Effects of Regulated Deficit Irrigation on Walnut (*Juglans regia*) Grafted on Northern California Black (*Juglans hindsii*) or Paradox Rootstock

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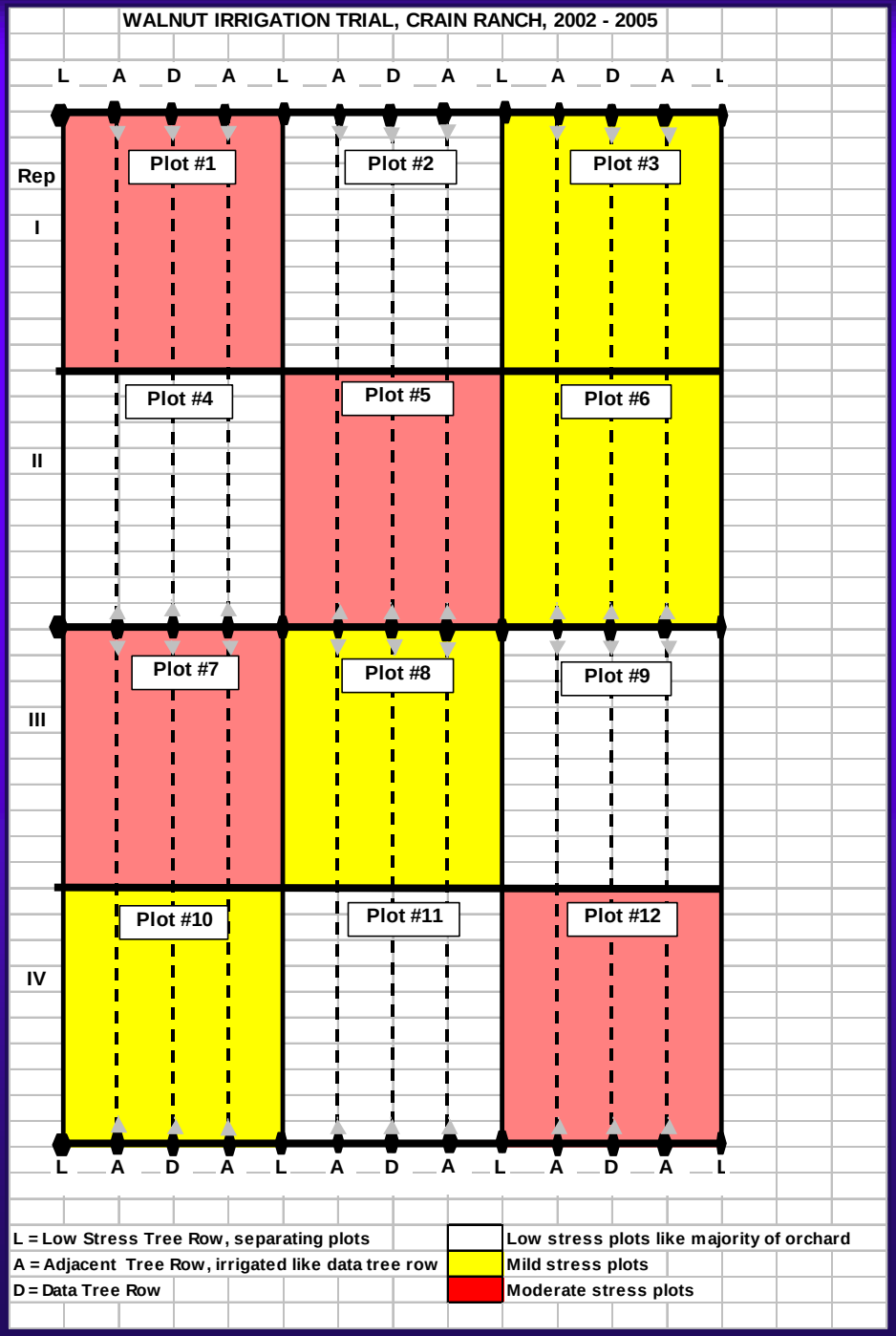
Potential ET = 10,650 Ml/ha

Little or no effective rainfall

Nearly all California walnut acreage is irrigated


WALNUT IRRIGATION TRIAL, CRAIN RANCH, 2002 - 2005
L A D A L A D A L A D A L
Rep
I
II
III
IV
Plot #1
Plot #2
Plot #3
Plot #4
Plot #5
Plot #6
Plot #7
Plot #8
Plot #9
Plot #10
Plot #11
Plot #12
L = Low Stress Tree Row, separating plots
A = Adjacent Tree Row, irrigated like data tree row
D = Data Tree Row
Low stress plots like majority of orchard
Mild stress plots
Moderate stress plots

Chandler on Paradox and NCB

9.1 m x 5.5 m (197 trees/ha)

Maywood sandy loam consisting of stratified soils

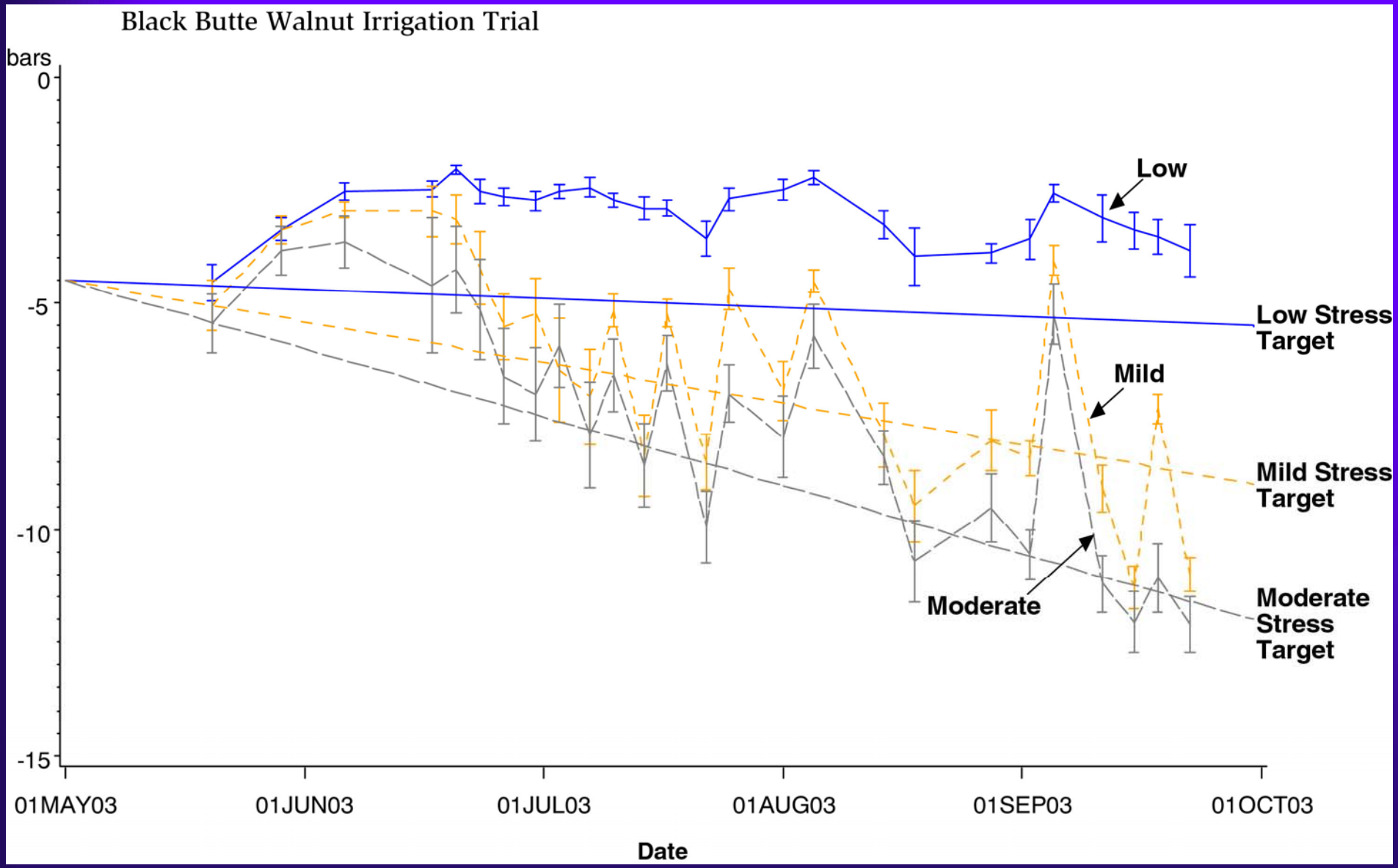
One Nelson R5 microsprinkler per tree (.76 – 1.27 mm/hr)

Campbell Pacific Neutron Probe at 20, 45, 76, 106 and 137 cm depths

Watermark + AM 400 Data Logger at 25, 45, 76, 106 cm depths

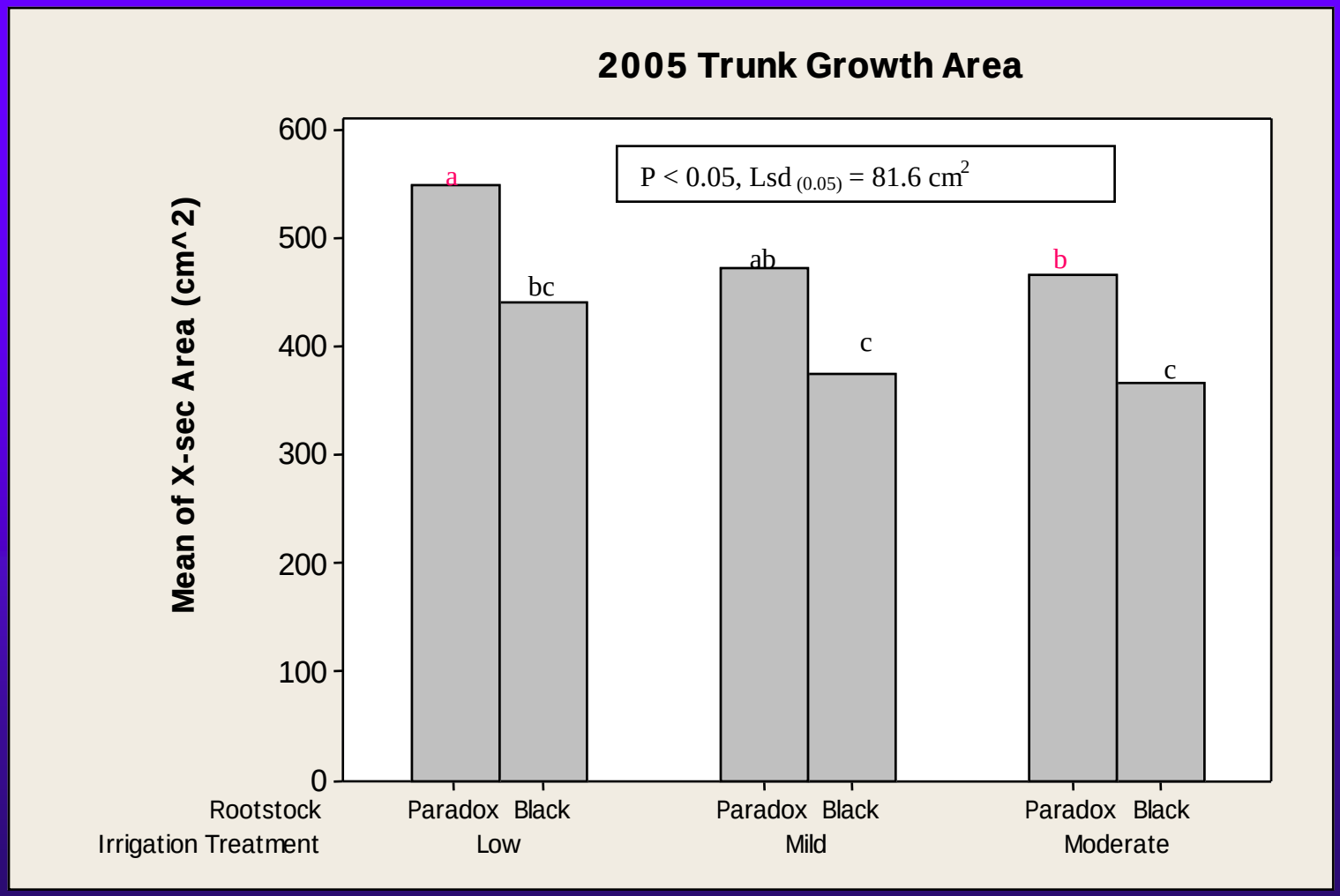
Midday Stem Water Potential


wharf to wharf race 2006

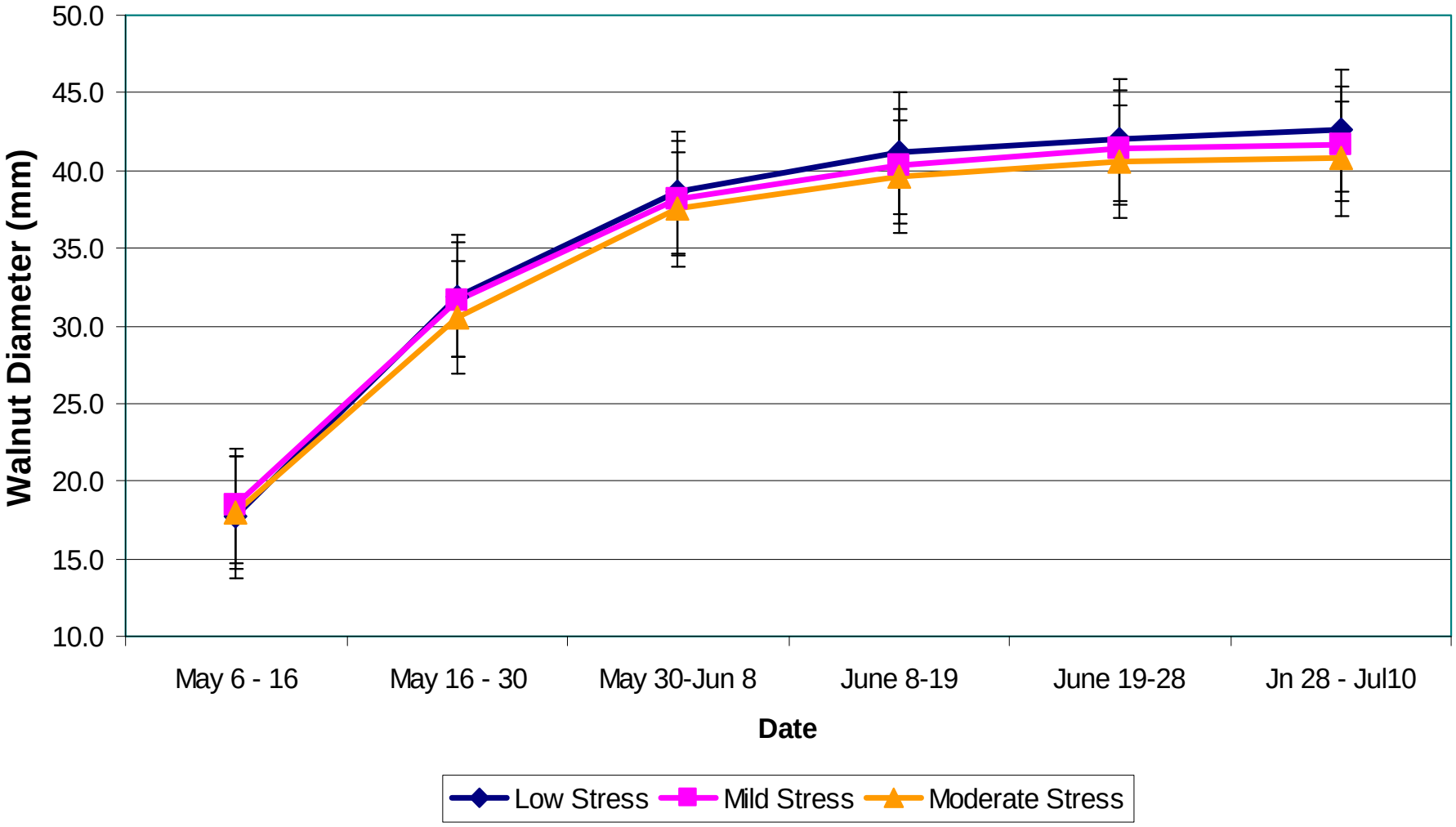

Black Butte Walnut Irrigation Trial
bars
0
-5
-10
-15
Low
Low Stress Target
Mild
Mild Stress Target
Moderate
Moderate Stress Target
01MAY03
01JUN03
01JUL03
01AUG03
01SEP03
01OCT03
Date

Monthly Average	2002 Season			2003 Season			2004 Season			2005 Season		
	Low	Mild	Mod	Low	Mild	Mod	Low	Mild	Mod	Low	Mild	Mod
May	-.42	-.45	-.54	-.38	-.42	-.44	-.26	-.27	-.28	-.46	-.41	-.42
June	-.40	-.48	-.65	-.25	-.40	-.51	-.48	-.58	-.69	-.54	-.44	-.41
July	-.34	-.60	-.78	-.28	-.65	-.75	-.50	-.76	-.89	-.61	-.65	-.60
Aug	-.33	-.66	-.77	-.32	-.79	-.89	-.32	-.64	-.85	-.56	-.82	-.80
Sept	-.28	-.89	-.96	-.34	-.85	-1.02	-.28	-.60	-.81	-.61	-.73	-.98
Season Avg.	-.35	-.62	-.74	-.31	-.62	-.72	-.37	-.57	-.70	-.56	-.61	-.64
Applied Water (ML/ha)	11081	7886	6488	11278	6587	5489	10880	6686	5887	9681	7386	6587

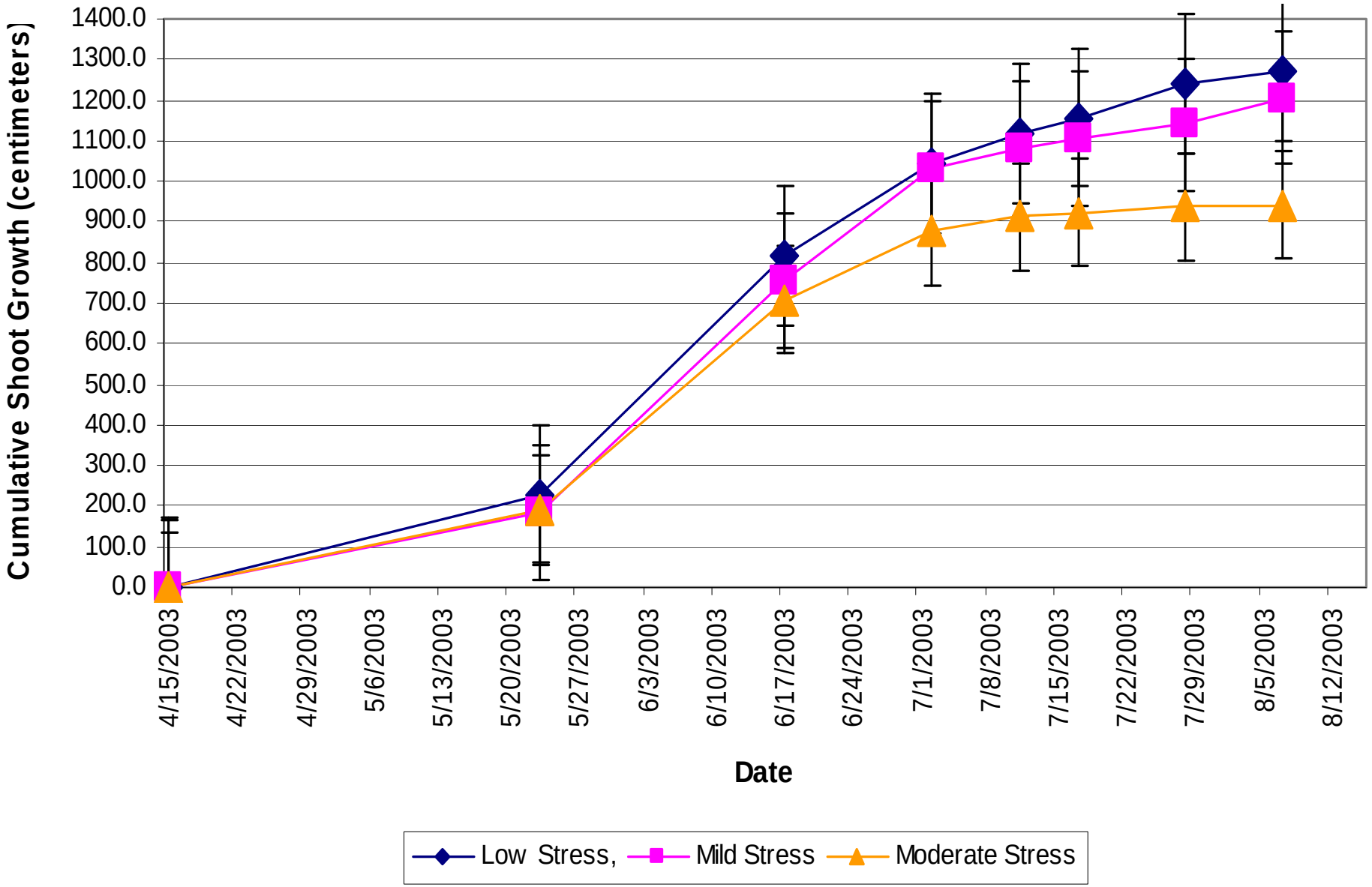
Figure 1. Summary of monthly average MSWP (MPa), applied water (ML/ha) and the three different irrigation strategies imposed on Chandler walnut, 2002-2005.


2005 Trunk Growth Area
P < 0.05, Lsd (0.05) = 81.6 cm2
Mean of X-sec Area (cm^2)
600
500
400
300
200
100
0
a
bc
ab
c
b
c
Rootstock
Paradox Black
Paradox Black
Paradox Black
Irrigation Treatment
Low
Mild
Moderate

Cumulative nut sizing of Chandler walnut on Paradox Rootstock grown under low, mild, and moderate levels of tree stress. Tehama County, 2002.



Cumulative growth (centimeters) of pruned Chandler walnut shoots grown on Paradox Rootstock in low, mild, and moderate stressed irrigation treatments.



Harvest evaluations for the three RDI treatments

- Nut weight
- Nut size
- Kernel color
- Off grade
- Shell stain
- Mold
- Kernel shrivel
- Insect damage
- % large in shell
- Edible kernel
- Yield
- Nut load

Rootstock	Irrigation Treatment	Edible Yield (%) 2002	2003	2004	2005
Paradox	Low	49.31 ab	53.72 a	47.30	46.20 a
Paradox	Mild	48.97 ab	51.35 bc	48.35	46.32 a
Paradox	Moderate	49.76 a	49.40 d	47.82	46.32 ab
NCB	Low	48.42 bc	52.47 ab	48.84	45.36 ab
NCB	Mild	47.81 c	50.66 cd	48.51	44.24 bc
NCB	Moderate	47.90 c	49.58 d	48.85	42.88 c
P value		p<0.01	p<0.01	p=0.13	p<0.01
LSD (0.05)		0.92	1.28	NS	1.62

Figure 3. Edible Yield for each year by irrigation treatment and rootstock. Subsample analysis by Diamond Walnut of California.

Rootstock	Irrigation Treatment	% Large Sound In-shell Walnuts 2002	2003	2004	2005
Paradox	Low	92.05 a	82.38 a	72.66	73.04 c
Paradox	Mild	92.12 a	84.97 a	81.05	80.78 b
Paradox	Moderate	85.41 bc	85.08 a	78.55	82.69 ab
NCB	Low	91.17 a	81.85 ab	75.02	80.70 b
NCB	Mild	89.99 a	75.39 b	80.45	83.22 ab
NCB	Moderate	84.08 c	78.71 ab	78.49	85.91 a
P value		p<0.01	p<0.05	p=0.32	p<0.01
LSD (0.05)		5.26	6.80	NS	4.96

Figure 2. Percent Large Sound In-shell Walnuts for each year by irrigation treatment and rootstock. Subsample analysis by Diamond Walnut of California.

Rootstock	Irrigation Treatment	% Large Sound In-shell Walnuts 2002	2003	2004	2005
Paradox	Low	92.05 a	82.38 a	72.66	73.04 c
Paradox	Mild	92.12 a	84.97 a	81.05	80.78 b
Paradox	Moderate	85.41 bc	85.08 a	78.55	82.69 ab
NCB	Low	91.17 a	81.85 ab	75.02	80.70 b
NCB	Mild	89.99 a	75.39 b	80.45	83.22 ab
NCB	Moderate	84.08 c	78.71 ab	78.49	85.91 a
P value		p<0.01	p<0.05	p=0.32	p<0.01
LSD (0.05)		5.26	6.80	NS	4.96

Figure 2. Percent Large Sound In-shell Walnuts for each year by irrigation treatment and rootstock. Subsample analysis by Diamond Walnut of California.

Rootstock	Irrigation Treatment	Nut Load (nuts/tree) 2002	2003	2004	2005
Paradox	Low	2312 a	3955 a	2652 a	3073 a
Paradox	Mild	2245 a	3557 ab	1915 b	2401 b
Paradox	Moderate	2195 a	3119 bc	1576 c	2033 bc
NCB	Low	1543 b	2727 c	1947 b	1671 cd
NCB	Mild	1493 b	1948 d	1323 cd	1288 de
NCB	Moderate	1583 b	1840 d	1058 d	1019 e
P value		p<0.01	p<0.01	p<0.01	p<0.01
LSD (0.05)		312	546	301	498

Figure 4. Total number of walnuts per tree for each year of irrigation treatment and rootstock. Nut load is the product of individual tree dry in-shell weight and count per kilogram.

Rootstock	Irrigation Treatment	Yield (kg/ha) 2002	2003	2004	2005	4 Year Total Yield
Paradox	Low	5355 a	7041 a	5652 a	6041 a	24,089 a
Paradox	Mild	4936 ab	6215 ab	4222 b	4861 b	20,234 b
Paradox	Moderate	4562 b	5539 bc	3436 cd	4088 bc	17,625 c
NCB	Low	3507 c	5140 c	4048 bc	3347 cd	16,042 c
NCB	Mild	3311 c	3748 d	2896 de	2643 de	12,598 d
NCB	Moderate	3323 c	3461 d	2289 e	2135 e	11,208 d
P value		p<0.01	p<0.01	p<0.01	p<0.01	p<0.01
LSD (0.05)		674	1006	672	977	2587

Figure 5. Yield and four year total yield by irrigation treatment and rootstock. Yields were taken on individual trees (yield conversion to hectare using 197 trees/ha).

Effect of three consecutive years of irrigation and water stress on bud development of first year fruit wood on Chandler walnut grown on Paradox rootstock.

Treatment Three year average Midday SWP	Reduction in buds that opened (%)	Reduction in floral buds (%)	Reduction of flowers per floral bud (%)	Reduction in nut load (%)
Low	0 a	0 a	0 a	0 a
Mild	-1 a	-18 a	-3 a	-24 a
Moderate	-12 b	-12 b	-9 b	-31 b

Summary

- Chandler walnuts do not appear to be good candidates for RDI
- Both rootstocks responded negatively to water stress
- Paradox out-yielded NCB, however, the yield advantage of Paradox can be compromised by water stress
- Water stress can negatively affect kernel quality
- Water stress reduced nut load primarily by reducing the number of flower buds

Interpreting MSWP Measurements in Walnuts

SWP Reading (- MPa)	
0 to –.20	Not commonly observed
–.20 to –.40	Fully irrigated, low stress, commonly observed when orchards are irrigated according to estimates of real-time evapotranspiration (ETc), long term root and tree health may be a concern
–.40 to –.60	Low to mild stress, high rate of shoot growth visible, suggested level from leaf-out until mid June when nut sizing is completed
–.60 to –.80	Mild to moderate stress, shoot growth in non-bearing and bearing trees has been observed to decline especially with Black Walnut Rootstock. These levels do not appear to affect kernel development and may be appropriate during kernel development
–.80 to –1.00	Moderate to high stress, shoot growth in non-bearing trees may stop, nut sizing may be reduced in bearing trees
–1.00 to –1.20	High stress, temporary wilting of leaves has been observed. New shoot growth may be sparse or absent and some defoliation may be evident. Nut size likely to be reduced.
–1.20 to –1.40	Relative high levels of stress, moderate to severe defoliation, should be avoided
–1.40 to –1.80	Severe defoliation, trees are likely dying