CUSTOMISING DRIP IRRIGATION FOR PROFITABLE VEGETABLE PRODUCTION

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ABSTRACT

Ongoing drought throughout irrigated vegetable growing areas of Australia has seen a substantial shift to drip irrigation. With reduced bore flow rates and accessible water volumes, growers have invested significant capital and labour switching from sprinkler systems. A primary focus is maintaining capacity to fulfil their vegetable supply contracts.

Optimising economic returns from drip irrigation in vegetables requires customisation of drip/crop configurations, irrigation frequency and soil water management. In an experiment investigating these issues (August 2007), we transplanted broccoli into clay-loam alluvial soils at the DPI&F Gatton Research Station in south-east Queensland. We planted 2 broccoli rows per 1.5 m wide bed, and applied standard agronomic practices across the experiment, except for irrigation management.

We compared a single, central row of drip tape, with 2 rows of drip tape per bed (adjacent to each row of crop). In both cases the pressure-compensated, no-drain drip tube was pegged at the soil surface. We also compared pulse irrigation (4 times per day) with irrigation every day, or every second day. We measured soil water status using tensiometers, irrigation volumes, as well as broccoli yields and head quality.

In our experiment, we achieved excellent broccoli yields (nearly 12,000 kg/ha of fresh heads) with both the central drip line for every 2 rows of broccoli, or with drip lines adjacent to every broccoli row. Similarly, there were no differences in broccoli yields or quality from pulse irrigating, irrigating once a day, or irrigating every second day.

Managing soil water conditions in the crop root zone was much easier with a drip line adjacent to every broccoli row, compared to the single, central drip line. With 2 drip lines per bed, we generally kept tensiometer values in the main crop root zone less than 40 kPa, whilst encouraging use of deeper soil water reserves. In contrast, with the single, central drip line, it was difficult to move water laterally into the main broccoli root zone. In this latter treatment, and there was also greater propensity for wetter soil conditions at 60 cm, a precursor to deep drainage.

The bed configurations with drip lines adjacent to every broccoli row reduced irrigation requirement by 25%, compared to the configurations with a single, central drip line.

Additional investment installing and maintaining two drip lines per bed, compared to a single, central line, will probably only be cost effective in situations where availability of irrigation water is limiting the grower’s production area.

On clay loam soils, there appears to be little current benefit investing in infrastructure to pulse irrigate vegetable crops (such as broccoli) several times per day. We could not observe any benefit from pulsing in improving lateral spread, nor any reduction in water use, when compared with the single daily irrigation.

INTRODUCTION

Ongoing drought throughout irrigated vegetable growing areas of Australia has seen a substantial shift to drip irrigation (Hickey *et al.* 2006). With reduced bore flow rates and accessible water volumes, growers have invested significant capital and labour switching from sprinkler systems. A primary focus is maintaining capacity to fulfil their vegetable supply contracts.

Optimising economic returns from drip irrigation in vegetables requires customisation of drip/crop configurations, irrigation frequency and soil water management. Lockyer Valley vegetable growers are still experimenting with various arrangements of bed size, crop rows per bed and rows of drip tape per bed (Henderson 2007). Issues include investment costs in reconfiguring bed-forming and planting machinery, metres of drip tape per ha (including fittings), and agronomic impacts of different crop row / drip tape configurations.

Once a configuration is installed, the next management decision faced by vegetable growers is irrigation scheduling. Many producers (recently switching over from overhead systems) irrigate every 2-3 days, analogous to the way they operated their solid-set sprinklers. Other growers irrigate daily, and a few growers pulse irrigate every few hours, using automated systems.

There is still extensive debate in the literature, and in practice, about the value of high frequency pulse irrigation in field vegetable production (Cote *et al.* 2003; Elmaloglou and Diamantopoulos 2007; Mostaghimi *et al.* 1981). The current rationale for most growers attempting pulse irrigation is to achieve maximum lateral spread from the drip tape, and thus reduce the amount of drip tape they require in their crop.

Using broccoli as an example crop, we report here on an experiment investigating these issues.

MATERIALS AND METHODS

This experiment was conducted at the Department of Primary Industries and Fisheries Gatton Research Station, Queensland. The soil was a moderately self-mulching Black Vertosol. In August 2007, we transplanted broccoli (cv. Babylon) into beds 1.2 m wide and separated by 0.3 m furrows. Broccoli rows were 0.35 m off the centreline of each bed, with intra-row spacing of broccoli plants of 0.33 m. Each experimental plot consisted of 3 beds (a central measurement bed, with a buffer bed either side), and was 10 m in length. We conducted all our measurements on broccoli plants in the central 8 m of the measurement bed (generally 22-23 plants in each of the 2 rows). Standard agronomic practices for nutrition, weed and pest management (Heisswolf *et al.* 2004) were imposed across the experimental area.

We used Plastro Hydro PCND drip tube (pressure compensating, no drain), with12 mm external tube diameter and 0.15 m emitter spacing. Emitter output at a pressure compensated 200 kPa was 1.15 L/hr, giving a linear drip tube output of 7.67 L/m/hr. We used no-drain emitters to enable us to accurately measure water volumes applied to the plots, without having to adjust for differential drainage after each irrigation. The drip tube was laid on the soil surface, and held in place by an inverted v-shaped wire inserted into the soil.

Our experimental design was a factorial with 2 drip configuration treatments * 3 irrigation scheduling treatments. Our 2 drip configurations were: (i) a single line of drip tube down the centre of the bed and (ii) 2 lines of drip tube per bed, adjacent to the broccoli rows. Our irrigation schedules were (i) every two days; (ii) daily and (iii) pulse irrigated 4 times per day (8 am, 11 am, 1 pm and 3 pm). Thus we had a total of 6 treatments in our experiment.

Apart from irrigation, side dressings of N and K fertilisers were applied by the drip system 4, 5 and 6 weeks after transplanting. The same total amounts of nutrient were applied to each treatment on each occasion.

We measured total water volumes applied to each treatment at each irrigation, as well as daily rainfall and pan evaporation from an adjacent weather station. At 8-9 am each day, we manually measured soil water potential at 0.15 m and 0.6 m below the surface, using tensiometers adjacent to the northern broccoli row of each bed.

The amount of irrigation we applied was determined using crop factors and net pan evaporation (accounting for rain) since the previous irrigation. For the pulse irrigation treatment, the 8 am irrigation was standardised at 0.5 mm, with the remaining 3 irrigations allocated to provide the same water volume as the daily irrigation. Occasionally, the pulse irrigation treatment received the initial 8 am irrigation; however no further irrigation was applied after reviewing the tensiometer values. The crop factors for each treatment were regularly adjusted on the basis of tensiometer values. If the shallow tensiometer values were rising (i.e. the soil was drying out), the crop factors were increased (increasing the irrigation applied) for the next event, whilst the converse was also true. The deep tensiometer values were monitored to look for excessive irrigation past the root zone, in which case crop factors (and thus irrigation) were generally reduced.

We made general notes on the health of the broccoli plants during the growing period, and took aerial photos of the crop to assess growth and canopy cover on a weekly basis (not reported here). We harvested the broccoli heads as they matured on 3 sequential dates; 16/10/2007, 19/10/2007 and 23/10/2007. We selected the appropriate harvest dates for each head to maximise the match with industry product specifications. We assessed each head against those specifications, measuring fresh head weight, head diameter, and the presence of major and minor defects. The main defects that occurred in our experiment were: no head (due to early insect damage or genetic deformity), undersize (less than 90 mm diameter), grossly immature, small leaves growing through the head, or uneven head shape.

RESULTS AND DISCUSSION

AGRONOMIC PERFORMANCE

There were no significant differences ($p \leq 0.05$) in broccoli yields or quality due to either the drip tape configuration or irrigation timing. All treatments had an average harvest date of 63 days after transplanting, with a standard deviation 2.1 days either side. Across the experiment, 96 ± 3% (± standard error of the mean) of plants produced marketable heads, with an average head weight of 336 ± 20 g, and head diameter of 133 ± 3 mm. On an area basis, this provided 11,900 ± 900 kg/ha of broccoli heads, equivalent to nearly 1,500 icepacks per hectare. This was an exceptionally high yield; industry statistics refer to yields of 1,100 icepacks/ha as high (Heisswolf *et al.* 2004).

However, there were 2 quality issues that may have impacted on price received for these heads, particularly if the market was oversupplied and buyers could afford to be choosy. A substantial proportion of heads had small leaves growing through the florets; 54 ± 7% in the single drip tube treatments, compared to 48 ± 7% in the double drip tube treatments; a statistically non-significant ($p=0.054$) and agronomically unimportant difference. Around ¼ of the marketable heads had an uneven shape (note that some heads were both uneven and had internal leaves), a common outcome when harvesting extends into a warm Spring. Only 39 ± 6% of heads were considered prime and unblemished product.

Because there were no significant differences in broccoli performance, any impacts of the irrigation treatments on profitability (or otherwise) of the systems under evaluation will depend on how they affect input efficiency, particularly water requirement.

IRRIGATION PERFORMANCE

For the first 4 weeks after transplanting, plant water requirements were mainly supplied by rain (Fig. 1a) and stored soil moisture. There was no substantial difference in irrigation supplied to any of the treatments (Fig. 1b), reflected in both shallow (Fig. 2a) and deep (Fig. 2b) tensiometer values.

Between 4 and 6 weeks after transplanting, shallow tensiometer values in the root zone of the beds with only a single drip line down the centre continued to increase (solid lines in Fig. 2a). This observation was particularly noticeable in the treatment watered every 2 days. In contrast, the beds with two lines had relatively consistent root zone soil moisture tension values, despite receiving substantially less irrigation than their single line companions. Deep soil zones beneath the crop rows were also consistently wetter in the single line treatments (Fig. 2b).

In the period 6-8 weeks after transplanting, shallow tensiometers values in all treatments reached 40-60 kPa on occasions; generally greater values in the single tube beds. The other point to note is that in the treatments with drip lines adjacent to the crop rows, it was much easier to reduce tensiometer values back below 40 kPa, using lower volumes of irrigation. Note that it was also easier to encourage slight drying of the deeper subsoil in these treatments (Fig. 2b), whereas deep soil in the single line treatments stayed wet. The 20 mm rain event 8 weeks after transplanting rewet most of the crop root zones, with the exception of the driest treatment (watered every 2 days).

Hot dry weather in Week 9, with consequent high plant water use, (and exacerbated by a Sunday with no irrigation applied), caused dramatic increases in tensiometer values across all treatments (Fig. 2). Catch-up irrigations in the ensuing 10 days managed to reduce tensiometer readings to desirable values during the harvest period.

Across the growing period, in the treatments with 2 drip lines per bed, there were only 4-5 days with tensiometer values in the root zone greater than 40 kPa. Of the single line treatments, the one irrigated every second day had 26 days with shallow readings >40 kPa, whilst both daily and pulse treatments had 14 days >40 kPa.

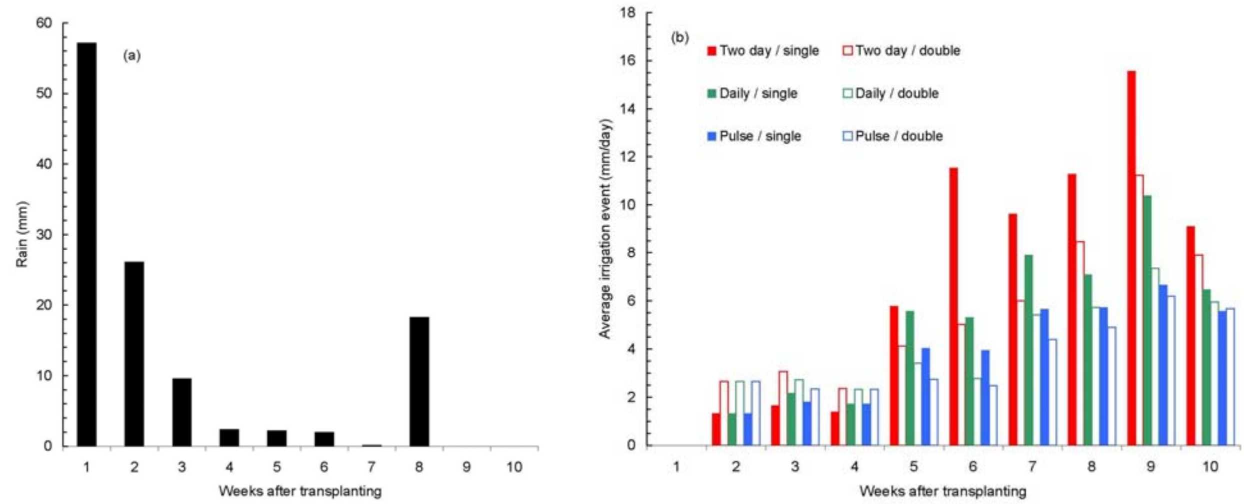

Figure 1. Water applied by (a) rain and (b) irrigation on broccoli beds with single or double drip lines per bed, and irrigated every second day, every day, or pulse irrigated 4 times per day.

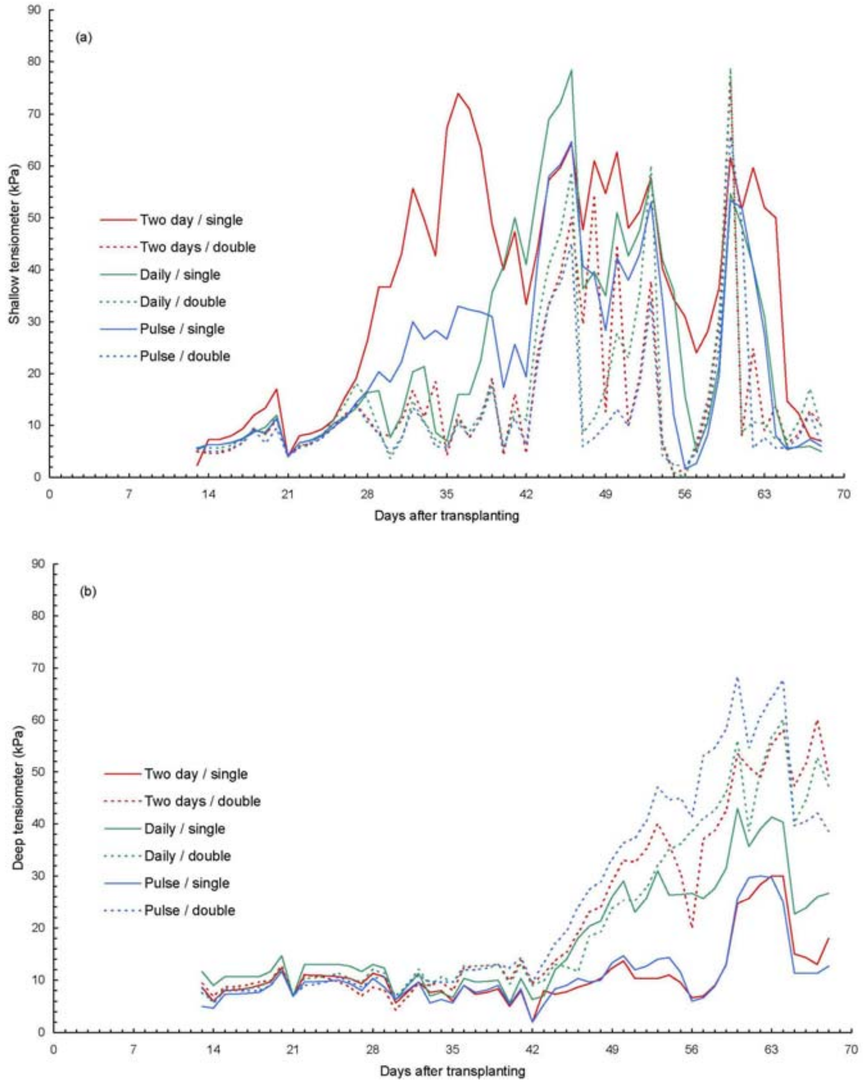

Figure 2. Daily soil water tensions from tensiometers installed (a) 15 cm and (b) 60 cm below the surface, adjacent to broccoli crop rows. Treatments are from broccoli beds with single or double drip lines per bed, and irrigated every second day, every day, or pulse irrigated 4 times per day.

From 4 weeks after transplanting until harvest, the single line treatments received appreciably more irrigation per application, than their double line counterparts. As previously mentioned, this was to try and supply sufficient water laterally to the crop root zone. In order to test the benefit of pulsing, we reduced this irrigation supply difference between single and double drip lines in the pulsing treatments (Fig. 1b).

Viewing the cumulative water (irrigation plus rain) inputs for each of the treatments compared to cumulative pan evaporation (Fig. 3), there was obviously very little difference between any of the treatments with a single, central drip line. In this experiment, we applied 2.1-2.2 ML/ha for each of these single line treatments, whether irrigated every second day, daily, or pulsed 4 times per day.

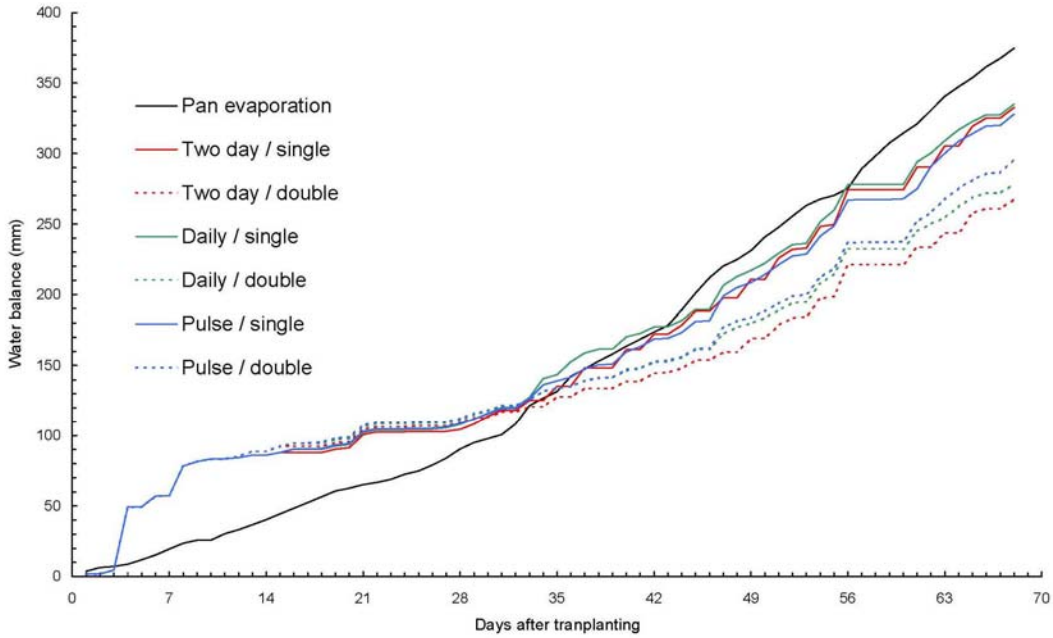

Figure 3. Cumulative water applied (rain plus irrigation) under 6 different broccoli irrigation treatments, with single or double drip lines per bed, and irrigated every second day, every day, or pulse irrigated 4 times per day. Cumulative water applied is compared with pan evaporation for the same period.

We applied considerably less water where there were irrigation lines adjacent to each crop row (dotted lines in Fig. 3). In these double line treatments, the pulsing treatment received 1.8 ML/ha of irrigation, the daily treatment 1.6 ML/ha, and the beds watered every second day the least irrigation (at 1.5 ML/ha). Because deep tensiometers in the pulsing treatment were reaching values exceeding 70 kPa late in the growing period, we increased irrigation on those plots to try and reduce that value slightly.

ECONOMIC CONSIDERATIONS

In this experiment, there were no broccoli outturn differences between the treatments, therefore all economic evaluations are based on the efficiency of input use; in this case irrigation water.

Compared to daily irrigation, pulsing several times per day did not seem to provide better lateral spread of irrigation water to the crop root zones (based on shallow tensiometer values in the single drip line treatments). Pulsing is a relatively complex irrigation procedure, requiring an automated irrigation system to avoid excessive labour. On our soils, it is unlikely that additional investment in pulsing-friendly drip tube and irrigation automation equipment could be justified solely on the basis of improved irrigation efficiency.

In a single line system, the biggest difficulty was rewetting the remote root zone once the beds had started to dry out. Delays in irrigation may exacerbate this problem, therefore the capacity to water every day, or at least every second day is probably required. Based on our experiment, if using a single line drip line per bed configuration, the lowest cost system that can manage regular irrigation would be most economic.

There could be substantial opportunities for using less irrigation water where drip lines are located close to crop rows. In our experiment, we found we could reduce irrigations in anticipation of rain, because we knew we could easily rewet the root zone with irrigation if required. We could also effectively encourage use of deeper soil water by applying less irrigation, yet still maintain low surface soil water tension values. Although not measured in our experiment, salt pushed to the margins of the wetted area would be displaced from the crop root zone, rather than toward it. In our experiment, we used on average 0.5 ML/ha less irrigation water in the treatments with 2 drip lines per bed, compared to those with one drip line per bed. This was a water saving of 25%.

However, there are significantly increased material, installation, maintenance and disposal costs associated with double the number of drip lines per hectare! In our experiment, the only material benefit from this marked increase in irrigation investment was the reduced water use, as there was no crop performance benefit. At this time we are uncertain how to cost the 'ease of management' benefit. In a situation where availability of irrigation water is not limiting production, it is highly unlikely that the savings in water cost (even at $300-400/ML) would justify the increased investment in drip infrastructure required by two drip lines per bed. However, the situation changes when water IS a limiting resource (Henderson 2003; Hickey *et al.* 2006). In that situation, water saved can be used to grow additional hectares of profitable crop, so although the $/ha return may be lower, the increased production area more than compensates. The authors envisage a more comprehensive economic analysis of this experiment will be presented at a later date.

CONCLUSIONS

- Excellent broccoli yields are achievable with either a central drip line for every 2 rows of broccoli, or with a drip line adjacent to every broccoli row.
- Managing soil water conditions in the crop root zone is much easier with a drip line adjacent to every broccoli row, compared to a single, central drip line.
- A bed configuration with a drip line adjacent to every broccoli row may reduce irrigation requirement by 25%, compared to a configuration with a single, central drip line.
- Additional investment installing and maintaining two drip lines per bed, compared to a single, central line, will probably only be cost effective in situations where availability of irrigation water is limiting the grower's production area.
- On clay loam soils, there appears to be little current benefit investing in infrastructure to pulse irrigate vegetable crops (such as broccoli) several times per day.

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