Managing irrigation with a Wetting Front Detector

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WFD is not the Water Framework Directive in this instance but the Wetting Front Detector. This is a relatively low-cost device developed at CSIRO in Australia for aiding and supporting good irrigation scheduling. It is also a useful tool for monitoring nutrient losses and so in this way it could prove to be a very useful tool for compliance with the more traditional meaning of WFD.

Irrigation scheduling is about knowing when to apply water and how much. The scientific tools needed to schedule irrigation are well developed. Tensiometers have been used since the 1930s (Richards and Neal 1936), and may still be the most widely used piece of equipment for monitoring soil water status. The Neutron Probe was developed in the 1950s (Gardner and Kirkham 1952) and five decades later is regarded by many scientists as the most accurate method of measuring soil water content (Evett et al. 2002). More recently a range of 'user friendly' capacitance devices have come onto the market, based on the measurement of the dielectric property of soil (Charlesworth 2005).

Given these tools, and the inexpensive logging equipment that goes with them, irrigation scheduling should be easy. It remains a conundrum therefore that the latest agricultural census in Australia, a country in the forefront of irrigation research and development and facing severe water shortages, showed that almost 80% of commercial irrigators still do not monitor soil water status (ABS 2005).

Water front detector

In response to low adoption of existing irrigation tools, a Wetting Front Detector (WFD) was developed in an attempt to attain maximum simplicity. A WFD is basically a switch, which alerts the irrigator that a front of a given strength has passed a given depth in the soil (Stirzaker 2003). The WFD comprises a specially shaped funnel, a filter and a mechanical float mechanism (figure 1).

The funnel is buried in the soil within the root zone of the plants or crop. When rain falls or the soil is irrigated, water moves downwards through the root zone. The infiltrating water converges inside the funnel and the soil at the base becomes so wet that water seeps out of it, passes through a filter and is collected in a reservoir. This water activates a float, which in turn operates an indicator flag above the soil surface. There are no wires, no electronics and no batteries.

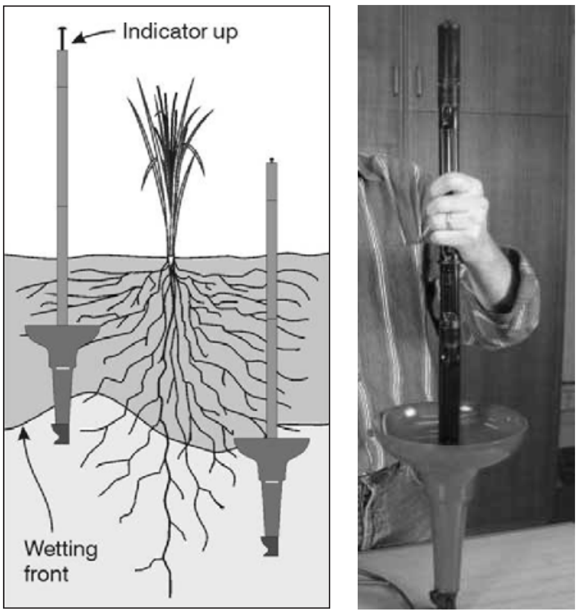

FIGURE 1
A FullStop Wetting Front Detector (WFD). The funnel part is buried in the soil with the black tube protruding above the soil surface. When a wetting front reaches the detector a red indicator pops up. Detectors are usually placed in pairs, about one third and two thirds down the active root zone.

If the soil is dry before irrigation, the wetting front will not penetrate deeply because the dry soil absorbs most of the water. A long irrigation would be needed to activate a detector. However, if the soil is relatively wet before irrigation, it cannot store much more water, so the wetting front penetrates deeply (Stirzaker 2003, Stirzaker and Hutchinson 2005).

Knowing how deep a wetting front moves into the soil is critical for irrigation management. If a crop is given frequent but light sprinklings of water, the wetting front will not go deep and the WFD will not be activated. Much of the water will evaporate from the soil surface. If too much water is applied at one time, the wetting front will go deep into the soil, perhaps below the rooting depth of the crop, wasting water, nutrients and energy.

An interactive tool

The WFD is an interactive tool. Even before placing the detectors in the ground, the irrigator has to decide how deep he wants the water to go and why. Wetting Front Detectors are usually used in pairs. The first is buried about one third of the way down the active root-zone. The second is buried about two-thirds the depth of the active root-zone (Figure 1). The active root-zone is depth of soil in which most of the roots are found, or the maximum depth of soil aimed to wetted by irrigation. The irrigator then watches the shallow and deep detectors respond through the season, to see how this matches their expectations.

One of the more common findings on-farm is that water penetrates more deeply under drip irrigation than many irrigators expect. Wetting Front Detectors have also alerted growers that they tend to apply too much water at the start of the season and tool little during the exponential growth phase (e.g. Stirzaker and Wilkie 2002).

Nutrient sampling

As well as informing the irrigator that the wetting front has reached a certain depth, the detector retains a sample of water which can be extracted via a tube using a syringe. This can be analysed for its salt or nitrate concentration. This is done using a simple field salinity meter or colour nitrate test strip (Figure 2). Our experience has been that monitoring electrical conductivity or nitrate levels can tell you more about irrigation management than measuring water content itself. For example nitrate levels will drop sharply if over-irrigation occurs (Stirzaker and Wilkie 2002). Depending on the quality of the irrigation water, EC levels will gradually rise during periods of under-irrigation (Stirzaker et al 2004, Stirzaker and Thomson 2004).

Soil water monitoring is far more advanced than soil solution monitoring. But in the case of nitrate the two are inextricably linked. Stirzaker (1999) estimated the N-use efficiency for a selection of horticultural crops in Australia by comparing the application rates recommended by State agencies against the N-removal in crops. Even if farmers limited themselves to recommended rates, and obtained high yields, the efficiency of N-use would be 30 to 50%. Greenwood et al. (1974) present N recoveries of 7% for lettuce, rising to 65% for potatoes under conditions in the United Kingdom. This highlights the need for farmers to manage their water and nutrients together.

Some limitations

All tools have their limitations and it is necessary to work within them. The WFD does not tell an irrigator when to start irrigating - it simply informs them how well the last irrigation filled the profile and helps them to make a decision about the timing and duration of the next irrigation. The WFD also has a sensitivity limitation of 2 to 3 kPa. After irrigation has ceased and redistribution of water occurs down the profile, the

FIGURE 2
Each time a Wetting Front reaches the detector a small sample of water is retained. This can be removed using a syringe. Routine measurement with a robust field Electrical Conductivity meter can show if fertilizer levels are too high or low, or when leaching is required to remove salt. Colour strips can be used to give a quick check of nitrate levels in the soil.

wetting fronts become weaker and can fall below the detection limits of the WFD. In some situations we have observed significant amounts of water passing deep detectors without activating them. Work is continuing on more sensitive WFDs for specific applications.

Availability

The commercial version of the Wetting Front Detector has now been released for one year with several thousand in use. Feedback from irrigators is largely positive, but the depth of placement is critical to success. A common problem has been placing the deep detector too deeply - where it is rarely activated. The key to getting the best response from the WFD is to ensure that the placement depths are right for the irrigation method, frequency and soil type. This 'fine-tuning' can only be done at farm/region level - the optimum placement depths need to be worked out on the ground by the leading farmers and advisors.

The Wetting Front Detector does not replace other scheduling tools, but should be used together with whatever method a farmer is comfortable with. One of the key insights the researchers have gained in working with farmers is that the detector is a learning tool. It gets farmers and extension workers talking and asking questions, and ultimately learning together.

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