A LIGHTER TOUCH

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Agroecological approaches to insect pest control in perennial crop systems

Establishing floral resources for improved biological control

PART 1: ESTABLISHMENT

The aim of this project is to develop an understanding of how overall biodiversity and specific natural predators can be enhanced within an orchard environment (using citrus as the model crop production system) to better manage insect pests by enhancing the abundance of beneficial insect predators and to potentially reduce the need for applications of agrichemicals.

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Introduction

The aim of this project is to develop an understanding of how overall biodiversity and specific natural predators can be enhanced within an orchard environment (using citrus as the model crop production system) to better manage insect pests by enhancing the abundance of beneficial insect predators and to potentially reduce the need for applications of agrichemicals.

The approach taken to enhance the abundance and diversity of naturally occurring beneficial insects as biological control agents (BCAs) will be through the establishment of alternative food sources and refugia to provide **S**helter, **N**ectar, **A**lternative prey and **P**ollen (SNAP) by planting selections of service plants to enhance biodiversity within the orchard.

The project involves the establishment of beneficial plant species in the orchard via planting interrow, intra-row (under canopy), and annual flower strips. The practical approaches to establish, manage and monitor these plantings will be trialled over 2 years to ensure methodologies are 'fit-for-purpose' across all types of fruit production.

This information in this report forms part of a toolkit that records the four phases of the project: (1) establishment, (2) monitoring, (3) management, and (4) evaluation. The aim is to record the process by which perennial and annual plant species can be successfully established in an orchard, their management alongside other orchard activities, and the measurable benefits of establishing these biodiverse plantings in an orchard.

The focus of this report is on the establishment phase and records the learnings and insights through this stage.

2

Establishment of perennial and annual plant species in the orchard

This project is all about ecological enhancement to increase the abundance and diversity of naturally occurring beneficial insects in the orchard. The case study location for this project is on two citrus orchards in Gisborne.

To achieve this, biodiversity plantings that comprise a mixture of perennial and annual species need to be established. The plant species commonly used for this purpose are a mixture of primarily perennial legumes and non-grasses to be grown under the trees where the current herbicide strip is and a diverse grass-based pasture with a range of legumes and forbs in the inter-row.

When considering how to approach establishing beneficial plant species in an orchard, the fundamental question to begin with is deciding what to plant, where to plant, and when to plant it. The mechanics and logistics of planting seed is also an important consideration, and the approach taken will depend on the equipment available.

What are the benefits of biodiversity plantings?

- Providing food sources, such as nectar and pollen, and refugia for beneficial insects that will attack insect pests in the orchard.
- Improving soil health by planting a variety of species with different root structures that will help address soil compaction issues, weed management, improve soil water holding capacity, reduce nutrient loss, and provide additional organic inputs.

Before. Traditional orchard, herbicided under trees and short mown pasture in the inter-row alley

After. Pasture strip (inter-row) replaced by beneficial plants. Flower strips established in the pasture strip and under the tree canopy, with annuals added between under-tree vegetation and pasture strip

Often the approach of establishing beneficial plantings is referred to by several different names such as cover crops, service crops, and living mulches. Generally, cover crops are annual plants grown for a fixed period of time and then killed whereas living mulch is where a low height perennial plant is grown under a crop. There is no agreed definition and cover crop, living mulch and service crop are used interchangeably in the research literature.

The concept of establishing plant species to attract beneficial insects is simple but requires some preplanning and preparation.

Ideally, the ultimate aim is to achieve a varied ground cover within the orchard that will provide suitable **s**helter, **n**ectar, **a**lternative prey and **p**ollen (SNAP) to the beneficial insects that will control crop pests.

Considerations

- That beneficial plantings are practical and economical
- That they do not interfere with orchard operations (e.g. pruning, spraying, harvest)
- That they do not affect tree growth and crop yield.

2.1 Beneficial plant species

Phacelia

Beneficial plants separate into three main categories or functional groups:

- Grasses
- Legumes
- Forbs/everything else

The key with choosing plant species is that all the competition is at root level as the plants are below the crop canopy so there can be no light competition with the actual crop (Merfield, 2022; Merfield and Shields, 2021).

Grasses

Grasses have the most competitive root system of all with perennial crops, as they are shallow and fibrous so directly compete for the same volume of soil that the tree roots occupy. This effect has been seen in research trials, with living mulches often reducing yield. It is best to avoid planting grasses close to the tree crop and preferably plant in the inter-rows, unless the trees are over-vigorous (Merfield, 2022).

Legumes

Legumes have the least competitive root systems of the three groups as they can fix their own nitrogen so don't need to compete with other plants for it. Many legumes also have deep vertical tap roots, which means they occupy different soil volumes to shallow tree feeder roots. In addition, the N fixed by the legumes increases soil N which the crop can use (Merfield, 2022).

Forbs

As forbs include all non-grass and non-legume plants they are clearly a highly diverse group. What is clear from the experience with grasses and legumes, is to choose forb species on their root architecture (Merfield, 2022).

All perennial crops have shallow feeder roots as they have evolved in forests where the nutrient supply comes from the leaf litter on the soil surface. Forbs that have vertical tap roots with few shallow roots are therefore likely to be the least competitive with the shallow crop feeder roots as they will occupy different areas of the soil.

All three types of beneficial plant species will provide **s**helter, but they vary in how well they provide **n**ectar, **p**ollen and **a**lternative prey. This is further complicated as different beneficial insect species need different resources and therefore any one plant species may provide a large boost to one beneficial species but not another. It is also likely that some plant species that are good for beneficials may not be good options, as they compete with the trees (Merfield, 2022).

Perennial versus annual species

The benefit of using perennial species is to maintain vegetation cover year-round. This also simplifies management, reduces costs, and reduces soil disturbance. The presence of year-round vegetation also provides shelter and refugia for many beneficial insect species.

There are also many annual plant species that will provide similar benefits to perennials although they can have a defined, and often short flowering period (Merfield and Shields, 2021).

The types of plants which are known as being beneficial to beneficial insects are listed (Table 1). The plant species listed in Table 1 is not a definitive list and is provided as a guide to the types of beneficial plants that could be considered. Other beneficial plant species may be more suitable in different regions, climates and orchard situations.

Buckwheat (*Fagopyrum esculentum*) in a New Zealand vineyard to enhance biological control of leafrollers. Photo credit: Jean-Luc Dufour, Accolade Wines

Sweet alyssum is a low growing ground cover that can be planted inter-row to attract attract and support beneficial insects and enhance control of crop pests.

Table 1. Plants identified as being beneficial for beneficial insects, grouped according to type and lifespan (after Merfield and Shields, 2021).

	Perennials	Annuals	Both
Grasses	Cocksfoot Perennial grasses Perennial ryegrass	Ryecorn	
Legumes	Lucerne Red clover Strawberry clover White clover	Crimson clover	
Forbs	Alyssum Dandelion Fennel	Basil Buckwheat Coriander Dill Phacelia	Asteraceae Marigolds (Tagetes)

2.2 Planning biodiversity plantings

For any orchard, beneficial plant species can be established in two areas;

- in the inter-row
- in the area under the tree canopy (Intra-row).

Planting in each of these areas requires a slightly different approach, consideration of the species being planted, and when these plants should be established. Before attempting to plant, a **planting plan** should be developed, and the species selected appropriate to the location, region and climate.

The planting scheme used to establish ground cover for this project is provided as an example of the plant species that could be selected and established in the orchard (Table 2).

Generally, the **inter-row species** will comprise mostly of perennial species, a mixture of grasses and legumes with high species diversity. The aim is to have a long duration supply of pollen, and the variety provides a good level of biodiversity. As Merfield and Shields (2021) noted, the legumes have been limited due to the clover dominant intra-row area, but some legumes are required for N fixation. Persian clover is an annual, but annual clovers have evolved to be in pasture, and they have large seeds which makes for large strong seedlings so it may be able to persist. Plantain is added for diversity as it is in a different family to the other species. Dandelion is in the Asteraceae family, and is a good nectar source (Merfield and Shields, 2021).

Annual flower strips can also be established in the inter-row area. The suggested approach is to use strip tillage in the established inter-row area. It is important to create a space for the annuals to establish and flower amongst the perennial inter-row sward.

In the **intra-row (under tree)** area the suggested mixture of species is principally perennial clovers. The benefit of clovers is that they produce dense foliage and will keep outcompete weeds. Alyssum is considered an excellent floral resource, it is perennial, very hardy and can also grow quite large, so should be able to compete with the clovers. Plantain is included for diversity and will compete with clovers. The sowing density is recommended to be light (in this example 5.15 kg/ha) so that individual plants can achieve a good size.

Table 2. Plant species mix (seed selection) and planting rate for this biodiversity project (after Merfield and Shields, 2021).

Under tree – Intra-row	Lifespan	Type	Rate kg/ha
Red clover	Perennial	Legume	2
Strawberry clover	Perennial	Legume	0.5
White clover (large leaf cultivars)	Perennial	Legume	1
Alsike clover	Perennial	Legume	0.5
Birdsfoot Trefoil AKA Lotus	Perennial	Legume	0.25
Alyssum	Perennial	Forb	0.15
Plantain	Perennial	Forb	0.75
Total			**5.15**

Inter-row	Lifespan	Type	Rate - kg/ha
Lucerne	Perennial	Legume	2
White clover	Perennial	Legume	2
Persian clover	Perennial	Legume	2
Dandelion	Perennial	Forb	0.25
Plantain	Perennial	Forb	0.75
Yarrow	Perennial	Forb	0.15
Marigold (*Tagetes erecta*)	Annual	Forb	-
Cocksfoot	Perennial	Grass	3.5
Perennial Ryegrass	Perennial	Grass	3
Timothy	Perennial	Grass	1.5
Smooth Meadow-grass KBLG	Perennial	Grass	2
Tall fescue	Perennial	Grass	1.5
Red fescue	Perennial	Grass	1.5
Meadow fescue	Perennial	Grass	1.5
Chicory	Perennial	Forb	1
Total			**22.65**

Annual Flower Strips	Lifespan	Type	Rate - kg/ha
Buckwheat	Annual	Forb	35
Coriander	Annual	Forb	0.25
Crimson Clover	Annual	Legume	2
Chicory	Perennial	Forb	1
Phacelia	Annual	Forb	2
Ryecorn	Annual	Grass	30
Total			**70.25**

Seed mix for intra-row application

Pasture seed mix in the hopper for planting in the inter-row

Regarding the annual flowers, Merfield and Shields (2021) noted that all of these plants can grow to be quite substantial, up to 0.5 m high, particularly when they go to flower, so the sowing rate needs to be reasonably low to allow individual plants to achieve sufficient size. With the cultivation associated with strip tillage there is a likelihood that weeds may establish with the sown plants, however, unless these are known to cause real and actual harm, e.g., hosting pests or diseases, they should be considered 'non-crop plants' adding to overall biodiversity.

As previously noted, various plant species will perform differently in different parts of the orchard environment. It is important to consider your own individual situation and select seed mixes accordingly.

Local seed supply companies should be able to supply seed mixes to your own specifications and will be able to advise on the best species for your area from the list of species in Table 2.

2.3 Field preparation

Spraying and mowing

Around 6 weeks before sowing it is important to reduce/remove as much of the competing weed and grass cover as possible. This will give the sown seed a chance to establish.

If there is an existing grass strip in the inter-row this can be sprayed off using glyphosate. If the grass sward is too high, one option is to spray first and then mow a few days later once the grass has died back. Spraying 6 weeks prior to sowing is recommended to allow the sward and its roots to decay.

Recently mown orchard

Soil compaction

If the soil is compacted, then consider a light cultivation using a spring-tine weeder or similar equipment such as a small power harrow to loosen the top few centimetres of soil to create a better seed bed.

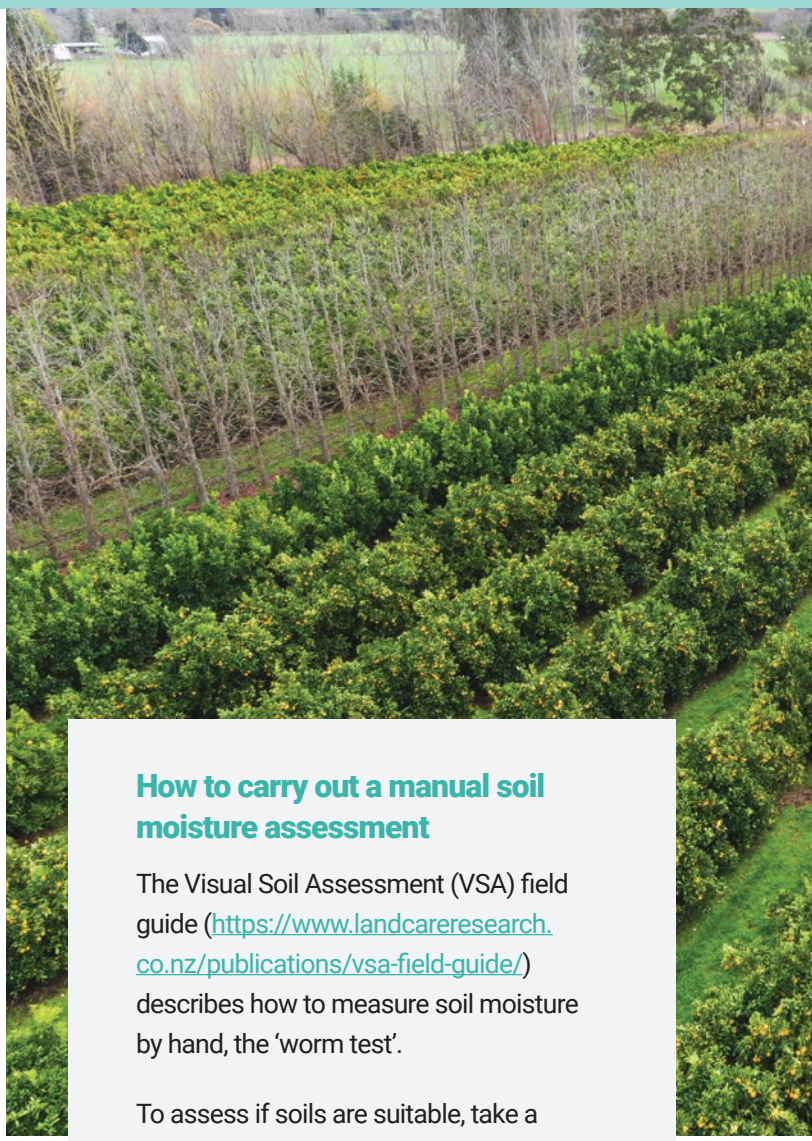
The approach to prepare the area for sowing will depend on individual blocks and the equipment that is available to sow or drill the seed. It is important to consider how friable the soil is, as a hard pan is not ideal.

Weed seed bank

There will be a weed seed bank, so the beneficial plant species selected will need to be able to outcompete germination of this weed seed bank.

Soil moisture

Autumn is generally considered a good time for sowing as the temperatures are still favourable for seed germination, and the ground has some moisture. To check soil moisture dig down to the depth of the seeder to gauge moisture levels. Sowing can occur prior to rain being predicted, but it is likely that germination will be more successful if the soil is already damp but not sodden.



How to carry out a manual soil moisture assessment

The Visual Soil Assessment (VSA) field guide (https://www.landcareresearch.co.nz/publications/vsa-field-guide/) describes how to measure soil moisture by hand, the 'worm test'.

To assess if soils are suitable, take a piece of soil (half the volume of your index finger) and press firmly to form a pencil with your fingers. Roll the soil into a 'worm' on the palm of one hand with the fingers of the other until it is 50 mm long and 4 mm thick. Exert sufficient pressure with your fingers to reduce the diameter of the worm to 4 mm in 15 to 20 complete forward and back movements of the fingers. Conditions are suitable for sowing/cultivation if the soil cracks before the worm is made, or you cannot form a worm (for example, in sandy soils). The soil is too wet if you can make the worm.

Manging the tree canopy

Mature trees often overhang into the inter-row. This will affect equipment access, particularly closer to the understory area. Ideally trees should be pruned before sowing beneficial plants to remove any overhanging branches. Pruning also has the advantage of opening the canopy and improving light access.

2.4 Sowing seed

Sowing seed

Depending on the region, generally the best times to sow seed are during spring (September, October, November) or at the tail end of summer into Autumn (from February to May).

Inter-row

Inter-row species and annual flower strips (see Table 3 for a description of plant species for the seed mix) will comprise mostly of perennial species, a mixture of grasses and legumes with high species diversity.

Intra-row area (under trees)

In citrus orchards this area is generally kept weed-free using herbicides, creating a barren area or herbicide strip. Because of the lack of cover and shading created by the tree canopy this is the most challenging area of the orchard to establish beneficial plants.

2.5 Maintenance

Correct ongoing maintenance of both the inter- and intra-row is essential. It is vital that they are not regularly mown and/or mown short. Flower production is a key objective for most of the species, including the pasture, the vegetation needs to be allowed to become quite long / tall (Merfield and Shields, 2021).

This concept of leaving these grasses and annuals to grow is quite at odds with the expected aesthetic of orchards where often short mown grass and herbicide strips are the norm. However, with time this new aesthetic should come to be valued.

While regular low mowing will be highly detrimental, there may well be a need for strategic mowing to 'reset' the plants as they move from flower to seed production.

Some seed production and shed may be valuable for the plant communities to self-regenerate, but, at the same time it is important to ensure the plants produce flowers through the part of the season when pests are most present (Merfield and Shields, 2021). This may require the plants to be 'topped' with the top third mown off.

The best approach to managing the beneficial plantings will need to be established through trial and error. It is suggested that small areas which are manually cut (shears, weed eater), will be the best way to establish the best techniques, rather than just mowing the whole area at once.

Consider topping every third or fourth row, at one time, so as not to remove all the flowers in the orchard in one go, but to leave the majority of the plants with flowers, and when the topped rows are re-flowering, to then top another third / fourth of the rows.

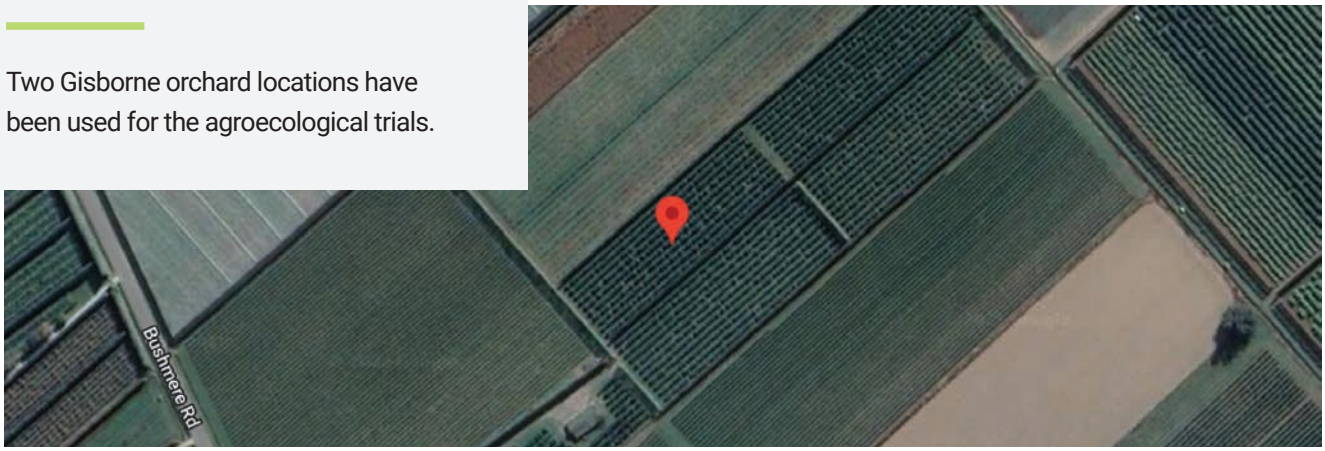
Ideally all mowing's should be left in situ to contribute to the build-up of a detritus layer and soil organic matter. However, if the mowing's are quite thick and they could suppress the plants they may need to be removed.

3

Case study: Establishment of biodiverse plantings in Gisborne Citrus Orchards

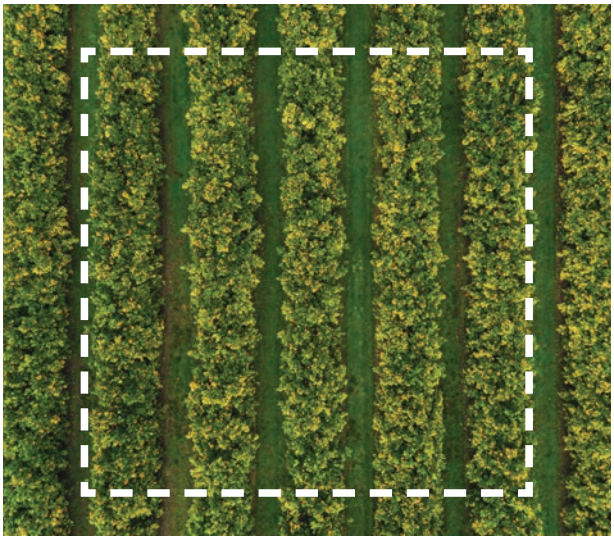
3.1 Trial sites

Two Gisborne orchard locations have been used for the agroecological trials.



Braemark Vineyards – Bushmere Road (GPS 38°37'54.77"S 177°55'56.98"E) Afourer mandarin block

IKO Orchard – Waingake Road (GPS 38°42'15.79"S 177°50'24.04"E) Washington navels



Trial area 50m x 50m located within the larger 1ha orchard

3.2 Trial design

- 50 x 50m trial areas (0.25ha), located within larger area of 1+ ha (buffer). A 50 x 50m control area was also located in the larger block.
- The orchards were chosen for their block size and varieties.
- Other considerations were that these varieties were less likely to need critical insecticide applications. This allows time for the beneficial insects (BCAs) to have an effect without compromising crop quality.
- Other citrus crops such as lemons, need critical insecticide applications for export market quality.

3.3 Planting the trial sites

For the trials on citrus orchards in Gisborne, the approach to establish the **inter-row** and **intra-row** plantings used a staged approach.

Inter-row

1. Inter-row areas were mowed and sprayed to remove grass/weed cover.
2. A power harrow can be used to cultivate the soil prior to sowing.
3. To plant the inter-row, a disc drill - in this case a Duncan vineyard seeder was used to sow the seed. A disc drill disturbs the soil to a pre-determined depth, places the seed then presses it closed creating good seed to soil contact to optimise germination. The seed selected for the inter-row plantings is detailed in Table 2.
4. To 'bed in the seed' roll the inter-row area using a roller.
5. The timing of the first sowing was over November 2021. While not ideal timing as it was a bit late in the season, the plantings were timed to coincide with forecast rainfall. Soil moisture was also checked prior to sowing.
6. Pasture were sown over 4 rows.

The only difference between the two orchard sites was that at the Braemark orchard pasture species were sown into the inter-row over 4x rows, and then intra-row areas were sown with annual flower species. A vineyard seeder was used at both locations.

In Iko Orchard, 4 rows were sown in pasture, then one row in annual flower species. This approach minimised disturbance in the rows that had already been sown and appeared to work well.

Seeder

Equipment list for sowing

Inter-row area:
Power harrow
Tractor and disc drill
Roller

Intra-row
Tractor and compost spreader
Hand seed spreader

Intra-row (understory)

The intra-row area in a citrus orchard is difficult to access due to the overhanging canopy, therefore the soil could not be easily tilled using the equipment that was used to seed in the inter-row. Instead, compost was spread first using a compost spreader into the intra-row area at a rate of 20T/ha.

The benefit of using compost was to ensure good seed contact with the soil. The compost also provides better moisture retention.

For orchards having deciduous trees, the option of lightly cultivating the soil in the intra-row could be considered prior to sowing seed.

An alternative approach that was considered, but not tried, is to mix the seed into the compost before applying to the intra-row. Using this approach, the seed/compost mix would need to be well mixed and then applied immediately as there is a risk of heating the seed.

The compost application rate of 20T/ha was found to be too light to create a layer over the top of the soil. The compost needs to be laid at 50-60T/ha. For future plantings compost will be spread at this higher rate.

Following compost application the intra-row seed mix was spread using a hand spreader at a rate of 5kg/ha.

The most effective method for planting the understory is still a work in progress to find the right approach that suits the orchard, and the equipment that is available.

Seeding the ground

3.4 Visual record

19th November 2021

Compost/seed coverage

6th December 2021

Seedling establishment

Seedling establishment

Diverse pasture species

6th January 2022

Establishment in the main trial block – a bit patchy

This block has 4 full rows of pasture species, and every 5th row is the annual flower strip row.

Establishment has been better as sheep were run through after drilling and the weather was favourable, giving some decent rain after planting.

Better establishment in the IKO orchard

28th January 2022








April 2022

IKO Orchard – the pasture rows have been mown, there was a significant rainfall event in early April.

The pasture is still very weedy, so considering spraying the worst half out and looking after the other half. This approach will give spring versus autumn sown comparisons. Some tidy up under the trees.

Most of the broadleaf mix (lucern, white, persian clover, plantain) has germinated.

Under tree mix has germinated to an extent. Clovers and plantain are visible

5th May 2022

IKO orchard trail block, pasture species

IKO Orchard pasture plantings in the inter-row

27th April 2022

Braemark Vineyard: The inter-row areas of the orchard were resown on the 27th April 2022. The intra-row plantings will be sown early Spring.


DUNCAN
VS
VINEYARD SEEDER


DUNCAN
VS
VINEYARD SEEDER

Steps to establish perennial and annual plant species in the orchard

Step 1:

Survey your orchard, decide what area and where the biodiversity plantings could be established.

Step 2:

Design your planting strategy for the inter-row and intra-row, and annual flower seed mix. Contact your local seed supplier to source the seed mixes.

Step 3:

Make sure you have access to the right **equipment** such as a sprayer, mower and a direct drill (e.g. vineyard seeder) for sowing seed.

Step 4:

Prepare the orchard. You may need to spray and mow the existing green cover. Compacted soil may need light tillage. This could be done prior to or at sowing. Prune back overhanging branches and open the canopy allowing light penetration for establishment of sowings.

Step 5:

Before sowing seed, **check your soil moisture levels.** Also consider the weather forecast and when rain might be expected.

Step 6:

Sow seed mixes in the inter-row and intra-row and watch it grow.

Step 7:

Sow annual flower strips either through the inter-row or at the edge of the inter-row pasture strips or as a separate floral strip in the orchard.

4

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NZ seed suppliers

Wesco Seeds
https://wesco.co.nz/

Kiwiseed
https://kiwiseed.co.nz/

Soil matters
https://www.soilmatters.co.nz/

Farmlands
https://www.farmlands.co.nz/

Wrightsons Seeds
https://www.pggwrightsonseeds.com/

Notes

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