VEGETABLE FARMING ON THE BEACH – IMPROVING IRRIGATION SCHEDULING TO AVOID THE ENVIRONMENTAL BACKWASH

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ABSTRACT

About half of Western Australian vegetable production is on coarse sandy soils that have a clay content of less than 3 per cent and that are low in organic carbon. The high hydraulic conductivity and low ionic capacity of these soils maximise the potential for water and nutrients to pass beyond the rooting zone of plants and present a major production and environmental challenge for the vegetable industry.

In 2005 a Horticulture Australia Ltd/Vegetable industry levy funded project allowed the Department of Agriculture and Food, Western Australia to employ a development officer to work with farmers growing vegetables on sandy soils in Western Australia to encourage adoption of better irrigation and nutrient management.

The project aim was to use a multi-pronged approach to educate and encourage vegetable growers to adopt available new technology to improve their water and fertiliser use efficiency. Soil moisture probes and continuously recording rain gauges installed on farm advised growers of their irrigation timing and depth via a graphical interface emailed to them regularly. Weekly soil analysis and measurement of leachate collected in lysimeters installed below the crop monitored fertiliser practice and leaching and estimated crop water use. Crop factors, derived from linesource experiments, and recommended for scheduling irrigation were validated by research trials at the Medina Research Station. The on-farm program was supported by extension articles published in the local grower magazine.

Twenty five crops, carrot (8), leafy crops (11), corn (2), leek (2) and potato (2) were fully monitored and a further 15 were monitored with soil moisture probes and rain gauges only. Few growers reliably scheduled irrigation to meet crop water demand for different growth stages and consequently most crops were subjected to periods of either over or under-watering. The soil moisture probes used were reliable and could be used to fine tune irrigation scheduled using crop factors applied to daily evaporation to account for individual crop differences caused by site specific differences.

Fertiliser practice for carrot production was generally good with only 23 per cent of the average 200 kg of nitrogen applied for each crop being recorded in leachate. In contrast, more than 60 per cent of the nitrogen applied to leafy crops was collected in leachate. Semi-quantitative test strip nitrate analysis of soil proved to be a good indicator of the effectiveness of fertiliser programs and the nitrogen status of crops.

INTRODUCTION

Over half of Western Australian vegetable production occurs on a narrow strip of land between the coast and the Darling scarp called the Swan Coastal Plain. The Aeolian soils of this region contain less than 3 per cent clay, and 1 per cent organic carbon, are coarse textured and are void of structure. Vegetable production on these coarse sandy soils can result in a high percentage of applied fertiliser being leached below the root zone into groundwater, (Sharma et al. 1994, Lantzke 1997). Increasing demand for groundwater for urban use and for maintaining natural ecosystems means that continued access to water, and the expansion of vegetable cropping on sand will depend on the vegetable industry being able to demonstrate efficient water and nutrient use.

In the absence of quantitative information a common view was that vegetable growers had poor irrigation practice and that few growers reliably scheduled irrigation to meet crop water demand for different growth stages. In order to achieve high yield crops were generally over watered and supplied with excess nitrogen fertiliser. Evaporation data, available from nearby weather stations, and locally developed evaporation replacement factors (crop factors) were not being used to schedule irrigation efficiently.

The coarse nature, low clay content, high hydraulic conductivity and low field capacity of the sandy soils of this area mean that in order to achieve optimum yields these soils must be maintained near field capacity. Producing optimum yields while minimising nutrient leaching can only be achieved by adopting good irrigation practice and applying appropriate rates of fertiliser, with correct timing and placement.

Horticulture Australia Ltd/National Vegetable Levy funding enabled Department of Agriculture and Food, Western Australia (DAFWA) to appoint a development officer, to work on-farm with vegetable growers to encourage improvement in irrigation systems, and water and nutrient use efficiencies. The approach of working closely with growers on farm was adopted as the preferred method of knowledge transfer, tailoring a program for each individual farm. This approach was seen as an essential follow-on from group training provided by the WaterWise program.

Grower involvement facilitated the collection of data on current practice and the education of the new technologies available to assist with scheduling irrigation. Water and nutrient use was intensively monitored on participating farms by installing soil moisture probes and rain gauges to continuously record soil moisture and irrigation. Samples to determine soil nutrient status and nutrient leaching were taken weekly.

A series of articles published in WA's vegetable growers' magazine, *The WA Grower,* introduced the project to growers, supplied written information and reinforced the water and nutrient use efficiency message. Articles detailed how growers could test and improve their irrigation systems, schedule irrigation using daily evaporation and crop factors, use soil moisture probes to validate irrigation and invited growers to participate in the project.

A web-based irrigation scheduling module is being developed and linked to the Department's online weather station network. This is being done in collaboration with the WA Vegetable Growers' Association with support from a Western Australian Government Premier's Water Foundation Grant as part of a State Water Initiative. Additional weather stations have been established and live weather information made available through a mobile phone text message service to assist growers to use daily evaporation to schedule irrigation.

ON FARM MONITORING

Before monitoring commenced the participating farm's irrigation system was assessed and sprinkler uniformity was tested to establish that it was operating at an acceptable standard. The accepted standards of DU 75% and CU of 85% were considered a minimum requirement to allow irrigation to be scheduled without the risk of some areas of the crop being severely under-watered. Minor operating changed were made to enure that sprinklers were operating at recommended pressures, that sprinkler risers were straight, that all sprinklers had the same nozzles and that all sprinklers in the monitored area were of the same type. Where possible the grower was involved in the sprinkler testing process to gain a greater understanding of the irrigation uniformity and 'applied' versus 'calculated' application rate.

A typical area of the farm was chosen. Depth and timing of irrigation were measured with a continuously recording tipping bucket and weekly irrigation totals confirmed using simple rain gauges. Volumetric soil moisture and drainage were continuously monitored for at least three depths by TDR soil moisture probes placed in the top 60 cm of the soil profile. Sensors at 0-15 cm and 15-30 cm monitored the effective root zone soil moisture while a lower probe at 30-60 cm probe monitored water that moved beyond the effective root zone.

On most sites soil tension at 15 cm and 30 cm depth was continuously monitored using a tensiometer fitted with a pressure transducer.

Computer software 'R-Logger', developed using the freely available 'R' program, allowed irrigation timing, depth and soil moisture to be summarised via a graphical interface and emailed as a PDF to participating growers regularly.

Drainage and nutrients leaching below the root zone were estimated weekly using simple drainage lysimeters installed to collect water at a depth of 1 metre.

Nitrogen fertiliser practice was monitored each week by estimating the quantity of plant available nitrogen (kg/ha) in the soil. Twelve soil samples, taken at two depths, 0-15 cm and 15-30 cm using a sand auger, were bulked and analysed for nitrate concentration using an R.Q. Flex® meter after 50: 50 v/v aqueous extraction.

EQUIPMENT

The monitoring equipment used on farms:
Campbell's CR200 data logger.
Campbell Scientific CS-625 volumetric water content (vwc) probes, logged every 15 minutes.
Irrometer® tensiometers fitted with a low tension tip and a pressure transducer.
Ecowatch® 7852 tipping bucket rain recording in 0.2 mm increments. Time stamping of the data enabled the timing and quantity of each irrigation event to be recorded.
Maxon MM-5100 modem.
The logger and modem were housed in a safe case.
The unit was powered by a 7.5 Ah, 12 Volt sealed lead acid battery recharged by a 10 watt solar panel.
Each complete unit had an approximate cost of $3000.

The Campbell's scientific TDR-type probes were selected from the range of commercially available soil moisture probes because of their relatively large sphere of influence, robust build, high resolution and precision. The probe consists of two stainless steel rods 300 mm in length and 3.2 mm in diameter, spaced at 32 mm, connected to a printed circuit board which is encased in an epoxy resin. The cables for each probe can be up to 300 m long (5-15 m used). Where necessary this allows the logger unit to be positioned outside the crop and reduces the risk of damage by machinery or workers. Soil moisture within a 3 cm radius around each probe is measured and averaged over the length of the probe (0.8 L of soil volume). Soil moisture over each 0-15 cm profile was measured by inserting the probes at the appropriate depth at a 30 degree angle into the undisturbed soil under a plant. Minimal disturbance of the soil profile being measured gave a good representative value with no preferential pathways formed around the probe. CS-625 probes measure volumetric water content of 0-50% with an accuracy of ±2.5% with a resolution of 0.1% and a repeatability (precision) of 0.1%. Field capacity of the sandy soils measured ranged from 9 to 13%.

Lysimeters were specially manufactured 700 mm deep plastic drums 500 mm in diameter. The collection area, 250 mm from the bottom, was separated from the soil by 100 micron geo-fabric supported on a grate. Two hoses, air inlet and collection, were run to the soil surface and leachate was collected by vacuum pump. The lysimeters were installed by hand, such that the geo fabric was 1m below the soil surface. A template, slightly larger than the lysimeters, was used during installation to minimise the disturbance of the soil. Care was taken not to mix the soil profile.

The DAFWA weather station network has 8 live stations on the Swan Coastal Plain. These stations measure: wind speeds, wind direction, solar radiation recorded at 3 m above ground, air temperature and relative humidity measured at 1.5 m height, soil temperatures at 40 mm below ground surface and rainfall at standard raingauge height of 350 mm to a resolution of 0.2 mm. A modified Penman Monteith equation is used to calculate evaporation equivalent to a Class A evaporation pan. The live weather stations are accessible from the Department's website (www.agric.wa.gov.au) and from a link on the vegetablesWA website (www.vegetableswa.com.au).

In September 2006 a service to send live weather station evaporation data direct to vegetable growers by mobile phone text message was introduced. This was a cooperative project with vegetablesWA (vegetable growers association) funded by the Western Australian Premier's Water Foundation. The daily text message is sent at a time set by the grower and includes daily evaporation from midnight to midnight, rainfall for the 24 hours prior to the message being sent and the weather forecast from the nearest Bureau of Meteorology forecasting site.

DATA PRESENTATION

Growers received charts (Figure 1) of soil moisture and irrigation at least weekly. The charts allowed irrigation timing and depth, to be compared to the changes in soil moisture in each profile. They showed the time taken for the wetting front to move through each profile and to what depth each irrigation event affected soil moisture. An increase in soil moisture of the 0-15 cm profile was seen when irrigation was applied. Soil moisture in this profile then decreased as a result of crop water use, evaporation and drainage. If irrigation was heavy and greatly exceeded the field capacity of the soil a steep decrease in soil moisture of the 0-15 cm profile and an increase of soil moisture at 15-30 cm indicated drainage to this profile. An increase of soil moisture in the 30-60 cm profile indicated deeper drainage. The steepness of the rise and the fall of the slope of the soil moisture chart indicated the severity of the drainage event.

When irrigation scheduling was good no major change was seen in the soil moisture level of the 30-60 cm profile but if irrigations were too heavy or too light this deeper probe would start to rise or fall.

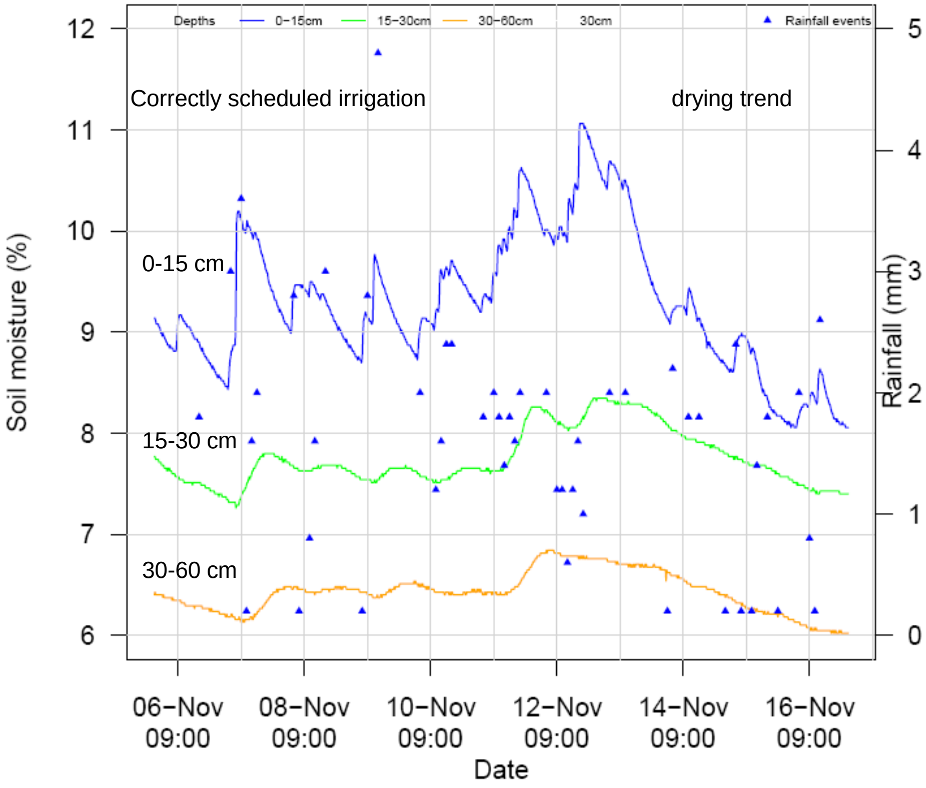

Figure 1. Soil moisture at 3 depths showing decreased irrigation frequency causing lower profiles to dry. Irrigation events or rainfall indicated by triangles.

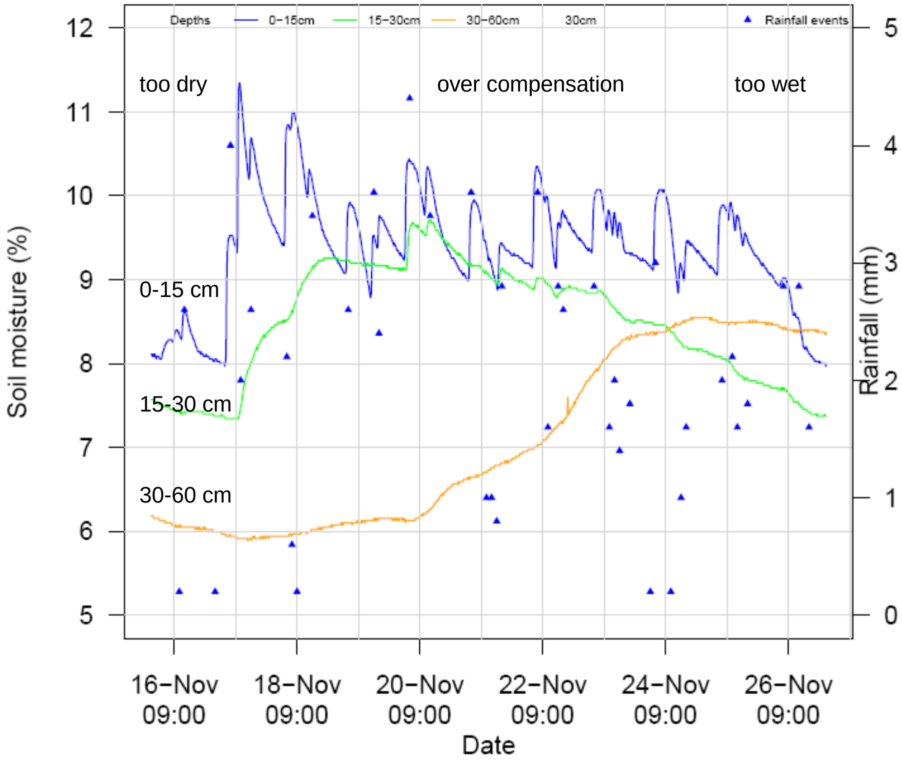

Figure 2. Soil moisture at 3 depths,showing increased irrigation depth and frequency causing 30-60 cm profile to become too wet after a dry period. Irrigation events or rainfall indicated by triangles

Soil nitrate nitrogen content, the volume of leachate and the quantity of nitrate nitrogen collected in the lysimeters was discussed with growers each week. A chart showing weekly soil nitrate nitrogen, nitrate leached and nitrogen applied as fertiliser was prepared after crop harvest (Figure 3).

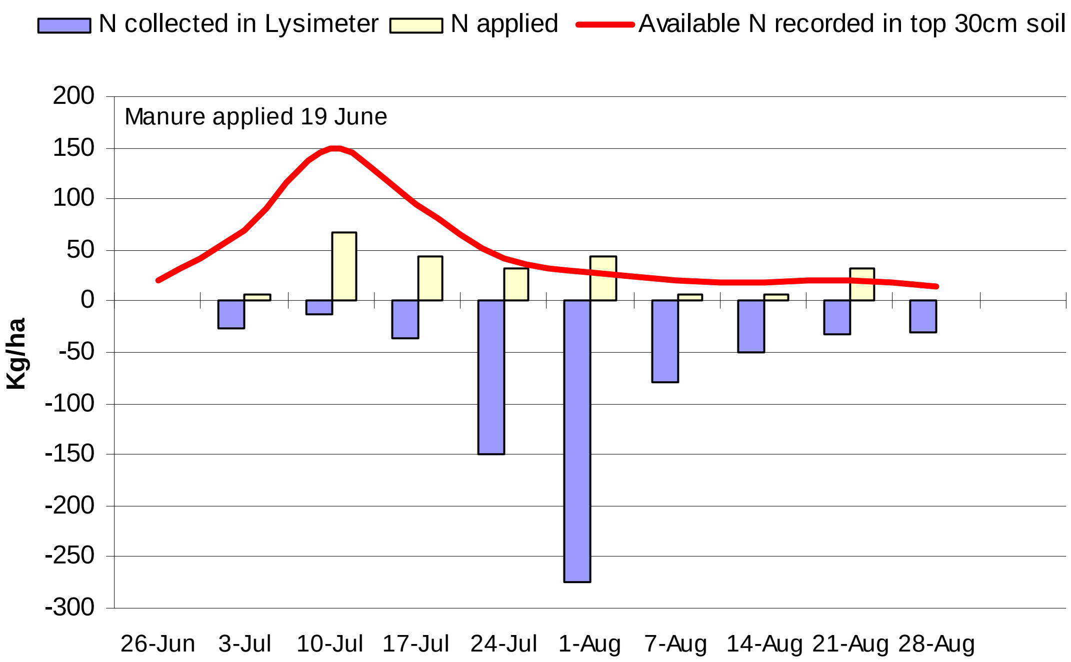

Figure 3. Soil nitrate nitrogen 0-30 cm, fertiliser nitrogen applied during the cropping period (negative figures indicate estimated nitrate nitrogen leached). 50 m^3/ha pre-plant fowl manure applied to crop.

SUMMARY

Twenty-five crops, carrot (8), leafy crops (11), corn (2), leek (2) and potato, (2), on fifteen properties were monitored using TDR probes, tipping bucket rain gauges and simple catch can lysimeters and a further 15 crops were monitored using TDR soil moisture probes only.

Initially the majority of crops were not scheduled using evaporation and recommended crop factors. Management and farm issues such as spraying, wind conditions and water availability often led to irrigation being altered.

Once growers were confident in the use of the soil moisture probes they were asked to schedule using evaporation from local weather stations and crop factors derived from linesource experiments validated by research trials at the Medina Research Station.

Five of the eight carrot crops monitored received less total water than the amount calculated using daily evaporation and crop factors recommended for carrots. Two crops received more water and one received the recommended amount. The two crops that received more water than recommended were grown over summer-autumn. All crops experienced periods of over and under watering.

Six of the 11 leafy crops monitored received more water than recommended but three of these were grown during periods with significant rainfall. The remaining five received less water than recommended.

The average plant water use, calculated by subtracting drainage from applied irrigation, was 95 per cent of evaporation for carrots and 70 per cent for leafy crops.

On average 200 kg of fertiliser nitrogen was applied to carrot crops and 23 per cent of this was collected in the lysimeters installed below the crop. Leafy crops fertilised with pre-plant poultry manure received an average of 427 kg of applied nitrogen and 68 per cent of this was collected in the lysimeters. Crops fertilised with inorganic fertiliser only, received an average of 340 kg of nitrogen, 63 per cent of which was collected in the lysimeters.

CONCLUSIONS

The monitoring system developed allowed growers to view the level of soil moisture under their crops and determine how evaporation, irrigation depth and timing controlled their crops demand and supply of water. Growers developed an understanding of how decisions to apply additional water for sand control, crop cooling or fertigation affected nutrient supply and leaching and how restriction to watering because of spraying, cultivation or water shortages impacted on plant water availability.

Monitoring confirmed that the crop factors recommended by DAFWA maintained sandy soils close to field capacity and water savings could be made by using soil moisture probes to adjust crop factors to account for individual crop vigor and site specific soil and location variation.

The process of change in irrigation management in the vegetable industry is slow and challenging. The use of crop factors and daily evaporation adjusted to specific farm conditions using soil moisture monitoring will improve water use efficiency on the coarse sandy soils in WA. The tools and the system are available to industry and the activities of this project have drawn favourable comment and interest in improving current irrigation practice. The project has initiated improvement in people's knowledge of irrigation scheduling and is precipitating change in grower attitude towards managing the interaction of water and nutrients on coarse sandy soils. The next step is to achieve industry-wide adoption of good irrigation and nutrient practices.

REFERENCES

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