



# Grower Summary

## **TF 210**

Deriving irrigation set points to improve water use efficiency, fruit quality and sustainability of irrigated high intensity apple and sweet cherry orchards

Final 2016

## **Disclaimer**

While the Agriculture and Horticulture Development Board seeks to ensure that the information contained within this document is accurate at the time of printing, no warranty is given in respect thereof and, to the maximum extent permitted by law the Agriculture and Horticulture Development Board accepts no liability for loss, damage or injury howsoever caused (including that caused by negligence) or suffered directly or indirectly in relation to information and opinions contained in or omitted from this document.

©Agriculture and Horticulture Development Board 2016. No part of this publication may be reproduced in any material form (including by photocopy or storage in any medium by electronic mean) or any copy or adaptation stored, published or distributed (by physical, electronic or other means) without prior permission in writing of the Agriculture and Horticulture Development Board, other than by reproduction in an unmodified form for the sole purpose of use as an information resource when the Agriculture and Horticulture Development Board or AHDB Horticulture is clearly acknowledged as the source, or in accordance with the provisions of the Copyright, Designs and Patents Act 1988. All rights reserved.

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 AHDB Horticulture office (hort.info.@ahdb.org.uk), quoting your AHDB Horticulture number, alternatively contact AHDB Horticulture at the address below.

AHDB Horticulture,  
AHDB  
Stoneleigh Park  
Kenilworth  
Warwickshire  
CV8 2TL

Tel – 0247 669 2051

AHDB Horticulture is a Division of the Agriculture and Horticulture Development Board.

<b>Project title:</b>	Deriving irrigation set points to improve water use efficiency, fruit quality and sustainability of irrigated high intensity apple and sweet cherry orchards
<b>Project number:</b>	TF 210
<b>Project leader:</b>	Dr Mark A. Else, East Malling Research
<b>Report:</b>	Final Report, March 2016. Revised 23 May 2016.
<b>Previous report:</b>	Annual Reports March 2014, April 2015
<b>Key staff:</b>	Mike Davies, Dr Eleftheria Stavridou, Clare Hopson, Helen Longbottom
<b>Location of project:</b>	East Malling Research
<b>Industry Representatives:</b>	Mark Holden (Adrian Scripps), Nigel Kitney (Old Grove Farm) and Will Dixon (AR Neaves & Sons)
<b>Date project commenced:</b>	1 April 2013
<b>Date project completed:</b>	31 March 2016

## **Grower Summary**

### **Headlines**

- It is not necessary to apply frequent irrigation events to maintain the soil near to field capacity to deliver good commercial yields in 'Gala/M.9' and 'Braeburn/M9'.
- Adopting the Alternate Wetting and Drying (AWD) irrigation regime with a lower set point of -200 kPa (matric potential averaged throughout the rooting zone) from 6 weeks after full bloom until harvest will optimise both on-farm water use efficiency and crop productivity in 'Gala/M.9' and 'Braeburn/M9'.
- In 'Merchant/Gisela5', mild soil drying during fruit growth Stage 1 will significantly reduce both yield and number of Class 1 fruit per tree
- Significant saving of water (and fertilisers) can be achieved without reducing Class 1 yields of 'Kordia/Gisela5' and 'Merchant/Gisela5' if AWD is used with lower irrigation set points of -60 and -200 kPa during Stages I-II, and III respectively.

### ***Background and expected deliverables***

The tree fruit sector is increasingly reliant on irrigation to deliver the fruit size and quality demanded by retailers and consumers. However, the move to more intensive growing systems and the impacts of climate change on evaporative demand and summer water availability mean that irrigation water needs to be used more efficiently. Under the Government's Abstraction Licence Reform programme, drip irrigators will no longer be exempt from abstraction licencing and when implementation of the new system begins in November 2016, drip irrigators will have to demonstrate an efficient use of irrigation water.

The challenge is to put in place measures that improve irrigation water productivity, especially in areas of water vulnerability, but also maintain or improve marketable yields and consistency of fruit quality at harvest and after removal from store. In Project TF 198, scientists at East Malling Research developed an alternate wetting and drying (AWD) irrigation regime for high-intensity pear production. Irrigation was applied at a pre-determined irrigation set point; this was informed by measuring the trees' responses to declining water availability throughout the cropping season. The duration of each irrigation event was adjusted to ensure that the soil throughout the rooting zone was returned to field capacity. The AWD approach delivered water savings of over 50%, compared to current commercial practice, and yields and quality of marketable fruit were maintained. AWD is now being tested on a commercial farm in a project funded by a major retailer and a leading tree fruit Producer Organisation. In this Project, a

similar approach has been used to identify, develop and test water-saving irrigation set points for apples (Gala/M.9, 'Braeburn/M9') and cherries ('Kordia/Gisela5' and 'Merchant/Gisela5').

### ***Summary of the project and main conclusions***

#### *Years 1 and 2*

- It is not necessary to apply frequent irrigation events to maintain the soil near to field capacity throughout the season to deliver good commercial yields in 'Gala/M9' and 'Braeburn/M9'. This approach will increase leaching of N and other nutrients past the rooting zone.
- Adopting AWD and using an irrigation set point of -200 kPa (matric potential averaged throughout the rooting zone) from six weeks after full bloom until harvest, will optimise both on-farm water use efficiency and crop productivity in 'Gala/M.9' and 'Braeburn/M9'. It is important that soil is returned to field capacity following each irrigation event.
- Soil should be maintained at or near to field capacity from anthesis until six weeks after full bloom to prevent potential detrimental effects of soil water deficits on marketable yields.
- In 'Kordia/Gisela5', average soil matric potentials fell to -65, -218, -581 and -900 kPa in the Deficit Irrigation (DI) treatments imposed at stages I, II, III and post-harvest, respectively. Rates of photosynthesis were similar irrespective of treatment and there were no significant treatment effects on 'Kordia' Class 1 yields, which ranged from 1.6 to 3.2 Kg per tree.
- In 'Merchant/Gisela5', average soil matric potentials fell to -115, -22, -332 and -925 kPa during the four DI treatments. The mild soil drying imposed during Stage 1 significantly reduced both yield (2 Kg vs 3 Kg) and number (172 vs 285) of Class 1 fruit per tree, compared to the CC treatment where soil was maintained around field capacity.

#### *Year 3*

To optimise irrigation water productivity when using AWD, the frequency and duration of irrigation events must be managed carefully to avoid run-through of water and nutrients past the rooting zone. 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 MPS2 sensors, which measure soil matric potential, and Decagon

10HS sensors, which measure soil volumetric moisture content, were used to provide this information.

Two experiments were conducted on the sweet cherry varieties 'Kordia/Gisela5' and 'Merchant/Gisela5':

- 1) The effects of soil moisture deficits during the flower initiation phase (the post-harvest treatment) in 2014 on yields and quality of 'Kordia' and 'Merchant' Class 1 fruit in the subsequent cropping year (2015).
- 2) In 2015, soil matric potential was maintained above -60 kPa during Stages I and II, then different irrigation set points were tested during Stage III in each cultivar, and treatment effects on Class 1 yields were compared to those under the Commercial Control (CC) regime.

### **Experiment 1**

In 2014, five treatments were applied; a CC treatment to maintain the average soil matric potential above -20 kPa throughout the season (well-watered, field capacity), and four DI treatments of different duration and intensity that were imposed during fruit growth stages I (cell division), II (pit hardening) and III (cell expansion), and postharvest during the flower initiation stage; at all other stages, soil was maintained near to field capacity (see TF 210 Annual Report 2015). The effects of these treatments on return bloom, marketable yield and quality in the subsequent cropping year (2015) was determined.

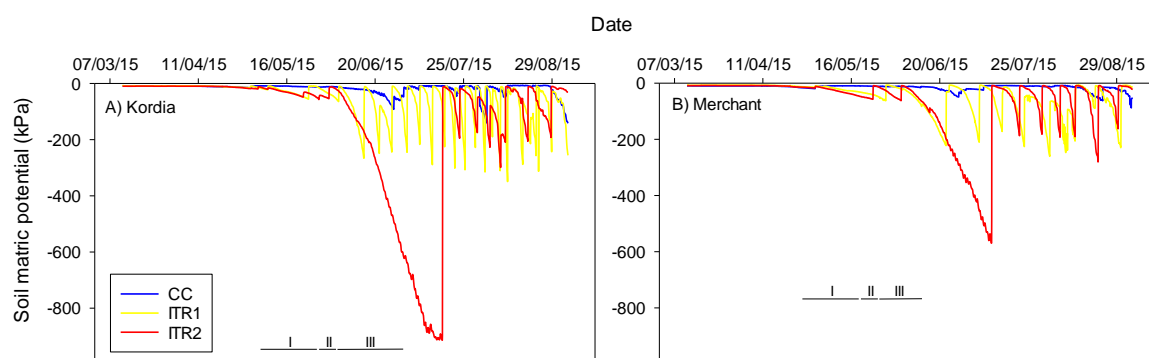
### **Results**

The DI treatments applied during the different growth stages in 2014 had no statistically significant effects on return bloom, fruit bud number, Class 1 yield or fruit quality in either variety in 2015. The most significant soil drying was imposed post-harvest in 2014 (ITR3) and published work reported that fruit yields and quality of 'New Star' could be reduced in the subsequent cropping year following post-harvest water stress applied to control vegetative vigour. However, Class 1 yields and individual fruit fresh weights of both 'Kordia/Gisela5' and 'Merchant/Gisela5' were unaffected by the ITR3 treatments applied in the previous season.

### *Experiment 2*

The aim was to test whether the irrigation set points derived in 2014 maintained fruit yields and quality whilst significantly reducing water inputs. In 2015, three irrigation treatments were imposed (Figure 1);

- 1) A well-watered commercial control (CC) where irrigation decisions were taken by EML's Farm Manager Mr Graham Caspell;
- 2) An Irrigation Test Regime 1 (ITR1) where soil matric potential was maintained above -60 kPa during Stages I and II, and above -200 kPa during Stage III and post-harvest;
- 3) An Irrigation Test Regime 2 (ITR2) where soil matric potential was maintained above -60 kPa during Stages I and II, and during Stage III and post-harvest, irrigation was withheld until leaf physiological responses were detected. Irrigation was then applied to return soil to field capacity and thereafter, irrigation was applied once the soil matric potential reached -200 kPa.



**Figure 1.** Changes in soil matric potential averaged over the top 60 cm of soil in each of the three irrigation treatments applied to A) 'Kordia/Gisela 5' and B) 'Merchant/Gisela 5' trees in 2015.

## Results

Leaf physiological responses were measured to assess whether trees were experiencing soil water deficit stress under the ITR1 and ITR2 treatments. On 17 July 2015 during the post-harvest period, midday stem water potentials of 'Kordia/Gisela5' trees under the ITR1 treatment measured at the irrigation set point of -200 kPa, were significantly reduced compared to CC values; however,  $P_n$  and  $g_s$  were unaffected by the ITR1 treatment on that date, indicating that trees were experiencing a mild but transient soil water deficit stress. In the ITR2 treatment, midday stem water potential was reduced significantly, compared to the CC treatment when measured on 29 June 2015, one day prior to harvest, but was not affected 4 days earlier. Photosynthesis was also reduced significantly in the ITR2 treatment during this time, when average soil  $\psi_m$  ranged from -430 to -599 kPa in the ITR2 treatment. Stomatal conductance was reduced significantly at an average soil  $\psi_m$  of -900 kPa which occurred during the post-harvest stage.

However, although trees in the ITR1 and ITR2 treatments showed signs of mild water deficit stress, Class 1 yields did not differ significantly between treatments, with yields of 6.7, 7.0 and 8.6 kg per tree from the CC, ITR1 and ITR2 treatments, respectively. Individual fruit weight was reduced significantly in the ITR1 (11.9 g) and ITR2 (11.8 g) treatments, when compared to the CC (12.6 g); there was no evidence that limited soil water availability in the ITR treatments limited fruit expansion and this effect was likely due to differences in crop load. There were no differences in fruit firmness or %BRIX between the treatments. Total water application to each tree was 1,622, 450 and 244 L for the CC, ITR1 and ITR2 trees respectively.

'Merchant/Gisela5' under the ITR1 treatment showed reduced midday stem water potentials on 14 July 2015, indicating that they were experiencing a mild water deficit stress at an average soil  $\psi_m$  of -200 kPa. In the ITR2 treatment, physiological responses were triggered at an average soil  $\psi_m$  between -475 and -550 kPa, but again, these responses occurred post-harvest. There were no significant treatment differences in Class 1 yields, which averaged 6.9, 5.9 and 5.7 kg per tree under the CC, ITR1 and ITR2 regimes respectively. Individual fruit weight was not significantly different between treatments with values of 11.0, 11.1 and 10.8 g for the CC, ITR1 and ITR2 treatments respectively. There were no differences in fruit firmness or % BRIX between the treatments. Total water application to each tree was 1,754, 209 and 188 L for the CC, ITR1 and ITR2 trees, respectively.

### *Main conclusions*

Many tree fruit growers use irrigation to maintain soil moisture around field capacity throughout much of the cropping season, since mild or severe soil moisture deficits can limit rates of fruit expansion. However, this approach can lead to significant leaching of water and fertilisers and any rain that falls within the cropping season is not utilised effectively. This research has shown that irrigation may not be necessary in years when sufficient rainfall occurs at regular intervals throughout the cropping season. Nevertheless, to ensure consistency of yields of Grade I fruit in successive cropping seasons, drip irrigation is essential to avoid soil moisture deficits that limit fruit expansion.

Stone fruit growers growing under covers rely on irrigation to optimise yields and fruit quality but excessive irrigation prior to harvest can result in the skin of fruit rupturing on the way to the pack house. The alternate wetting and drying approach developed in this project will optimise both resource use efficiency and Class 1 yields and quality, without adverse effects on return bloom, yields or quality of 'Kordia/Gisela5' and 'Merchant/Gisela5', provided that the irrigation set points of -60 and -200 kPa are used in growth stages I-II and III, respectively.



The outputs of this research will also enable those stone fruit growers who do not use covers to schedule their irrigation more effectively around seasonal rainfall events.

A key output of this research project has been the identification of the range of soil water availabilities over which Grade 1 yields, fruit quality and storage potential are optimised in apple and sweet cherry varieties. Sensors that measure changes in soil moisture availability at different rooting depths have been used in experiments to trigger irrigation automatically, so that soil water availability is optimised, whilst leaching of water and nutrients is minimised. Access to this information can now be gained remotely using an 'App' developed for smartphones which provides alerts to tree fruit growers of the need to irrigate. The automated precision irrigation system can also be used to apply DI during specific crop development stages, in an attempt to improve aspects of fruit quality, without reducing fruit size. The challenge now is to incorporate environmental metrics and weather probability forecasting into a grower-facing irrigation decision support system. This will enable soil water availability to be optimised during specific cropping stages in changeable weather by making the most effective use of rainfall in tree fruit production, and by scheduling irrigation effectively to protected stone fruit crops.

### **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). In EMR's ERDF-funded WATERR project, data gathered from tree fruit growers suggested that optimising irrigation timing and duration is more important than improving water use efficiency per se, in maximising returns. The top 50% of apple growers (in terms of financial returns) used twice as much water per tonne than other growers, and also applied three times more irrigation water per hectare, but their achieved average yields of 31 tonnes per hectare were 55% higher than other growers. The growers estimated the financial benefit of irrigation to be ~15% of their gross proceeds. The importance of irrigation in helping growers to optimise fruit size and quality was also reflected in the fact that, on average, the top 50% of apple growers achieved crop selling prices that were 34% higher than other producers. These top 50% achieved average net proceeds after irrigation costs of £20,000 per hectare compared with £10,000 per hectare for other growers.

The top 50% of pear producers in terms of financial returns achieved net proceeds after irrigation costs of £17,000 per hectare on average, compared with £12,000 per hectare for other growers. On average, there was little difference in yields between the top and bottom 50% of growers, with overall average yields of 23 and 22 tonnes, respectively. Likewise, both

groups used similar volumes of water per tonne and per hectare. However, the importance of irrigation scheduling and timing in helping growers to optimise fruit size and quality is reflected in the fact that on average the top 50% of growers achieved crop selling prices that were 34% higher than other producers.

### **Action points for growers**

- Consider installing sensors 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.
- For 'Gala/M.9' and 'Braeburn/M.9', maintain soil around field capacity during flowering and for six weeks after full bloom. Using the AWD approach with a lower irrigation set point of -200 kPa (matric potential averaged throughout the rooting zone) from six weeks after full bloom will optimise both on-farm water (and fertiliser) use efficiency and crop productivity.
- Significant saving of irrigation water can be achieved without reducing Class 1 yields of 'Kordia/Gisela5' and 'Merchant/Gisela5' if AWD is used with lower set points of -60 and -200 kPa during Stages I-2, and III respectively.