CHAPTER TWO

ORCHARD DEVELOPMENT

NZKGI
NEW ZEALAND KIWIFRUIT GROWERS

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There are around 14,664 hectares of kiwifruit vines that are currently producing kiwifruit in New Zealand. The development of kiwifruit orchards has significantly advanced over the last 120 years, particularly in the last 10 years. This chapter identifies important aspects of orchard development.

THE SECTION IS DIVIDED AS FOLLOWS

2.1 SITE SELECTION

Kiwifruit is a vine that requires relatively specific climatic conditions:

- Warm, sunny summers for accumulation of dry matter
- Sufficient winter chill (600-1100 hrs below 7°C) for good bud burst and floral development

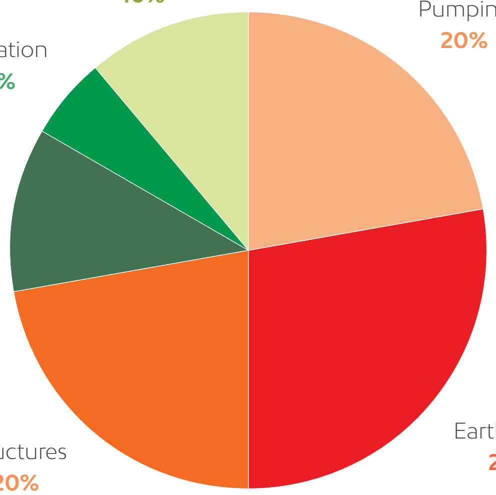
Ideally, sites should be north-facing and relatively flat. Higher elevations are cooler and wetter, so 200m above sea level is considered the upper limit for successful production. With climate change making rainfall patterns more unpredictable, access to water for irrigation and frost protection must be a consideration, so water consent requirements in the area should be known.

The term "greenfield conversion" is used when land used for farming or another use is converted to a kiwifruit orchard. The conversion process involves initial capital costs of:

- Site preparation (with possible earthworks for contouring)
- Establishment of shelter
- Establishment of water supply and reticulation
- Marking out configuration, establishing support posts and wires
- Canopy structure (steel ag-beam and wire)
- Planting of rootstock and grafting kiwifruit or planting pre-grafted kiwifruit plants
- In some orchards, frost protection (via water or windmill) and overhead hail protection may be included

Once the initial capital work has been completed, vine and orchard maintenance is required to establish the orchard to the producing stage in around three years. Consideration needs to be given to the lack of return for a period of 3-5 years before orchards reach maturity and are covering their annual growing costs.

Right:
Figure One: Breakdown of the development costs per hectare



2.2 SITE PREPARATION

Soil quality can be critical for good kiwifruit production. The initial site choice in locating an orchard can save a lot of ongoing work. Well drained loam soils with moderate pH (6-6.5) and organic matter >4% are ideal. Compacted soils, or soils with little drainage and high clay content, and/or low organic matter are generally unsuitable and will require considerable modification before being fit for kiwifruit production. Kiwifruit require relatively high levels of nitrogen in their establishment phase and high levels of potassium once cropping.

Soil Quick facts

Clay soils have high potential fertility but drain slowly and are slow to warm in spring. They are prone to compaction.

Sandy soils drain and warm quickly but require frequent inputs to maintain fertility.

Silt soils have characteristics between clay and sandy soils.

Loams are mixtures of clay, sand and silt that avoid the extremes of each type.

Peat soils are very high in organic matter and have good moisture retention.

Chalky soils are very alkaline and may be light or heavy.

Right:
Knowing the soil texture and structure is important when establishing an orchard

Contouring involves using heavy machinery to modify the surface to even out the bumps and hollows across a block, or to make slopes more workable. There is risk of compaction and an uneven distribution of topsoil which can impact on soil structure and fertility later.

2.3 SHELTER

It is important to have shelter established before kiwifruit vines are planted. Shelter traditionally referred to vertical wind breaks but more recently overhead cover as well. With climate change, weather patterns are predicted to bring more frequent extreme events e.g., hail. Some of the biggest potential biosecurity risks are incursions by insect species (fruit fly, Brown marmorated stink bug).

Good shelter is also an effective tool for managing spray drift, allowing significantly reduced buffer zones if spraying near sensitive areas. Due to increasing community concerns around agrichemical use, the presence of boundary shelter is becoming a significant factor in maintaining the industry's social licence to operate. Growers should check their district plans because some have requirements about shelter heights and setback distances from boundaries that need to be complied with, otherwise, a resource consent may be required.

Kiwifruit vines do not tolerate wind well. Wind leads to increased physical damage and blowouts of shoots, so young plants and spring canopies are slower to establish. Physical damage can also be an entry point for Psa infection. Shelter is also important for reducing water loss via evapotranspiration when plants are becoming established.

In all orchards, good shelter improves productivity by raising temperatures in the orchard - hastening growth, encouraging bee activity during pollination, and promoting normal flower and fruit development. Shelter also reduces fruit loss due to defects such as wind rub. Gold and Red varieties are more sensitive to this than Green.

Left:
Trees planted for natural shelter

Right:
Internal shelter helps to keep temperatures up, reduce wind and improve the growth of developing vines

Types of Shelter

Wind reduction is affected by the height, length and porosity of the shelterbelt. Ideally, it should be planted at right angles to the prevailing wind. While there may be site specific constraints such as powerlines, the ideal shelter height is a minimum of 5m. An effective shelterbelt acts as a filter rather than a solid barrier and it should be continuous as the wind will funnel through gaps with increased speed. There are pluses and minuses with all shelter types so careful consideration needs to be made of site-specific factors.

- Natural tree shelterbelts take a considerable time to establish but tend to look more pleasing to the eye. Care should be taken to avoid tree species that harbour pests e.g. Poplar (scale), or any deciduous species. Cryptomeria and Casurina spp. are more commonly used. Natural shelter comes with regular maintenance costs, including trimming, mulching and spraying for pests. It also takes up productive land area, and uses resources that could otherwise be used by the vines.
- Artificial windbreaks are more expensive to install than natural shelter but give immediate protection without competing with the vines. It can be a temporary solution while natural shelters grow up, or for filling gaps. Shelter cloth usually has a ten-year warranty, so the maintenance costs beyond ten years may be much greater than for natural shelter.

Undervine shelter is windbreak cloth run along a row from ground to canopy every 3-5 rows. This also reduces wind damage and retains some warmth in the orchard, without the infrastructure costs involved in installing the large upright supports for vertical shelter. However, it can interfere with some on-orchard practices such as girdling, pruning and harvesting, and reduce spray coverage.

Overhead shelters cover kiwifruit vines with hail netting on the roof and additional windbreak cloth on the sides. Overhead shelters have an expensive outlay cost, but the financial rewards can be significant, particularly for sites where wind may impact productivity. The benefits include:

- Eliminating the impact of a hail event, provided the cloth is in good condition
- Significant reduction in wind speed
- Elimination of wind turbulence
- Reduced leaf wetness and vine damage, minimising the risk of Psa infection and spread
- Improved pest control (if orchards are completely enclosed)
- Earlier production
- Higher yields resulting from fewer rejects

Overhead shelter has been associated with greater bee mortality and decreased pollination with traditional pollination systems. Ongoing research is revealing new strategies for improving pollination while maintaining hive health.

Table 1. Natural Shelter	
Advantages	**Disadvantages**
• Cheap to establish • Withstands strong winds • Can provide biodiversity • Can be a good barrier to spray drift	• Utilises productive land • Competes with vines for light, water and nutrients • Long establishment time • Can harbour pests • High annual maintenance costs
Artificial Shelter	
Advantages	**Disadvantages**
• Instantly established • Allows full land utilisation • Relatively easy to maintain • Does not compete for resources with the vine • Can assist pest control	• Expensive • Unattractive to some people • May constrain some orchard activities • May impact bee activity

2.4 WATER

Historically, access to water has been relatively straight forward, with the early orchards established in the Bay of Plenty where regular rainfall and deep ash soils allowed crops to flourish without irrigation. Climate change, changing land use, increases in plantings and expansion into other regions, are all increasing industry demand for water. At the same time there are increasing constraints on water use, due to fully or over-allocated local water resources, along with societal demands to demonstrate the prudent use of water. Access to water, including water storage, is now a key factor in decision making for orchard development. For more on the industry water strategy see Ch 4.

Research has been completed on Kiwifruit water demands. Kiwifruit vines fulfil their water requirements from available soil moisture, rainfall or irrigation. Vines lose water through evapotranspiration (ET). A measure of their water needs therefore equals the daily ET, measured in millimetres (mm), which depends on the size of the canopy as well as environmental factors (solar radiation, air temperature, humidity and wind speed). ET in spring is 2-3mm per day and rises in midsummer to 4-5mm per day, dropping away through autumn. Usefully, 1mm equals one litre per square metre, so in mid-summer kiwifruit vines use 4 to 5 litres of water per square metre of canopy per day.

	Spring	Summer
7 day average ET	3mm	5mm
Canopy extent	24m^2	24m^2
Canopy fill	75%	100%
Daily kiwifruit water use	54 litres	120 litres

Figure 1. Daily vine water use is calculated by multiplying ET by the effective canopy area per vine.

Young developing vines have different water requirements from mature vines due to their smaller canopies and root systems. A new vine may begin the season with only around 1m^2 of canopy compared with 35m^2 for a mature vine. However, because the newly developing leaves are more exposed, and the root ball is small, the volume of water required per vine is greater than the figures above suggest. Soil type is a significant factor in determining how much and how often a block of kiwifruit is watered. Variation of soil types within an orchard requires some precision irrigation so that water is not wasted and vines are not stressed. Soils with a high proportion of pumice will drain more quickly than soils with a high proportion of clay and will require more frequent watering.

Kiwifruit vines that run short of water, especially during phases of rapid growth, will wilt and the leaves will quickly go brown. Kiwifruit vines suffering from drought will produce smaller fruit and excessive drought can reduce the following season's yield. Excessive irrigation, particularly in clay soils, can also be detrimental to the productivity of kiwifruit vines. Kiwifruit roots are sensitive to a lack of air and if the roots remain under water for 24-48 hours it will result in root death from which the vine is slow to recover. Growers are paid for both fruit size and dry matter. Water stress can constrain fruit growth any time in the growing season but will have the greatest impact in the six weeks after flowering. Some growers reduce irrigation later in the season to improve dry matter, however this should be managed with caution as it can have a detrimental effect on fruit size and vine health.

Irrigation is generally applied through drippers, micro-jets or micro-sprinklers. Drippers focus water delivery next to or in between the vines while jets and sprinklers will target a wider area. Some systems can be raised or lowered to provide both irrigation and frost protection services. Irrigation methods that wet the canopy can contribute to an increase in Psa disease risk.

Right:
Sprinkler used for irrigation

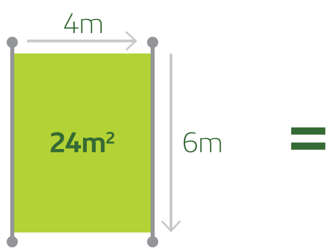
2.5 SUPPORT STRUCTURES

Kiwifruit vines need to be trained onto a support structure for commercial cultivation. Historically, vines were grown on a T-Bar system which was cheaper to construct and easier to maintain. However, greater yields (>20%) are achievable with pergola systems. These allow the canopy area to utilise virtually 100% of the land area with maximum light interception, resulting in a more consistent crop. With labour constraints forecast to continue, research is ongoing into new growing systems that may provide solutions such as mechanised pruning or harvesting.


Left:
Grafted kiwifruit stumps with pergola structures and wires in place ready for training
(Shane Max, Zespri)

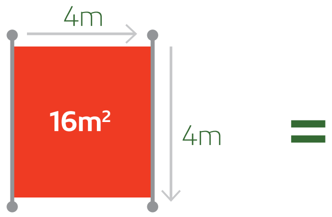
Right:
T-Bar grown kiwifruit vines

Ideally, rows should be oriented in a north-south direction to optimise light onto both sides for the vine. Depending on the extent of shelter, rows should be at right angles to the prevailing wind. There is no standard bay size or planting configuration in the industry, and there are advantages and disadvantages to consider in both. Row spacing around the world ranges from 3-6m, with 3.5-4.5m being the most common in NZ. Post spacing refers to the distance between posts within a row, with a bay being defined by the 4 posts in each corner. Vine spacing refers to the distance between vines within a row, which may or may not be the same as the post spacing. Sometimes vine density is increased to speed up canopy establishment – one vine between posts is "single planting" while two is "double planting". Bay size cannot be changed once the orchard is established but planting density can be altered later by adding or removing plants.



LARGER BAYS

- Reduced infrastructure inputs
- Less plants per ha
- Slower leader establishment & canopy fill rate



SMALLER BAYS

- Increased infrastructure costs
- 20% more plants
- Faster establishment and time to production

2.6 PLANTING

The ratio of male to female plants, and how they are arranged, has implications on the amount of canopy available for growing fruit. The closer a female flower is to a male flower the more likely it is to achieve full pollination. The two main options are Strip Males or Opposing Female (also called Matrix Male).

F	-	F	-	F	-	F
F	M	F	M	F	M	F
F	-	F	-	F	-	F
F	M	F	M	F	M	F
F	-	F	-	F	-	F
F	M	F	M	F	M	F
F	-	F	-	F	-	F
F	M	F	M	F	M	F
F	-	F	-	F	-	F

Strip Males

Every second row is planted with only Male plants. The male plants may be spaced out (alternate bays). This is most effective with narrower rows (3-4m). This configuration can be very labour efficient as the males are trained along the leader wire and do not take up much canopy space within the bay. It allows every female plant to be in close proximity to a male.

F	F	F	F	F	F	F
F	M	F	M	F	M	F
F	F	F	F	F	F	F
F	M	F	M	F	M	F
F	F	F	F	F	F	F
F	M	F	M	F	M	F
F	F	F	F	F	F	F
F	M	F	M	F	M	F
F	F	F	F	F	F	F

Opposing Female (also called Matrix Male)

Males are interspersed between females in every alternate row, either every second or every third bay. Ideally their footprint is kept small. Male grafts can be added on to the female vines rather than planting separate plants. More labour is required to keep the opposing females from tangling in the middle of the bay, but it is an effective method in wider rows.

M	-	M	-
F	F	F	F
F	F	F	F
-	M	-	M
F	F	F	F
F	F	F	F
M	-	M	-
F	F	F	F
F	F	F	F
-	M	-	M

East-west Strip Males

This is a hybrid of the two configurations and is often used to increase the male distribution in an established orchard. Male plants are planted by the posts and trained across the pergola beam rather than along the leader wire. This requires more careful management to avoid shading the female leaders.

Different kiwifruit cultivars have different ploidy (sets of chromosomes) and not every male cultivar is therefore compatible with every female cultivar. A range of male cultivars have been bred with emphasis on male characteristics such as Psa tolerance, flower numbers, pollen fertility, a long flowering period, attractiveness to bees, and low vigour. Often more than one male cultivar is planted in an orchard to ensure there is cross over of flowering times with the female throughout the whole pollination period. Generally, it is important to use males with the same or higher ploidy than the female for successful pollination.

Example Female Cultivar	Ploidy	Sets of Chromosomes
Hort16A	Diploid	2x
Gold3	Tetraploid	4x
Hayward	Hexaploid	6x

Ploidy	Male Cultivars
2x	Bruce, CK2
4x	M33, M91
6x	Chieftain

2.6.1 Rootstocks

Kiwifruit cultivars that produce desirable fruit do not necessarily have good root systems or resistance to disease. Commercial kiwifruit plants are not grown from seed but are the result of grafting a good fruit-producing cultivar (termed the scion) onto another cultivar with better root growing capability (the rootstock). The rootstock can also impart its characteristics on to the scion, such as low vigour in vegetative growth.

The two most common rootstocks in kiwifruit are Bruno and Bounty (also called Bounty71). Bruno was a commercial cultivar itself up until the 1970s, when Hayward took over due to its better storing properties. Bruno rootstock is grown from open pollinated seed so retains some level of variability. It is hardy, easy to propagate and resilient – particularly in its resistance to Psa. Bounty is a clonal rootstock i.e. it is propagated through cuttings (cloned) so has very little variation in its attributes.

Rootstocks can confer tolerance to climatic and environmental challenges such as waterlogging, drought, extremes in temperature and poor-quality soils. This has allowed for kiwifruit production to spread into more marginal growing areas and may in the future help mitigate the impacts of climate change.

The choice of rootstock can also impact on the timing of the vines development throughout the season (phenology) by as much as one week. This has financial implications for those growers whose fruit is early enough to make the first shipment of fruit to market. Bounty is less vigorous than Bruno and requires higher planting densities to speed up full canopy establishment. Growers developing new blocks can purchase rootstock plants and carry out their own grafting or buy pre-grafted plants, where grafting has been done in the nursery.

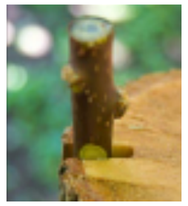
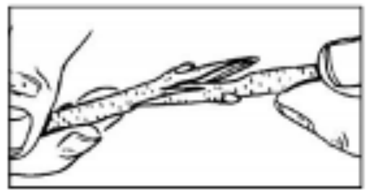
2.6.2 Grafting

Grafting is also used when there is a need to change cultivars e.g., from Hayward to Gold3, or as occurred post Psa. Grafts can be applied in different places on the vine: notch grafting (side graft); stump grafting; and sucker/rootstock grafting. There are also different techniques: kerf (chainsaw) grafting; cleft grafting; and whip and tongue grafting. In every case the aim is to line up the transport systems of both scion and rootstock so that there is continuous transport of water and nutrients from the roots to the leaves, and carbohydrate from the leaves to the roots. This is easier to achieve before there is extensive sap flow, the pressure of which can be enough to dislodge grafts.

Right:
Successfully grafted kiwifruit vines. Notch grafted (left), Stump grafted (centre) and Sucker grafted (right)

Mid-winter is the best time to begin grafting and should be completed by late winter. The grafting success rate declines once sap flow starts. The timing of sap flow depends upon several factors including weather conditions, soil moisture and the chosen rootstock. Sap flow normally lasts six to eight weeks.

Below:
Characteristics of various grafting methods

Kerf (chainsaw) Grafting	Cleft Grafting	Whip & Tongue Grafting
• The whole stump is not split making for easier wound protection/vine health. • Suitable for **stump** and **notch** grafting types. • Can be used on stumps cut very close to the ground. • Section has to be cut to fit the slot. • Rootstock needs to be at least 120mm in diameter (this method is best for larger old vines).	• Suitable for all grafting types **(stump, notch and sucker).** • Difficult to split the stump if cut close to the ground. • Tension of the cleft helps to hold the scion in securely. • Difficult to re-graft failures. • Size of graft wood not a factor.	• Suitable for **sucker/rootstock** grafting. • Size of graft wood not a factor. • Tension of the whip and tongue helps hold the scion wood securely.
		

Right:
Looking down on a kiwifruit stump where the canopy has been cut off and two short pieces of budwood (scion) cleft grafted on

Summer grafting is possible, but sap flow must be carefully managed. Summer grafting is generally not as successful as winter grafting and is usually only used when abnormal conditions exist. For example, if there was a high rate of grafting failure in winter, or high levels of Psa infection in the grafts. The earlier summer grafting is undertaken (November) the better the subsequent growth.

Post grafting care and graft hygiene are of the utmost importance when it comes to ensuring graft success. New shoot growth is vulnerable to damage from birds, caterpillars, bronze beetle, slugs, and snails, as well as diseases such as Psa. It is important to keep the base of stump free of weeds and use slug pellets around the base and on top of the stump.

Grafting wounds can be sealed with a wound protectant to prevent water from entering the graft union and will protect the graft against infection.

The links below are two videos showing the grafting methods outlined above.

READ MORE HERE:

www.youtube.com/watch?v=4Ikpc7pv41g
www.youtube.com/watch?v=QV4AICjPUIE

2.7 FROST PROTECTION

Frost damaged fruit are not edible or saleable and frost damage to vines can kill flowerbuds and negatively impact productivity of kiwifruit vines the following season. Gold and Red varieties are more at risk of spring frost damage as budbreak occurs earlier than in Green. Hayward fruit is more susceptible to autumn frost damage as they are generally harvested later.

Most of the horticulturally significant frosts in New Zealand are radiation type (rather than advection frosts, which are when a blast of freezing air occurs). Radiation frosts occur on nights with clear skies and little or no wind. As heat is radiated away from the ground and vegetation surfaces, the warmed air rises and is replaced by cold air moving down. This creates an inversion layer. This cold air draws further heat from the plant material. When the cold air is below 0° Celsius a frost occurs, which can result in irreversible damage to the plant tissue.

There are three main types of frost protection: heating, mixing (to disturb the temperature inversion) and radiation barriers. In kiwifruit, the most widely used methods are sprinkler systems (heating) and wind machines (mixing).

Left:
Severely frost damaged kiwifruit leaves
(*Shane Max, Zespri*)

Right:
Ice on kiwifruit
(*Shane Max, Zespri*)

Heating

Sprinkler-based frost protection systems use the heat released when water changes state from a liquid to a solid. Spraying water at an appropriate rate onto a crop under frost conditions causes a layer of ice to slowly develop over the vines. Provided the surface of this ice layer is kept wet, the temperature of the enclosed plant tissue will not drop below about minus half a degree, even though the surrounding air may be at a much lower temperature. This requires a considerable amount of water (≥ 3mm/hr/ha or around 300,000L per hour on a 10ha orchard, greater than the flow rate required for irrigation). Sufficient water supply and well-draining soils are critical.

An older method of frost protection is direct heating by portable heaters and/or frost pots, fueled by combustion (oil, natural gas, LPG, special solid fuel blocks, candles made from wax, compressed wood waste or other similar materials). Effectiveness decreases with distance from the heat source.

Right:
New growth protected from frost damage by a sprinkler system

Mixing

A wind machine or frost fan is essentially a large fan at the top of a 10 or so metre high tower, located in the center of the area to be protected. The 'jet' of air produced by the fan draws the warm air from above the orchard and mixes it into the colder air closer to the ground. Depending on topography and block layout, one fan can protect an area of 4-6 ha. Flying a helicopter at relatively slow speed across the orchard area can also effectively mix the air and provide frost protection. The advantage over wind machines is that the helicopter can concentrate on selected areas if required and fly at greater elevations to provide added mixing capability. There are noise considerations with both methods.

Left:
Windmill used for frost protection
(*Shane Max, Zespri*)

Right:
Helicopters used for frost protection

Radiation Barriers

The principle of a radiation barrier is to reduce the heat lost from the vines and soil surface, and hence increase the vine temperatures. This is achieved by intercepting the outgoing radiation by means of frost cloth or similar.

Right:
Overhead shelter
(*Shane Max, Zespri*)

Cold Air Drainage

Since cold has a greater density than warmer air, it settles at the lowest point that it can easily flow to. In kiwifruit orchards, natural or artificial shelter can trap cold air so that it pools, where it can lead to frost damage. Maintaining cold air drainage involves modifying downhill shelter so that cold air can freely drain out of the orchard. This can include removing the lowest metre of foliage from natural shelters so that cold air can flow under, or repositioning shelter to allow for cold air to escape.

2.8 STRINGING

Many orchardists, during the conversion or establishment stages of orchard development employ a management practice called stringing. This is when new growth from the grafted scions is grown up strings to boost vigour through apical dominance. When the strings are lowered these new canes become the leaders; they switch to a lateral growth habit which fills the canopy area and allows growers to move into production sooner. Once the canopy has developed, some growers choose to train their vines to a low vigour system, while other growers will continue to grow canes up strings every season, effectively refreshing their canopy each year. However, canes growing up strings above the canopy receive far less spray coverage than those trained along the pergola wires, as the canopy acts as a barrier to spray reaching those canes.

Right:
Pergola kiwifruit block set up for growing up strings
(*Shane Max, Zespri*)

Left:
Kiwifruit vines growing up strings

Right:
Kiwifruit block set up for growing up strings
(*Shane Max, Zespri*)

"Once the canopy has developed, some growers choose to train their vines to a low vigour system, while other growers will continue to grow canes up strings every season."

2.9 ESTABLISHMENT

Getting healthy plants up and running as quickly as possible has been likened to paying off the mortgage on your house early. High quality planting, grafting and establishment all have a huge ripple effect on the long-term profitability of an orchard for years to come.

Young vines need care to establish well. This can be summarised by the "Three S's":

- **Shelter** – keep them protected from the extremes of the elements
- **Support** – robust and secure structures support good growth
- **Spray** – protect new growth from pests and diseases, and control weeds