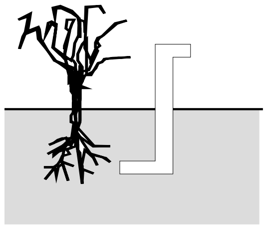
Irrigation Scheduling

THE AIM

Most farmers know their acreage on the surface, but the sub-surface is often a mystery to them. Yet this area of a few feet of soil, where the rootzone exists, is the 'factory' for crop production. The more one can learn about conditions in this soil zone, the more one can improve the whole 'crop production' operation.



This fact has long been recognised, and there are various devices ranging from the shovel, to tensiometers, gypsum blocks and the neutron probe, that can be used to measure subsurface moisture. The neutron probe is widely recognised as being the most accurate and reliable source of gathering soil moisture data today.

HOW DOES A NEUTRON PROBE WORK

The soil moisture is measured by lowering a source of fast neutrons and a detector down a hole in the soil. Holes are drilled at selected locations in the crop (usually three per monitored area), and cased with aluminium tubing to prevent 'cave-in'. Measurements are taken through the soil profile usually down to a depth of 100-120cm. Fast neutrons are emitted from the source and fly through the aluminium tubing (just like light passing through a glass window), in a football shape pattern. The neutrons collide with objects in the soil, and bounce back to a detector. The neutrons are only slowed down by hydrogen atoms as they are of similar size and mass. The detector only detects slow returning, low energy neutrons. The count on the probe screen is therefore a reflection of the number of hydrogen atoms that have been recorded at a particular depth.

The only varying source of hydrogen in a soil is the hydrogen in water. Each neutron probe has a calibration to calculate the 'volumetric water' percentage at varying depths, and once that is known a calculation can turn water percentage into mm of water at chosen depths. The transfer of hydrogen counts into water percentage and mm of water are calculated in minutes using a software package designed for use with the probe. By taking six to seven measurements through the soil profile and plotting them graphically, one is able to get an understanding of how the soil moisture is changing.

BENEFITS OF IRRIGATION SCHEDULING WITH A NEUTRON PROBE.

1. Better use of natural rainfall and a possible increase in area irrigated.
2. Reduced waterlogging, soil compaction and plant disease.
3. Better knowledge of when to commence irrigation after rain, and the ranking of fields from driest to wettest.
4. Reduced cost of irrigation
5. Development of a data bank for future management decisions

Irrigation Scheduling

The questions to be answered are

- How much water to apply

- When to apply

We need to know

- The current rate of depletion
- the water content at which to irrigate (the refill point)
- the maximum water holding capacity (the full point, or field capacity) - to get the amount

Field Capacity Definition

- The maximum water content a soil can hold against gravity, once through-drainage of excess water has ceased
- Like pulling a saturated sponge out of a bath of water - when the sponge stops dripping it is at the 'Full Point' or 'Field Capacity'

Finding the Full Point

- Take soil moisture readings when the soil is wet after heavy rain/irrigation
- Identify the rooting depth by studying the depth graphs
- Any movements below the current rooting depth, particularly at 80cm and below, suggest over-wet readings
- Looking for the wettest readings in the top 50-60cm with no movement at depth.

Figure 1 illustrates a series of readings ranging from dry (lines on the left of the graph) getting progressively wetter (lines moving to the right of the graph), with no change at depth up to the full line. Readings wetter than the full line give changes at every depth, thus showing over-wet readings.

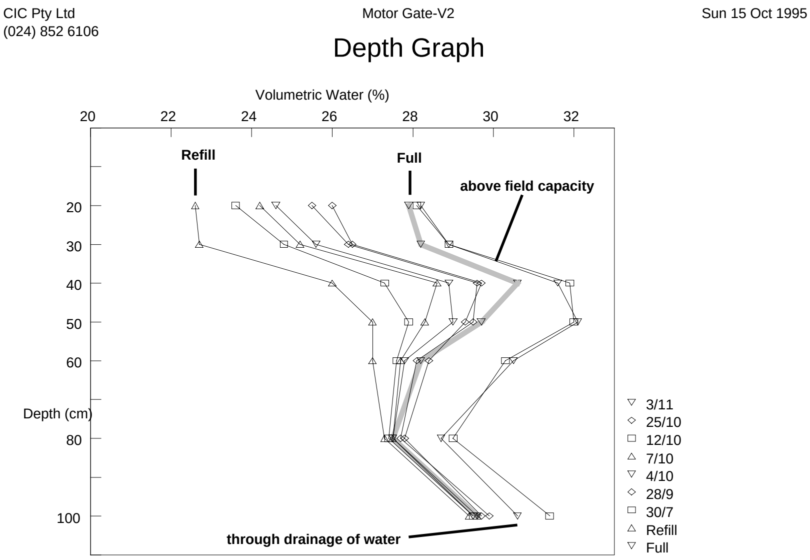


Fig 1 Field capacity

Refill point - Definition

- The point beyond which optimum growth starts to decline

Finding the Refill Point

Whilst the moisture content is maintained in the 'optimum zone', the drying cycle lines on the graph will appear to change in a 'wedge shape', that is to say the majority of the water will be extracted in the top 40 cm, with some extraction taking place below. This will always represent a plant extracting water under a 'happy working environment'.

When plants get near the refill point, there are three distinctive changes

1. The extraction lines on the depth graph become parallel
2. There is usually sudden deeper extraction of water in the soil profile
3. Combined with the above two symptoms, there is usually a decline in the daily water use of the crop.

The refill point is usually the last reading taken without any of the above symptons showing. Figure 2 shows a series of readings from wet to dry, the dates of the readings, and the water uses. The water use steadily increased on the potato crop from 2/6 up to 30/6. After 30/6 the crop water use slowly declines, the lines on the graph are parallel, and there is deeper extraction of water.

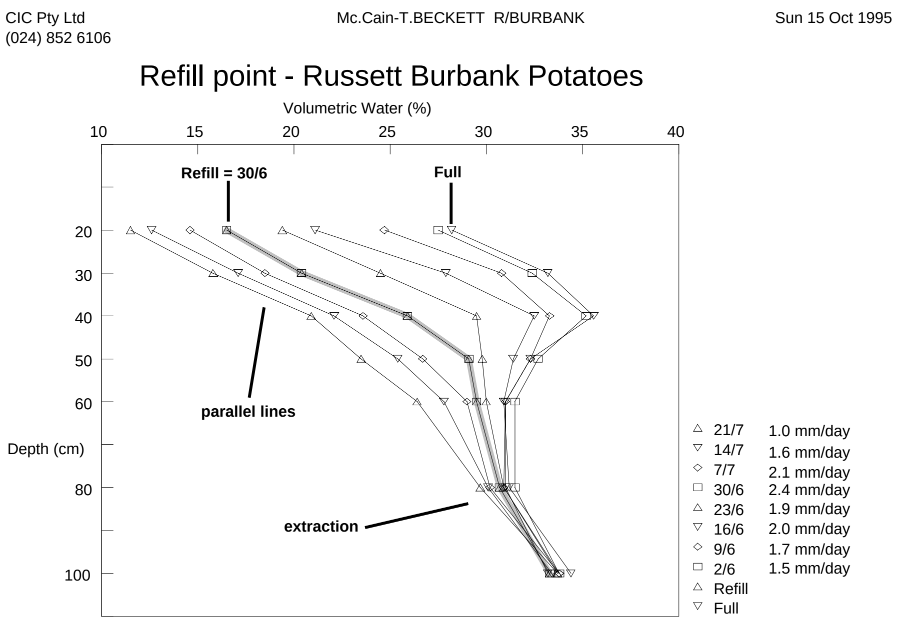


Fig 2 Refill Point

The refill point may change through the season. A potato grower interested in scab control will only want to dry down to a soil moisture deficit (SMD) of 10-20 mm (depending on soil type), during the high scab risk period. This is commonly less than half of the technical refill point. An apple grower may wish to stress the crop beyond the refill point to stop or slow down shoot growth, at certain times of the year.

The difference between the full and refill point will alter for every field, depending on soil type, type of crop, and the state of the soil (compacted, for example).

Refill from time graph

Another way of finding the refill point is to study the time graph, and look at the rate of loss from the soil. Figure 3 shows that the refill should be set where the rate of loss changes, at about 215 mm.

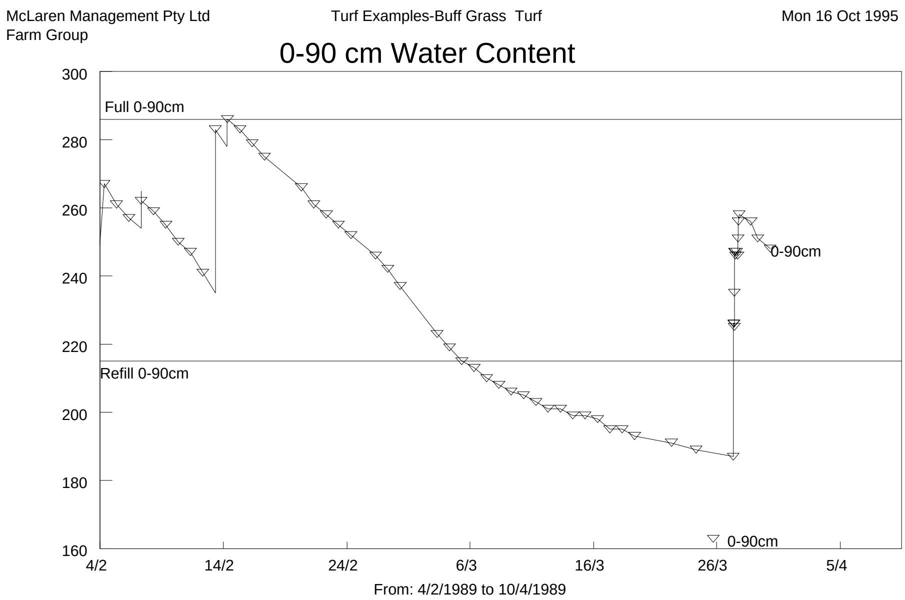


Figure 3 Refill point of turfgrass

The full point can also be determined from a time graph. When a soil is over-wet the 'daily water use' appears high, but what is happening is that the water loss from the soil is actually drainage of excess water, and the point at which the losses start to slow down will be the full point. Figure 4 illustrates both full and refill.

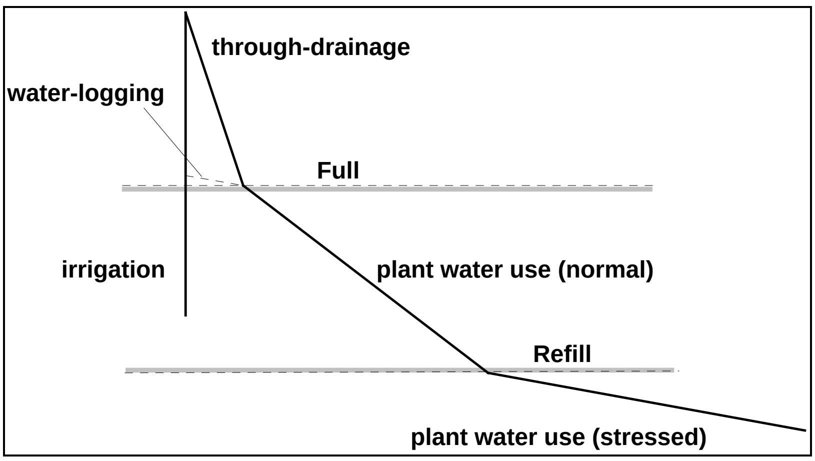


Figure 4 Full and refill points

Determining Irrigation Efficiency

Figures 5 & 6 show two depth graphs displaying the full and refill points, as well as readings before and after irrigations. The volumes applied were within 2 mm of one another, one being

28mm and the other 30mm, but the amounts that could be accounted for are totally different, illustrating the differences that can be experienced between night and day irrigations. The crop model working in the area where this information was obtained assumed a 20% loss regardless of time-of-day. By taking objective probe readings one is able to see how far out the model is.

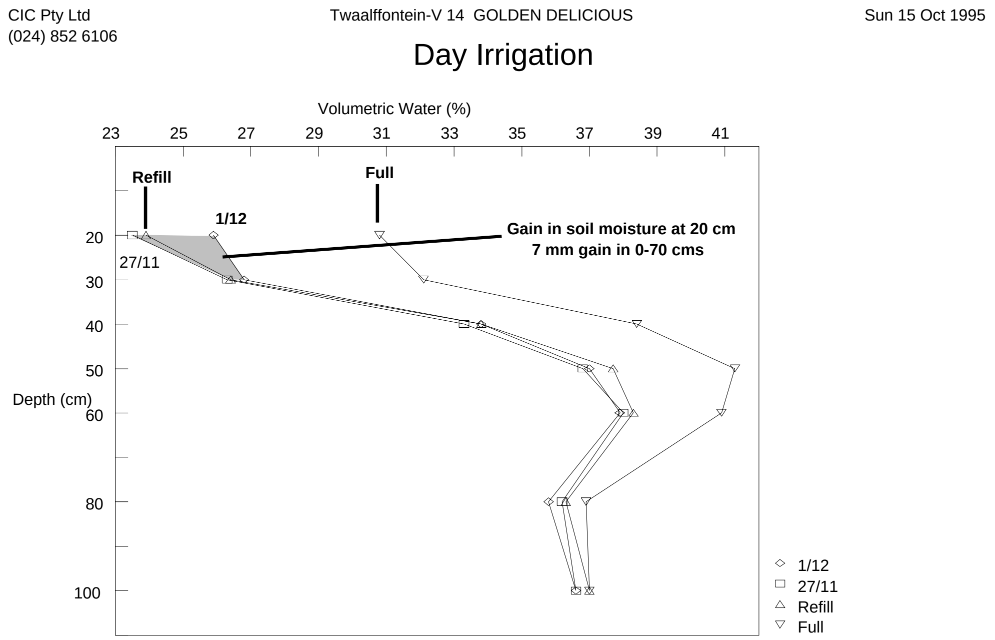


Figure 5. Day irrigation - can account for only 13 mm of 28 mm applied = 45% efficient

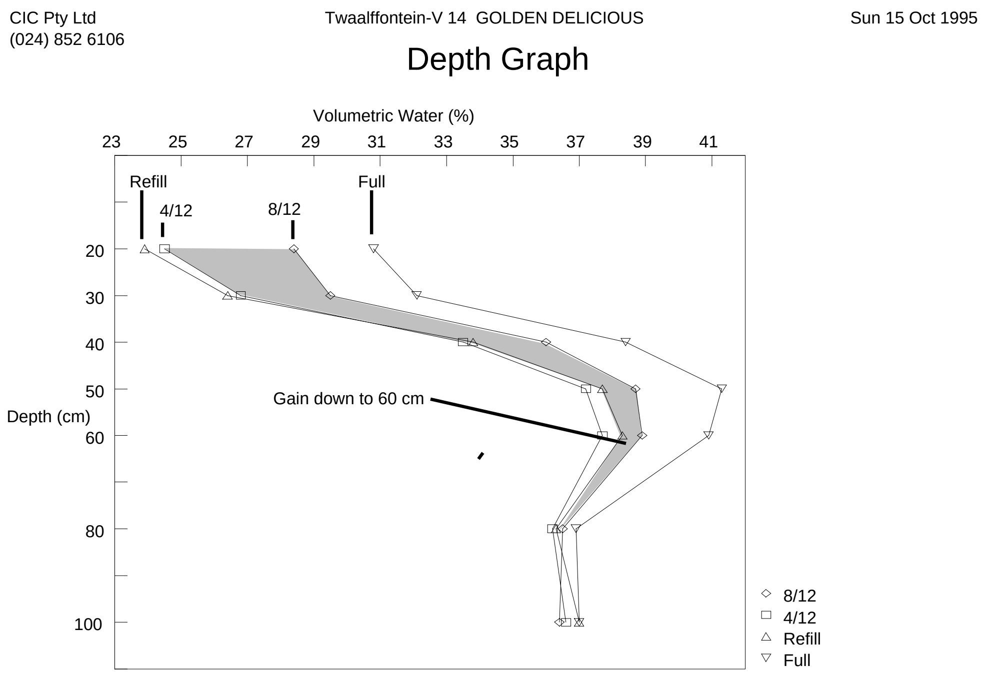
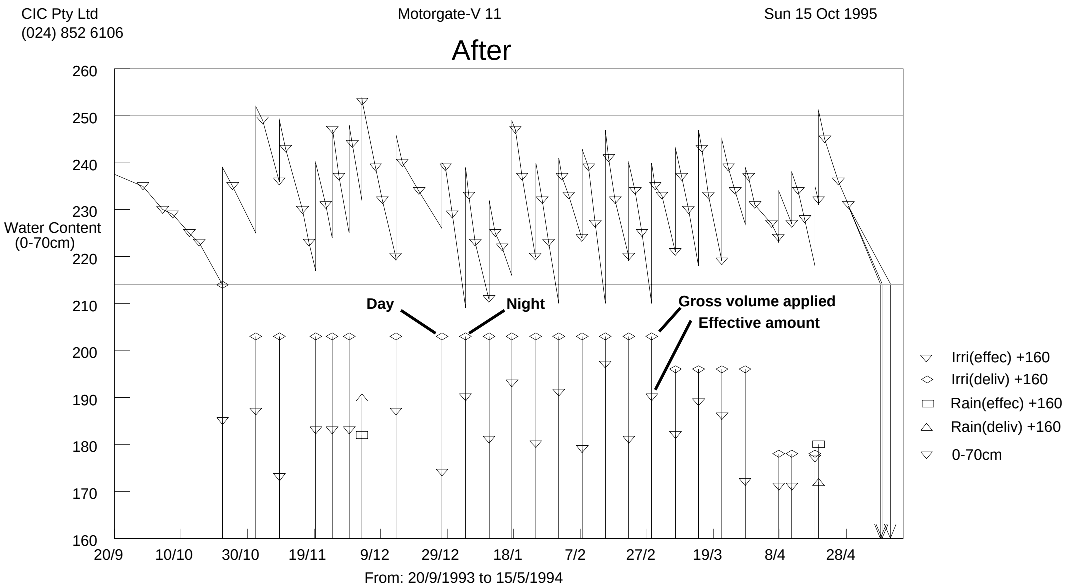


Figure 6. Night irrigation - can account for 26 mm of 30 mm applied = 86% efficient

One can also see from figures 5 & 6 the difference in the penetration of the irrigation water. In figure 5, the day irrigations, the water made the soil wetter (the line moved to the right) in only the top 20cm. On figure 6 however, the night irrigation, the soil got wetter as far as 60cm. The grower whose farm this information came from now irrigates one week during the day and the following week at night.



Depth	Full	Refill	Previous	Current	Defct	PDWU	Date	EDWU	Date	Amount
0-70cm	250	214	236	231	19	1.6	8/5	1.3	11/5	36 mm

Figure 7. Time graph illustrating trend between night and day irrigations.

Figure 7 shows a time graph that clearly illustrates the different irrigation efficiencies of day and night irrigations (the grower had to contimue with some day irrigations because of irrigation system capacity).

Summary Report

A summary appears at the bottom of both the depth and time graphs

Depth Most crops monitored by the neutron probe have a rooting zone in the top 70cm of the soil (although the software can set this to any zone to meet specific crop needs) - hence depth = 0-70cm

Depth	Full	Refill	Previous	Current	Deficit	PDWU	Date	EDWU	Date	Amount
0-70cm	250	214	236	231	19	1.6	8/5	1.3	11/5	36 mm

Full The total amount of water measured by the probe when the full point was determined, in this case 250mm. Any figure less than this value will become a soil moisture deficit. That is, if the value were 240mm there would be an SMD of 10mm.

Refill The amount of water measured in the profile when the refill point was determined, in this case 214 mm.

Previous The amount of water the previous time a reading was taken.

Current The most recent reading.

Deficit The SMD calculated at the most recent reading. Full-Current = 250-231=19.

PDWU Probe daily water use - the loss between the two most recent readings, divided by the number of days between those readings.

Date The date that the crop will reach the refill point based on the PDWU and EDWU rate. Currently there is an SMD of 19mm, if the crop continues to use 1.6mm/day then on 8/5 the crop will need an irrigation.

EDWU A crop water use rate that the user can enter. This will be based on user experience and long term data, helping to predict what the crop might do in the next few days. In this case the user predicted that the crop use may decline to 1.3 mm/day, in which case the second date delays irrigation by a further 3 days.

Amount The difference between Refill and Full ie 250mm - 214mm = 36 mm. This figure may not be the amount that actually needs to be applied to take the soil moisture from refill back to full. Figures 5 & 6 demonstrate that there is always some evaporation during irrigation, and that needs to be taken into account by the user when deciding on a gross volume to apply. Regular probe readings either side of the irrigations will soon determine if the volumes being applied are correct.

Sites Report

Once the irrigation dates have been determined for each field or site, a sites report can be printed ranking the sites from driest to wettest, using either the probe predicted date or the estimated predicted date.

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Motor Gate

Site Num.	Site Name	Full Point	Refill Point	Defici	-Last--Probe-Readi Date	Amount	Balanc	Probe-Predic DWU	Date	Estima-Predic DWU	Date	Global-Predic DWU	Date	LatestState Amount	Date	Last-Irrig Amount	Date	Gain mm
06	V 15	233	197	36	3/11	214	17	1.4	16/11	1.8	13/11	6.4	6/11	214	3/11	220	30/10	41
07	V 5	233	207	27	3/11	233	26	1.5	20/11	2.1	15/11	6.4	7/11	233	3/11	239	30/10	48
05	V 8	242	202	39	3/11	229	26	1.4	22/11	1.5	21/11	6.4	7/11	229	3/11	234	30/10	41
08	V 16	248	207	41	3/11	222	14	0.7	23/11	1.5	13/11	6.4	5/11	222	3/11	235	20/10	25
01	V2	201	173	28	3/11	209	36	1.6	26/11	2.1	20/11	6.4	9/11	209	3/11	212	1/11	61
02	V 11	250	214	36	3/11	249	35	1.3	30/11	1.7	23/11	6.4	8/11	249	3/11	254	30/10	50
03	V 14	250	215	35	3/11	250	35	1.2	3/12	1.5	26/11	6.4	9/11	250	3/11	255	30/10	57
04	V 3	244	208	35	3/11	247	39	1.2	6/12	1.7	26/11	6.4	9/11	247	3/11	252	30/10	58

Figure 8 Sites report, ranked by Probe date

In this example, site 6 - Field V15 - is using 1.4mm/day and is due to be irrigated on 16/11, followed four days later by site 7 - Field V5 - on 20/11. However, Field V15 will need to be irrigated on 13/11 if the daily water use rises to 1.8 mm/day

Crop Management

Other information can be recorded and graphed with the software, which can then be related back to soil moisture measurements and irrigation scheduling. The neutron probe can be used as a complete management tool rather than just an instrument to measure soil moisture.

Data can be either entered manually (fruit size, for example), or imported automatically from weather stations or other soil moisture loggers. The data appears to the user in one consistent form - on the screen, in graphs, or in reports

The software can also do calculations, such as ‘rate-of-change-of size’ or ‘accumulate’ daily water use to give total water consumption.

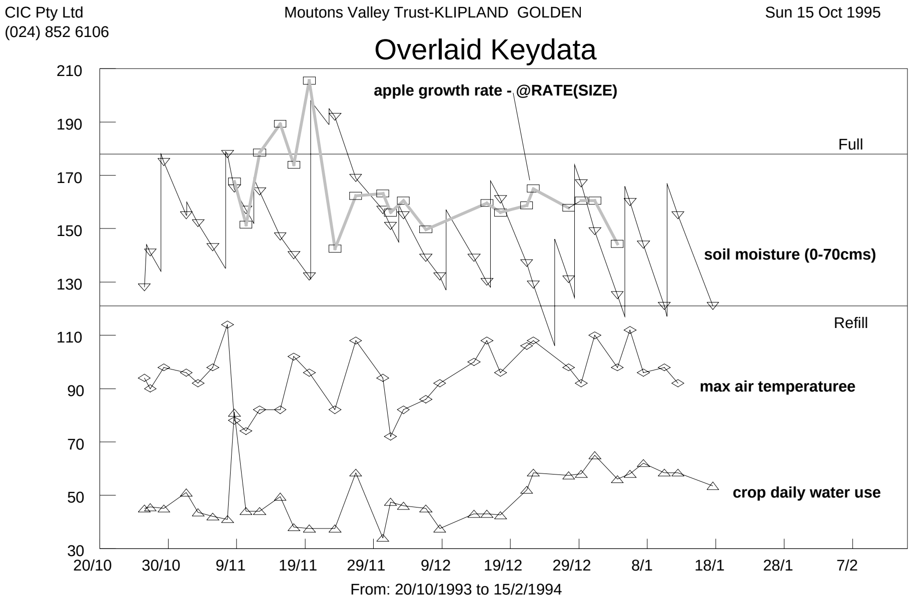

Figure 9 Time graph displaying moisture, daily water use, temperature and growth rate of the crop

The crop size was recorded in the software as item **`SIZE`**, and a formula - **`@RATE(SIZE)`** - then automatically calculated the rate-of-growth. In this example the mean air temperature was entered manually, but could have been downloaded from a weather station or service and automatically plotted on every time graph.

Figure 10 shows a comparison between six varieties of potatoes and their total cumulative water consumption. The formula **`@CUM(ProbeDWU)`** will automatically do the calculation. In this trial the total water consumptions of different varieties was being compared with the resulting yield - there is typically a strong correlation between yield and water through the plant.

The six sites were plotted on the same graph by ‘overlaying’.

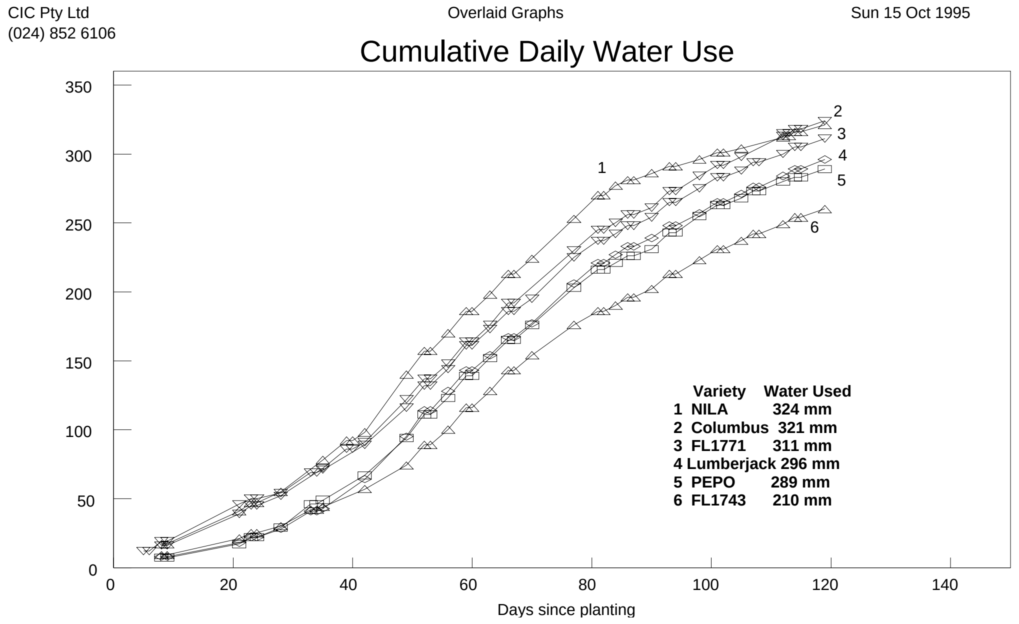

Figure 10 Time graph displaying cumulative water use for different varieties of potatoes from planting through to maturity.

Figure 11 is from apples, and allows the grower to compare the actual fruit size with the ideal size required by the packing shed at different stages of the season. In practice, the graph would also show total root zone water content and crop water use to find the relationship between growth and soil water status.

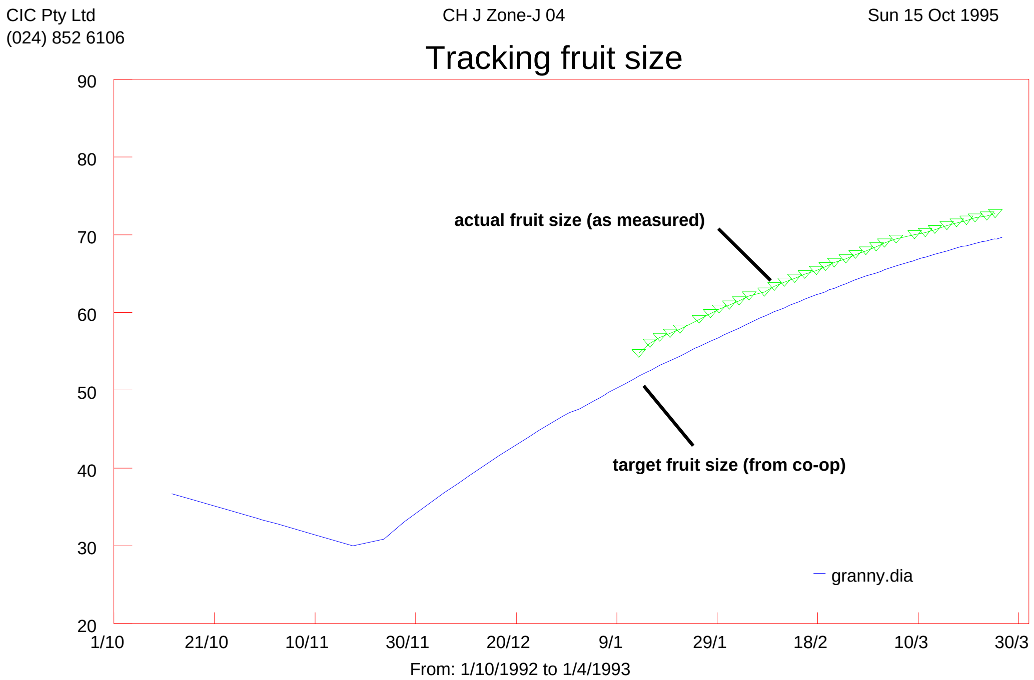

Figure 11 Tracking fruit size - actual fruit size and packhouse target fruit size

The actual fruit size was measured from the crop, and recorded in the software. The packhouse target line was based on target sizes supplied by the packers and entered just once in a ‘lookup’ table - it can then be displayed on any site’s time graph

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