Scholefield Robinson
HORTICULTURAL SERVICES

Managing soil degradation in orchards which utilise high fertiliser inputs

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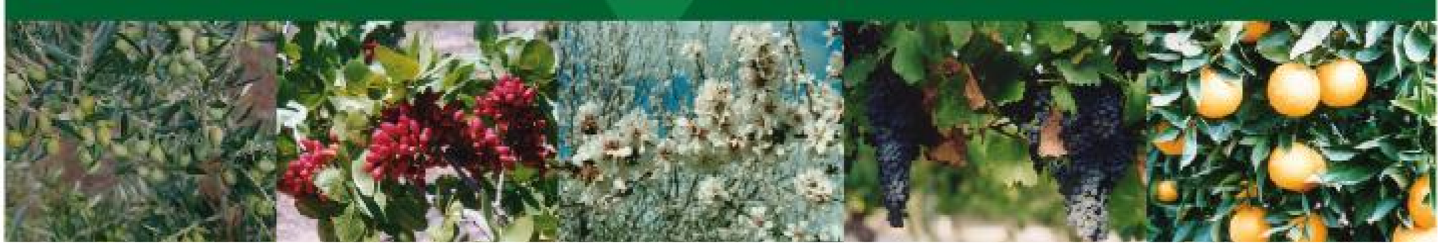

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1 EXECUTIVE SUMMARY

In recent years, there has been a major change in the approach to fertiliser management in almond and citrus production in Australia. Along with improvements in irrigation management and fertiliser application methods (e.g. fertigation), the amount of fertiliser (particularly nitrogen and potassium) applied by many growers has increased substantially. However, whilst increased fertiliser inputs may result in increased yields in almond and citrus orchards, the potential impacts of these rates of application on soil chemical characteristics, particularly soil pH, has not been assessed.

Through assessment of the impact of high fertiliser inputs in almond and citrus orchards, this project aimed to increase the sustainability of land use in the Riverland West Local Action Planning (RWLAP) area. Specific aims of the project included:

1. Assessment of the impacts of high fertiliser inputs on key soil parameters in almond and citrus (orange) orchards in the RWLAP area.
2. Assessment of leaching of nutrients through the use of FullStop™ wetting front detectors.
3. Development of Microsoft® Excel® based calculators of soil pH change in almond and citrus orchards.

Impacts of high fertiliser inputs on key soil parameters

Composite topsoil and subsoil samples were collected by growers from three positions at each site (under trees, mid row and a nearby external reference (undeveloped) location) following a simple sampling protocol. Key issues highlighted by the soil analysis data include:

- There has been significant acidification of soil under trees in two of the almond orchards. Acidification of under tree soils has also occurred in the remaining almond orchard but to a lesser extent. This acidification is probably related to the use of acidifying nitrogen fertilisers and the extensive removal of alkalinity as fruit.
- There has been considerably less acidification of soils in the citrus orchards compared to that observed for almonds. This probably reflects the lower rates of acidifying nitrogen fertiliser used in citrus orchards.
- There has been no accumulation of phosphorus reserves in the almond orchard soils despite the application of phosphorus fertiliser. There is a need to further investigate the phosphorus fertiliser use by almond growers.
- There are good reserves of phosphorus in the mid row and under tree soils from all citrus orchards. Further applications of phosphorus fertiliser to these orchards are not necessary at this stage. Instead, the growers should rely on the reserves of phosphorus in the soil and use leaf analysis to monitor the phosphorus status of the trees.
- Accumulation of potassium in the almond orchard soils reflects the substantial quantities of potassium fertiliser applied to these orchards in recent seasons.

FullStop™ wetting front detectors

FullStop™ wetting front detectors were installed by growers at each site to assess leaching of nutrients from the soil profile. These proved to be an inexpensive tool that growers can use to assess their irrigation practice and if placed at sufficient depth, could feasibly be used as a guide to leaching requirements. However, whilst it was possible to assess the presence or absence of nitrate-nitrogen in leachate collected from the FullStop™ wetting front detectors, the volume of leachate generated was generally insufficient to allow laboratory analysis.

Calculators of Soil pH Change

Calculators of Soil pH Change were developed for almond and citrus orchards using soil analysis data generated in the project and management information provided by growers. Note that whilst calculators were developed for citrus orchards, the lack of data on ash alkalinity of citrus fruit resulted in these calculators not being fully functional. Once data is available, these calculators will be functional and can be validated.

Conclusions

The Calculators of Soil pH Change developed for almond and citrus orchards using soil analysis and orchard management information will be valuable tools for almond and citrus growers across Australia. Although not absolutely accurate, the calculators can be used to provide a reasonable estimate of the rate of soil pH change as a result of a set of particular orchard management practices. In fact, the calculators can and should be regarded more as 'learning' tools as they enables growers to alter management strategies to limit soil pH change. It should be remembered that the Calculators were designed to be used in conjunction with but not instead of regular soil testing which remains the most reliable method of assessing soil pH.

Apart from being used to validate the Calculators of Soil pH Change, analyses conducted on soil samples collected from almond and citrus orchards in the RWLAP area highlighted several key issues including significant acidification of soil in two of the almond orchards, accumulation of phosphorus reserves in the citrus orchard soils and accumulation of potassium in the almond orchard soils.

FullStop™ wetting front detectors were installed at each orchard site and proved to be inexpensive tools that growers can use to assess their irrigation practice. These detectors could feasibly be used to assess loss of nutrient via leaching if sufficient leachate is generated from the detectors to allow laboratory analysis.

2 BACKGROUND

In recent years, there has been a major change in the approach to fertiliser management in almond and citrus production in Australia. Along with improvements in irrigation management and fertiliser application methods (e.g. fertigation), the amount of fertiliser (particularly nitrogen and potassium) applied by many growers has increased substantially. For example, traditional rates of nitrogen and potassium fertiliser applied to an almond orchard over a season would be in the vicinity of 150kg actual nitrogen and 100kg actual potassium per hectare of orchard. However, in recent trial work in the Riverland, favourable almond yield increases in response to higher fertiliser applications has seen some growers use rates of nitrogen and potassium fertiliser as high as 400kg actual nitrogen and 600kg actual potassium per hectare of orchard. Whilst the rates used for citrus production are not as high as this, there has also been a general increase in fertiliser use in this industry.

Whilst increased fertiliser inputs may result in increased yields in almond and citrus orchards, the potential impacts of these rates of application on soil characteristics has not been assessed. In particular, there is a real potential to induce soil acidification and soil sodicity at these rates. Both can have serious and lasting impacts on productivity and the soil environment. Whilst amelioration of these conditions is possible with lime and gypsum, this can be very costly, especially if lower soil layers need to be treated.

Through assessment of the impact of high fertiliser inputs in almond and citrus orchards, this project aimed to increase the sustainability of land use in the RWLAP area. Specific aims of the project included:

1. Assessment of the impacts of high fertiliser inputs on key soil parameters in almond and citrus (orange) orchards in the RWLAP area.
2. Assessment of leaching of nutrients through the use of FullStop™ wetting front detectors.
3. Development of Microsoft® Excel® based calculators of soil pH change in almond and citrus orchards.

3 MATERIALS AND METHODS

3.1 Site Selection

In consultation with RWLAP association and interested local irrigators, three orange blocks and three almond blocks within the RWLAP area were selected for soil sampling and installation of FullStop™ wetting front detectors. Participating growers were also asked to complete a questionnaire (Appendix 1) regarding orchard details and management practices. A summary of the management information provided by each grower is shown in Table 1.

3.2 Soil Sampling and Analysis

Composite topsoil (0-15cm deep) and subsoil (15-30cm, 30-45cm and 45-60cm deep) samples were collected by growers from three positions at each site (under trees, the mid row and a nearby external reference (undeveloped) location) following a simple sampling protocol (Appendix 2). The external reference site provided an indication of soil parameters prior to orchard development.

In summary, samples were collected from:

- 6 sites (3 citrus and 3 almond)
- 3 sampling positions (under dripper, mid row and an external reference point).

- 4 sampling depths (0-15cm, 15-30cm, 30-45cm and 45-60cm deep).

Composite soil samples were sent for analysis by CSBP Laboratories in Perth, Western Australia. Each sample was analysed for the following:

- Soil pH (water) (Method 4A1 – Rayment and Higginson, 1992)
- Soil pH (calcium chloride) (Method 4B2 – Rayment and Higginson, 1992)
- Organic Carbon (Walkely and Black, 1934)
- Nitrate-nitrogen – 2M KCl extraction (Searle, 1984)
- Ammonium-nitrogen – 2M KCl extraction (Searle, 1984)
- Extractable Phosphorus – Colwell method (Method 9B1 – Rayment and Higginson, 1992)
- Extractable Potassium – Colwell method (Method 9B1 – Rayment and Higginson, 1992)
- Extractable Sulfur – 0.25M KCl extraction (Blair *et al*., 1991)
- Exchangeable Cations (Ca, Mg, Na, K) – 0.1M $BaCl_2$ / 0.1M NH_4Cl extraction (Method 15E1 – Rayment and Higginson, 1992)
- DTPA Extractable Trace Elements (Cu, Zn, Mn, Fe) (Method 12A1 – Rayment and Higginson, 1992)
- Extractable Boron – Hot 0.01M $CaCl_2$ extraction (Method 12C1 – Rayment and Higginson, 1992)
- Extractable Aluminium – 0.01M $CaCl_2$ extraction (Bromfield, 1987)
- Electrical Conductivity – 1:5 soil:water extract (Method 3A1 – Rayment and Higginson, 1992)
- Electrical Conductivity – saturated paste extract (Method 2D1 – Rayment and Higginson, 1992)
- Soluble Chloride (Method 5A2 – Rayment and Higginson, 1992)

3.3 FullStop™ Wetting Front Detectors

3.3.1 Installation and settling

FullStop™ wetting front detectors were installed by growers at each orchard site according to manufacturer's instructions (Appendix 3). Briefly, the installation process involved construction of the detectors, preparation of installation holes, installation of detectors and backfilling. During installation there was considerable disturbance of the soil surrounding the detectors. Therefore, following installation in May 2008, the detectors were allowed to 'settle' for several months prior to leachate being collected.

Table 1: Summary of management information for each site selected in the project

Site	Variety	Rootstock	Tree Age	Soil Type	Yield (5 year average) t/hectare	Irrigation method	Years on current method and previous method	Irrigation rate ML/hectare		Fertiliser Inputs (5 year average) kg/hectare		Fertiliser application method
								2007/8	2008/9	Nitrogen	Potassium	
Citrus 1	Washington Navel	Rough Lemon	40+	Sandy loam	37.2	Undertree sprinkler	10 (previously overhead sprinkler)	11.5	8	122	75	Broadcast
Citrus 2	Washington Navel	Troyer Citrange	18	Sand	38.1	Undertree sprinkler (30% coverage)	2 (previously full cover sprinkler)	9	9	84	41	Fertigation in 2008/9. Previously broadcast.
Citrus 3	Washington Navel	Rough Lemon	24	Sandy loam	40.5	Microsprinkler (60% coverage)	NA	8.5	8.5	57	22	Fertigation in 2008/9. Previously broadcast.
Almond 1	Nonpareil, Carmel, NePlus, Price	Nemaguard	19	Sand	4.1	Full cover sprinkler	NA	16	16	357	544	Fertigation
Almond 2	Nonpareil, Carmel, NePlus	Hybrid	18	Sand	3.4	Drip	2 (previously full cover sprinkler)	15	15	300	330	Fertigation
Almond 3	Nonpareil, Carmel, Peerless, NePlus	Nemaguard	20	Sand	3.6	Full cover sprinkler	NA	15	15	310	339	Fertigation

3.3.2 Assessment of function of FullStop™ wetting front detectors

At regular intervals, growers were contacted to determine whether they had observed triggering of the FullStop™ wetting front detectors. If they had observed triggering of a detector, growers were then asked whether leachate collected from the detector contained any nitrate-nitrogen.

Initially, it was planned to conduct complete analysis of any leachate collected from the FullStop™ wetting front detectors. However, observations by growers indicated that the volume of leachate collected from the detectors was insufficient to enable complete analysis.

As a result, Hach® nitrate nitrogen test strips (Product No. 2745425) were provided to each grower to enable quick assessment of the presence of absence of nitrate-nitrogen in leachate collected in the FullStop™ wetting front detectors.

3.3.3 Grower impressions of FullStop™ wetting front detectors

Growers were asked to provide their overall impressions of the FullStop™ wetting front detectors. This included usefulness, strengths and weaknesses.

3.4 Calculators of soil pH change

3.4.1 General Information

Soil pH affects the availability of many nutrients to plants. In acidic soils, root growth is also restricted reducing the inability of a plant to explore the soil volume for water and hence nutrients. In alkaline soils, growth of plants can be adversely affected by zinc, iron, manganese and copper deficiencies.

Previous work has shown that long term use of ammonium or urea based nitrogen fertiliser results in acidification of soil whilst in some other districts, soil pH has tended toward alkalisation, presumably due to the composition of irrigation water.

The Australians and Natural Resource Management 2002 report published by the National Land and Water Resources Audit (NLWRA) estimated annual losses caused by soil acidification that were considered to be too high by the industry. In response to these claims, Scholefield Robinson Horticultural Services (Scholefield Robinson) completed a project for Land and Water Australia (LWA) in 2003-2004 entitled “Vineyard Acidification Audit” in which a Calculator of Soil pH Change in Drip Irrigated Vineyards was developed to allow assessment of the risk of soil pH change in drip irrigated vineyards. This calculator was then refined in a GWRDC funded project entitled “Soil pH Changes in Drip Irrigated Vineyards”.

Using soil analysis data and management information collected for this project, the Calculator of Soil pH Change in Drip Irrigated Vineyards was modified to produce Calculators of Soil pH Change for almond and citrus orchards.

3.4.2 Ash alkalinity of harvested almonds or citrus

To modify the Calculator of Soil pH Change in Drip Irrigated Vineyards for use in almond and citrus orchards, it was necessary to determine the ash alkalinity of the harvested almonds or citrus. Ash alkalinity (see Slattery *et al*., 1991) enables the estimation of removal of alkalinity in harvested almond fruit (hull, shell and kernel) and the resultant effect of acidifying soil. Ash alkalinity is calculated using the difference in molar concentrations of cation and anion analyses of harvested fruit/produce. It is recognised that this method may result in errors as nitrate and other trace element cations are not accounted for, but these errors are considered to be very small and hence insignificant.

To estimate ash alkalinity of almond or citrus fruit, comprehensive analysis of whole fruit is required. For almonds, data was available from previous nutritional analysis of almond fruit samples conducted by Scholefield Robinson. For citrus, attempts were made to locate nutritional analysis of whole fruit but were unsuccessful.

4 RESULTS AND DISCUSSION

4.1 Impacts of high fertiliser inputs on key soil parameters

Detailed soil analysis data for each site are shown in Appendix 4.

4.1.1 Soil pH and Exchangeable Calcium

Soil pH and exchangeable calcium results for almond and citrus orchards are shown in Table 2. Soil pH_{water} and soil pH_{Ca} are included as pH_{water} and pH_{Ca} are more reliable measures of pH in alkaline and acidic soils respectively. In the case of exchangeable calcium, the soils are not prewashed prior to analysis for exchangeable cations and so it is feasible to assume that calcium carbonate present in the soils will be reflected in the analysis.

Key results shown in Table 2 include:

- In Almond 1, there has been considerable acidification of soil under trees to a depth of 60cm. The mid row soils in Almond 1 have also been acidified but to a lesser extent compared to the under tree soil.
- In Almond 2, there has been moderate acidification of the topsoil under the trees. Lower soil depths and soils from the mid row have not been acidified to any great extent.
- In Almond 3, there has been considerable acidification of the topsoil under trees and in the mid row. Lower soil depths have not been acidified to any great extent.
- In Citrus 1, there has been moderate acidification of the topsoil and 15-30cm deep subsoil from under trees and the mid row space. Lower soil depths have not been acidified to any great extent.
- In Citrus 2 and Citrus 3, there has been some minor acidification of the topsoil under trees and mid row space. Lower soil depths have not been acidified.
- In all almond and citrus orchards, there have been reductions in the concentration of exchangeable calcium in most soils.

Table 2: Soil pH and exchangeable calcium

Site	Analysis	Position	Soil depth			
			0-15cm	15-30cm	30-45cm	45-60cm
Almond – all sites	pH_{water}	External reference	8.7	8.7	8.9	9.0
	pH_{Ca}	External reference	7.9	7.7	7.9	8.0
	Exchangeable calcium (meq/100g)	External reference	6.2	6.7	6.7	6.7
Almond 1	pH_{water}	Mid row	6.6	7.1	7.7	8.9
		Under tree	6.8	6.6	6.7	7.9
	pH_{Ca}	Mid row	5.7	6.3	6.7	8.0
		Under tree	5.8	5.6	5.7	6.9
	Exchangeable calcium (meq/100g)	Mid row	3.2	2.7	2.8	5.1
		Under tree	1.8	1.6	1.5	2.5
Almond 2	pH_{water}	Mid row	8.6	8.9	9.1	9.1
		Under tree	7.6	8.3	9.0	8.9
	pH_{Ca}	Mid row	7.7	7.9	8.1	8.1
		Under tree	6.6	7.9	8.0	7.9
	Exchangeable calcium (meq/100g)	Mid row	4.6	6.2	7.3	8.6
		Under tree	3.2	4.3	6.2	7.3
Almond 3	pH_{water}	Mid row	6.5	8.7	8.9	9.0
		Under tree	6.4	8.3	9.0	9.1
	pH_{Ca}	Mid row	5.5	7.8	8.0	8.1
		Under tree	5.4	7.4	8.1	8.1
	Exchangeable calcium (meq/100g)	Mid row	2.6	4.1	6.3	6.5
		Under tree	2.1	3.1	6.2	6.9
Citrus 1	pH_{water}	External reference	8.9	8.9	9.0	9.1
		Mid row	6.9	8.2	8.9	8.1
		Under tree	6.9	7.4	8.7	9.0
	pH_{Ca}	External reference	8.1	8.1	8.2	8.3
		Mid row	6.3	7.3	8.0	8.1
		Under tree	6.2	6.7	7.8	8.1
	Exchangeable calcium (meq/100g)	External reference	5.9	5.3	5.2	5.7
		Mid row	3.8	3.7	6.5	6.4
		Under tree	2.9	3.1	5.5	6.3
Citrus 2	pH_{water}	External reference	8.5	8.8	8.9	8.8
		Mid row	8.4	8.8	8.9	9.0
		Under tree	8.2	8.7	8.8	8.8
	pH_{Ca}	External reference	7.7	8.0	8.1	7.9
		Mid row	7.8	7.9	8.0	8.0
		Under tree	7.5	7.9	7.9	7.9
	Exchangeable calcium (meq/100g)	External reference	7.7	7.3	6.6	7.2
		Mid row	6.5	8.5	10.1	-
		Under tree	4.4	6.8	-	9.2
Citrus 3	pH_{water}	External reference	8.7	8.9	9.2	9.2
		Mid row	8.4	8.8	9.0	9.3
		Under tree	7.9	8.9	9.0	9.1
	pH_{Ca}	External reference	7.9	8.1	8.3	8.4
		Mid row	7.4	8.1	8.0	8.3
		Under tree	7.1	7.9	8.1	8.2
	Exchangeable calcium (meq/100g)	External reference	7.6	8.5	9.1	8.7
		Mid row	7.1	6.7	6.9	7.0
		Under tree	4.6	5.6	6.1	5.5

The acidification of the topsoil sample from Almond 3 and the topsoil, 15-30cm and 30-45cm deep soils from Almond 1 reflect the substantial use of acidifying nitrogenous fertilisers in these orchards (urea and ammonium based fertilisers) and the removal of alkalinity in the form of almond fruit. This removal of alkalinity in fruit results in an acidification effect in the orchard.

As discussed above, the soil analysis method used to assess exchangeable calcium does not include a prewash and so it is feasible to assume that calcium carbonate present in the soils was reflected in the analyses. Taking this into account, the decrease in exchangeable calcium in many of the almond and citrus orchard soils may reflect, to some extent, neutralisation of free calcium carbonate as a result of acidification. However, neutralisation of calcium carbonate would be expected to release calcium and an increase in exchangeable calcium might be expected. Alternatively, the calcium may have moved through the soil profile or been taken up by the trees. Clearly, further work is needed to determine the fate of calcium released when calcium carbonate is neutralised in these soils.

The presence of calcium carbonate in soil can be seen as a "safeguard" against acidification. However, once the carbonate is neutralised, soil pH may decrease rapidly if the soil has a low pH buffering capacity.

Treatment of soil acidity usually involves the application of lime and the use of non-acidifying nitrogen fertilisers. In this regard, a simple lime calculator has been included in conjunction with the Calculators of Soil pH Change. This allows growers to estimate the quantity of lime required to treat soil acidity depending on mode of application (i.e. broadcast, banded or applied under drippers).

4.1.2 Phosphorus

The phosphorus content of the soils from almond and citrus orchards are shown in Figure 1 and Figure 2.

Figure 1: Soil phosphorus - Almond

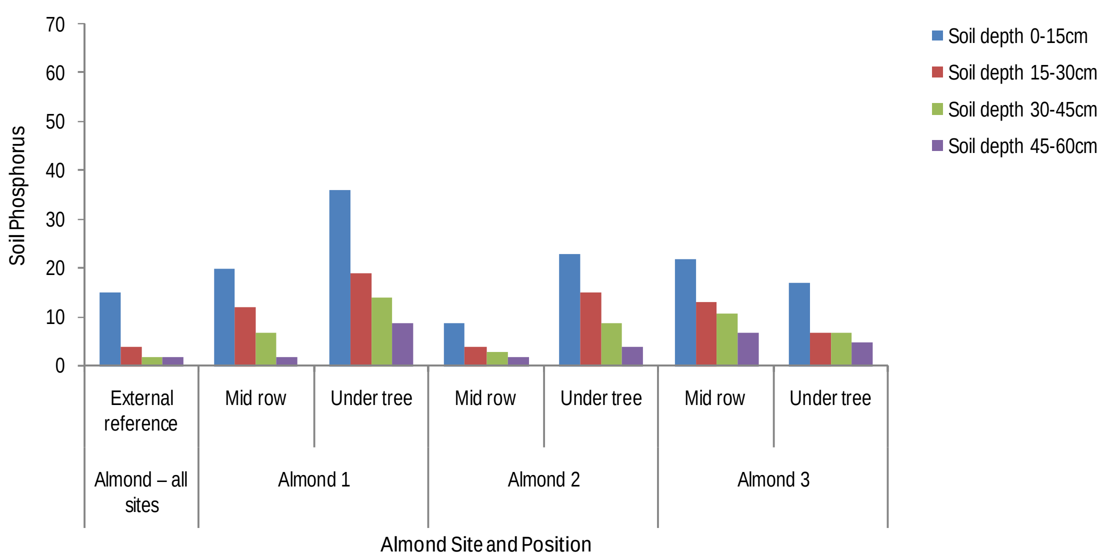
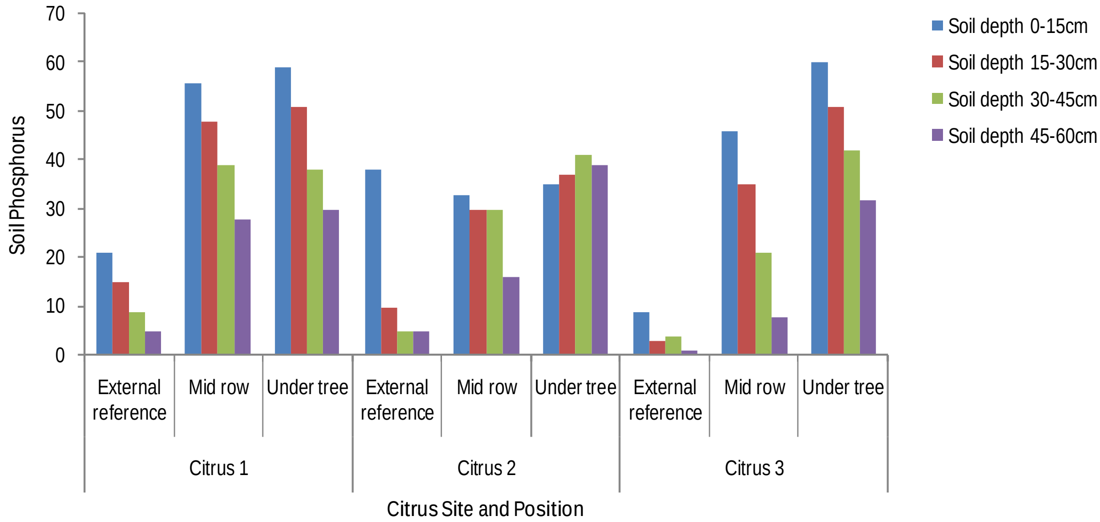


Figure 2: Soil phosphorus - Citrus



Key results shown in Figure 1 and Figure 2 include:

- There has been minimal accumulation of phosphorus in the soil in all almond orchards.
- There has been considerable accumulation of phosphorus reserves in the mid row and under tree soils in all citrus orchards. There has also been movement of phosphorus through the profile in the citrus orchards as shown by increases in the concentration of phosphorus in lower soil layers.

Whilst there has been some accumulation of phosphorus in the almond orchard soils, it was surprising that there were not greater reserves of phosphorus in these soils given that phosphorus fertilisers have been applied to the orchards in the past. This suggests that the phosphorus fertiliser applied has either been taken up by the trees or has been fixed in a form that is not available to the trees (and hence not detected in the soil analysis which assesses the amount of plant available in the soil).

The accumulation of phosphorus in the mid row and under tree soils in all citrus orchards reflects the substantial and regular applications of phosphorus fertiliser in these orchards. In the case of the mid row soils, the accumulation reflects the broadcast application of the phosphorus fertiliser. These results indicate that more than enough phosphorus fertiliser has been applied to these orchards in the past and further applications of phosphorus fertiliser to these orchards are not necessary at this stage. Instead, the growers should rely on the reserves of phosphorus in the soil and use leaf analysis to monitor the phosphorus status of the trees.

4.1.3 Potassium

The potassium content of the soils from almond and citrus orchards are shown in Figure 6 and 7.

Figure 3: Soil potassium - Almond

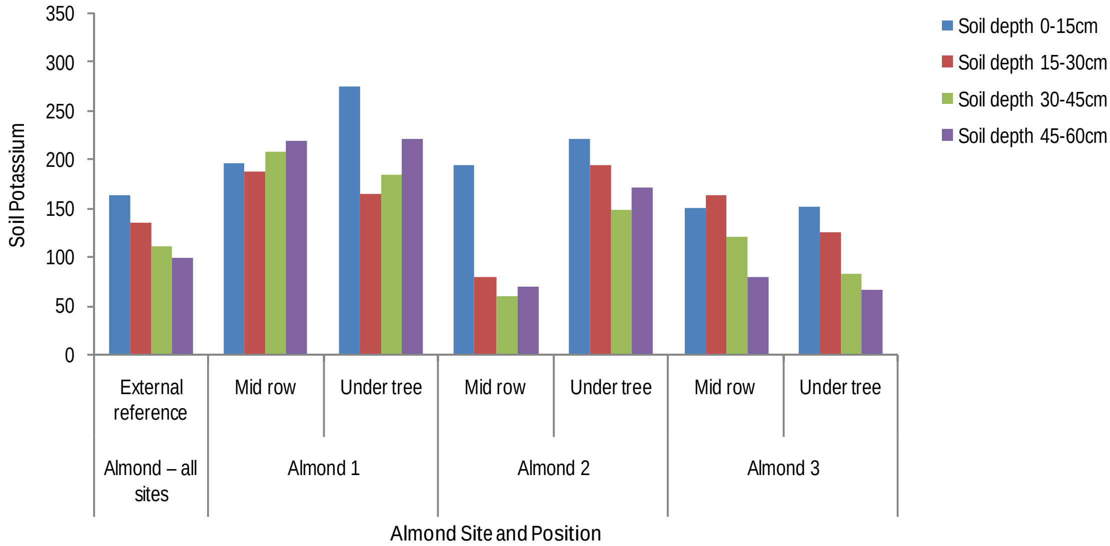
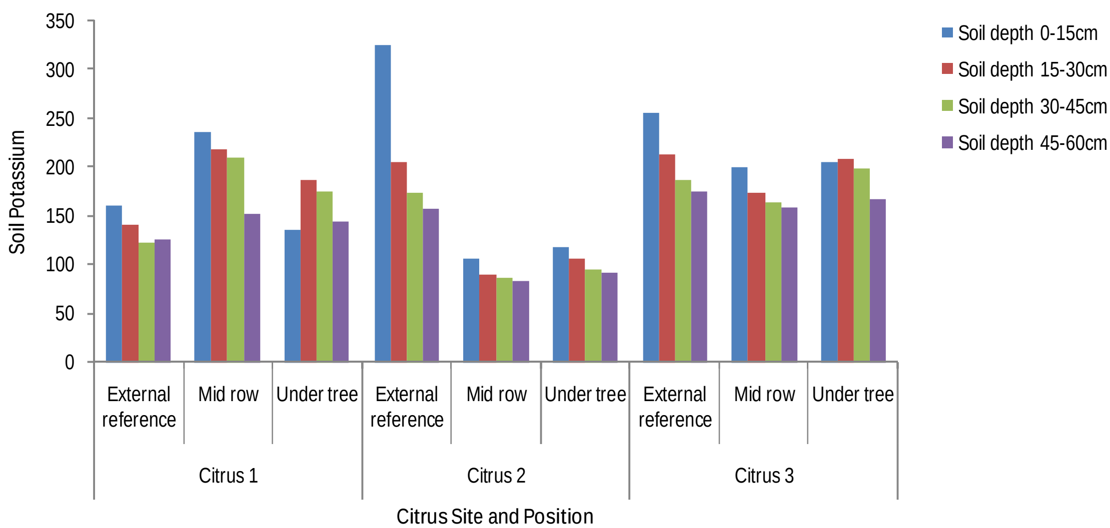


Figure 4: Soil potassium - Citrus



Key results shown in Figure 3 and Figure 4 include:

- There has been considerable accumulation of potassium in the under tree soils in all almond orchards. There has also been accumulation of potassium in the mid row soils from Almond 1.
- There appears to be less potassium reserves in the under tree soil samples compared to the mid row soils in Citrus 1. Similar trends are not evident in Citrus 2 or Citrus 3.

The accumulation of potassium in the mid row and under tree soils in Almond 1 reflects the substantial quantities of potassium fertiliser applied to this site in recent seasons. In the case of the mid row soils, the accumulation reflects the application of the potassium fertiliser through the full-cover sprinkler system.

The use of potassium fertiliser in almond production has increased considerably in recent times in response to a Horticulture Australia Limited and Industry funded trial which has shown that increased inputs of nitrogen and potassium fertiliser along with increased irrigation can result in significantly higher almond yields. The current project has demonstrated however, that unless managed carefully, increasing the rates of nitrogen and potassium fertiliser can lead to acidification of the soil and potentially inefficient use of potassium fertiliser. Clearly, there is a need to investigate the recovery of potassium fertiliser applied to almond orchards possibly through the use of radioactively labelled potassium fertilisers. This may then enable more efficient use of potassium fertiliser in almond production.

In comparison to almonds, there is little difference in the concentration of potassium in the under tree, mid row and external reference soils from Citrus 1 and Citrus 3. This indicates that potassium fertiliser applications by these growers have been replacing the potassium removed in the form of fruit.

In the case of Citrus 2, the lower concentration of potassium in the under tree and mid row soils compared to the external reference soils suggests either the external reference soils were of different composition or that this grower has not applied sufficient potassium fertiliser to replace that being removed in the fruit. In fact, the concentrations of potassium in the under tree and mid row soils from Citrus 2 indicate that an application of potassium fertiliser is needed to build up the reserves of potassium in the soil.

4.1.4 Salinity

Soil salinity results for almond and citrus orchards are shown in Figure 5 and Figure 6. Soil salinity was measured as electrical conductivity of a saturated paste extract (EC_{se}) which is a more reliable measure of soil salinity compared to electrical conductivity of a 1:5 soil:water extract.

Figure 5: Soil salinity (EC_{se}) - Almond

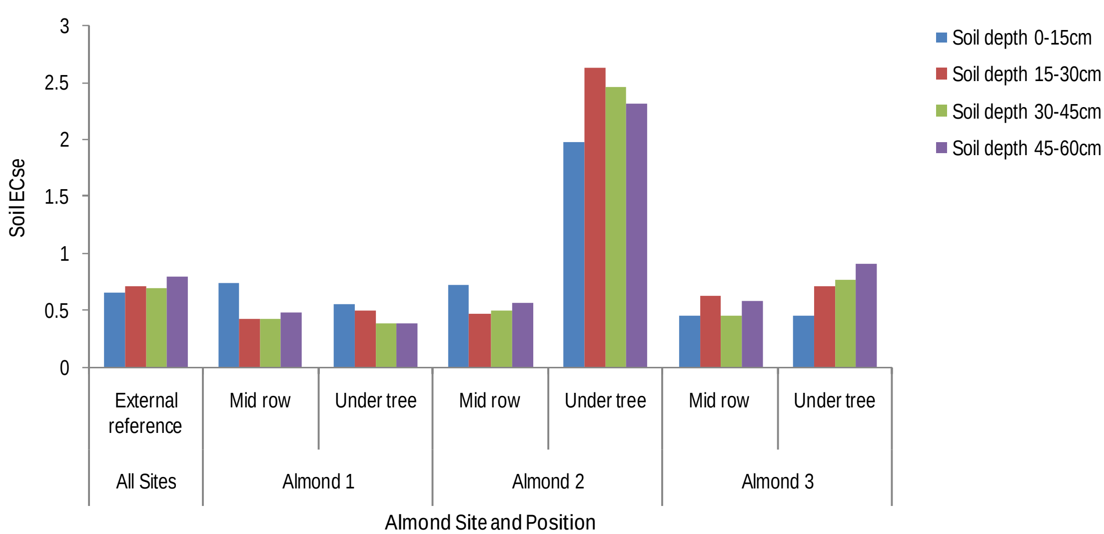
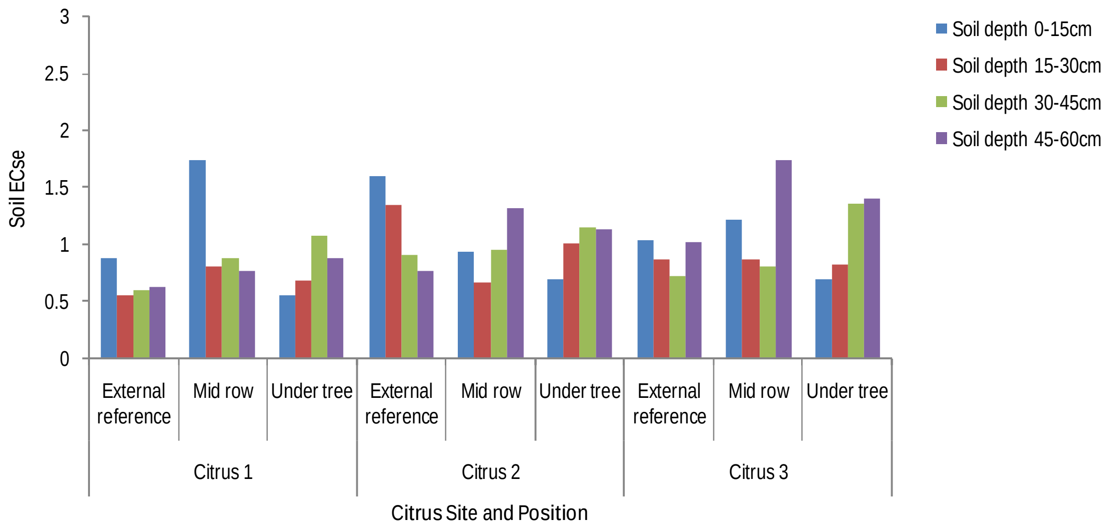


Figure 6: Soil salinity (EC_{se}) - Citrus



Key results shown in Figure 5 and Figure 6 include:

- In Almond 1 and Almond 3, there has been no accumulation of salt in the under tree or mid row soils. In contrast, there has been some accumulation of salt in the under tree soils in Almond 2.
- There has been no accumulation of salt in the under tree or mid row soils in all Citrus orchards.

In the case of Almond 1, Almond 3 and all Citrus orchards, the lack of accumulation of salt in the soil indicates that there has been sufficient leaching of salts from the soil either as a result of winter rainfall of leaching irrigations. Furthermore, sprinkler irrigation results in more widespread irrigation and so accumulation of salt at the edges of wetted patterns is less likely.

In contrast, salt has accumulated in the under tree soils in Almond 2. This is common in drip irrigated orchards where the water evaporates at the edges of the wetted pattern resulting in an accumulation of salt. Ideally, this salt would be leached from the root zone of the trees either with winter rainfall or the use of leaching irrigations. However, the current drought has severely limited leaching in recent seasons.

Note also that the soil samples were collected in July and so there may have been some leaching of salts from the soils in Almond 1, Almond 3 and all Citrus orchards following completion of the previous growing seasons. The use of soil analysis at the start and end of the irrigation season should be used when growers are concerned about soil salinity. If salts have accumulated in the soil at the end of the season, growers should (if possible) investigate the use of leaching irrigations to remove the salt.

4.2 FullStop™ Wetting Front Detectors

4.2.1 Assessment of function of FullStop™ wetting front detectors

Citrus growers reported limited triggering of FullStop™ wetting front detectors. This was usually related to insufficient irrigation applied to trigger the detectors.

In contrast, almond growers reported regular triggering of shallow and deep detectors in sprinkler irrigated orchards. Triggering of the deep detector in the drip irrigated orchard was rare.

Grower experience with the FullStop™ wetting front detectors is summarised in Table 3.

Table 3: Grower experiences with FullStop™ wetting front detectors

Site	Irrigation method	Frequency of triggering of detector	Presence or absence of nitrate-nitrogen in leachate
Almond 1	Full cover sprinkler	Regular – shallow and deep detectors	Present
Almond 2	Drip	Rare at either depth.	Present
Almond 3	Full cover sprinkler	Regular – shallow and deep detectors	Present
Citrus 1	Microsprinkler (60% coverage)	Occasional. Shallow and deep detectors triggered every 2nd and 3rd irrigation respectively.	Not tested.
Citrus 2	Microsprinkler (30% coverage)	Rare. Only shallow detector.	Generally low with one high result
Citrus 3	Microsprinkler (60% coverage)	Very rare.*	Present

* - possible faulty detectors

4.2.2 Grower impressions of FullStop™ wetting front detectors

Growers provided an assessment of the strengths and weaknesses of the FullStop™ wetting front detectors. These are summarised in Table 4.

Table 4: Strengths and weaknesses of FullStop™ wetting front detectors

Strengths	Weaknesses
• Inexpensive • Good indicator of irrigation depth • No electronics or computerisation required • Can be used to detect the presence of nitrate-nitrogen which can then be followed up more critically in the orchard	• Considerable volume of irrigation required to trigger detector • If soil moisture is maintained, difficult to apply enough water to trigger detector. • Insufficient leachate collected within detector to allow complete analysis. • Manually operated. No automation possible.

The FullStop™ wetting front detectors proved to be an inexpensive tool that growers can use to assess their irrigation practice. It provided a useful guide to the amount of irrigation that resulted in potential loss of water and nutrient via leaching and if placed at sufficient depth, could feasibly be used as a guide to leaching requirements.

Unfortunately, it was not possible to collect and analyse leachate from the FullStop™ wetting front detectors due to lack of volume of leachate and in the case of the citrus orchards and the drip irrigated almonds (Almond 2), inconsistent triggering of the detectors. Despite this, the use of nitrate-nitrogen test strips was successful and allowed growers to detect the presence of nitrate-nitrogen in the leachate collected in the FullStop™ wetting front detectors. In this regard, the detection of nitrate-nitrogen in the leachate should then be followed up by growers to try to determine if irrigation and fertiliser practices can be altered to try to limit any loss of nitrate-nitrogen via leaching. Reducing the amount of nitrate-nitrogen in leachate would also have obvious environmental benefits.

4.3 Calculators of Soil pH Change

Hard copies of the Calculators of Soil pH Change for Almond Orchards are shown in Appendix 5. Once finalised, fully functional versions of the Calculators will be available from www.srhs.com.au. Similar calculators were developed for citrus orchards but the lack of ash alkalinity data for citrus fruit (see below) means these calculators are not fully functional. As a result, copies of these calculators have not been included.

4.3.1 Ash alkalinity of harvested almonds

Ash alkalinity values for almond fruit (hull, shell and kernel) samples are presented in Table 5.

Table 5: Ash alkalinity values for harvested almonds

Sample	Ash alkalinity of almond fruit ($kg\ CaCO_3/kg\ DW$)	Dry weight factor
A	0.029	0.97
B	0.029	0.99
C	0.023	0.96
D	0.026	0.95

Average ash alkalinity of almond fruit is 0.026kg $CaCO_3$ per kg dry weight. This means that for every tonne of almond fruit harvested (equivalent to 300kg almond kernel), the equivalent of 26kg $CaCO_3$ is removed from the orchard. This has an acidifying effect on the soil in the orchard.

4.3.2 Ash alkalinity of harvested citrus

Unlike almonds, there was insufficient published data to allow calculation of ash alkalinity values for citrus. As a result, calculators of soil pH change were prepared for citrus orchards but are not currently operational until the ash alkalinity data for oranges and other citrus is available.

4.3.3 Validation of Calculators - Almond

An attempt was made to validate the Calculators of Soil pH Change by modifying the mathematics slightly so that the 'critical' soil pH value became the current pH of the under tree or mid row soils. It is then possible to estimate the time period taken to reduce the pH of the under tree topsoil to its current value using the external reference topsoil as a starting value. This can then be compared to the actual age of the orchard. Results of this comparison for the almond orchards are shown in Table 6.

Table 6: Estimated vs. Actual age of almond orchards

Orchard	Topsoil starting pH_{Ca}	Topsoil current pH_{Ca}	Actual age (years)	Calculator estimated age (years)	Comments
Almond 1	7.9	5.8	19	16.5	Significant acidification has already occurred
Almond 2	7.9	6.6	18	9.2	Converted to drip irrigation from full cover sprinkler irrigation 2 years ago
Almond 3	7.9	5.4	20	22	

The estimated age of Almond 1 and Almond 3 were close to the actual ages of these orchards. However, the estimated age of Almond 2 was lower than the actual age which is probably due to the presence of some calcium carbonate in the soil from this orchard. Free calcium carbonate in the soils, as discussed earlier, will neutralise any acidity for many years. Once the carbonate is neutralised, soil pH would be expected to fall rapidly.

It should also be noted that it was assumed that management of the various orchards is the same as that used in recent seasons. However, management practices such as fertiliser application methods, fertiliser rates and irrigation methods have varied over time and would have a bearing on the predicted age.

4.3.4 Validation of Calculators - Citrus

Validation of the Calculators of Soil pH Change for citrus orchards was not possible due to a lack of ash alkalinity data for citrus. Once data for ash alkalinity of citrus fruit is available, validation of the calculators can be conducted.

5 CONCLUSIONS

The Calculators of Soil pH Change will be valuable tools for almond and citrus growers across Australia. Although not absolutely accurate, the Calculators can be used to provide a reasonable estimate of the rate of soil pH change as a result of a set of particular orchard management practices. In fact, the Calculators should be regarded more as "learning" tools as they enable growers to alter management strategies to limit soil pH change. It should be remembered that the Calculators were designed to be used in conjunction with but not instead of regular soil testing which remains the most reliable method of assessing soil pH.

Apart from being used to validate the Calculators of Soil pH Change, analyses conducted on soil samples collected from almond and citrus orchards in the RWLAP area highlighted the following key issues:

- There has been significant acidification of soil under trees in two of the almond orchards. Acidification of under tree soils has also occurred in the remaining almond orchard but to a lesser extent. This acidification is probably related to the use of acidifying nitrogen fertilisers and the extensive removal of alkalinity as fruit.
- There has been considerably less acidification of soils in the citrus orchards compared to that observed for almonds. This probably reflects the lower rates of acidifying nitrogen fertiliser used in citrus orchards.
- There has been no accumulation of phosphorus reserves in the almond orchard soils despite the application of phosphorus fertiliser.
- There are good reserves of phosphorus in the mid row and under tree soils from all citrus orchards. Further applications of phosphorus fertiliser to these orchards are not necessary at this stage. Instead, the growers should rely on the reserves of phosphorus in the soil and use leaf analysis to monitor the phosphorus status of the trees.
- Accumulation of potassium in the almond orchard soils reflects the substantial quantities of potassium fertiliser applied to these orchards in recent seasons.

FullStop™ wetting front detectors installed at each orchard site proved to be an inexpensive tool that growers can use to assess their irrigation practice. They provided a useful guide to the amount of irrigation that resulted in potential loss of water and nutrient via leaching and if placed at sufficient depth, could feasibly be used as a guide to leaching requirements. However, whilst it was possible to assess the presence or absence of nitrate-nitrogen in leachate collected from the FullStop™ wetting front detectors, the volume of leachate generated was generally insufficient to allow laboratory analysis.

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Appendix 1

Soil Sampling Questionnaire

Scholefield Robinson
HORTICULTURAL SERVICES

NLP COMMUNITY SUPPORT PROJECT - SOIL SAMPLING QUESTIONNAIRE

Participant details

Company name: ………………………………………………………………………………………………..

Contact name: ………………………………………………………………………………………………...

Address: …………………………………………………………………………..Postcode: ……………........

Phone: …………………………..Fax: ………………………………Mobile: ………………………………...

Block details:

Block name:

Irrigation method:

Block area (ha):

Variety:

Tree age:

Rootstock:

Tree spacing in row:

Row width:

Dripper/microspringkler spacing:

No. trees per hectare:

Soil type:

Previous history of land:

Has organic matter been applied? (Y/N) If yes, please specify type of organic matter used:

Is the orchard mulched? (Y/N) If yes, what with?

Irrigation history:

Water source:

Years on current irrigation method:

Has any other irrigation method been used in the past? (Y/N) If yes, please specify previous method:

Irrigation rate (ML/ha/year):

Normal irrigation: mm or L per vine per irrigation.

Normal fertigation strategy:

Harvest (tonnes/ha) for this block in last 5 years:

Year	**Harvest (tonnes/ha)**
2007/8	
2006/7	
2005/6	
2004/5	
2003/4	

Nitrogen fertiliser, manure and lime applications in last 5 years (attach separate sheet if necessary):

Year	Product	%N, %P, %K	Tree row or Mid row	Broadcast or Fertigation	Rate/ha

Any other comments:

Appendix 2

Soil Sampling Protocol

Scholefield Robinson
HORTICULTURAL SERVICES

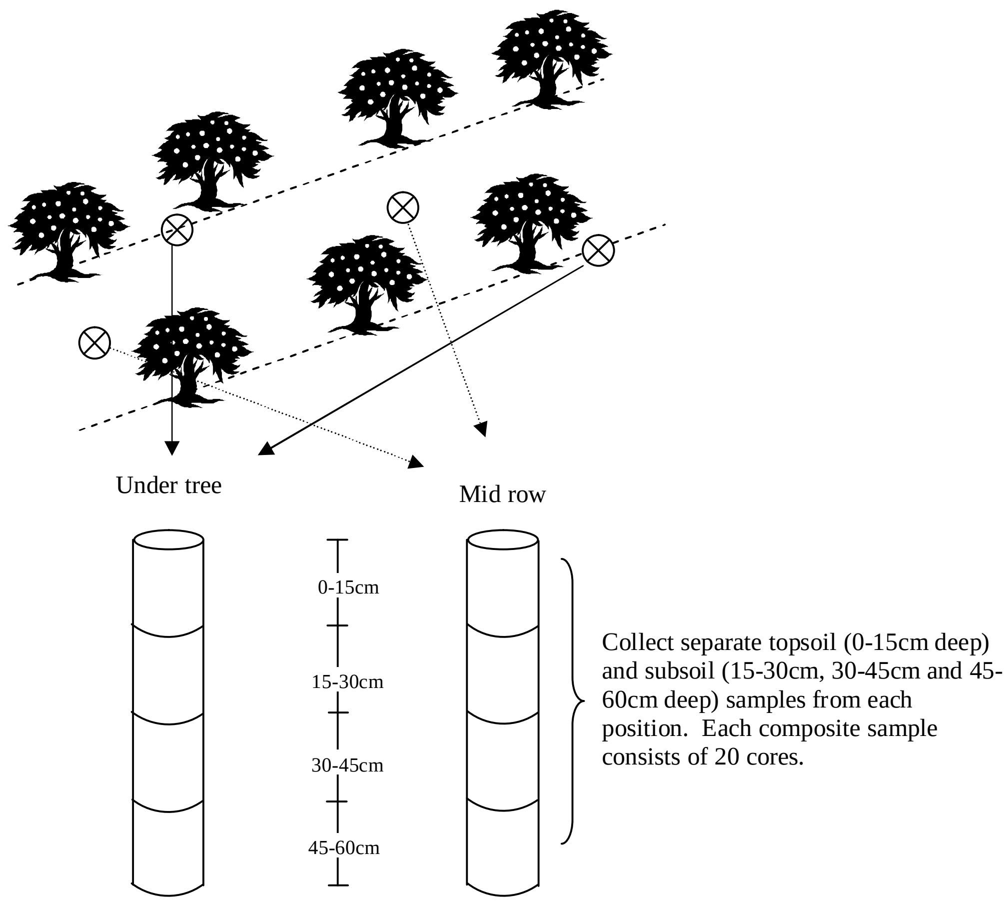
[redacted]

You will need:

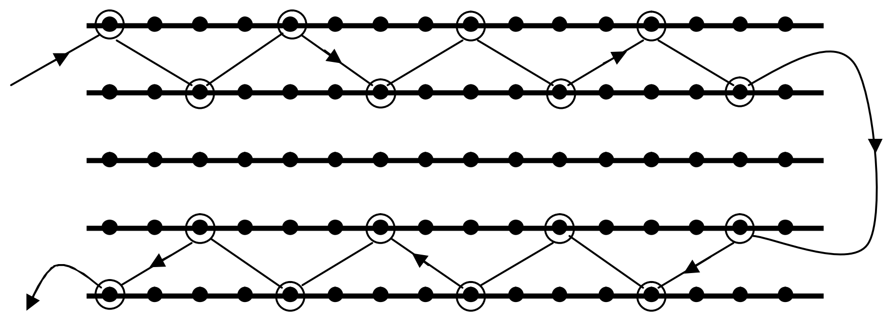
- A soil core sampler (often referred to as a soil spear or digstick)
- clean plastic buckets to collect the samples in
- clean labelled plastic bags in which to send the samples to the laboratory. These have been provided along with Express Post bags.

The soil samples that we send to the laboratory are composites of a number of individual cores collected across the area of interest. The idea of this is to minimise the effect of the variability which exists in the soil. To collect the sample(s):

- After selecting a suitable block for sampling, review the area to be sampled to ensure that the cores are taken from an area with uniform tree growth and elevation.
- For this project, separate composite samples consisting of 20 cores need to be collected from the topsoil (0-15cm deep) and subsoil (15-30cm, 30-45cm and 45-60cm deep) layers from the following positions in the chosen block (see diagram below):
  - Under the tree row beneath the drippers or microsprinklers
  - In the mid row space
  - At a nearby external reference site with a similar soil type that has not received any fertilisers, irrigation etc. (e.g. a scrub block or fenceline).



- Moving up and down at least two pairs of rows in the block in a zigzag pattern (see diagram below), stop and sample as often as needed to collect 20 cores. In the present case, it is usually easier to collect the under tree row cores first and then retrace your steps to collect the mid row samples. Obviously, you collect the external reference sample separately.



- At each stop, use a shovel to remove any grass or thatch from the surface of the soil.
- Using a soil spear/digstick, collect a soil core to 60cm deep. This core is then split into 0-15cm, 15-30cm, 30-45cm and 45-60cm depths. Place each depth interval into a separate appropriately labelled clean bucket and move on to the next spot.
- Once 20 cores have been collected, break up any clods, pick out any major pebbles etc. and mix the composite thoroughly. The composite sample that is sent to the laboratory should be about 750g of this mixed soil.
- Place each composite sample into the appropriately labelled plastic sample bag provided. Clearly label each bag with your orchard and block name. At the end of sampling, you should have 12 composite soil samples as follows:
    - Under tree row – 0-15cm deep.
    - Under tree row – 15-30cm deep.
    - Under tree row – 30-45cm deep.
    - Under tree row – 45-60cm deep.
    - Mid row – 0-15cm deep.
    - Mid row – 15-30cm deep.
    - Mid row – 30-45cm deep.
    - Mid row – 45-60cm deep.
    - External reference site – 0-15cm deep.
    - External reference site – 15-30cm deep.
    - External reference site – 30-45cm deep.
    - External reference site – 45-60cm deep.
- Place the samples into the addressed Express Post bags supplied (3 composite samples per Express Post Bag) and send the soil samples to our contracted laboratory (CSBP in Perth). Fill out the Sample to Laboratory form provided and place a copy into each Express Post Bag.. Please send another copy of the Sample to Laboratory form to Scholefield Robinson so we can keep track of the samples.

If at any stage you have any queries regarding the soil sampling procedure, please do not hesitate to contact Ben Thomas on (08) 8373 2488 or 0438 732 488.

Appendix 3

FullStop™ wetting front detector installation instructions

FullStop™
Wetting Front Detectors

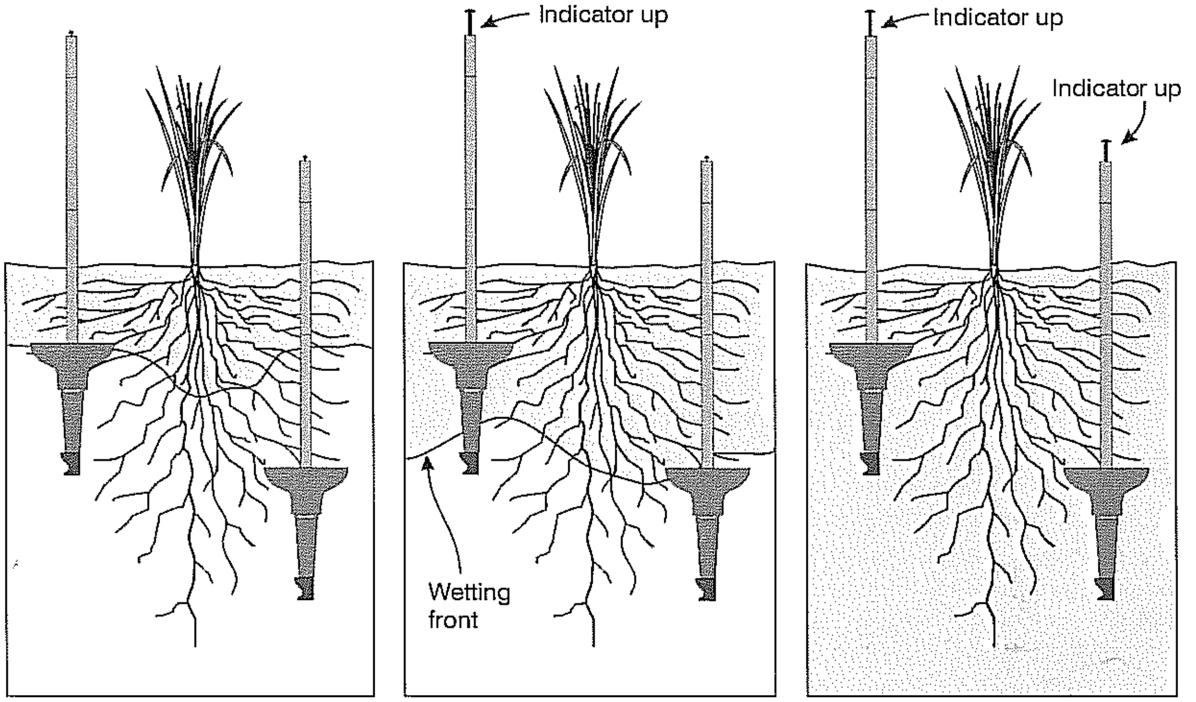
Important: Please read these instructions before assembly

The ***FullStop***™ Wetting Front Detector shows how deep water infiltrates into the soil after irrigation or rain. It takes a soil water sample so that the movement of plant nutrients and salt through the soil can be monitored.

The Wetting Front detector can be used to:

- find out if you are irrigating too little or too much
- assist in the management of fertilizer and salt
- show if the soil is water-logged.

The FullStop Wetting Front Detector helps you to "see" what is happening down in the root zone when you irrigate the soil. Wetting Front Detectors are usually buried at two depths in the root zone and pop up an indicator to show when the infiltrating water goes past. They also capture and store a sample of water from the wetting front.



Shallow Indicator: DOWN Deep Indicator: DOWN	Shallow Indicator: UP Deep Indicator: DOWN	Shallow Indicator: UP Deep Indicator: UP
If neither indicator is triggered, then watering is generally too shallow	Water has moved *past* the shallow detector to the lower part of the root zone.	The deep indicator should be triggered only when it is necessary to fill the whole root zone.

For more detailed instructions on assembly and use of the Wetting Front Detector for irrigation, fertilizer and salt management see

www.fullstop.com.au

Assembly

This box contains

- red funnel (x2)
- base piece with steel mesh filter (x2)
- black extension tubes (x5)
- locking ring (x2)
- indicator cap (x2)
- foam floats (x14)
- green flexible tubing (x2)
- syringe (x1)
- bag of filter sand (x1)

See picture opposite and follow 7 steps below.

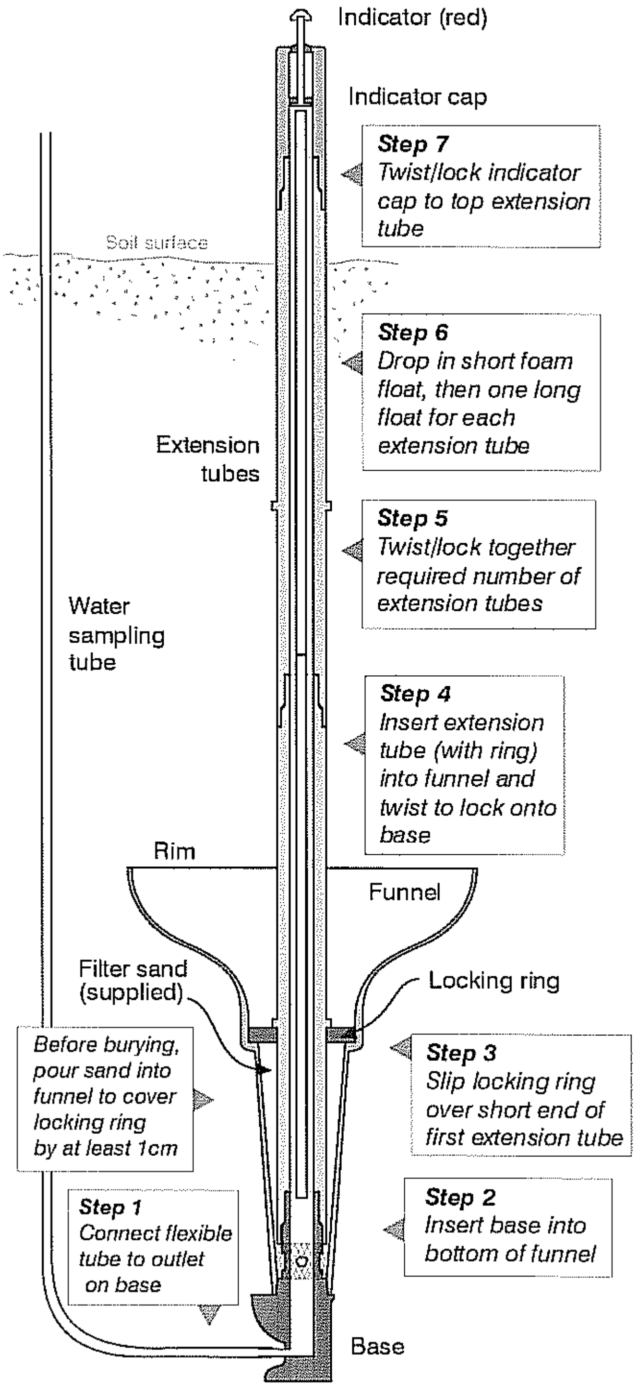
Before starting step 1, practise joining the base to an extension tube. A cup of very hot water is needed. Dip the last 5 cm of the wide (female) end of the extension tube into hot water to soften the plastic. Insert the base piece into the wide end of the extension tube by lining up the lugs, pushing and twisting hard. The fitting will be in the locked position after a quarter of a turn clockwise. Undo this fitting and follow the steps below.

Step 1: Dip one end of green flexible tubing into hot water and connect to the 4 mm barbed outlet on base piece.
Step 2: Insert the base into the bottom end of the funnel and push in as far as it will go.
Step 3:
Slip the locking ring over the wide end of extension tube that was previously dipped into hot water. Move locking ring one third of way up to the ridge on the extension tube. The spokes on one side of the locking ring are rounded. The rounded side should face upwards.
Step 4: Dip the wide end of the extension tube (with locking ring) into hot water again. Pick up the base piece and funnel and join the extension tube to the base through the funnel. This requires a firm pushing and twisting action (quarter turn). When correctly joined there will be a watertight seal with no gap between the base and the funnel.
Step 5: Add one or two more extension tubes, depending on depth of installation (no hot water treatment needed).
Step 6: Drop in the foam floats. 5 floats are required if two extension tubes are used and 7 floats are needed if three extension tubes are used. Use the float marked with blue paint last (it is shorter). The last float must protrude 1 to 2 cm above the opening of the extension tube.
Step 7: Add indicator cap - yellow for the shallow and red for the deep wetting front detector. The indicator should be in the fully down position.

Testing

Test each detector for leaks after it has been assembled by adding a syringe full of water into the funnel, with the flexible tube held upright to ensure water does not escape. The indicator will then rise and be held up by a magnet. No water should be visible at the join between the funnel and the base. Let the water out via the flexible tube and tap the indicator down to release the magnetic 'latch'. The supplied filter sand **must not** be added until you are ready to install the detector.

If you need to disassemble, remove floats first.

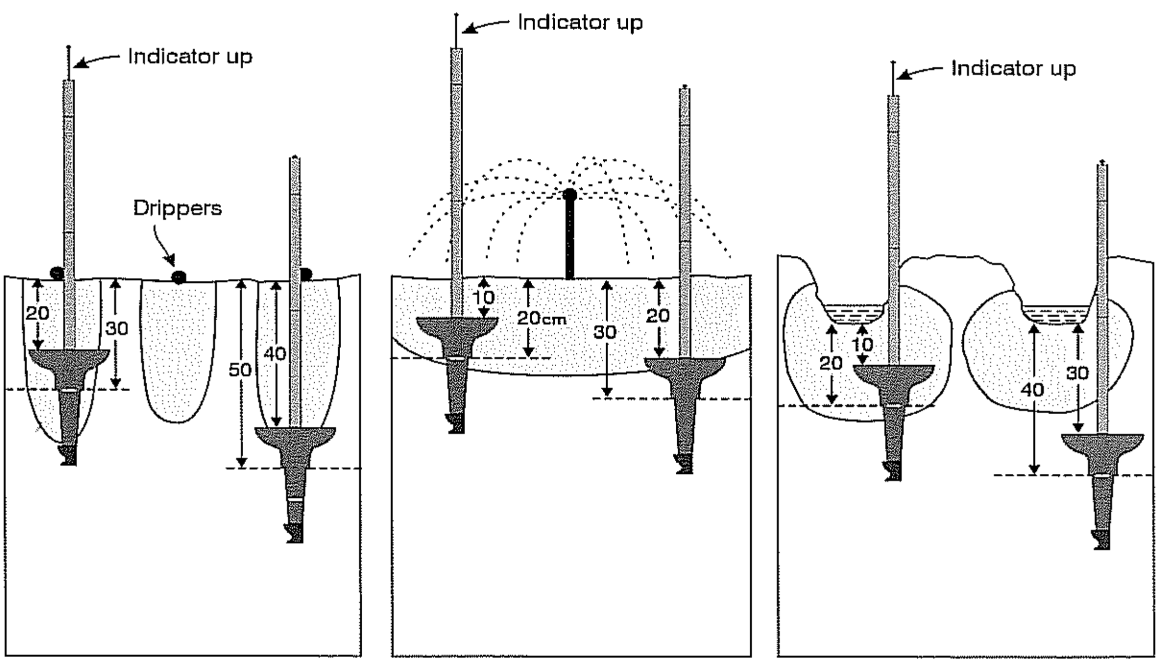


Depth Placement

The optimum depth of placement depends on the irrigation method and the frequency of irrigation, as well as the type of crop and soil. The table below is given as a guide, based on our experience. Placement depths are measured from the **soil surface to the locking ring**. If measuring to the rim of the funnel, subtract 10 cm from the depths in the table. With experience, these recommendations can be adjusted for local conditions.

Type of irrigation	Notes	Shallow Detector	Deep Detector
Drip	Amount applied per dripper usually less than 6 litres at one time (e.g. row crops, pulsing)	30 cm	45 cm
Drip	Amount applied per dripper usually more than 6 litres at one time (perennial crops)	30 cm	50 cm
Sprinkler	Irrigation is usually less than 20 mm at one time (e.g. centre pivot, micro-jets)	15 cm	30 cm
Sprinkler	Irrigation is usually more than 20 mm at one time (e.g. sprinklers and draglines)	20 cm	30 cm
Flood	Deeper placements than shown needed for infrequent irrigations or very long furrow	20 cm	40 cm

When the float is in the up position a wetting front has moved ***past*** the detector. The soil above the detector is as wet as it can be (almost saturated). That is why the above depths may appear to be shallow. A third detector, 10 cm below the deep detector depth shown above, can be installed if necessary.



DRIP

The detector must always be placed **directly under a dripper**.

It is common for detectors to respond quickly under drip because the water is concentrated around the dripper. If so, apply less water more often.

SPRINKLER

Wetting patterns tend to be shallower under sprinkler irrigation than drip or furrow irrigation.

Detectors will usually not be activated by applications under 15 mm, unless the soil is quite wet before irrigation

FLOOD

Detectors should be positioned half under the furrow and half under the bed with the extension tube rising through the shoulder of the bed.

This placement is also suited for sprinkler irrigated crops grown on raised beds.

Installation

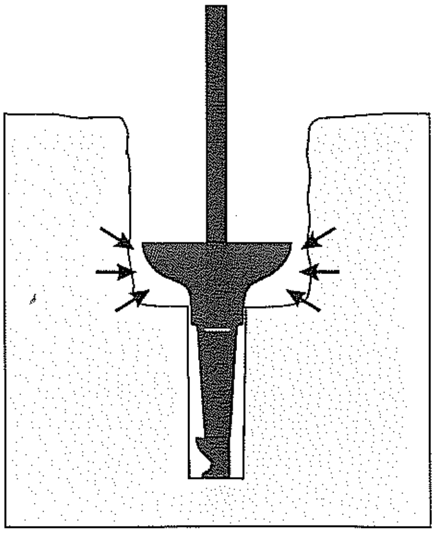
Step 1 – digging the hole

The detector is easiest to install using two augers: an auger (20 cm or larger in diameter) for the wide end of the detector funnel and another (5–10 cm in diameter) for the narrow end of the funnel. Alternatively, a spade and trowel can be used. Keep different soil layers separate when removing them from the hole if the soil type changes with depth. Installation is easiest when the soil is moist, rather than when it is very wet or dry.

Step 2 – add filter sand and insert into hole

Pour the supplied filter sand into the funnel until it covers the locking ring by at least 1 cm. Lower the detector into the hole and measure the distance to the locking ring (or rim of the funnel) to check it is at the desired depth.

Holding the extension tube vertically upright in the hole, fill the funnel with soil removed from the layer at the same depth and firm down lightly. Hold the flexible tube alongside the funnel up to the soil surface. Pack soil under and around the sides of the funnel until it is firmly in place as indicated in the diagram below. The deeper narrow hole does not need to be packed with soil.



Step 3 – bury the FullStop detector

Break the sides of the hole as you return soil above the detector, as smooth sides may restrict the growth of roots and the movement of water. The hole must be filled by returning the removed soil to its original layer. Soil should be firmed down by hand but not compacted. All the soil should be returned to the hole leaving a slight hump over the installation. After settling, check to make sure the soil level over the installation site is the same as the surrounding soil so that water does not run towards or away from the *FullStop* detector.

Step 4 –Activate the float

Water the site over the detector after installation to trigger the float. This may require 20 litres or more for a deeper installation.

Step 5 –Maintenance

Occasional testing and maintenance should be carried out to ensure the detector is operating as expected.

Ensure there are no leaks before installation. After installation, there are two further checks that should be carried out every few months.
Float mechanism: Inject 30 ml of water from syringe into the green 4 mm tubing. The float should pop up.
Filter: Irrigate till float pops up – then remove water from 4 mm tube with syringe and reset float. Float should pop up again within 5 minutes.

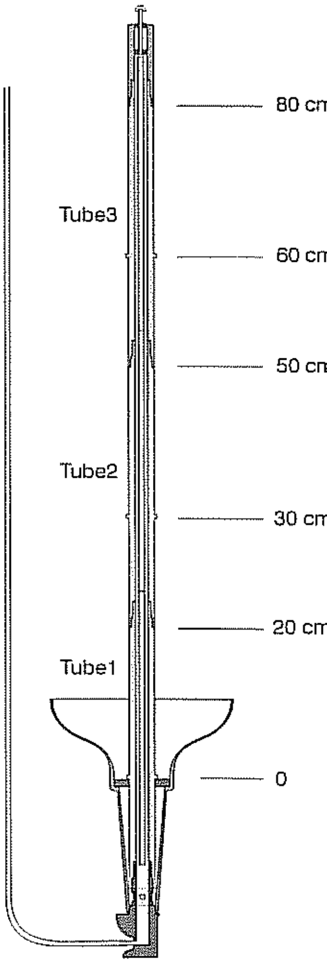
If either test fails, see troubleshooting on back page.

Depth of placement

The depth of placement depends on the irrigation method and the frequency of irrigation.

The indicator pops up when the wetting front has moved about 10 cm below the rim of the funnel, labeled "0" in the diagram below. The position of the lock up ring is the approximate depth of measurement.

The position of the ridge on the extension tube can be used to show the depth after installation. If the ridge on tube 2 is at the surface, the depth of detection is 30 cm. If the ridge on tube 3 is at the surface, the depth of detection is 60 cm.



Improving irrigation practice

When starting out, we recommend you continue to irrigate according to your normal practice while you get a 'feel' for how the detectors are responding. Then compare your normal practice to what the *FullStop* shows you as summarized in the table below.

Once you have developed some confidence in the way the detectors are working, you are ready to improve irrigation, nutrient and salt management. Change your water use practice at the rate at which you are comfortable, taking into account the growth and/or yield response of the plants. Note that it is no necessary to get the desired detector response after each irrigation – the general trends are more important.

Shallow Indicator	Deep Indicator	Meaning*	Action
Down	Down	Insufficient water for established crops	Apply more water at one time or shorten the interval between two irrigations
Up	Down	Wetting front has penetrated into the lower part of the root zone	Most of the time this is the desired result. During hot weather or when the crop is at a sensitive growth stage, the deep detector should respond. .
Up	Up	The wetting front has moved to the bottom or below the root zone	If this happens regularly then over-watering is likely. Reduce irrigation amounts or increase the time interval between irrigations.
Down	Up	Soil or irrigation are not uniform or the soil surface is uneven	Go through troubleshooting steps Ensure the soil surface is level over the detectors. Check uniformity of irrigation or location of drippers.

* this assumes that detectors have been placed at depths suited to the irrigation system and management regime

Four things you need to know

1. Resetting the indicator

Water is 'sucked out' of the detector after irrigation by the soil around it. You must reset the detector after the indicator pops up by pushing the indicator gently down to release the magnetic latch. If the indicator immediately pops up again, it means that the soil is still very wet. If the detector will not reset for several days after irrigation, the soil is close to waterlogged.

2. Indicator up means a *strong* front has moved *past* the detector

A wetting front will always move deeper than the detector after the indicator pops up. If the soil below the detector is dry, the wetting front will only move a short distance further. If the soil below the detector is wet, the wetting front can move a long way past the detector after the indicator pops up. Therefore it is important not to place detectors too deep, particularly for sprinkler irrigation.

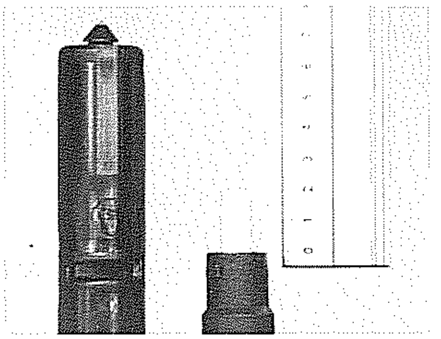
3. Effect of soil disturbance

The soil structure is disturbed during installation of the detectors. This is not a problem for installation into ploughed soil. In the case of perennial crops the soil will need to settle and the roots grow back into the disturbed zone before the detector will give reliable information.

4. How many *FullStop detectors* do you need?

It is best to have three pairs in a field, because irrigation is usually not uniform and soil properties and crop growth vary. Some irrigation systems (e.g. mini-sprinklers) tend to have large variability over small distances. Uniformity of wetting patterns should be measured and detectors placed in 'wetter' and 'drier' spots to give an indication of variability in wetting front depths.

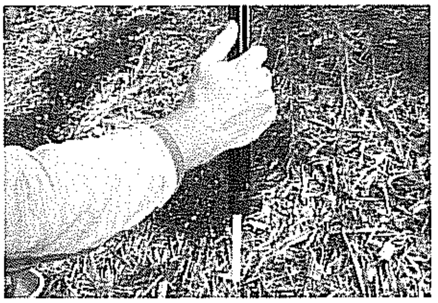
Troubleshooting



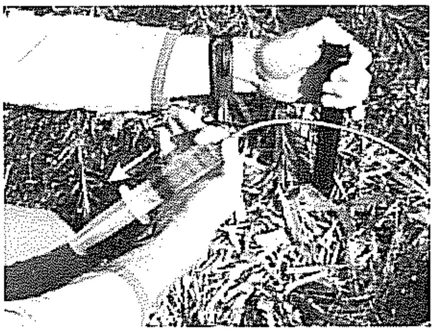
Before installation:

1. **Check for leaks**: After assembly there must be no leaks between the base piece and the funnel.
If leaks, reassemble using hot water for extension tube to base fitting. Spokes on locking ring should be 'rounded' side up.

After installation:



2. **Check the Float Indicator:** Inject 30 ml of water from syringe into the green 4 mm tubing. The float should pop up.
If float remains down, remove indicator cap and check that the last float protrudes 1 to 2 cm above extension. Check for stuck floats: Remove indicator cap, pour water down extension tube until all floats pop out. Check float pieces can pass through an extension tube without getting stuck. If indicator will not latch up, check top magnet is secured in ceiling of indicator cap.
3. **Check the filter:** Irrigate till float pops up – then remove all water from 4 mm tube with syringe and reset float. Float should pop up again within 5 minutes.
If not, Back-flush filter: To back-flush, remove indicator cap and one float. Press thumb over extension tube to seal opening. Force 60 ml of water from syringe into 4 mm tubing. Repeat. Back-flushing should be carried out after installation and once per year.



4. **Check the depth:** Look for ring on extension tube. From the ring to the depth of measurement is 30 cm (for 2 extension tubes) or 60 cm (3 extension tubes). Use yellow indicator for shallow detector and red indicator for deep detector.

Service Pack

A service pack containing floats, indicator cap, syringe and extension tube is available

Monitoring nutrients and salt

Water trapped in the detector can be sucked out with a syringe via the flexible tube and monitored for its electrical conductivity or nutrient concentration. Samples should be taken soon after irrigation. Note that the detector retains a small sample of water after self-emptying. This should be removed prior to irrigations from which samples for nutrient analysis are required.

Limitations

The ***FullStop***™ Wetting Front Detector has been designed to respond to 'strong' wetting fronts. In soil physics terms, the strength of the front must be around 2 to3 kPa suction or wetter for the indicator to rise. In practice this means that 'weak' fronts will not be detected and water can move past a detector without activating the indicator. Wetting fronts get weaker as they move deeply into the soil after the irrigation has been turned off. Weak fronts also occur during light rain, or when small amounts of water are applied at frequent intervals.

Appendix 4

Soil analysis data for each orchard

Scholefield Robinson Horticultural Services Pty Ltd
A.B.N. 63 008 199 737
PO Box 650 Fullarton SA 5063
Ph: 08 8373 2488 Fax: 08 8373 2442

Client: NLP Community Project

Almond - all sites

EXTERNAL REFERENCE SITE

Element or Test	Soil depth 0-15cm	15-30cm	30-45cm	45-60cm
Colour	Brown	Brown	Brown	Brown
Texture (rough value only)	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
pH (water)	8.7	8.7	8.9	9
pH (calcium chloride) - Preferred value	7.9	7.7	7.9	8
Organic carbon - (%)	0.32	0.29	0.33	0.27
Nitrate - nitrogen (NO3 - N) - (mg/kg)	15	7	4	7
Ammonium - nitrogen (NH4 - N) - (mg/kg)	1	1	2	2
Colwell Phosphorus (P) - (mg/kg)	15	4	2	2
Colwell Potassium (K) - (mg/kg)	164	136	112	100
Extractable Sulfur (S) - (mg/kg)	9.5	6.9	6.2	11.8
Exchangeable Potassium (K) - (meq/100g)	0.32	0.27	0.21	0.19
Exchangeable Calcium (Ca) - (meq/100 g)	6.2	6.68	6.67	6.67
Exchangeable Magnesium (Mg) - (meq/100 g)	0.77	0.93	0.96	1.18
Exchangeable Aluminium (Al) - (mg/kg)	0	0	0	0
Exchangeable Sodium (Na) - (meq/100 g)	0.05	0.1	0.23	0.32
Cation exchange capacity - (meq/100 g)	7.3	8.0	8.1	8.4
Exchangeable sodium percentage	1	1	3	4
DTPA Extractable Copper (Cu) - (mg/kg)	0.55	0.16	0.17	0.15
DTPA Extractable Zinc (Zn) - (mg/kg)	2.43	0.27	0.22	0.15
DTPA Extractable Manganese (Mn) - (mg/kg)	1.03	0.7	0.64	0.54
DTPA Extractable Iron (Fe) - (mg/kg)	3.01	3.13	3.44	3.21
Extractable Boron (B) - (mg/kg)	0.7	0.7	0.8	1.2
Extractable Aluminium (Al) - (mg/kg)	0	0	0	0
EC based on 1:5 extract (dS/m)	0.096	0.081	0.081	0.083
EC as a saturation paste extract (dS/m)	0.66	0.72	0.70	0.80
Chloride (mg/kg)	20	22	20	19

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Almond 1

	UNDER TREE				MID ROW			
	Soil depth				Soil depth			
Element or Test	0-15cm	15-30cm	30-45cm	45-60cm	0-15cm	15-30cm	30-45cm	45-60cm
Colour	Brown Red	Brown Orange	Brown Orange	Brown Orange	Brown	Brown	Brown Orange	Brown Orange
Texture (rough value only)	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
pH (water)	6.8	6.6	6.7	7.9	6.6	7.1	7.7	8.9
pH (calcium chloride) - Preferred value	5.8	5.6	5.7	6.9	5.7	6.3	6.7	8
Organic carbon - (%)	0.65	0.28	0.23	0.16	0.7	0.28	0.16	0.17
Nitrate - nitrogen (NO3 - N) - (mg/kg)	11	5	3	5	16	3	1	2
Ammonium - nitrogen (NH4 - N) - (mg/kg)	3	2	1	1	10	1	1	3
Colwell Phosphorus (P) - (mg/kg)	36	19	14	9	20	12	7	2
Colwell Potassium (K) - (mg/kg)	276	166	186	222	197	189	208	220
Extractable Sulfur (S) - (mg/kg)	7.6	8.3	8.2	8.7	17.3	9.7	4.7	6
Exchangeable Potassium (K) - (meq/100g)	0.62	0.32	0.35	0.45	0.47	0.36	0.41	0.46
Exchangeable Calcium (Ca) - (meq/100 g)	1.83	1.62	1.49	2.48	3.17	2.71	2.77	5.06
Exchangeable Magnesium (Mg) - (meq/100 g)	0.81	0.72	0.82	0.92	0.73	0.65	0.75	0.94
Exchangeable Aluminium (Al) - (mg/kg)	0	0	0	0	0	0	0	0
Exchangeable Sodium (Na) - (meq/100 g)	0.07	0.13	0.16	0.23	0.14	0.15	0.18	0.23
Cation exchange capacity - (meq/100 g)	3.3	2.8	2.8	4.1	4.5	3.9	4.1	6.7
Exchangeable sodium percentage	2	5	6	6	3	4	4	3
DTPA Extractable Copper (Cu) - (mg/kg)	4.9	0.68	0.24	0.19	3.04	0.51	0.15	0.18
DTPA Extractable Zinc (Zn) - (mg/kg)	6.03	1.08	0.17	0.15	7.2	0.65	0.17	0.17
DTPA Extractable Manganese (Mn) - (mg/kg)	2.74	3.48	2.89	1.26	2.77	1.26	0.62	0.47
DTPA Extractable Iron (Fe) - (mg/kg)	37.14	20.08	12.32	5.33	31.46	15.04	7.24	4.89
Extractable Boron (B) - (mg/kg)	0.5	0.4	0.5	0.5	0.6	0.5	0.5	0.5
Extractable Aluminium (Al) - (mg/kg)	0	0	0	0	0	0	0	0
EC based on 1:5 extract (dS/m)	0.044	0.038	0.034	0.067	0.069	0.042	0.043	0.089
EC as a saturation paste extract (dS/m)	0.57	0.51	0.39	0.39	0.75	0.44	0.43	0.49
Chloride (mg/kg)	5	7	17	18	17	10	9	13

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Almond 2

	UNDER TREE				MID ROW			
	Soil depth				Soil depth			
Element or Test	0-15cm	15-30cm	30-45cm	45-60cm	0-15cm	15-30cm	30-45cm	45-60cm
Colour	Brown	Brown	Brown Orange	Brown Orange	Brown	Brown Orange	Brown Orange	Brown Orange
Texture (rough value only)	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
pH (water)	7.6	8.3	9	8.9	8.6	8.9	9.1	9.1
pH (calcium chloride) - Preferred value	6.6	7.9	8	7.9	7.7	7.9	8.1	8.1
Organic carbon - (%)	0.75	0.6	0.25	0.19	0.42	0.22	0.19	0.18
Nitrate - nitrogen (NO3 - N) - (mg/kg)	13	6	4	2	14	5	2	1
Ammonium - nitrogen (NH4 - N) - (mg/kg)	3	2	3	5	2	3	4	7
Colwell Phosphorus (P) - (mg/kg)	23	15	9	4	9	4	3	2
Colwell Potassium (K) - (mg/kg)	222	195	150	173	195	80	61	70
Extractable Sulfur (S) - (mg/kg)	24.7	28.3	35.5	30.8	4.5	4	3.9	5.3
Exchangeable Potassium (K) - (meq/100g)	0.44	0.38	0.28	0.37	0.39	0.18	0.13	0.16
Exchangeable Calcium (Ca) - (meq/100 g)	3.2	4.28	6.23	7.3	4.59	6.21	7.27	8.59
Exchangeable Magnesium (Mg) - (meq/100 g)	1.11	0.87	0.92	1.1	0.92	1.02	1.35	1.68
Exchangeable Aluminium (Al) - (mg/kg)	0	0	0	0	0	0	0	0
Exchangeable Sodium (Na) - (meq/100 g)	0.48	0.85	0.85	1	0.09	0.13	0.19	0.27
Cation exchange capacity - (meq/100 g)	5.2	6.4	8.3	9.8	6.0	7.5	8.9	10.7
Exchangeable sodium percentage	9	13	10	10	2	2	2	3
DTPA Extractable Copper (Cu) - (mg/kg)	7.11	0.38	0.16	0.19	1.51	0.31	0.19	0.2
DTPA Extractable Zinc (Zn) - (mg/kg)	12.71	0.71	0.27	0.13	4.88	0.17	0.13	0.12
DTPA Extractable Manganese (Mn) - (mg/kg)	5.01	2.91	1.2	0.86	1.36	0.73	0.53	0.48
DTPA Extractable Iron (Fe) - (mg/kg)	39.96	14.51	7.59	4.15	7	6.67	4.69	4.59
Extractable Boron (B) - (mg/kg)	0.8	0.4	0.5	0.5	0.6	0.5	0.6	0.6
Extractable Aluminium (Al) - (mg/kg)	0	0	0	0	0	0	0	0
EC based on 1:5 extract (dS/m)	0.159	0.225	0.241	0.24	0.087	0.067	0.098	0.085
EC as a saturation paste extract (dS/m)	1.98	2.63	2.47	2.33	0.73	0.48	0.51	0.58
Chloride (mg/kg)	152	156	170	163	6	9	16	24

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Almond 3

	UNDER TREE				MID ROW			
	Soil depth				Soil depth			
Element or Test	0-15cm	15-30cm	30-45cm	45-60cm	0-15cm	15-30cm	30-45cm	45-60cm
Colour	Brown	Brown Orange	Brown Orange	Brown Orange	Brown	Brown Orange	Brown Orange	Brown Orange
Texture (rough value only)	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
pH (water)	6.4	8.3	9	9.1	6.5	8.7	8.9	9
pH (calcium chloride) - Preferred value	5.4	7.4	8.1	8.1	5.5	7.8	8	8.1
Organic carbon - (%)	0.36	0.23	0.19	0.19	0.57	0.39	0.24	0.19
Nitrate - nitrogen (NO3 - N) - (mg/kg)	10	3	2	2	10	4	2	1
Ammonium - nitrogen (NH4 - N) - (mg/kg)	5	2	2	1	3	3	3	3
Colwell Phosphorus (P) - (mg/kg)	17	7	7	5	22	13	11	7
Colwell Potassium (K) - (mg/kg)	152	126	83	68	151	165	122	80
Extractable Sulfur (S) - (mg/kg)	4.9	10.8	11.4	10.7	4.8	5.5	4.2	5.8
Exchangeable Potassium (K) - (meq/100g)	0.28	0.23	0.17	0.14	0.27	0.32	0.23	0.16
Exchangeable Calcium (Ca) - (meq/100 g)	2.07	3.11	6.22	6.86	2.63	4.1	6.32	6.48
Exchangeable Magnesium (Mg) - (meq/100 g)	0.75	0.89	1.05	1.15	0.83	0.76	0.81	0.96
Exchangeable Aluminium (Al) - (mg/kg)	0.07	0	0	0	0	0	0	0
Exchangeable Sodium (Na) - (meq/100 g)	0.16	0.22	0.26	0.32	0.14	0.23	0.19	0.21
Cation exchange capacity - (meq/100 g)	3.3	4.5	7.7	8.5	3.9	5.4	7.6	7.8
Exchangeable sodium percentage	5	5	3	4	4	4	3	3
DTPA Extractable Copper (Cu) - (mg/kg)	2.19	0.33	0.2	0.16	3.15	0.4	0.2	0.19
DTPA Extractable Zinc (Zn) - (mg/kg)	5.62	0.17	0.13	0.12	10.07	0.2	0.13	0.15
DTPA Extractable Manganese (Mn) - (mg/kg)	2.84	1.03	0.67	0.62	3.05	0.9	0.63	0.52
DTPA Extractable Iron (Fe) - (mg/kg)	18.19	7.39	4.91	3.01	24.12	9.5	4.19	2.84
Extractable Boron (B) - (mg/kg)	0.6	0.5	0.6	0.6	0.6	0.5	0.5	0.5
Extractable Aluminium (Al) - (mg/kg)	0.2	0	0	0	0	0	0	0
EC based on 1:5 extract (dS/m)	0.045	0.077	0.091	0.079	0.04	0.074	0.074	0.085
EC as a saturation paste extract (dS/m)	0.46	0.72	0.77	0.91	0.47	0.63	0.47	0.59
Chloride (mg/kg)	13	18	36	50	14	10	12	24

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Citrus 1

	UNDER TREE				MID ROW				EXTERNAL REFERENCE SITE			
	Soil depth				Soil depth				Soil depth			
Element or Test	0-15cm	15-30cm	30-60cm	60-90cm	0-15cm	15-30cm	30-60cm	60-90cm	0-15cm	15-30cm	30-60cm	60-90cm
Colour	Brown	Brown	Brown	Brown	Brown	Brown	Brown	Brown	Brown	Brown	Brown	Brown
Texture (rough value only)	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
pH (water)	6.9	7.4	8.7	9	6.9	8.2	8.9	9	8.9	8.9	9	9.1
pH (calcium chloride) - Preferred value	6.2	6.7	7.8	8.1	6.3	7.3	8	8.1	8.1	8.1	8.2	8.3
Organic carbon - (%)	0.69	0.38	0.31	0.25	0.87	0.39	0.48	0.27	0.29	0.28	0.27	0.27
Nitrate - nitrogen (NO3 - N) - (mg/kg)	7	4	5	6	33	14	11	8	11	4	3	4
Ammonium - nitrogen (NH4 - N) - (mg/kg)	2	3	2	2	6	2	2	3	1	2	3	2
Colwell Phosphorus (P) - (mg/kg)	59	51	38	30	56	48	39	28	21	15	9	5
Colwell Potassium (K) - (mg/kg)	136	188	175	145	237	219	211	152	161	142	124	126
Extractable Sulfur (S) - (mg/kg)	6.9	6.7	12.4	8.6	10.2	5.2	9.1	6.1	14.2	6.5	6.4	6.9
Exchangeable Potassium (K) - (meq/100g)	0.34	0.46	0.42	0.36	0.53	0.45	0.44	0.36	0.37	0.33	0.33	0.3
Exchangeable Calcium (Ca) - (meq/100 g)	2.93	3.14	5.5	6.33	3.8	3.71	6.52	6.39	5.87	5.31	5.22	5.74
Exchangeable Magnesium (Mg) - (meq/100 g)	0.91	1.09	1.23	1.24	1.12	1.24	1.43	1.18	0.67	0.79	0.97	0.87
Exchangeable Aluminium (Al) - (mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0
Exchangeable Sodium (Na) - (meq/100 g)	0.17	0.23	0.29	0.3	0.2	0.18	0.19	0.19	0.14	0.11	0.21	0.17
Cation exchange capacity - (meq/100 g)	4.4	4.9	7.4	8.2	5.7	5.6	8.6	8.1	7.1	6.5	6.7	7.1
Exchangeable sodium percentage	4	5	4	4	4	3	2	2	2	2	3	2
DTPA Extractable Copper (Cu) - (mg/kg)	12.78	3.59	1.07	0.74	3.2	1.39	0.6	0.5	2.35	1.41	0.51	0.43
DTPA Extractable Zinc (Zn) - (mg/kg)	14.72	2.08	0.6	0.48	7.58	0.54	0.24	0.27	1.4	0.77	0.33	0.24
DTPA Extractable Manganese (Mn) - (mg/kg)	3.84	2.44	1.17	0.92	3.59	1.66	0.94	0.82	1.28	1.24	1.02	0.9
DTPA Extractable Iron (Fe) - (mg/kg)	34.8	9.11	1.29	6.46	15.75	4.64	2.11	-1	17.49	14.86	-1	3.37
Extractable Boron (B) - (mg/kg)	0.6	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Extractable Aluminium (Al) - (mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0
EC based on 1:5 extract (dS/m)	0.061	0.071	0.125	0.113	0.116	0.095	0.112	0.112	0.094	0.095	0.092	0.093
EC as a saturation paste extract (dS/m)	0.56	0.69	1.09	0.89	1.74	0.82	0.89	0.78	0.89	0.57	0.61	0.64
Chloride (mg/kg)	17	27	50	42	71	34	28	26	14	23	19	17

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Citrus 2

	UNDER TREE				MID ROW				EXTERNAL REFERENCE SITE			
	Soil depth				Soil depth				Soil depth			
Element or Test	0-15cm	15-30cm	30-60cm	60-90cm	0-15cm	15-30cm	30-60cm	60-90cm	0-15cm	15-30cm	30-60cm	60-90cm
Colour	Brown	Brown	Brown	Brown	Light Brown	Light Brown	Light Brown	Light Brown	Light Brown	Light Brown	Light Brown	Light Brown
Texture (rough value only)	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
pH (water)	8.2	8.7	8.8	8.8	8.4	8.8	8.9	9	8.5	8.8	8.9	8.8
pH (calcium chloride) - Preferred value	7.5	7.9	7.9	7.9	7.8	7.9	8	8	7.7	8	8.1	7.9
Organic carbon - (%)	0.76	0.53	0.34	0.3	0.54	0.37	0.4	0.35	0.88	0.4	0.27	0.41
Nitrate - nitrogen (NO3 - N) - (mg/kg)	2	1	1	1	8	2	2	1	25	3	2	3
Ammonium - nitrogen (NH4 - N) - (mg/kg)	2	2	2	2	2	2	2	2	3	2	2	1
Colwell Phosphorus (P) - (mg/kg)	35	37	41	39	33	30	30	16	38	10	5	5
Colwell Potassium (K) - (mg/kg)	118	106	95	92	106	91	87	84	326	205	174	158
Extractable Sulfur (S) - (mg/kg)	6.1	6	6.7	6.8	6.2	6	9.3	8.3	15.7	15	37.3	8.8
Exchangeable Potassium (K) - (meq/100g)	0.22	0.21	I.S	0.21	0.22	0.19	0.21	I.S	0.77	0.42	0.35	0.39
Exchangeable Calcium (Ca) - (meq/100 g)	4.38	6.81	I.S	9.2	6.45	8.49	10.13	I.S	7.69	7.29	6.58	7.21
Exchangeable Magnesium (Mg) - (meq/100 g)	1.17	1.06	I.S	1.15	1.08	1.04	1.18	I.S	1.44	1.25	1.16	1.28
Exchangeable Aluminium (Al) - (mg/kg)	0	0	I.S	0	0	0	0	I.S	0	0	0	0
Exchangeable Sodium (Na) - (meq/100 g)	0.3	0.41	I.S	0.3	0.23	0.26	0.33	I.S	0.36	0.29	0.24	0.25
Cation exchange capacity - (meq/100 g)	6.1	8.5	I.S	10.9	8.0	10.0	11.9	I.S	10.3	9.3	8.3	9.1
Exchangeable sodium percentage	5	5	I.S	3	3	3	3	I.S	4	3	3	3
DTPA Extractable Copper (Cu) - (mg/kg)	6.45	2.18	0.63	0.42	4.36	1.14	0.4	0.37	1.02	0.5	0.29	0.32
DTPA Extractable Zinc (Zn) - (mg/kg)	6	1.47	0.48	0.62	4.41	0.72	0.35	0.32	8.88	2.21	0.62	0.36
DTPA Extractable Manganese (Mn) - (mg/kg)	1.46	0.74	0.65	0.6	1.55	0.61	0.49	0.48	3.13	1.09	0.56	0.77
DTPA Extractable Iron (Fe) - (mg/kg)	10.68	4.93	3.4	2.87	6.26	3.01	2.89	1.46	4.53	1.88	2.29	2.22
Extractable Boron (B) - (mg/kg)	0.4	0.5	0.6	0.6	0.6	0.5	0.6	I.S	2.4	2.1	2.1	1.5
Extractable Aluminium (Al) - (mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0
EC based on 1:5 extract (dS/m)	0.12	0.15	0.16	0.12	0.12	0.1	0.12	0.13	0.21	0.16	0.13	0.13
EC as a saturation paste extract (dS/m)	0.71	1.01	1.16	1.14	0.95	0.68	0.96	1.33	1.60	1.35	0.91	0.77
Chloride (mg/kg)	51	78	57	53	44	33	76	77	81	68	34	41

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Citrus 3

	UNDER TREE				MID ROW				EXTERNAL REFERENCE SITE			
	Soil depth				Soil depth				Soil depth			
Element or Test	0-15cm	15-30cm	30-60cm	60-90cm	0-15cm	15-30cm	30-60cm	60-90cm	0-15cm	15-30cm	30-60cm	60-90cm
Colour	Brown Orange	Brown Orange	Brown Orange	Brown Orange	Brown Red	Brown Orange	Brown Orange	Brown Orange	Brown Orange	Brown Orange	Brown Orange	Brown Orange
Texture (rough value only)	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
pH (water)	7.9	8.9	9	9.1	8.4	8.8	9	9.3	8.7	8.9	9.2	9.2
pH (calcium chloride) - Preferred value	7.1	7.9	8.1	8.2	7.4	8.1	8	8.3	7.9	8.1	8.3	8.4
Organic carbon - (%)	0.63	0.41	0.34	0.29	0.65	0.4	0.31	0.21	0.96	0.54	0.41	0.31
Nitrate - nitrogen (NO3 - N) - (mg/kg)	3	1	1	3	19	5	3	4	12	7	3	3
Ammonium - nitrogen (NH4 - N) - (mg/kg)	1	1	1	1	1	1	1	1	6	2	1	1
Colwell Phosphorus (P) - (mg/kg)	60	51	42	32	46	35	21	8	9	3	4	1
Colwell Potassium (K) - (mg/kg)	205	208	199	168	201	174	164	160	257	214	188	175
Extractable Sulfur (S) - (mg/kg)	5.7	4.9	7.4	11	10.2	6.1	5.2	12.8	18.7	19.7	16.1	28
Exchangeable Potassium (K) - (meq/100g)	0.42	0.42	0.42	0.38	0.41	0.39	0.36	0.32	0.6	0.48	0.4	0.36
Exchangeable Calcium (Ca) - (meq/100 g)	4.57	5.62	6.05	5.45	7.12	6.66	6.88	7.02	7.56	8.5	9.08	8.67
Exchangeable Magnesium (Mg) - (meq/100 g)	1.23	1.39	1.73	1.48	1.55	1.7	1.62	1.65	0.95	0.94	1.03	1.19
Exchangeable Aluminium (Al) - (mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0
Exchangeable Sodium (Na) - (meq/100 g)	0.24	0.29	0.44	0.33	0.31	0.29	0.38	0.74	0.09	0.13	0.17	0.23
Cation exchange capacity - (meq/100 g)	6.5	7.7	8.6	7.6	9.4	9.0	9.2	9.7	9.2	10.1	10.7	10.5
Exchangeable sodium percentage	4	4	5	4	3	3	4	8	1	1	2	2
DTPA Extractable Copper (Cu) - (mg/kg)	7.21	1.81	0.76	0.47	4.57	2.38	0.56	0.36	0.32	0.29	0.22	0.18
DTPA Extractable Zinc (Zn) - (mg/kg)	12.63	1.49	0.63	0.28	11.04	0.83	0.23	0.25	0.72	0.32	0.39	0.21
DTPA Extractable Manganese (Mn) - (mg/kg)	2.8	1.23	1.08	0.54	2.35	1.09	0.96	0.79	3.48	1.25	0.58	0.47
DTPA Extractable Iron (Fe) - (mg/kg)	11.3	5.59	4.21	3.46	6.86	3.56	1.77	1.44	4.87	4.46	1.49	1.38
Extractable Boron (B) - (mg/kg)	0.7	0.7	0.7	0.7	0.9	0.9	0.8	0.8	1.4	1.2	1.2	1.3
Extractable Aluminium (Al) - (mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0
EC based on 1:5 extract (dS/m)	0.054	0.091	0.116	0.136	0.114	0.09	0.098	0.13	0.109	0.094	0.088	0.093
EC as a saturation paste extract (dS/m)	0.71	0.83	1.37	1.41	1.22	0.87	0.82	1.74	1.04	0.87	0.73	1.03
Chloride (mg/kg)	24	26	45	56	42	35	21	109	23	10	10	8

Appendix 5

Calculators of Soil pH Change – Almond

Calculator of Soil pH Change for Drip Irrigated Almond Orchards

Values calculated are indicative only.

This calculator is a simple acidity/alkalinity balance that aims to help predict the effects of orchard management on soil pH changes. It requires simple annual inputs that should help managers make decisions about whether or not an orchard soil is acidifying or becoming alkaline.
Read the cell comments - indicated by the small red triangle in the top right corner.

Always use soil testing to check actual soil condition.

Column N contains hidden cells used in calculations

Work downwards through the worksheet

Yellow boxes data require values	Blue boxes calculate answers/predictions
Green boxes calculate an alkaline input	Clear boxes are constants or calculated values
Orange boxes calculate an acidic input	These boxes relate to values calculated for sodic irrigation water.

If soil tests show that the soil is layered, you can use depth weighted averages, otherwise assume the soil is uniform.

ORCHARD INFORMATION

Block Name			Block area	13.793	hectares
Variety			Rootstock		
Tree age	18	years	Irrigation system	Drip	
Row width	6.653	m	If drip, no. per tree	24	
Tree spacing in row	6.538	m			
No. of trees per hectare	230				

ORCHARD MODULE

Yield (fresh weight)		Dry wt factor	Yield (dry weight)	Ash alkalinity of almond fruit	Acidity through almond export per dripper	
kg kernel/hectare	*kg fruit/hectare*		*kg fruit/hectare*	*kg $CaCO_3$/kg DW*		
3400	11333	0.97	10993	0.026	-0.0518	*kg $CaCO_3$*

Assumes that alkalinity exported as almond fruit comes from the irrigated wetted area

SOIL MODULE

Fill in data from soil tests or table to the right					pHBC	Bulk Density
pH_{ca}	Organic C %	Ave Clay %	AW *vol%*	Soil $CaCO_3$ %		
6.6	0.75	5	6.8	0	0.40	1.59
or use pH_w - 0.9					*t $CaCO_3$/ha 10 cm*	*g/cc*

Field texture	Average Clay % Ave Clay %	Available Water AW vol %
Sand	2	6.1
Loamy sand	5	6.8
Clayey sands	7.5	7.1
Sandy loam	15	7.9
Loam	20	8.7
Silt loam	20	11.9
Sandy clay loam	25	8.2
Clay loam	28	10.2
Silty clay loam (& silty clay)	32	13.5
Sandy clay	32	8.3
Light clay	40	9.9
Medium clay	50	10.7
Heavy clay	55	11.1

WATER MODULE

Total Irrigation *ML/hectare/year*	Volume of water applied per irrigation *mm*	Volume of soil wetted per irrigation *Litres*	No of irrigations per year	Irrigaton water analysis *mg/L*			Sodium Adsorption Ratio *SAR*
				Na	Ca	Mg	
15	2.1	308824	714	17.7	4.1	5.1	1.38

FERTIGATION MODULE

Type	Amount applied		Equivalent soil acidity of alkalinity *kg $CaCO_3$*	Fertiliser acidity/alkalinity per dripper	
	kg fertiliser/hectare	*kg actual N/hectare*			
Urea	180	82.8	-149	-0.027	*kg $CaCO_3$*
Ammonium nitrate	176	61.6	-111	-0.020	*kg $CaCO_3$*
Ammonium sulfate	360	75.6	-408	-0.074	*kg $CaCO_3$*
UAN	0	0.0	0	0.000	*kg $CaCO_3$*
DAP - N	0	0.0	0	0.000	*kg $CaCO_3$*
MAP - N	191	22.9	-124	-0.022	*kg $CaCO_3$*
Potassium nitrate	610	236.1	765	0.139	*kg $CaCO_3$*
Calcium nitrate - N	0	0.0	0	0.000	*kg $CaCO_3$*
Lime (*kg/ha $CaCO_3$*)	0		0	0.000	*kg $CaCO_3$*

Calculator results

The soil wetted by the dripper is becoming more:

ACIDIC	Yes
ALKALINE	No
SODIC	No

Water should not be increasing soil sodicity

Acidity calculator

Net *acidification* (-ve) or *alkalisation* (+ve) rate based on annual inputs and exports

-0.057	*kg $CaCO_3$/dripper/year*
-313	*or kg $CaCO_3$/ha/yr*

Estimated time to pH_{ca} 5.5 — 7.3 *years*

A negative number means the soil is becoming alkaline and the estimated time should be ignored.

Estimated time to pH_{ca} 4.8 — 12.0 *years*

A negative number means the soil is becoming alkaline and the estimated time should be ignored.

If the soil has free lime ($CaCO_3$), that is, there is a value in cell E40 above, and the soil is acidifying:

It will take about 0 years to neutralise it and decrease the soil pH

Add this number to the times in years given above.

"Not acidifying" means that the soil is becoming more alkaline and the calcium carbonate in the soil should not decompose.

Notes on water chemistry

- Water chemistry may be critical if soil pH is found to be increasing, especially its sodium and calcium content (or SAR).
- *Previous work with grapevines indicates that a high concentration of sodium bicarbonate in water does not seem to affect prediction of soil pH and is therefore ignored. However, when water has a Langelier Index that indicates calcium carbonate precipitation is possible, this is likely to be a factor that adds alkalinity to the soil.*
- High sodium values will cause the soil to become more sodic and the pH_{Ca} of the soil may increase beyond about 7.5 (pH_w = 8.4). Sodium salts are very soluble and may leach in winter, lowering pH. A critical value for SAR of 3 is used, following Rengasamy and Olssen (1993)

Assumptions and sources of error

- Values for soil and water tests are taken as given. Water alkalinities and SAR values vary with time and soil properties vary spatially. Therefore, the value of the data used depends on adequate sampling and laboratory analysis.
- Difficulties arise through changes in soil properties with depth, especially pH buffer capacity, which depends on carbon and clay content and the presence of free carbonates. These changes in properties are ignored as their inclusion would greatly complicate the data and calculations required. Instead, the calculator concentrates on the upper soil layers which are usually sampled for soil analysis.
- It is assumed that alkaline and acidic processes operate uniformly through the dripper wetted zone.
- The calculator estimates a volume of soil at the inputted field texture value without considering the shape of the wetted volume of soil.
- It is assumed that water and fertiliser is applied or moves from the surface downwards and outwards. The predictions made by the calculator should therefore be more realistic for the near-surface layers. *This is supported by validations using actual management information.*
- Note that decomposition of organic matter will usually produce some alkalinity. However, the effect has not been investigated and may only affect the top few cm of soil. As a result, it is not considered here, but could be added to future calculators.