Performance of 'Golden Russet Bosc' Pear on Five Training Systems and Nine Rootstocks

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Abstract

A replicated trial was established in a commercial orchard to evaluate the performance of 'Golden Russet Bosc' (GRB) on five training systems and nine rootstocks (45 combinations of five single tree replicates). The first group of trees consisted of 2-year-old nursery- trees grafted on clonal rootstocks Old Home x Farmingdale (OHxF, Brooks series) 69, 97, 217, 333 and 513 and seedling rootstocks *Pyrus betulifolia*, planted in May 1993. The second group consisted of 1-year-old OHxF 40, 97 rootstocks and 2-year-old Comice/Quince BA29C interstem trees field-grafted to GRB at planting time. Tree spacing the different systems was 1.5×5 m (797 t/ha) for the freestanding perpendicular fan and the Tatura trellis systems, and 3×5 m for the central leader, 3-leader, and parallel hedgerow systems. Final tree height was approximately 4.5-4.7 m for the freestanding trees and 2.7 m for the Tatura trellis. No fruit thinning was performed and delayed heading and summer pruning were performed on all systems except the parallel hedgerow which was managed with typical grower's practice of dormant pruning only. Of the first group, Tatura trellis and parallel hedgerow training systems had the highest accumulated gross returns (AGR) from 1999-2002, as well as significantly higher light interception and subsequently higher yields per hectare. OHxF 69 had the highest AGR of the six rootstocks, and the combination of Tatura trellis/OHxF 69 the highest AGR of all combinations. In 2005, there were no significant differences in gross return among training systems or combinations, however OHxF 69 and 97 grossed significantly higher among rootstocks based on yield. The second group of rootstocks, though only one year behind the first group, failed to attain equivalent yields or returns by 2005, indicating either inherent lesser qualities than the first group of rootstocks, or persistent effects of competition. Rootstock performance varied with training system.

INTRODUCTION

High density orchard plantings are common worldwide and are being increasingly considered in the United States to enable earlier returns on investment. Pears are particularly problematic as there are very few *Pyrus* size controlling and/or precocious rootstocks to control excessive vigor and induce early crops (Elkins et al., 2007).

In the early 1970s Australian researchers at the Irrigation Research Institute in Tatura, Victoria, Australia, developed a trellised high density "V" system they named the 'Tatura trellis'. This system was designed to 1) efficiently capture sunlight and 2) reduce labor costs by either permitting mechanized cultural operations or eliminating the need for ladders for pruning, thinning and harvest (Chalmers et al., 1978). Most research in Australia has combined the Tatura trellis with *Pyrus calleryana* seedling rootstock (van den Ende, Chalmers and Terie, 1987; van den Ende, 2008). *P. calleryana* is rarely planted in the United States due to its variable growth habit and propensity to harbor pear psylla, the major vector of the mycoplasma causing pear decline disease (Reil et al., 2007).

Interest in testing the Tatura trellis as a high density option for new orchards in northern California was a major impetus for establishing a replicated trial to evaluate 45 training system and rootstock combinations. Rootstocks were selected based on potential for early bearing and potential commercial availability in western United States. Of the selected rootstocks, none had been tested on Tatura trellis in Australia, although several were tested in Oregon (Sugar and VanBuskirk, 1994; Mielke and Seavert, 1994). Seven commercially available selections of 'Old Home x Farmingdale' (OHxF) (Brooks selections) clonal rootstocks (Westwood et al., 1976) were chosen and compared to Quince BA29C, a known size-controlling standard, and *P. betulifolia*, a standard rootstock for clay soils.

The Tatura trellis was compared to other standard and alternative training systems in order to determine its relative potential. These included central leader, 3-leader, a tall palmette-type system referred to as the parallel hedgerow, used in the cooperating grower's orchards, and the Kearney Agricultural Center Perpendicular "V" (KAC-V). The KAC-V, developed for peaches, was modified to a perpendicular "fan" and planted as free-standing trees at the same density as the Tatura trellis in order to determine whether early yields could be obtained without incurring the installation costs of the trellis (DeJong et al., 1994).

MATERIALS AND METHODS

Two-year-old nursery trees of 'Golden Russet Bosc' (GRB) grafted on 5 clonal rootstocks from the 'Old Home x Farmingdale' (OHxF) series (69, 97, 217, 333, and 513), and on *P. betulifolia* were planted in May 1993 on a sandy clay loam soil in Kelseyville, Lake County, California. Ungrafted clonal OHxF 40 and 87 and Comice/Quince BA29C interstem trees were planted at the same time and were grafted to 'Bosc' in June 1993 after planting. The trial design was a randomized complete block, with nine scion/rootstock combinations each replicated five times on the five different training systems, for a total of 45 training system/rootstock combinations. The five training systems were: Central leader system (spacing 5×3 m = 797 trees/ha), 3-leader system (spacing 5×3 m = 797 trees/ha), parallel hedgerow system (spacing 5×3 m = 797 trees/ha) freestanding perpendicular fan system (spacing 1.5×5 m = 1,594 trees/ha) and Tatura trellis systems (spacing 1.5×5 m = 1,594 trees/ha) (DeJong et al., 1994; Elkins and DeJong, 2002; Elkins et al., 2007). The Tatura was formed by heading trees at planting, to develop two scaffold arms. The other four systems received delayed heading, pinching of upright and narrow, angled young shoots, selective limb tying, and summer pruning. The parallel hedgerow 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 the Tatura trellis height was limited to 2.7 m to maximize sunlight penetration and avoid the use of ladders. Trunk circumference and tree height were measured from 1994-1999 and trunk cross-sectional area (TCA) calculated from trunk circumference. Total yield and fruit number per tree were measured from 1996-2002 (4^{th}-10^{th} leaf) and yield per hectare, yield efficiency and average accumulated and annual gross economic returns were calculated. Returns were calculated using FOB prices for 20 kg cartons (USDA-AMS, 1996-2005). Data were collected again in 2005 (13^{th} leaf) for only those rootstocks that had showed acceptable size control from 1996-2002 (OHF 40, 69, 87, Q.BA29C and OHF 97), and with the assumption that all trees were now at stable full bearing. Results were subject to ANOVA and where significant differences were observed the means were compared using Tukey's HSD ($p \leq 0.05$).

RESULTS AND DISCUSSION

Average calculated accumulated gross return from 1996-2002 for the 30 combinations on 2-year-old grafted trees varied significantly among systems and rootstocks (Table 1). The range was from nearly $135,000 to $46,000. Accumulated gross return, number of fruit per tree and yield per tree varied the most; yield efficiency, yield per meter tree height, per hectare yield and average gross return varied less, and fruit size varied the least. Five Tatura trellis/OHxF combinations (69, 97, 217, 333 and 513 in descending order) had the highest accumulated gross returns and annual returns, ranging from nearly $135,000 for OHxF69 to $90,400 for OHxF513. Interestingly, OHxF333 and

513 were also the least profitable in combination with the 3-leader and free standing 'fan' systems ($46,000 and $54,000 accumulated returns, respectively).

The main factors influencing accumulated return were spacing and yield in the early years of the trial (1996-1999). F-ratios for yield per hectare were always highly significant ($p \leq 0.0001$), were largest from 1996-1999 and decreased linearly through 2002. Number of fruit per tree and spacing accounted for most of the differences. Fruit size also was a contributor but exhibited much less variability among combinations (Table 2). Number of fruit per tree was in turn, directly influenced by training system characteristics. The Tatura trellis was trained to the ideal light intercepting and fruit bearing angle with minimal pruning. This contrasted with the perpendicular free-standing fan which, while equally closely-spaced, but required repeated pruning to attain the desired configuration. Light interception measurements taken in 2000 confirmed the light capturing efficiency of the Tatura trellis (data not shown).

Yield efficiency was also somewhat variable, ranging from 0.37 for the parallel hedgerow/OHxF333 to 0.13 for the free standing fan/OHxF513. The fan system accounted for the six lowest combinations, likely due to pruning severity. Cropping efficiency, calculated as a function of tree height was less variable and revealed similar rankings as when calculated using TCA. Efficiency was highest with Tatura trellis/OHxF69 when calculated with tree height while the parallel hedgerow/OHxF333 was the most efficient when calculated using TCA (data not shown).

There were fewer differences among the field grafted trees compared to the finished nursery trees. Accumulated average gross return was much lower than for the field grafted trees, ranging from about $51,000 to about $24,000 per hectare from 1996-2002. Unlike the 2-year old nursery trees, there were no significant differences in gross annual return, as indicated by lack of significant differences in tonnage or fruit size. There were greater differences in per tree yield, based exclusively on number of fruit per tree.

Differences among combinations were also small in 2005 (year 13). Tatura trellis/OHxF69 remained the best performing combination ($97,623), however the perpendicular fan/OHxF97 had the second highest returns ($91,156), suggesting increased bearing in later years. The poorest performing combinations in 2005 were central leader/OHxF87 and Tatura trellis/OHxF40. This suggests that the Tatura trellis may not be ideal choice for some rootstocks, particularly those with less vigor (Tables 1 and 3).

Economic analyses were performed on trial results to ascertain net return to the grower for the Tatura trellis versus a standard planting (data not shown) (Elkins et al., 2008).

CONCLUSIONS

Several conclusions can be drawn from our data:

1) Key factors in achieving high consistent accumulated returns were tree spacing in combination with good light interception and precocity. A factor less clearly defined is physiological compatibility (e.g. match between vigorous/non-vigorous training system and rootstock).
2) Trees on OHxF69 produced early and consistent crops. All rootstocks generally produced the best on Tatura trellis and/or parallel hedgerow and worst on free-standing "fan" and 3-leader systems.
3) The Tatura trellis allows for early bearing, and hence early returns, but may be unsuitable for certain rootstocks (e.g. OHxF40) and/or scion cultivars.
4) Training systems requiring excessive pruning to train reduce early bearing potential, although such systems may eventually bear good crops (i.e. perpendicular "fan").

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Tables

Table 1. Overall performance summary showing the best and worst performances of 'Golden Russet Bosc' pear on 45 training system/rootstock combinations for Lake County, California, 1996-2002 and 2005.

Variable	Significance (Tukeys $p<0.05$)	Combination	
		Best	Worst
2002 accumulated gross return			
Set 1 (2-year old trees of OHxF 69, 97, 217, 333, 513, P.bet.)	***	Tat/69	3-L/513
Set 2 (field grafted trees OHxF 40, 87, Quince BA29C)	NS	PH/40	Fan/40
Average gross annual return			
Set 1	***	Tat/69	3-L/513
Set 2	*	PH/40	Fan/40
2005	***	Tat/69	CL/87, Tat/40
Yield per hectare			
Set 1	***	Tat/69	3-L/513
Set 2	***	PH/40	Fan/29C, 40; CL/29C
2005	***	Tat/69, PH/97	CL/87, Tat/40
Yield per tree			
Set 1	***	PH/97, BET	Fan/69, 217, 333, 513
Set 2	***	PH/40	Fan/29C, 40
2005	***	3-L/69	Tat/40, 87; Fan/40
Fruit per Tree			
Set 1	***	PH/69	Fan/217, 513
Set 2	***	PH/40	Tat/87; Fan/29C, 40
2005	***	3-L/69	Tat/40
Fruit size			
Set 1	***	CL/217	3-L/513
Set 2	NS	No differences	
2005	NS	No differences	
Yield efficiency (based on TCA)			
Set 1	***	PH/333	Fan/97, 513
Set 2	***	PH/40	Fan/29C
2005	***	PH/40	Tat/97, 40
Yield efficiency (based on tree height)			
Set 1	***	Tat/69	Fan/513
Set 2	***	PH/40	Fan/29C, 40
2005	***	3-L/69, Tat/69	Fan/40, Tat/40

Tat=Tatura, CL=Central Leader, PH=Parallel Hedgerow, Fan=Freestanding perpendicular fan, 3-L= 3-Leader.

Table 2. F-values for yield factors, 'Golden Russet Bosc' pear on 45 training and rootstock combinations, Lake County, California, 1996-2002.

Year	F-value of factor				
	Average accumulated return	Average annual return	Yield/ha	No. fruit	Fruit size
1996	5.39	5.39	6.45	4.95	1.34
1997	6.29	5.05	5.05	3.80	1.71
1998	5.64	3.95	4.22	4.79	2.56
1999	5.51	3.81	4.53	6.31	1.64
2000	5.61	2.93	3.03	5.24	1.74
2001	4.97	3.03	3.27	10.40	3.95
2002	2.56	2.33	2.47	7.34	1.61
Avg. 1996-2002	5.14	3.78	4.15	6.14	2.08
2005		2.68	2.54	3.54	1.48

Table 3. Number of instances in which training system and rootstocks performed best and worst among 45 combinations, Lake County, California, 1996-2002 and 2005.

Training system or rootstock	No. of instances	
	Best	Worst
Parallel hedgerow	12	0
Tatura trellis	8	9
3-Leader	3	5
Central leader	1	3
Perpendicular fan	0	20
OHxF 69	11	1
OHxF 40	7	12
OHxF 97	2	1
OHxF 217	1	2
OHxF 333	1	1
P. betulifolia	1	0
OHxF 87	0	4
OHxF 513	0	8
Quince BA29C	0	7