Effect of Partial Rootzone Drying on Vine Water Relation, Vegetative Growth, Mineral Nutrition, Yield Components, Fruit Composition, and Wine Quality in Sauvignon Blanc Grapevines

Final Report (1999-2002) for Research Project Funded by
American Vineyard Foundation
California Competitive Grant Program for Research in Viticulture and Enology
California State University-Agricultural Research Initiative

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I. Project Title

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II. Principle Investigators and Cooperators

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III. Summary

Partial rootzone drying (PRD) is an irrigation technique designed to keep part of the rootzone dry and the rest of the rootzone well-watered, in comparison with conventional drip irrigation (CDI) with the entire rootzone irrigated. The objective of this research was to investigate the feasibility and effect of PRD on vine water relation, vegetative growth, mineral nutrition, yield components, fruit composition, wine chemistry, and wine sensory characteristics in mature Sauvignon blanc grapevines (*Vitis vinifera* L.) grown in the San Joaquin Valley of California. Vineyard water use and canopy microclimate were also evaluated. This study was conducted in a 15-acre bilateral cordon trained mature Sauvignon blanc/Freedom vineyard on Hanford Sandy Loam in the California State University, Fresno Agricultural Laboratory. Treatment factors included irrigation method (PRD and CDI) and irrigation rate (0.4 or 0.8 evapotranspiration, ETc), resulting in 4 treatments, CDI-0.4, CDI-0.8, PRD-0.4, and PRD-0.8. Partial stomatal closure due to reduced irrigation rate resulted in a decrease in stomatal conductance (g), transpiration rate (E), and vine vegetative growth, and in turn, an improvement in water use efficiency. Yield, fruit composition and wine chemistry were not significantly affected by either irrigation method or irrigation rate. Three years' field experiments demonstrated that reducing irrigation rate offers a way for producing a vine with a better balance between vegetative and reproductive development, reducing vine water use,

controlling vine vigor and canopy density, while maintaining crop yield when compared to standard vineyard irrigation practices. Most of the observed PRD-0.4 effect on vine performance and vine physiology was the result of the reduced irrigation rate rather than

keeping part of the rootzone dry and the rest of the rootzone well watered.

IV. Objectives and Experiments Conducted to Meet Stated Objectives

The objective of this research was to investigate the feasibility and effect of PRD on vine water relation, leaf chlorophyll fluorescence characteristics, vegetative growth, mineral nutrition, yield components, fruit composition, wine chemistry, and wine sensory characteristics in mature Sauvignon blanc grapevines (*Vitis vinifera* L.) grown in the San Joaquin Valley of California. Vineyard water use and canopy microclimate were also evaluated.

Experimental Design. This study was conducted in a 15-acre bilateral cordon trained mature Sauvignon Blanc/Freedom vineyard on Hanford Sandy Loam in the California State University, Fresno Agricultural Laboratory. Row orientation was north-to-south and spacing of vines is 8' x 12' (vine x row). The experiment was designed as a randomized complete block with four replications. Treatment factors included irrigation method (PRD vs. CDI) and irrigation rate (0.4 and 0.8 evapotranspiration, ETc), resulting in four treatments, CDI-0.4, CDI-0.8, PRD-0.4, and PRD-0.8. Viticulture data was collected from three representative vines located in the middle row of each irrigation treatment plot.

Irrigation System Design. Drip irrigation system for PRD and control was designed, installed, and tested in May 1999. Vines were serviced by emitters spaced 48 inches apart down the row between trunks except CDI-0.4 which is serviced by emitters at the trunk during the period of PRD experiment. The PRD treated blocks were designed with two-polyethylene (PE) tubes. One side of the vines was serviced by emitters on one PE tube while the other PE tube supplied water to the other side. This allows wetting and drying of either side of the vine, depending on the tube selected for irrigation and cycle time. PRD-0.8 was achieved by using twice as many emitters on each side of the vine. All the emitters had a flow rate of 0.5 gallon per hour and they were all pressure-compensated (Netafim Irrigation, Inc., Fresno, California).

Irrigation Schedule. The vines were irrigated daily throughout the growing season and PRD was applied to the assigned treatments from fruit set to harvest. CDI-0.8 was used for all the treatments prior to and after PRD treatment (Table 1).

Water Use. Amount of water applied was calculated by multiplying the hours of irrigation by flow rate and number of the emitters.

Vine Water Relations and Leaf Chlorophyll Fluorescence Characteristics. Stomatal conductance (g) and transpiration rate (E) of recently-matured leaves were measured with a porometer (Li-1600; Li-Cor, Inc., Lincoln, Nebraska) during the application of PRD every 1 to 7 days. Diurnal changes of g and E were measured at early, middle, and late stages of one PRD cycle in 2000 and two PRD cycles in 2001. Chlorophyll florescence characteristics of same leaves as for g and E measurement were recorded with Fluorescence Monitoring System (FMS 2; Hansatech Instruments Ltd., England) on July 26, 28, 30 and August 1, 2000 and same schedule as g and E in 2001, respectively.

Canopy Microclimate. Canopy radiation in fruiting zone was assessed at veraison on July 19, 1999, July 11, 2000 and July 11, 2001, using a Li-Cor model Li-191SB quantum line sensor and Li-Cor model Li-185B photometer.

Yield Components. Cluster number and yield were collected at harvest on August 26, 1999, August 16 and August 21, 2000 and August 2, 2001.

Fruit Composition and Maturity. Samples were taken on August 10, 17, and 26, 1999, July 25, 31, August 4, 15 and 20, 2000 and July 17, 24, 30, and August 3, 2001. Berries were analyzed for berry weight, % soluble solids (Brix), titratable acidity (TA), and pH.

Water Use Efficiency. Water use efficiency was calculated and expressed as gallons of water used per pound of fruit produced.

Vine Nutrition. Petiole samples taken at veraison in 1999 and at full bloom in 2000 and 2001 were analyzed for macro- and micro-nutrients (N, P, K, Ca, Mg, Mn, S, Fe, Cu, B, and Zn) to determine the mineral nutritional status of the vine.

Vegetative Growth. The number of primary and lateral shoots and pruning weight were recorded during the dormant season as a measure of vegetative responses to the treatments. Number of growing tips were recorded at veraison in 2001.

Wine Making and Wine Analysis. Berries harvested at total soluble solids content of 23°Brix were pressed for wine making. Must samples were analyzed for Brix, TA, and pH. Wines were analyzed for alcohol content, TA, volatile acidity (VA), pH, and total phenolics. Wine sensory evaluation was conducted using triangle test in 1999 and 2000.

Data Analysis. Data was analyzed with variance analysis procedures of selected variables according to the experimental design.

V. Summary of Major Research Accomplishments and Results

Water Use and Soil Water Moisture. Water use of vines irrigated with 0.4 ETc (CDI-0.4 and PRD-0.4) is 50% of that for vines irrigated with 0.8 ETc (CDI-0.8 and PRD-0.8) during the PRD treatment. Amount of water applied was the same for all the treatments at the level of

0.8 ETc prior to and after PRD treatment. Total water usage of PRD-0.4 and CDI-0.4 was 64% and 61% of CDI-0.8 in 1999 respectively, 69% in 2000, and 71% in 2001, respectively (Table 2). Soil moisture in the depth of 20 and 40 cm was reduced quickly on the non-irrigated side of PRD treated vines and restored quickly after PRD switch (Fig. 1).

Yield Components and Water Use Efficiency. Yield and yield components were not influenced by either irrigation methods or the amount of water applied, except cluster weight and berry weight were reduced at lower rate of 0.4 ETc in 1999 and 2001. Water use efficiency was higher in vines irrigated with 0.4 ETc in 1999 and 2001 (Table 3).

Berry Weight, Fruit Composition, Must Composition, and Wine Chemistry. Fruit composition at harvest and must composition were not influenced by either irrigation method or irrigation rate, except lower fruit pH, higher fruit and wine TA in 2000; and higher TA of fruit, must, and wine in 2001 at higher irrigation rate (Table 4). Berry weight and TA were significantly affected by irrigation rate earlier during the maturation process in all three years (Fig. 2). Fruit were harvested with statistically comparable composition on the same date in 1999 and 2001. However, harvest was conducted 5 days later for vines irrigated at lower rate of 0.4 ETc due to a slightly slower fruit maturation in 2000 (Table 4).

Wine Sensory Characteristics. In 1999, wines were statistically comparable between CDI-0.8 and PRD-0.4, and also between PRD-0.8 and CDI-0.4. However, significant sensory differences were detected between CDI-0.8 and CDI-0.4, between CDI-0.8 and PRD-0.8, between PRD-0.8 and PRD-0.4, and between CDI-0.4 and PRD-0.4. In 2000, significant sensory differences of wines were detected only between treatments with different irrigation rates regardless of irrigation methods (Table 5).

Fruiting Zone Light Penetration and Vine Vegetative Growth. Light penetration into fruiting zone was not influenced by irrigation methods or the irrigation rate except greater light penetration into fruiting zone from the west side of canopy at lower irrigation rate in 2001.

Number of primary shoots was statistically comparable for all the treatments. Number of laterals and pruning weight were reduced when vines were irrigated at lower rate of 0.4 ETc regardless of irrigation methods. There were fewer growing tips at veraison when vines were irrigated at lower rate of 0.4 ETc in 2001(Table 6).

Petiole Mineral Nutrition. Petiole mineral nutrient contents at veraison in 1999 and full bloom in 2000 and 2001 were not influenced by irrigation methods except Mg in 1999 and Ca in 2000. Vines irrigated with lower rate of 0.4 ETc had lower NO_3-N and Mg content in 1999, higher P content and higher Ca content in 2000, and lower K content in 2001. Vines irrigated with 0.8 ETc had higher B content than that with 0.4 ETc (Table 7).

Vine Water Relation. In general, significant effect of irrigation method on water relation occurred only when the vines were experiencing greater environmental stresses such as high temperature. In addition, most of the significant differences were caused by irrigation rate, not by the irrigation methods. g and E responded to irrigation method and irrigation rate similarly and were well correlated to each other. The earlier the time of the season, the longer it was from PRD switch to the day when significant difference of g and E among the treatments was detected. No significant difference of g and E was detected during the first PRD cycle (Fig. 3).

Rain occurred in the middle of the 1st PRD cycle in June of both 1999 and 2000 and may have reduced the effect of PRD or the lower irrigation rate of 0.4 ETc. All the significant differences were related to irrigation rate, not to the irrigation method, with an exception on the 7th day of 4th PRD cycle in 2000 and on the 9th day of 5th PRD cycle in 2001 when CDI-0.4 showed a lower g than PRD-0.4 (Fig. 3).

Diurnal change of g and E was not affected until the 14th day during the 3rd PRD cycle in 2000 when irrigation rate affected g and E from 10 AM to 4 PM while irrigation methods only significantly affected g at noon when CDI-0.4 had lower g and E (Fig. 4).

Chlorophyll Fluorescence Characteristics. In 2000, Efficiency of photosystem II photochemistry of mature leaves was measured four times during the 3rd PRD cycle by chlorophyll fluorescence. Photochemical quenching was higher in vines treated with PRD-0.8, compared to other treatments earlier during the PRD cycle, 1 and 3 days after PRD switch.

Efficiency of photosystem II photochemistry was lower when vines were irrigated at lower rate of 0.4 ETc 3 days after PRD switch. At the end of 3rd PRD cycle on August 1, actual quantum yield of photosystem II, an indicator of efficiency of photosystem II photochemistry, was higher on PRD treated vines than that of CDI treated vines, regardless of irrigation rate.

Other chlorophyll fluorescence characteristics including maximum quantum efficiency of PSII photochemistry (Fv/Fm, an index of plant stress), non-photochemical quenching, and electron transfer rate were not affected by irrigation methods nor amount of water applied (Table 8). In 2001, all the chlorophyll fluorescence characteristics we measured at 10:00 am (Fig. 6) as well as diurnal changes of the chlorophyll fluorescence characteristics during 3rd and 6th switching cycle at early, middle and late stage. None were affected by irrigation method or irrigation rate (Figs. 7 and 8).

Three years' field experiments demonstrated that reducing irrigation rate offers a way for producing a vine with a better balance between vegetative and reproductive development, reducing vine water use, controlling vine vigor and canopy density. Most of the observed

PRD-0.4 effect on vine performance and vine physiology was result of the reduced irrigation rate rather than keeping part of the rootzone dry and the rest of the rootzone well watered. It seemed possible to achieve similar vine vigor, canopy characteristics, yield components, fruit composition, and wine quality by managing irrigation at a reduced irrigation rate without switching the wetting and drying sides using PRD.

VI. Outside Presentations of Research

A number of presentations have been made at various locations to audiences representing the grape and wine industry of California. In addition, an article was published as part of the research project. The presentations and the article are listed as follows.

Refereed Journal Manuscript in Preparation

Effect of partial rootzone drying and irrigation rate on vine growth, yield components, and fruit composition in field grown Sauvignon blanc grapevines.

Effect of partial rootzone drying and irrigation rate on water relation and chlorophyll fluorescence characteristics of mature leaves in field grown Sauvignon blanc grapevines.

Professional Presentations

Sanliang Gu, Guoqiang Du, David Zoldoske, and Abdul Hakim, Effect of Partial Rootzone Drying on Leaf Water Relation and Chlorophyll Fluorescence Characteristics in Sauvignon Blanc Grapevines. ASEV 53rd Annual Meeting, Portland, Oregon, June 2002, Submitted

Sanliang Gu, Guoqiang Du, David Zoldoske, Abdul Hakim, Kenneth Fugelsang, and Greg Jorgensen. Effect of Partial Rootzone Drying on Vine Water Relation, Vegetative Growth, Mineral Nutrition, Yield Components, Fruit Composition, and Wine Chemistry in Sauvignon Blanc Grapevines. ASEV 52nd Annual Meeting, San Diego, CA, June 30, 2001

Sanliang Gu and David Zoldoske. Partial rootzone drying (PRD) to improve fruit quality and water use efficiency. 2000 California Plant and Soil Conference. Stockton, California, January 19-20.

Industry Presentations

Sanliang Gu, Partial rootzone drying for winegrape production. The American Vineyard Grape Expo – Central Valley. Madera, California. March 1, 2000.

Sanliang Gu. Partial rootzone drying for winegrape production. The Grape Grower Magazine Farm Show Central. Caruthers, California. March 1, 2000.

David Zoldoske. Evaluation of partial rootzone drying on winegrapes. California Irrigation Institute 38th Annual Meeting – Irrigation in the 21st Century, Who are the Players, What is the Game. Sacramento, California, January 24-25, 2000.

Sanliang Gu and David Zoldoske. Partial rootzone drying, is it an alternative to regulated deficit irrigation? Advances in Irrigation. Parlier, California, November 17, 1999.

Sanliang Gu and David Zoldoske. Partial rootzone drying in grapes to improve wine quality. Grower Appreciation Workshop. Lodi Irrigations, Inc. Lodi, California, November 17, 1999.

Trade Journal and Extension Articles

Sanliang Gu, Simon Graves, David Zoldoske, and Greg Jorgensen. 2000. Partial rootzone drying: doing more with less. Grape Growers Magazine. 2000(7):30-32.

Sanliang Gu, Simon Graves, David Zoldoske, and Greg Jorgensen. 2000. Effect of partial rootzone drying on vine water relation, vegetative growth, mineral nutrition, yield components, fruit composition, and wine quality in Sauvignon blanc grapevines. *CATI VERC Research Note*. CATI Publication #000702.

Proceeding Article

Sanliang Gu, David Zoldoske, Simon Graves, and Greg Jorgensen. 2000. Effect of partial rootzone drying on vineyard water use, vine water relation, yield components, and fruit composition in field-grown mature Sauvignon blanc grapevines – A preliminary evaluation in California. Proceedings of 2000 California Plant and Soil Conference. Stockton, California, January 19-20 2000. pp 75-80.

News Reports

The research has also been reported by various agricultural and environmental media including trade journals such as Grape Grower, Fruit Grower, Newspapers and Newsletters such as Fresno Bee and CSU CATI Update, Societies such as the Society of Environmental Journalists.

VII. Research Success Statements

For the first time in the U.S.A., this research evaluated the feasibility of PRD as a useful vineyard irrigation practice for wine grape production areas with dry growing season such as the San Joaquin Valley of California and separated the effect of reduced irrigation rate from switching the wetting and drying sides. It was demonstrated that the observed benefit such as saving irrigation water, increasing water use efficiency, and controlling vine vigor while maintaining crop yield is mainly originated from the reduced irrigation rate, not from switching the wetting and drying side. It seemed possible to achieve similar vine vigor, canopy characteristics, yield components, fruit composition, and wine quality by managing

irrigation at
a reduced amount of irrigation water without switching the wetting and drying sides using
PRD.

VIII. Funds Status

This research project was funded jointly by the American Vineyard Foundation, the California Competitive Grant Program for Research in Viticulture and Enology, California
Agricultural Technology Institute, and California State University-Agricultural Research Initiative. The funds have been used for Visiting Scientist, Technical Support, Student Assistantship, Materials, Supplies, and Outside Services as proposed. The project was in a
good financial health and has been completed without difficulties.

IX. Acknowledgement

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Agricultural Operations for their help on vineyard management and data collection, Netafim
Irrigation, Inc. for their supply of drip emitters, Netafim Irrigation, Inc. and PhyTech for making Phytomonitors available, and staff and students at the Viticulture and Enology Research
Center for their administrative and technical assistance.

Treatment Prior to PRD During PRD Post PRD
1999 4/12~5/24 5/25~8/21 (6/22, 7/9, 7/24, 8/7)[z] 9/1~10/22
2000 4/12~5/24 5/25~8/21 (6/13, 6/28, 7/13, 7/25, 8/1, 8/7, 8/15) 8/28~10/12
2001 4/2~5/14 5/15~8/6 (5/29, 6/12, 6/26, 7/10, 7/21, 7/31) 8/7~10/21
[z]Date of PRD switching.
Table 1. Irrigation schedule for partial rootzone drying (PRD)
and conventional drip irrigation (CDI) at 0.4 or 0.8 ETc in Sauvignon blanc grapevines
8
% of
Left Right Trunk Vine Left Right Vine Left Right Vine Vine Acre CDI-0.8
CDI-0.4 0 0 482 482 108 108 216 93 93 186 884 400286 61
CDI-0.8 525 525 0 1051 108 108 216 93 93 186 1453 658061 100
PRD-0.4 298 228 0 525 108 108 216 93 93 186 927 420114 64
PRD-0.8 570 436 0 1007 108 108 216 93 93 186 1409 638233 97
CDI-0.4 0 0 461 461 155 155 311 132 132 263 1035 468869 69
CDI-0.8 461 461 0 921 155 155 311 132 132 263 1495 677394 100
PRD-0.4 253 208 0 461 155 155 311 132 132 263 1035 468715 69
PRD-0.8 506 415 0 921 155 155 311 132 132 263 1495 677394 100
CDI-0.4 0 0 404 404 104 104 208 194 194 388 1001 453453 71
CDI-0.8 404 404 0 808 104 104 208 194 194 388 1405 636556 100
PRD-0.4 217 187 0 404 104 104 208 194 194 388 1001 453453 71
PRD-0.8 434 375 0 808 104 104 208 194 194 388 1405 636556 100
2001
Table 2. Amount of water applied to vines treated with partial rootzone drying (PRD)
and conventional drip irrigation (CDI) at 0.4 or 0.8 ETc in Sauvignon blanc grapevines
Total, gal. Treatment

2000
1999
During PRD, gal. Prior to PRD, gal. After PRD, gal.
9
Yield
lb/vine T/acre % of CDI-0.8
CDI 0.4 177 0.27 b[z] 1.22 b 47.8 10.8 84 19 b
CDI 0.8 184 0.31 a 1.69 a 57.1 12.9 100 25 a
PRD 0.4 213 0.29 ab 1.27 b 61.2 13.9 107 15 b
PRD 0.8 180 0.31 a 1.42 b 56.0 12.7 98 25 a
PRD vs CDI NS NS NS NS NS
0.8 vs 0.4 ET NS 0.0458 NS NS NS
CDI-0.4 215 0.28 1.36 32.9 7.5 79 32
CDI-0.8 218 0.29 1.50 41.8 9.5 100 38
PRD-0.4 207 0.29 1.40 33.6 7.6 80 33
PRD-0.8 209 0.29 1.49 42.2 9.6 101 36
PRD vs CDI NS NS NS NS NS NS NS
0.8 vs 0.4 ET NS NS NS NS NS NS NS
CDI-0.4 82 0.30 b 1.35 c 24.4 5.5 78 41 a
CDI-0.8 84 0.37 a 1.60 a 31.1 7.1 100 46 b
PRD-0.4 89 0.32 b 1.47 bc 28.3 6.4 91 36 a
PRD-0.8 81 0.35 a 1.54 ab 28.7 6.5 92 52 b
PRD vs CDI NS NS NS NS NS NS NS
0.8 vs 0.4 ET NS NS NS NS
[z]Means within columns for each year followed by different letters are significantly different by Fisher's LSD at P=0.05 level. [y]NS, non-significant or P value of significance.
0.0393 0.0414 0.0022
Treatment
2000
NS
0.0040
NS[y]
1999
Berry
0.0008
2001
Water use
efficiency, gal./lb
Table 3. Effect of partial rootzone drying (PRD) and conventional drip irrigation (CDI)
at 0.4 and 0.8 ETc on yield components and water use efficiency in Sauvignon blanc grapevines
weight, g
Clusters
/vine
Cluster
weight, lb
10
Harvest Phenolics Phenolics VA Alcohol Phenolics
date Brix pH mg/L pH mg/L pH g/L % mg/L
CDI-0.4 8/26 25.2 3.75 22.6 3.40 4.66 3.43 7.01 0.15 14.6
CDI-0.8 8/26 22.9 5.03 20.1 3.34 5.89 3.40 7.62 0.17 13.4
PRD-0.4 8/26 23.0 3.88 20.9 3.37 5.08 3.38 6.79 0.13 13.4
PRD-0.8 8/26 22.8 4.55 21.5 3.34 5.70 3.47 7.35 0.16 13.9
PRD vs CDI NS[Y] NS NS NS NS NS NS NS NS
0.8 vs 0.4 ET NS NS NS NS NS NS NS NS NS
CDI-0.4 8/21 21.4 4.07 a[z] 4.21 b 22.2 3.54 5.21 248 3.52 5.56 b 0.24 12.9 219
CDI-0.8 8/16 22.4 3.93 b 5.86 a 21.6 3.56 5.93 264 3.46 7.15 a 0.31 13.4 219
PRD-0.4 8/21 22.2 4.06 a 4.52 b 22.3 3.59 5.20 243 3.57 5.52 b 0.26 13.3 225
PRD-0.8 8/16 22.7 3.93 b 5.32 a 21.2 3.48 6.32 244 3.43 7.00 a 0.33 13.6 213
PRD vs CDI NS NS NS NS NS NS NS NS NS NS NS
0.8 vs 0.4 ET NS NS NS NS NS NS NS NS NS NS
CDI-0.4 8/2 24.4 4.17 5.28 c 455 23.1 3.50 5.25 b 268 3.44 7.32 b 0.938 15.11 278
CDI-0.8 8/2 23.5 4.12 6.71 a 453 22.1 3.48 6.92 a 275 3.45 8.71 a 0.878 14.14 291
PRD-0.4 8/2 23.7 4.23 5.43 bc 494 22.8 3.52 5.37 b 271 3.43 7.27 b 0.881 14.63 284
PRD-0.8 8/2 23.4 4.19 6.11 ab 486 22.1 3.47 6.35 a 262 3.46 8.01 ab 0.951 14.09 266

PRD vs CDI NS NS NS NS NS NS NS NS NS NS NS NS NS
0.8 vs 0.4 ET NS NS NS NS NS NS NS NS NS NS
zMeans within columns for each year followed by different letters are significantly different by Fisher's LSD at P=0.05 level. yNS, non-significant
or P value of significance.
0.0006 0.0012
2001
0.0005 NS
3.93
3.54
1999
g/L Brix
Table 4. Effect of partial rootzone drying (PRD) and conventional drip irrigation (CDI) at 0.4 and 0.8 ETc
on fruit and must composition and wine chemistry in Sauvignon blanc grapevines
g/L
Treatment
Wine
g/L
Must Berry at harvest
TA TA
0.0000
TA
0.0284 0.0001
NS
NS
NS
2000
3.89
3.85

Treatment CDI-0.8 PRD-0.8 CDI-0.4
PRD-0.4 19ns z 23** 24**
CDI-0.4 21* 17ns
PRD-0.8 21*
PRD-0.4 27*** 23** 18
CDI-0.4 23** 20*
PRD-0.8 15
zEach of comparison consisted of 40 judgments. NS, *, and **, non-significant, significant
at p=0.05 and 0.01level by triangle test, respectively.
1999
2000
Table 5. Effect of partial rootzone drying (PRD) and conventional drip irrigation (CDI)
at 0.4 and 0.8 ETc on wine sensory comparison in Sauvignon blanc grapevines

Top West East Primary
CDI-0.4 340 90 73 98 9 bz 3.65 b
CDI-0.8 230 66 51 114 31 a 5.69 a
PRD-0.4 286 95 97 108 11 b 4.06 b
PRD-0.8 216 50 60 102 25 a 4.75 ab
PRD vs CDI NSy NS NS NS NS
0.8 vs 0.4 ET NS NS NS NS
CDI-0.4 40 36 23 73 22 b 6.69 a
CDI-0.8 48 45 30 77 51 a 9.02 b
PRD-0.4 79 42 50 70 24 b 6.72 a
PRD-0.8 59 27 23 73 46 a 8.56 b
PRD vs CDI NS NS NS NS NS
0.8 vs 0.4 ET NS NS NS NS
CDI-0.4 321 43 a 141 2 c 44 b 43 b 6.65 b
CDI-0.8 194 24 b 63 55 a 51 a 56 a 10.29 a
PRD-0.4 443 37 a 123 8 c 46 b 43 b 7.44 b
PRD-0.8 524 25 b 65 42 b 46 b 51 a 8.41 ab
PRD vs CDI NS NS NS NS
0.8 vs 0.4 ET NS NS
zMeans within columns for each year followed by different letters are significantly different by Fisher's LSD
at P=0.05 level. yNS, non-significant or P value of significance.

0.0000
NS
1999
2000
NS
0.0052 0.0036
weight, lb/vine
Fruiting zone light level at veraison, uE
Table 6. Effect of partial rootzone drying (PRD) and conventional drip irrigation (CDI)
at 0.4 and 0.8 ETc on canopy characteristics in Sauvignon blanc grapevines
Pruning Treatment Lateral
Growing tip
No./vine
Shoots/vine
NS
0.0168 0.0314
NS
2001
0.0019 0.0000
0.0029 0.0162
NS
13
Zn Mn Fe Cu Na Cl S
ppm ppm ppm ppm % % %
CDI-0.4 1725 b[z] 0.27 2.04 1.31 b 1.78 44 279 51 4 28.3 0.03 0.26 0.30
CDI-0.8 2698 a 0.25 2.73 1.46 ab 2.16 37 230 60 5 26.8 0.03 0.39 0.26
PRD-0.4 2108 b 0.24 1.91 1.45 ab 2.04 39 282 70 4 28.5 0.04 0.29 0.28
PRD-0.8 2850 a 0.23 2.18 1.60 a 2.21 47 293 56 5 28.0 0.03 0.31 0.29
PRD vs CDI NS[y] NS NS NS NS NS NS NS NS NS NS NS
0.8 vs 0.4 ET 0.0351 NS NS NS NS NS NS NS NS NS NS NS
CDI-0.4 2488 0.42 a 2.12 0.81 1.72 a 30 115 49 16 36 0.04 0.06 0.23
CDI-0.8 3138 0.35 b 2.71 0.76 1.33 b 29 73 53 15 36 0.04 0.08 0.24
PRD-0.4 2678 0.49 a 2.37 0.83 1.39 b 32 90 48 15 37 0.05 0.07 0.23
PRD-0.8 2640 0.32 b 2.59 0.73 1.30 b 26 73 56 15 37 0.05 0.05 0.23
PRD vs CDI NS NS NS NS NS NS NS NS NS NS NS NS
0.8 vs 0.4 ET NS NS NS NS NS NS NS NS NS NS NS
CDI-0.4 3104 0.51 2.09 b 0.80 1.52 47 170 58 14 31 b 0.03 0.05 0.33
CDI-0.8 4368 0.56 2.90 a 0.78 1.51 54 160 53 13 34 a 0.02 0.05 0.36
PRD-0.4 3358 0.51 2.26 ab 0.85 1.49 54 144 63 12 32 b 0.03 0.05 0.36
PRD-0.8 3948 0.54 2.97 a 0.80 1.59 48 165 55 13 35 a 0.02 0.06 0.33
PRD vs CDI NS NS NS NS NS NS NS NS NS NS NS NS NS
0.8 vs 0.4 ET NS NS NS NS NS NS NS NS NS NS NS
ppm %
0.0068 0.0176
0.0309
0.0191
2001 at full bloom
level. [y]NS, non-significant or P value of significance.
Treatment
[z]Means within columns for each year followed by different letters are significantly different by Fisher's LSD at
P=0.05
0.0317
0.0082
0.0014
P
2000 at full bloom
Ca B
Table 7. Effect of partial rootzone drying (PRD) and conventional drip irrigation (CDI)
at 0.4 and 0.8 ETc on petiole mineral nutrients in Sauvignon blanc grapevines
1999 at veraison
Mg
ppm
NO_3-N K

% % %
14
Quantum yield of PSII Non-photochemical
Maximum (Fv/Fm)3 quenching
CDI-0.4 311 0.18 0.38 bz 0.79 0.81 0.79
CDI-0.8 373 0.24 0.51 b 0.79 1.05 0.99
PRD-0.4 355 0.21 0.49 b 0.78 0.94 0.89
PRD-0.8 367 0.33 0.95 a 0.76 1.15 1.47
CDI vs PRD NS NSy NS NS NS
0.4 ET vs 0.8 ET NS NS NS NS NS
CDI-0.4 342 0.17 0.38 b 0.77 0.92 0.67
CDI-0.8 403 0.23 0.55 b 0.77 1.10 0.81
PRD-0.4 335 0.15 0.40 b 0.66 0.48 0.81
PRD-0.8 389 0.28 0.81 a 0.76 1.06 1.06
CDI vs PRD NS NS NS NS NS
0.4 ET vs 0.8 ET NS NS NS NS NS
CDI-0.4 337 0.16 0.45 0.78 1.02 0.55
CDI-0.8 353 0.16 0.46 0.77 1.03 0.50
PRD-0.4 318 0.20 0.50 0.78 0.99 0.65
PRD-0.8 330 0.15 0.41 0.79 1.17 0.48
CDI vs PRD NS NS NS NS NS NS
0.4 ET vs 0.8 ET NS NS NS NS NS NS
CDI-0.4 574 0.13 c 0.00 0.57 0.74 0.56 c
CDI-0.8 371 0.17 bc 0.39 0.78 0.96 0.75 c
PRD-0.4 394 0.24 a 0.89 0.74 1.39 1.09 ab
PRD-0.8 401 0.21 ab 1.09 0.74 1.33 0.91 bc
CDI vs PRD NS NS NS NS
0.4 ET vs 0.8 ET NS NS NS NS NS NS
photochemistry. zMeans within columns for each date followed by different letters are significantly different
by Fisher's LSD at P=0.05 level. yNS, non-significant or P value of significance.
1Efficiency of photosystem II photochemistry, 2Photochemical quenching, 3Maximum efficiency of photosystem II
0.0016
7 days after 3rd PRD switch (8/1)
0.0007
5 days after 3rd PRD switch (7/30)
Table 8. Effect of partial rootzone drying (PRD) and conventional drip irrigation (CDI) at 0.4 and 0.8 ETc
on chlorophyll fluorescence characteristics of mature leaves in Sauvignon blanc grapevines in 2000
0.0259
Open (qP)2 Treatment
Actual (ÖPSII)1 Minimum
1 day after 3rd PRD switch (7/26)
ETR
0.0199
0.0163
NS
3 days after 3rd PRD switch (7/28)
15
Fig. 1. Soil moisture in partial rootzone drying (PRD) at 0.4 ETc
and conventional drip irrigation (CDI) at 0.8 ETc during
two PRD cycles in June and July 2000.
0
5
10
15
20
25
30
35
40
6/8 6/15 6/22 6/29 7/6 7/13 7/20 7/27
20 cm
40 cm
PRD-0.4
0
5
10

15
20
25
30
35
40
6/8 6/15 6/22 6/29 7/6 7/13 7/20 7/27
CDI-0.8
16
each parameter followed by different letters are significantly different by Fisher's LSD at P=0.05 level.
2001
Fig. 2. Effect of partial rootzone drying (PRD) and conventional drip irrigation (CDI) at 0.4 or 0.8 ETc on berry weight and fruit composition in Sauvignon blanc grapevines. zMeans within sampling dates
2000 1999
c
b
ab
a
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
8/7
8/10
8/13
8/16
8/19
8/22
8/25
8/28
Berry weight (g)
CDI-0.4
PRD-0.4
PRD-0.8
CDI-0.8
15
17
19
21
23
25
27
8/7
8/10
8/13
8/16
8/19
8/22
8/25
8/28
Brix
3.0
3.2
3.4
3.6
3.8
4.0
4.2
4.4
8/7 8/10 8/13 8/16 8/19 8/22 8/25 8/28
pH
c
b
bc
b ab
a
a
a
0
2
4
6
8
10
12
14
16
8/7 8/10 8/13 8/16 8/19 8/22 8/25 8/28
TA, g/L
15
17
19
21
23
25
27
7/21
7/25
7/29
8/2
8/6
8/10
8/14
8/18
8/22
Brix
3.0
3.2
3.4
3.6

3.8
4.0
4.2
4.4
7/21 7/25 7/29 8/2 8/6 8/10 8/14 8/18 8/22
pH
c
b
bc
b
ab
a
a
a
0
2
4
6
8
10
12
14
16
7/21 7/25 7/29 8/2 8/6 8/10 8/14 8/18 8/22
TA, g/L
b
c
b
c
ab
bc a
b
a
ab a
a a a a
a
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
7/14
7/17
7/20
7/23
7/26
7/29
8/1
8/4
Berry weight (g)
15
17
19
21
23
25
27
7/14
7/17
7/20
7/23
7/26
7/29
8/1
8/4
Brix
3.0
3.2
3.4
3.6
3.8
4.0
4.2
4.4
7/14 7/17 7/20 7/23 7/26 7/29 8/1 8/4
pH
c
b b
bc
b
b
ab
b
b
a
a
a
0
2
4
6
8
10
12
14
16
7/14 7/17 7/20 7/23 7/26 7/29 8/1 8/4
TA, g/L
b
a
b
a
1.0
1.1
1.2
1.3
1.4
1.5
1.6

1.7
1.8
7/21
7/25
7/29
8/2
8/6
8/10
8/14
8/18
8/22
Berry weight (g)
11

Fig. 3. Effect of partial rootzone drying (PRD) and conventional drip irrigation (CDI) at 0.4 or 0.8 ETc on stomatal conductance (g) and transpiration
2001
rate (E) of mature leaves in Sauvignon blanc grapevines. + indicate sgnificance at P=0.05 level.
1999 2000

0
100
200
300
400
500
600
5/23
5/29
6/4
6/10
6/16
6/22
6/28
7/4
7/10
7/16
7/22
7/28
8/3
8/9
8/15
8/21
g, mmol m^{-2} s^{-1}
CDI-0.4 CDI-0.8
PRD-0.4 PRD-0.8
Rate Switching
0
2
4
6
8
10
12
14
16
18
5/23
5/29
6/4
6/10
6/16
6/22
6/28
7/4
7/10
7/16
7/22
7/28
8/3
8/9
8/15
8/21
E, mmol m^{-2} s^{-1}
0
100
200
300
400
500
600
5/20
5/26
6/1
6/7
6/13
6/19
6/25
7/1
7/7
7/13
7/19
7/25
7/31
g, mmol m^{-2} s^{-1}
0
2
4
6
8
10
12
14
16
18
5/20
5/26
6/1
6/7
6/13
6/19
6/25
7/1
7/7
7/13
7/19
7/25
7/31
E, mmol m^{-2} s^{-1}

0
100
200
300
400
500
600
5/9
5/15
5/21
5/27
6/2
6/8
6/14
6/20
6/26
7/2
7/8
7/14
7/20
7/26
8/1
8/7
8/13
g, mmol m^{-2} s^{-1}
0
2
4
6
8
10
12
14
16
18
5/9
5/15
5/21
5/27
6/2
6/8
6/14
6/20
6/26
7/2
7/8
7/14
7/20
7/26
8/1
8/7
8/13
E, mmol m^{-2} s^{-1}
18
Fig. 4. Effect of partial rootzone drying (PRD) and conventional drip irrigation (CDI) at 0.4 or 0.8 ETc on diurnal changes of
mature leaf stomatal conductance (g) and transpiration rate (E) in Sauvignon blanc grapevines in 2000. [z]Means within sampling times for each date followed by different letters are significantly different by Fisher's LSD at P=0.05 level.
0
50
100
150
200
250
300
350
400
450
6:00
AM
8:00
AM
10:00
AM
12:00
PM
2:00
PM
4:00
PM
6:00
PM
7:00
PM
g, mmol $\cdot m^{-2} \cdot s^{-1}$
CDI-0.4
PRD-0.4
CDI-0.8
PRD-0.8
1 day after 3rd PRD switch (6/29)
0
50
100
150
200
250
300
350
400

450
6:00
AM
8:00
AM
10:00
AM
12:00
PM
2:00
PM
4:00
PM
6:00
PM
7:00
PM
g, mmol ·m-2· s-1
8 days after 3rd PRD switch (7/6)
b
c b
c
b
bc
a
bc
a
ab
a ab
a
a a az
0
50
100
150
200
250
300
350
400
450
6:00
AM
8:00
AM
10:00
AM
12:00
PM
2:00
PM
4:00
PM
6:00
PM
7:00
PM
g, mmol ·m-2· s-1
14 days after 3rd PRD switch (7/12)
0
2
4
6
8
10
12
14
6:00
AM
8:00
AM
10:00
AM
12:00
PM
2:00
PM
4:00
PM
6:00
PM
7:00

PM
E, mmol $\cdot m^{-2} \cdot s^{-1}$
1 day after 3rd PRD switch (6/29)
0
2
4
6
8
10
12
14
6:00
AM
8:00
AM
10:00
AM
12:00
PM
2:00
PM
4:00
PM
6:00
PM
7:00
PM
E, mmol $\cdot m^{-2} \cdot s^{-1}$
8 days after 3rd PRD switch (7/6)
b
c
b
c b
bc
a
bc
ab
a
ab
a
a
a
a
a[z]
0
2
4
6
8
10
12
14
6:00
AM
8:00
AM
10:00
AM
12:00
PM
2:00
PM
4:00
PM
6:00
PM
7:00
PM
E, mmol $\cdot m^{-2} \cdot s^{-1}$
14 days after 3rd PRD switch (7/12)

Fig. 5. Effect of partial rootzone drying (PRD) and conventional drip irrigation (CDI) at 0.4 or 0.8 ETc on diurnal changes of mature leaf stomatal conductance (g) and transpiration rate (E) in
Sauvignon blanc grapevines (2001). [z]Means within sampling times for each date with different letters are significantly different by Fisher's LSD at P=0.05 level.
b
c c
b
b
bc bc a
ab a
a
a
ab
a ab
a
0
50

100
150
200
250
300
350
400
450
6:00 8:00 10:00 12:00 14:00 16:00 18:00
g, mmol $\cdot m^{-2} \cdot s^{-1}$
CDI-0.4
PRD-0.4
CDI-0.8
PRD-0.8
2 days after 3rd PRD switch (6/14)
z
b
d d
b b
b b
c c b
a
a
a
a
a
a b
b
a
a
0
50
100
150
200
250
300
350
400
450
6:00 8:00 10:00 12:00 14:00 16:00 18:00
g, mmol $\cdot m^{-2} \cdot s^{-1}$
7 days after 3rd PRD switch (6/19)
b
c
b
bc
a
a
b ab
0
50
100
150
200
250
300
350
400
450
6:00 8:00 10:00 12:00 14:00 16:00 18:00
g, mmol $\cdot m^{-2} \cdot s^{-1}$
14 days after 3rd PRD switch (6/26)
b
b
b
a
0
50
100
150
200
250
300
350
400
450
6:00 8:00 10:00 12:00 14:00 16:00 18:00
g, mmol $\cdot m^{-2} \cdot s^{-1}$
2 days after 6th PRD switch (7/23)
c
bc
ab
a
0
50
100
150
200
250
300
350
400
450
6:00 8:00 10:00 12:00 14:00 16:00 18:00
g, mmol $\cdot m^{-2} \cdot s^{-1}$
6 days after 6th PRD switch (7/27)
0
50
100
150
200
250
300
350
400
450
6:00 8:00 10:00 12:00 14:00 16:00 18:00
g, mmol $\cdot m^{-2} \cdot s^{-1}$
10 days after 6th PRD switch (7/31)
c
c
c bc
bc
bc
bc
c
ab a
a
a
ab
ab
a
a
0
2
4
6
8
10

12
14
16
18
20
6:00 8:00 10:00 12:00 14:00 16:00 18:00
E, mmol ·m-2· s-1
CDI-0.4
PRD-0.4
CDI-0.8
PRD-0.8
2 days after 3rd PRD switch (6/14)
b
c b
b b
b
c
b
b
b
a
a a
a a
a
a
a
a
b
0
2
4
6
8
10
12
14
16
18
20
6:00 8:00 10:00 12:00 14:00 16:00 18:00
E, mmol ·m-2· s-1
7 days after 3rd PRD switch (6/19)
c
bc
a
ab
0
2
4
6
8
10
12
14
16
18
20
6:00 8:00 10:00 12:00 14:00 16:00 18:00
E, mmol ·m-2· s-1
14 days after 3rd PRD switch (6/26)
b
b
b
a
0
2
4
6
8
10
12
14
16
18
20
6:00 8:00 10:00 12:00 14:00 16:00 18:00
E, mmol ·m-2· s-1
2 days after 6th PRD switch (7/23)
c
bc
ab
a
0
2
4
6
8
10
12
14
16
18
20
6:00 8:00 10:00 12:00 14:00 16:00 18:00
E, mmol ·m-2· s-1
6 days after 6th PRD switch (7/27)
0
2
4
6
8
10
12
14
16
18
20
6:00 8:00 10:00 12:00 14:00 16:00 18:00
E, mmol ·m-2· s-1
10 days after 6th PRD switch (7/31)
20

Fv/Fm, Maximum quantum yield of PSII; Fo, minimum quantum yield of PSII; qP, photochemical quenching; ÖPSII, actual quantu yield of PSII; ETR, electron transfer rate; and qNP, Non-photochemical quenching.

Fig. 6. Effect of partial rootzone drying (PRD) and conventional drip irrigation (CDI) at 0.4 and 0.8 Etc on chlorophyll fluorescence characteristics of mature leaves in Sauvignon blanc grapevines (2001). (triangle) denotes date of PRD swicthing.

0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

5/10
5/16
5/22
5/28
6/3
6/9
6/15
6/21
6/27
7/3
7/9
7/15
7/21
7/27
8/2
8/8
8/14
Fv/Fm
CDI-0.4
CDI-0.8
PRD-0.4
PRD-0.8
Switching
0
50
100
150
200
250
300
350
400
450
500
5/10
5/16
5/22
5/28
6/3
6/9
6/15
6/21
6/27
7/3
7/9
7/15
7/21
7/27
8/2
8/8
8/14
Fo
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
5/10
5/16
5/22
5/28
6/3
6/9
6/15
6/21
6/27
7/3
7/9
7/15
7/21
7/27
8/2
8/8
8/14
ÖPSII
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
5/10
5/16
5/22
5/28

6/3
6/9
6/15
6/21
6/27
7/3
7/9
7/15
7/21
7/27
8/2
8/8
8/14
ETR
0.0
0.5
1.0
1.5
2.0
2.5
5/10
5/16
5/22
5/28
6/3
6/9
6/15
6/21
6/27
7/3
7/9
7/15
7/21
7/27
8/2
8/8
8/14
qP
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
5/10
5/16
5/22
5/28
6/3
6/9
6/15
6/21
6/27
7/3
7/9
7/15
7/21
7/27
8/2
8/8
8/14
qNP

Fig. 7. Effect of partial rootzone drying (PRD) and conventional drip irrigation (CDI) at 0.4 or 0.8 ETc on chlorophyll fluorescence characteristics of mature leaves during the 3rd PRD cycle in Sauvignon
blanc grapevines (2001). Fv/Fm, Maximum quantum yield of PSII; Fo, minimum quantum yield of PSII; qP, photochemical quenching; ÖPSII, actual quantum yield of PSII; ETR, electron
2 days after 3rd PRD switch (6/14) 7 days after 3rd PRD awitch (6/19) 14 days after 3rd PRD switch (6/26)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
6:00 8:00 10:00 12:00 14:00 16:00 18:00
Fv/Fm
CDI-0.4
CDI-0.8
PRD-0.4
PRD-0.8
0
100
200

300
400
500
600
6:00 8:00 10:00 12:00 14:00 16:00 18:00
Fo
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
6:00 8:00 10:00 12:00 14:00 16:00 18:00
ÖPSII
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
6:00 8:00 10:00 12:00 14:00 16:00 18:00
ETR
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
6:00 8:00 10:00 12:00 14:00 16:00 18:00
Fv/Fm
0
100
200
300
400
500
600
6:00 8:00 10:00 12:00 14:00 16:00 18:00
Fo
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
6:00 8:00 10:00 12:00 14:00 16:00 18:00
ÖPSII
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
6:00 8:00 10:00 12:00 14:00 16:00 18:00
ETR
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
6:00 8:00 10:00 12:00 14:00 16:00 18:00
Fv/Fm
0
100
200
300
400
500
600
6:00 8:00 10:00 12:00 14:00 16:00 18:00
Fo
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
6:00 8:00 10:00 12:00 14:00 16:00 18:00
ÖPSII
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
6:00 8:00 10:00 12:00 14:00 16:00 18:00
ETR
0.0
0.2
0.4
0.6
0.8
1.0
1.2
6:00 8:00 10:00 12:00 14:00 16:00 18:00
qP
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
6:00 8:00 10:00 12:00 14:00 16:00 18:00
qNP

0.0
0.2
0.4
0.6
0.8
1.0
1.2
6:00 8:00 10:00 12:00 14:00 16:00 18:00
qP
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
6:00 8:00 10:00 12:00 14:00 16:00 18:00
qNP
0.0
0.2
0.4
0.6
0.8
1.0
1.2
6:00 8:00 10:00 12:00 14:00 16:00 18:00
qP
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
6:00 8:00 10:00 12:00 14:00 16:00 18:00
qNP
22
7/23/2001 7/27/2001 7-312001
Fig. 8. Effect of partial rootzone drying (PRD) and conventional drip irrigation (CDI) at 0.4 or 0.8 ETc on chlorophyll fluorescence characteristics of mature leaves during the 6th PRD cycle in Sauvignon
blanc grapevines (2001). Fv/Fm, Maximum quantum yield of PSII; Fo, minimum quantum yield of PSII; qP, photochemical quenching; ÖPSII, actual quantum yield of PSII; ETR, electron transfer rate; and qNP, Non-photochemical quenching.
6 days after 6th PRD switch (7/27) 2 daya after 6th PRD switch (7/23) 10 days after 6th PRD switch (7/31)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
6:00 8:00 10:00 12:00 14:00 16:00 18:00
Fv/Fm
CDI-0.4
CDI-0.8
PRD-0.4
PRD-0.8
0
100
200
300
400
500
6:00 8:00 10:00 12:00 14:00 16:00 18:00
Fo
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
6:00 8:00 10:00 12:00 14:00 16:00 18:00
ÖPSII
0.0
1.0
2.0
3.0
4.0
5.0
6:00 8:00 10:00 12:00 14:00 16:00 18:00
ETR
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
6:00 8:00 10:00 12:00 14:00 16:00 18:00
Fv/Fm
0
100
200
300
400
500
6:00 8:00 10:00 12:00 14:00 16:00 18:00
Fo
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
6:00 8:00 10:00 12:00 14:00 16:00 18:00
ÖPSII

0.0
1.0
2.0
3.0
4.0
5.0
6:00 8:00 10:00 12:00 14:00 16:00 18:00
ETR
0.0
0.1
0.2
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0.4
0.5
0.6
0.7
0.8
0.9
1.0
6:00 8:00 10:00 12:00 14:00 16:00 18:00
Fv/Fm
0
100
200
300
400
500
6:00 8:00 10:00 12:00 14:00 16:00 18:00
Fo
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
6:00 8:00 10:00 12:00 14:00 16:00 18:00
ÖPSII
0.0
1.0
2.0
3.0
4.0
5.0
6:00 8:00 10:00 12:00 14:00 16:00 18:00
ETR
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
6:00 8:00 10:00 12:00 14:00 16:00 18:00
qP
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
6:00 8:00 10:00 12:00 14:00 16:00 18:00
qNP
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
6:00 8:00 10:00 12:00 14:00 18:00
qP
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
6:00 8:00 10:00 12:00 14:00 16:00 18:00
qNP
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
6:00 8:00 10:00 12:00 14:00 16:00 18:00
qP
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
6:00 8:00 10:00 12:00 14:00 16:00 18:00
qNP