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

Annual 2012

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 A. Else
Contractor:	East Malling Research
Industry Representative:	Mark Holden, Adrian Scripps Ltd
Report:	Annual Report 2012
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Previous report/(s):	None
Start Date:	1 April 2011
End Date:	31 March 2013
Project Cost:	£25,505

Headline

- Irrigation Test Regimes applied in the Concept Pear Orchard at EMR delivered water savings of between 48 and 72%, compared to the commercial controls.

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. However, 76% 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. At the time of writing (March 2012), the south east is already officially under drought and other major tree fruit growing regions are at high risk of drought in 2012 (Figure GS 1). Future legislation will require that drip/trickle irrigators demonstrate an efficient use of water and current EA concerns about the impact of horticulture on groundwater quality in the south east will focus attention on improving nutrient use efficiency in tree and soft fruit production.

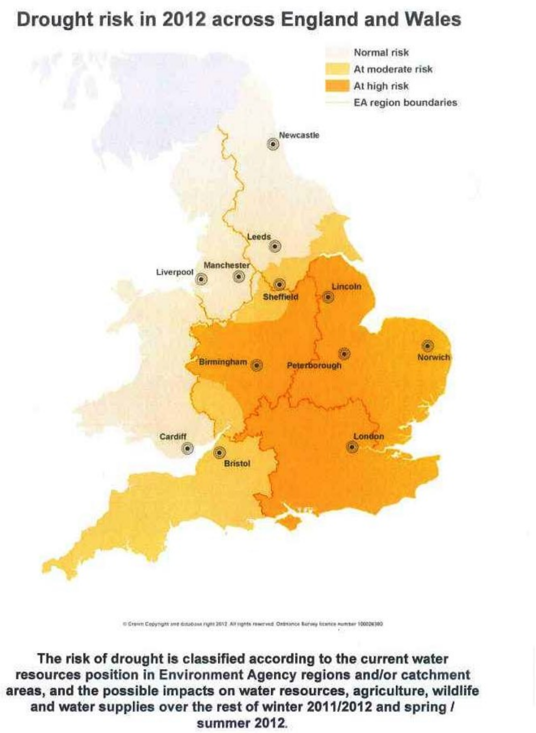

Figure GS 1. Assessment of drought risk across England and Wales for 2012. Source: the Environment Agency

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 type 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) are being 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 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 GS 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 GS 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 CPO, one for each of the growing systems, with two irrigation treatments per experiment. The two irrigation treatments were a Commercial Regime (CR) in which the frequency and duration of irrigation events was decided by Graham Caspell, EML's farm manager and an 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 6 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 20 min daily *via* 1.6 L h^{-1} emitters spaced 50 cm apart from 'white bud' (9 April 2011) until 22 July 2011 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 3 August until harvest on 31 August 2011. After harvest, all trees were un-irrigated throughout autumn and winter 2011-2012.

Identifying irrigation set points for the Irrigation Test Regimes

Irrigation was withheld from the ITR experimental blocks from 1 July 2011. Soil matric potential and volumetric soil moisture content declined steadily over this period in each of the growing systems and as expected for these relatively young trees, the soil at 20 cm dried more quickly than at 40 cm. Measurements of leaf stomatal conductance, extension rate, water potential and fruit diameter and length were carried out regularly throughout the drying period. The first indication that the trees within the ITRs were beginning to respond to drying soil was noted on the 15 July 2012 in the Central Leader (CL) system when leaf extension growth began to slow under the ITR, compared to that under the CR. On this day, the average soil matric potential measured at 20 and 40 cm depth within the rooting zone was -190 kPa. Irrigation was reinstated to the ITR in the CL system on 15 July 2012; 2 h of irrigation was sufficient to raise the soil in the rooting zone to field capacity without overly wetting the soil.

Statistically significant differences in tree and fruit responses to drying soil under the ITR in the other three growing systems were not detected during July 2011 although there were indications that leaf physiology was beginning to be affected under the ITRs. Due to the impending harvest date, and the need to develop a 'low risk' irrigation scheduling strategy in the first year of the project, the decision was taken by the Project Leader to use the same lower irrigation set point determined for the CL system, rather than continuing to withhold water from trees in the ITR in the V-, Traditional and U-systems. Also, 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'. Thus, the initial irrigation was applied once the average soil matric potential measured at 20 and 40 cm depth reached -190 kPa in each growing system. This occurred on 15 July, 30 July and 01 August 2011 for the Traditional, V-system and U-system respectively.

Implementing the Irrigation Test Regimes

Following the identification of the soil matric potential at which tree physiology was first affected, the lower irrigation set point for each ITR was set at 70 kPa above this value (-120 kPa). Irrigation was then applied throughout July and August once the lower irrigation set point was reached (Figure GS 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. Following harvest on 31 August 2011, irrigation to the ITRs was turned off to replicate the situation in the CR and the commercial orchard.

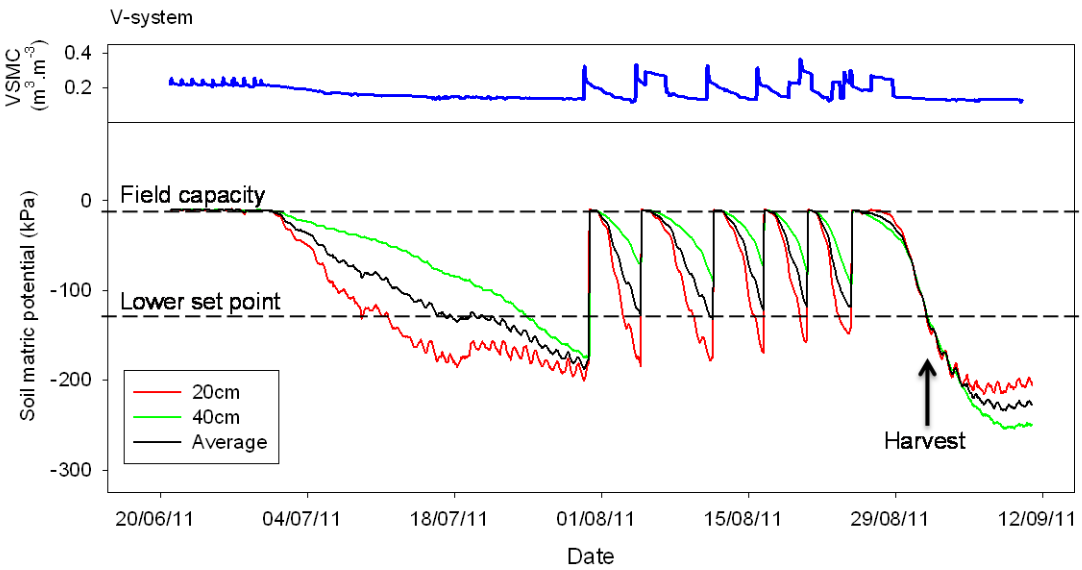

Figure GS 3. Changes in average soil matric potential (kPa) and volumetric soil moisture content (m^3 m^{-3}) in the rooting zone of four representative trees under the irrigation test regime (ITR) in the V-system. Six irrigation events were applied between 30 July and 27 August 2011.

Effects of the irrigation regimes on fruit growth

Fruit diameter and height were unaffected by irrigation regime in the V-, Traditional and U-systems (e.g. Figure GS 4). Average fruit length was significantly greater in the ITR compared to the CR in the CL system throughout the experiment but this difference was present before the ITR was imposed. Estimates of increases in fruit volume were used to calculate daily fruit expansion rates and these were unaffected by irrigation regime in the Traditional and U-systems. For both the V- and CL systems, fruit expansion rates were either similar or significantly higher under the ITR than in the CR.

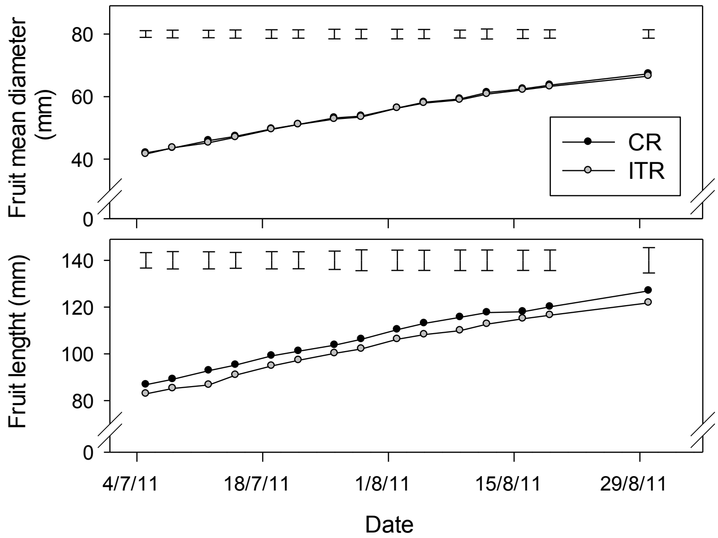

Figure GS 4. Increases in fruit diameter and height over the 2011 season under the commercial regime (CR) and the irrigation test regime (ITR) in the U-system. Vertical bars are LSD values at *p*<0.05; there were no statistically significant differences between the irrigation treatments.

Fruit harvest

Fruit was harvested from the orchard on 31 August 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 (>65 mm diameter), Class 2 (<65 mm diameter) and waste (fruit that were very small, misshapen, damaged, where rough russetting was present, or deemed to be nutrient deficient). 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.

Fruit yields and size at harvest

The yield and number of Class 1 fruit from each tree was not significantly different between those grown under the two irrigation regimes for the V-, Traditional or the CL systems (Figure GS 5). However, in the U-system, trees under the ITR produced significantly greater Class 1 yields than trees under the CR (9.3 and 7.0 kg per tree, respectively). This was due to an increase in the number of Class 1 fruit produced by trees under the ITR, 49 per tree as opposed to 35 per tree for those in the CR.

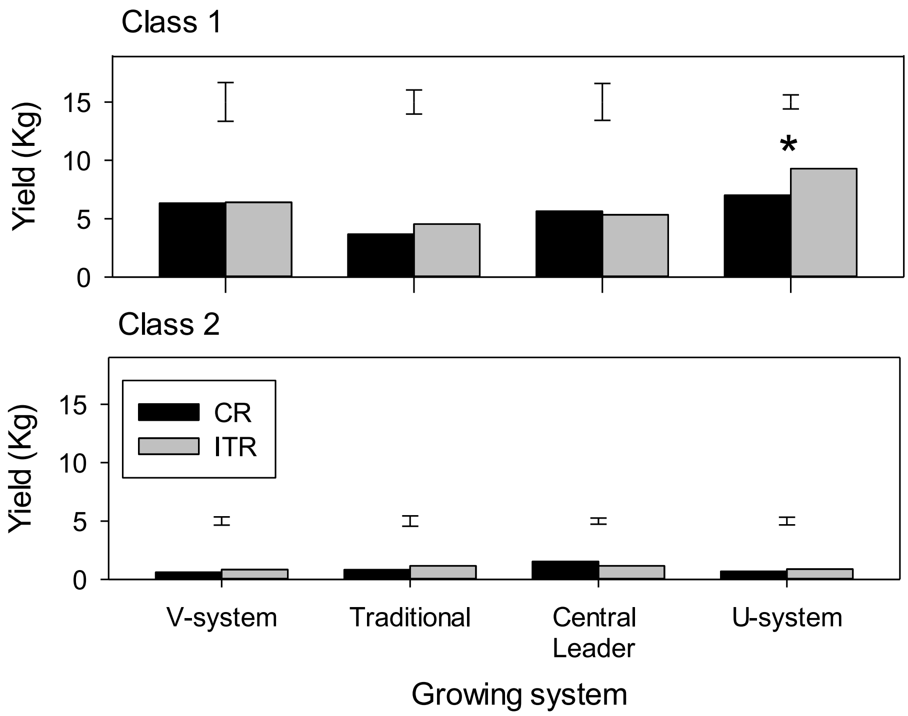

Figure GS 5. Yields of Class 1 and Class 2 fruit per tree under the commercial regime (CR) and irrigation test regime (ITR), for each growing system. Results are the average of 6 trees. Vertical bars are LSD values at $p<0.05$. * indicate statistically significant differences between the

There were no significant differences in Class 2 yields between the ITR and CR in any growing system (Figure GS 5). The mass of waste fruit (due to small size, insect damage, misshape, rots *etc.*) was generally below 0.6 kg per tree, except from the CR in the Traditional system where waste was 1.2 kg (this was due to a high number [92] of small fruit from one individual tree). 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 GS 6); individual fruit weight in the Traditional system was the lowest at 172 g and the highest in the V-system at 226 g. As anticipated, estimated fruit volumes at harvest mirrored the individual fruit weights noted above with the lowest volume (98 cm^3) in the Traditional system and the highest volume (165 cm^3) in the V-system.

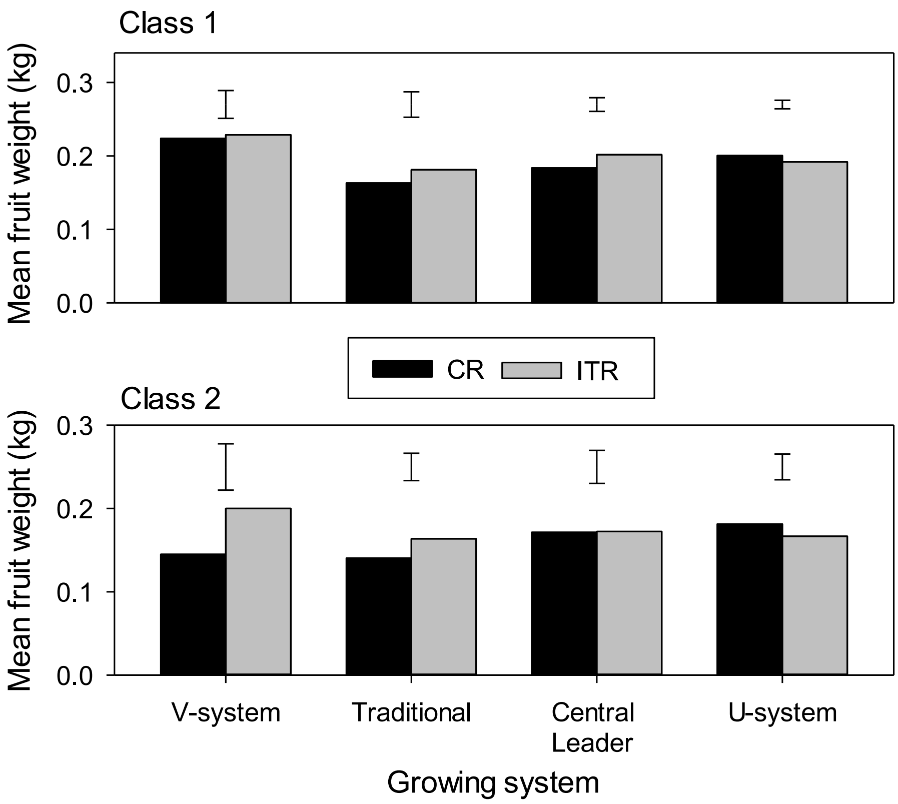

Figure GS 6. Average mass of Class 1 and Class 2 fruit from trees under the commercial regime (CR) and irrigation test regime (ITR), for each growing system. Results are the average of 6 trees. Vertical bars are LSD values at p<0.05; there were no statistically significant differences between the treatments.

Fruit quality components at harvest

There were no significant differences between irrigation treatments in values of firmness, SSC (% Brix) or percent smooth russetting of fruit harvested from any of the four growing systems (Table GS 1). In general, none of the colour parameters measured at harvest were affected by irrigation regime, except for the a* parameter (a measure of 'redness) which was significantly reduced (F. probability = 0.049) in fruit harvested from the ITR in the V-system (Table GS1).

Table GS 1. Fruit firmness (maximum load) and soluble solids content (SSC), % smooth russetting and colour parameters (L*, a* and b*) at harvest for fruit from the commercial regime (CR) and irrigation test regimes (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. Statistically significant differences are highlighted in bold text.

Growing system	**Irrigation regime**	**Firmness (N)**	**SSc (% Brix)**	**Russetting (%)**	**Colour parameter**		
					L*	***a****	***c****
V-system	CR	61.6	13.2	9.2	53.0	-15.1	36.7
	ITR	61.2	13.1	8.2	55.1	-16.1	38.1
	F. prob.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	LSD	2.9	0.80	10.92	2.54	2.46	1.70
Traditional	CR	59.3	13.3	15.8	53.3	-14.5	36.4
	ITR	58.4	14.0	23.3	53.6	**-12.8**	36.4
	F. prob.	n.s.	n.s.	n.s.	n.s.	**0.049**	n.s.
	LSD	4.69	1.47	19.1	2.12	1.75	1.61
Central Leader	CR	60.9	12.9	16.1	53.4	-15.2	35.8
	ITR	58.7	13.4	22.3	53.1	-14.5	36.5
	F. prob.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	LSD	3.92	1.01	21.0	2.62	2.34	1.25
U-system	CR	59.8	12.7	14.1	54.4	-15.9	36.8
	ITR	57.3	12.9	9.7	54.6	-15.4	36.6
	F. prob.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	LSD	3.28	0.96	13.7	13	2.47	2.11

Irrigation volumes applied in the two regimes

Although irrigation was applied daily to all trees from the beginning of April 2011, the ITRs were first applied on 1 July and so the number of hours of irrigation and the resulting volumes of water applied to the ITRs from 1 July to 31 August 2011 in each of the growing systems was calculated (Table GS 2). In the CR, irrigation was applied for 20 min daily from 1 – 22 July 2011 before being turned off until 3 August 2011 to trigger the setting of the terminal buds. Irrigation was then applied for 60 min every day until harvest on 31 August 2011. 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 GS 2). Water savings of between 48 and 72% were achieved under the ITRs, compared to the CRs. The volume of water applied to the four growing systems under the ITRs also varied; 32 L per tree was applied to the Traditional system whilst 59 L per tree was applied to the CL system (Table GS 2).

Table GC 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 1 July and 31 August 2011.

Growing system	Irrigation regime	Irrigation applied		% Saving in ITR
		h	***L***	
V-system	CR	35.3	113	
	ITR	12.3	39	65
Traditional	CR	35.3	113	
	ITR	10	32	72
Central Leader	CR	35.3	113	
	ITR	18.3	59	48
U-system	CR	35.3	113	
	ITR	16	51	55

Main 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.
- Class 1 yields and components of fruit quality at harvest were not affected by the ITRs.
- Water savings of between 48 and 72% were achieved under the ITRs, compared to the CRs.
- 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).
- Average individual fruit mass (and volume) were greatest in the V-system (266 g) and lowest in the Traditional system (172 g).
- The higher yields 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

- Presentation of the experiments and discussion of results in the CPO to the West Sussex Fruit Group, 12 July, EMR.
- The project's aims and objectives and results to date were presented in the CPO to members of HortLINK 0194 Project Consortium, 14 July 2011.
- The experiments in the CPO were included in the Farm Tours during Fruit Focus 2011, 20 July, EMR.
- The project's aims and objectives and results to date were presented in the CPO to members of the International Fruit Tree Association, 24 July, EMR.
- Presentation of the experiments and discussion of results in the CPO to a delegation from the Chinese Government during a visit to EMR, 25 August, EMR.
- The project's aims and objectives were included in an article written for Horticulture Week by Professor Geoff Dixon, Dec 2011.
- The project aims, objectives and results from the first year work were presented at the Sainsbury's 'Profitable Pear Production in the UK' day, February 2012, EMR.
- Discussion of the project aims, objectives and results to date during an interview for BBC Radio 4's Farming Today, 21 March 2012.
- Discussion of the project aims, objectives and results to date during an interview for BBC South East regional News, 21 March 2012.
- Article in the HDC's Tree Fruit Review, 2012.

Plans for 2012

- Four additional MPS1 sensors were installed under representative trees in the middle ITR block in each growing system on 23 March 2012. The average soil matric potential value from eight MPS1 sensors will be used to schedule irrigation throughout 2012. An additional 10HS probes has also been installed in the middle ITR block in each system.
- Two MPS1 probes and a 10HS probe were installed under representative trees in the middle CR block in each system. Changes in soil matric potential in the CRs will now be monitored continuously.
- Water meters will be installed into each of the ITR irrigation lines and connected to a GP1 data logger to record the volumes of irrigation water used throughout the season.
- Additional rain gauges have been installed under emitters in the CR and ITR blocks in the Traditional, CL and U-system to enable irrigation outputs to be monitored over the season.

- Irrigation to each ITR will be triggered automatically once the lower irrigation set point is reached using SM200 soil moisture probes and Delta-T GP1 data loggers connected to the Galcon irrigation controllers.
- Data on fruit size, fruit weight and the Archimedes' principle will be used to construct a regression equation that will enable non-destructive estimates of fruit volume to be made accurately. The increase in fruit volume over the season in the CRs and ITRs will be determined using this regression equation.

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 in the CPO 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. The potential to target fertilisers more efficiently to the rooting zone under the ITRs may be of more immediate interest to 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 record accurately the volumes of water used to produce 1 tonne of Class 1 fruit.
- Monitoring water inputs and changes in soil water availability/content in just one block 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.