PARADOX DIVERSITY STUDY – ORCHARD TRIALS 2005

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ABSTRACT

Paradox continues to be the most widely planted rootstock for walnuts in California. Although it tends to perform well throughout the state, differences in performance have been observed within and between orchards and nursery sources. These differences may be the result of genetic variation between source trees or from within a source tree. There is a need to identify superior paradox rootstocks, clonally or from superior parents, that then can be propagated to produce superior orchards in the future. Evaluation of such traits as growth rate, transplantability, resistance to crown gall, nematodes, and *Phytophthora* crown and root rot can be performed efficiently under laboratory and/or greenhouse conditions. Long-term survival, growth and productivity under field conditions require several additional years to evaluate.

Four orchard trials were planted in 1998 in Yolo and San Joaquin Counties and in 1999 in Tehama and Kings Counties. Approximately thirty paradox rootstock sources are replicated four times with either three or six trees per replicate at each site. The two orchards planted in 1998 were grafted to Chandler. The Tehama County orchard was grafted to Howard and the Kings County orchard was grafted to Tulare.

Yield was evaluated in the San Joaquin and Kings trials for the third year and in the Yolo trial for the fifth and final year in 2005. Harvest yields were not taken in the Tehama County trial again due to the large variability in tree size resulting from regrafting required due to a scion mix-up followed by frost damage. Yield at the Yolo trial in 2005 for trees grown on paradox varied from a high of 3.96 (DX) to a low of 2.60 (OZ) tons per acre. Trees grown on black walnut varied from a high of 2.60 (YZ bl) to a low of 2.01 (AW bl) tons per acre in the Yolo trial. In the San Joaquin County trial grafted to Chandler, the highest yield for the paradox rooted trees was 1.92 tons per acre (UZ) and the lowest 1.24 tons per acre (CX). In the Kings County trial grafted to Tulare the highest yielding rootstock was GZ which produced 3.46 tons per acre. The lowest producing rootstock in the Kings trial was EZ which produced 1.76 tons per acre.

The four largest rootstocks across all sites are Vlach, OX, DX and PZ which all have *Juglans hindsii* (Jh) crossed with *J. regia* (Jr) as parents. The black rootstocks were generally small at all sites with YZ tending to be the largest of the blacks at all sites. Three of the four rootstocks containing all four (Jm, Jn, Jh, Jr) parents were consistently smaller than most others. Other rootstocks that were smaller were three of those containing the three (Jh, Jn, Jr) parents (PX, HX and OZ). Of the Jh x Jr crosses, JX, QZ and WX tended to be smallest at all sites.

OBJECTIVES

Seedlings were produced by the Paradox Diversity Study from 36 commercial Paradox sources and from controlled crosses made at UC Davis. Trees produced from these seedlings have been planted in 4 grower orchard trials, located in Yolo, San Joaquin, Tehama, and Kings Counties. The Yolo and San Joaquin trials were planted in 1998 and the Kings and Tehama trials in 1999. The farm advisor in each of the counties is the principal investigator for the trial in that county. The plan is to collect 5 years of yield data at each site. The seedling Walnut rootstocks were first grown for one year in three different commercial nurseries. All three nurseries are equally represented in each plot. A six tree plot included two trees from each of the three nurseries. A three tree plot included one tree from each nursery. The trees were then dug in early winter and handled and stored using acceptable commercial nursery practices. Trees were transported to the fields and planted with standard planting crews. Individual trees are marked and can be traced to the nursery. The two trials planted in 1998 are grafted to Chandler. The grower cooperators are responsible for the general farming of the trees. Tree identification, growth measurements and extra care is provided by the farm advisors. The main objective of the trial is to measure and quantify differences between paradox sources and to identify superior paradox trees. The Yolo trial was harvested starting in 2001 while the San Joaquin and Kings trials were harvested starting in 2003.

PROCEDURES FOR YOLO COUNTY TRIAL

The Yolo County trial was planted on March 3 and 4, 1998 at Deseret Farms near the Sacramento River. It is planted on Lang sandy loam. The orchard site had previously been in walnuts for over 50 years. The original orchard was removed the previous year with the ground prepared and then fumigated. Trees were sprayed with K-84 (Galltrol) at planting time. The trees were spaced at 30 x 30 feet in a square planting. Furrow irrigation was used the first 3 years when the field was converted to flood irrigation under non-tillage. Weed control is practiced down the tree row. Normal fertilizer and management practices have been followed.

Trees were grafted on April 5, one month following planting. The trees that were lost in 1998 were replanted in 1999. Trees have been grafted in 1999 and 2000 with grafting completed in 2000 except for 1 tree that was run over.

Growth has been good to excellent with most grafts attaining a height of 7 to 9 feet the first year. Scaffolds grew 5 to 8 feet the second year and limbs grew 5 to 8 feet the third year. In 2002 some of the trees were touching across the 30 foot tree and row spacing. By 2004, the orchard was becoming difficult to move equipment through and mechanical hedging was initiated by the grower (every third row each year).

Paradox rootstocks are designated by a two letter code. Black walnut rootstocks use a two letter code followed by a “bl”. The Vlach is a paradox rooted cutting and the grower treatment consists of paradox seedlings that were planted in the trial and in the rest of the orchard.

RESULTS AND DISCUSSION FOR YOLO COUNTY TRIAL

Total tree loss in 1998 was 25 trees of the 720 trees planted. Six hundred and five trees were successfully grafted one month after planting. Sixty one trees were grafted in 1999. Additionally, 45 trees were whip grafted in 2000 and eight trees were patch budded.

There are 29 paradox seed sources, Vlach clonally propagated paradox, the grower selection of paradox purchased from another nursery and 4 black walnut sources represented in the trial.

Crown gall was not considered a serious problem in 2001. Eighteen trees were identified with crown gall at the crown in 2001. In 2002 this number has increased to fifty three in the paradox and one in the black walnut rootstocks. In 2003 the number has increased to 62 in the paradox and 1 in the black. The orchard was planted on a site previously planted to walnuts that was pulled and fumigated before replanting. Galls are being treated. The highest number of galls occurred on XX (33%), JX (25%), KX (17%), PX(17%),VX (17%), PZ (17%) and Vlach (17%). The trial was not designed to evaluate crown gall so it is not possible to tell from these numbers statistical differences in susceptibility.

The Yolo trial was harvested and trunk growth measured in 2001, 2002, 2003, 2004 and 2005. Yield is listed as tons per acre. Yield from only trees grafted the first year are included in the 2001 and 2002 data. The 2003, 2004 and 2005 data includes trees grafted in both the first and second years. Trunk circumference is shown for all trees in 2005.

The tables are arranged by parents of the rootstock. The parents are listed in the tables for those rootstocks where the parents have been identified to species. Abbreviations give the initials of the scientific name.

Jh equals Juglans hindsii
Jr equals Juglans regia
Jm equals Juglans major
Jn equals Juglans nigra
Jc equals Juglans californica

Four rootstocks did not have identifiable parents on record.

Table Y1 lists the rootstocks and the trunk circumference as measured in December 2005. There is also a column that shows the rank of the circumference compared to the total of the 35 rootstocks in the trial. Trunk circumference measurements were made approximately six inches above the graft. The Paradox seedlings varied from a low trunk circumference of 71.5 cm for AZ and NZ to a high of 81.6 cm for DX. The Northern California Black varied from a low of 62.6 for AW black to a high of 73.4 inches for YZ black.

Table Y2 shows the tons per acre yield of the different rootstocks for 2001, 2002, 2003, 2004 and 2005. In 2005, the Paradox selections varied from a low yield of 2.60 tons per acre for OZ to a high of 3.96 tons per acre DX. For NC black the lowest yielding selection was AW black with 2.01 tons per acre and the highest was YZ black with 2.60 tons per acre.

For paradox rootstock, the five year total yield ranged from a low of about 7.5 tons per acre to a high of almost 11 tons per acre (Fig. Y1). Cumulative yields were generally closely related to the December 2005 trunk circumference (Fig. Y1). The five year cumulative yield for the Northern California Black rootstocks ranged from 6.5 to just over 7 tons per acre and was again closely related to trunk circumference (Fig. Y1).

Trees on Paradox have generally been larger than trees on Northern California Black in this study and have also produced higher yields. For the five year cumulative yield, black rootstocks were generally lowest (Fig. 1). The 2005 harvest was the fifth and final harvest for the Yolo trial. The trees have generally filled in their allotted space at the trial and the grower is now doing mechanical hedging to maintain access through the orchard.

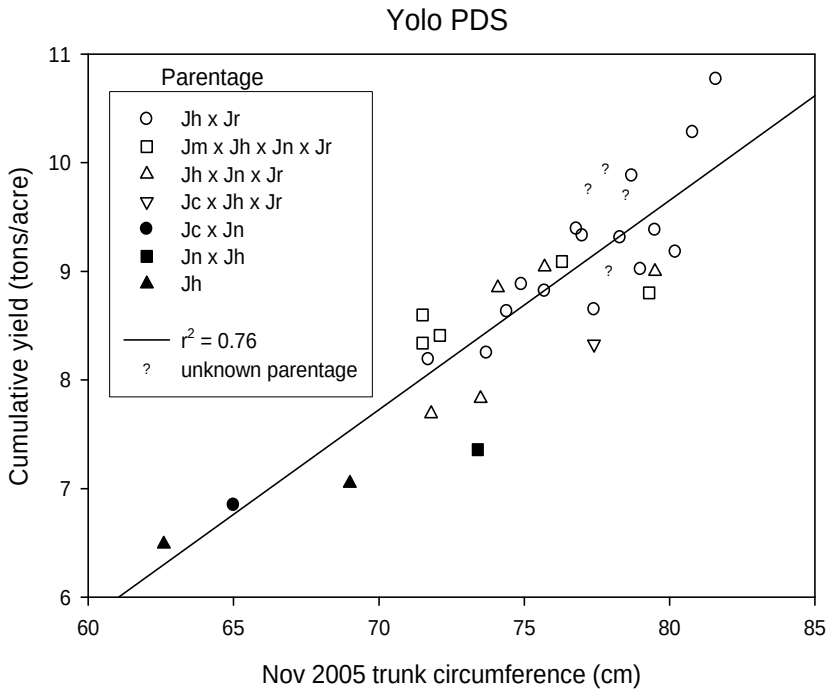


Fig. Y1. Five year cumulative yield versus 2005 trunk circumference for trees in the Yolo trial separated out by parentage.

Table Y1: Trunk circumference for all the trees at the Yolo PDS trial 2005. The rank in relation to the other rootstocks is also shown.10

		Average of All Trees			
Rootstock	Parents	No. Trees	Trunk circ (cm)		Rank
AW	JhxJr	12	77.4	abc	14
DX	JhxJr	24	81.6	a	1
JX	JhxJr	24	75.7	abcd	19
KX	JhxJr	12	78.3	abc	10
OX	JhxJr	12	80.8	ab	2
SX	JhxJr	24	79.0	abc	7
VX	JhxJr	24	74.4	abcd	22
WX	JhxJr	24	73.7	abcd	24
CZ	JhxJr	12	71.7	cde	29
PZ	JhxJr	24	76.8	abcd	17
QZ	JhxJr	24	77.0	abc	16
RZ	JhxJr	24	74.9	abcd	21
SZ	JhxJr	24	78.7	abc	8
UZ	JhxJr	12	79.5	abc	4
VLACH	JhxJr	24	80.2	ab	3
CX	JmxJnxJhxJr	24	79.3	abc	6
MX	JmxJnxJhxJr	24	76.3	abcd	18
AZ	JmxJnxJhxJr	24	71.5	cde	31
NZ	JmxJhxJnxJr	21	71.5	cde	30
JZ	JmxJhxJnxJr	24	72.1	cde	28
HX	JhxJnxJr	24	74.1	abcd	23
LX	JhxJnxJr	12	79.5	abcd	5
NX	JhxJnxJr	24	75.7	abcd	20
PX	JhxJnxJr	24	73.5	bcd	25
OZ	JhxJnxJr	24	71.8	cde	27
XX	JcxJhxJr	24	77.4	abc	13
LZ		24	77.8	abc	12
BW		24	78.5	abc	9
IZ		24	77.9	abc	11
WZ		12	77.2	abc	15
BX bl	JcxJn	24	65.0	ef	33
YZ bl	JnxJh	12	73.4	bcd	26
AW bl	Jh	12	62.6	f	34
UZ bl	Jh	12	69.0	def	32
LSD .05			6.3		

Table Y2: Yield per acre by year and rootstock source for 2001-2005.

Source	2001		2002		2003		2004		2005	
	Yield (ton/A)		Yield (ton/A)		Yield (ton/A)		Yield (ton/A)		Yield (ton/A)	
AW	0.30	abcde	0.96	bcdefghi	2.24	Abcd	1.77	d	3.38	abc
DX	0.27	abcdefg	1.12	abc	2.60	A	2.82	abc	3.96	a
JX	0.23	defg	0.99	abcdefgh	2.06	Bcdefg	2.32	abcd	3.22	abc
KX	0.35	a	1.03	abcdef	2.26	Abcd	2.53	abcd	3.14	bcd
OX	0.26	abcdefg	1.02	abcdef	2.44	Ab	3.08	a	3.48	ab
SX	0.27	abcdefg	0.84	defghi	2.25	Abcd	2.55	abcd	3.11	bcd
VX	0.30	abcde	0.84	defghi	2.12	Bcdef	2.57	abcd	2.80	bcde
WX	0.27	abcdefg	1.03	abcdef	2.07	Bcdefg	2.23	abcd	2.65	cdef
CZ	0.25	abcdefg	0.85	defghi	2.18	Abcdef	1.85	cd	3.06	bcd
PZ	0.25	abcdefg	1.09	abcd	2.35	Abcd	2.56	abcd	3.14	bcd
QZ	0.29	abcdefg	1.06	abcd	2.28	Abcd	2.53	abcd	3.17	bcd
RZ	0.27	abcdefg	0.91	cdefghi	2.14	Abcdef	2.43	abcd	3.13	bcd
SZ	0.30	abcde	1.00	abcdefg	2.42	Ab	3.02	a	3.14	bcd
UZ	0.34	ab	0.79	fghi	2.15	Abcdef	2.75	abcd	3.35	abc
Vlach	0.27	abcdefg	0.97	abcdefghi	2.15	Abcdef	2.51	abcd	3.28	abc
CX	0.27	abcdefg	0.90	cdefghi	2.10	Bcdefg	2.49	abcd	3.04	bcd
MX	0.26	abcdefg	0.94	bcdefghi	2.23	Abcde	2.90	ab	2.76	bcdef
AZ	0.25	bcdefg	0.82	efghi	2.04	Bcdefg	2.47	abcd	3.02	bcd
NZ	0.22	efg	0.86	defghi	2.16	Abcdef	2.31	abcd	2.79	bcde
JZ	0.24	bcdefg	0.77	ghi	2.18	Abcdef	2.36	abcd	2.86	bcde
HX	0.26	abcdefg	0.91	cdefghi	2.27	Abcd	2.49	abcd	2.92	bcd
LX	0.33	abc	1.08	abcd	2.13	Bcdef	2.15	abcd	3.31	abc
NX	0.27	abcdefg	0.93	bcdefghi	2.26	Abcd	2.48	abcd	3.10	bcd
PX	0.20	fg	0.75	ghi	1.95	Cdefg	2.15	abcd	2.78	bcdef
OZ	0.22	defg	0.88	cdefghi	1.91	Defgh	2.08	abcd	2.60	cdef
XX	0.29	abcdefg	0.96	bcdefghi	1.96	Cdefg	2.31	abcd	2.81	bcde
LZ	0.30	abcdef	1.21	a	2.38	Abc	2.83	abcd	3.22	abc
BW	0.32	abcd	1.05	abcde	2.34	Abcd	2.65	abcdef	3.34	abc
IZ	0.29	abcdefg	0.98	abcdefgh	2.25	Abcd	2.50	abcdefg	2.99	bcd
WZ	0.31	abcde	1.01	abcdefg	2.37	Abcd	2.64	abcdefg	3.43	abc
BX bl	0.23	cdefg	0.78	ghi	1.65	gh	1.83	gh	2.36	def
YZ bl	0.21	efg	0.80	fghi	1.78	Efgh	1.97	efgh	2.60	cdef
AW bl	0.19	g	0.52	i	1.47	H	2.30	abcdefgh	2.01	f
UZ bl	0.22	efg	0.73	hi	1.75	Fgh	2.27	abcdefgh	2.08	ef
LSD .05	0.10		0.25		0.46		0.81		0.66	

PROCEDURES FOR TEHAMA COUNTY TRIAL

The Tehama PDS is located in Northern Tehama County close to Cottonwood on the Bengard Ranch. The Tehama soil survey describes the soil as Zamora silt loam with one corner of the plot on Columbia silt loam. Both are well drained class one soils. The site was previously planted to walnuts. Preplant soil samples indicated relatively high populations of lesion nematode, P. vulnus. The entire block was fumigated prior to planting.

Rootstocks were planted into augured holes, April 7, 1999. Conditions were dry and windy but trees were planted quickly and kept moist. All rootstocks were spray treated with K84 (galtrol) at a rate of one plate per gallon per 100 trees. Trees were planted 24 feet square with a Cisco/Franquette pollenizer row every 10th row. The plot itself has a pollenizer row to the immediate North and South plus a pollenizer row directly down the center. Prevailing wind is North-South. The irrigation system is solid set sprinkler. Sprinklers are located in the tree row at equal distance between trees.

The plot was grafted to Howard on May 4, 1999. In September unusual variation between trees was observed, which led to variety integrity questions. Isozyme analysis confirmed field observations that the plot was not 100% Howard. To solve the varietal problem, all grafts were pruned off during the following winter. Cuts were made all the way back to rootstock to eliminate any interstem effect. The entire plot was grafted again on April 7, 2000 with known Howard wood. Initial graft take was 70%. Failed grafts were regrafted June 6, 2000. Graft take on the second try was 61%. Remaining trees were grafted again May 16, 2001.

The Tehama PDS is a randomized complete block design with 38 treatments and 4 replicates. Trees were planted in either 6-tree or 3-tree blocks depending upon seedling availability. Three different nurseries grew the rootstocks and all three are equally represented in each plot. A 6-tree plot included 2 trees each from the red, white and blue nurseries. A 3-tree plot includes 1 tree from each coded nursery. Rootstock sources are coded as well using letter designations. Only trees grafted in 2000 were used for comparison and evaluation. Measurements were made on Howard trunks 12” above the graft union reported as diameter in inches.

RESULTS AND DISCUSSION FOR TEHAMA COUNTY TRIAL

The Tehama County Paradox Diversity Trial is in its fifth year following grafting. Frost damage during the fall of 2002 killed many of the smaller trees and damaged nut bearing wood. For 2004, there was not enough crop to justify a harvest. Tree growth information for 2001, 2002, 2003, 2004 and 2005 are reported in Tables T1 and T2. At the end of the 2005 season, largest diameters were KW, CZ, RZ, Vlach, OX and SX with the smallest being BX (black), YZ (black), QZ , AZ, GX and AWB (black). Yields were not taken in 2005 due to the great variability in trees size resulting from the grafting and frost problems.

Rootstock Source	'01 Howard Trunk Diameter (in)	Rootstock Source	'02 Howard Trunk Source
FX	2.07 a	DX	3.24 a
XX	2.04 a	Vlach	3.23 ab
Vlach	2.00 ab	FX	3.21 ab
UZ	2.00 ab	XX	3.18 abc
PX	1.99 ab	KW	3.16 abcd
CX	1.98 ab	UZ	3.15 abcd
KX	1.98 ab	XZ	3.13 abcde
DX	1.96 abc	SX	3.13 abcde
SX	1.96 abcd	RZ	3.12 abcde
PZ	1.95 abcd	PZ	3.12 abcdef
KW	1.92 abcd	AW	3.11 abcdef
VX	1.91 abcd	GZ	3.11 abcdef
NX	1.90 abcd	PX	3.11 abcdef
LX	1.90 abcd	NX	3.09 abcdef
DW	1.90 abcd	CX	3.06 abcdef
XZ	1.89 abcd	OX	3.04 abcdefg
RZ	1.87 abcd	OZ	3.02 abcdefg
WX	1.87 abcd	KX	3.02 abcdefg
OX	1.87 abcd	VX	3.00 abcdefgh
GZ	1.86 abcd	LX	2.98 abcdefgh
BX	1.85 abcd	WX	2.97 abcdefgh
SZ	1.84 abcd	DW	2.97 abcdefgh
OZ	1.84 abcd	JX	2.96 abcdefgh
NZ	1.84 abcd	BX (black)	2.92 abcdefgh
HX	1.83 abcd	NZ	2.91 abcdefgh
AW	1.82 abcd	HX	2.91 abcdefgh
LZ	1.81 abcd	SZ	2.91 abcdefgh
JX	1.80 abcde	CZ	2.89 abcdefgh
AZ	1.80 abcde	LZ	2.88 bcdefgh
EW	1.76 bcde	QZ	2.85 cdefgh
AWB	1.75 bcde	YX	2.85 cdefgh
GX	1.75 bcde	GX	2.83 defgh
MX	1.75 bcde	MX	2.79 efgh
QZ	1.74 bcde	EW	2.78 efgh
YX	1.74 bcde	AWB (black)	2.78 fgh
CZ	1.70 cde	AZ	2.71 gh
YZ	1.68 de	YZ (black)	2.69 gh
EZ	1.53 e	EZ	2.66 h

Table T1. Average Howard trunk diameter (in) for the 38 seed sources in the Tehama County Paradox Diversity study. Rootstocks were planted in 1999 and grafted to Howard in 2000. Trunks were measured 10/23/01, 11/5/02, 11/19/03 and 10/25/04 12 inches above the graft union. Only trees grafted in 2000 were used for comparison. Numbers followed by the same letter are not significant at the 5% level.

Rootstock Source	'03 Howard Trunk Diameter (in)	Rootstock Source	'04 Howard Trunk Diameter (in)	Rootstock Source	'05 Howard Trunk Diameter (in)
KW	4.47 a	KW	5.54 a	KW	6.61 a
NX	4.29 a	OZ	5.44 ab	CZ	6.60 a
DX	4.29 a	RZ	5.44 ab	RZ	6.55 ab
RZ	4.27 a	OX	5.36 abc	Vlach	6.40 abc
PZ	4.26 a	CZ	5.29 abcd	OX	6.37 abc
Vlach	4.26 a	PZ	5.29 abcd	SX	6.33 abc
CX	4.25 a	Vlach	5.28 abcd	OZ	6.32 abc
AW	4.22 a	AW	5.25 abcd	PZ	6.28 abc
OX	4.19 a	XZ	5.25 abcd	EW	6.27 abc
GZ	4.19 a	PZ	5.25 abcd	LZ	6.25 abc
SX	4.17 a	NX	5.23 abcd	AW	6.22 abcd
UZ	4.17 a	HX	5.21 abcd	PX	6.22 abcd
CZ	4.15 a	SX	5.20 abcd	NX	6.22 abcd
PX	4.14 a	FX	5.19 abcd	XZ	6.20 abcd
XX	4.13 a	CX	5.17 abcde	LX	6.20 abcd
LX	4.12 a	LX	5.17 abcde	CX	6.17 abcd
XZ	4.12 a	DX	5.16 abcde	FX	6.17 abcd
FX	4.11 a	UZ	5.15 abcde	GZ	6.13 abcd
HX	4.11 a	GZ	5.14 abcde	UZ	6.12 abcd
KX	4.11 a	XX	5.12 abcde	HX	6.12 abcd
OZ	4.10 a	VX	5.12 abcde	VX	6.09 abcd
VX	4.08 a	WX	5.07 abcde	XX	6.08 abcd
WX	4.06 a	KX	4.97 abcde	DX	6.07 abcd
BX (black)	4.05 a	LZ	4.96 abcde	WX	6.00 abcd
SZ	4.02 a	DW	4.96 abcde	KX	5.93 abcd
LZ	4.00 a	BX (black)	4.95 abcde	EZ	5.89 abcd
DW	3.99 a	NZ	4.39 bcde	SZ	5.85 abcd
NZ	3.99 a	SZ	4.91 bcde	NZ	5.84 abcd
YX	3.98 a	JX	4.91 bcde	JX	5.84 abcd
JX	3.97 a	QZ	4.91 bcde	DW	5.82 abcd
EW	3.91 a	EW	4.89 bcde	YX	5.81 abcd
MX	3.91 a	MX	4.87 bcde	MX	5.80 abcd
EZ	3.89 a	YX	4.87 bcde	BX (black)	5.77 abcd
YZ (black)	3.86 a	EZ	4.82 cde	YZ (black)	5.69 bcd
AWB (black)	3.79 a	YZ (black)	4.72 de	QZ	5.68 bcd
GX	3.76 a	GX	4.59 e	AZ	5.54 cd
QZ	3.76 a	AWB (black)	4.58 e	GX	5.54 cd
AZ	3.71 a	AZ	4.58 e	AWB (black)	5.34 d

Table T2. Average Howard trunk diameter (in) for the 38 seed sources in the Tehama County Paradox Diversity study. Rootstocks were planted in 1999 and grafted to Howard in 2000. Trunks were measured on 10/23/01, 11/5/02, 11/19/03, 10/25/04 and 11/17/05 at a height 12 inches above the graft union. Only trees grafted in 2000 were used for comparison. Numbers followed by the same letter are not significant at the 5% level.

PROCEDURES FOR SAN JOAQUIN COUNTY

The experimental plot is located in a commercial 26' X 26' walnut planting owned by Richard and Joseph Dondero near Farmington, California. The plot is configured as randomized complete block design, with four 3- or 6-tree plots, in fifteen adjacent rows within the orchard.

Ungrafted Paradox rootstocks from three nursery sources were planted June 2, 1998. Planting was delayed due to unseasonably late spring rains. All trees were grafted with Chandler scions in spring 1999. A small number of trees that died or made poor growth in 1998 were replaced with Paradox seedlings in spring 1999, and these were subsequently budded to Chandler in fall 1999. Buds on a few of these trees failed, and these trees were grafted in spring 2000. A few trees from the 1998 and 1999 plantings died during the 1999 season and were replaced with Chandler-grafted trees on the appropriate Paradox selections in spring 2000. Trees that died in 2001 and 2002 were replaced with Chandler-grafted trees on Paradox rootstock obtained by the grower.

Soil at the site is a clay loam. The orchard is sprinkler irrigated, and was formerly planted to field and row crops. Soil at the site was not fumigated prior to planting.

Tree growth through 2005 was evaluated by measuring the trunk diameter 12 inches above the graft union in late November.

The trial was commercially harvested for the first time in 2003. Prior to harvest, trees from the 1998 (budded in spring, 1999) and 1999 (budded in fall, 1999) appeared to have similar crop loads and were harvested together in 2003 and in 2004. Trees planted in 2000 and after were not harvested.

Nuts were shaken, windrowed and weighed separately from each 6- or 3-tree plot. A 20-30 pound sample was collected at random from nuts harvested in each of the 15 rows of the trial. These samples were weighed, hulled, dehydrated and weighed again to calculate a factor for converting the weight of field-harvested nuts from each plot to its equivalent dehydrated weight. A small (2.4 pounds) sub-sample of nuts each sample was dried completely to determine the dehydrated moisture content of each sample and the conversion factors adjusted in order to express all plot yields on an 8% (wet basis) moisture content basis.

RESULTS AND DISCUSSION FOR SAN JOAQUIN COUNTY TRIAL

There were no significant differences in trunk circumference among trees on rootstocks from different Paradox sources in 2000 or 2001 (data not shown). Statistically significant differences in trunk diameter began emerging among trees on the various stocks in 2002 and persisted in 2005 (Table SJ1).

In 2004, significant yield differences occurred for the first time and they continued in 2005. Yields varied widely among paradox sources, ranging from 1.24 (CX) to 1.92 (UZ) tons per acre (Table SJ1).

Table SJ1. Average trunk circumference and pounds per acre yield by seedling source[1], 2005. The rank in relation to the other rootstocks is also shown.

Rootstock	Parents	Trunk circ (cm)		Rank	Yield (tons/acre)		Rank
AW	JhxJr	52.1	abcdef	19	1.30	abcde	21
DX	JhxJr	51.9	abcdef	21	1.34	abcde	20
JX	JhxJr	53.7	abcde	13	1.69	abcd	4
KX	JhxJr	52.5	abcdef	17	1.34	abcde	19
OX	JhxJr	53.7	abcde	12	1.47	abcd	13
SX	JhxJr	54.0	abcde	9	1.27	bcde	24
VX	JhxJr	54.9	abcd	5	1.56	abcd	6
WX	JhxJr	52.1	abcdef	20	1.37	abcde	18
CZ	JhxJr	50.4	bcdef	24	1.48	abcd	11
PZ	JhxJr	57.2	a	1	1.84	abc	3
QZ	JhxJr	50.2	bcdef	25	1.26	bcde	25
RZ	JhxJr	54.3	abcd	7	1.55	abcd	7
SZ	JhxJr	54.8	abcd	6	1.44	abcde	15
UZ	JhxJr	54.1	abcde	8	1.92	a	1
VLACH	JhxJr	56.1	ab	2	1.88	ab	2
CX	JmxJnxJhxJr	52.9	abcdef	16	1.24	cde	26
MX	JmxJnxJhxJr	52.1	abcdef	18	1.42	abcde	16
AZ	JmxJnxJhxJr	51.6	abcdef	22	1.44	abcde	14
NZ	JmxJhxJnxJr	50.9	bcdef	23	1.49	abcd	9
HX	JhxJnxJr	49.2	def	27	1.30	abcde	22
LX	JhxJnxJr	53.6	abcde	15	1.29	bcde	23
NX	JhxJnxJr	53.7	abcde	14	1.47	abcd	12
PX	JhxJnxJr	53.9	abcde	10	1.40	abcde	17
OZ	JhxJnxJr	53.8	abcde	11	1.48	abcd	10
XX	JcxJhxJr	55.6	abc	4	1.62	abcd	5
LZ		56.0	ab	3	1.52	abcd	8
BW						not harvested	
BX bl	JcxJn	48.1	ef	28	1.19	de	27
YZ bl	JnxJh	49.9	cdef	26	1.09	de	28
AW bl	Jh	47.6	f	29	0.83	e	29
LSD .05		4.9			0.50		

PROCEDURES FOR KINGS COUNTY TRIAL

The Kings County PDS trial was planted January 15-16, 1999 in a Kimberlina fine sandy loam soil. Originally saline-alkali, years of row cropping and reclamation have now rendered it low in salts. Although it is a very deep, well drained alluvial soil derived from igneous and sedimentary parent material, backhoe evaluation revealed sufficient stratification to justify pre-plant modification. Hence, the orchard site was slipplowed to a depth of six feet on six-foot centers. Following irrigation, it was then bermed and planted north-south as a 26' x 26' equilateral triangle. Post-plant irrigation was performed in single furrows 18 inches from either side of the tree row. Tree paint was then applied over the entire tree as soon as the orchard could be accessed.

The 816 rootstocks were whip grafted one month after planting to the walnut cultivar 'Tulare'. Four weeks after the first grafting attempt, seedlings that appeared to have not taken were regrafted. This resulted in a 93 percent take.

Prior to the beginning of the 2000 season, rootstock diameters were collected. It was also necessary to excavate around most of the trees and saw off the whirl of buds developed at the trunk base. This problem developed in the nursery when the laterals were not removed from the seedlings as they are for commercially grown trees. Trees receiving any cut below ground were recorded for future crown gall monitoring. Grafting of trees missed last season was performed in February. Regrafting of the few grafts failed from February was purposely not performed to allow recovery of the rootstock.

During the second growing season (2000), summer pruning was required on most of the trees to reduce vigor and excessive weight on the south side. Notching of unbroken buds was also performed in early June in an attempt to force more growth in the northwest quadrant. Furrows adjacent to the tree rows were used throughout the second season for irrigation.

Pruning of the block during the 2000 and 2001 winters was performed by the farm advisor. In April, 2001, the 14 ungrafted trees were grafted, waxed, rewaxed and painted.

Every tree in the trial now has a tag suspended from a scaffold indicating its exact identity and location.

In the winter of 2002, the trees received their first commercial tower pruning under the direction of the farm advisor. In April, five trees within the experiment were regrafted.

The first commercial harvest was performed in October of 2002. Collection of yield data was postponed until 2003 after discussions with Dr. Dave Ramos, Walnut Board Research Director and Wilbur Reil, U.C. Farm Advisor. Both indicated that the variability inherent in the fourth year data collected by Reil in the Yolo trial did not justify the effort. Grower delivery records indicated the average production was 564 dry in-shell pounds per acre.

In November, trunk circumference measurements were taken six inches above the graft union and the trees were visually rated for crown gall. When the visual rating indicated the presence of galls, excavation of every tree crown to a depth of eight inches was performed with hand trowels sterilized between each tree with hydrogen peroxide. Trees with suspected gall were flagged and reviewed by Bob Beede and Dr. Lynn Epstein on December 8 and 10, 2002. Epstein performed an analysis of the data for the effect of nursery on the incidence of infection. The farm advisor also performed a summarization of infection by rootstock. Resources have not yet allowed determination of the possible correlation between the incidence of crown gall and the 1999-2000 winter wounding of rootstocks associated with underground node removal.

In an attempt to reduce vigor and maximize yield, no pruning was performed prior to the 2003 season. Cultural practices and irrigation decisions were executed by the grower. On September 10, per the farm advisor's recommendation, the grower applied ethephon as a pre-harvest aid to maximize fruit removal and yield data accuracy. Prior to harvest, identification stakes were placed at the beginning and end of each plot.

Yield data was collected from each of the 152 plots in 2003, 2004 and 2005. Due to the absence of buffer rows, alternate rows were mechanically shaken and the nuts windrowed on either side. The harvest crew was then instructed to create a break in the windrow at both ends of each plot. The harvester, with a load-cell weighing nut buggy attached, then picked the nuts up on the east side and then the west side of the tree row. Beginning and ending weights were recorded for each plot. In addition, a six-pound sample (approximate) for drying was collected from each plot.

In November, trunk circumference measurements were taken six inches above the graft union and statistically analyzed using the same above design.

RESULTS AND DISCUSSION FOR KINGS COUNTY TRIAL

Most of the trees "on schedule" are well above average in canopy size for their age. Twelve trees have required support by 8- foot long, 6-inch diameter end posts due to excessive leaning.

Data is presented in this report for the 2004 and 2005 seasons. Figures 1-4 show the diameters of the scions six inches above the graft after the 2004 and 2005 seasons. At the end of the 2005 season, the overall average diameter was 8.07 inches. The smallest rootstocks are EZ, NZ, AZ, YZ, and MX. Of these, only EZ is statistically smaller than most of the other rootstocks.

The six largest rootstocks after the fifth year are XG, DX, GZ, HX and DW. However, examination of the figures shows that few significant differences exist among all the selections being tested. The lack of differences is not surprising considering the site represents virgin walnut soil which received thorough preplant modification and excellent care during establishment.

Figures 5-8 show the yield performance of the 38 rootstocks in pounds per acre for 2004 and 2005. Dry inshell yield ranged from 3530 to 6916 lbs/ac. The five highest yielding stocks were GZ, DX, XZ, DW, XX and FX. Their yields ranged from 6916 to 5911 lbs/ac. However, they were not statistically significant from one another. The five lowest yielding rootstocks were EZ, AW, MX, BX, YZ and OX. Their production ranged from 3530 lbs/ac. to 4685 lbs/ac. However, again, they were not statistically significantly different from one another.

Figure 1. Kings County PDS Trial 2004 Scion diameters taken six inches above the union, 12/30/04. Grand Mean of 7.55 inches indicated by horizontal gridline. Rootstocks with similar letters are not significantly different at p=0.05.

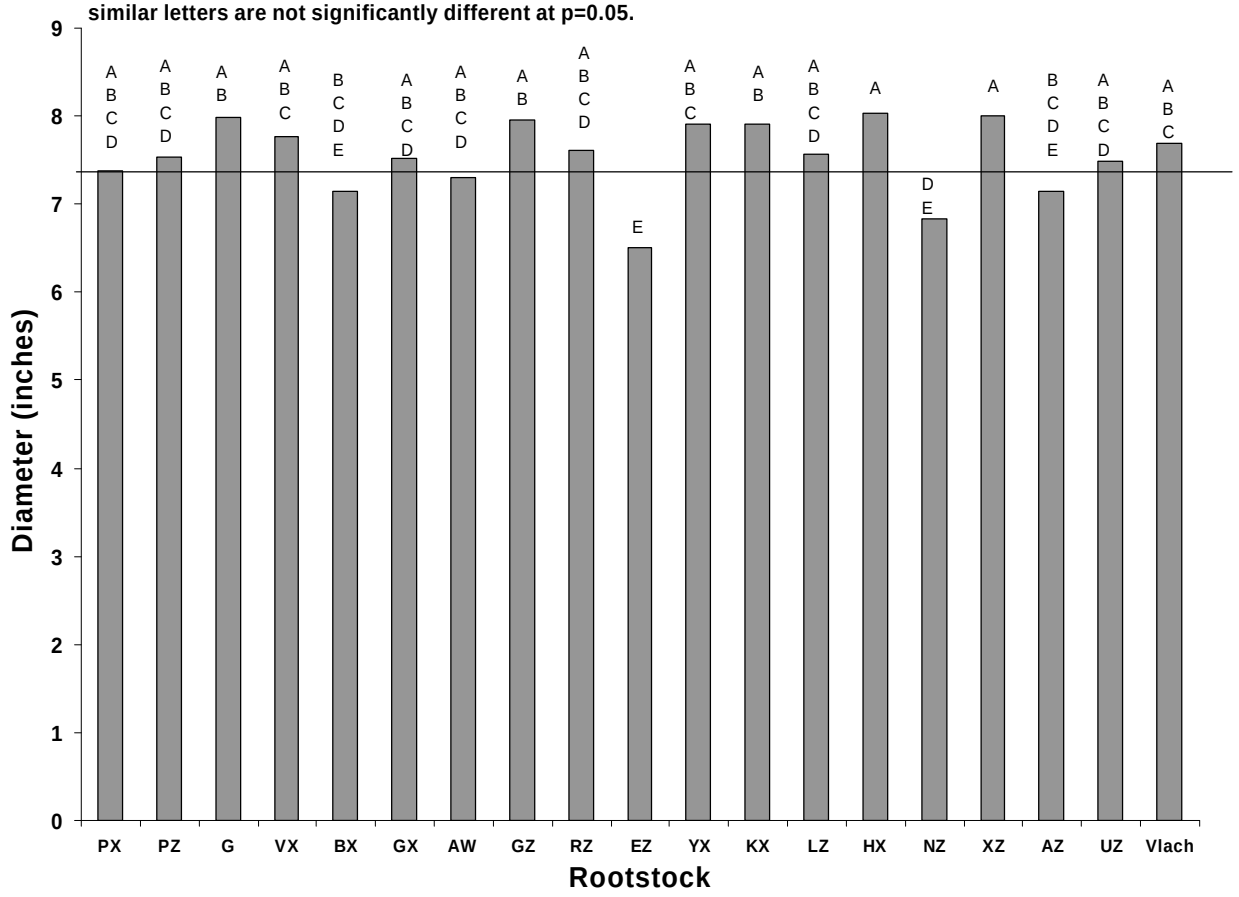


Figure 2. Kings County PDS Trial 2004 Scion diameters taken six inches above the union, 12/30/04. Grand Mean of 7.55 inches indicated by horizontal gridline. Rootsstocks with similar letters are not significantly different at p=0.05.

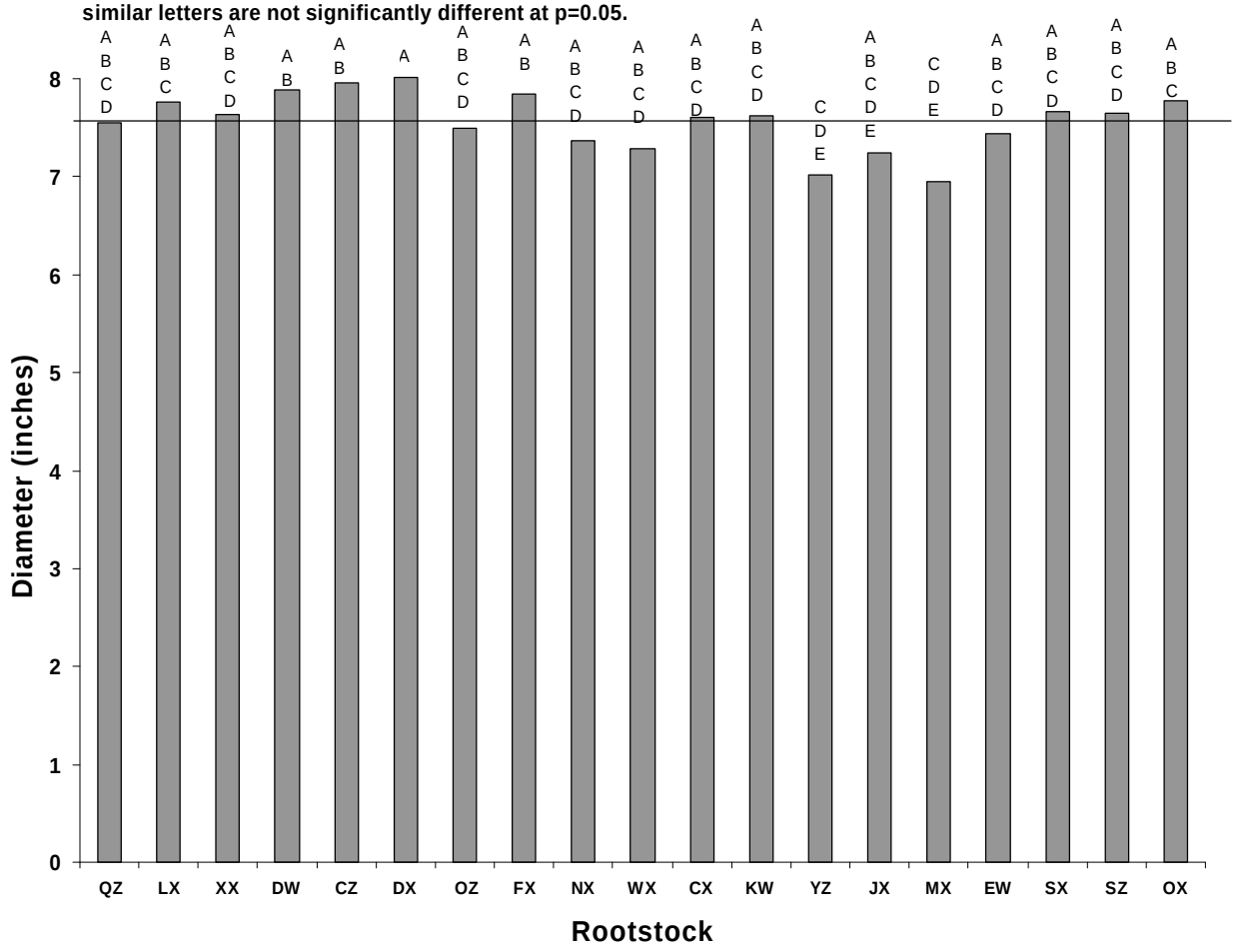


Figure 3. Kings County walnut PDS Trial Scion diameters (Tulare cultivar) taken six inches above the bud union, 11/28/05. Grand Mean of 8.07 inches indicated by horizontal gridline. Rootsocks with similar letters are not statistically significant at p = 0.05

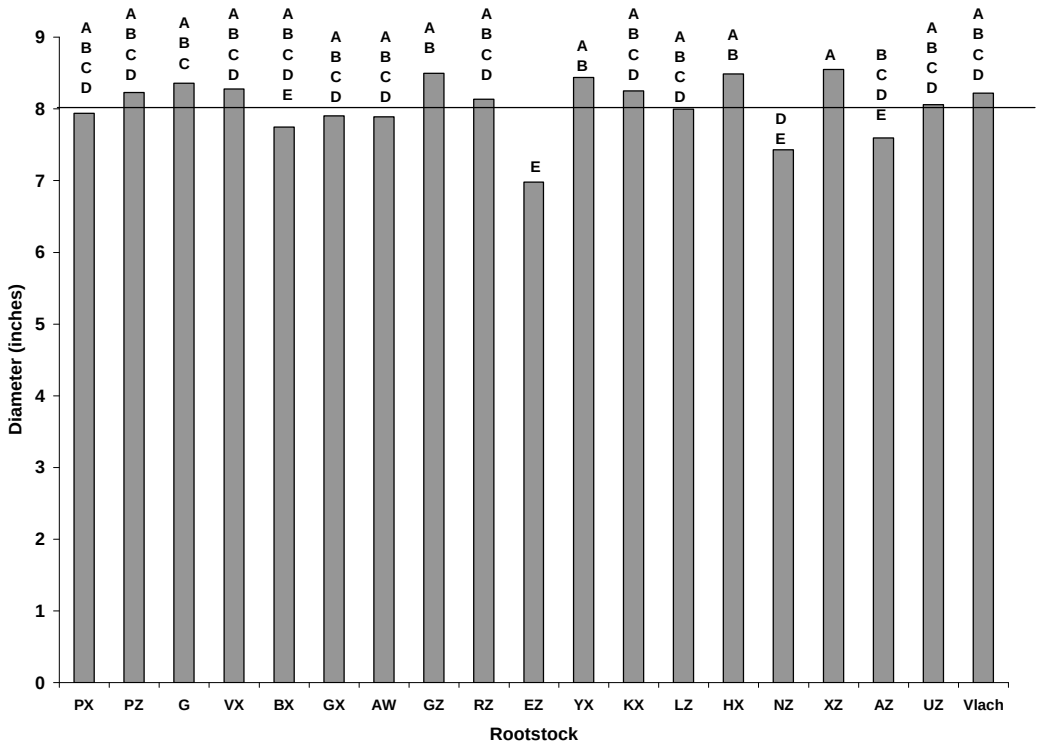


Figure 4. Kings County walnut PDS Trial Scion diameters (Tulare cultivar) taken six inches above the bud union, 11/28/05. Grand Mean of 8.07 inches indicated by horizontal gridline. Rootsocks with similar letters are not statistically significant at p = 0.05

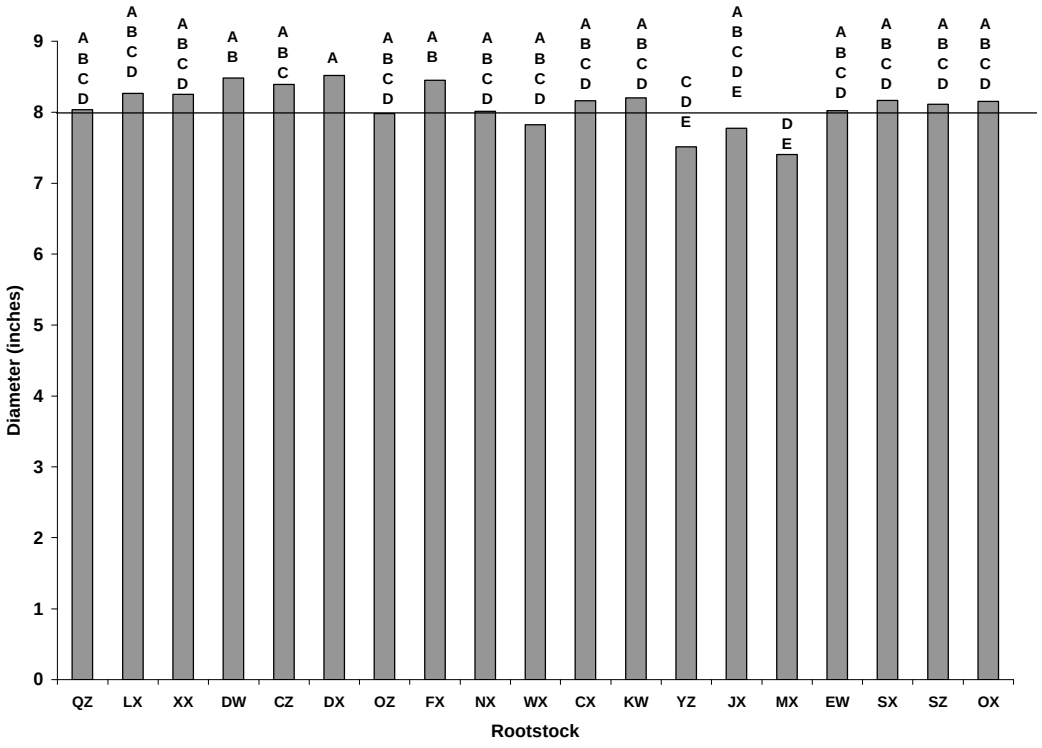


Fig. 5. Dry inshell yield per acre for 2004 (sixth leaf). Kings County paradox diversity trial. Tulare cultivar. Grand mean of 6040 lbs/ac indicated by horizontal gridline. Four replications per mean. Treatments with similar letters are not statistically p=0.05.

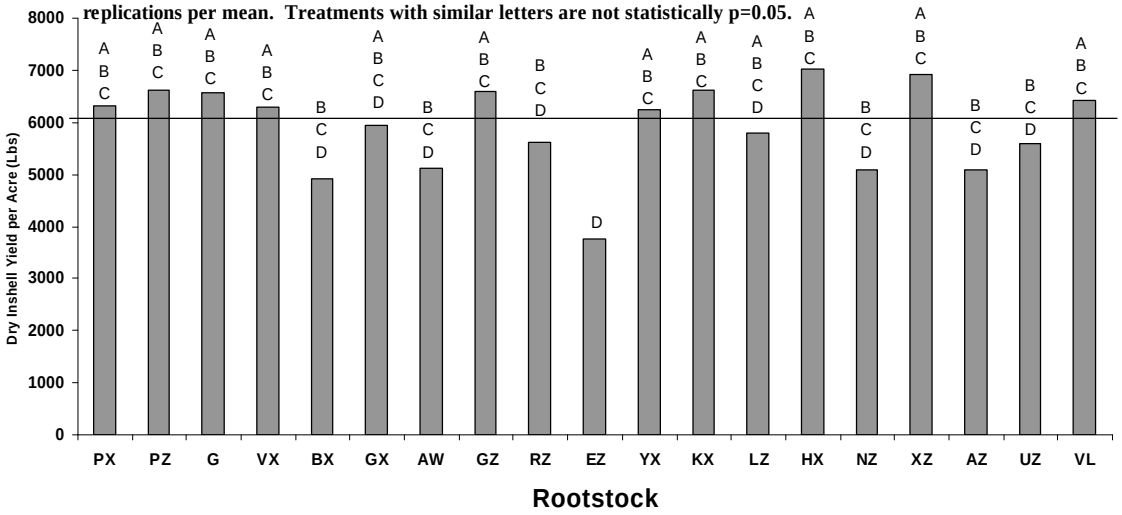


Fig. 6. Dry inshell yield per acre for 2004 (sixth leaf). Kings County paradox diversity trial. Tulare cultivar. Grand mean of 6040 lbs/ac indicated by horizontal gridline. Four replications per mean. Treatments with similar letters are not statistically p=0.05.

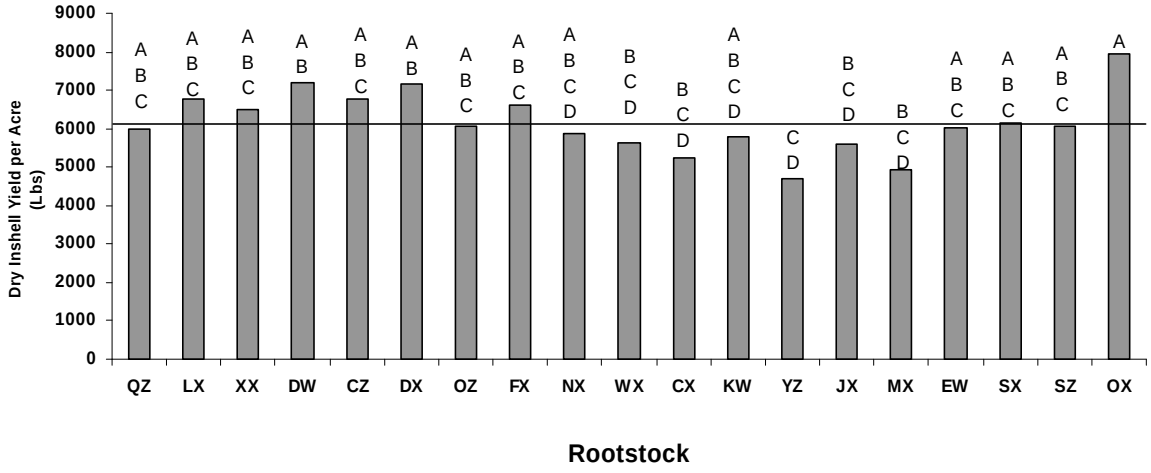


Figure 7. Dry inshell yield per acre for 2005 (seventh leaf). Kings County paradox diversity trial, Tulare cultivar. Grand mean of 5233 lbs/ac indicated by horizontal gridline. Four replicatios per mean. Treatments with simialr letter are not statically significant at p = 0.05.

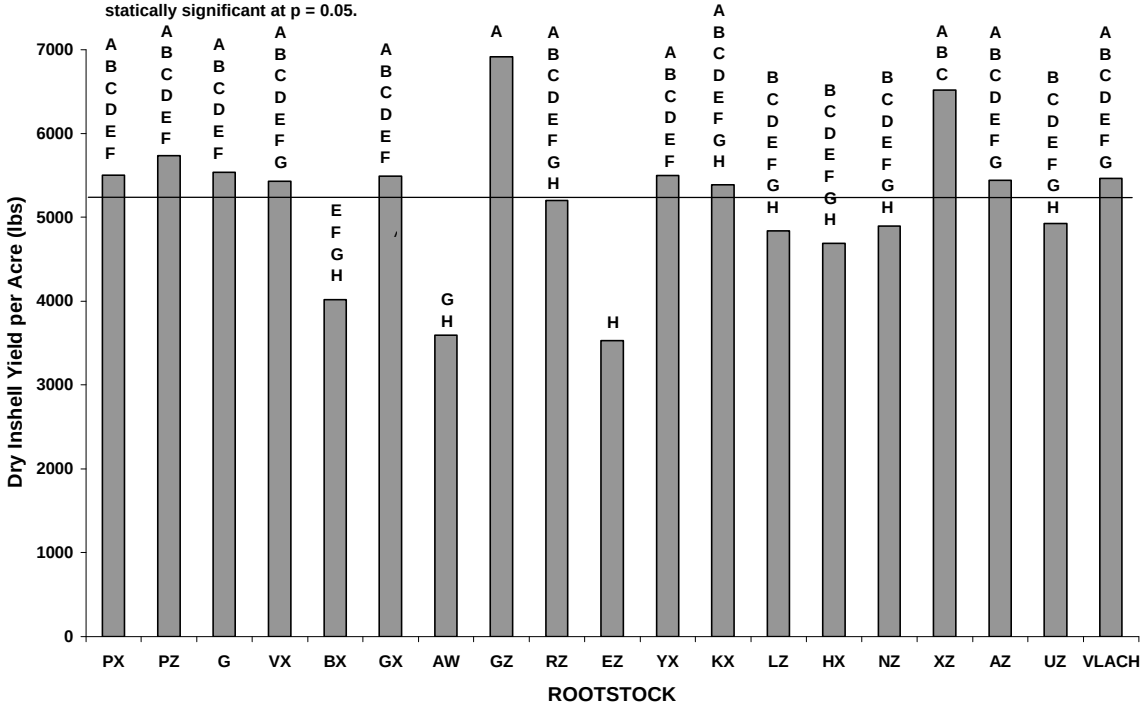
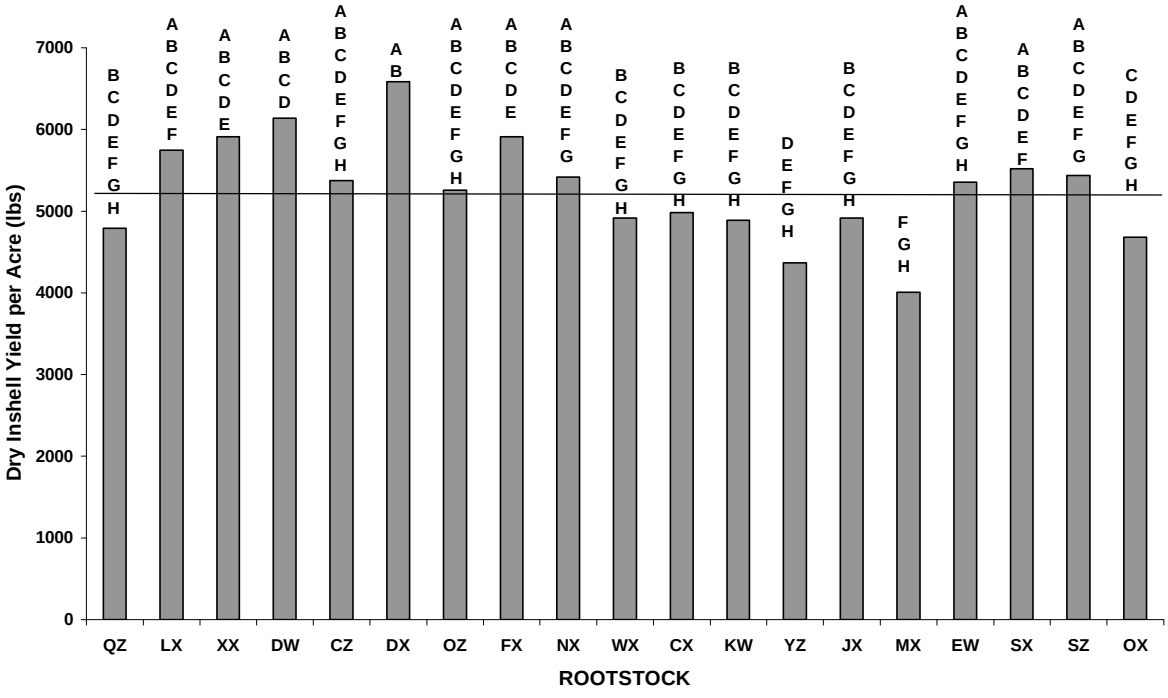


Figure 8. Dry inshell yield per acre for 2005 (seventh leaf). Kings County paradox diversity trial, Tulare cultivar. Grand mean of 5233 lbs/ac indicated by horizontal gridline. Four replicatios per mean. Treatments with simialr letter are not statically significant at p = 0.05.



RESULTS AND DISCUSSION, ALL FOUR TRIALS

Table S1 shows the average trunk circumference for the various sources at all four sites at the end of the 2005 season. The rootstocks that have *Juglans hindsii* (Jh) crossed with *J. regia* (Jr) included 4 rootstocks that were large in all four trials (DX, OX, PZ, and Vlach). There was considerable variation in size of most of the other rootstocks when comparing the four trials with some rootstocks performing quite differently among the trials. In general, trunk circumference tended to correlate pretty well with yield, particularly when the cumulative average yield is used as the comparison (see Figure Y1 earlier in report).

The black rootstocks that were planted in all four trials were some of the smallest trees and tended to be low yielding. Three of the four rootstocks containing all four (Jm, Jn, Jh, Jr) parents were consistently smaller than most others (MX, NZ and AZ). There were also three Jh x Jr crosses that tended to be smaller at all four sites (JX, QZ and WX). Several rootstocks containing the three (Jh, Jn, Jr) parents also tended to be smaller at all sites (PX, HX and OZ).

Average yield for all rootstock sources is shown in Fig. S1. The yields at the Yolo and Kings sites are similar while those at the San Joaquin site are somewhat less. The 2005 harvest was the last for the Yolo site. Although looking at Fig. S1, it appears that the Yolo site might not have reached its maximum yield potential, the confounding factors thrown in by differential tree size in adjacent rows (each rootstock is planted in one individual row in each replication) makes yield data from this point on less reliable. This is because a large rootstock next to a small one can take more than its allotted space and thus exaggerate yield potential. Data collection will continue on the Kings, San Joaquin and Tehama County sites in 2006.

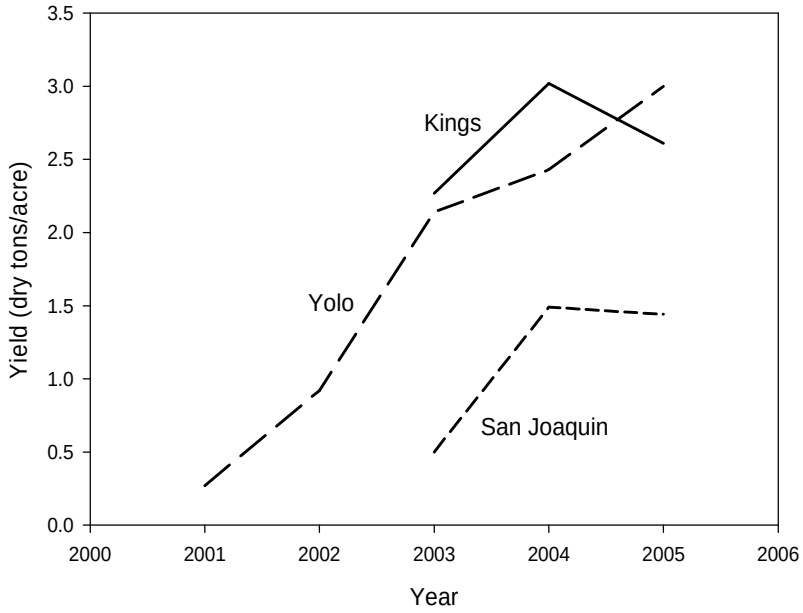


Fig. S1. Average overall dry tons per acre yield by site and year

Table S1. Trunk average trunk circumference for all four sites at end of 2005 growing season.

Rootstock	Parentage	circumference (cm)
VLACH	JhxJr	63.24
OX	JhxJr	62.59
DX	JhxJr	62.48
PZ	JhxJr	62.44
LX	JhxJnxJr	62.13
LZ	?	61.87
XX	JcxJhxJr	61.84
SX	JhxJr	61.76
UZ	JhxJr	61.68
CX	JmxJnxJhxJr	61.64
RZ	JhxJr	61.59
SZ	JhxJr	61.23
KX	JhxJr	60.99
NX	JhxJnxJr	60.74
AW	JhxJr	60.52
VX	JhxJr	60.44
CZ	JhxJr	60.43
PX	JhxJnxJr	60.09
HX	JhxJnxJr	59.96
OZ	JhxJnxJr	59.93
YZ bl	JnxJh	59.59
JX	JhxJr	59.51
QZ	JhxJr	59.16
WX	JhxJr	59.03
MX	JmxJnxJhxJr	58.43
NZ	JmxJhxJnxJr	57.07
AZ	JmxJnxJhxJr	56.98
BX bl	JcxJn	55.24
AW bl	Jh	50.94