MORE PROFIT FROM NITROGEN

Optimising nitrogen management in cherry orchards

Optimising nitrogen (N) management allows efficient utilisation of resources, can improve returns for growers and minimise environmental harm.

Guideline Background

Guidance to cherry tree growers on the application of nutrients has been limited, especially in relation to the critically important major nutrient of N. Research was undertaken by the Tasmanian Institute of Agriculture through the More Profit from Nitrogen program from 2017 to 2020. Trials were conducted at three sites in Tasmania to deliver a more comprehensive and accurate understanding of the N-cycle within cherry orchards.

The project aimed to determine:

- how **application timing** of N fertiliser can be managed to best meet cherry tree N requirements;
- whether **different rates** of N application affect its uptake efficiency;
- if the **form of N** applied affects N uptake by young trees;
- **how much N is returned to the soil** through decomposition of plant litter/mulch; and
- what proportion of applied N fertiliser is **lost to the environment.**

About the research

The study of N use efficiency (NUE) in a 5-year-old Lapin cherry orchard followed the path of labelled N applied at different rates (90 or 180 kg/ha), using 3 different timing strategies:

1. **Pre-harvest:** weekly fertigation from early November for four weeks (90 kg N/ha)
2. **Post-Harvest:** weekly fertigation from mid-January (1 week after harvest) for 4 weeks (90 kg N/ha)
3. **Split Application:** fortnightly fertigation from early November for 4 weeks and again from mid-January for 4 weeks (90 kg N/ha)
4. **Split Application:** fortnightly fertigation from early November for 4 weeks and again from mid-January for 4 weeks (180 kg N/ha)

The uptake of labelled N into the different parts of the plant as well as losses to the atmosphere were measured. The fate of fertiliser N through the decomposition of fallen leaves and prunings was also tracked. An additional study investigated the fate of different forms and rates of N when applied to young trees and leaching of N below the root zone.

Fruit ready for harvest at the Wandin Valley Farms trial site, Rosegarland, Tasmania.

A trial tree at the Wandin Valley Farms trial site, Rosegarland, Tasmania, netted prior to harvest to capture any shed material.

DID YOU KNOW?

Nitrogen, in the form of di-nitrogen gas (N_2), constitutes 78% of the atmosphere but is unavailable to plants in that form. It needs to be 'fixed' by breaking the strong bond between the two N atoms to create plant-available forms. Lightning achieves this, as do some soil microorganisms, most notably those associated with the roots of legumes, e.g., beans, lucerne. The production of ammonia (NH_3) by the Haber-Bosch process also results from breaking the N_2 bond and is the first step in the production of synthetic, mineral (non-organic) N fertilisers. Food produced with the use of synthetic N fertilisers now sustains over 50% of the human population.

KEY FINDINGS

- **Rate and timing:** N application rate and timing had no effect on fruit yield or quality.
- **N use efficiency:** The timing of N application to mature trees, pre-harvest, post-harvest or split application (50:50) made no difference to the efficiency of its uptake (average of 38%) but did affect its distribution within the tree.
- **Distribution:** Trees directed more pre-harvest N to fruit and more post -harvest N to vegetative growth.
- **Storage:** Only a small proportion of total tree N (19%) came from annual fertiliser application, emphasising the importance of N storage in the tree and soil.
- **Remobilisation:** The production of cherry flowers is totally dependent on the remobilisation of stored N, as is the early spring growth of leaves, stems and fine roots, with root uptake beginning about 30 days after full bloom.
- **N form:** Young trees grew equally well whether N was applied in mineral form (calcium nitrate) or organic forms, when measured over 3 years.
- **Decomposition:** N derived from leaf litter residue can provide 3-5% of tree N requirements within 12 months, with release of N from stems considerably slower.
- **Leaching:** More nitrate leaching below the root zone occurred at higher rates of nitrate N application, with 14.4, 20.5 and 30.2 kg N/ha leached in one year from respective applications of 0, 150 and 300 kg N/ha.
- **Nitrous oxide emissions:** A heavy rainfall event resulted in the loss of 2% of applied nitrate fertiliser as the potent greenhouse gas nitrous oxide. Irrigation had little influence on nitrous oxide emissions.
- **Monitoring:** Ongoing monitoring of plant and soil N, with regular application of limited N doses and avoidance of excessive irrigation, is the key to efficient N use and preventing losses through leaching and nitrous oxide emissions.

Nitrogen cycling

The use of N by plants is part of a complex cycle involving transformations of different forms of N through the plant, soil, and atmosphere. Figure 1 shows the important transformations that take place in the N-cycle when N is applied to cherry trees in the nitrate form.

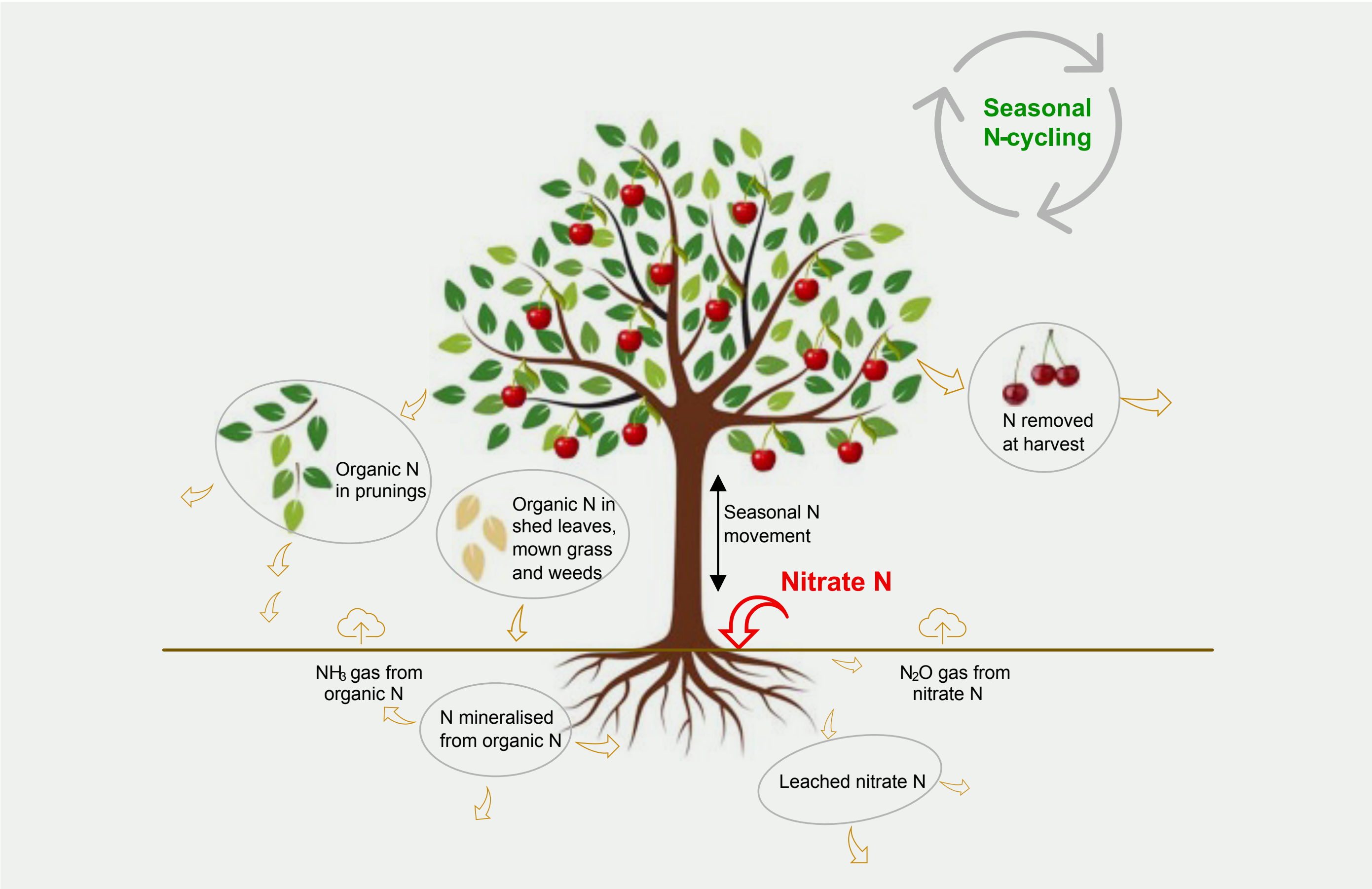

***Figure 1** - The elements of seasonal N-cycling for orchard cherry trees, including nitrate-N, organic-N, ammonia (NH_3) and nitrous oxide (N_2O).*

Nitrogen inputs

In cherry orchards, almost all direct N inputs come from applied fertiliser, generally in synthetic, mineral forms such as calcium nitrate, but sometimes in organic forms such as chicken litter. Humus contains organic N, mostly in the form of amino acids, of which some can be taken up by plants in limited amounts, particularly if mineral N is in short supply. Organic N is made much more readily available to plants by the process of **Mineralisation**.

Soil humus contains organic N derived from the decomposition of leaves, prunings, roots, inter-row herbage and suppressed weeds. In a mature orchard, much of the organic N in humus originates from applied fertiliser, making it a very important source of recycled N from cherry leaves, prunings and herbage in the tree line and inter-row.

Nitrogen inputs: prunings, shed litter and fertigation/irrigation tubing at Wandin Valley Farms trial site.

Nitrogen fertilisers

There are two broad categories of N fertilisers: mineral forms such as urea, nitrate and ammonium, and organic forms such as manures and manufactured products, e.g., fish emulsion fertilisers. The most commonly used N fertilisers in orchards are the mineral nitrate forms, either calcium or potassium nitrate. They are highly soluble, so can be easily applied by fertigation or spread in prilled form and are readily taken up by trees. Urea is also commonly used but has an acidifying effect on soil.

The potential for losing N from the orchard system varies with the form of N applied:

- Nitrate forms of N are easily leached from soil when excess water drains away from trees' root zone. When soil is very wet, they can also lose N to the atmosphere as nitrous oxide gas through **Denitrification**.
- Fertiliser containing the ammonium form of N can lose large quantities as ammonia gas (NH_3) through Volatilisation. These include urea, which in the presence of soil moisture converts to ammonium N and carbon dioxide over a few days. The losses tend to be greater when such fertilisers are surface applied.
- Organic forms of N are for the most part not easily available to plants until transformed by Mineralisation. The initial product of this process is ammonium N, so losses as NH_3 gas can be significant, if surface applied. This is a high risk with manure forms such as chicken litter, often containing a high percentage of ammonium N to begin with.

Remobilisation from storage

Nitrogen is stored by deciduous trees during winter dormancy in branches, buds, trunk, and roots for potential Remobilisation to promote new growth in spring. The process of N storage begins in autumn. As daylight hours and temperatures decrease, N is withdrawn from leaves and stored in buds, branches, trunk, and roots (Figure 2).

The highest concentration of stored N is in the fine roots and buds, followed by new stem growth (Table 1). Roots, branches and trunk are the major storage organs (Figure 2).

Table 1 *- Concentration of nitrogen in tree organs at dormancy in trees with N applied in the previous season at 90 kg/ha.*

Tree organ	N concentration (mg N/g dry organ)
Fine roots (< 2 mm)	13.1
Buds	11.4
New stems (1st year)	8.0
All roots	6.4
Trunk	2.4
Branches (including 1st year)	2.3

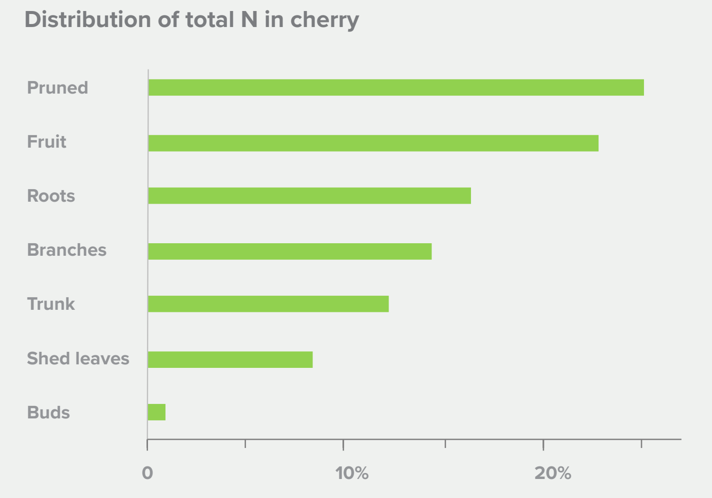

Figure 2 *- Total N distribution in trees with 90 kg N/ha applied in that season, split 50:50 pre- and post-harvest, and fruit yield of 18.2 kg/tree.*

In cherries, uptake of N from soil only commences about 30 days after full bloom, so the first growth in spring draws upon remobilised N from stored reserves.

The production of cherry flowers and the early spring growth of leaves, stems and new fine roots is fully dependent on the remobilisation of stored N.

Trees in full bloom at Wandin Valley Farms trial site, spring 2017

Mineralisation

All synthetic fertiliser N is in a mineral or inorganic form. Trees convert mineral forms of N to organic N forms. The N content of fallen leaves and prunings must be mineralised by soil microbes before it can be easily re-utilised by the tree. The same is true of fertiliser N that is taken up by weeds or inter-row herbage, both adding to the pool of organic N in orchards that has the potential to be recycled within the soil/tree production system.

The carbon: nitrogen ratio

The amount of N mineralisation is dependent on the total N content, temperature and soil moisture of the soil. Soil microbes use carbon (C) as an energy source during mineralisation, emitting carbon dioxide in the process, and the C:N ratio of decomposing matter has a large influence on mineralisation. A ratio of about 25:1 is the ideal microbial diet for their growth, where the energy available from C is in balance with the N supply. If the ratio is above around 30:1 the decomposing microbes may absorb mineral N already present in the soil, e.g., as ammonium or nitrate, resulting in its immobilisation.

With a C:N ratio of less than about 22:1, mineralised organic N can be released into the soil, initially as ammonium N. Much of the ammonium can be quickly converted to nitrate N by nitrifying bacteria, with the rate of conversion increasing rapidly with temperature, as does mineralisation. Soil moisture also influences mineralisation – little occurs in very dry soil, but the rate increases to a maximum when soil moisture is close to field capacity, then declines markedly as the soil wets further toward saturation. In addition, soil pH influences mineralisation, being slower in acidic soils.

In the study of the fate of N from leaves and prunings, a soil C:N ratio of 12:1 was recorded. This is very favourable to mineralisation.

Leaf litter bags for decomposition measurement at Wandin Valley Farms trial site.

Nitrogen losses

Denitrification

When soil moisture levels are very high, nitrate N can be transformed by soil microbes through denitrification into nitrous oxide gas (N_2O). Nitrous oxide is a potent greenhouse gas, with about 300 times the warming potential of carbon dioxide. Emissions of N_2O from human activity are responsible for about 6% of climate warming, the third most significant after carbon dioxide (66%) and methane (16%). It is now also close to being the main cause of the destruction of ozone in the stratosphere. Emissions of N_2O from agriculture account for almost 70% of those from human activity. If soils become saturated, denitrification can reach completion and produce the harmless gas N_2. This would be unusual in an orchard situation.

Leaching of nitrogen

Frequent applications of nitrate fertiliser in smaller doses helps prevent N leaching. The nitrate forms of N, unlike the ammonium forms, are very easily leached away from the root zone of trees, either deeper into the soil and/or sideways away from the main root area. Rainfall or excessive irrigation are the primary causes, by wetting soil beyond its capacity to hold water. Leaching of nitrate into groundwater, streams and rivers is well-recognised as a major source of N pollution, contributing to algal blooms, de-oxygenation of coastal waters and other harmful effects upon the environment.

The research found that leaching of applied nitrate N is more likely to occur:

- within a week or two of fertiliser application, as are emissions of N_2O; and
- if the amount of N applied is more than the tree can take up within that period. For example, N applied before flowering may be lost to the environment as the tree is not actively taking up N.

Volatilisation

Nitrogen can be lost from the soil through volatilisation as ammonia gas (NH_3), often in very substantial quantities. Typically, the greatest losses occur from animal dung and urine, ammonium-based fertilisers and urea fertiliser. Nitrate fertilisers are not a direct source for losses of soil N through volatilisation. Volatilisation of N can also occur during mineralisation of organic N, with ammonium N being volatilised before conversion to the nitrate form. Such losses would be influenced by numerous factors but would generally be far less than from previously mentioned sources.

A heavy rainfall event resulted in the loss of 2% of applied nitrate fertiliser as the potent greenhouse gas nitrous oxide. Irrigation had little influence on nitrous oxide emissions.

More nitrate leaching occurred when higher rates of nitrate N were applied, with 14.4, 20.5 and 30.2 kg N/ha leached in one year from respective applications of 0, 150 and 300 kg N/ha.

When N is applied as nitrate fertiliser, losses from volatilisation are generally very low compared to other N losses.

Nitrogen Use Efficiency

Nitrogen use efficiency (NUE) describes how much of applied N fertiliser is taken up by the tree. It is shown as a percentage of the total amount of N applied. For example, if you applied 100 kg of N fertiliser and 65 kg ended-up in the trees, then the NUE would be 65%. This would be an exceptionally good outcome, as in many crops NUE has been measured at considerably less than 50%. Low NUE can be related to many factors including excessive application of N, poorly timed application, poor choice of N form applied, excessive irrigation and poor plant health.

The research tested three fertiliser application timings of 90 kg N/ha: pre-harvest, post-harvest and split application (50:50), and two rates of a split application: 90 kg N/ha and 180 kg N/ha.

The Optimising Nitrogen Use section discusses ideas on how improvements in NUE can be made.

Application timing did not affect NUE with an average of 38.4% for 90 kg N/ha. The split application at 180 kg N/ha had a NUE of 29.6%, suggesting that this higher rate of N was greater than the tree required.

N uptake pattern and storage

The N in a mature cherry tree is a combination of N derived from previous uptake (storage) and current season uptake from both soil and applied fertiliser. In one season, 18.8% of the whole tree's N was accounted for purely from fertiliser uptake (calcium nitrate), when applied at 90 kg N/ha split 50:50 between pre- and post-harvest. Figure 3 shows the relative proportions of N in the cherry tree derived from applied fertiliser and N from tree and soil reserves.

The small proportion of total tree N (19%) derived from annual fertiliser application emphasises the importance of N storage in the tree and soil in mature cherry orchards.

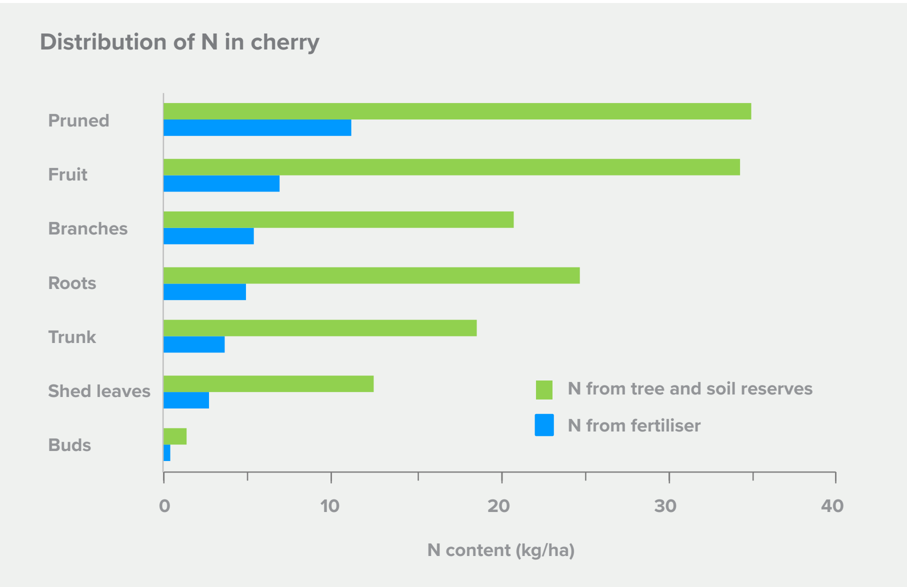

Figure 3 *- Fertiliser N and N from tree and soil reserves of trees with 90 kg N/ha applied in that season, split 50:50 pre- and post-harvest, and fruit yield of 18.2 kg/tree.*

Excavated tree stump at Wandin Valley Farms trial site, June 2019.

Timing of fertiliser application

The timing of fertiliser N application affected where the N was distributed in the tree. When all N was applied pre-harvest, a higher percentage of N went into fruit. When all N was applied post-harvest, a higher percentage was distributed to branches which were pruned in the winter (Figure 4).

Applying more N than required at any time is likely to result in wastage and a reduction in NUE. This emphasises the need for applying little and often.

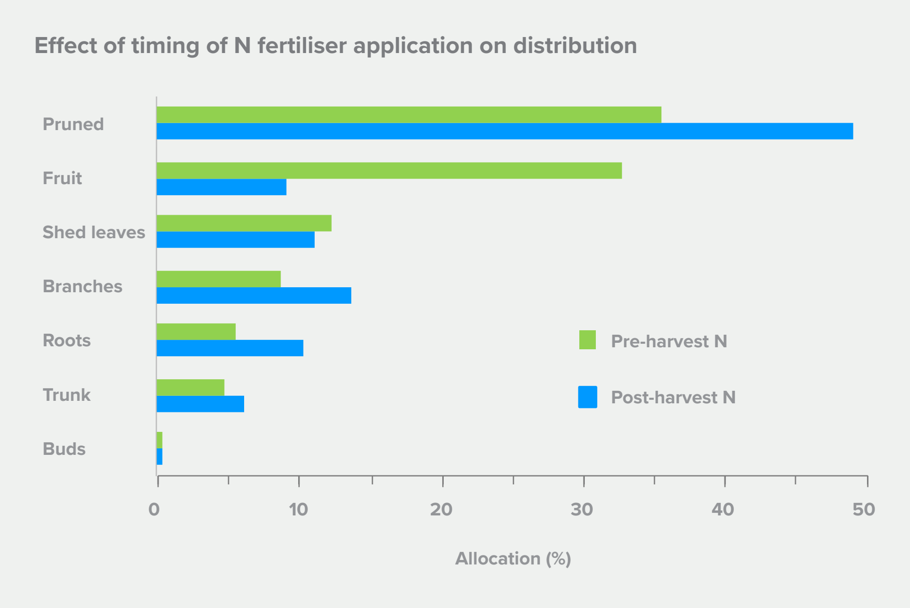

Figure 4 *- Distribution of utilised fertiliser N over 2 seasons, when applied at 90 kg N/ha pre- or post-harvest in the first season only.*

Soil sampling at Reid Fruits' Honeywood Orchard trial site, Jericho, Tasmania.

Optimising nitrogen use

For mature cherry trees, observing annual trends of N content over 3 seasons will provide a sound basis for optimising N use. This will show the balance between fertiliser N uptake, mineralisation of litter and pruned material N content and N losses to the environment.

Measuring N content to establish optimal N rates and timing

- **Prunings:** prune at close to the same time of the year in each autumn and test stems for N content.
- **Soil:** test soil for total, ammonium and nitrate N (and other nutrients) at bud burst – vital for measuring year-to-year trend of available N (ammonium and nitrate), including the contribution to all 3 forms of N from recycling of litter and prunings. Soil type will have a bearing on ideal nutrient concentrations: for example, ranging from sandy to heavy soils, 0 - 15 mg nitrate-N/kg soil and above 0.15% - 0.30% of total N respectively, would be ideal, with C:N ratios in the region of 10 – 12 (Environmental Analysis Laboratory, Southern Cross University).
- **Early season leaves:** test for N content no later than 2 weeks after full bloom.
- **Fruitlets:** test for N content to assist in determining how much pre-harvest N to apply.
- **Agronomist:** use the results of soil, leaves and fruitlets, in consultation with an agronomist, to help determine the amount of N required for spring application.
- **Begin N application 30 days after full bloom, approximately when soil N uptake commences.**
- **Fruit:** test fruit N content to determine how much N is needed to replace that transported off-site. Replacement N can be applied post-harvest or split post-harvest / following spring. Post-harvest application should commence quickly and finish within 6-7 weeks of harvest.
- **Minimise N losses** by applying frequent, small doses rather than larger, less frequent ones. Application should be avoided if substantial rainfall is forecast within the next 5-7 days, which could result in significant losses of N through leaching and as nitrous oxide gas. Similarly, over-irrigation can lead to such losses.

These practices of testing, monitoring and N application strategies, with sound agronomist advice, will help ensure good tree health and yields while fine tuning the optimum use of N, year-to-year.

Partitioning of tree roots, Tasmanian Institute of Agriculture

MPfN

FURTHER INFORMATION

FOR FURTHER INFORMATION ON THE MPfN PROGRAM:

Optimising nutrient management for improved productivity and fruit quality in cherries project, contact the project leader:

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Visit www.utas.edu.au

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