FRUIT COMPOSITION, GROWTH, AND WATER RELATIONS OF 'BRAEBURN' APPLES UNDER REDUCED PLANT WATER STATUS

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ABSTRACT

Water plays a major role in the physiological processes of plants. Effective irrigation relies on a comprehensive understanding of the impact of water on plant processes. As water becomes an increasingly scarce resource, the impact of reduced plant water status on crop performance (quality and yield) requires investigation. The effects of reduced plant water status on fruit composition, growth, and water relations were therefore studied using both field-grown and container-grown 'Braeburn' apple trees. Vegetative growth and carbon assimilation were also measured. Plant water deficit was imposed at various times during the growing season. The treatments were: control, which was fully irrigated during the experimental period, entire-season deficit, deficit irrigation from 55 days after full bloom (DAFB) until final fruit harvest (183 DAFB), early-season deficit (from 55 - 100 DAFB) followed by rewatering, and late-season deficit (from approximately 105 DAFB until final harvest).

Reduced leaf water potential developed in all deficit irrigated trees during the stress period. Only the entire-season deficit irrigation treatment resulted in a significant reduction in vegetative growth as measured by total leaf area, shoot growth, and trunk growth. Return bloom was reduced under an early-, but not late-season deficit. Photosynthesis was generally reduced in water deficit treatments, as was stomatal conductance.

Only an entire-season deficit irrigation reduced individual fruit weight. Fruit soluble solids and sugar concentration were generally increased under deficit irrigation treatments. However, upon rewatering of the early-season deficit trees, the values again became the same as controls. Fruit mineral concentration did not show consistent differences between treatments and the incidence of storage disorders was low in al

treatments and unaffected by deficit irrigation.

Early-season water deficit lowered both fruit water potential and osmotic potential. Despite turgor maintenance within the fruit during the stress period, growth was reduced at this time. A late-season water deficit did not modify fruit water relations.

It appears that 'Braeburn' fruit are resilient to periodic water deficit during the season, and that water conservation is possible with limited impact on total crop yield. Additionally, a late-season deficit may even enhance some fruit quality attributes, such as increased total soluble solids. An early-season deficit reduced return bloom and must therefore be used with caution. An entire-season water deficit is not recommended due to the reduction in fruit size.

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I have been most fortunate to have Dr M. Hossein Behboudian as my chief supervisor. Hossein, aside from being an expert in this field of research and a widely published and respected scientist, is a generous and compassionate person who has the academic and personal well being of his students at heart. Dr Brent Clothier, my second supervisor has also given me invaluable assistance. He has a broad understanding of many research areas and always makes a supreme effort to review my written work thoroughly. I feel privileged to have had such excellent supervision throughout my PhD studies. I must also thank the rest of the Environment Group, HortResearch, Palmerston North for providing me with an interesting and fun place to work. HortResearch has not only given me the opportunity to pursue my PhD but I have had the advantage of excellent computer and statistical support services. Nihal DeSilva warrants special mention as he bore the brunt of my numerous statistical queries.

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LIST OF ABREVIATIONS AND SYMBOLS

Treatment

Control, Expt. 1.	C1
Control, Expt. 2.	C2
Control, Expt. 3.	C3
Control, Expt. 4.	C4
Deficit, Expt. 1.	D1
Deficit, Expt. 2.	D2
Deficit, Expt. 3.	D3
Deficit, Expt. 4.	D4
Deficit Irrigation	DI
Early Deficit, Expt. 4.	ED4
Late Deficit, Expt. 2.	LD2
Late Deficit, Expt. 4.	LD4

Water Relations

Fruit Water Potential (MPa)	Ψ_{fw}
Fruit Osmotic Potential (MPa)	Ψ_{fs}
Fruit Turgor Potential (MPa)	Ψ_{fp}
Leaf Water Potential (MPa)	Ψ_{l}
Days After Full Bloom	DAFB
Days In Storage	DIS
Experiment	Expt.
Figure	Fig.
Hour	h

Internal CO_2 Concentration ($\mu mol \cdot mol^{-1}$)	C_i
Irradiance ($W \cdot m^{-2}$)	Ir
Metre	m
Photosynthetic Rate ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	Pn
Probability	*P*
Ratio $^{13}C:^{12}C$	$\delta^{13}C$
Regulated Deficit Irrigation	RDI
Seconds	s
Soil volumetric water content ($m^3 \cdot m^{-3}$)	θ
Stage 1 harvest	S1
Stage 2 harvest	S2
Standard error	SE
Stomatal Conductance ($mmol \cdot m^{-2} \cdot s^{-1}$)	g_s
Time Domain Reflectometry	TDR
Titratable Acidity (% malic acid)	TA
Total Soluble Solids (% Brix)	TSS
Transpiration ($mmol \cdot m^{-2} \cdot s^{-1}$)	T
Treatment	TRT
Vapour Pressure Deficit (KPa)	VPD
Weight (g)	wt

FIGURE CAPTIONS

Fig. 1 Water content of root medium (θ) for Expts. 1 (A), 2 (B), and 4 (C). Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 21, 18 and 12 experimental units (trees) for A, B, and C respectively. When pooled experimental error differed between treatments due to different n values per treatment, the maximum error has been presented. Abbreviations are for C1=control, Expt. 1 (n=10); D1=deficit, Expt. 1 (n=11); C2=control, Expt. 2 ($n \geq 7$); D2=deficit, Expt. 2 ($n \geq 4$); LD2=late deficit, Expt. 2 ($n \geq 7$); C4=control, Expt. 4 (n=4); ED4=early deficit, Expt. 4 (n=4); and LD4=late deficit, Expt. 4 (n=4). Arrows indicate the beginning of LD2 treatment, rewatering of ED4 treatment and the beginning of LD4 treatment.

Fig. 2 Midday leaf water potential (Ψ_l) for Expts. 1 (A), 2 (B), 3 (C) and 4 (D). Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 21, 18 and 12 experimental units (trees) for A, B, and C respectively. When pooled experimental error differed between treatments due to different n values per treatment, the maximum error has been presented. Abbreviations are for C1=control, Expt. 1 (n=10); D1=deficit, Expt. 1 (n=11); C2=control, Expt. 2 ($n \geq 7$); D2=deficit, Expt. 2 ($n \geq 4$); LD2=late deficit, Expt. 2 ($n \geq 7$); C3=control, Expt. 3 (n=6); D3=deficit, Expt. 3 (n=3); C4=control, Expt. 4 (n=4); ED4=early deficit, Expt. 4 (n=4); and LD4=late deficit, Expt. 4 (n=4). Arrows indicate the beginning of LD2 treatment, rewatering of ED4 treatment and the beginning of LD4 treatment.

Fig. 3 Mean midday transpiration rate (T) for Expts. 2 (A), and 4 (B). Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 18 and 12 experimental units (trees) for A, and B respectively. When pooled experimental error differed between treatments due to different n values per treatment, the maximum error has been presented. Abbreviations are for C2=control, Expt. 2 ($n \geq 7$); D2=deficit, Expt. 2 ($n \geq 4$); LD2=late deficit, Expt. 2 ($n \geq 7$); C4=control, Expt. 4 (n=4); ED4=early deficit, Expt. 4 (n=4); and LD4=late deficit, Expt. 4 (n=4). Arrows indicate the beginning of LD2 treatment, rewatering of ED4 treatment and the beginning of LD4 treatment.

Fig. 4 Pre-dawn leaf water potential (Ψ_l) for Expts. 2 (A) and 4 (B). Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 4 (or 6 from 120 DAFB) and 12 experimental units (trees) for A and B respectively. C2=control, Expt. 2 (n=2); D2=deficit, Expt. 2 (n=2); LD2=late deficit (n=2), Expt. 2; C4=control, Expt. 4 (n=4); ED4=early deficit, Expt. 4 (n=4); and LD4=late deficit, Expt. 4 (n=4). Arrows indicate the beginning of LD2 treatment, rewatering of ED4 treatment and the beginning of LD4 treatment.

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Fig. 7 Photosynthetic rate (Pn) for Expts. 1 (A), 2 (B), and 4 (C). Measuements were taken at midday. Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 21, 18 and 12 experimental units (trees) for A, B, and C respectively. When pooled experimental error differed between treatments due to different n values per treatment, the maximum error has been presented. Abbreviations are for C1=control, Expt. 1 (n=10); D1=deficit, Expt. 1 (n=11); C2=control, Expt. 2 ($n \geq 7$); D2=deficit, Expt. 2 ($n \geq 4$); LD2=late deficit, Expt. 2 ($n \geq 7$); C4=control, Expt. 4 (n=4); ED4=early deficit, Expt. 4 (n=4); and LD4=late deficit, Expt. 4 (n=4). Arrows indicate the beginning of LD2 treatment, rewatering of ED4 treatment and the beginning of LD4 treatment.

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2 ($n \geq 7$); C4=control, Expt. 4 (n=4); ED4=early deficit, Expt. 4 (n=4); and LD4=late deficit, Expt. 4 (n=4). Arrows indicate the beginning of LD2 treatment, rewatering of ED4 treatment and the beginning of LD4 treatment.

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(stage 1 harvest) when n=6 and at 180 DAFB (stage 2 harvest) when n=4), D1=deficit (n=11 upto 170 DAFB (stage 1 harvest) when n=6 and at 180 DAFB (stage 2 harvest) where n=5); C2=control, Expt. 2 (n≥7); D2=deficit, Expt. 2 (n≥4); LD2=late deficit, Expt. 2 (n≥7); C3=control, Expt. 3 (n=6); D3=deficit, Expt. 3 (n=3); C4=control, Expt. 4 (n=4); ED4=early deficit, Expt. 4 (n=4); and LD4=late deficit, Expt. 4 (n=4). Arrows indicate the beginning of LD2 treatment, rewatering of ED4 treatment and the beginning of LD4 treatment.

Fig. 16 Fruit firmness for Expt. 1. Bars indicate standard errors of the means. Abbreviations are for C1= control (n=10 upto 170 DAFB (stage 1 harvest) when n=6 and at 180 DAFB (stage 2 harvest) when n=4), D1=deficit (n=11 upto 170 DAFB (stage 1 harvest) when n=6 and at 180 DAFB (stage 2 harvest) where n=5).

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error bars of treatment means for each measurement time are based on the pooled experimental error of 21 (or 12 at 170 DAFB and 9 at 180 DAFB), 4 (or 6 from 120 DAFB), 9, and 12 experimental units (trees) for A, B, C, and D respectively. When pooled experimental error differed between treatments due to different n values per treatment, the maximum error has been presented. Abbreviations are for C1=control, Expt. 1 (n=10 upto 170 DAFB (stage 1 harvest) where n=6 and 180 DAFB (stage 2 harvest) where n=4); D1=deficit, Expt. 1 (n=11 upto 170 DAFB (stage 1 harvest) where n=6 and 180 DAFB (stage 2 harvest) where n=5); C2=control, Expt. 2 (n=2); D2=deficit, Expt. 2 (n=2); LD2=late deficit, Expt. 2 (n=2); C3=control, Expt. 3 (n=6); D3=deficit, Expt. 3 (n=3); C4=control, Expt. 4 (n=4); ED4=early deficit, Expt. 4 (n=4); and LD4=late deficit, Expt. 4 (n=4). Arrows indicate the beginning of LD2 treatment, rewatering of ED4 treatment and the beginning of LD4 treatment.

Fig. 21 Ethylene evolution for Expts. 1 (A), and 2 (B). Bars indicate standard errors of the means. Abbreviations are for C1= control, Expt. 1 (n=10 upto 170 DAFB (stage 1 harvest) when n=6 and at 180 DAFB (stage 2 harvest) when n=4); D1=deficit, Expt. 1 (n=11 upto 170 DAFB (stage 1 harvest) where n=6 and 180 DAFB (stage 2 harvest) where n=5); C2=control, Expt. 2 (n=2 upto 180 DAFB where n=7); D2=deficit, Expt. 2 (n=2 upto 180 DAFB where n=4); and LD2=late deficit, Expt. 2 (n=2 upto 180 DAFB where n=7).

Fig. 22 Fruit Ca^{2+} concentration for Expts. 1 (A), 2 (B), 3 (C) and 4 (D). Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 21 (or 12 at 170 DAFB and 9 at 180 DAFB), 4 (or 6 from

120 DAFB), 9, and 12 experimental units (trees) for A, B, C, and D respectively. When pooled experimental error differed between treatments due to different n values per treatment, the maximum error has been presented. Abbreviations are for C1=control, Expt. 1 (n=10 upto 170 DAFB (stage 1 harvest) when n=6 and at 180 DAFB (stage 2 harvest) when n=4); D1=deficit, Expt. 1 (n=11 upto 170 DAFB (stage 1 harvest) where n=6 and 180 DAFB (stage 2 harvest) where n=5); C2=control, Expt. 2 (n=2); D2=deficit, Expt. 2 (n=2); LD2=late deficit, Expt. 2 (n=2); C3=control, Expt. 3 (n=6); D3=deficit, Expt. 3 (n=3); C4=control, Expt. 4 (n=4); ED4=early deficit, Expt. 4 (n=4); and LD4=late deficit, Expt. 4 (n=4). Arrows indicate the beginning of LD2 treatment, rewatering of ED4 treatment and the beginning of LD4 treatment.

Fig. 23 Fruit Mg^{2+} concentration for Expts. 1 (A), 2 (B), 3 (C) and 4 (D). Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 21 (or 12 at 170 DAFB and 9 at 180 DAFB), 4 (or 6 from 120 DAFB), 9, and 12 experimental units (trees) for A, B, C, and D respectively. When pooled experimental error differed between treatments due to different n values per treatment, the maximum error has been presented. Abbreviations are for C1=control, Expt. 1 (n=10 upto 170 DAFB (stage 1 harvest) when n=6 and at 180 DAFB (stage 2 harvest) when n=4); D1=deficit, Expt. 1 (n=11 upto 170 DAFB (stage 1 harvest) when n=6 and at 180 DAFB (stage 2 harvest) when n=5); C2=control, Expt. 2 (n=2); D2=deficit, Expt. 2 (n=2); LD2=late deficit, Expt. 2 (n=2); C3=control, Expt. 3 (n=6); D3=deficit, Expt. 3 (n=3); C4=control, Expt. 4 (n=4); ED4=early deficit, Expt. 4 (n=4); and LD4=late deficit, Expt. 4 (n=4). Arrows indicate the beginning of LD2 treatment, rewatering of ED4 treatment and the beginning of LD4 treatment.

Fig. 24 Fruit P concentration for Expts. 1 (A), 2 (B), 3 (C) and 4 (D). Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 21 (or 12 at 170 DAFB and 9 at 180 DAFB), 4 (or 6 from 120 DAFB), 9, and 12 experimental units (trees) for A, B, C, and D respectively. When pooled experimental error differed between treatments due to different n values per treatment, the maximum error has been presented. Abbreviations are for C1=control, Expt. 1 (n=10 upto 170 DAFB (stage 1 harvest) when n=6 and at 180 DAFB (stage 2 harvest) when n=4); D1=deficit, Expt. 1 (n=11 upto 170 DAFB (stage 2 harvest) when n=6 and at 180 DAFB (stage 2 harvest) when n=5); C2=control, Expt. 2 (n=2); D2=deficit, Expt. 2 (n=2); LD2=late deficit, Expt. 2 (n=2); C3=control, Expt. 3 (n=6); D3=deficit, Expt. 3 (n=3); C4=control, Expt. 4 (n=4); ED4=early deficit, Expt. 4 (n=4); and LD4=late deficit, Expt. 4 (n=4). Arrows indicate the beginning of LD2 treatment, rewatering of ED4 treatment and the beginning of LD4 treatment.

Fig. 25 Fruit K^+ concentration for Expts. 1 (A), 2 (B), 3 (C) and 4 (D). Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 21 (or 12 at 170 DAFB and 9 at 180 DAFB), 4 (or 6 from 120 DAFB), 9, and 12 experimental units (trees) for A, B, C, and D respectively. When pooled experimental error differed between treatments due to different n values per treatment, the maximum error has been presented. Abbreviations are for C1=control, Expt. 1 (n=10 upto 170 DAFB (stage 1 harvest) when n=6 and at 180 DAFB (stage 2 harvest) when n=4); D1=deficit, Expt. 1 (n=11 upto 170 DAFB (stage 1 harvest) when n=6 and at 180 DAFB (stage 2 harvest) when n=5); C2=control, Expt. 2 (n=2); D2=deficit, Expt. 2 (n=2); LD2=late deficit, Expt. 2 (n=2); C3=control, Expt. 3 (n=6);

D3=deficit, Expt. 3 (n=3); C4=control, Expt. 4 (n=4); ED4=early deficit, Expt. 4 (n=4); and LD4=late deficit, Expt. 4 (n=4). Arrows indicate the beginning of LD2 treatment, rewatering of ED4 treatment and the beginning of LD4 treatment.

Fig. 26 Titratable acidity (TA), total soluble solids (TSS) and fresh mass for C3 and D3 fruit for days after full bloom (DAFB) and days in storage (DIS). Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 9 experimental units (trees). Abbreviations are C3=control, Expt. 3 (n=6), D3=deficit, Expt. 3 (n=3).

Fig. 27 Concentration ($mg \cdot g^{-1}$ fresh weight) of fructose, sucrose glucose, and sorbitol for C3 and D3 fruit for days after full bloom (DAFB) and days in storage (DIS). Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 9 experimental units (trees). When pooled experimental error differed between treatments due to different n values per treatment the maximum error has been presented. Abbreviations are C3=control, Expt. 3 (n=6), D3=deficit, Expt. 3 (n=3).

Fig. 28 Concentration ($mg \cdot g^{-1}$ fresh weight) of total soluble sugars (fructose, sucrose glucose, and sorbitol) for C3 and D3 fruit for days after full bloom (DAFB) and days in storage (DIS). Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 9 experimental units (trees). Abbreviations are C3=control, Expt. 3 (n=6), D3=deficit, Expt. 3 (n=3).

Fig. 29 Concentration of calcium and nitrogen for C3 and D3 fruit for days after full bloom (DAFB) and days in storage (DIS). Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 9 experimental units (trees). Abbreviations are C3=control, Expt. 3 (n=6), D3=deficit, Expt. 3 (n=3). An analytical error has been assumed responsible for the outlier at 192 DAFB as no rational explanation for this anomaly can be offered.

Fig. 30 Fruit water potential (Ψ_{fw}) (A), osmotic potential (Ψ_{fs}) (B), and turgor potential (Ψ_{fp}) (C) measured at midday during the season for C2, D2 and LD2 in Expt. 2. Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 4 (or 6 from 120 DAFB) experimental units (trees). Abbreviations are C2=control, (n=2), D2=deficit, (n=2), and LD2=late deficit, (n=2). Arrows indicate the beginning of LD2.

Fig. 31 Fruit water potential (Ψ_{fw}) (A), osmotic potential (Ψ_{fs}) (B), and turgor potential (Ψ_{fp}) (C) measured at predawn during the season for C4, ED4 and LD4. Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 8 (or 12 from 128 DAFB) experimental units (trees). Abbreviations are C4=control, Expt. 4 (n=4), ED4=early deficit, Expt. 4 (n=4), and LD4=late deficit, Expt. 4 (n=4). Arrows indicate time of rewatering of the ED4 trees and the beginning of the LD4.

Fig. 32 Fruit water potential (Ψ_{fw}) (A), osmotic potential (Ψ_{fs}) (B), and turgor potential (Ψ_{fp}) (C) measured at midday during the season for C4, ED4 and LD4.

Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 8 (or 12 from 128 DAFB) experimental units (trees). Abbreviations are C4=control, Expt. 4 (n=4), ED4=early deficit, Expt. 4 (n=4), and LD4=late deficit, Expt. 4 (n=4). Arrows indicate time of rewatering of the ED4 trees and the beginning of the LD4.

Fig. 33 Fruit water potential (Ψ_{fw}) (A), osmotic potential (Ψ_{fs}) (B), and turgor potential (Ψ_{fp}) (C) measured at dusk during the season for C4, ED4 and LD4. Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 8 (or 12 from 128 DAFB) experimental units (trees). Abbreviations are C4=control, Expt. 4 (n=4), ED4=early deficit, Expt. 4 (n=4), and LD4=late deficit, Expt. 4 (n=4). Arrows indicate time of rewatering of the ED4 trees and the beginning of the LD4.

Fig. 34. Mean total sugar concentration for fruit of Expt. 2 (A) and Expt. 4 (B). Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 4 (or 6 from 134 DAFB), and 8 (or 12 from 128 DAFB) experimental units (trees) for A and B respectively. Abbreviations are C2=control, Expt. 2 (n=2), D2=deficit, Expt. 2 (n=2), LD2=late deficit, Expt. 2 (n=2). C4=control, Expt. 4 (n=4), ED4=early deficit, Expt. 4 (n=4), and LD4=late deficit, Expt. 4 (n=4). Arrows indicate the beginning of the LD2 treatment, time of rewatering of the ED4 treatment and the beginning of the LD4 treatment.

Fig. 35 Mean concentration of sucrose (A), glucose (B), fructose (C), and sorbitol

(D) ($mg \cdot g^{-1}$ fresh wt) for Expt. 2. Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 4 (or 6 from 134 DAFB) experimental units (trees). Abbreviations are C2=control (n=2), D2=deficit (n=2), and LD2=late deficit (n=2). Arrows indicate the beginning of the LD2 treatment.

Fig. 36 Mean concentration of sucrose (A), glucose (B), fructose (C), and sorbitol (D) ($mg \cdot g^{-1}$ fresh wt) for Expt. 4. Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 8 (or 12 from 128 DAFB) experimental units (trees). Abbreviations are C4=control (n=4), ED4=early deficit (n=4), and LD4=late deficit (n=4). Arrows indicate the time of rewatering of the ED4 treatment and the beginning of the LD4 treatment.

Fig. 37 Fruit water potential (Ψ_{fw}) (A), osmotic potential (Ψ_{fs}) (B), and turgor potential (Ψ_{fp}) (C) measured on C4 (n=4) at predawn, midday and dusk throughout the season in Expt. 4. Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 8 (or 12 from 128 DAFB) experimental units (trees).

Fig. 38 Fruit water potential (Ψ_{fw}) (A), osmotic potential (Ψ_{fs}) (B), and turgor potential (Ψ_{fp}) (C) measured on ED4 (n=4) at predawn, midday and dusk throughout season in Expt. 4. Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 8 (or 12 from 128 DAFB) experimental units (trees). Arrows indicate time of rewatering of the ED4 treatment.

Fig. 39 Fruit water potential (Ψ_{fw}) (A), osmotic potential (Ψ_{fs}) (B), and turgor potential (Ψ_{fp}) (C) measured on LD4 (n=4) at predawn, midday and dusk throughout season in Expt. 4. Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 8 (or 12 from 128 DAFB) experimental units (trees).

Fig. 40 Mean total sugar concentration of C4 (A), ED4 (B), and LD4 (C) measured at predawn, midday and dusk throughout season. Standard error bars of treatment means for each measurement time are based on the pooled experimental error of 8 (or 12 from 128 DAFB) experimental units (trees). Arrows indicate time of rewatering of the ED4 treatment.

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Table 5. Leaf area for experiments 1, 2, and 4. Abbreviations are for C1=control, Expt. 1; D1=deficit, Expt. 1; C2=control, Expt. 2; D2=deficit, Expt. 2; LD2=late deficit, Expt. 2; C4=control, Expt. 4; ED4=early deficit, Expt. 4; and LD4=late deficit, Expt. 4. Column values followed by different letters are significantly different at $P < 0.05$.

Table 6. Trunk circumference increase for experiments 1, 2, and 4. Abbreviations are for C1=control, Expt. 1; D1=deficit, Expt. 1; C2=control, Expt. 2; D2=deficit, Expt. 2; LD2=late deficit, Expt. 2; C4=control, Expt. 4; ED4=early deficit, Expt. 4; and LD4=late deficit, Expt. 4. Column values followed by different letters are significantly different at $P < 0.05$.

Table 7. Return bloom (number of flowers) recorded for experiments 1 and 4. Abbreviations are for C1=control, Expt. 1; D1=deficit, Expt. 1; C4=control, Expt. 4; ED4=early deficit, Expt. 4; and LD4=late deficit, Expt. 4. Column values followed by different letters are significantly different at $P < 0.05$.

Table 8. Difference in the red and green colouration of 'Braeburn' apple fruit at final harvest for experiments 1, 3, and 4. Abbreviations are for C1= control, Expt. 1, D1=deficit, Expt. 1, C3=control, Expt. 3, D3=deficit, Expt. 3, C4=control, Expt. 4, ED4=early deficit, Expt. 4, and LD4=late deficit, Expt. 4. For each year, column values followed by different letters are significantly different at $P < 0.05$.

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