NATIONAL PROGRAM FOR
Sustainable Irrigation

Open Hydroponics: Risks and Opportunities

Stage 1

Water, Nutrient and Salt Balance Simulations

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Table of Contents

Introduction

Open hydroponics (OH) is best defined as the continuous field application of nutrients by drip irrigation. Nutrients and water are applied to match the crop's requirement to optimise vegetative growth, and maximum yield and fruit quality. By contrast, in soil-less hydroponics the nutrient concentration in the water solution and the volume of water is in excess of the crop's requirement.

The number of emitters per plant in an OH system is less than a conventional drip irrigation system to enable the non-stop or high frequency application of water and nutrients. Fewer emitters per plant means that the wetted soil volume will be smaller than conventional drip and much less than the potential available soil volume for root growth in most horticultural situations. The small wetted soil volume in OH allows greater precision over the supply of nutrients to the crop but at the same time needs to be large enough to provide sufficient anchorage of the crop to avoid uprooting during high wind.

Given that OH will create an environment that encourages the development of a small active root-zone, it is important that the irrigation system is designed and managed to (1) prevent the soil water content declining excessively such that plants are water stress, (2) minimise leakage of nutrients into waterways, and (3) avoid excessive build up of salt in the root-zone. For example, can an OH system be designed to run non-stop with minimal leakage of nutrients? Alternatively can an OH system be managed by pulsing irrigation events during the day to prevent water stress and minimise leakage?

The objective of this study was to investigate water requirements of an OH orchard and the potential impact on water and nutrient leakage and salt accumulation in the root-zone. The practicalities of management for optimum performance of OH are discussed.

Materials and Methods

The effects of (i) non-stop (ii) daytime and (iii) pulse irrigation on soil water content and drainage were investigated over a 12-month period from 1 January 2004 in a hypothetical OH citrus orchard by using a soil water balance model. Diurnal crop evapotranspiration was estimated from a radiation interception model and meteorological data. Potential nutrient leakage was estimated from a daily fertigation program. Accumulation of salt in the root-zone was estimated from the average salinity of the water supply.

Soil water balance

A soil water balance (Allen et al., 1998) was used as the base model behind the simulations presented in this report. The approach estimates components of water applied and lost from the crop's root zone from the water balance equation:

$$ET_c + R_{off} + D + SF_{out} = I + R + CR + SF_{in} + (SWC_{t-1} - SWC_t) \qquad \text{(Equation 1)}$$

where ET_c is crop evapotranspiration, R_{off} is surface run off, D is below root-zone drainage, SF_{out} is horizontal sub-surface flow out of the root-zone, I is irrigation applied, R is rainfall, CR is upward flux of water into the root-zone by capillary rise, SF_{in} is horizontal sub-surface flow into the root-zone, SWC_t is the soil water content at time t and SWC_{t-1} is the soil water content at time t-1. All parameters are expressed in units of mm of water.

For the purposes of this study R_{off}, SF_{out}, R, SF_{in}, and CR were set to zero. In most OH sites SF_{out} and SF_{in} will be minor (unless on steep slopes) and thus can be ignored. Similarly under drip irrigation on light textured soils R_{off} will be negligible. CR may be an issue at some sites (e.g. perched water table), however, it would be impossible to restrict the size of the wetted root-zone and effectively employ OH in a situation where CR contributed significantly to the supply of water to the tree. Equation 1 was therefore simplified to:

$$ET_c + D = I + (SWC_{t-1} - SWC_t) \qquad \text{(Equation 2)}$$

Dynamic simulation of D and SWC_t was undertaken by assuming a constant wetted soil volume that defined root distribution. When water inputs resulted in the soil water content equalling or exceeding the upper limit (SWC_{UL}), SWC_t was set to SWC_{UL} and D was calculated from:

$$D = I - ET_c + (SWC_{t-1} - SWC_{UL}) \qquad \text{(Equation 3)}$$

When water inputs resulted in the soil water content remaining below SWC_{UL}, D was set to zero and SWC_t was calculated from:

$$SWC_t = I - ET_c + SWC_{t-1} \quad \text{(Equation 4)}$$

Average SWC_t in the wetted zone ($WZSWC_t$; cm^3/cm^3) was calculated from:

$$WZSWC_t = \frac{SWC_t}{RZD.f_{WZ}} \quad \text{(Equation 5)}$$

where RZD was root-zone depth (mm) and f_{WZ} was the wetted fraction of available soil defined on the horizontal plane by the row and tree spacing.

Crop evapotranspiration

Diurnal crop evapotranspiration (ET_c) was estimated by the procedure developed for peach (Goodwin et al., 2005):

$$ET_c = 1.1 f\ ET_o \quad \text{(Equation 6)}$$

where f is the fraction of direct beam solar radiation intercepted by the tree's foliage and ET_o is reference crop evapotranspiration. f was simulated for the hypothetical citrus orchard from a geometrical light interception model (Goodwin, 2004). Instantaneous estimates of ET_o were calculated from hourly measurements of temperature, humidity, solar radiation and wind speed (Allen et al., 1998) at Dareton. Cohen (1991) used a similar approach to compute potential transpiration of grapefruit from the fraction of sunlit leaves.

Soil evaporation was assumed to be negligible and not included in the calculation of ET_c. The combination of a small wetted soil surface in OH and shading of the wetted soil from the tree's foliage would significantly reduce soil evaporation compared with a sprinkler-irrigated orchard.

Hypothetical orchard

A hypothetical hedgerow citrus orchard growing in a sandy loam soil was used for simulations. Tree and row spacing were set to 1.8 and 5.0 m, respectively, and row orientation was north-south. Tree cover, defined as the proportion of the soil surface covered by foliage when observed from the vertical, was set to 80 %. Leaf area density was set to a constant 2.5 m^2/m^3 and a spherical leaf angle distribution was assumed. RZD, SWC_{UL} in the wetted zone ($WZSWC_{UL}$) and readily available water (RAW) were set to 0.55 m, 0.38 and 0.055 cm^3/cm^3, respectively. The lower limit of soil water content for OH was set to 10 % of RAW.

Irrigation scenarios

(i) Non-stop irrigation. Irrigation was operated continuously over the 12-month period. The irrigation system consisted of a single drip-line with emitters spaced at 0.6 m having an output of 1.6 l/h. The wetting pattern was described as a 1 m wide strip wetting approximately 20 % of the available soil volume (i.e. f_{WZ} = 0.2).

(ii) Daytime irrigation. Irrigation was operated during the daytime for a constant or variable duration over the 12-month period. Constant daytime irrigations (commencing at 0730 h) for 12 h and 14 h were compared. Variable daytime irrigation changed each month commencing when the midpoint of the required run time to replace 120 % of average daily ET_c coincided with average maximum hourly rate of ET_c. The irrigation system was the same as for non-stop irrigation.

(iii) Pulse irrigation. Irrigation was operated multiple times during a day over the 12-month period. Fixed interval pulse was compared with flexible pulse irrigation. Fixed interval pulse irrigation was scheduled for 1 h on and 1 h off with the first and last irrigation at 0730 and 2030 h, respectively. Flexible pulse irrigation was scheduled to start when $WZSWC_t$ approached 10 % RAW and stopped when $WZSWC_t = WZSWC_{UL}$ (i.e. 0 % RAW). The irrigation system consisted of two drip-lines positioned 1 m each side of the tree row with emitters spaced at 0.9 m having an output of 2.3 l/h. The wetting pattern of each emitter was assumed cylindrical in shape with a diameter of 0.9 wetting up approximately 30 % of the available soil volume (i.e. f_{WZ} = 0.3).

Nitrogen leakage

A balanced complete fertiliser program for citrus orchards was used to determine leakage of nitrogen for non-stop, daytime and pulse irrigation. This program assumed best possible practice with respect to matching plant nutrient requirement.

Nitrogen accumulation and root-zone salinity

The accumulation of nitrate in the wetted zone and hence the potential for leakage from rainfall events was examined for 40, 60, 80 and 90 % nitrate uptake efficiencies assuming no leaching of nitrate below the root-zone.

Root-zone soil salinity (EC_e) was calculated from the total amount of salts applied to a tree (nutrient solution and irrigation source) for 40, 60, 80 and 90 % nutrient uptake efficiencies assuming no leaching of salt below the root-zone. Electrical conductivity of the irrigation source was set to 0.24 dS/m for the months August to October and to 0.3 dS/m for remaining months based on average measurements at Dareton. A modified Rhoades equation (Gutteridge et al. 1998) was used to estimate the leaching fraction required to maintain EC_e at the threshold recommended for citrus of 1.7 dS/m (Maas, 1990).

Results

Water Balance and Nitrogen Leakage

(i) Non-stop irrigation

Non-stop irrigation for a 12-month period resulted in an application of 4647 mm of water (Table 1). For the same period ET_c and D were 1525 mm and 3122 mm, respectively. Total loss of nitrogen was 97 kg/ha, which equated to 61 % of that applied. Monthly irrigation efficiency was lowest from May to September when ET_c was low. Nitrogen application was minimal during winter but increased in spring. Maximum loss of nitrogen occurred in spring and early summer.

Table 1. Monthly irrigation, crop evapotranspiration (ET_c), drainage, irrigation efficiency, nitrogen application and nitrogen leakage under non-stop irrigation.

Month	Irrigation (mm)	ET_c (mm)	Drainage (mm)	Irrigation efficiency (%)	Nitrogen applied (kg/ha)	Nitrogen leakage (kg/ha)
Jan	394	194	201	49	20	10.1
Feb	369	180	189	49	17	8.7
Mar	394	162	233	41	13	7.7
Apr	382	113	268	30	6	4.0
May	394	69	325	18	4	3.4
Jun	382	50	332	13	3	2.4
Jul	394	53	342	13	4	3.2
Aug	394	88	306	22	11	8.8
Sept	382	101	281	26	16	12.1
Oct	394	169	225	43	22	12.7
Nov	382	164	218	43	20	11.3
Dec	386	183	203	47	24	12.6
Total	4647	1525	3122		160	97

Figure 1a shows changes in $WZSWC_t$ for the 12-month period. $WZSWC_t$ was lower than 10 % of RAW on 126 days. During the summer months $WZSWC_t$ was regularly lower than 10 % of RAW. Diurnal changes in $WZSWC_t$ for a four-day period from 1 January are shown in Figure 1b. $WZSWC_t$ was lower than 10 % RAW for approximately 6 h from 1130 to 1730 h. On 4 January, $WZSWC_t = WZSWC_{UL}$ corresponding to $ET_c < I$.

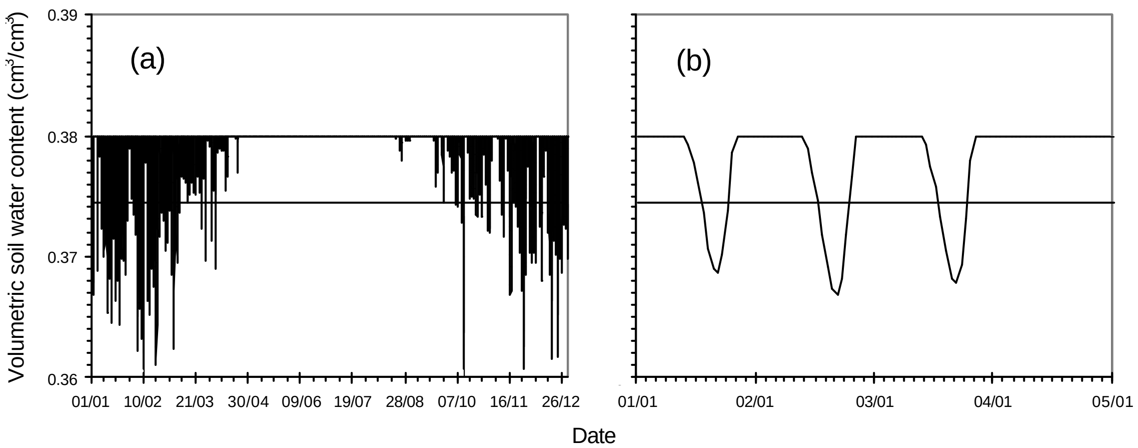

Figure 1. Changes in average volumetric soil water content in the wetted zone under non-stop irrigation for (a) 12-months, and (b) 4 days in January. Upper limit soil water content in the wetted zone was set to 0.38 cm^3/cm^3. Horizontal line indicates 10 % of readily available water.

(ii) Daytime irrigation

Comparison of 12 and 14 h daytime irrigation (commencing at 0730 h) over a 12-month period revealed an increase in D from 804 to 1183 mm (Table 2). During summer D was 20 mm, irrigation efficiency was > 94 % and nitrogen leakage was 2.3 kg/ha in the 12 h daytime irrigation scenario. . By contrast, D was 112 mm, irrigation efficiency ranged from 84 - 94 % and nitrogen leakage was 10.3 kg/ha in the 14 h daytime irrigation scenario. The majority of drainage occurred from April to September in both the 12 and 14 h daytime irrigation scenarios. Leakage of nitrogen was greatest in August and September.

Table 2. Comparison of monthly drainage, irrigation efficiency and nitrogen leakage for 12 and 14 h daytime irrigation.

Month	Drainage (mm)		Irrigation efficiency (%)		Nitrogen leakage (kg/ha)	
	12 h	14 h	12 h	14 h	12 h	14 h
Jan	9	37	95	84	0.9	3.2
Feb	0	35	100	84	0.0	2.8
Mar	34	68	83	70	2.3	3.9
Apr	78	109	59	51	2.3	2.8
May	128	161	35	30	2.6	2.9
Jun	141	173	26	22	2.0	2.1
Jul	145	177	27	23	2.7	2.9
Aug	109	142	45	38	6.2	7.0
Sept	90	122	53	45	7.7	9.0
Oct	28	61	86	74	3.2	5.9
Nov	32	59	83	74	3.3	5.3
Dec	11	40	94	82	1.4	4.3
Total	804	1183			35	52

Corresponding $WZSWC_t$ for the 12-month period is shown in Figure 2. $WZSWC_t$ in the 12 h daytime irrigation was below 10 % RAW throughout most days in summer and reached a minimum of 0.28 cm^3/cm^3 in January (Fig. 2a). $WZSWC_t$ in the 14 h daytime irrigation did not fall below 0.35 cm^3/cm^3 (Fig. 2b).

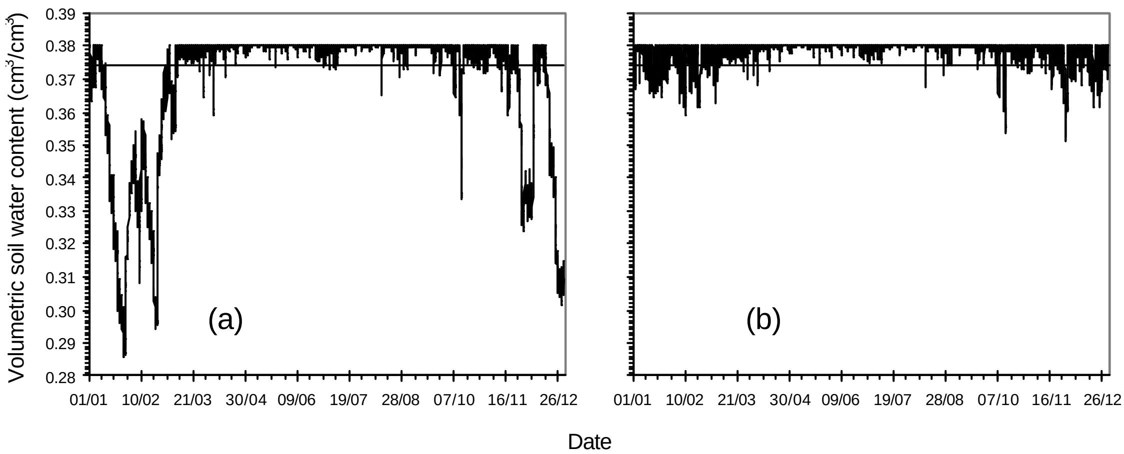

Figure 2. Changes in average volumetric soil water content in the wetted zone for (a) 12 h daytime irrigation, and (b) 14 h daytime irrigation. Upper limit soil water content in the wetted zone was set to 0.38 cm^3/cm^3. Horizontal line indicates 10 % of readily available water.

Run time for variable daytime irrigation ranged from 14 h in January and February to 4 h in June and July (Table 3). Start time varied from 0730 in January and February to 1130 h in May, June and July. D and nitrogen leakage over a 12-month period was 294 mm and 25 kg/ha, respectively. Irrigation efficiency was > 75 %.

Table 3. The effects of variable daytime irrigation on drainage, irrigation efficiency and nitrogen leakage.

Month	Run time (h)	Start time (h)	Drainage (mm)	Irrigation efficiency (%)	Nitrogen leakage (kg/ha)
Jan	14	0730	37	84	3.2
Feb	14	0730	35	84	2.8
Mar	12	0830	36	82	2.4
Apr	9	1030	30	79	1.2
May	5	1130	13	84	0.7
Jun	4	1130	16	75	0.7
Jul	4	1130	12	81	0.7
Aug	6	1030	16	83	1.9
Sept	8	0930	20	84	2.6
Oct	12	0830	28	86	3.2
Nov	12	0830	31	84	3.3
Dec	13	0830	20	90	2.3
Total			294		25

Corresponding $WZSWC_t$ for the 12-month period is shown in Figure 3. $WZSWC_t$ for most of the 12-month period was greater than 10 % of RAW, although in late August $WZSWC_t$ decreased to less than 0.32 cm^3/cm^3 when daily ET_c exceeded average values for the month by more than 20 %. Similarly, $WZSWC_t$ decreased noticeably in late September and late November.

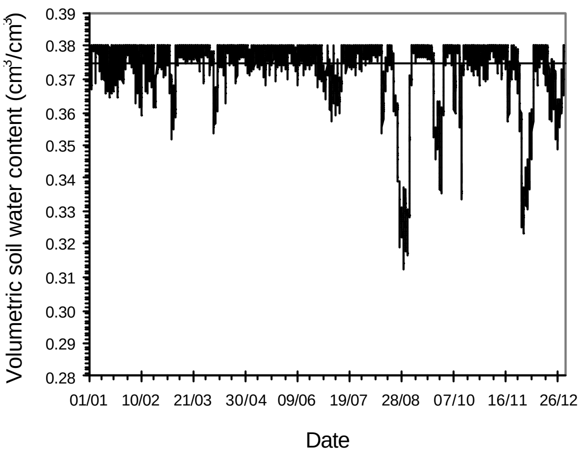

Figure 3. Changes in average volumetric soil water content in the wetted zone under variable daytime irrigation. Run time was calculated from average daily ET_c and start time was based on the time of day when ET_c was at its maximum rate. Irrigation run time ranged from 14 h in January to 4 h in June.

(iii) Pulse irrigation

Total irrigation and D were 2979 and 1456 mm, respectively, and nitrogen leakage was 62 kg/ha for fixed interval pulse irrigation over the 12-month period (Table 4). D peaked during late autumn and winter, and nitrogen leakage was greatest during late winter and spring.

Table 4. The effects of fixed interval pulse irrigation on drainage, irrigation efficiency and nitrogen leakage.

Month	Irrigation (mm)	Drainage (mm)	Irrigation efficiency (%)	Nitrogen leakage (kg/ha)
Jan	253	59	77	4.7
Feb	237	56	76	4.0
Mar	253	91	64	4.7
Apr	245	132	46	3.0
May	253	184	27	3.0
Jun	245	195	20	2.2
Jul	253	200	21	3.0
Aug	253	166	34	7.4
Sept	245	144	41	9.6
Oct	253	84	67	7.4
Nov	245	81	67	6.6
Dec	246	63	74	6.1
Total	2979	1456		62

$WZSWC_t$ for the fixed interval pulse irrigation was lower than 10 % RAW on 170 days and did not fall below 36 cm^3/cm^3 (Fig. 4a). Diurnal changes in $WZSWC_t$ for a four-day period from 1 January are shown in Figure 4b. One-hour pulse irrigations were insufficient to reduce $WZSWC_t$ to

$WZSWC_{UL}$ during high rates of ET_c (1 – 3 January). By contrast, on 4 January $WZSWC_t$ > 10 % RAW.

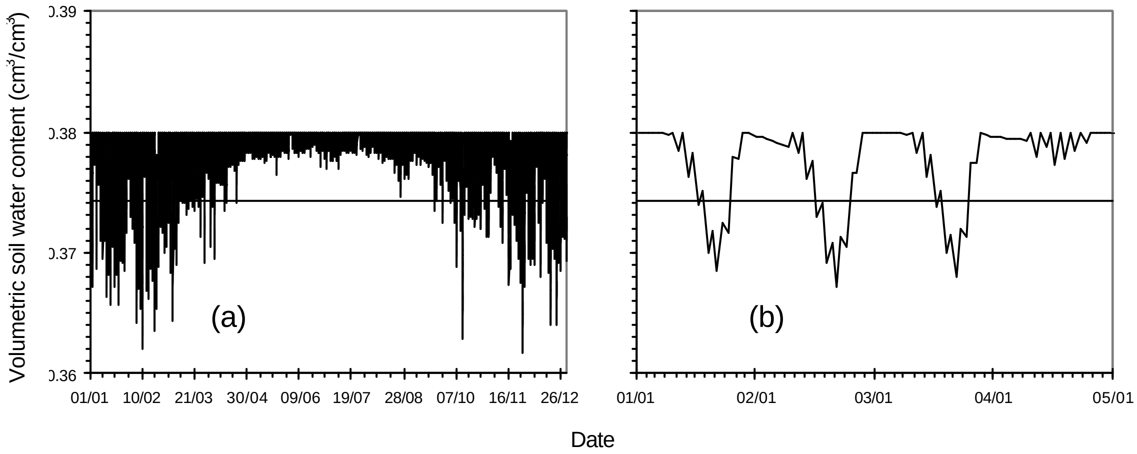

Figure 4. Changes in average volumetric soil water content in the wetted zone under fixed interval 1 h pulse irrigation for (a) 12 months, and (b) 4 days in January. Eight irrigations were applied commencing at 0730 h. Upper limit soil water content in the wetted zone was set to 0.38 cm^3/cm^3. Horizontal line indicates 10 % of readily available water.

Flexible pulse irrigation altered the interval and duration of irrigation depending on ET_c. Diurnal changes in $WZSWC_t$ for 1 – 4 January are shown in Figure 5. Irrigation was applied from 2 – 3 times each day for 1 – 4 h. For example, on 3 January irrigation was applied at 0930 for 2 h, at 1230 for 4 h and then finally at 1730 h for 1 h duration. Under this scenario, D and nitrogen leakage were negligible and irrigation efficiency approached 100 %.

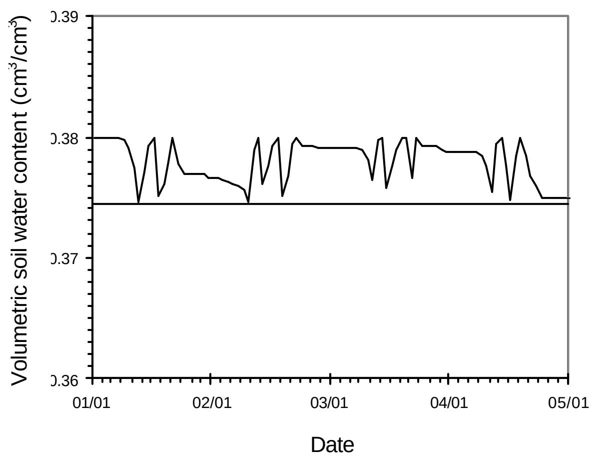

Figure 5. Changes in average volumetric soil water content in the wetted zone under flexible pulse irrigation. Irrigation was scheduled to start when the soil water content in the wetted zone approached 10 % of readily available water and stopped when the upper limit soil water content in the wetted zone was attained. The upper limit was set to 0.38 cm^3/cm^3. Horizontal line indicates 10 % of readily available water.

Root-zone nitrate accumulation

Total nitrogen applied to the hypothetical orchard was 160 kg/ha (Table 1). Approximately 85 % of applied nitrogen was in the form of nitrate. Figure 6 shows the effects of tree uptake efficiency on the accumulation of nitrate in the wetted zone when the $WZSWC_t = WZSWC_{UL}$. The rate of nitrate accumulation was greatest during spring and summer corresponding to the greatest application of nitrogen. Over a 12-month period from January to December nitrate concentration in the wetted zone reached 95, 190, 380 and 570 ppm at 90, 80, 60, 40 % uptake efficiencies, respectively.

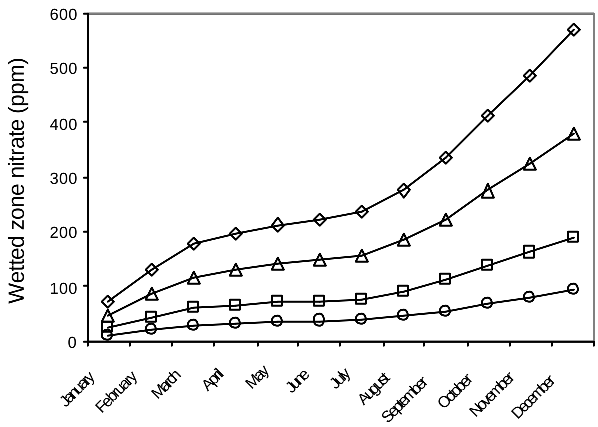

Figure 6. Wetted zone nitrate concentration (at the upper limit of soil water content) over a 12-month period (assuming no leaching) at tree nitrate uptake efficiencies of 90 % (○), 80 % (□), 60 % (△) and 40 % (◇). Total annual application of nitrogen was 160 kg/ha of which 85 % was supplied as nitrate.

Root-zone salinity

EC_e in the wetted zone exceeded the threshold for yield decline in citrus after one month of irrigation during January for all uptake efficiencies (Fig. 7). Total applied irrigation for the 12-month period was 15.3 Ml/ha (i.e. irrigation matched ET_c). EC_e reached 6.9 dS/m after 12 months irrigation at 100 % uptake efficiency, and at 40 % uptake efficiency, EC_e reached 12.2 dS/m.

The leaching fraction requirement to maintain EC_e below the threshold for citrus was estimated to be 0.05 for 90 and 100 %, and 0.06, 0.07 and 0.08 for 80, 60 and 40 % nutrient uptake efficiencies, respectively. Such leaching fractions equated to an annual drainage requirement of 67, 76, 85, 104 and 123 mm for 100, 90, 80, 60 and 40 % uptake efficiencies.

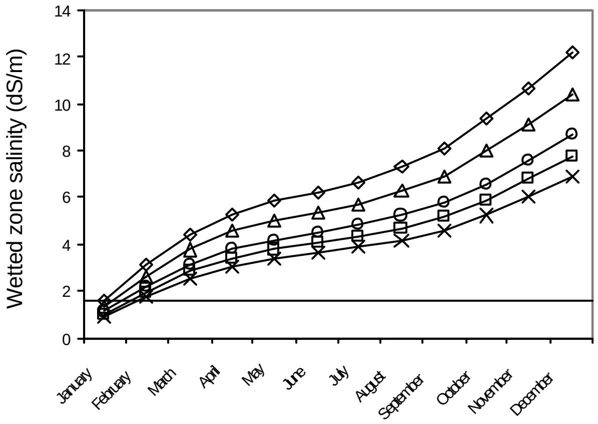

Figure 7. Wetted zone soil salinity over a 12-month period under flexible pulse irrigation at tree nutrient uptake efficiencies of 100 % (×), 90 % (○), 80 % (□), 60 % (△) and 40 % (◇). Irrigation water electrical conductivity was set to 0.24 dS/m for the months of August to October and 0.30 dS/m for all other months. Horizontal line indicates EC_e threshold for yield decline in citrus.

Discussion

The results of this simulation study showed that both drainage and nitrogen leakage were high under non-stop irrigation. Approximately 67 % of applied irrigation ended up below the root-zone, potentially taking with it over 60 % of the applied nitrogen. Drainage was greatest in winter and nitrogen leakage was high in spring. Soil water content was drier than 10 % of RAW on most days in mid-summer despite the non-stop application of water. This occurred in the mid-afternoon when ET_c was at its maximum rate. Any reduction in irrigation application rate to reduce drainage and nitrogen losses would result in considerably drier conditions in the wetted zone at this time.

Daytime irrigation of 14 h reduced drainage by approximately one-third. A further reduction in run time to 12 h resulted in even less drainage but the wetted zone dried out to well below RAW in late spring and summer. Alternatively, variable daytime irrigation reduced drainage to 294 mm and nitrogen leakage to 16 % of applied nitrogen. Here, irrigation run time and start time for each month remained constant and were based on average daily ET_c and the time of maximum ET_c. Such an approach to estimate irrigation requirement is simple and could be further improved by using a fortnightly rather than monthly average daily ET_c.

Fixed interval pulse irrigation did not reduce drainage compared with daytime irrigation. In fact, pulse irrigation set to one hour on, one hour off and eight per day resulted in more drainage and similar $WZSWC_t$ as 14 h daytime irrigation. However, the advantage in pulse irrigation is that irrigation can be applied to maintain soil water content within a defined range. Unlike the single drip line design for continuous and daytime irrigation, the application rate of the twin drip line design was able to supply water in excess of maximum rates of ET_c for this hypothetical orchard. This was clearly shown by forcing the simulation to commence irrigation when $WZSWC_t$ approached 10 % RAW, and cease irrigation when $WZSWC_t = WZSWC_{UL}$ (Figure 5).

A flexible pulse system has the capability of containing drainage and nutrients but there is still a risk of nutrient build up in the wetted zone that is susceptible to leakage from rainfall events. The amount of nitrate accumulated in the wetted zone under flexible pulse irrigation depended on tree uptake. Even at 90 % uptake efficiency the concentration of nitrate after 12-months reached 95 ppm. This is equivalent to potential loss of 60 kg/ha of nitrate below the root-zone. Rainfall events could readily leach this pool of nitrate past the root-zone.

Both root depth and the extent of the wetted zone will influence drainage, nutrient leakage and the rate of soil drying. Root depth was assumed constant at 0.55 m in this study. Syvertsen and Lloyd (1995) cited several studies that showed the fibrous root-zone in citrus was above 0.5 m depth irrespective of soil type, and citrus roots concentrate in the wetted zone. Total root depth may be greater. Allen et al. (1998) reported maximum root depth in citrus to range from 0.8 to 1.5 depending on tree size. These deeper roots may have the capacity to mop up at least some of the nutrients leached below the fibrous root-zone.

The horizontal extent of the wetted zone was also assumed constant in these simulations. Based on the model WetUp (CSIRO, 2005) the width of the wetting pattern would be anticipated to increase by approximately 15 % under continuous compared to 14 h daytime irrigation for a sandy loam soil. This increase, however, does not consider concurrent soil drying during the daytime from root water extraction, which is further exacerbated under pulse irrigation. For the purposes of this study the assumed constant wetted zone was sufficient but it should be noted that drainage, leakage and $WZSWC_t$ will be influenced by the size of the wetting pattern and henceforth the size of the root-zone.

Rainfall was set to zero in this study. Rainfall would have contributed to drainage and caused higher levels of nitrogen leakage than reported here. The effect of rainfall on drainage, nitrogen leakage and $WZSWC_t$ depends on the intensity, timing and duration of each rainfall event. For example, there was approximately 3 mm of water held between 10 % RAW and $WZSWC_{UL}$ in the hypothetical orchard. Therefore a maximum of 3 mm rainfall can be captured under flexible pulse irrigation. In practice, delaying irrigation events is difficult and reliance must be placed on measurements of soil water content.

OH, like any other irrigation system, requires a leaching fraction to remove salts that accumulate in the root-zone. A rapid increase in EC_e in the wetted zone was simulated from spring to autumn corresponding to high ET_o. EC_e reached threshold levels for yield decline in citrus within two months and this time frame decreased to one month when nutrient uptake efficiency was 40 %. These results will change with irrigation water salinity levels. Values recorded at Dareton of 0.24 to 0.3 dS/m were used but these could be substantially higher in other irrigation districts. Rainfall can leach salts out of the root-zone but this is probably not reliable in many climates. Reliance on rainfall to leach salts is therefore not recommended and a leaching fraction should be incorporated into irrigation events. Calculated leaching fraction ranged from 0.04 to 0.08 depending on nutrient uptake efficiency. Inevitably a leaching fraction will lead to loss of nitrogen (and other nutrients) below the root-zone in OH. This could be reduced or overcome by strategic leaching fractions of nutrient-less water.

Conclusion

Simulations for a hypothetical citrus orchard highlighted the need for flexible management and appropriate design to match maximum ET_c so drainage is minimised and periods of water stress are avoided. Pulse irrigation appeared to have advantages because the frequency and duration of pulses can be altered according to ET_c. An OH orchard triggered to irrigate when the soil water content reached a threshold was presented. Alternatively, irrigation events could be triggered based on continuous computations of ET_o. Such an approach requires accurate estimates of ET_c, wetted volume of soil and RAW. Irrigation triggered by soil water content or ET_c requires sophisticated management. A system that combines an estimate of ET_c and measurements of soil water content with appropriate feedback systems (i.e. monitoring of plant water stress, salt accumulation and drainage) would be ideal.

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