Field lab: Controlling Water Imbalance to Reduce Tomato Losses

Final report

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1 Field lab aims

The aim of the field lab was to try and reduce food wastage and increase farmgate profitability by reduction of physiological fruit disorders occurring in the growing process. The key disorders identified on two specific varieties; blossom end rot (BER) on beef tomato and fruit cracking on cherry vine tomato.

2 Background

APS have been successfully growing tomatoes for a number of years, but with certain types of tomato they have been experiencing physiological fruit disorders, which in some weeks could result in up to 50% waste and across the production season, up to 10% loss of total yield.

The two main disorders identified were Blossom end rot (BER) and fruit cracking, both of which are thought to occur due to imbalance of water within the plant.

BER is caused by lack of calcium getting to the cells at the base of the fruits during their growth phase. As calcium is only moved in the xylem of the plant with the water flow, it considered that if the plant is under stress the correct amount calcium will not be transported to the expanding cells.

Fruit cracking or split fruits have often been linked with too much water within the plant cells and the root pressure forcing the water into the fruits. This could be caused by starting irrigation too early, with the lower salt content water easily being taken up by the plant or by not activating the plant, with too high humidity in the glasshouse.

By optimising the water balance, we should improve the quality of tomato fruit, minimising loss from fruit splitting and other disorders such as blossom end rot which are also caused by temporal imbalances in water availability. A better understanding of plant physiology in these contexts also enables us to further improve the efficiency of water and nutrient applications through understanding of crop requirements through the day.

3 Methodology and data collection

The Field Lab trialled and evaluated the use of sensors measuring continual sap flow and stem diameter (2Grow sensors) on tomato crops, in order to identify periods of water imbalance within the plant. Field labs were set up in three glasshouses with sensitive varieties; beef tomato (Isle of Wight, grown in coir), organic cherry on the vine (Isle Of Wight, grown in the soil) and cherry on the vine (Yorkshire, grown in rockwool). We believed that the development of these sensors will enable identification of physiological water deficit (and excess) within the plant, enabling us to better target the application of water needs.

The sensors were supplied by 2Grow, and the crop managers fitted them once the stem diameter was around 10mm. The data from the sensors was sent to the 2Grow system via a mobile dongle, allowing us to access real time data on multiple devices. The continual data from this system showed both the stem diameter (measured in 1000th of mm) and sap flow (measured in g/hr) in a graphical format.

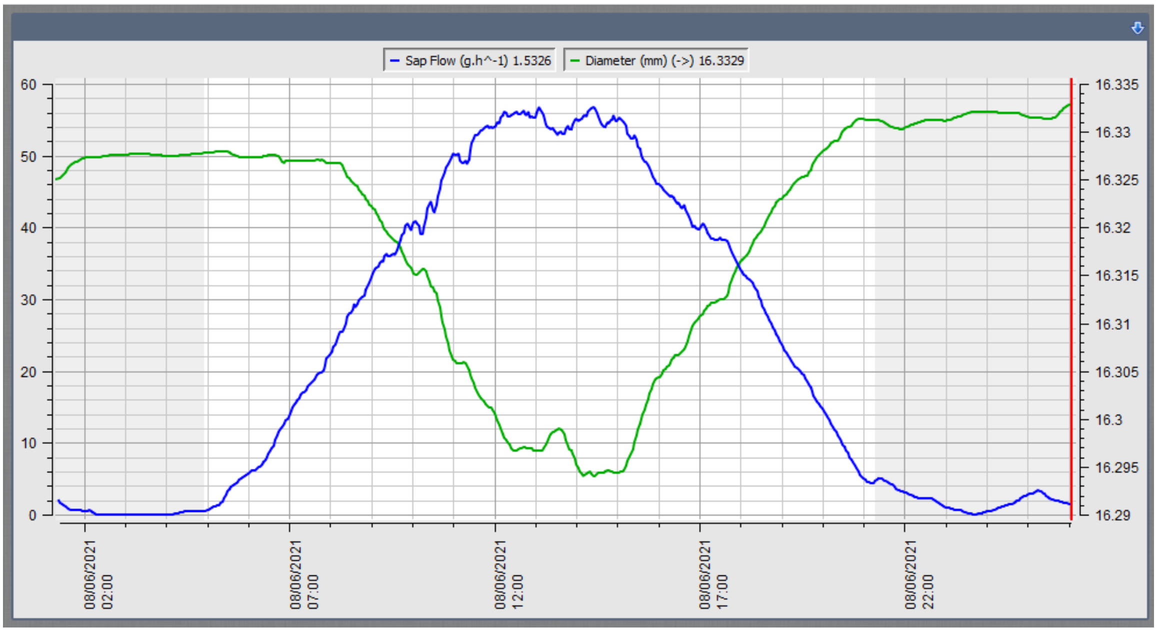


fig. 1 typical mirror curve of sap flow and stem diameter

Fig1 is what we would expect on a normal day. As the radiation increases the sap flow (blue) increases due to the stomatal opening. As the plant reacts to this, the cells become less turgid as the plant uses up some of its internal water reserves, thus lowering the stem diameter (green line). As the radiation decreases from midday the transpiration reduces and the plant can catch up with the demand, increasing the stem diameter to around the same as the start of the day. The theory is that if the stem diameter increases higher than the previous day, for several days in a row, it is an indication of vegetative growth and the reverse is an indication of the plant becoming more generative. In addition if we see the stem diameter increasing in the morning and only a small sap flow it indicates that we have started irrigation too early and the root pressure will be swelling the cells increasing the risk of fruit cracking. If towards the end of the day, as transpiration is slowing and plant does not recover stem diameter, it is an indication of the conditions that cause BER.

The glasshouse climate is controlled by an environmental computer (Priva) collecting a range of data; outside conditions, temperature, humidity, Co2, vent positions, energy screen position, air exchange and irrigation information, which needed to be viewed/ considered when making an analysis of the data from the 2Grow sensors. In addition we also had another measuring system from 30MHz which would collect information from the soil/ growing media, such as water content, EC (dissolved salt level) and temperature.

For ease of analysis, we were able to bring all the information together (Priva, 2Grow and 30MHz) on a single platform from 30MHz called Zensie.

The data was continually monitored by the crop managers sometimes more than 10 times a day, especially if conditions arose that would affect water balance in the plant, such as a very dark rainy day or a very bright or changeable days. The technical engineers at 2Grow would also be monitoring the information within Zensie and would give a direct opinion via whatsapp if they saw something in the data that looked like it could lead to a fruit quality issue. On a fortnightly basis the growers, 2Grow and other stakeholders would discuss the detailed data. This meeting gave the growers the opportunity to feed back plant observations and for 2 Grow to explain their interpretation of the data.

To verify the assumptions made from the data, waste figures were monitored and compared to previous years. The beef crop was relatively easy as historical data existed for the last three years and the cropping plan had remained the same. From previous waste analysis we also knew that most of the waste generated from the beef crop was due to BER. The organic Piccolo only had one year of data behind it as previously in had been grown in a different location and was treated differently with some of the cultural practices. The previous analysis of the waste was not as clear cut with split fruit making up to 60% of the waste but this was mixed with green tail fruits from the end of the vines. For both the beef and organic Piccolo crops, the assumption was made that the total waste was a comparable figure and therefore compared.

4 Results and discussions

The vast amount of information we gained from the sensors showed the effect of a lot of practices within the glasshouse and the impact this had on the crops. To be able to gain insight of the effects that small adjustments and growers decisions made, was continuous very useful.

Effects of opening of the blackout screens in the morning (beef crops)

One of the first observations made was that we were opening the blackout screen too early in the morning at sun rise. The beef crop is grown under lights during the winter months and they are turned on between midnight and 4am in the morning, depending on the time of year. To aid our local environment and reduce light pollution a black cloth curtain is drawn across the top of the glasshouse as the lights are turned on. To receive as much natural light as possible and to allow the bees to forage effectively, the curtain is drawn back at sunrise when the light will not cause such a nuisance. We have always known that the opening of the curtain is difficult to do, as cold air above the curtain needs to mix with the warmer air around the crop slowly to ensure there are no sudden temperature shocks.

The graph below shows a big drop in the sap flow (blue line) and an increase in the stem diameter (green line) at 8am. Our conclusion was that the screen opened too fast, dropping cold air on to the head of the plant, which closed the stomata. With the stomata closed/ reduced opening we saw the fast increase of the diameter and decrease of flow, which would result in reduced growth and nutrient uptake.

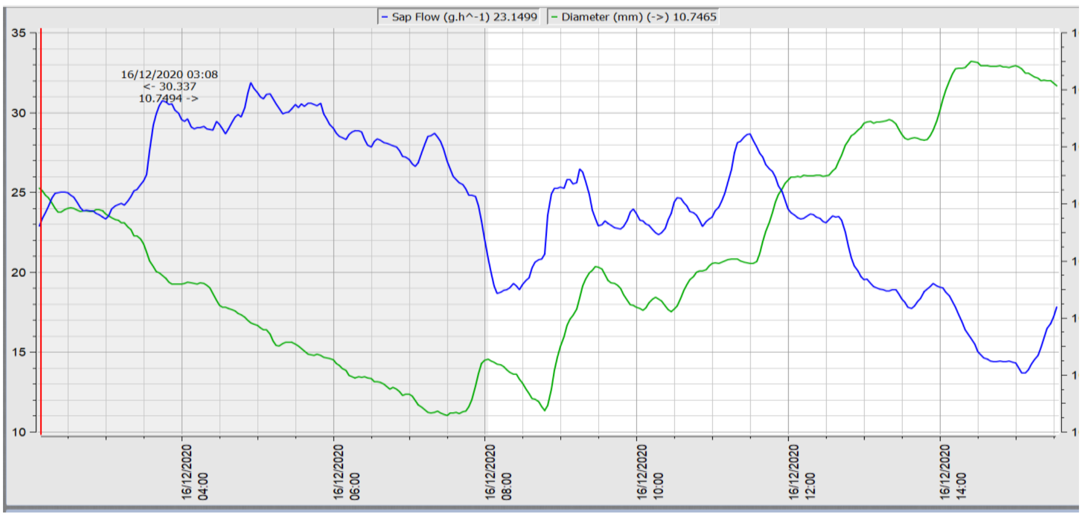


fig 2 showing a rapid drop in flow and increase in stem diameter as the curtain was opened at 8am.

By adjusting the curtain to open over a period of 45 minutes from 10 minutes we were able to get a much smoother transition (fig 3), with the sap flow remaining fairly constant.

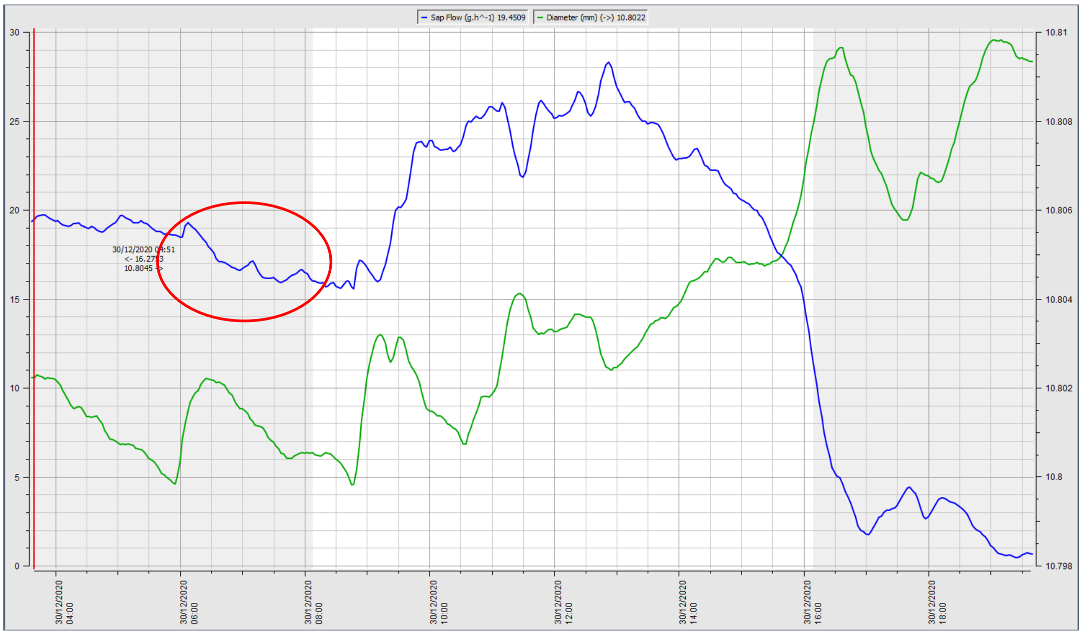


Fig 3 showing a more constant sap flow after curtain settings change

Effects of Redufuse IR (Beef crops and organic Piccolo)

Redufuse IR https://www.redusystems.com/en/products/ReduFuse-IR is a coating applied to the outside of the glasshouse normally around April through to October. The product reduces around photosynthetic active radiation (PAR) by 10 – 12% but the light is scattered so therefore penetrates deeper into the crop canopy, with the net photosynthesis increasing. The product also reflects higher levels of infrared light, which allows us to maintain a lower temperature in the glasshouse. The coating would be added to crops which are known as weak or can develop BER and were applied on the beef and organic Piccolo crops. After application the glasshouse temperature can be seen to be cooler compared to a non treated house but the sensors have shown the full effect of the treatment.

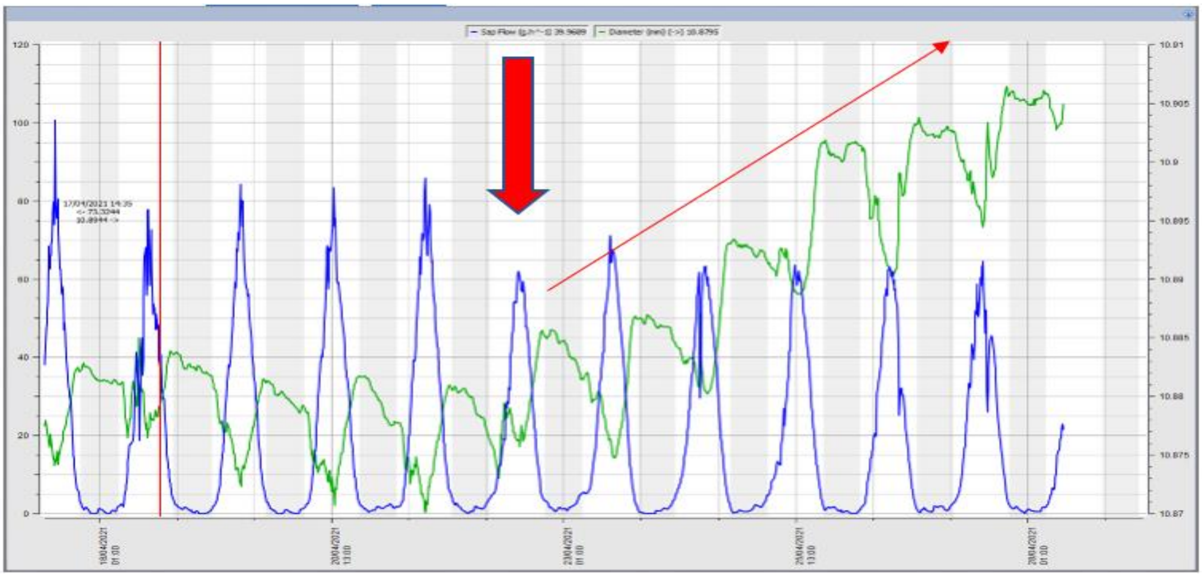


Fig 4 showing a rapid change after the application of Redufuse IR.

In the beef crops (fig 4) the application was made on the 22nd of April and we immediately saw a vegetative response from the coating with the sap flow being lower and the plant recovering beyond its starting point each day. This easing of the stress is exactly what we would expect but we have never been able to quantify the effect. In Theory the removal of the stress should reduce the risk of BER and the plant should stay stronger.

Fig 5 showing lower sap flow with similar radiation.

The organic Piccolo had the coating applied later than the beef due to contractor availability. The application was made early (8am) on the 18th of May. Although the response was not as great, it is clear to see that the sap flow was less and the stem diameter did not drop as low even though the radiation was similar.

<u>Blossom End Rot (BER) development (beef crops)</u>

Although we were not able to identify the conditions that lead to BER in the beef crop at the time, on closer analysis there were subtle signs.

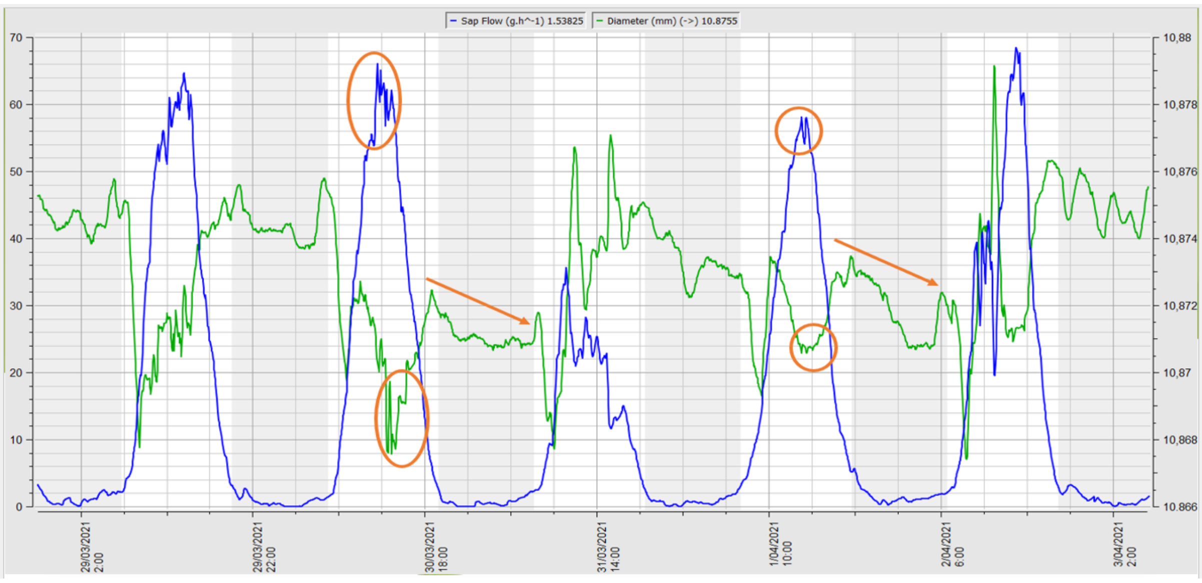


Fig 6 showing some extreme points which could have triggered BER

There were some days prior to the application of the Redufuse IR, where the imbalance between highest point of activity and lowest point of diameter indicated stress in the plant. When this is extreme the 2Grow analysts see higher levels of BER. There were occasions as well where shrinkage was happening during the night which was not normal.

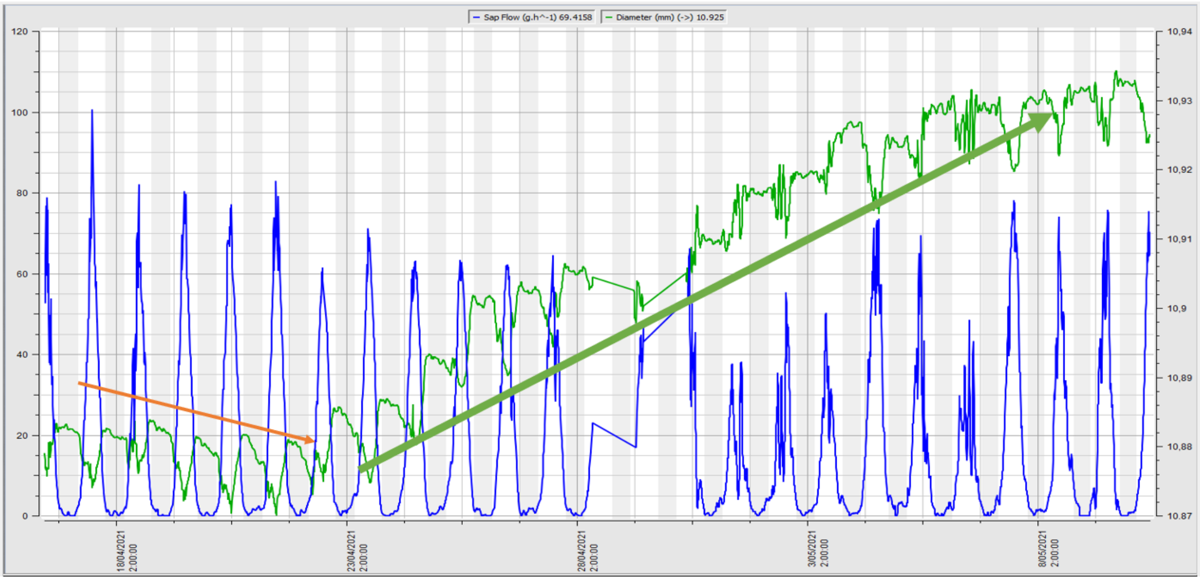


Fig 7 showing shrinkage prior to the Redufuse IR application

The data that 2Grow analysed did not show the conditions for BER which they would typically see. That said the variety of beef tomato APS grows is very sensitive and subtle conditions needed closer investigation. They could not identify very high stress levels at the end of the day, which is what they were expecting to see. We believe that this was partly down to bad luck and the plant with the sensor attached seemed to have less BER than many others around it. This was discussed with 2Grow but they believed that the same stress conditions would still be seen in the data.

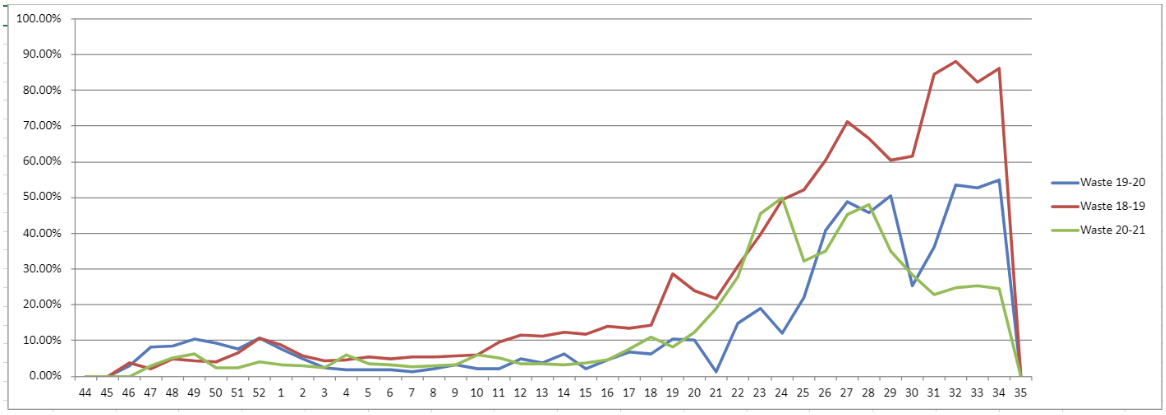


Fig 8 showing weekly waste percentage

Year	cumulative waste %
2018 - 19	27%
2019 - 20	17%
2020 - 21	15%

The actual results from the data shows a marginal improvement on the previous year. Fig 8 shows the greater amount of BER came between weeks 20 and 25 in 2021, which were fruits developing in the high stress period before Redufuse IR application. It is interesting to note that significantly less BER was seen in weeks 30 to 35 in 2021. This could have been from management of the climate with information from the sensors, or a possible reaction to a poor summer, with light levels down 6.6% on the 10 year average from weeks 25 to 31 (the development weeks from harvesting weeks 30 to 35). In Fig 9, 2020 shows waste from BER has a strong relationship to light (therefore temperature and stress), off set by 6 to 8 weeks. In 2019 no shading of any form was applied which is why we think the waste figures are so much higher.

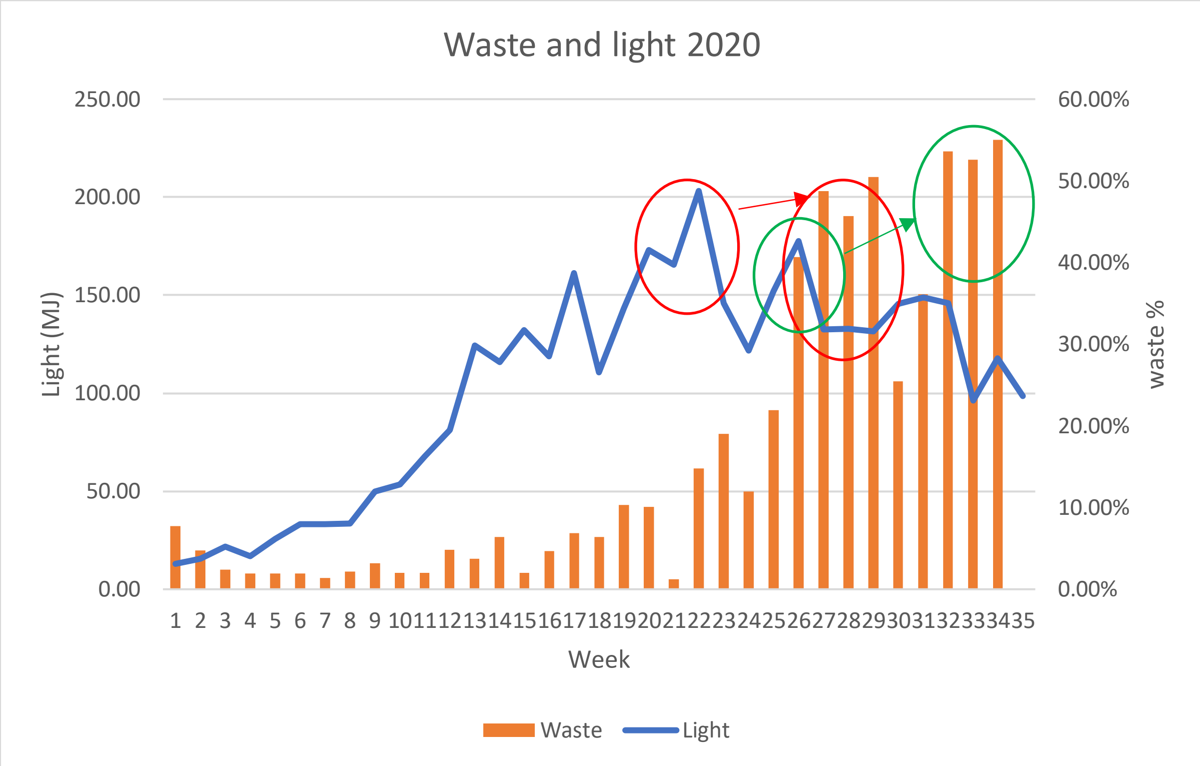


Fig 9 showing sowing high light followed by increased waste 6 to 8 weeks later

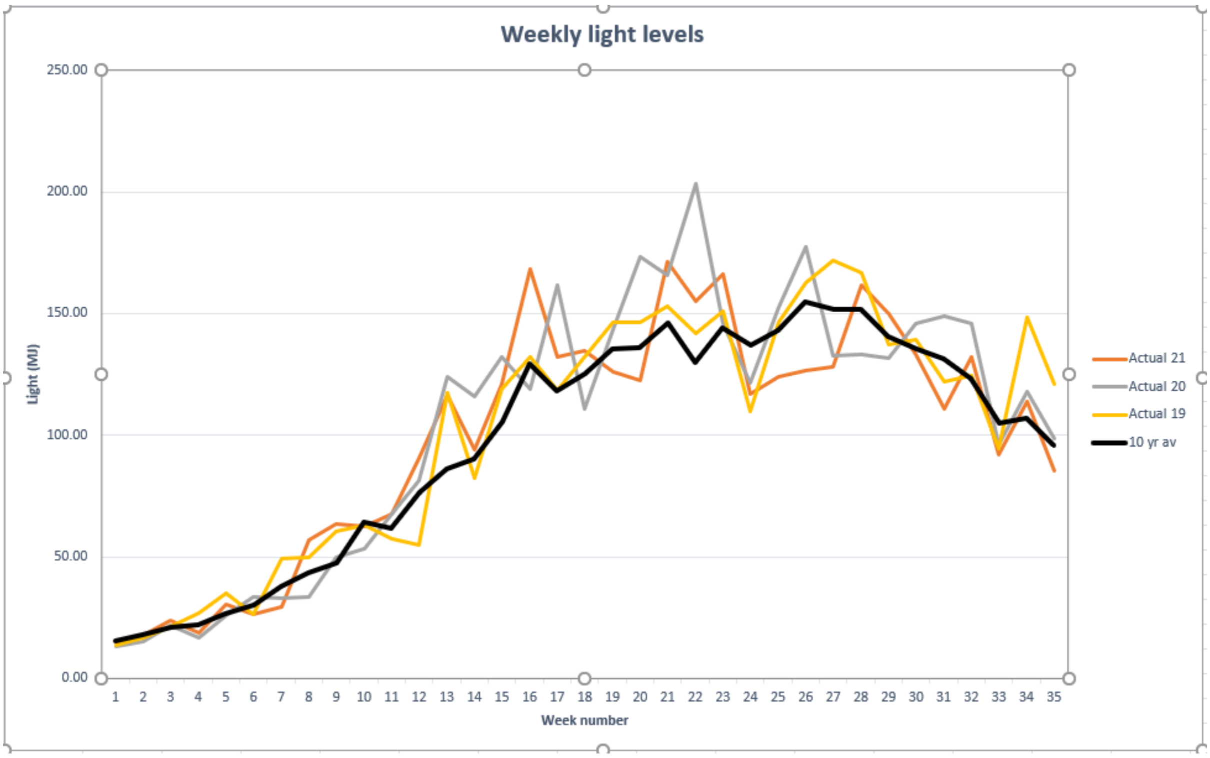


Fig 10 showing weekly light against 10 year average

Irrigation management (all three sites)

As well as ensuring the plant had enough water in its reserves there were times where we felt we could be applying too much water, resulting in split of cracked fruits. Currently irrigation is started by radiation and radiation sum. This is looked at in combination of moisture content of the growing media, either as a manual or sensor assessment. The general idea is that the plant should be transpiring before the first watering is applied, to avoid too much root pressure and splitting the fruits.

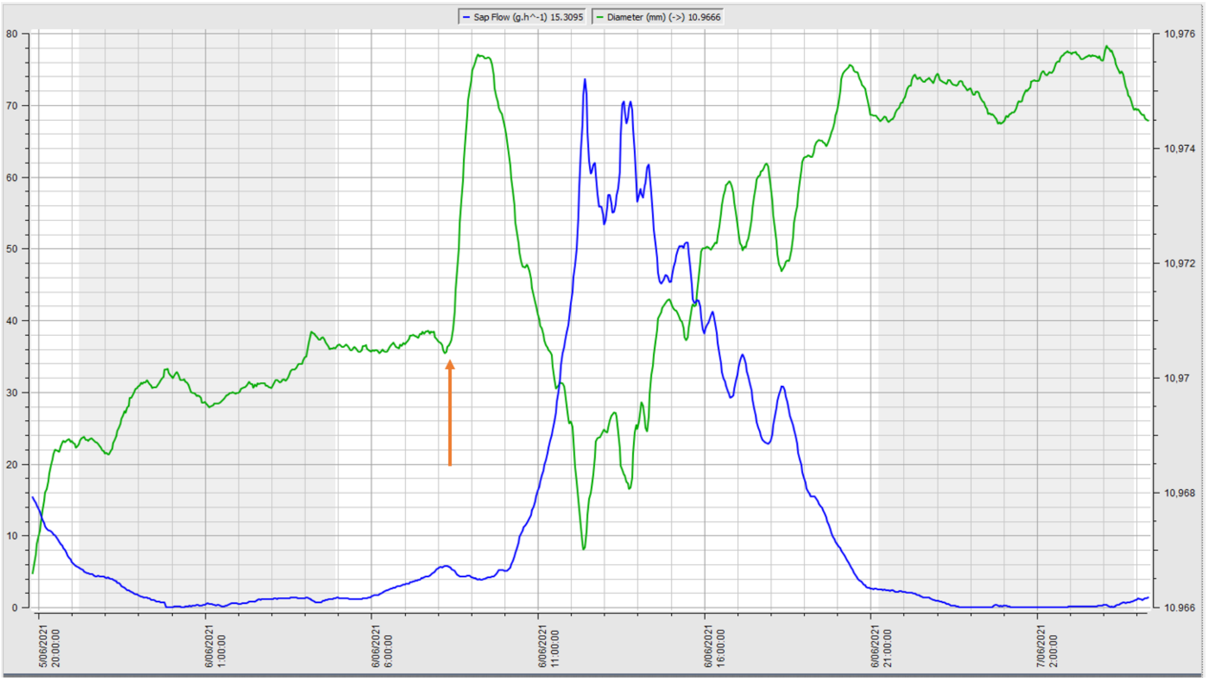


Fig 11 showing effect on irrigating too early

Fig 11 shows when water was applied to the crop too early on a poor day and a clear increase in the stem diameter can be seen. The sap flow is very low (blue line) and the cells inflate with water. This did not cause a splitting event in this case, but it certainly a risk. Once transpiration increases the stem diameter reduces.

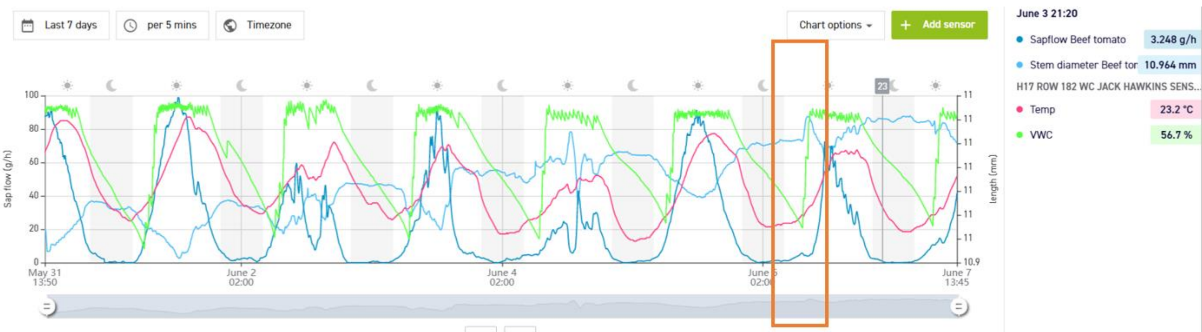


Fig 12 showing effect on irrigating too early

Although the beef tomato is very unlikely to split due to type and no splitting events we seen, fig 12 does show that the cells do become inflated very quickly if watered too early on a poor day, with a sharp increase in stem diameter after the first irrigation. Although rarely seen, guttation would cause issues with crop disease and fruit quality so early watering should be avoided.

At Branfield the sensor was able to pick up the effect of the irrigation being stopped too early in the day time. Figure 13 shows the drop in VWC (water content) dropping for several nights in a row. The lack of water made it had for the plant to recover at the end of the day resulting in a reduction in stem diameter.

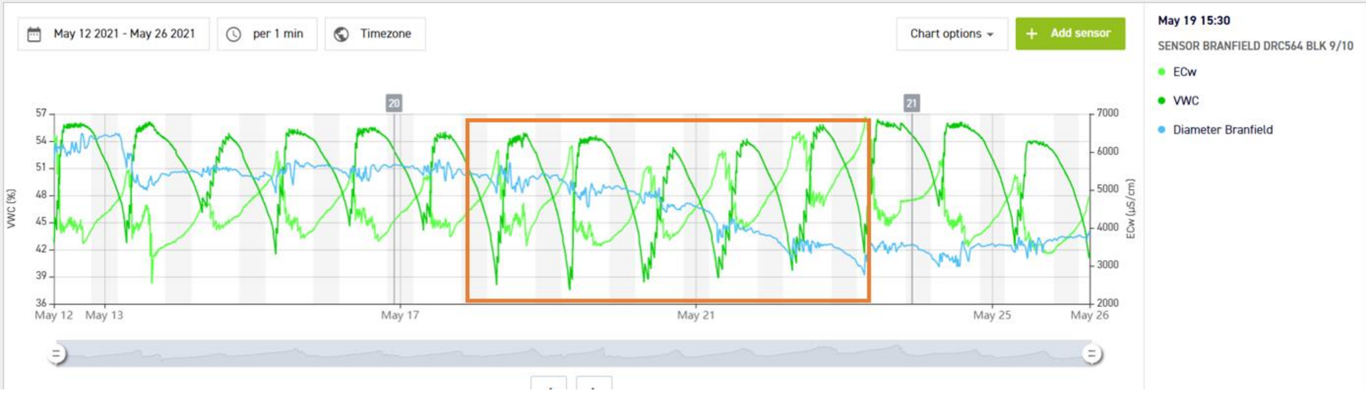


Fig 13 showing irrigation being stopped too early

<u>Prenight effect</u>

The 'Prenight' practice is carried out on many nurseries as general advice from many crop advisors to deliver better fruit size and a more generative plant. The thought process is that by having a rapid decrease in temperature at sunset, the assimilates accumulated during the day will be attracted to the warmest part of the plant. Due to the mass of the fruits being the greatest, these would cool down slowest and therefore attract more assimilates and become bigger faster. There is no scientific data to prove this concept and the 2 Grow sensors have given us an in sight.

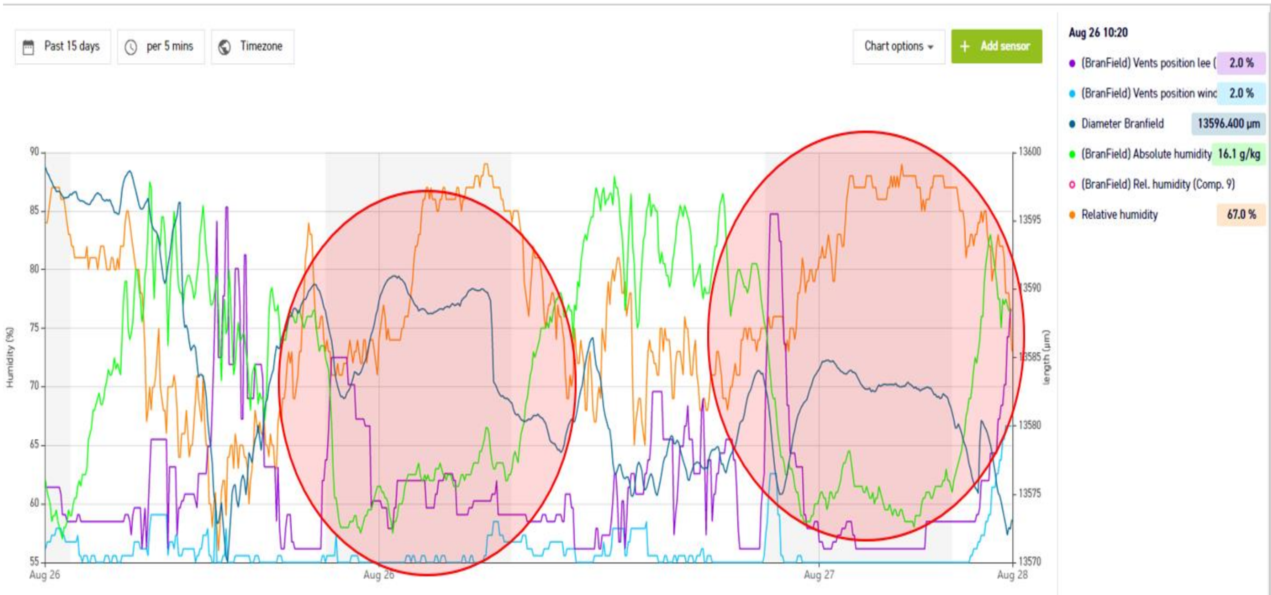


Fig 15 showing reduced humidity

Figure 15 shows how the effect of the pre night on the cherry crop in Yorkshire. At the end of the day the vents (purple and light blue lines) open fast. This releases the humidity held in the glasshouse, which can be seen in the fast drop of actual humidity (AH) (green line). There is also a drop in the relative humidity (RH), but being temperature dependant, this gives us less information. The stem diameter (dark blue) does not recover in the evening to its starting point, indicating that this is a weakening or generative steering tool. Although a prenight can be useful, it seems the influence is more humidity lead rather than fruit temperature. Figure 16 is showing the longer term effect of this action, although caution is required in the interpretation of the data as there can also be other aspects intwined such as irrigation control.

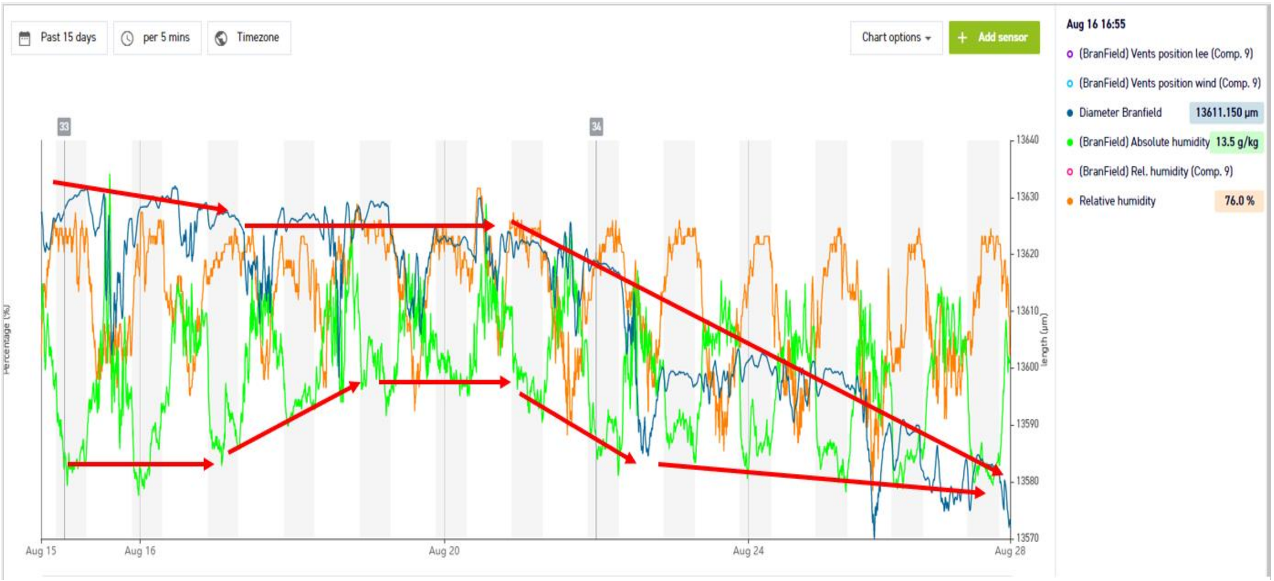
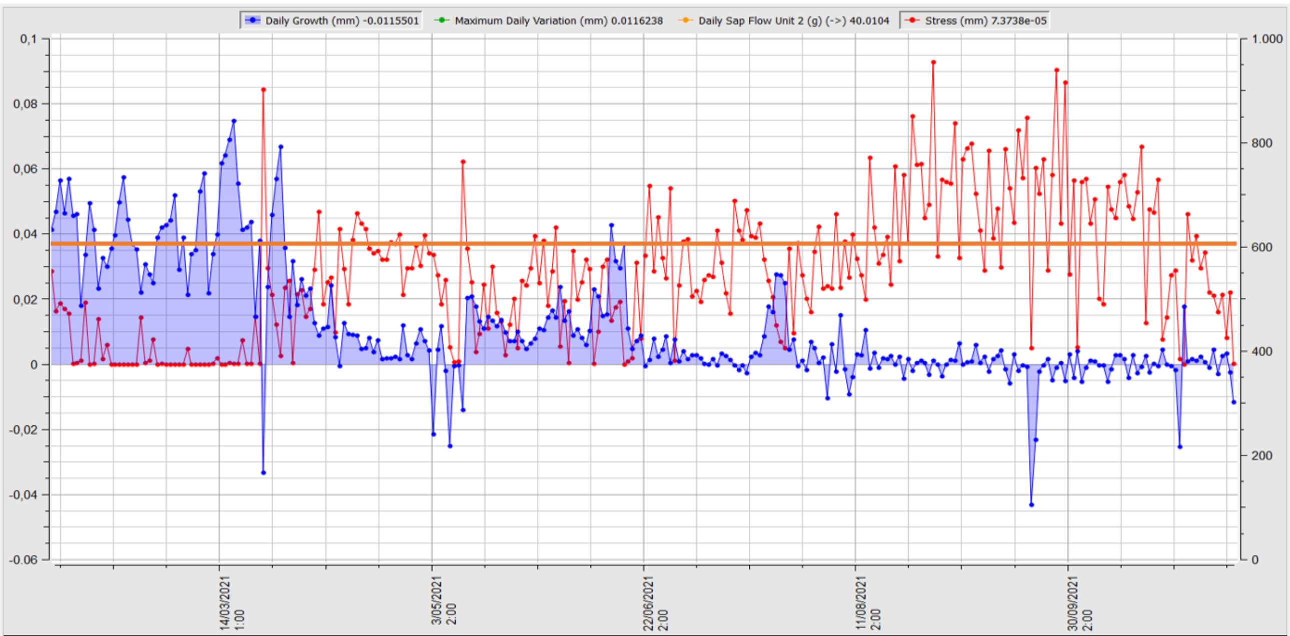


Fig 16 showing longer term effect of reduced humidity

Plant balance and stress

From the readings, 2Grow are able to measure the stress the plant is under. This is done by looking at the daily high and low points of stem diameter. From the experience of the 2Grow analysts, they believe that any measurement above 0.4mm is classed as stressful on the plant. The organic Piccolo saw over double this reading meaning that the plant was under a lot of stress especially through August and September.



Discussion

Number of sensors

All the data was driven by one sensor in the glasshouse which could be up to 40,000 plants. In the case of the beef crop we are sure that the chosen plant was either stronger on in a position where it was less stressed than many plants around it, as it had less BER than others. 2Grow believe that the stress factors would still be seen even if symptoms not displayed. As growers we think it would be better to have two or three sensors/ ha but this has to be balanced with the cost.

Quantitative plant data

In many cases the 2Grow analysists were describing our plant to us based on the sensor readings and advising the direction of steering (vegetative or generative) from this. On several occasions we wanted to steer the plant more vegetative and this was showing on the sensors, but 2Grow did not 'see' plant or understand why the grower needed to drive in a specific direction. If the sensors were to be used in the future plant measurement data (stem thickness in the head, leaf length, flowering truss, picking truss and fruit load) could also be supplied and used to form a better picture of the plant by the analysts.

5 Conclusions

The trial of the sensors did not give us the dramatic reduction in BER that we were hoping for, nor could the situation that led to the BER be wholly identified by the analysts. However, the sensors have given a lot of valuable insights into water balance within the plants, which we would not be aware of without them. What we will not know is if we did not have the sensors could the BER be worse? The information we gained, particularly the irrigation starting and stopping times, would affect the production, especially fruit size. In addition, the information on the pre night was very interesting and together with plant measurements, this can be used to steer the plant in the direction required and with the use of the sensor, the grower would know when to also stop the action.

Although the system gave a lot of information it needs to be developed further to give a more pro-active approach. On many occasions we were highlighted to issues well after the event has happened. The final goal would be integration of the sensors in to the main Priva control computers for the environment and irrigation. This could allow changes to a range of processes from starting and stopping of the irrigation, controlling the screens, vents and other factors affecting air exchange. It is possible that an intermediary would be some form of notification to the growers if an aspect was identified outside of setpoints.

If the moment that the BER had been initiated was identified in the beef crop there would be no question that the system would become a standard piece of equipment within glasshouse culture. The current plan is to repeat the use of the sensors in both beef crops and cherry crops to further investigate causes leading to the disorders throughout 2022. APS will include crops grown under LED lights in 2022, where there can be a lot of fast changing factors which would affect the water balance within the crop. Further use will be determined on the results of 2022and how 2Grow develop the system, but there is still a productivity gain to be had in these crops by eradicating these disorders. Furthermore, with the current challenging supply chain issues and tough economic times, the sensors may offer more insights to growing with less fertiliser and energy.

7 Further reading

https://2grow.earth/en/

https://www.30mhz.com/news/30mhz-new-2grow-app-offers-detailed-plant-insights-to-grow-smarter

Innovative Farmers is part of the Duchy Future Farming Programme, funded by The Prince of Wales's Charitable Fund through the sales of Waitrose Duchy Organic products. The network is backed by a team from LEAF (Linking Environment and Farming), Innovation for Agriculture, the Organic Research Centre and the Soil Association