretically be less with smaller, trellised trees, thus leading to further cost savings and even earlier accumulated return on investment, provided the tree canopy is managed to optimize light interception.

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Tables

Table 1a. Effect of training and rootstock on average yield, fruit size, yield efficiency and calculated return of 4 to 10-year-old 'Golden Russet Bosc' pear trees, Lake County, California, 1996–2002.

	Fruit per tree (no.)	Fruit weight (kg/tree)	Fruit size (g/fruit)	Yield (tonnes/ha)	Yield efficiency (kg/cm²)	Yield efficiency (height) (kg/m)	Average gross calculated return ($ per ha)	Accum. gross calculated return ($ per ha)
Training[1,2]								
Central leader	111 b	26.7 b	230	21.2 b	.27 ab	6.0 b	22,888 b	160,219 b
Three-leader	113 b	26.3 b	218	21.0 b	.24 b	6.2 b	22,471 b	157,294 b
Parallel hedgerow	147 a	33.9 a	233	27.0 a	.30 a	8.0 a	28,510 a	199,571 a
Free-standing "fan"	55 d	13.2 d	228	21.1 b	.16 c	3.3 c	23,087 b	161,610 b
Tatura trellis	84 c	18.4 c	221	29.5 a	.26 b	7.2 ab	29,873 a	209,111 a
Rootstock[1,2]								
OHxF 69	123 a	27.5 a	223 abc	27.9 a	.28 ab	7.2 a	29,011 a	203,075 a
OHxF 97	98 b	24.1 ab	235 ab	24.3 ab	.23 bc	6.2 ab	26,423 ab	184,964 ab
OHxF 217	91 b	22.7 ab	240 a	22.9 ab	.24 abc	5.6 ab	24,961 ab	174,729 ab
OHxF 333	107 ab	23.4 ab	212 c	23.9 ab	.28 a	6.5 ab	24,370 ab	170,590 ab
OHxF 513	89 b	20.3 b	220 bc	20.8 b	.22 c	5.6 b	21,933 b	153,529 b
P. betulaefolia	105 ab	24.3 ab	225 abc	24.1 ab	.23 abc	5.8 ab	25,497 ab	178,479 ab
ANOVA[3]								
Block	NS	NS	NS	NS	NS	NS	NS	NS
Training	***	***	*	***	***	***	***	***
Rootstock	***	*	***	**	***	*	**	**
Training x Rootstock	NS	NS	NS	NS	NS	NS	NS	NS

[1]Data is shown for each training system and rootstock overall. Data not shown for each training system/rootstock combination.

[2]Within columns, training or rootstock treatment means significantly different (Tukey HSD multiple range test, P≤0.05).

[3] *, **, *** Indicate significance at P ≤ 0.05, 0.01, and 0.001 respectively. NS indicates not significant (P>0.05).

Table 1b. Effect of training and rootstock on yield, fruit size, yield efficiency and calculated return of 13-year-old 'Golden Russet Bosc' pear trees, Lake County, California, 2005.

	Fruit per tree (no.)	Fruit weight (kg/tree)	Fruit size (g/fruit)	Yield (tonnes/ha)	Yield efficiency (kg/cm^2)	Yield efficiency (height) (kg/m)	Calculated gross return ($ per ha)
Training[1,2]							
Central leader	122 bc	28.4 bc	231	22.5	.13 bc	6.1 ab	44,234
Three-leader	180 a	38.7 a	216	30.6	.19 a	8.4 a	59,112
Parallel hedgerow	154 ab	33.7 ab	225	26.9	.17 ab	7.3 a	52,927
Free-standing "fan"	103 c	21.3 cd	215	33.8	.13 bc	4.7 b	64,809
Tatura trellis	79 c	17.6 d	228	28.3	.11 c	6.6 ab	55,665
Rootstock[1,2,4]							
OHxF 40	116 ab	25.1 bc	224	23.5	.17	5.8 b	45,867 b
OHxF 69	150 a	33.8 ab	233	35.7 ab	.14	8.3 a	70,413 a
OHxF 87	100 b	21.4 c	219	21.8 c	.15	5.0 b	42,069 b
OHxF 97	157 a	35.4 a	226	35.8 a	.13	8.2 a	69,611 a
Quince BA 29C	115 ab	24.0 bc	214	25.2 bc	.13	5.8 b	48,788 b
ANOVA[3]							
Block	NS	NS	**	NS	NS	NS	NS
Training	***	***	NS	NS	***	***	NS
Rootstock	**	***	NS	***	NS	***	***
Training x Rootstock	NS	NS	NS	NS	NS	NS	NS

[1]Data is shown for each training system and rootstock overall. Data not shown for each training system/rootstock combination.

[2]Within columns, training or rootstock treatment means significantly different (Tukey HSD multiple range test, $P \leq 0.05$).

[3] *, **, *** Indicate significance at $P \leq 0.05$, 0.01, and 0.001 respectively. NS indicates not significant ($P > .05$).

[4]OHxF40, OHx87, and Quince BA 29C initial fruiting one year behind OHxF69 and 97.

Table 2. Comparison of planting costs, specialty pears, high density versus standard plantings, Lake and Mendocino Counties, 2006.

Spacing	Tree type	Trees per hectare	Tree cost per hectare ($)	Trellis open v cost ($)	Total cost per hectare ($)
High density	Sleeping eye	3,073	7,682	4,199	21,300
High density	Standard	3,073	7,962	4,199	33,004
Standard	Standard	598	3,826	---	13,160

Figures

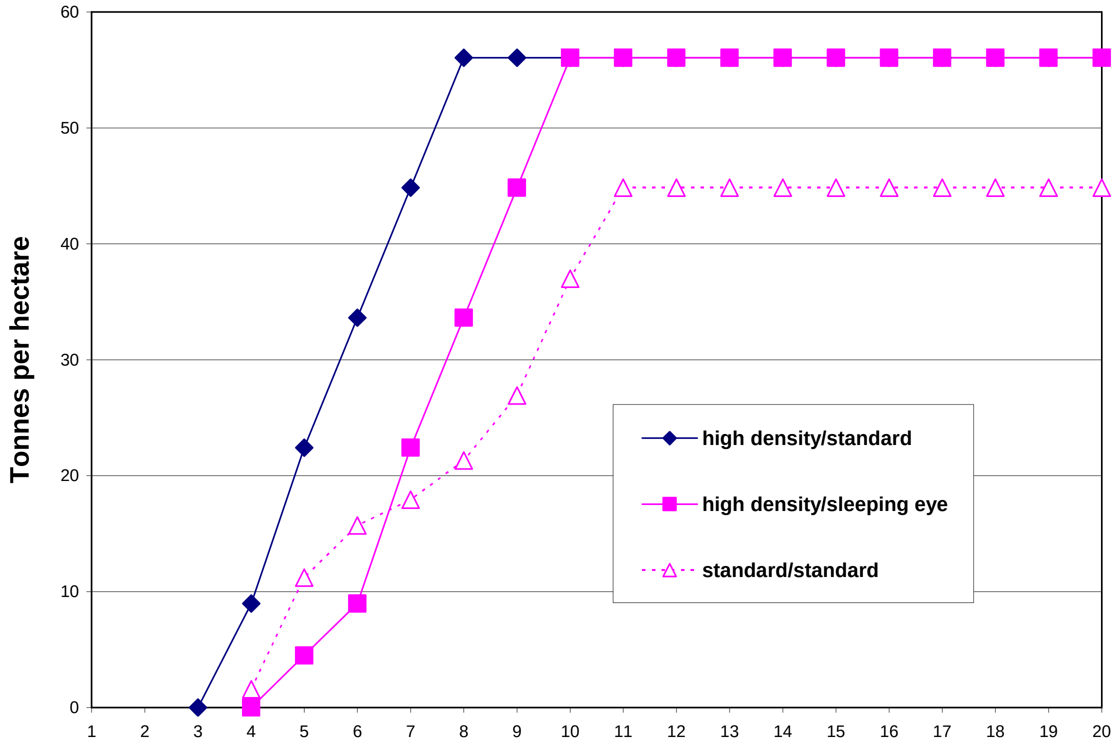

Fig. 1. Expected yields per hectare for high density versus standard plantings of specialty pears, Lake and Mendocino Counties, California, 2006.

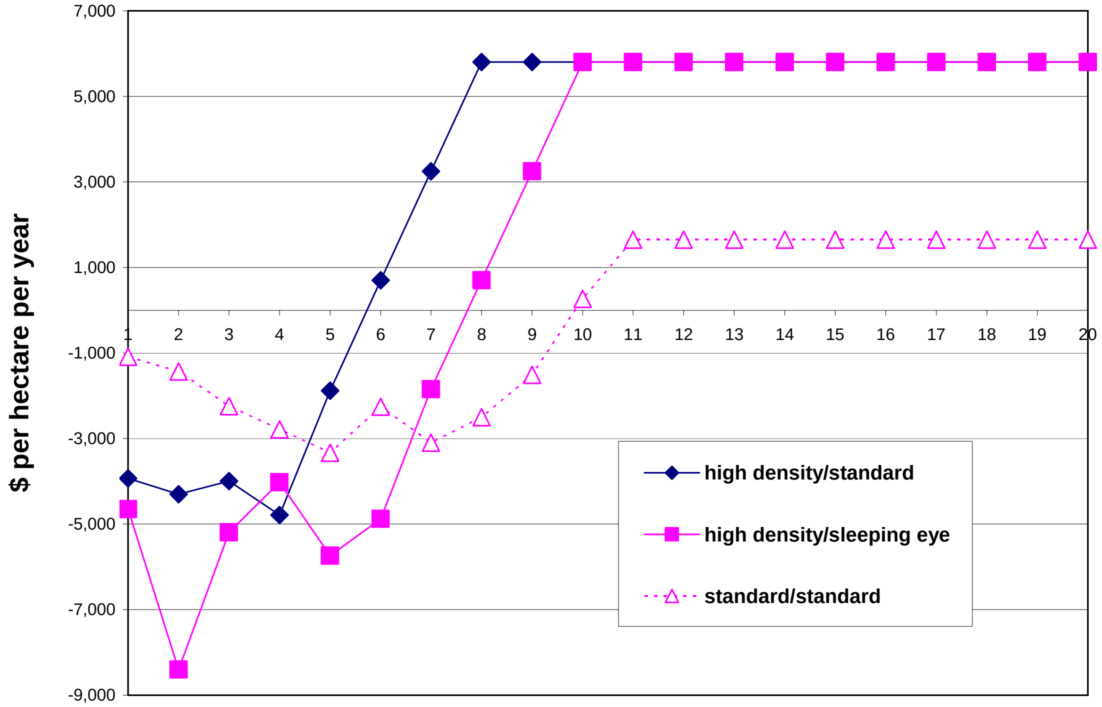

Fig. 2. Expected net returns above operating costs per hectare for high density versus standard plantings of specialty pears, Lake and Mendocino Counties, California, 2006.

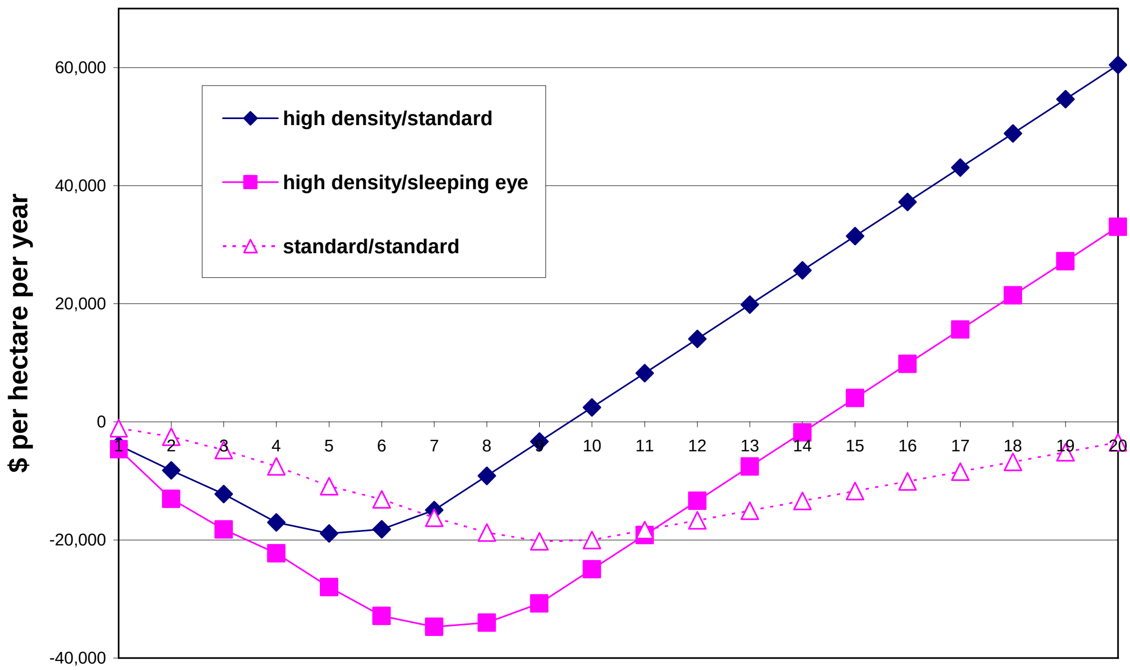

Fig. 3. Expected accumulated net returns above operating costs per hectare for high density versus standard plantings of specialty pears, Lake and Mendocino Counties, California, 2006 (omits cost of buildings, tools, irrigation system, fencing, land and equipment).