CALIFORNIA PISTACHIO ROOTSTOCK TRIALS: 1989-2000

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EXECUTIVE SUMMARY

Currently, the California pistachio industry relies upon four rootstocks, two species and two interspecific hybrids, all members of the genus *Pistacia*. They are *P. atlantica*, *P. integerrima* (PGI), *P. atlantica* x *P. integerrima* (PGII and UCB-1). The first three are open pollinated, the last a result of closed pollination. All knowledge of these rootstocks prior to this trial is anecdotal. As the industry has matured and new production niches are being explored the climatic and soil adaptability of rootstocks becomes more important. Further, effects of rootstock on yield, nut quality and physiological problems, like alternate bearing, have not been experimentally determined.

PROCEDURES

When these trials were planted and budded, is detailed in Table 1. There are 400 trees, divided into 100, four-tree plots containing one of each of the four rootstocks. Ten of these four-tree plots are grouped into a 40-tree irrigation set. All of the trees are budded with the same female and male. With these locations, and this design, we are attempting to observe the behavior of the different rootstocks under a range of climatic conditions.

Table 1.

Location	**Planted**	**Budded**
Madera County	5/28/88+	+
KAC	2/22/89	7/10/89
Kern County	3/4/89	8/14/89

+This demonstration plot was established independently a year before this trial using budded trees, and a different field design.

RESULTS

Table 2. Effect of rootstock on crop year 2000 yield and grade out. *

	County	UCB	PGII	PGI	Atlantica
2000 Yield/Tree Total Edible Weight 2000 Yield/Acre Total Edible Weight @ 112/Bearing Trees/Acre (kg dry inshell split)	Fresno	17.7a 1982	15.4b 1724	14.8bc 1658	13.3c 1490
	Kern	15.7a 1758	14.3ab 1602	13.2bc 1478	12.0c 1344
	Madera	11.8a 1322	10.2a 1142	10.3a 1154	7.5b 840
% Total Edible Split Inshell; USDA Sample	Fresno	73	70	73	72
	Kern	62	62	59	64
	Madera	74	68	72	71
# Nuts per Ounce	Fresno	23b	23b	24ab	25a
	Kern	23	24	23	22
	Madera	22	233	23	25
Cumulative Yield to 2000	Fresno	9602a	8142c	8614b	6892d
(lbs/acre @ 112 trees/acre)	Kern	11805a	10248b	10269b	8834c
	Madera	7106a	6285b	5643c	4258d

*Values within a row followed by different letters are significantly different. Lack of letters indicates no significant differences within a horizontal row.

CONCLUSIONS AND PRACTICAL APPLICATIONS

As the trees in these plots were budded with Kerman and Peters buds from the same trees all growth and yield differences can be attributed to the rootstock. It is clear that among all the rootstocks UCB-1 produces the highest cumulative early yields. As there are no significant rootstock effects on nut quality or size among the rootstocks these differences in early yield are the result of trees on UCB-1 rootstocks producing more pounds of fruit per tree. This yield increase is the result of more clusters per tree, not more nuts per cluster or larger nuts.

These trials have also confirmed that the climate and soil conditions in the West Side of the southern San Joaquin Valley are better for production of pistachios than those in the central portion of the valley.

We will continue to monitor annual growth, yield and nut quality data in these three field trials. These results will be used to determine if there is a rootstock effect on alternate bearing. This monitoring will also, potentially, identify superior individual rootstocks for further rootstock improvement programs using traditional breeding or clonal propagation.

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SUMMARY

Currently, the California pistachio industry relies upon four rootstocks, two species and two interspecific hybrids, all members of the genus *Pistacia*. They are *P. atlantica*, *P. integerrima* (PGI), *P. atlantica* x *P. integerrima* (PGII and UCB-1). The first three are open pollinated, the last a result of closed pollination. All knowledge of these rootstocks prior to this trial is anecdotal. As the industry has matured and new production niches are being explored the climatic and soil adaptability of rootstocks becomes more important. Further, effects of rootstock on yield, nut quality and physiological problems, like alternate bearing, have not been experimentally determined.

These five rootstock trials were established in the different pistachio production areas of California. The plots are located in Shasta, Fresno, Madera and Kern Counties. The trials were established in 1989 (Table 1) and are now completing their eleventh year in the ground. Previously, these trials demonstrated significant differences among the rootstocks in Verticillium wilt tolerance, freeze tolerance, and micronutrient uptake (Beede, et al., 1991; Epstein, et al., 1992; Ferguson, L., 1990; Ferguson, 1991; Ferguson, et al., 1991; Ferguson and Brown, 1990; Ferguson et al., 1990; Ferguson, et al., 1991, Morgan, et al., 1992). Furthermore, physiological investigations in 1992 (Ferguson, L., et al., 1993) demonstrated these differences in growth rate and early bearing are not the result of differences in the ability of the rootstocks to conduct water to, or affect the photosynthetic rate, of the Kerman scion.

Results thus far, 1989 though 2000, demonstrate significant differences in growth, and early yield, but not in nut quality or size, among the four rootstocks. Trees on UCB-1 rootstocks have consistently produced significantly better cumulative yields within the first eleven years of orchard life than trees on any of the other three rootstocks. Further, these trials demonstrate trees grown on the west side of the southern San Joaquin Valley will consistently produce higher early yields than trees grown in the central San Joaquin Valley, irrespective of rootstock.

PROCEDURES

When these trials were planted and budded, is detailed in Table 1. There are 400 trees, divided into 100, four-tree plots containing one of each of the four rootstocks. Ten of these four-tree plots are grouped into a 40-tree irrigation set. This is to facilitate later irrigation, fungicide, growth regulator, pesticide, or nutrition trials. All of the trees are budded with the same female and male. With these locations, and this design, we are attempting to observe the behavior of the different rootstocks under a range of climatic conditions. This is particularly facilitated by budding with the same clonal material at all the plots. One location, WSFS in Fresno County, has high levels of Verticillium generated in the soil.

Table 1.

Location	**Planted**	**Budded**
Madera County	5/28/88+	+
KAC	2/22/89	7/10/89
Kern County	3/4/89	8/14/89
Shasta County	6/12/89	8/8/90•
WSFS	4/8/92*	*

+This demonstration plot was established independently a year before this trial using budded trees, and a different field design.

•This plot suffered heavy freeze damage in 1990 and is behind the other plots. Therefore, the results are no longer statistically comparable to Kern and Fresno County plots, but the plot is being maintained for demonstration and comparison purposes.

*This plot was terminated in 1991 due to extensive freeze damage and replanted with budded trees in 1992. The results are reported separately as Verticillium tolerance is the main objective of this plot.

As can be seen in Table 1, the WSFS plot was replanted 4/8/92 because damage from the 1990 freeze made the plot statistically invalid. Also, the Shasta County plot sustained heavy freeze damage in both 1989 and 1990 and therefore growth measurements are statistically invalid as individual trees are in different stages of rebudding and training. The Shasta County plot is being maintained as demonstration plot. Data from the Madera and Kern Counties, and KAC plots, will be discussed here.

RESULTS AND DISCUSSION

Early Bearing and Quality

Early bearing was determined by individual tree harvest and grading of all trees. Starting in 2000 nuts were graded using USDA standards at Paramount Farming Companies grading facility. The results are given in Table 2. From this table it can be seen that trees on UCB-1 rootstocks produced significantly higher, early cumulative yields than trees on the other three rootstocks. Over the life of this trial there have been exceptions within individual years and plot locations. Generally, rootstock effect on yield ranked as follows: UCB-1 > PGI = PGII > Atlantica. As these plots age the differences in yield among rootstocks with *P. integerrima* parentage may dissipate. However, these trees are now considered mature, and thus far, trees on UCB-1 rootstocks have produced the highest early yields. This is consistent over all three plot locations.

Earlier than expected, in the tenth year of the trial, 1999, trees in all three trial locations began to alternate bear sharply. This is true for trees on all four rootstocks. This will make it possible to

have a calculated alternate bearing index within four years, by 2003. Three, two-year cycles, are required to calculate a reliable alternate bearing index. The 1998 through 2000 yields have provided the first half of the data required for this calculation.

Table 2. Effect of rootstock on yield and grade out. *

	County	UCB	PGII	PGI	Atlantica
2000 Yield/Tree Total Edible Weight 2000 Yield/Acre Total Edible Weight @ 112/Bearing Trees/Acre (kg dry inshell split)	Fresno	17.7a 1982	15.4b 1724	14.8bc 1658	13.3c 1490
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	Madera	11.8a 1322	10.2a 1142	10.3a 1154	7.5b 1840
2000 Yield Total Edible Split Inshell Weight (kg dry inshell split)	Fresno	16.4a	14.3b	13.8b	12.1c
	Kern	13.2a	12.0ab	10.7bc	10.3c
	Madera	10.7a	9.1a	9.5a	6.7b
% Total Edible Split Inshell; USDA Sample	Fresno	73	70	73	72
	Kern	62	62	59	64
	Madera	74	68	72	71
# Nuts per Ounce	Fresno	23b	23b	24ab	25a
	Kern	23	24	23	22
	Madera	22	23	23	25
Yield Efficiency (g nuts produced/cm2 trunk cross sectional area)	Fresno	65b	45c	74a	57b
	Kern	43b	35c	48ab	53a
	Madera	76a	58b	60b	64ab
Cumulative Yield to 2000	Fresno	38.8a	32.9c	34.8b	28.2d
(kg/tree)	Kern	47.7a	35.4c	41.6b	35.7c
	Madera	28.7a	25.4b	22.8c	15.4d
Cumulative Yield to 2000	Fresno	9602a	8142c	8614b	6892d
(lbs/acre @ 112 trees/acre)	Kern	11805a	10248b	10269b	8834d
	Madera	7106a	6285b	5643c	4258d

*Values within a row followed by different letters are significantly different. Lack of letters indicates no significant differences within a horizontal row.

Thus far, rootstock does not appear to have an effect on nut quality or size. In all locations there were no consistent, significant differences in the percentage of total edible split inshell nuts, or nuts per ounce, among the four rootstocks.

CONCLUSIONS

As the trees in these plots were budded with Kerman and Peters buds from the same trees all growth and yield differences can be attributed to the rootstock. The results given here demonstrate consistent, significant differences in the yield of young pistachio trees on different rootstocks in the first eleven years of orchard life. It is also clear that among all the rootstocks UCB-1 produces the highest cumulative early yields. As there are no significant rootstock effects in nut quality among the rootstocks these differences in early yield are the result of trees on UCB-1 rootstocks producing more pounds of fruit per tree. This yield increase is the result of more clusters per tree, not more nuts per cluster or larger nuts.

Recent evidence being developed by Dr. Lynne Epstein (Epstein et al, 2000) increasingly demonstrates trees on UCB-1 rootstocks possess Verticillium tolerance equal to that of trees grown on PGI rootstocks. Thus far trees on both rootstocks have had no mortality, trees on UCB-1 are producing better yields, and trees on both rootstocks both are rated equally well in terms of general vigor. Cumulatively, this evidence suggests trees on PGI rootstocks possess no clear advantage over trees on UCB-1 rootstocks in terms of Verticillium tolerance.

Trees on UCB-1 rootstocks are also clearly more cold tolerant than trees on PGI rootstocks. An evaluation of young tree mortality, and freeze damage, after the December 1989 freeze clearly demonstrated trees on UCB-1 are significantly more cold tolerant (Ferguson, 1991).

Trees on UCB-1 rootstocks are also as tolerant of saline conditions as trees grown on PGI rootstocks. In the currently ongoing field trials trees on UCB-1 rootstocks are as tolerant of saline irrigation water up to 8 dS/m as trees on PGI rootstocks (Ferguson et al, 2000b). Tank trials produced a similar result with trees on UCB-1 being more tolerant, but not significantly so, of higher salinity levels than trees on PGI rootstocks (Ferguson, et al, 2000a).

The combination of significantly better yields, better cold tolerance, and equal Verticillium and salinity tolerance, of trees on UCB-1 rootstocks versus trees on PGI rootstocks suggests UCB-1 would be the more productive rootstock for most locations and climates. Grower observations also indicate it is more tolerant of saturated soils.

These trials have also confirmed that the climate and soil conditions in the West Side of the southern San Joaquin Valley are better for production of pistachios than those in the central portion of the valley. This is most likely a result of higher cumulative heat units, high boron content of southern San Joaquin Valley soils and the generally more even, better quality, deeper soils without hardpan layers. The first condition ensures a higher percentage of the crop will ripen and split, the second, a higher percentage of fruit set, and the last is better for good production.

Thus far, from 1989 through 2000, these rootstock trials have demonstrated significant differences in growth, early bearing, cold tolerance, micronutrient uptake, salinity and Verticillium tolerance among the four pistachio rootstocks (Beede, et al., 1990; Epstein, et al., 1992; Ferguson, L., 1990; Ferguson, 1991; Ferguson and Brown, 1990; Ferguson, et al., 1990; Ferguson, et al., 1991; Morgan, et al., 1992). The experimental information for which these plots were initially designed has been obtained. However, the plots will be continue to be

maintained for use in other experiments. Currently three other experiments are being conducted within these rootstocks trials; effects of oil on dormancy breaking, rootstock salinity tolerance, and rootstock Verticillium tolerance. These trees are also used for short term disease and entomology trials. We will continue to monitor annual growth, yield and nut quality data in these three field trials. These results will be used to determine if there is a rootstock effect on alternate bearing. This monitoring could also, potentially, identify superior individual rootstocks for further rootstock improvement programs using traditional breeding or clonal propagation.

There have been, since 1999, field observations of uneven, poor growth of trees on UCB-1 rootstocks in commercial orchards (Ferguson, 2000a, 2000b, 2000c). Similar poor growth of individual trees has been observed in these trials, particularly in the WSFS trial. This poor growth may be a result of genetic variability in this hybrid, an Atlantica pollinated by Integerrima, or perhaps the result of rogue pollination. Attempts will be made to identify a possible explanation in these trials by examining the variability of yield among individual trees on UCB-1 rootstocks within these trials. However, it would be better if this question were addressed in a younger trial in which it could be determined if visibly poor early growth correlated with poor yield behavior, and a different DNA fingerprint.

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LITERATURE CITED

Beede, Robert H., Joseph Maranto, and Louise Ferguson. 1991. Effect of the 1990 winter freeze on pistachios. Annual Pistachio Day, Kearney Agricultural Center, January 30, 1991.

Epstein, L., L. Ferguson, S. Kaur, R. H. Beede, and H. Reyes. 2000. Rootstock Field Trial in Soil Infested with *Verticillium dahliae*. California Pistachio Industry Annual Report, Crop Year 1999-2000.

Epstein, Lynn, Louise Ferguson, and David P. Morgan. 1992. Rootstock field trial in Verticillium-infested soil. California Pistachio Industry Annual Report, Crop Year 1991-92, pp. 165-166.

Ferguson, L. 2000a. Off-types in UCB-1 Seedlings. FPMS Pistachio Newsletter – UCB-1 Hybrid Pistachio Rootstock. C.L. Covert, Ed. No. 1, pp. 1. & 4.

Ferguson, L. 2000b. Investigations Underway to Determine Cause of Stunting of Orchard Trees on UCB-1 Rootstock. FPMS Pistachio Newsletter – UCB-1 Hybrid Pistachio Rootstock. C.L. Covert, Ed. No. 1, pp. 1. & 5.

Ferguson, L. 2000c. Pistachio Rootstock Update. FPMS Pistachio Newsletter – UCB-1 Hybrid Pistachio Rootstock. C.L. Covert, Ed. No. 1, pp. 7-10.

Ferguson, L., B. Beede, L. Epstein, G. M. Crisosto, R. Buchner, Mark Freeman, J. Maranto, R. Teranishi, K. Shackel, P. Brown and H. Cruz. 1993. Pistachio Rootstock Trials: 1992. California Pistachio Industry Annual Report, Crop Year 1991-92, pp. 95-97.

Ferguson, Louise, Robert Beede, Lynn Epstein, Richard Buchner, Mark Freeman, Heraclio Cruz and Paul Metheney. 1993. California Pistachio Rootstock Trials. California Pistachio Industry Annual Report, Crop Year 1992-93, pp. 60-63.

Ferguson, L., J. Maranto, R. Buchner, and R. Beede. 1991. Relative Freeze Damage of Pistachios by Rootstock. Purely Pistachio, Summer 1991, p. 7.

Ferguson, L. 1991. A preliminary report - freeze damage to pistachios. Purely Pistachio, Spring 1991, pp. 6-7.

Ferguson, L., B. Beede, R. Buchner, M. Freeman, J. Maranto, R. Teranishi, and L. Epstein. 1991. California pistachio rootstock trials: first year progress report. California Pistachio Industry Annual Report, Crop Year 1990-91, pp. 74-77.

Ferguson, L., C. Grieve, J. Poss, C. Wilson, E. Cross, T. Donovan, S. Grattan, B. Sanden, H. Reyes. 2000a. Pistachio Rootstock Salinity Tank Trial. Californis Pistachio Commission Annual Report, Crop Year 1999-2000. pp. 108-109.

Ferguson, L., B. Sanden, S. Grattan, H. Reyes. 2000b. Pistachio Rootstock Salinity Trial. California Pistachio Commission Annual Report, Crop Year 1999-2000. pp 110-111.

Ferguson, L. 1990. Nutritional differences among pistachio rootstocks. Purely Pistachio, April 1990, pp. 6-7.

Ferguson, L. and Patrick Brown. 1990. Rootstock physiology, pistachio rootstocks, and pistachio rootstock trials. Pistachio Production: A Pomology Short Course, October 29-November 2, 1990, Visalia, CA.

Ferguson, L. and Patrick Brown. 1990. IV-2 California rootstocks. Pistachio: A Potential Crop for Far West Texas. Proceedings of the First West Texas Pistachio Conference & Workshop, May 31-June 1, 1990, El Paso, Texas, pp. 30-33.

Ferguson, L., Lynn Epstein, Rick Buchner, Mark Freeman, Joe Maranto, and Rocky Teranishi. 1990. California pistachio rootstock trials: Preliminary results. Pistachio Production: A Pomology Short Course, October 29-November 2, 1990, Visalia, CA.

Ferguson, L., Epstein, L., R. Buchner, M. Freeman, J. Maranto, and R. Teranishi. 1990. California Pistachio Rootstock Trials; Preliminary Results. Purely Pistachio, Summer 1990, p. 6.

Morgan, D. P., L. Epstein, and L. Ferguson. 1992. Verticillium wilt resistance in pistachio rootstock cultivars: assays and an assessment of two interspecific hybrids. Plant Disease 76(3): 310-313.

ROOTSTOCK FIELD TRIAL IN SOIL INFESTED WITH *VERTICILLIUM DAHLIAE*

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Introduction

Verticillium wilt, caused by *Verticillium dahliae*, remains a serious disease of pistachio nut trees in California. During the 1980's, two interspecific hybrid rootstock cultivars were introduced into California: UCB-1 and PGII. In 1992, we started a rootstock field trial at the University of California West Side Field Station in Verticillium-infested soil in order to test the long-term performance of the hybrid UCB-1; for comparisons, we included the two standard rootstocks (the Verticillium-susceptible *P. atlantica* and the Verticillium-resistant *P. integerrima*), and the hybrid PGII.

Results.

Our trial at the West Side Field Station (WSFS) has 64 trees per rootstock in a completely randomized block design. When the soil was originally prepared for the field trial ten years ago in 1990, the field contained 40 microsclerotia per gram air-dried soil. In our relatively weed-free plot, the microsclerotia population dropped to 4 microsclerotia per gram air-dried soil by fall 1994 and has remained at 2 microsclerotia per gram air-dried soil since the fall of 1997.

Table 1. General health of pistachio trees in September, 2000 in a trial in *Verticillium*-infested soil at the West Side Field Station[a].

	General Tree Vigor						
Rootstock	Excellent	**Good**	Fair	Poor	Died in 2000[b]	Died before 2000[b]	Statistical group[c]
	Percentage of trees						
P. integerrima	73	27	0	0	0	0	a
P. atlantica	30	29	11	16	3	11	b
PGII	11	27	31	20	0	11	c
UCB I	66	31	3	0	0	0	a

[a] Sixty four trees per rootstock were planted in 1992.

[b] All appear to have died from Verticillium wilt.

[c] Based on pairwise comparisons, rootstocks followed by the same letter were not significantly different ($P<0.05$) by Fisher's exact test for categorical data.

As expected, *P. atlantica* and *P. integerrima* have performed in our trial as Verticillium-sensitive and resistant rootstocks, respectively (Tables 1 and 2). PGII has performed as a Verticillium-sensitive rootstock, consistent with previous results (Morgan et al. 1992. Plant Disease 76:310-313). Our major questions are the following. 1) In comparison to the Verticillium-resistant standard *P. integerrima*, how resistant is UCBI? 2) How does UCBI perform horticulturally

when it is under disease pressure? For the first time in 1998, the vigor of *P. integerrima* was rated more highly than was UCBI. However, in 2000, the vigor and symptomatic ratings *of P. integerrima* and UCBI were statistically indistinguishable (Tables 1 and 2). In the year 2000, nut yield and quality data were collected for the third year (Table 3) . Please note that the yield figures below are not adjusted for a loss in yield due to death of any of the *P. atlantica* and PGII rootstocks. Although yield of split nuts per surviving tree was statistically indistinguishable for the four rootstocks, UCB-1 was numerically the highest. Similarly, although total yield of UCB-1 per tree was only statistically greater than for PGII, the total yield of UCB-1 was numerically the largest. However, the percentage of splits was significantly higher in both *P. atlantica* and in PGII than in either *P. integerrima* or UCB-1.

Table 2. Symptoms of Verticillium wilt in pistachio trees in September, 2000 in a trial in *Verticillium*-infested soil at the West Side Field Station. [a]

Rootstock	Strike symptom	Died before 2000[b]	*Free of strike symptoms in 2000*	Statistical group[d]
	Percentage of trees			
P. integerrima	0	0	100	a
P. atlantica	9 [c]	11	80	b
PGII	8	11	81	b
UCB I	2	0	98	a

[a] Sixty four trees per rootstock were planted in 1992.

[b] All appear to have died from Verticillium wilt.

[c] Two *P. atlantica* trees with severe Verticillium strike symptoms died in 2000.

[d] Based on pairwise comparisons, rootstocks followed by the same letter were not significantly different ($P<0.05$) by Fisher's exact test for categorical data.

Table 3. Yield and quality of nuts in 2000 from surviving female pistachio trees in a trial in *Verticillium*-infested soil at the West Side Field Station [a]

Rootstock	*Kg of split nuts/tree*	Total Edible kg nuts/tree	*Split nuts, %*
P. integerrima	3.8 a	5.3 ab	49 b
P. atlantica	4.4 a	5.4 ab	63 a
PGII	3.8 a	4.5 b	68 a
UCB-1	4.7 a	6.2 a	54 b

[a] Values within a column followed by the same letter did not differ by Duncan's multiple range test ($\alpha=0.05$). Note that yield loss due to tree death is not included in this data.

Conclusions and Practical Applications

1) It is unclear whether or not *P. integerrima* is more resistant to Verticillium than UCB-1. *P. atlantica* is susceptible, and PGII is the most susceptible to *Verticillium*.
2) The most common symptom of Verticillium wilt is poor vigor, rather than the more definitive "strike" symptom.
3) In our relatively weed-free field, the concentration of *Verticillium* inoculum dropped 10-fold in just 5 years and has remained at a relatively low but stable concentration of two

microsclerotia per gram soil thereafter. That is, a pistachio field does not appear to be a very good location to build-up a population of *Verticillium*.

4) In the field trial with moderate disease pressure, in terms of nut yield and quality, UCB-1 is doing at least as well as *P. integerrima*.