Grower Summary

TF 198

Developing water- and fertiliser-saving strategies to improve fruit quality and sustainability of irrigated high-intensity, modern and traditional pear production

Final 2013

Disclaimer

The results and conclusions in this report may be based on an investigation conducted over one year. Therefore, care must be taken with the interpretation of the results.

Use of pesticides

Only officially approved pesticides may be used in the UK. Approvals are normally granted only in relation to individual products and for specified uses. It is an offence to use non-approved products or to use approved products in a manner that does not comply with the statutory conditions of use, except where the crop or situation is the subject of an off-label extension of use.

Before using all pesticides check the approval status and conditions of use.

Read the label before use: use pesticides safely.

Further information

If you would like a copy of the full report, please email the HDC office (hdc@hdc.ahdb.org.uk), quoting your HDC number, alternatively contact the HDC at the address below.

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Project Number:	TF 198
Project Title:	Developing water- and fertiliser-saving strategies to improve fruit quality and sustainability of irrigated high-intensity, modern and traditional pear production
Project Leader:	Dr Mark Else
Contractor:	East Malling Research
Industry Representative:	Mark Holden, Adrian Scripps Ltd
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Headline

Irrigation Test Regimes applied in the Concept Pear Orchard at EMR delivered water savings of between 62 and 85%, compared to the commercial controls and class 1 yields and fruit quality were maintained or improved.

Background and expected deliverables

Irrigation is essential for the successful establishment and continued productivity of high-intensity tree fruit growing systems. Modern and traditional orchards also rely increasingly on irrigation to deliver the yields and quality needed for a profitable business. More efficient use of inputs, including labour, water and fertilisers, is vital to the future success of the industry. Seventy six per cent of tree fruit growers farm in areas where water resources have already been classified by the Environment Agency (EA) as under increasing stress and abstraction rates in these areas are currently unsustainable. Recent droughts, particularly affecting the southeast, east and midlands regions (Figure 1), have highlighted the need for growers to use water (and fertilisers) more efficiently.

Figure 1 Assessment of drought risk across England and Wales for 2012. Source: Environment Agency

Projected increases in agricultural water demand in the 2050s in England and Wales range from 25% to 180% of current demand (EA, 2008). One useful indicator of aridity that is widely used is the potential soil moisture deficit (PSMD), which represents the balance between rainfall and potential crop water use over the year. It is estimated that in the southeast the average annual maximum PSMDs that currently occur every five years will occur every two years by 2080 and deficits that currently occur every 15 years will occur every five years by

2080. Therefore, there will be an increasing reliance on irrigation to ensure profitable tree fruit production.

Trickle/drip irrigators have so far been exempt from legislation designed to safeguard resources and limit damage to the environment (e.g. Water Framework Directive 2000, Water Act 2003). However, Defra and the Welsh Government are working with the Environment Agency and Ofwat on a project to reform the water abstraction licensing system (http://www.defra.gov.uk/abstraction-reform/). It is envisaged that all drip irrigators will require an abstraction licence in future and growers must be able to demonstrate an efficient use of available water before time-limited abstraction licences are renewed.

If tree fruit growers are to maintain or increase yields against a backdrop of increasing summer temperatures, dwindling water supplies, and governmental demands for greater environmental protection, new production methods that improve water and nutrient use efficiency and utilise ‘best practice’ are needed. However, there are few guidelines for growers on how best to schedule irrigation, and matching demand with supply can be difficult in changeable summer weather and at different stages of crop development. The aim of TF 198 was to develop irrigation scheduling regimes for intensive pear orchards that optimise water and nutrient inputs and minimise run-through past the rooting zone, without reducing Class 1 yields or quality.

Current best practice irrigation recommendations for Conference pear are to maintain soil matric potential within the rooting zone between field capacity (approximately -10 kPa) and -30 kPa during flowering and for up to six weeks after petal fall. Soil is then allowed to dry to -60 kPa between irrigation events until early July before irrigation is withheld to encourage the cessation of extension growth and set of the terminal bud. During the latter half of July and during August, irrigation should then be scheduled to maintain soil matric potenntial between -10 and -25 kPa. These guidelines were developed overseas and, although they provide a useful starting point, new guidelines are needed for use by UK tree fruit growers to ensure that high yields of quality fruit with good shelf-life potential can be produced in an environmentally sustainable way. This is especially important for the UK tree fruit industry, since the major areas of production are in regions where pressure on limited water supplies is increasing. The scientific underpinning work needed to develop improved irrigation best practice guidelines is being carried out in this project. All experiments were carried out in the Chingford’s Concept Pear Orchard (CPO) at EMR.

Expected deliverables are:

- Irrigation guidelines to optimise water use efficiency in modern and high-intensity growing systems on a range of soil types used for fruit growing in the UK.

- Improved understanding of how to manage irrigation to set the terminal bud without affecting yields or quality.
- Increased awareness of the effects of scheduled versus unscheduled irrigation on canopy growth and fruit quality.
- Improved sustainability of irrigated pear production.
- Demonstrable compliance with legislation (Water Framework Directive, The Water Act, The Nitrate Directive).
- Delivery of research needed to develop deficit irrigation regimes to control shoot extension and improve fruit quality and storage potential.

Summary of the project and main conclusions

In this project, Irrigation Test Regimes (ITRs) were developed for each of the four growing systems in the CPO to try to optimise water use efficiency (WUE) without reducing Class 1 yields or quality. To optimise WUE, the frequency and duration of irrigation events must be managed carefully to avoid excessive irrigation inputs and to limit run-through of water and nutrients past the rooting zone. In order to achieve this, information on changes in soil water availability and soil moisture content at different depths within the rooting zone throughout the season is needed. In this project, Decagon MPS1 probes and Decagon 10HS probes (Figure 2) were used to measure soil water availability and soil moisture content, respectively. Additional data on soil moisture content was provided by Sentek 'EnviroScan' multi-depth capacitance probes.

Figure 2. Decagon MPS1 probes and 10HS probes used to measure soil water availability and soil moisture content in the concept pear orchard at EMR

Experimental design

Four experiments were set up in the Concept Pear Orchard (CPO), one for each of the growing systems, with two irrigation treatments per experiment. The two irrigation treatments were:

- Commercial Regime (CR), in which the frequency and duration of irrigation events was decided by Graham Caspell, EML's farm manager;
- Irrigation Test Regime (ITR), in which irrigation was scheduled once soil water availability reached a pre-determined value (soil matric potential - see below).

Within each growing system, three central rows each containing 28 trees were selected for inclusion in the experiment. Each row was an experimental block. Half of the trees within each block received the CR and half the ITR. The ITR was imposed by installing a separate irrigation line to 14 trees in the middle of each of the three rows and irrigation to these plots was controlled using Galcon irrigation controllers in each of the four growing systems. To the north and south of the 14 ITR trees, seven trees receiving the CR were included in the block. Within each experimental block, two CC and two ITR trees were selected on which all physiological and fruit yield/quality measurements were conducted; there were six replicate trees per treatment in each experiment.

Scientific approach

The approach used in this project was to impose temporary and gradual soil drying so that the soil matric potential (water availability) within the rooting zone at which tree physiology is first affected could be identified. This information can then be used to set the lower irrigation set point for each growing system. Since the aim of this work was to develop a 'low-risk' strategy for commercial growers, the lower irrigation set point was set 70 kPa above the value (soil matric potentials are negative values) at which physiological responses were first detected. Additional Decagon 10HS probes and multi-depth capacitance probes that measure volumetric soil moisture content were also inserted within and below the rooting zone to help to inform the development of the ITRs.

Irrigation to the commercial trees

The frequency and duration of irrigation events under the CR (and the majority of the CPO) were decided by Mr Graham Caspell (EML's farm manager) with advice from Mr Henk Nooteboom (Verbeek Boomkwekerijen B.V.). Irrigation was applied for 30 min daily *via* 1.6 L h^{-1} emitters spaced 50 cm apart from white bud (13 April 2012) until 11 August 2012, when irrigation was withheld temporarily to terminate extension growth and encourage the terminal bud to set. Irrigation was then applied for 1 h each day from 21 August. On 30 August, irrigation time increased by 30 min until harvest on 16 September 2012 to avoid drought stress. After harvest, all trees were un-irrigated throughout autumn and winter 2012-2013.

Irrigation Test Regimes

Irrigation was withheld from the ITR experimental blocks from 8 July 2012 until the average soil matric potential measured at 20 and 40 cm depth within the rooting zone reached -190 kPa. The frequent rainfall over the summer meant that the soil matric potential remained near to field capacity (-11 kPa) until 23 June when the soil beneath the ITR trees began to dry. The soil matric potential fell to -120 kPa at the beginning of July, when prolonged heavy rainfall returned the soil to field capacity. The soil began to dry down again in mid-July and reached the target of -190 kPa on 2, 3, 4 and 13 August 2012 for the Traditional, Central leader, U -system and V-system respectively. Then, irrigation was reinstated to the ITR treatments; 2 h of irrigation was sufficient to raise the soil in the rooting zone to field capacity without overly wetting the soil. The target set point of -120 kPa was considerably lower than the -70 kPa current 'best practice' value for this stage of development and was expected to deliver significant water savings compared to current 'best practice'. Irrigation was then applied throughout July and August once the lower irrigation set point was reached (Figure 3). The duration of each subsequent irrigation event was adjusted to ensure that the soil in the rooting zone was returned to field capacity but that run-through of water and fertilisers past the rooting zone was minimised.

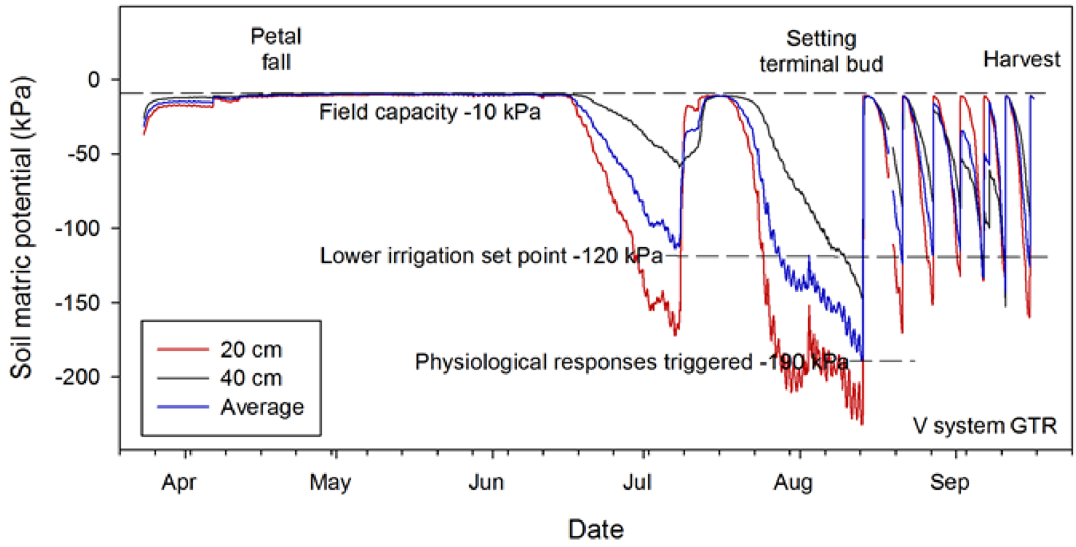

Figure 3. Changes in average soil matric potential (kPa) in the rooting zone of four representative trees under the irrigation test regime in the V-system. Seven irrigation events applied between 13 August and 15 September 2012.

Effects of the irrigation regimes on fruit growth and yields

Fruit diameter and height were unaffected by irrigation regime in all the four systems (Figure 4). Estimates of increases in fruit volume were used to calculate daily fruit expansion rates and these were also unaffected by irrigation regime.

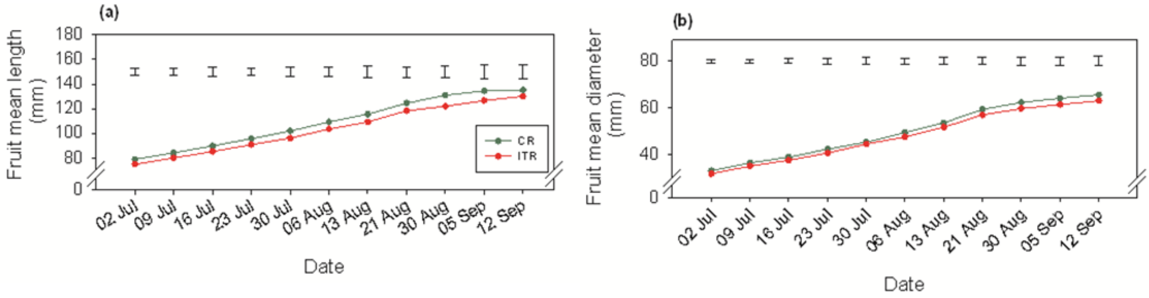

Figure 4. Cumulative fruit diameter (a) and height (b) over the 2012 season under the commercial (CR) and the irrigation test regime (ITR) in the V-system. Vertical bars are LSD values at $p<0.05$; there were no statistical significant differences between the irrigation treatments.

Fruit yields and size at harvest

Fruit was harvested from the orchard on 16 September 2012. In each growing system, fruit from the 12 trees on which physiological and fruit growth measurements had been recorded were picked into individual crates, which were then graded into three classes, Class 1 (>50 mm diameter), Class 2 (45-50 mm diameter) and waste (fruit that were <45 mm diameter, misshapen, damaged, where rough russet was present, or deemed to be nutrient deficient, scab infected etc.). The number and fresh weight of fruit in each of these classes were recorded, and the reason for classifying individual fruit as waste was noted.

The yield and number of Class 1 fruit from each tree was not significantly different between those grown under the two irrigation regimes (Figure 5a). There were no significant differences in Class 2 yields between the ITR and CR in any growing system (Figure 5b). The mass of waste fruit (due to small size, insect damage, misshape, rots etc.) ranged between 1.6 and 3.1 kg. The average weight of individual Class 1 and Class 2 fruit at harvest did not differ significantly between irrigation regimes within a growing system (Figure 6 a and b); individual fruit weight was the lowest in the Traditional system at 180 g and highest in the V-system at 220 g. As anticipated, estimated fruit volumes at harvest mirrored the individual fruit weights noted above with the lowest volume (123 cm^3) in the Traditional system and the highest volume (143 cm^3) in the V-system.

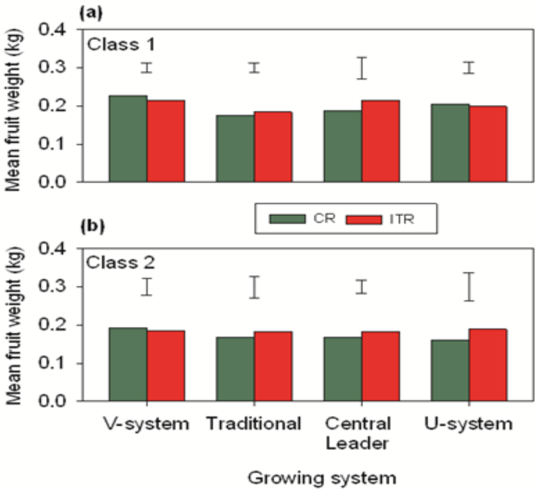

Figure 5. Average mass of Class 1 and Class 2 fruit per tree under the commercial (CR) and irrigation test (IRT) regimes for each growing system. Results are the average of six trees. Vertical bars are LSD values at *p*<0.05; there were no statistical significant differences between the irrigation treatments.

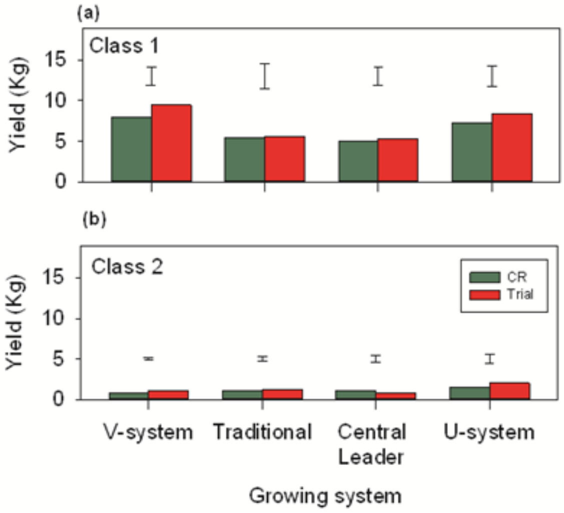

Figure 6. Yields of Class 1 and Class 2 fruit per tree under the commercial (CR) and irrigation test (IRT) regimes, for each growing system. Results are the average of six trees. Vertical bars are LSD values at *p*<0.05; there were no statistical significant differences between the irrigation treatments.

Table 1. Fruit firmness (maximum load) and soluble solids content (SSC), % smooth russet and colour parameters (L*, a* and b*) at harvest for fruit from the commercial regime (CR) and irrigation test regime (ITR) from each of the four growing systems. Values presented are the averages of 18 fruit, three from each of six replicate trees. LSD's are at $p<0.05$, SED=8.

Growing system	Irrigation regime	Firmness (N)	SSc (% Brix)	Russet (%)	Colour parameter		
					L*	a*	c*
V-system	CR	61.4	14.5	60.6	52.4	-5.3	28.7
	ITR	61.6	14.4	62.2	52.6	-5.6	29.3
	F. prob.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	LSD	1.92	0.98	14.5	1.7	2.2	1.8
Traditional	CR	64.1	14.0	60.1	51.2	-5.7	27.3
	ITR	61.9	14.0	63.3	52.2	-5.6	28.4
	F. prob.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	LSD	9.29	0.70	17.3	1.6	3.1	2.4
Central Leader	CR	61.7	14.6	68.2	51.9	-5.3	28.1
	ITR	61.5	14.9	55.8	50.6	-5.0	27.0
	F. prob.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	LSD	3.29	0.86	15.6	1.7	1.9	1.9
U-system	CR	63.7	14.1	54.3	50.9	-6.1	27.2
	ITR	62.7	13.8	55.0	51.0	-5.2	26.5
	F. prob.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	LSD	2.19	0.75	18.5	1.2	2.0	1.3

Fruit quality components at harvest

There were no significant differences between irrigation treatments in values of firmness, SSC (% Brix), percentage smooth russet or the colour parameters of fruit harvested from any of the four growing systems (Table 1). A relatively high degree of russeting was noted due to the wet conditions in 2012.

Irrigation volumes applied in the two regimes

Although irrigation was applied daily to all trees from mid April 2012, the ITRs were first applied on 8 July 2012 and so the number of hours of irrigation and the resulting volumes of water applied to the ITRs from 8 July to 16 September 2012 in each of the growing systems was calculated (Table 2). In the CR irrigation was applied for 20 min daily from 1 July till 11 August 2012 before being turned off to trigger the setting of the terminal buds. Between 21 and 30 August 2012 irrigation was applied for 60 min each day, after which the daily irrigation duration was increased to 90 min until harvest on 16 September 2012. Assuming that two 1.6 L h^{-1} emitters spaced 50 cm apart effectively irrigated each tree, the total volume of water applied to each tree under the CR and ITR in the four different growing systems was calculated (Table 2). Water savings of between 64 and 77% were achieved under the ITRs compared to the CRs. The volume of water applied to the four growing systems under the ITRs also varied; 45 L per tree was applied to the V-system whilst 70 L per tree was applied to the CL system (Table 2). Since trees were fertigated at each irrigation event until 30 August 2012, the total amounts of the macro and micro nutrients applied were reduced in proportion to the irrigation volume. Consequently, fertiliser savings of between 62 and 85% were achieved using the ITR. Despite these reduced inputs no visual deficiencies were observed.

Table 2. Total irrigation (h) and calculated volumes of water (L) applied to the commercial regime (CR) and the irrigation test regime (ITR) in each of the four growing systems between 8 June and 16 September 2012.

Growing system	Irrigation regime	Irrigation applied		% of savings	
		h	L	Water	Fertigation
V-system	CR	60	192		
	ITR	14	45	77	85
Traditional	CR	60	192		
	ITR	20	64	67	62
Central Leader	CR	60	192		
	ITR	22	70	64	70
U-system	CR	60	192		
	ITR	20	64	67	70

Water productivity values were also calculated for each irrigation regime and for each system (Table 3). The volume of water applied was recorded when ITRs were first applied. The water productivity (WP) values indicated the potential of using irrigation scheduling to reduce the volume of water used to produce 1 kg of Class 1 fruit. A lower WP value indicates a higher irrigation water use efficiency.

Table 3. Water productivity values achieved under each irrigation regime for the four growing systems

Growing system	Irrigation regime	
	CR	ITR
V-system	24	5
Traditional	35	11
Central Leader	38	13
U-system	27	8

Conclusions

- The soil matric potential at which physiological responses to drying soil were first triggered was identified for trees under the ITR in the CL system; leaf elongation rate was significantly slowed at a soil matric potential of -190 kPa.
- A ‘low risk’ irrigation strategy was developed to schedule irrigation in the ITRs in each of the growing systems; irrigation was applied once the lower irrigation set point of -120 kPa was reached.
- Rates of soil drying under the ITRs differed in the four growing systems and this dictated the frequency of irrigation events and the volumes of water applied.
- Tree and fruit physiology were not affected under the ITRs in 2011 and 2012.
- Class 1 yields and components of fruit quality at harvest were not affected by the ITRs in each growing season.
- Water savings of between 48 and 77% were achieved under the ITRs compared to the CRs over the two seasons.
- In 2011 yields of Class 1 fruit were highest under the ITR in the U-system (9.3 kg per tree) and lowest under the CR in the Traditional system (3.7 kg per tree). In 2012 yields of Class 1 fruit were highest under the ITR in the V-system (9.5 kg per tree) and lowest under the CR in the Central Leader system (5.0 kg per tree).
- Average individual fruit mass (and volume) were greatest in the V-system (220 g) and lowest in the Traditional system (180 g).
- The higher yields in 2011 under the ITR, compared to the CR, in the U-system were unlikely to be due to the irrigation treatments.
- The scientifically-derived irrigation scheduling guidelines being developed in this project will help growers to optimise WUE and environmental sustainability of high intensity ‘Conference’ pear production.

Knowledge Exchange and Technology Transfer activities

- The project aims, objectives and results were presented to BIFGA during a visit to EMR, 25 April 2012.
- Demonstration of TF 198 in CPO to AG Thames, 21 May 2012, EMR.
- Demonstration of TF 198 in CPO to Rupert Kruger (Thames Water) and Sarah Ward (EM Trustee), 13 June 2012, EMR.
- The project aims, objectives and results were presented at the Waitrose Top Fruit Grower Conference 26 June 2012, Waitrose Aylesford.
- Demonstration of TF 198 in CPO to Kent Regional Water Summit, 26 June 2013, EMR.

- Discussion of EMR water research and demonstration of TF 198 in CPO with David Cooper, Jemilah Bailey et al. (Defra), 10 July 2012, EMR.
- Demonstration of TF 198 in CPO to Waitrose Board members and Technical staff, 31 July 2013, EMR.
- Demonstration of TF 198 in CPO to Ziv Charit, Netafim, 4 September 2013, EMR.
- Demonstration of TF 198 in CPO to Alan Turner, KCC, 25 September 2013, EMR.
- Demonstration of TF 198 to Kent Rural Business Group, 26 October 2012, EMR.
- The project aims, objectives and results were presented at the Kent Water Summit: Water security for Farmers and Growers, 12 November 2012, EMR.
- The project aims, objectives and results were presented during a visit to FAST Ltd 30 January 2013, Faversham, Kent.

Overall Project results

- A new irrigation scheduling strategy has been developed for pear production that reduces losses of water and fertiliser past the rooting zone.
- Water savings up to 77% were delivered without reducing Class 1 yield using the irrigation scheduling strategy. Since nutrients were added at each irrigation event, significant fertiliser savings have also been achieved in the CPO at EMR.
- The lower fertiliser inputs did not cause any visual nutrient deficiencies.
- New fertigation regimes need to be developed to optimise tree nutrition under water-saving irrigation strategies.

Financial benefits

The true economic value of water used for the irrigation of high-intensity tree fruit orchards is difficult to quantify, as are the financial benefits associated with water savings (unless mains water is used as a source of irrigation water). A full cost/benefit analysis would require three irrigation treatments to be set up at EMR (or elsewhere):

1) A commercial control irrigated using current ‘best practice;
2) The ITR developed in this project;
3) No irrigation applied throughout the season.

Differences in Class 1 yields obtained under the three regimes could then be used to estimate the gain or loss of revenue, which could be balanced against the expenditure needed to implement the different irrigation strategies. This information will be obtained for apple and sweet cherry in a new HDC-funded project (TF 210). The potential to target fertilisers more efficiently to the rooting zone under the ITRs may be of more immediate interest to some growers since there is the potential to reduce both inputs and direct costs.

Action points for growers

- Consider installing probes to measure soil water availability or soil moisture content within the rooting zone to help develop effective irrigation scheduling strategies.
- Consider installing water meters to accurately record the volumes of water used to produce 1 tonne of Class 1 fruit.
- Consider monitoring water inputs and changes in soil water availability/content in just one block as this will help to improve awareness of the effectiveness of current irrigation strategies and will highlight opportunities for improvement.
- Consider using compost at planting and as a mulch thereafter to help improve soil water retention and limit evaporative losses from the soil surface.