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Exploring opportunities for protected cropping in Northland

Conroy D, Gan I, Lin B, Fahn H, Graham D, Adams C, George S

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Report prepared by:

Denise Conroy
Principal Scientist/Science Team Leader, Market Analysis & Behaviours
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Report approved by:

TC Chadderton
Science Group Leader, Health & Consumer Sciences
October 2025

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Plant & Food Research Group, Bioeconomy Science Institute Auckland

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With its warm, subtropical climate and suitability to produce a diverse range of tropical and subtropical crops, Northland (Te Tai Tokerau) is a region brimming with horticultural opportunity. One such possibility is protected cropping systems, which provide growers with the ability to fine-tune the environment in which their crops are grown and avoid many of the pitfalls associated with open-field cultivation. Particularly, protected cropping systems have the potential to mitigate weather-related risks, extend the growing season for high-value and high-quality crops, and enable the cultivation of novel tropical crops that are otherwise not viable for open-field production in Northland.

A variety of protective structures are available to suit the needs of different crops in the region, ranging from more affordable options to premium systems, with the key benefits of protected cropping including greater certainty of production aligned with specific growing objectives, and improved working conditions.

The potential of protected cropping is currently underexplored in the Northland region. Therefore, the purpose of this research was to interview growers and other stakeholders in order to better understand the potential benefits and drawbacks of adopting this growing system – particularly for growing novel and high-value crops such as dragon fruit, papaya, and blueberries. The choice of crop focus was motivated by the understanding that substantial capital investment is required for initial set-up, hence high-value fruits are more likely to realise a substantial return and therefore warrant the initial investment.

Interviews with growers provided insight into their positive experiences with covered cropping such as crop protection from climate events, the production of early to market crops and much better experiences for workers no longer exposed to weather. The interviews also identified the drawbacks they had experienced such as unanticipated pests not previously associated with a crop when it was grown outdoors, to the lack of accessible knowledge on how to address an issue because the industry is still embryonic. Indeed, one of the most frequent issues cited was the fragmentation of local knowledge and experience and the need for greater collaboration to address emerging challenges to build a more resilient and informed sector.

There is clear interest from supermarkets and wholesalers in sourcing locally grown produce from Northland. However, individual growers may face difficulties in establishing direct relationships with these outlets. As production volume grows in the future, a cluster approach where groups of growers collaboratively supply the same crop could potentially streamline market access and enhance supply reliability. Furthermore, while “locally grown” is a valuable selling point, it should be paired with other tangible benefits e.g. novel variety, excellent taste profile, and freshness, to appeal to a broader customer base.

An Economic Analysis Guide is commissioned to AgFirst, a specialised horticultural consultancy, as part of this project to guide Northland growers through key financial considerations when evaluating investments in protected cropping. This guide compiles critical economic and financial factors relating to a potential development of protected cropping systems and provides a decision matrix to prompt growers to consider the various components of such a development.

For further information please contact:

Denise Conroy
Plant & Food Research Group, Bioeconomy Science Institute
Private Bag 92169
Auckland Mail Centre
Auckland 1142
NEW ZEALAND

Tel: +64 9 925 7000

Email: denise.conroy@plantandfood.co.nz

1 Introduction

With its warm, subtropical climate and suitability to produce a diverse range of tropical and subtropical crops, Northland (Te Tai Tokerau) is a region brimming with horticultural opportunity (Coriolis Research 2019). However, like many other regions in the world, Northland has been affected by climate change. These effects are slowly but surely reshaping growing systems and bringing both uncertainty and possibility in equal measure (Vetharaniam et al. 2024). Increasing temperatures, rainfall, strong winds, and extreme weather patterns pose significant challenges for growers and traditional growing systems, whilst also opening the door to explore growing crops once thought ungrowable in Northland (Ministry for Primary Industries 2023).

One possibility is protected cropping systems, which provide growers with the ability to fine-tune the environment in which their crops are grown and avoid many of the pitfalls associated with open-field cultivation (Sanmukh et al. 2019). By making use of structures such as greenhouses, tunnelhouses, or rain roofs, growers can reduce the damaging effects of extreme weather, improve the quality of their crops, extend the growing season beyond what would otherwise be possible, and diversify into high-value products (Jain et al. 2023). These systems have already been widely implemented in agriculture around the globe, and are being used to produce a range of crops, from vegetables to flowers and specialty fruits (Sheeba et al. 2025). The potential of protected cropping systems in Northland is currently underexplored, as too is the market for its produce.

1.1 Objectives

Protected cropping systems have the potential to mitigate weather-related risks, extend the growing season for high-value and high-quality crops, and enable the cultivation of novel tropical crops that are otherwise not viable for open-field production under Northland’s current climate. The objectives of this project are three-fold:

- To inform Northland growers about the potential benefits and limitations of various protected cropping systems.
- To share insights and experiences from exemplar growers currently operating under cover to support peer learning.
- To provide a financial framework to guide growers in evaluating and selecting protected cropping structures.

1.2 Research approach and methodology

A mixed-method approach was adopted to achieve the project objectives:

- Desk research was conducted to provide an overview of current world-wide protected cropping practices and to present evidence of their benefits and limitations.
- Stakeholder engagement and interviews were carried out to gather insights from growers currently operating under cover, and with other stakeholders in the value chain to understand market potential for production from protected cropping systems in Northland.
- Economic analysis was undertaken to develop a financial framework that supports growers in evaluating protected cropping investments.

2 Protected cropping infrastructure

2.1 Protected cropping overview

Protected cropping systems are agricultural practices that involve growing crops within protective structures designed to create a modified and controlled environment. These systems could act as a barrier against external factors such as pests, diseases, excessive rainfall, drought, wind, and extreme temperatures, while also allowing growers to optimise conditions for plant growth.

Protected cropping systems such as greenhouses, tunnels and shade nets have consistently demonstrated advantages over open field growing for a wide range of crops. These systems help growers better manage climatic risks, improve productivity, and capture new market opportunities. However, they also present management and cost challenges that must be carefully considered. Tables 1 and 2 provide a summary of the key advantages and challenges of various protected cropping solutions. For more information, please refer to Appendix 1: Desk research on selected crops' performance under cover.

Table 1. Advantages of different protected cropping systems.

Advantages	Detail
Extended Growing Season	By protecting plants from external conditions, production cycles can be extended, and in some cases, year-round cultivation is possible, boosting overall yields compared with open-field farming (Sheeba et al. 2025).
Consistent Quality	Stable and consistent growing conditions reduce plant stress and support predictable results. This results in uniform size, colour, and flavour (Sanmukh et al. 2019).
New Crop Opportunities	Protected cropping systems make it possible to grow new and higher-value crops that might not thrive in local climates (Aditya et al. 2023). Farmers can try varieties that need cooler, warmer, or more stable conditions than the natural environment offers (Sheeba et al. 2025).
Rainfall Protection	Heavy rain can lead to fruit splitting, flower loss, and fungal outbreaks. Protected cropping structures help prevent direct rainfall from reaching plants, reducing these risks while also protecting soil structure and integrity (Castilla & Baeza 2013; Sanmukh et al. 2019).
Water Conservation	When combined with drip irrigation and fertigation, protected cropping systems significantly reduce evaporation and enhance water-use efficiency, making them especially valuable in drought-prone regions (Sanmukh et al. 2019).
Temperature Control	Protected cropping shields crops from frost damage in cooler climates and mitigates heat stress in hotter regions. By moderating the microclimate, these systems help minimise fruit losses and maintain consistent production (Patil et al. 2024).
Pest and Disease Management[1]	Protected cropping systems play a key role in sustainable pest management, helping growers reduce chemical use while maintaining high crop quality. Structures such as insect netting or enclosed greenhouses prevent pest entry and reduce reliance on chemical sprays (Galán Saúco 2015).
Improved Working Conditions for Workers	Protected cropping systems provide shade and protection from rain, high UV levels, and extreme temperatures, creating a safer and more comfortable work environment (Elverding 2024). This not only enhances worker wellbeing and reduces fatigue and weather-related injuries but can also improve job satisfaction and lower turnover, supporting both workforce stability and productivity (Jackson & Rosenberg 2010; Morabito et al. 2021).

[1] Noting, however, that in warmer climates a rain-shelter designed without sides or ends can facilitate improved pest and disease control through better air movement and flow of natural enemies in and out of the structure.

Table 2. Challenges of different protected cropping systems.

	Challenges	Detail
	Labour and Skills[2]	Protected cropping can create new job opportunities but also requires careful management. Workers need the right skills and knowledge for tasks like managing the greenhouse environment, pruning plants, monitoring pests, and scheduling irrigation (Bruce et al. 2019). Without proper training, the full benefits of the system may not be achieved.
	Capital Investment	Setting up protected cropping systems requires an initial investment. The cost of greenhouses, tunnels, irrigation systems, and environmental controls could be a challenge for small- and medium-sized growers (Sheeba et al. 2025).
	Site Requirements	Choosing the right site is key for healthy crops and long-term success. Ideally, the land should be level or gently sloping with well-drained soil, since waterlogging can damage plants (Castilla & Baeza 2013; FAO 2022). The site should also receive ample sunlight each day, with even light distribution across the crops (FAO 2022).
	Energy and Inputs[3]	Fully enclosed systems like greenhouses often need heating, cooling, ventilation, and supplemental lighting. These energy needs can raise operational costs and affect profitability if not managed efficiently (FAO, 2022).

[2] Noting, however, that protected cropping businesses can enjoy better staff utilisation and be less reliant on a seasonal workforce since a variety of crops can be grown and harvested all year round.

[3] Noting, however, that an advantage for Northland protected cropping growers is the naturally warmer, year-round growing environment, reducing the need for artificial heating.

2.2 Types of protected cropping infrastructure

In the protected cropping space, there exists a wide range of systems and configurations that, although functionally similar, may serve very different purposes. Around the world, there is a wide variety of fruit, vegetable, and spice crops being grown under various protected cropping systems. Table 3 provides a summary of the commonly used protected cropping systems and their benefits and drawbacks that have been documented in the literature.

Table 3. Types of protected cropping infrastructure and their benefits and drawbacks.

Protected cropping systems	Key benefits and drawbacks
Greenhouses Greenhouses are enclosed structures made of transparent material to enable a high degree of control over their internal environment (Heuvelink et al. 2024; Castilla 2013). 	**Benefits** • **Flexible construction**: It can be built from glass or various plastics in different shapes and sizes. (Badji et al. 2022) • **Weather protection**: It shields crops from wind, rain, and extreme temperatures, helping maintain consistent quality (Messelink et al. 2021; Maraveas et al. 2023) • **Extended growing season**: It keeps production going for longer periods and minimises the impact of harsh seasons on fruit quality (Güneş et al. 2022; Helmey et al. 2023; InsonGreen 2024). • **Better water use**: It simplifies irrigation and improves water efficiency, helping you save resources and maintain consistent yields. (Galán Saúco 2015; Gübbük et al. 2024). **Drawbacks** • **Extra management systems**: It may need heating, cooling, ventilation, or lighting systems to maintain optimal growing conditions. • **Pollination limitations**: Its enclosed structure can restrict access for natural pollinators. • **Pest and disease issues**: Although protected cropping systems can reduce the risk of pests and diseases, any that do become established can be very difficult and expensive to manage without relying on harmful synthetic chemicals (Chavan et al. 2022). **Examples of global crops cultivated under the system** • Papaya, mango, pineapple, banana, turmeric and ginger (Salinas et al. 2021; Helmey et al. 2023; Hormaza 2023; Gubbuk et al. 2016; Silaru et al. 2024).

Protected cropping systems	Key benefits and drawbacks
Tunnelhouses/High Tunnels Tunnelhouses (or high tunnels), a type of greenhouse, are relatively cheap structures comprising a 'tunnel' of tubing covered with clear plastic (Walton et al. 2018; Sparks et al. 2018). 	**Benefits** • **Weather protection**: These structures provide shelter from wind and rain, reducing environmental stress on crops (Kaiser & Ernst 2021; Walton et al. 2018; Sparks et al. 2018). • **Cost efficiency**: Cheaper and simpler construction compared with greenhouses. **Drawbacks** • **Temperature regulation**: The systems may require heating or cooling mechanisms to maintain suitable growing conditions (Walton et al. 2018; Sparks et al. 2018). **Examples of global crops cultivated under the system** • Dragon fruit, banana, turmeric and ginger, blueberry (Belbase et al. 2025; Choudhury et al. 2022; Li & Bi 2019; El Horri et al. 2025; Cui et al. 2000).
Nethouses/Screenhouses Nethouses and screenhouses utilise permeable netting or 'screens' instead of plastic or glass. 	**Benefits** • **Temperature control**: The systems allow natural air circulation to help keep crops cooler in hot climates (Tanny 2019; Castilla & Baeza 2013).

Protected cropping systems	Key benefits and drawbacks
	• **Pest protection**: They can reduce the need for pesticides, protecting crops from insects while maintaining airflow (Tanny 2019; Jain et al. 2023)[4]. • **Wind, rain and hail protection**: The systems help reduce wind spend and lessens the impact of heavy rain or hail to protect crops (Tamaki 2022; Saboki & Jafari 2025). **Drawbacks** • **Extreme weather limitation**: Very high winds can still cause damage, especially with knitted screens compared with woven ones (Tamaki 2022; Pirkner et al. 2014). **Examples of global crops cultivated under the system** • Papaya, dragon fruits, banana, pineapple (Choudhury et al. 2022; Chien et al. 2024; Araújo et al. 2022; Saboki & Jafari 2025).
Shade Nets/Covers Shade nets are open structures that utilise large nets of varying thickness to provide shade for crops growing underneath, deployable both alone or as supplementary to other covered cropping systems. 	**Benefits** • **Heat protection**: The systems reduce solar radiation, lowering canopy temperature and preventing sunburn and heat stress on crops (Patil 2024). **Drawbacks** • **Ventilation considerations**: In dry climates, adding shade nets to greenhouses can reduce natural roof ventilation, which may affect airflow and cooling (Mahmood 2018). **Examples of global crops cultivated under the system** • Mango, pineapple, dragon fruits, turmeric and ginger, coffee, mandarin (Zhao et al. 2020; Roets et al. 2018; Lin 2007; Patil et al. 2024; Scuderi et al. 2022).

[4] Noting, however, that once introduced, pests in a net house environment can effectively be trapped in the structure and are then extremely difficult and costly to eradicate.

Protected cropping systems	Key benefits and drawbacks
Rain Shelters/Plastic Roofs Rain shelters, typically in the form of plastic roof covering or sheets, are unenclosed structures that shield crops from rainfall (Børve et al. 2003; Kratky 2006). 	**Benefits** • **Rain and hail protection**: Plastic roofs or covering protect crops from rainfall (Børve et al. 2003; Kratky 2006). **Drawbacks** • **Limited impact on water stress**: While effective against rain, these shelters do not necessarily address water stress, which depends on soil moisture levels (Meland & Skjervheim 1997; Palma et al. 2023). **Examples of global crops cultivated under the system** • Mango, blueberry (Morales et al. 2024; Jutamanee & Onnom 2016).

2.3 Protected cropping systems in New Zealand

The information in Table 4 provides details on the suppliers and operators offering protected cropping systems across New Zealand. These companies provide solutions ranging from simple canopy covers through to advanced climate-controlled greenhouses, catering to a diverse range of horticultural crops.

Table 4. Protected cropping systems suppliers.

Supplier	Location	Products/Services	Web Link
Redpath	Palmerston North, Manawatu	Greenhouses, tunnelhouses, shadehouses	Home - Redpath
Harfords Greenhouses	Christchurch Canterbury	Residential and commercial greenhouses, tunnelhouses (crop topper)	Harford Greenhouses | Quality Greenhouses - Horticultural Solutions
Haygrove	Manawatu	Polytunnels, greenhouses, substrate systems	Polytunnel Suppliers I Berry and Cherry Growers | Haygrove
APEX	Waiuku, Auckland	Commercial greenhouses, packing sheds, greenhouse equipment	About - Apex Greenhouses
Quiedan NZ	Te Puna, Bay of Plenty	Tunnelhouses & composite poles	TUNNEL HOUSES | Quiedan NZ
JaCo Constracting	Whangarei, Northland	Greenhouse / tunnel house repairs, maintenance, and modification	About JaCo Contracting Ltd
Primehort	Kaiwaka ,Northland	Greenhouses & glasshouses	Primehort - Smarter Growing
PGG Wrightson	Numerous locations throughout New Zealand	Knitted shade cloth for crops, available in various degrees of thickness	Online Store | Shop Online | PGG Wrightson
Orchard Cover	Te Puke, Bay of Plenty	Orchard shelters (e.g., overhead shelter and vertical high shelter)	Crop Net Protection Service in New Zealand | Orchard Cover
Hortivate	Motueka, Tasman District	Hail protection netting, available in several colours and configurations	Basic Products Archive - Hortivate
Morrifield Greenhouses	Invercargill, Southland	Tunnelhouses and polycarbonate greenhouses, available in a wide range of sizes and with additional features such as wind bracing and irrigation	NZ-Made Tunnelhouses for Sale in NZ | Morrifield Greenhouses
NZ Canopies	Cromwell, Central Otago	Netting canopies, as well as canopy design and construction	Crop Protection Net Systems from NZ Canopies

Table 5 below also provides insights from several protected cropping system suppliers for Northland growers to consider, should they wish to explore the opportunities offered by protected cropping. Table 6 further provides examples of the features associated with some low-, medium-, and higher-spec structures.

Table 5. Insights from Protected Cropping Systems Suppliers to Northland Growers.

Insights from Glen Williams, Redpath NZ	Insights from Adrian Hoogerburg, Quiedan NZ
• Three factors that contribute to making Northland an attractive region to establish protected cropping: ○ Relatively inexpensive land prices ○ Labour costs can be slightly lower other areas, such as Auckland ○ Energy – warmer Northland temperatures are a great advantage, saving businesses significant heating costs. • Even on an overcast winter's day a simple rainshelter will on average increase the inside growing environment temperature by 3–4°C. • The high humidity in Northland creates greater pest and disease pressure in covered crops. • 45% of costs of a new tunnel-house can be associated with the on-site construction; however, budget structures can be put together by growers – Redpath can provide a supervisor to oversee construction. • Lower cost structures use less steel, lighter weight fasteners, do not have gutters between tunnels to enable access to the roof and a simple ventilation system. • Higher cost houses provide a more accurate growing environment especially for year-round growing, utilising rack and pinion ventilation systems have a 25-year design life but will generally last 35 years. • Aside from berryfruit, Redpath is seeing variety of crops in Northland being grown under cover, e.g. nashi, passionfruit, chillis, herbs, orchids. Organic production is difficult. Common vegetables are a good backstop. Grow what you enjoy! • Hard to make a living from 1000 m^2; however, there is a good opportunity for growers to form clusters to supply a market opportunity. • Be more collaborative, less competitive – give new growers the opportunity to visit and learn about your protected cropping structure and growing systems.	• Very important to match capital costs of a structure to the crop. • Observing more "mum and dad" folk getting into protected cropping in Northland with a view to supplying local markets – which are a growing opportunity. • Tunnelhouses are effectively an insurance policy for your crop. • From a labour utilisation point of view you can still pick in the rain. • Wind can be an issue – remember these structures are not buildings – there can be benefits to establishing artificial windbreaks around protected cropping structures in Northland. • While rain-shelter structures with no ends or sides are often very suitable for growing tropical crops in Northland, it is important to have the option to be able to close off the ends in the winter. • Birds can be an issue, "they will always find a way in". For some projects, Quiedan have constructed netting structure across the top of tunnelhouses to prevent bird invasions. • Amount of automation involved, e.g. vents can be the most significant factor involved in the difference between low cost and expensive structures. • Quiedan also specialise in protected cropping of avocado orchards – some of their observations related to a monitored orchard: ○ 98% pack-out – no rots and no proximity, wind-rub marking ○ fruit maturing 2–3 weeks earlier than adjacent uncovered crop ○ lower water demand ○ fruit can be harvested during rain events ○ no alternate/biennial bearing ○ no pollination issues compared with an adjacent uncovered crop ○ pruning system enables fruit to be harvested from the ground – no need for Hydralada ○ current trials have yielded 18 t/ha on mixed age trees 3–6 years with the objective of 40+ t/ha bringing per tray production cost down to well under $5. Uncovered production averages about 10 t/ha with production costs around $10/tray.

Table 6. Examples of the features associated with some low-, medium-, and higher-spec structures.

Type of structure	Low-cost rain shelter	Medium cost rain cover
Example	 (Redpath Simple Self Build Crop Cover)	 (Redpath Rain Cover Arch)
Features	• For basic weather protection; post height 2 m; • Self built by owner, larger area cover on undulating ground; • Supplied with or without gutters; • No concrete required. No design engineering; • From $15 per sqm for large areas.	• Post height 3.5 m, high wind load capability; • NZ design certification engineered for building permit; • Concreted into the ground for durability and long life, 25-year frame design; • All Rectangular Hollow Section structure, long-life Duratough covers, offered as a kit or fully constructed; • From $45 kitset, or erected from $80 sqm.
Type of structure	**Medium cost roof vented greenhouse**	**Higher cost roof vented greenhouse**
Example	 (Redpath Super Single Roof Vented)	 (Redpath Twin Roof Vented)
Features	• High post height up to 4.5 m; high wind capability; • Truss pitched roof for condensation run off control; • Roof vent located at apex can be fully automated for temperature open/close, wind shut down, rain shut down; • NZ design certification engineered for building permit; • Concreted into the ground for durability and long life, 25-year frame design; • All Rectangular Hollow Section structure, long-life Duratough covers, offered in kit or fully constructed; • From $75 kitset, or erected from $110 sqm	• High post height up to 4.5 m; high wind capability; • Truss pitched roof for condensation run off control; • Double butterfly or gullwing roof ventilation located at apex can be fully automated for temperature open/close, wind shut down, rain shut down; • Twin-skin or single skin cladding (in cool climates twin-skin offers up to 50% reduction in heating cost); • NZ design certification engineered for building permit; • Concreted into the ground for durability and long life, 25-year frame design; • All Rectangular Hollow Section structure, long-life Duratough covers, offered in kit or fully constructed; • From $88 kitset, or erected from $120 sqm

Note: the tunnelhouse manufacturers who the authors consulted in preparing this report (e.g. Harford's, Haygrove, Quiedon and Redpath), and as listed in Table 4, offer low-, medium-, and higher-spec structures.

3 Plants for growing under cover

3.1 Plant Variety Rights

If a plant variety is intended to be grown for commercial activity, it must first be checked if it is a protected variety. This is because the owner of a protected variety holds certain exclusive rights to it. The owner's permission may need to be secured before taking intended actions. The owners or agents of a granted Plant Variety Right (PVR) can take legal action against anyone who sells or commercially propagates plants of their variety without permission.

Please refer to Appendix 2 Plant Variety Rights (PVRs) Fact Sheet for more information about PVR.

3.2 Importing plants into New Zealand

Some of the crop varieties suitable for growing under cover may have to be sourced from overseas. Importing plants into New Zealand must meet strict Import Health Standards (IHSs), which require obtaining a phytosanitary certificate from the exporting country's national plant protection organisation and ensuring the plants are free of pests, soil, and other contaminants. The specific requirements vary depending on the type of plant, its intended use, and the country of origin, so it is crucial to check this link Plants for planting - Import Health Standard to ensure a correct phytosanitary certificate is issued before export.

Key steps for importing plants

1. Identify the plant and Check its Status: Determine the specific type of plant you wish to import and search for the corresponding Import Health Standard on the MPI website.

2. Confirm with the Exporter: Your exporter must arrange with the National Plant Protection Organisation (NPPO) of the exporting country to meet New Zealand's IHS requirements before the plant is shipped.

3. Obtain a Phytosanitary Certificate: The NPPO in the exporting country must issue a phytosanitary certificate, which confirms that the plant meets all IHS requirements, including any necessary treatments.

4. Prepare for Border Clearance: Once the plant arrives in New Zealand, it will be inspected by MPI for biosecurity clearance.

Important considerations

- Pest and Soil Free: Plants must be visually free of regulated plant pests, soil, and any unwanted plant material.

- Phytosanitary Certificate: The phytosanitary certificate is crucial; if it is missing, incorrect, or incomplete, the goods may be destroyed or returned to the country of origin at the owner's expense.

- Transitional Facilities: Consignments may need to be sent to an MPI-approved transitional facility for inspection and testing before being released. For more information about post-entry quarantine, see this link Post-entry quarantine facilities at the Plant Health and Environment Laboratory | NZ Government

- Non-Compliance: If your plants do not comply with New Zealand laws, they may be treated, destroyed, or sent back to the country of origin.

3.3 Propagation

There are a number of registered growers and hobby suppliers of plant material to Northland Growers. Table 7 provides a list of commercial suppliers of tropical plants within New Zealand. In addition, tissue culture is widely used for propagation of a range of crops – particularly for amenity horticulture in New Zealand. In many countries, bananas, dragon fruit, jackfruit, plantains, pineapples, and papayas are propagated via tissue culture; however, some cultivars of these fruit types are difficult to propagate this way. Mango and avocado are particularly difficult to propagate by tissue culture.

Table 7. Commercial tropical plant suppliers

Supplier	Location	Examples of Plants Supplied	Web Link
Kotare Subtropicals	Maungatapere, Northland	Arrowroot, Banana, Black Sapote, Canistel, Cassimoroa, Cherimoya, Davidson Plum, Giant Asian Guava, Green Sapote, Jabuticaba, Miracle Fruit, Papaya, Passionfruit, Pawpaw, Pineapple, Rollinia, Sapodilla, Starfruit, Surinam Cherry, Taro, Turmeric	Kotare Subtropicals | subtropical plants for sale
Subtropica	Gisborne	Aloe Vera, Atemoya, Babaco, Banana, Black Sapote, Brazilian Grape, Cardamom, Cherimoya, Davidson's Plum, Etrog Citron, Guava, Inga Bean, Kei Apple, Moringa, Papaya, Passionfruit, Pawpaw, Pineapple	Subtropical Fruiting Plants | Subtropica | New Zealand
KoruKai Herb Farm	Banks Peninsula, Canterbury	Ginger, Turmeric, Yacon	KoruKai Herb Farm
Flying Dragon Nursery	Waipapa, Northland	Atemoya, Banana, Black Sapote, Coffee, Dragonfruit, Finger Lime, Guava, Lime, Papaya, Passionfruit, Pineapple, Starfruit, Soursop, Sugarcane, Surinam Cherry	Flying Dragon Nursery – flyingdragonnursery
Exotica NZ Plants	Far North District	Banana, Black Sapote, Cherimoya, Coffee, Dragonfruit, Inga Bean, Longan, Lychee, Pineapple	About Exotica NZ / Our story & passion
Lynwood Nurseries	Whangarei	Avocados and other tropical and subtropical crops	Lynwood Avocado Nursery - Hass, Bacon, Reed and Fuerte
Te Hana Nurseries	Te Hana	Range of tropical and subtropical plants	Te Hana Nurseries
Multiflora Laboratories	Henderson, Auckland	Tissue culture of a wide range of plants	Home » Multiflora
Lifetech Laboratories	Albany, Auckland	Tissue culture of a wide range of plants	LIFETECH LABORATORIES LTD

4 Input suppliers and technical help

Growing inputs are integral for a successful production, and there are some factors needed to be taken into account if a grower is looking for a new investment in growing a novel crop in a protected cropping system. Table 8 summaries some critical insights from input suppliers in this regard.

Table 8. Insights from input suppliers.

Insights from Craig Lamb, PGG Wrightson	Insights from Jon Harris, Horticentre
• If considering growing a novel crop – return on investment is key, which means a thorough understanding of the market opportunity is required. • Work backwards – what is the market demand? Even very good growers can go out of business if they are not making a return on their ventures. • Many crop protection products are not labelled for minor crops, for example herbs. And because input suppliers are not allowed to make off-label recommendations due to concerns around residues, pest and disease control for smaller operators under cover can be an issue.	• There are benefits from learning to grow crops in soil before attempting to grow in substrate as growing in substrate is less forgiving when water, nutrition, fertigation goes wrong. • Cocoa fibre has made growing in substrate easier – but it still requires growers to become very knowledgeable about nutrition and water quality, i.e. how to adjust pH. A good, secure water source is very important – needs to be clean and free from the risk of agrichemical contamination. • It is possible to grow organically but to do it properly requires utilisation of beneficial insects and natural enemies – requiring growers to become knowledgeable on how to implement biological pest control. • Because many ag-chems used in Integrated Pest Management programmes are often packed in larger containers, the upfront cost can be expensive and unfortunately a barrier to purchase for small growers. • Alternative less expensive knockdown, more broad-spectrum products, e.g. neem, fatty acids, often need to be sprayed more frequently – every 5–7 days. These products can be broad spectrum and kill beneficial insects. • Growers also need to be aware of the potential for phytotoxicity, particularity the issue of spraying soft growth on hot days with some of these products.

In addition to the insights above, Table 9 below provides a list of input suppliers, research organisations, and regional agencies that growers can contact for further technical assistance.

Table 9. Technical help available to Northland Growers.

Supplier	Location	Technical Advisor	Web Link
Horticentre (Growing inputs and irrigation)	43 Porowini Ave, Whangarei 0110 09 438 1045 0800 855 255	Jon Harris (Protected Cropping) Jon.harris@horticentre.co.nz Rhod Mitchell Technical Field Advisor rhod.mitchell@horticentre.co.nz	Whangarei - Horticentre Group
PGG Wrightson (Growing inputs and irrigation)	Kaitaia 09 408 6130 Waipapa 09 407 4835 Kaikohe 09 405 2795 Whangarei 09 470 2521 Dargaville 09 439 3340 Wellsford 09 423 9170	Louise Shepherd Technical Horticultural Representative Shepherd@fruitfedsupplies.co.nz	PGG Wrightson / Fruitfed Supplies Waipapa
Farmlands (Growing inputs and irrigation)	Kaitaia 09 408 4031 Waipapa 09 407 6953 Kamo 09 435 5037 Whangarei 09 438 8824 Dargaville 09 439 7693 Wellsford 09 423 7957	josh.cousins@farmlands.co.nz	Farmlands
PrimeHort NZ (agronomy, growing and irrigation inputs, and packhouse)	2168 State Highway 1, Kaiwaka 0573	Andrew Wearmouth Andrew@primehort.co.nz	Primehort - Smarter Growing
Bioeconomy Science Institute (Research)	121 Keri Downs Road, Kerikeri 0294	Dr Annette Richardson annette.richardson@plantandfood.co.nz	Bioeconomy Science Institute
BioForce (Biological Control Agents)	72 Sim Road, Karaka	John Thompson office@bioforce.net.nz	Bioforce - Biological Control of Plant Pests
Hort New Zealand (Industry sector support)	Level 4, Kiwi Wealth House, 20 Ballance Street, Wellington 6011	Grower free phone: 0508 467 869 info@hortnz.co.nz	Grower resources | Horticulture New Zealand — Ahumāra Kai Aotearoa
Northland Inc. (Technical Transfer)	The Orchard Business & Events Hub 35 Walton Street, Whangarei	Jeanette Johnstone Tuputupu Grow Northland Team jeanette.johnstone@northlandnz.com	Northland New Zealand: Official Regional Site
Grower2Grower	Online Protected Growing Information Centre	Stefan Vogrincic	Contact Us - Grower2Grower
Chemtest (Protected cropping climate and irrigation systems)	Greenmount, Auckland	Stephen Thompson	Chemtest

5 Experiences of growing under cover

According to participants, protected cropping has been practiced by some growers in Northland for approximately a decade, primarily for high-value crops such as kiwifruit pollen blocks, avocado seedlings, and berries. Additionally, in recent years various trials of growing under cover have been conducted with tropical crops, including banana, dragon fruit, mango, papaya, and pineapple, to explore opportunities for diversification and to assess their commercial viability under the region's climate conditions.

A diverse group of grower participants was selected for interviews to reflect the range of protected cropping systems in use (from rain shelter to partially enclosed and fully enclosed greenhouse), the types of crops cultivated (from berry fruits to dragon fruits, bananas, and kiwifruits), and the varying scales and stages of production (from smaller experimental sites to medium and large commercial operations). From these participants, three grower cases were chosen to illustrate distinct business scenarios and demonstrate how protected cropping systems are applied in practice. Across these cases, growers identified both common benefits and challenges, as well as business-specific circumstances. These are illustrated below to highlight the diverse applications and experiences with protected cropping systems.

5.1 Case selection

The selected cases include:

- Family-run medium- to large-scale commercial operation: Protected cropping is used to safeguard high-value crops from rain and other adverse weather events, ensuring reliable returns on investment and long-term business sustainability. In this case, although protected cropping requires substantial capital investment, it also enables the production of high-quality, high-value crops within a shorter timeframe compared with some alternatives, thereby accelerating the return on investment. Furthermore, high-quality crops have strong potential to access overseas markets, where premium standards and consistent quality are often key entry requirements.
- Iwi-based enterprise: Focused on enhancing local employment and land use, this operation uses protected cropping to supply high-value crops early to market, capturing premium prices through strategic timing. Like the family-run commercial orchard, the significant investment required for protected cropping demands a premium return to justify the cost and ensure business viability and profitability. In this context, potential access to overseas markets represents a strategic opportunity, offering growers the chance to achieve higher returns through premium pricing and diversified market channels.
- Small-scale pioneering grower: Aimed at exploring best practices for growing tropical crops as a climate adaptation strategy in Northland. Protected cropping is used to trial suitable high-quality varieties and produce both marketable crops and seedlings. A high standard of compliance and high-quality crop varieties are associated with elevated costs; however, they are also considered critical for long-term business growth and success. This includes the potential to establish formal supply arrangements with national wholesalers and supermarket chains, and even access export markets.

5.2 Benefits of growing under cover

It is acknowledged by growers that severe weather events have become increasingly common in Northland, posing a significant threat to horticultural production. Without adequate protection, entire crops can be wiped out by a single event, such as the devastation caused by Cyclone Gabrielle in 2023. In such extreme cases, even some protected cropping structures sustained damage, highlighting the need for resilient infrastructure design for these growing systems. Thus, for high-value crops, protected cropping is adopted by growers as a strategy to provide greater production certainty and support reliable business outcomes.

Growers also noted that protected cropping can be “instrumental in meeting crop demand outside of the standard timing”. By controlling the growing environment, crops can be produced earlier or later than those grown outdoors, allowing growers to enter the market ahead of others. This early supply can attract a price premium, offering a competitive advantage, particularly for high-value crops.

For growers looking to diversify into tropical crops such as dragon fruit, banana, papaya, mango, and to some extent pineapple, protected cropping is almost essential for achieving consistent and commercially viable production. Although Northland’s temperature is forecasted to be increasingly warmer, the overall Northland climate remains suboptimal for tropical crops to grow outdoors. Some crops perform better under cover due to more favourable growing conditions, while others can only be grown under cover, as Northland’s outdoor climate does not meet the requirements needed to produce a reliable yield.

Another benefit of growing under cover is the creation of a more protected and consistent working environment for orchard workers. This allows essential tasks to continue regardless of weather conditions, aligning with the demands of the crop cycle. For example, harvesting can proceed without disruption, ensuring optimal timing and preserving fruit quality. More reliable work schedules and generally more comfortable conditions also help attract and retain a stable workforce. However, one grower also pointed out that working undercover can sometimes become uncomfortably hot, for example during summer, with temperatures reaching levels that compromise safety and efficiency. In such cases, it may be necessary to schedule shifts during cooler periods, such as early mornings or evenings, to avoid peak heat, maintain productivity, and improve worker wellbeing.

In summary, protected cropping structures offer greater certainty in production, thereby enhancing the reliability of returns on investment for growers.

5.3 Challenges of growing under cover

One of the key challenges in adopting protected cropping is the significant upfront capital investment required to establish the protective structures, along with ongoing maintenance costs and the need to replace some of the components over time. Depending on the crop type, growers can choose from a range of protected cropping systems, with some more affordable and others more capital-intensive. Selecting a sustainable and cost-effective system requires careful consideration of both financial and operational factors. Please refer to Section 2 Protected cropping infrastructure for more detailed information regarding cost estimation of various protected cropping systems. Some growers have incorporated crop-specific design features into their protective structures to enhance plant growth or simplify crop management. However, these features did not always serve the original intended purpose, once again highlighting a process of trial and error in adapting protective structures to crop-specific needs.

Furthermore, as one participant noted, “you can’t just put a cover over it and grow something without additional challenges… and often, those challenges are ones that haven’t been experienced by other traditional growers of that exact crop in that area.” Indeed, protected cropping structures not only regulate temperature and protect crops from rain but also modify the microenvironment in ways that can influence other environmental factors, thus requiring other adaptations in crop management. When an unknown issue arises, growers may not have immediate access to the relevant knowledge or expertise, unlike situations involving well-established problems where experience and information are more readily available. This can be especially challenging for smaller-scale growers who are new to protective cropping practices and lack a supporting network through which they can seek advice on unexpected issues.

One of the common learnings is that pest and disease management in protected cropping can differ significantly from open field cultivation. Elevated temperatures and humidity may create conditions more favourable for pests and diseases that are typically not problematic outdoors, or lead to outbreaks at different times. As these new scenarios emerge, existing solutions may not be applicable. For instance, if a pest outbreak occurs close to harvest, the recommended pesticide might be unsuitable due to its required pre-harvest interval that prevents its use at that stage, potentially leading to significant crop loss.

Another insight shared by growers is that protected cropping requires more intensive irrigation and nutrient management. While the structures shield crops from rain and hail, they also block natural rainfall, making access to a reliable water supply essential. In systems using substrates, irrigation and fertigation become even more critical, demanding constant monitoring and management not only of inputs but also of run-off volumes and quality. The newly built irrigation dams in Northland region could be of great benefit to undercover growers. With specific design, it is also possible to collect rainwater from the cover, or to recycle water and nutrient solution from the irrigation or fertigation system to improve circularity. Achieving these may also necessitate technological solutions such as remote monitoring, data collection, and automated control systems, which can pose additional challenges in terms of both capital investment and grower/worker capability.

Growers also reported various instances of suboptimal crop performance in their experience with different varieties grown under cover for the first time. Even when growing under cover, where the environment is more controlled, selecting crop varieties that are well suited to both the regional climate and the specific microclimate of the protected cropping system is critical for successful commercial outcomes. For novel crops, further testing and trials are necessary before a suitable variety can be confidently selected.

In addition, growers acknowledged that protected cropping systems exist within a broader ecosystem and interact with various elements such as pollinators, birds, and other wildlife. These interactions can give rise to additional challenges that may not be immediately apparent until certain points in the growing cycle or climate cycle.

5.4 Technical case – Bioeconomy Science Institute, Kerikeri

In addition to commercially focused growers, a more technical case is also presented in a research scenario to illustrate the process of how a protective structure was designed, manufactured, and installed, as well as the production benefits that this protected structure has brought to dragon fruit cultivation in Northland.

Structure: Three-module tunnelhouse rainshelter
Manufacturer: Harfords
Dimensions: L38m W28 H3
Cost: $35.5K plus installation
Crop: dragon fruit
Location: Bioeconomy Science Institute (BSI) Kerikeri

BSI Kerikeri has installed a rain shelter (no covered sides) on a site originally used for kiwifruit. Hargrove built the structure to fit with the location of the original kiwifruit poles, which have been converted to support growing structures for dragon fruit. The entire covered area comprises three modules, with six rows of large (250–300 mm diam.) wooden poles, rammed to a depth of 1.5 m to support the modules (Figures 1 and 2).

Figure 1. BSI's Research Orchard Manager, Gavin Lloyd, and the Kerikeri tunnelhouse built for dragon fruit.

Four rows of flat steel guttering run the length of the tunnels to carry roof water away and provide access to facilitate maintenance/cleaning of the plastic exterior skin. Water is channelled into 100-mm down pipe into an underground drainage system.

The manufacturer, Harfords, did not need to visit the site – instead they designed the structure from drawings and photographs provided by the BSI team who also installed the houses. The components were trucked from Christchurch on pallets and assembled by four BSI field staff over a five-day period – working from a manual "like kitset Lego" according to Research Orchard Manager, Gavin Lloyd.

The 200-micron plastic has an expected lifespan of 8–10 years and was installed by a Auckland-based contractor.

A basic trickle irrigation system connects to a portable fertigation unit, which was designed and built by Gavin. It has a 300-L venturi tank system that connects to pipework in one corner of the structure. Maintenance involves regularly flushing the system to remove calcium buildup on emitters – the flushing is designed to coincide with the regular irrigation schedule.

Figure 2. Portable fertigation unit (left); junction for connecting portable irrigation unit (middle); and channels that drain water that can be walked along to facilitate maintenance (right).

Production benefits

For dragon fruit grown undercover at BSI Kerikeri, the key benefit is the extended growth period of plants compared with the unprotected crop. In warm climates, dragon fruit wants to grow through the year. However, at the Kerikeri site, growth of dragon fruit plants outdoors slows around April through to September. In addition, the cold temperatures over winter can make the flesh of the plants soft and susceptible to pathogens. Undercover, the plants continue to grow over the winter. The expectation is that three crops of fruit per annum is achievable in the open tunnels compared with outdoors.

Table 10 details the differences in temperature and humidity between the inside and outside of the rain shelter.

Table 10. Average temperature and humidity data from BSI Kerikeri rainshelter.

Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Inside	21.4	22.8	20.7	19.3	16.3	14.1	13.6	13.0	15.1	17.4	-	21.9
Outside	19.6	20.8	19.1	16.6	13.8	13.1	12.5	11.8	14.5	-	17.5	19.8
Humidity	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Inside	70.4	71.0	71.5	85.7	81.6	84.8	85.1	80.8	78.3	76.7	-	71.3
Outside	74.3	75.1	74.6	94.0	87.3	89.7	89.3	83.7	81.2	-	76.7	75.7

5.5 A learning curve for all

As protected cropping has been adopted by more growers and applied to a wider range of crops in Northland, new knowledge has also been generated over time. However, since the history of protected cropping in Northland is relatively short for many crops and growers, challenges are still emerging and awaiting resolution. Due to the nature of horticulture, knowledge and learnings from other regions or crops may not necessarily be immediately applicable to local practices. Growers operating under cover often must navigate these challenges individually through trial and error, accumulating personalised experience related to their respective protective structures and crop types, which results in fragmented knowledge across growers and crops.

Although some growers are actively seeking opportunities to collaborate and share knowledge, it is acknowledged that others may feel the need to protect their competitive advantage by limiting participation in knowledge-sharing activities, partly due to perceived competition in the market. Whilst enabling and encouraging collaboration and peer learning is vital to accelerate the development of best practices and fostering the growth of a resilient protected cropping sector in the region, coordinated efforts to improve market access may also be critical to support and incentivise such knowledge sharing.

Overall, all grower participants view protected cropping as an essential component of their current operations. Given the significant investment required, protected cropping systems are considered more suitable for high-value crops that can benefit from the increased certainty of production, particularly when targeting niche markets. In the long term, as more unknown challenges become known and addressed, the adoption of protected cropping is expected to grow, driven by its multiple benefits that help safeguard business success.

6 Postharvest

Professional postharvest facilities and services play a vital role in maintaining product quality and shelf life, particularly when produce reaches significant volumes and is destined for markets beyond the Northland local region.

Northland has a range of established postharvest facilities with potential to support an emerging tropical crop sector. For example, Seeka’s Kerikeri packhouses primarily handle kiwifruit and avocado, along with a small volume of citrus, and currently operates to near full capacity. However, with the introduction of new machinery and technologies, there is potential to accommodate increased throughput. Maungatapere Packing, meanwhile, specialises in blueberry and kiwifruit flower milling. Outside of the blueberry and kiwifruit pollen seasons, the facility has capacity to expand into other crop types.

While these local facilities could be leveraged as production volumes grow, realising their full potential may require investment in specialised packing lines and postharvest expertise. Each crop has unique postharvest requirements, including treatment protocols, storage conditions, packing specifications, shelf-life considerations, and sensitivity to long-distance transport, which must be carefully managed to ensure product quality and market success.

7 Market opportunities

For growers who are at the beginning of growing undercover, especially with new crops, crop yield and quality may fluctuate between seasons. Local market outlets, such as farmers' markets, serve as a primary outlet for the produce, particularly for smaller growers. However, for larger scale and more commercially focused growers, pursuing markets outside of Northland region will be critical for successful business outcomes.

Within the domestic market, there are opportunities for Northland growers to engage with both retail supermarkets and wholesalers, who have access to a wider consumer base. In general, there is interest from supermarkets and wholesalers in sourcing New Zealand-grown produce as much as possible, for reasons including supporting local growers and avoiding hassles relating to importing, such as high freight costs, long transportation times, and biosecurity treatments. There is also expressed interest from retailers and wholesalers in exploring novel crops, in addition to the appeal of supplying during the shoulder season. Different retailers and wholesalers may take varying approaches regarding requirements for volume, consistency of supply, and compliance schemes, and may therefore require different procedures and timeframes to establish formal supply arrangements. Auckland-based Farro supermarkets, for example, could be a starting point to test customer preferences even at a small scale, as they are known for offering novel food experiences and are open to grower requests for tasting sessions via their online portal. In this way, growers can receive timely feedback from the market, helping them make more informed business decisions. For wholesalers, on the other hand, stable and consistent supply is often of higher priority, along with more stringent compliance requirements, for instance, mandatory Good Agricultural Practice (GAP) certification.

Locally grown produce is recognised by wholesalers and retailers as a valuable selling point that Northland growers can leverage to market tropical crops grown under cover. Organics growing under cover are a less recommended proposition due to the relatively small market size and the additional inputs and expenses required. However, customer acceptance, demand-supply dynamics, and competitive advantages over imported alternatives are key factors affecting ultimate market performance. To effectively compete with imported alternatives and command a premium, "locally grown" is best paired with other tangible benefits, such as novelty, unique varieties, exceptional taste, superior freshness, or early supply ahead of the season. For example, there have been reported cases where locally grown bananas struggled to compete with popular imported varieties due to higher prices and less-than-exceptional taste, whereas locally grown papaya has seen greater success due to offering unique varieties compared with imported ones. Therefore, growers are encouraged to carefully identify market gaps that can be addressed through undercover production which inherently involves higher costs, rather than risk oversupplying an already saturated market segment. Furthermore, broader awareness and recognition of locally grown tropical crops need to be cultivated among New Zealand consumers to support the growth of the domestic market.

For high-value crops intended for export markets, larger-scale operations are often necessary to ensure consistent volume and supply. While protected cropping requires significant upfront investment and more intensive management, it offers greater certainty in meeting export commitments, thereby helping safeguard business returns for growers aiming to establish a foothold in international markets.

8 Compliance

Compliance is a fundamental aspect of horticultural and food production activities. In addition to meeting standard requirements such as health and safety, biosecurity, and crop processing regulations, growers considering protected cropping must also account for compliance obligations related to the construction of the protected structures themselves. These requirements may include, but are not limited to:

- Resource consents
- Soil contamination reports
- Building consents
- Structural reports
- Building inspections.

Compliance requirements can vary depending on the region, the type of protected structure, and other site-specific factors. The following hypothetical example illustrates some of the considerations involved in constructing protected cropping structures.

John is a Whangarei District-based commercial grower looking to construct a brand-new protected cropping structure on his large rural property, envisioning a simple tunnelhouse for commercial food crop growing purposes only, 6 metres wide, 2.7 metres in height, and 20 metres in length. John's tunnelhouse will be fully enclosed, absent of any additional features such as a frost fan, located a significant distance away from neighbouring properties, and will not require the clearing of any vegetation to build. Other than his house, John also currently only has no other protected cropping structures or buildings in general on his property as of yet, and does not live near the sea or any rivers.

John wonders if he will need council approval to begin construction on his tunnelhouse, so he consults the Whangarei District ePlan available online on the council's website. Via referencing the plan map, John can see that his property is within what the district council defines as a 'rural production zone' and therefore subject to the associated zone-specific rules, excluding those specific to precincts 18 through 22 in which John's property is not located. As per the definitions outlined in the plan, the dimensions of John's planned construction exceed both the 2.2 metre height and 9 square metre ground coverage thresholds to qualify as a 'major structure', and as such the rules that John must consult are RPROZ-R3 through to R5 (for buildings and major structures), as well as RPROZ-R18 for farming activity. Whilst John may assume rule RPROZ-R13 for 'crop support' and 'artificial crop protection structures' would apply to his tunnelhouse, the provided definition for the former requires the structure to be 'open pervious' and the definition for the latter specifically excludes greenhouses. Therefore, being that John's tunnelhouse is closed and also falls under the scope of what would generally be considered a greenhouse, rule RPROZ-R13 and its associated exemption from rule RPROZ-R4 are not applicable.

Luckily for John, all relevant rules he must follow are listed as 'activity status: permitted', meaning that no council approval is required provided he is within rule requirements. Being that John's tunnelhouse is less than 10 m in height, further than 8 m away from site boundaries, 27 m from Mean High Water Springs or any river wider than 3 m, and in this case covers less than 20% of John's total site area alongside all his other buildings and major structures (currently only his house), he can proceed with constructing his tunnelhouse without worrying about council approval.

The above example is illustrative only. For more details, please consult the current district council plans available on each council's website, linked below:

- Whangarei: ePlan - Whangarei District Council
- Far North: Operative plan | Far North District Council
- Kaipara: Operative District Plan 2013, Kaipara District Council.

It is recommended that growers consult with construction specialists or compliance officers to discuss the specific compliance requirements that may apply to their chosen protected cropping structure.

9 Conclusion and recommendations

Protected cropping presents significant potential to add value for Northland growers who are interested in cultivating high-value and novel tropical crops. A variety of protective structures are available to suit the needs of different crops in the region, ranging from more affordable options to premium systems.

The key benefits of protected cropping include greater certainty of production aligned with specific growing objectives, and improved working conditions. While the substantial capital investment required for setup cannot be overlooked, the increased reliability and potential return on investment warrant careful consideration.

Given the relatively recent adoption of protected cropping across diverse crops in Northland, local knowledge and experience remain fragmented. Greater collaboration is needed to address emerging challenges and build a more resilient and informed sector.

There is clear interest from supermarkets and wholesalers in sourcing locally grown produce from Northland. However, individual growers may face difficulties in establishing direct relationships with these outlets. As production volume grows in the future, a cluster approach where groups of growers collaboratively supply the same crop could potentially streamline market access and enhance supply reliability. Furthermore, while "locally grown" is a valuable selling point, it should be paired with other tangible benefits to appeal to a broader customer base.

Given the significant capital investment involved, protected cropping represents a serious business decision that requires growers to think carefully and consider all relevant factors. To support this process, an Economic Analysis Guide has been developed by AgFirst, a specialised consultancy, to guide Northland growers through key financial considerations when assessing the viability of protected cropping for their operations. Please refer to Section 10 Economic Analysis Guide for Protected Cropping Systems for more details.

10 Economic Analysis Guide for protected cropping systems

This Economic Analysis Guide is commissioned to AgFirst by BSI as part of this project. AgFirst is a specialised agriculture and horticulture consultancy in New Zealand.

This guide compiles critical economic and financial considerations relating to a potential development of protected cropping systems and provides a decision matrix to prompt growers to consider the various components of such a development.

10.1 Business plan and strategy

When undertaking a new business venture, AgFirst recommends compiling a business plan or strategy at the outset to provide direction, guide activities, and clearly lay the path to success. This includes:

- Setting aspirations and direction of the enterprise, identifying value statements and aspects such as sustainability that guide decision making.
- Detailing ownership and management structure, with clearly defined roles and responsibilities. This enables the owners to either have an active hand in the operation, or a passive structure informed by regular updates.
- Identifying the management needs through time from inception to development and through to operation.
- Detailing timelines for each portion of the enterprise. This includes sourcing of parent crops and allowing for lead-in times for specific varieties from nursery providers, as well as detailing labour requirements for planting and operation.
- Outlining knowledge sourcing and knowledge gaps for the enterprise such as:
    1. Roles of personnel, and their associated fields of expertise;
    2. Requirements for consultancy services;
    3. Outlines key support relationships and product suppliers; and
    4. Mitigates any key weaknesses identified.

For those growers with existing enterprises, and considering diversification, AgFirst recommends the business plan focuses on how this may complement any current growing enterprises, including labour capacity and capability, cashflow, seasonal timings and existing relationships with suppliers.

10.2 Protected cropping system decision matrix

Following a range of interviews with existing growers utilising both high-tech and low-tech protective cropping systems, AgFirst have created a decision matrix (Figure 3). The matrix will help growers define their scope for development and ensure that the structure chosen is fit for purpose, through directed decision making.

Defining the crop being grown is the most important decision factor when undertaking a protected cropping development

The crop type grown will be the greatest influencing factor on all downstream decision making when undertaking a covered cropping development. This decision will influence the site location, protected crop structure chosen (if any) and, therefore, capital and operational expenditure.

When selecting a crop type, the grower should consider their own experience with the crop. If it is a new crop type to the grower, what support industry can they utilise for advice?

Other things to consider when selecting a crop type are: what the current market is; when the sales window is; what the current supply and demand outlook is; and how this new development will compliment that. The market is also important to understand as farm gate/farmers market sales vs domestic supermarket supply vs export sales will all have different crop specifications.

Once the crop type is selected, the next decision is to decide how the crop is grown.

Growers must consider what benefit growing the crop under a protected structure will provide, as this will then determine the type of structure to invest in. Will growing under a protective covering provide financial gain? This gain may be on improved Class 1 volume due to protection from environmental damage and preventing financial loss. This may be due to bringing the harvest timing forward into a higher value market window with increased demand, it may be due to the ability to increase the cropping rotations per hectare, or the ability to grow something in that climate which wouldn’t naturally grow within that environment.

Additionally, whether the crop is to be grown directly in soil, or whether an alternative substrate is to be used needs to be considered. If it is to be grown directly into soil, the soil quality will become a critical attribute of site selection but if grown in substrate then this needs to be costed into return on investment equation.

Once the crop type and how its grown has been established, the grower should consider the location for growing. What climatic factors (aside from those controlled through the protected cropping structure) need to be considered. What scale is needed for this investment to be of value and, therefore, how big does the development need to be?

It is only once these main decisions have been teased out, that a grower should continue. Due diligence is important with these types of investments, and although there is a wide range of crop types that may suit a protected cropping structure, the business case for the investment needs to be clear.

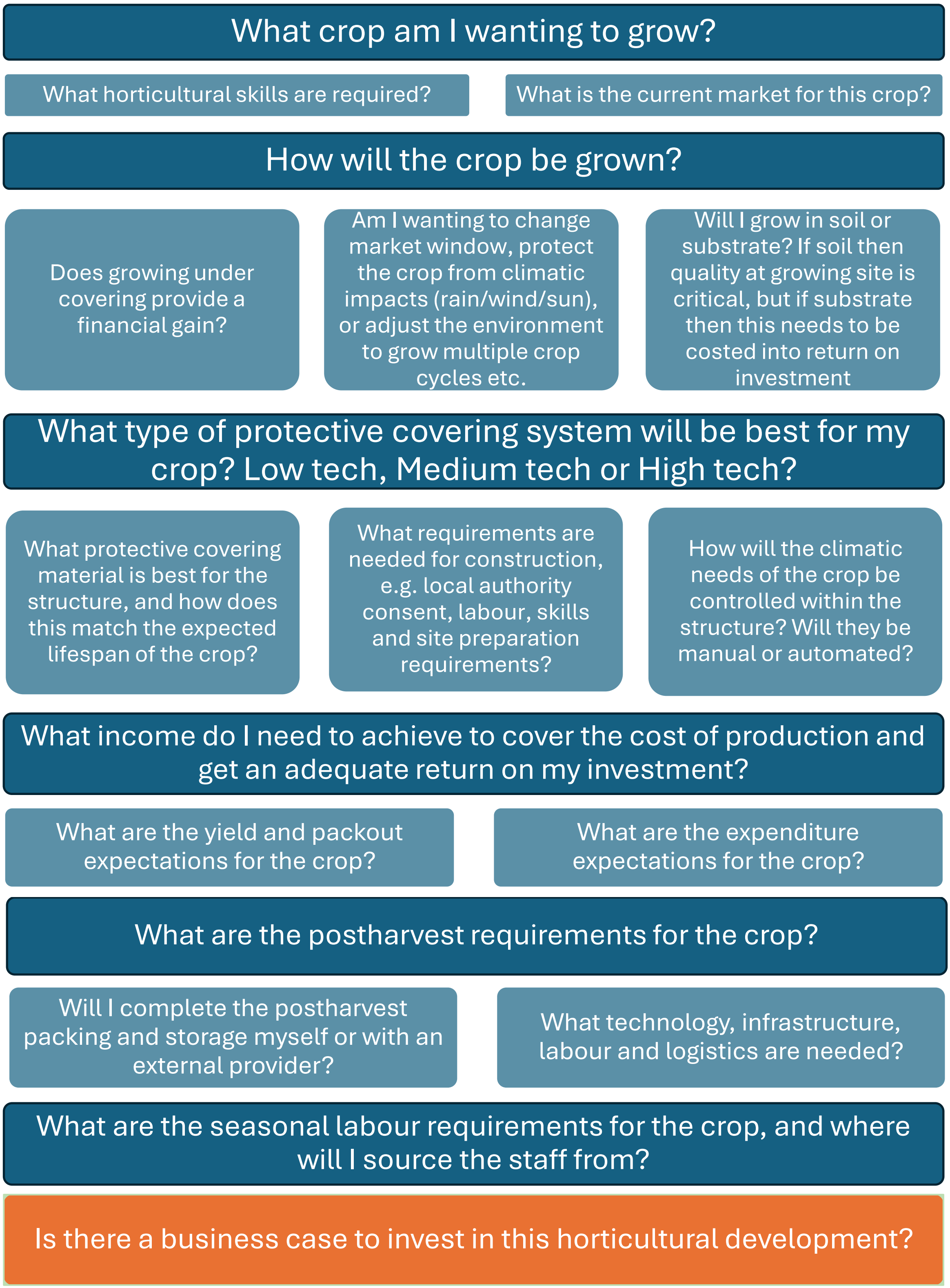

Figure 3. Protected cropping decision matrix.

10.3 Set-up and development cost considerations

10.3.1 Site selection

Site selection considerations will differ slightly to those for an uncovered crop; however, a grower should consider the following site selection attributes prior to development:

- Orientation of the structure with respect to the sun angle
- Predominant wind direction and, therefore, structure exposure
- Soil type (for those crops planted in situ rather than in substrate or hydroponics) and underlying geology
- Access to water, or water storage capabilities
- Height restrictions (e.g. powerlines)
- Site access/driveways
- Shelterbelts – location and height is important to consider for shading
- Site slope and any earthworks requirements
- Buffer between land uses
- Drainage system and/or soil drainage characteristics (if planting in soil)
- Understand the natural hazards of the zone being built in (e.g. earthquakes, flooding). Consenting requirements for resource use – includes consents for roading/accessways, structure, earthworks, etc.
- Source of power to run required systems (climate control/heating/automated venting)
- Proximity to support services such a such as postharvest facilities, horticultural suppliers, and a labour force.

The expected development footprint should be analysed in relation to the site, including headlands for manoeuvrability and machinery, and whether these will be covered or not. In addition, as for any new horticultural development, a staging area for access, parking, storage shedding and amenities would be required for a standalone enterprise. If the enterprise is to be doing their own postharvest work, this will also need to be considered relative to the site.

Once the site characteristics have been established, any remedial work should be completed prior to the installation of infrastructure and crop planting.

10.3.2 Capital investment requirements

It is important to note that all the capital investment requirements will be determined by the needs of the crop type being grown. Protected cropping structures have an element of adaptability to the crop type and its management after their establishment; however, a protected system that is fit for purpose is key.

Structures

There are a wide range of solutions for crop covers. Covers could include open-ended tunnels, overhead covers with open sides, or even fully enclosed systems. It is important to consider the specification of the infrastructure design and cover material alongside the crop requirements, covering benefits and capital outlay. Understanding the lifespan of the covering system and how this also relates to the lifespan of the crop will be important. The height of the structure will need to suit the crop type's growth habits. Internally, the structure needs to enable workable access around the crop and aspects of the structure such as the side screen winders via pathways.

There are three broad options of protected cropping system structures, low-tech, medium-tech and high-tech installations, with plastic and glass being the most popular covers. Low-tech structures are cheaper and easier to install but are generally more manual with less automated solutions, for example having manual side winders. High-tech structures are solid and have things such as computer-controlled units with sensors monitoring the climate and automated venting in response. The need for anchors, piles, and proper foundations will be dependent on the site attributes and the structure type chosen.

Erection of the protective covering will differ depending on the system selected, and whether the structure is available as a kitset for on-site construction or whether professional construction will be necessary. Timeframe expectations of the actual structure construction can vary slightly but are generally no longer than 6–9 months for a high-tech structure, following appropriate earthworks and site preparations have taken place. However, it is important to note that, particularly for high-tech structures, the consenting process can require significant lead-in time.

Expected structure/development costs will be largely dependent on design and covering material but can span from \$40–60/m^2 for a low-tech option, \$120/m^2 for a semi high tech option with proper venting but without irrigation, and up to \$500–700/m^2 for a high-tech glasshouse with lighting and heating systems.

For all structures, regular maintenance to keep the protective cover clean and free of algae is important for both light penetration ability, as well as to prolong the lifespan of the cover.

Irrigation

To enable consistent yields for horticultural crops, and climatic resilience, irrigation installations are a critical success factor. All horticultural enterprises rely on a suitable supply of water to enable irrigation, spray fill and washdown activities to be undertaken efficiently. However, as covered crops are not receiving natural rainfall, irrigation is critical to survival of the crop.

Consideration of the crop demand in an uncovered scenario, the way the cover changes the environment and therefore crop demand, the water source and any existing resource consents will all need to be worked through when designing an irrigation system. The specific type of irrigation system will also be dependent on the crop's response to free water as some crops do not like water on their leaves.

Climate control

Growers will need to consider climate control measures, airflow and humidity control, depending on the type of cover they install, and the susceptibility of the selected crop.

All covers create a barrier between the leaves of the crop and the sun, intercepting solar radiation and reducing the photosynthetically active radiation available. As the covers, therefore, reduce the light intensity, fruit colouring can be affected and needs to be considered for crops where returns are incentivised on colour or colour intensity.

Increased humidity under cover is a challenge for covered cropping systems because of the moisture from plant transpiration becoming trapped within the structure. This can result in increased pest and disease pressure, and negative crop quality outcomes such as russet and splitting.

Ventilation solutions might be manual or automated, with adjustments made according to temperature, wind or rain. Ventilation solutions may be through a top vent, gutter ventilation, sidewinders, or open ends/sides or gable vents. This will be dependent on the covering solution and crop requirements. For some crop types, venting may disrupt the climatic control within the protective structure, in which case open-ended tunnels with free air may be a better structure suited to the crop than closed structures.

Supplemental heat and lighting (especially in winter) can be used to increase yields and yield cycles.

Misting capability to keep the temperature down will be important for some crops, in addition to ventilation solutions.

Growing in situ vs growing in substrate

The decision of whether the crop will be grown direct into the soil (in situ) or grown in substrate will be necessary to understand the requirements of any additional capital costs. For crops planted into substrate, pots and substrate supply will need to be factored into expenditure.

Although growing in substrate can provide further control, it can increase crop failure risk because things can go wrong at a faster rate. As one interviewed grower noted, “growing in substrate in a protected covering system provides greater control but alongside greater responsibility”.

Site preparation, infrastructure and machinery requirements

Specific infrastructure and machinery requirements will be dependent on the crop type and covering chosen. Exclusive of the cover itself, requirements may include, but are not limited to:

- Irrigation – bore, headworks
- Fertigation, reticulation and waste discharge system
- Climate control (e.g. sensors, venting, fans)
- Shedding
- Tractors/forklifts
- General plant and equipment
- Other postharvest equipment (if required).

AgFirst notes that plant and equipment do not present a barrier to establishment of a horticultural growing enterprise, just a matter to be incorporated into the development budget and establishment timing considerations. Options for second-hand equipment also exist that would lower the investment burden.

Crop-specific considerations

There will be crop-specific considerations required prior to development, with the understanding of these factors critical to the success of the crop, exclusive of the covered system.

These can include:

- Marketable yield expectations for the specific crop type
- Number of achievable annual crop cycles
- Infrastructure requirements, e.g. dimensions of cover, substrate requirements
- Pollination requirements
- Intellectual property license/variety licenses
- Productive lifetime expectations
- Compliance and regulatory requirements.

Matching the crop intended to be grown, alongside the protected covering option chosen and understanding the return on investment and the yields required to be achieved is important due diligence to be undertaken prior to investment. The commercial scale will also be dependent on the crop grown. Currently, the average size of a covered crop in New Zealand is 1.8 ha.[5]

10.3.3 Financial outcomes

A covered cropping system will require significant capital outlay; therefore, it is imperative growers understand the financial metrics described in the following sections, and their use in measuring financial results, to understand what is required for that investment to be successful.

For most horticultural crops, production (yield) is the key driver of profitability and therefore the business case and return on investment required will be largely determined by the growers' ability to achieve the production used in the development budget modelling. The investor should make sure they are investing in the highest value crop type for the structure. Protected cropping systems specifically require a high-value product to be an economical decision and achieve the return on investment.

As there are numerous combinations of crop type and covering solutions available, growers must understand the yield expectations of the specific crop required to drive income, and therefore to achieve the return on investment for the specific covering structure, prior to the investment being undertaken. This will be outlined further throughout Section 11.3.3.

Internal rate of return

The internal rate of return (IRR) is a metric used to estimate the annual financial return that an investment is expected to return over its lifetime.

IRR is the discount rate that makes the Net Present Value of the investment equal to zero. IRR is the time adjusted or discounted cash flow measure of the expected rate of return expressed as a percentage. If the IRR is greater than the desired rate of return, then the investment is considered worthwhile.

[5] Tupu.nz, Land Use fact sheet Covered cropping.

For context, in a sensitivity analysis of a pipfruit orchard modelled over 15 years, AgFirst determine the yield, packout and price are key drivers of the IRR, emphasising the critical nature of crop husbandry execution.

Net present value

The net present value (NPV) technique expresses a future stream of costs and returns as a single figure. This figure gives the grower an impression of what the investment is worth in today's money, considering a discount rate; a value that reflects the real costs of capital and can include a risk factor.

A positive NPV means that the present value of the cash inflows exceeds the present value of the outflows. If the NPV is zero, the decision maker would be indifferent about making the investment. When choosing between different investments, the one with the highest NPV is the most desirable.

Again, AgFirst's experience with sensitivity analyses of pipfruit development identifies yield and packout as being the key drivers of NPV. Dropping the yield and packout will change the financial result dramatically.

Cumulative cash result

The cumulative cash result of an investment will show the surplus cash available at the end of the analysed period. Although a good guide, it is not as good a measure of profitability as NPV or IRR as it does not account for the cost of money.

Breakeven year

Breakeven year is defined as the year when the cumulative cash result exceeds $0. This gives the investor a guide as to the number of years required to cover cost of establishment, establishing the point where the investment transitions from losing money to generating profit. This calculation will help investors assess their appetite for risk and determine the feasibility of the venture. This will be particularly important to understand in a covered cropping scenario because of the upfront capital investment of the covering infrastructure, with the breakeven year indicating how long it will take to recoup the initial expenditure, move into positive cashflow and begin generating a return.

10.4 Income considerations

As outlined above, the income drivers of yield, packout, and price are all key to profitability. While awareness and management of costs is important with labour and postharvest being the dominant expenditure categories, producing high volumes of high-quality product, enables growers to maximise the available returns. Therefore, the execution of the crop husbandry, to achieve the yield targets, will drive the success of the horticultural business.

Growers should ensure their businesses are operating within systems and structures that support quality. An element of performance measurement is also helpful, utilising key insights to improve management, identifying areas that are performing to or exceeding targets, and allowing for adaptation to the strategy if necessary.

Having a good profit and loss statement, with key expenditure codes separated out, allows for easier cost tracking. An example of an expenditure list can be found in Table 13. This may be aggregated up where appropriate, but AgFirst advise growers to consider spending at least across the listed categories.

If the development of a covered crop system is in addition to an existing horticultural enterprise, coding these aspects of the business separately (i.e. having different cost centres) will provide great insight into the contributions each aspect is having to the total.

Growers should consider their gross yield, total volume of premium/class 1 yield, and total class 1 return, to understand their total income per hectare and total income per production unit. In Table 11, there are four modelled production unit scenarios highlighting the influences of the production, packout, and prices on the income achieved for a production unit, as well as the income per hectare.

An understanding of the potential for each of the yield, packout, and price income drivers, will help inform the production area needed for development viability. That is, what area makes economic sense as a minimum.

Table 11. Income example, with various scenarios showing production, packout, and price achieved and the impacts on income.

Income Example

Production Unit	Area (ha)	Yield/ha (tonnes)	Gross Yield (kg)	Class 1 (%)	Total Class 1 (kg)	Class 1 Return ($/kg)	Total Production Unit Income	Income per ha
Production Unit 1	1	60	60,000	80	4,800	$ 2.00	$ 9,600	$ 9,600
Production Unit 2	0.75	30	22,500	82	2,460	$ 1.50	$ 3,690	$ 4,920
Production Unit 3	1.2	40	48,000	60	2,400	$ 2.50	$ 6,000	$ 5,000
Production Unit 4	0.3	45	13,500	75	3,375	$ 1.90	$ 6,413	$ 21,375
Orchard Totals	**3.25**	**175**	**144,000**	**74.25**	**13035**	**$ 1.98**	**$ 25,703**	**$ 40,895**

10.4.1 Yield progressions

Understanding the expected productive lifespan of a crop, yield progressions, time to maturity and maximum mature yield, for average and an upper quartile performance will be important to set production targets. This will also inform the timing to expect the breakeven year for the development. This will be crop specific; however, the introduction of the covered system may allow for improvements in yield potential, or shortening of crop cycles.

Establishing a crop load within young production units, alongside supporting canopy establishment, and meeting crop husbandry requirements and timings will be vital to enable cumulative target yields to be achieved.

The higher the yield, the most kgs sold to spread costs over. Thus, as yield is a key driver to profitability and ensuring the return on investment of a development is achieved at a suitable rate, early yield will pay dividends over the lifetime of the production unit.

10.4.2 Packout expectations

Determining the market requirements for a product is critical to success. For example, are the size, shape or colour attributes important to achieving the market return? What quality attributes create a Class 1 product? The price able to be achieved by the grower will go down if market requirements are not met (quality, size, timing, volumes). This may influence some of the growing strategy implemented during the season.

Therefore, understanding packout expectations for the crop, the drivers of the packout class, and how to ensure the highest proportion of the crop is sold as Class 1 as possible, will be key to maximising available returns.

10.5 Expenditure considerations

AgFirst considers growers should understand the following expenditure elements as annual measures. This is to an EBITDAR level (earnings before interest, tax, depreciation, amortisation and rent).

As an example, for a pipfruit cropping system, the estimated proportion each expenditure category contributes to the total is as described in Table 12.

Table 12. Expenditure category proportion of total for a pipfruit orchard.

Expenditure Category	Proportion of Total Expenditure
Post Harvest Expenditure	39%
Labour Expenditure	41%
Working Expenditure	15%
Overhead Expenditure	5%

Table 13 outlines a comprehensive expenditure list, which AgFirst suggests growers allocate their expenditure to. Some categories may be aggregated up if required, and the labour expenditure categories may differ depending on the crop grown. It is also important to consider depreciation cost (especially for a capital-intensive covered crop), as well as lease/rent and debt servicing capability which are not captured within the list of annual operating costs. Note, the labour expenditure categories may differ depending on the crop requirements.

Table 13. Suggested Expenditure list, to align with the profit and loss expenditure categories.

Expenditure List Example

	Unit of Measurement
Post Harvest Expenditure	
Packing	$/gross kg
Packaging	$/Class 1 kg
Coolstorage	$/Class 1 kg
Freight (farm gate to packhouse)	$/gross kg
Levies	$/Class 1 kg
Other Postharvest Costs	$/Class 1 kg
Labour Expenditure	
Management	$/ha
Harvest	$/bin
Thinning	$/ha
Pruning	$/ha
Other Wages	$/ha
Employment Levies	$/gross kg
Working Expenditure	
Sprays and Fertiliser	$/ha
Pollination	$/ha
Electricity	$/ha
Vehicle	$/ha
Fuel	$/ha
Repairs and maintenance	$/ha
General expenses	$/ha
Contract machine work	$/ha
Overhead Expenditure	
Rates	$/ha
General insurance	$/ha
Communications	$/ha
Accountancy	$/ha
Legal and consultancy	$/ha
Other administration & compliance	$/ha
Total Property Working Expenses	

10.5.1 Postharvest expenditure

Elements to consider within this cost category include:

- Packing
- Packaging
- Coolstorage
- Freight (property to packhouse)
- Freight (to point of sale)
- Levies
- Other postharvest costs (commissions, postharvest treatments etc).

Postharvest timeframes, storage and management are all crop dependent and once harvested, getting fruit to market at the right time, in the right quality is critical. Packing, packaging, storage requirements and distribution to point of sale are all aspects that will need consideration, and the shelf life of the product will influence the postharvest management timeframes.

Growers will need to consider their postharvest requirements and capability for the intended crops. Will the postharvest process be done in house and, if so, what infrastructure, technology and labour requirements are needed to do so? If the postharvest process is to be carried out with an external provider, what is that providers locality to the growing operation, the expenditure required, and logistics required? Growers will also need to be aware what levies the crop will be subjected to, by both HortNZ and the industry sector body.

An understanding of what the market is will be is critical. Will the product be sold at a farmers' market, gate sales, cafes or supermarkets? Some growers may build a relationship with distributers or wholesalers, and other larger growers may deal directly with the supermarkets. For some market avenues such as export or supermarkets, a critical volume of consistent supply and quality is needed, and extra assurances or processes may need to be undertaken.

10.5.2 Labour expenditure

The performance and quality of staff, as well as their overall cost to the business and each kilogram of fruit produced directly influences the profitability of horticultural growing enterprises.

It is integral that sufficient thought and emphasis is placed on securing the right talent, within the right culture to maximise success. Horticultural management requires a high level of technical ability and plant husbandry skills alongside people management skills. Supervision of task execution is key for teams of people, to reduce variability and ensure production targets are met.

The following labour force structure should be considered:

- Management requirement per hectare
- Leading Hand (with supervision)
- Labourer/operator
- Seasonal staff requirement.

The FTE requirement per hectare will differ by crop type and seasonal fluctuations, but anecdotally this may be around 1 FTE/hectare of covered structure. This may also be several part-time people (depending on stage of the growing season). Labour task peaks and timings should be mapped out, with consideration made to those tasks where timing is critical (such as harvest), and those tasks where there is little to no time pressure on execution (such as mowing).

Once you have established the crop’s base labour requirements, the scale and associated labour units determined, the source of the labour will need to be considered. This includes both skilled permanent staff as well as seasonal staff. Some labour requirements will be driven by production and the volume of crop such as harvest, whereas other labour requirements will be more static. Consider also the postharvest requirements of the crop and if doing this in house, the labour requirements for that and how this may compliment the crop husbandry labour requirements.

10.5.3 Working expenditure

Specific expenditure categories will be influenced by the crop needs; however, elements to consider within this cost category include:

- Sprays – disease, weed and pest control products
- Pollination
- Fertiliser and lime
- Electricity
- Vehicles
- Fuel
- Repairs and maintenance
- General expenses
- Contract machine work.

Sprays and fertiliser expenditure items, as crop-specific working expenditure items will be discussed in further detail below.

Sprays

Crop protection requirements will depend on the crop-specific pests and diseases, and their mitigation alongside the compliance requirements for market. Integrated pest and disease management, which combines biological, cultural, and chemical controls to manage pests and diseases in a sustainable way, will also depend on production compliance requirements (through NZGAP or GLOBAL GAP assurance programmes), and horticultural supply groups such as Fruitfed, Farmlands, and Horticentre all offer excellent support in designing and implementing crop protection schedules. Growing within a covered system will require attention to pest and disease pressures because of the altered microclimate the crop is being grown within, including pressure from pests and diseases that may not be traditionally problematic for that crop.

Fertiliser

Each crop type grown under cover will have crop-specific nutrient requirements. This will also depend on the soil type, or substrate the crop is grown within. Regular soil and leaf testing is appropriate to understand plant available nutrients, alongside the crop demand and therefore fertiliser input requirements. Ground-applied, foliar-applied and fertigated fertiliser all have different requirements for input, and therefore different costs.

10.5.4 Overhead expenditure

Elements to consider within this cost category include:

- Rates
- General insurance
- Communications
- Accountancy
- Legal and consultancy
- Other administration and compliance.

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12 References

Aditya P, Rao V, Mohapatro S, Chandra V, Nanda C, Suman S 2023. Future trends in protected cultivation: A review. The Pharma Innovation Journal 12(8): 2025-2029.

Araújo HSd, Carmo SAd, Santos NCBd, Freitas PGN, Purquerio LFV 2022. Effect of shading screens on the production and quality of ‘Smooth Cayenne’pineapple. Pesquisa Agropecuária Tropical 51: e69594.

Badji A, Benseddik A, Bensaha H, Boukhelifa A, Hasrane I 2022. Design, technology, and management of greenhouse: A review. Journal of Cleaner Production 373: 133753.

Belbase P, Jayachandran K, Balaji Bhaskar MS 2025. Assessment of soil and plant nutrient status, spectral reflectance, and growth performance of various dragon fruit (Pitaya) species cultivated under high tunnel systems. Soil Systems 9(3): 75.

Børve J, Skaar E, Sekse L, Meland M, Vangdal E 2003. Rain protective covering of sweet cherry trees—effects of different covering methods on fruit quality and microclimate. HortTechnology 13(1): 143-148.

Bruce AB, Maynard ET, Farmer JR 2019. Farmers’ perspectives on challenges and opportunities associated with using high tunnels for specialty crops. HortTechnology 29(3): 290-299.

Castilla N 2013. Greenhouse technology and management. Cabi.

Castilla N, Baeza E 2013. Greenhouse site selection. Good Agricultural Practices for greenhouse vegetable crops, 21.

Chavan SG, Chen Z-H, Ghannoum O, Cazzonelli CI, Tissue DT 2022. Current Technologies and Target Crops: A Review on Australian Protected Cropping. Crops 2(2): 172-185.

Chien Y-H, Chu Y-C, Hsu Y-H, Chang J-C 2024. Synergistic effect of net-houses and light sources on the enhancement of off-season flowering waves and production of ‘Da Hong’red-fleshed pitaya. Scientia Horticulturae 329: 112982.

Choudhury S, Islam N, Mustaki S, Uddain J, Azad MOK, Choi KY, Naznin MT 2022. Evaluation of the different low-tech protective cultivation approaches to improve yield and phytochemical accumulation of papaya (Carica papaya L.) in Bangladesh. Horticulturae 8(3): 210.

Coriolis Research 2019. Regional growth opportunities in employment in the Northland food & beverage industry. coriolis_ifab_2019_RGO_Northland_101.pdf [accessed 28th October 2025]

Cui Z, Ai X, Zhao Y Yield effect of ginger in plastic house. China Vegetables (No. 3): 14–16.

El Horri H, Bartolini S, Remorini D, Ceccanti C, Florio M, D’Asaro L, Jain G, Massai R, Landi M, Guidi L 2025. Light down-conversion technology improves vegetative growth, berry production, and postharvest quality in tunnel-cultivated blueberry. Agronomy 15(7): 1708.

Elverding K 2024. 5 ways to address labour shortages with protected cropping solutions https://envirotecstructures.com.au/5-ways-to-address-labour-shortages-with-protected-cropping-solutions/ [accessed September 2025].

Food and Agriculture Organization of the United Nations 2022. Introduction and advantages of protected cultivation systems https://www.fao.org/family-farming/detail/en/c/1697565/ [accessed September 2025].

Galán Saúco V 2015. Advantages and disadvantages of cultivating mangoes (Mangifera indica L.) under subtropical conditions and potential of greenhouse cultivation of mango. Leuven International Society for Horticultural Science (ISHS). Pp. 167–177.

Gübbük H, Balkıc R, Altınkaya L 2024. Greenhouse cultivation. Dragon fruit: Botany, production and uses. CABI GB. Pp. 221-235.

Gubbuk H, Gunes E, Guven D 2016. Comparison of open-field and protected banana cultivation for some morphological and yield features under subtropical conditions. X International Symposium on Banana: ISHS-ProMusa Symposium on Agroecological Approaches to Promote Innovative Banana 1196, Montpellier, France. Pp. 173-178.

Güneş E, Öziyci HR, Gübbük H 2022. Quality of different papaya cultivars grown in the greenhouse throughout the year in subtropical regions. Food Science and Engineering 3(1): 20-30.

Helmey Z, Muhamad Hafiz M, Wan Mahfuzah W, Azdawiyah S 2023. Evaluation of growth, yield and fruit quality of Harumanis mango under greenhouse and open field conditions. Transactions of the Malaysian Society of Plant Physiology 30: 220-225.

Heuvelink E, Stanghellini C, Van't Ooster B 2024. Greenhouse horticulture: Technology for optimal crop production. Brill.

Hormaza J 2023. Mango production under Mediterranean climates. XIII International Mango Symposium 1415, Málaga, Spain. Pp. 19-24.

InsonGreen 2024. What can you grow in a greenhouse all year round in 2024 https://www.insongreen.com/all-year-round-plants-for-greenhouse/#:~:text=and%20financial%20gains.-,1.,%2C%20basil%2C%20and%20cilantro. [accessed September 2025].

Jackson LL, Rosenberg HR 2010. Preventing heat-related illness among agricultural workers. Journal of Agromedicine 15(3): 200-215.

Jain S, Kore DS, GK K, Mohapatra A, Baksh H, Kumar V, Mohanty S, Haokip SW 2023. A Comprehensive review on protected cultivation of horticultural crops: Present status and future prospects. International Journal of Environment and Climate Change 13(11): 3521-3531.

Jutamanee K, Onnom S 2016. Improving photosynthetic performance and some fruit quality traits in mango trees by shading. Photosynthetica 54(4): 542-550.

Kaiser C, Ernst M 2021. High tunnel overview. Cooperative Extension Service.

Kratky B 2006. Plastic-covered rainshelters for vegetable production in the tropics. Proceedings of the 33rd National Agricultural Plastics Congress American Society for Plasticulture, Bellafonte, PA.

Li T, Bi G 2019. Container production of southern highbush blueberries using high tunnels. HortScience 54(2): 267-274.

Lin BB 2007. Agroforestry management as an adaptive strategy against potential microclimate extremes in coffee agriculture. Agricultural and Forest Meteorology 144(1-2): 85-94.

Mahmood A, Hu Y, Tanny J, Asante EA 2018. Effects of shading and insect-proof screens on crop microclimate and production: A review of recent advances. Scientia Horticulturae 241: 241-251.

Maraveas C, Karavas C-S, Loukatos D, Bartzanas T, Arvanitis KG, Symeonaki E 2023. Agricultural greenhouses: Resource management technologies and perspectives for zero greenhouse gas emissions. Agriculture 13(7): 1464.

Meland M, Skjervheim K 1997. Rain cover protection against cracking for sweet cherry orchards. III International Cherry Symposium 468. Pp. 441-448.

Messelink GJ, Lambion J, Janssen A, van Rijn PC 2021. Biodiversity in and around greenhouses: Benefits and potential risks for pest management. Insects 12(10): 933.

Ministry for Primary Industries 2023. Growing Together 2035 Aotearoa Horticulture Action Plan – Strategy.

Morabito M, Messeri A, Crisci A, Bao J, Ma R, Orlandini S, Huang C, Kjellstrom T 2021. Heat-related productivity loss: benefits derived by working in the shade or work-time shifting. International Journal of Productivity and Performance Management 70(3): 507-525.

Morales L, Gollán A, Bello F, Rivadeneira MF, Vázquez D, Tripodi KE 2024. Anti-hail covers causes changes in the quality and biochemistry in two blueberry (Vaccinium corymbosum L.) cultivars. Technology in Horticulture 5(1).

Palma M, Sepúlveda Á, Yuri JA 2023. Effect of plastic roof and high tunnel on microclimate, physiology, vegetative growth and fruit characteristics of 'Santina' sweet cherry. Scientia Horticulturae 317: 112037.

Patil A, Kakade V, Kalalbandi B, Morade A, Chavan S, Salunkhe V, Nangare D, Basavaraj P, Jinger D, Reddy K 2024. Mitigating heat stress in dragon fruit in semi-arid climates: the strategic role of shade nets in enhancing fruit yield and quality. Environment, Development and Sustainability: 1-37.

Pirkner M, Tanny J, Shapira O, Teitel M, Cohen S, Shahak Y, Israeli Y 2014. The effect of screen type on crop micro-climate, reference evapotranspiration and yield of a screenhouse banana plantation. Scientia Horticulturae 180: 32-39.

Roets N, Ngwamba I, Tesfay S, Ngcobo M 2018. The effect of a low-density white shade net on physiology, phenology and production of mandarin (Citrus reticulata 'Nadorcott'). XXX International Horticultural Congress IHC2018: VII International Symposium on Tropical and Subtropical Fruits, Avocado, II 1299. Pp. 35-42.

Saboki E, Jafari A 2025. Impact of shade net cultivation on banana yield and quality. Discover Plants 2(1): 1-12.

Salinas I, Hueso JJ, Cuevas J 2021. Active control of greenhouse climate enhances papaya growth and yield at an affordable cost. Agronomy 11(2): 378.

Sanmukh S, Patel N, Sanjeev K 2019. Protected cultivation: future technology for vegetable crops. Conference: Global Conference on Technological Challenges and Human Resources for Climate Smart Horticulture-Issues and Strategies, Navsari, India.

Scuderi D, Gugliuzza G, Di Salvo G, Priola F, Passafiume R, Farina V 2022. Shading net and partial covering plastic film do not affect phenology, photosynthetic activity or fruit quality traits of Kensington pride mango. Plants 11(24): 3510.

Sheeba SM, Nirmala Devi M, Premavathi R, Shanmugasundaram KA, Dheebakaran G, Vanitha G 2025. Opportunities and challenges in the adoption of protected technologies in horticultural crops. Plant Science Today 12(2).

Silaru R, Duraisamy P, Madduri YK, Sounderarajan A, Veeraraghavan S, Subraya KK 2024. Deciphering the genotypic superiority of turmeric (Curcuma longa L.) for yield and quality traits under three contrasting production systems. Journal of Applied Research on Medicinal and Aromatic Plants 43: 100592.

Sparks E, Khan V, Ankumah R, Currington JE, Ellison N, Hunter Jr GX, Moore J 2018. The effect of two planting dates and methods on snap bean (Phaseolus vulgaris) production in a tunnel house. Professional Agricultural Workers Journal (PAWJ) 5(2): 32-38.

Tamaki M 2022. Specifying wind speeds causing damage to screen-house crops and quantifying effects on tidal damage. XXXI International Horticultural Congress (IHC2022): International Symposium on Innovative Technologies and Production 1377, Angers, France. Pp. 195-204.

Tanny J 2019. Advances in screenhouse design and practice for protected cultivation. In: Marcelis LFM, Heuvelink E eds. Achieving sustainable greenhouse cultivation. Burleigh Dodds Science Publishing. Pp. 53-74.

Vetharaniam I, Stanley CJ, Cummins M, van den Dijssel C, Müller K 2024. Modelling climate change impacts on location suitability for cultivating avocado and blueberry in New Zealand. Land 13(11): 1753.

Walton VE, Shange R, Khan V, Currington JE, Ankumah R, Sparks E, Ellison N, Hunter Jr GX, Moore JL 2018. Yield of two sweetpotato (Ipomoea batatas (L.) cultivars grown in a wiregrass model tunnel house under trellised and conventional planting systems. Professional Agricultural Workers Journal (PAWJ) 5(2): 23-31.

Zhao W, Yang W, Ma Z, Zhang X, Cha L, Liu S, Zhang Y 2020. Effects of time and height of shading on yield and quality of pineapple. IOP Conference Series: Earth and Environmental Science, vol 512. IOP Publishing. Pp. 012101.

13 Appendix 1. Desk research on selected crops' performance under cover

13.1 Papaya

Papaya- greenhouses and nethouses result in best yields and quality (Céccoli et al 2013; Choudhury et al 2022; Espadas-il et al 2019; Güneş et al 2022; Martelleto et al 2011; Reddy & Gouda 2014)). Siluet and Sensation varieties performed well in greenhouses in Spain (Salinas et al 2020) and in Sel 42 in Turkey (Gunes & Gübbük 2012). Active control of temperature and humidity remains important (Salinas et al 2021).

Authors, Title, Journal, Volume	Main country	Summary
Araujo DC de, Correa L de S, Boliani AC. 2006. Cultivation under protected structures on the papaya (Carica papaya L.): effects on the fruits production and mosaic virus control. Cultura Agronomica. 15(1):1–13.	Brazil. pawpaw cultivars Baixinho de Santa Amalia and Tainung n°2.	The 2 cultivars were compared in tests in 3 different environmental conditions (natural, screenhouse with 30% of light reduction and screenhouse with 40% of light reduction). The following parameters were used in the evaluation: PM Virus incidence; and fruit production. After the data analysis, the results showed that the Tainung n°2 was acceptable for screenhouse cultivation because, in the fifth month, the plants reached the screenhouse cover (4 m), which did not occur in the Baixinho de Santa Amalia cultivar until the end of the experiment. Also there were no plants with PMV symptoms in the screenhouse cultivation. Both cultivars showed good fruit production under natural conditions. However, at 12 months of harvest, plants with PMV symptoms were identified and 84% of them were eradicated in each cultivar.
Reddy PVK, Gowda VN. 2014. Influence of Greenhouse Cultivation on Fruit Quality of "Red Lady" Papaya. In: Chomchalow N, Chantrasmi V, Sukhvibul N, editors. Vol. 1024. [place unknown]; p. 109–114.	Bangalore, India. Red Lady' papaya	Seedlings of 'Red Lady' papaya were grown in insect proof nethouse and were transplanted (50 days) in two growing conditions viz., open field and greenhouse. Observations on yield and quality were observed by adopting standard procedures. Cultivation of papaya under greenhouse showed early flower initiation and high fruit yield compared to open field. At open field condition PRSV incidence appeared at 163.23 days with 100% incidence whereas greenhouse was disease free. Significant differences were observed between the two treatments on fruit physico-chemical characters. The fruits harvested from greenhouse were superior in all aspects of quality. Marketable parameters were also superior.
Céccoli G, Panigo E, Gariglio NF, Favaro JC, Bouzo CA. 2013. Fruit yield and growth parameters of several Carica papaya L. genotypes in a temperate climate.	The central part of the province of Santa Fe, Argentina	The aim of this work was to evaluate changes in growth and productivity parameters of different precocious hybrids and a naturalized variety of papaya under both greenhouse and field cultivation in a temperate climate (the center of the province of Santa Fe, Argentina). The purpose of the research was to identify further genotypes better suited for the cultivation of this species in temperate climates and demonstrate the need for the use of semi-controlled systems to make possible the cultivation of these promising genotypes in middle latitudes. The average yield was 291% higher in greenhouse than in the field. The average productivity for hybrid genotypes compared with the naturalized variety more than doubled in both environments. Considering behavior in height, leaf area index and yield parameters, hybrids H2 (principally), and H4 showed a great adaptation for use in semi-forced systems. The use of greenhouse and short stature papaya hybrids allows its feasible and surely profitable cultivation in non- tropical climates.

Authors, Title, Journal, Volume	Main country	Summary
Gunes E, Gübbük H. 2012. Growth, yield and fruit quality of three papaya cultivars grown under protected cultivation. Fruits. 67(1):23–29.	Turkey Cultivars ‘SS-45’, ‘BH65’ and ‘Sel-42’	Study was conducted in an unheated greenhouse in the Mediterranean region of Turkey. Three papaya cultivars (‘SS-45’, ‘BH65’ and ‘Sel-42’) were evaluated for their physical and physicochemical properties and yield. Results. There were no significant differences in chemical properties related to fruit cultivars. Conversely, certain features of the development cycle of these three cultivars varied: BH-65 flowered at only 65.4 cm compared with SS-45 (133.8 cm) and Sel-42 (135.1 cm). Fruit set was improved for Sel-42 (63.7 fruits) compared with SS-45 (49.3 fruits) and BH-65 (31.3 fruits). The corresponding yields for Sel-42, SS-45 and BH-65 were (28.3, 21.3 and 7.8) kg per plant, respectively. The Sel-42 cultivar presented the largest fruits (weight, 460.0 g; width, 11.7 cm; length, 16.7 cm), closely followed by those of SS-45 (433.3 g, 11.3 cm and 15.3 cm, respectively). In contrast, the cultivar BH65 produced the smallest fruits (weight, 250.0 g; width, 9.7 cm; length, 13.3 cm). The physical and chemical characteristics did not vary among the cultivars. Conclusion. Our results allow us to recommend the cultivars Sel-42 and SS-45 for greenhouse cultivation under a Mediterranean climate in Turkey.
Güneş E, Öziyci HR, Gübbük H. 2022. Quality of different papaya cultivars grown in the greenhouse throughout the year in subtropical regions. Food Science and Engineering. 20–30.		A comparison of papaya cultivation and harvesting periods throughout the year indicated that greenhouse conditions result in the production of more uniform fruit quality in part due to a uniform season. It was concluded that the growth in the greenhouse minimizes the harvest season effects on papaya fruit quality. Thus, greenhouse cultivation is recommended for a higher quality product, especially in a subtropical climate.
Honoré MN, Belmonte-Ureña LJ, Navarro-Velasco A, Camacho-Ferre F. 2019. The production and quality of different varieties of papaya grown under greenhouse in short cycle in continental Europe. International Journal of Environmental Research and Public Health. 16(10):1789.	Spain / Continental Europe Intenzza	Experiments have been carried out to assess the adaptation of papaya to protected cropping systems (under greenhouse) in the Southeast Spain region. In this paper, we showed the results obtained in an experiment with five varieties, taking the most cultivated variety as control, which was grafted on its own female rootstock, in addition to another four new varieties that were introduced. Transplanting was made with early sex-identified plants in the nursery. Cultivation was developed in a 446-day cycle, almost 15 months and fruits were always harvested from the soil, due to the height that the plant reached in that period. The best yield parameters and fruit characteristics were obtained from hermaphrodite Intenzza papaya grafted on female papaya rootstock, although there were also other varieties which gave results that made possible its cultivation under this production system. Cultivation was in multi-tunnel greenhouses covered with low-density polyethylene over fixed periods of 456 days and were considered a commercial success.
Salinas I, Pinillos V, Hueso JJ, Cuevas J. 2020. Protected cultivation of ‘BH-65’, ‘Siluet’, ‘Sensation’, ‘Intenzza’ and ‘Red Lady’ papaya cultivars in South East Spain. Rev Bras Frutic. 42(4).	SE Spain Siluet’ and ‘Sensation’	Papaya (Carica papaya L.) is a tropical fruit crop of rapid growth and early yielding. In recent years, papaya cultivation has extended to subtropical regions due to its commercial interest. In South East Spain, protected cultivation is, however, mandatory to ensure the optimal development of the crop. Even more, to assure profitability, the selection of plant material well adapted to the structural constrains and the climatic conditions inside greenhouses is essential. With this objective, different papaya cultivars with diverse geographical origin, characteristics and pedigree have been compared. ‘BH-65’, ‘Siluet’, ‘Sensation’, ‘Intenzza’ and ‘Red Lady’ papaya cultivars were thus grown under a plastic greenhouse in Almería, SE Spain and their growth, phenology, yield and fruit quality compared in a 21-month production cycle. The results showed that ‘Siluet’ and ‘Sensation’ papayas are well-adapted to greenhouse protected cultivation, produce high yield, and optimal fruit quality for long and short distance markets. Cultivars like ‘BH-65’ could be of interest for low-height greenhouses due to its reduced plant vigor and high fruit quality. However, ‘BH-65’ yield is low. According to the European consumer preferences, the cultivation of ‘Siluet’ and ‘Sensation’ is recommended, for the harsh conditions the greenhouse cultivation imposes in subtropics.
Salinas I, Hueso JJ, Cuevas J. 2021. Active control of greenhouse climate enhances papaya growth and yield at an affordable cost. Agronomy. 11(2):378.	Subtropical areas of southeast Spain	In order to compare the profitability of different climate control strategies in greenhouses located in subtropical areas of southeast Spain, we compared papayas growing in a greenhouse equipped with active climate control (ACC), achieved by cooling and heating systems, versus plants growing in another greenhouse equipped with passive climate control (PCC), consisting of only natural ventilation through zenithal and lateral windows. The results showed that ACC favored papaya plant growth; flowering; fruit set; and, consequently, yields, producing more and heavier fruits at an affordable cost. Climate control strategies did not significantly improve fruit quality, specifically fruit skin color, acidity, and total soluble solids content. In conclusion, in the current context of prices, an active control of temperature and humidity inside the greenhouse could be a more profitable strategy in subtropical regions where open-air cultivation is not feasible.

Authors, Title, Journal, Volume	Main country	Summary
Burns P, Saengmanee P, Doung-Ngern U. 2022. Papaya: the versatile tropical fruit. In: Tropical plant species and technological interventions for improvement [Internet]. [place unknown]: IntechOpen Rijeka		4. Papaya production Especially 4.2 Protected cultivation
Cabrera JA, Ritter A, Raya V, Pérez E, Lobo MG. 2021. Papaya (Carica papaya L.) phenology under different agronomic conditions in the subtropics. Agriculture. 11(2):173.	Tenerife	Meteorological variables (air temperature, relative humidity, and photosynthetically active radiation) and morphological characteristics (plant height, leaf emission rate, and leaf area) were recorded throughout the crop cycle. All the leaves and fruits were labeled in their anthesis week to calculate the source–sink ratio and to study the development and quality of the fruits. Data were collected in three commercial orchards representing two different types of systems, greenhouse and screenhouse, and two different regions: two plastic cover greenhouses located in the south (SP) and in the north (NP) of Tenerife, and one 40-mesh net screenhouse in the north of the island (NN). The selection of these cultivation systems and locations was made deliberately, so that the ambient variables within these crop protection structures were different throughout the cultivation cycle in order to better fit the model construction. The results suggested that in order to maintain good fruit quality, better environmental control is necessary inside the greenhouses and the screenhouse. Monitoring variables such as the growing degree days, the photosynthetically active radiation, and the number of fruits per plant leaf area ratio provided useful information for papaya production management in the Canary Islands and other subtropical areas, allowing farmers to predict harvest and fruit quality.
Choudhury S, Islam N, Mustaki S, Uddain J, Azad MOK, Choi KY, Naznin MT. 2022. Evaluation of the different low-tech protective cultivation approaches to improve yield and phytochemical accumulation of papaya (Carica papaya L.) in Bangladesh. Horticulturae. 8(3):210.	Bangladesh	This production system consists of three treatments, including net house, poly shed house, UV poly shed house, and open field conditions (control). The results revealed that plants grown in the net house had significantly higher leaf number (30), fruit number (68), and fruit yield (56.28 kg/plant) than the control grown plant. Papaya cultured in the net house also showed significantly higher accumulation of chlorophyll, ascorbic acid, total phenol, reducing sugar, and β-carotene than those grown in other environments. In terms of peel color, papaya grown in the net house had the highest a* value (redness), whereas that grown in the open field had the lowest. Thus, the study demonstrated that papaya can be cultivated successfully in a net house with increased yield and phytochemical content. The findings provide a fundamental production strategy for quality papaya production in Bangladesh.
Honoré MN, Belmonte-UreÃ\pma LJ, Molina-Aiz FD, Camacho-Ferre F. 2019. Effect on temperature of lightweight plant cover enveloping papaya fruit (Carica papaya L.) in a naturally ventilated Mediterranean greenhouse. In: International Symposium on Advanced Technologies and Management for Innovative Greenhouses: GreenSys2019 1296 [Internet]. [place unknown]; [accessed 2025 Aug 6]; p. 323–332.	Almeria, Spain	The plant growth in continental Europe presents the handicap of low winter temperatures. When air temperature falls below 12-14°C for several hours at night, papaya production can be affected. The objective of the present study was to analyze the effect of wrapping fruits with polypropylene lightweight non-woven curtain on the daily thermal oscillations and the production, in a naturally ventilated multispan greenhouse (1800 m2) in Almeria (Spain). White lightweight cover was placed around the fruit column, leaving the leaves out of the cover. As a result of the use of the plant cover, the minimum and mean temperature of the air inside of the thermal cover increased, respectively, 1 and 0.7°C. The augmentation of temperature seems to induce early production. The diurnal temperature range was reduced, and the reduction values were in the range of 0.4-1.2°C. No statistically significant increase in the yield (during the period using the plant cover) was observed in the wrapping plants, although production was 4.3 kg m-2 for protected plants and 3.5 kg m-2 without protection.

Authors, Title, Journal, Volume	Main country	Summary
Vieira MR, Correa L de S, Castro TMMG de, Silva LFS da, Monteverde M de S. 2004. Effect of papaya (Carica papaya L.) cultivated in a protected environment on the occurrence of phytophagous mites and whiteflies. Revista Brasileira de Fruticultura. 26(3):441–445.	Brazil	It was measured the effect of cultivating papaya cultivar "Baixinho de Santa Amália" in a protected environment and in three situations: without shade, and under screen shades of white polyethylene mesh sizes 2 x 2 mm or 2 x 1 mm. It was registered the number of plants with symptoms of recent attacks of the broad mite (Polyphagotarsonemus latus), symptoms and presence of the two-spotted spider mite (Tetranychus urticae) and the presence on leaves of adults or nymphs of whiteflies (Trialeurodes sp., Bemisia tabaci biotype B and a third unidentified species). Whitefly nymph and exuviae numbers were also counted in the laboratory. Cultivation in a protected environment favored the survival and development of the species under study, and some possible reasons for these are discussed along the text.
Martelleto LAP, Ribeiro R de LD, Sudo-Martelleto M, Vasconcellos MA da S, Pereira MB. 2011. Expression of female sterility and carpelloidy on papaya tree under different environments of protected cultivation- Expressão da esterilidade feminina e da carpeloidia em mamoeiro sob diferentes ambientes de cultivo protegido. Rev Bras Frutic [Internet]. [accessed 2025 Aug 25] 33:1185–1193.	Brazil Baixinho de Santa Amália	This present study aimed to evaluate the occurrence of female sterility and carpelloidy on hermaphrodite papaya cv. Baixinho de Santa Amalia growing under organic management in different types of environment protection and conducted with or without bifurcation of the trunk during the course of the four seasons. Three types of structures for crop protection were built side-by-side as follows: (i) greenhouse (plastic covering), (ii) shadowed greenhouse ('sombrite' net - 30% over the plastic sheet), and (iii) screenhouse ('sombrite' net - 30% exclusively), in an area of natural environment, for papaya (cv. Baixinho de Santa Amália) cultivation through organic farming system. Half of the plants in all treatments were submitted, right after sex determination, to apical incision for trunk bifurcation. For purposes of analysis of variance four blocks were considered by growth environment, each block having three replicates on how to conduct plant (with and without trunk bifurcation). For statistical analysis, it was proceeded the "jointly experiment analysis" method, in this case, the environments that were planted the plants. In papaya plant with a bifurcated trunk there was a decrease in the number of carpelloid fruits and increased number of female sterile flowers. However, this fact did not affect the production of normal fruits. During spring time, and especially in the greenhouse, the largest number of carpelloid fruits per plant was correlated at higher temperatures range, thermal amplitude and vegetative growth rate. The higher occurrence of staminate flowers was also correlated to high temperatures, low light and low vegetative vigor. Nevertheless, these same conditions favored the occurrence of perfect hermaphrodite fruits, thus contributing positively to papaya yield.
Galán Saúco V, Pérez Hernández E. 2020. Greenhouse cultivation. In: Mitra S, editor. The papaya: botany, production and uses [Internet]. Wallingford: CABI; [accessed 2025 Aug 25]; p. 226–236.		This chapter focuses on the advantages and disadvantages of the greenhouse cultivation of pawpaws. Information on the various greenhouse types, the importance of cultivar selection, cultivation techniques and pests and diseases affecting pawpaw cultivation in greenhouses are also presented.
Espadas-il FL, Morales-Landa J, Talavera-May CR, Patron Castro J, Camara F, Pantoja K, Perez-Ruiz M, Santamaria JM. 2019. Performance of hermaphrodite Carica papaya in-vitro plants grown under greenhouse conditions in the tropics. In: Ortiz GF, Castillo EBG, Ochoa L a. L, Santamaria JM, editors. V International Symposium on Papaya. Vol. 1250. Leuven 1: Int Soc Horticultural Science; p. 159–163.	Yucatan,Mexico	Three different genotypes of hermaphrodite papaya (Carica papaya L.) derived from in-vitro micropropagation were grown under semi-commercial conditions in a greenhouse located in Yucatan, Mexico. The greenhouse was ventilated, covered with a transparent plastic roof, and fitted with a fertirrigation system. The temperature inside the greenhouse was nearly 40 degrees C over the summer months. Plants were grown under these conditions for 1 year. Plants from all genotypes grew vigorously, and no symptoms of plant pathogens were found. Certainly, there were no incidences of viral or fungal diseases. Under these protected conditions, no sex reversal, flower abortion, nor fruit carpeloidy, or fruit abortion was observed in any of the three genotypes studied. Plants from all three genotypes had high fruit yields and excellent fruit quality.

13.2 Mango

Shading can help maintain photosynthetic activity and under plastic to reduce impact of rain, increase quality and reduce rot (Juntamanee 2008; Jutamanee & Onnom 2016, Xu et al 2019). Harvesting can be sped up by growing indoors as can yield in greenhouses (Lionakis & Loxou 1996). Critical wind speed for mangoes was found at 8 m/s (Tamaki 2023).

"Greenhouse cultivation – unheated, in many areas of the subtropics − facilitates cultivation of mangoes in the subtropics. The main advantages of greenhouse cultivation includes: i)Shortening of the juvenile period; ii) Protection from adverse climatic conditions, including avoiding sunburn; iii) Increase flowering and fruit set, due to higher diurnal temperatures and increase of foliar surface, which in turn increase photosynthesis; iv) Easier control of irrigation and possibility of obtaining out of season production through imposing water stress; v) Possibilities of extending harvesting season; and vi) Easier control of pests and diseases." (Galan Sauco 2015).

Authors, Title, Journal, Volume	Main country	Summary
Jutamanee K, Onnom S. 2016. Improving photosynthetic performance and some fruit quality traits in mango trees by shading. Photosynt. 54(4):542–550.	Thailand	Excess solar radiation under hot climate can lead to decline in photosynthetic activity with detrimental effects on growth and yield. **The aim of this study was to evaluate the use of a transparent plastic roof as shading for diurnal changes in photosynthetic gas exchange, chlorophyll fluorescence, fruit set and quality of mango** (Mangifera indica L.) cv. 'Nam Dok Mai' growth in the field conditions. It resulted in increased stomatal conductance and photosynthetic rates of the shaded leaves compared to those of the sunlit leaves, especially from the morning to midday. Furthermore, the reversible decrease of the maximal quantum yield of PSII was more pronounced in the sunlit leaves than that in the shaded ones. Shading increased the total fruit number; the shaded fruits developed better external color than that of the sun-exposed fruits. **Our results indicated that shading could maintain the high photosynthetic activity by reducing stomatal limitations for carbon supply and was effective in alleviating the photoinhibitory damage to PSII during bright and clear days with excessive radiation. Finally, shading could increase the number of fruits and improve mango peel color.**
Lionakis SM, Loxou BK. 1996. Behaviour of some mango cultivars in the greenhouse, under net and outdoors in the area of Chania Crete. In: V International Mango Symposium 455 [Internet]. [place unknown];	Chania region, Crete Zill, Haden, Keitt cvs	The behaviour of twelve mango cultivars grown in **the greenhouse, under net and outdoors at 3X3 in planting distance** - was studied in the area of Chania Crete, during 1990–1995. In the fifth year after planting, the various cultivars produced 5.34–31.46 Kg of fruits per tree in the greenhouse. The **cultivar Zill** produced 1.50 Kg per tree outdoors and 12.68 Kg in the greenhouse. **The production of the cultivars Haden and Keitt under the net was 8.51 and 5.25 Kg per tree respectively, compared to 18.25 and 31.46 Kg of fruits per tree in the greenhouse. The height and the diameter of the tree canopy was 1.50 and 1.80 m respectively for the cultivar Zill outdoors, 1.02–1.68 m and 0.70–1.50 m respectively for the cultivars Keitt and Haden under the net, while in the greenhouse it was 1.34–2.36 m and 1.15–1.86 m respectively for the twelve cultivars**. The number of flowers per inflorescence varied from 2000 to 5200. The percentage of flowers that set fruit ranged from 0.005 to 0.03, while the percentage of flowers that reached harvesting stage varied from 0.001 to 0.20 in the different cultivars. The harvesting of the twelve cultivars was carried out during August to January. **The harvesting was delayed about 35 days outdoors and 25 days under the net compared to that in the greenhouse.**
Juntamanee K, Onnom S, Yingjajaval S, Sangchote S. 2008. Leaf photosynthesis and fruit quality of mango growing under field or plastic roof condition. In: IV International Symposium on Tropical and Subtropical Fruits 975 [Internet]. [place unknown]; [accessed 2025 Aug 8]; p. 415–420.	India	Rain and high humidity during off-season flowering period cause low yield and poor quality. The objective of this experiment was to study the effect of **transparent PVC plastic roof on reducing splashing force of rains and increase fruit set and quality.** Comparisons of changing in microclimate and leaf gas exchange under plastic roof and natural condition were examined. Plastic roof could reduce photosynthetic photon flux by 26.61%. Both day and night temperature, relative humidity at night was not different. **Mango trees under plastic roof had more net photosynthesis rate at blooming period than field condition. Plastic roof could not increase fruit set but increased fruit quality by giving a lighter peel color at ripening time. Furthermore, plastic roof reduced anthracnose at pre- and post-harvest period, decreased severity of fruit rot at ripening stage and completely controlled thrip damage on the fruit surface.**

Authors, Title, Journal, Volume	Main country	Summary
Tamaki M. 2023. Specifying wind speeds causing damage to screen-house crops and quantifying effects on tidal damage. In: Rouphael Y, Michel J, editors. Vol. 1377. [place unknown]; p. 195–203.	Southwestern Japan	**Screen-houses used for growing crops on the islands of southwestern Japan can mitigate damage such as greenhouse collapse caused by strong winds**. Wind loads on greenhouses with screens are lower than those with plastic film because the screens are porous. The lower loads lead to reduced risks of greenhouse collapse. Nevertheless, air currents passing through a screen's mesh have frequently caused wind damage to screen-house crops. Wind damage, as used herein, refers to damage to leaves caused by wind pressure. **To use screen-houses for strong wind protection more effectively, greenhouses must be designed not only for collapse prevention, but also for crop damage mitigation**. Using field tests, this study **measured the air flow characteristics and wind reduction rates of screen-houses. Wind tunnel experiments elucidated the wind speeds sufficient to damage all major crops grown in screen-houses in the southwestern islands: mango, hot pepper, and okra.** As a result, the **critical wind speed for mangoes was found at 8 m s^{-1}**, for hot pepper leaves was set as 4 m s^{-1}, for okra leaves was set as 6 m s^{-1}. Knowledge of screen-house wind reduction rates and wind speeds sufficient to damage crops is useful to design wind damage reduction methods for crops in screen-houses. Results confirmed that wind speed reduction reduces wind damage to mangoes, and also reduces tidal damage.
Galan Sauco V. 2015. Advantages and Disadvantages of Cultivating Mangoes (Mangifera indica L.) under Subtropical Conditions and Potential of Greenhouse Cultivation of Mango. In: Espinal J, Sauco V, Ortiz J, editors. Vol. 1075. [place unknown]; p. 167–177.	Subtropical regions	**Greenhouse cultivation** – **unheated**, in many areas of the subtropics **– facilitates cultivation of mangoes in the subtropics. The main advantages of greenhouse cultivation includes: i)Shortening of the juvenile period; ii) Protection from adverse climatic conditions, including avoiding sunburn; iii) Increase flowering and fruit set, due to higher diurnal temperatures and increase of foliar surface, which in turn increase photosynthesis; iv) Easier control of irrigation and possibility of obtaining out of season production through imposing water stress; v) Possibilities of extending harvesting season; and vi) Easier control of pests and diseases.** Mangoes under greenhouse are also specially adapted to cultivation on trellises which facilitates pest control and harvesting. These cultivation advantages must be off-set against the initial infrastructure costs as well as the obligatory and timely provision of pollinating insects at flowering time. Prior, in-depth economic studies are thus required in order to ensure that the investment will be profitable in the long term.
Mizuno S, Yoshida T, Kiyokawa K, Sasaki M. 2007. Pattern of visiting flowers and pollination efficiency of three kinds of bees on "Irwin" mango fruits grown in plastic greenhouses. Japanese Journal of Tropical Agriculture. 51(3):116–122.	Japan	The pollination efficiency of two species of honey bees and bumble bees (Bombus ignitus) was compared for 'Irwin' mango fruits grown in plastic greenhouses. There were no differences in the number of bees leaving the hives on fine and rainy days. The seeded fruit ratio was high with all three pollinators: 71.7% for Japanese honey bees, 69.0% for European honey bees and 59.3% for bumble bees. Although a larger number of fruits weighed more than 200 g with European and Japanese honey bee pollinators, bumble bee pollinators produced many small fruits weighing less than 100 g. **Both the European and Japanese honey bees are effective pollinators for the production of large mango fruits.**
Scuderi D, Gugliuzza G, Di Salvo G, Priola F, Passafiume R, Farina V. 2022. Shading Net and Partial Covering Plastic Film Do Not Affect Phenology, Photosynthetic Activity or Fruit Quality Traits of Kensington Pride Mango. PLANTS-BASEL. 11(24).	Mediterranean Kensington Pride	Mango cultivation in a protected environment is becoming widespread in the Mediterranean basin where the species has to face unfavourable weather conditions which do not occur in its native cultivation areas. **Besides open-air cultivation, greenhouses-and other protection systems such as shading nets and partial covering of plastic films-have been tested recently. In this study, we focused on assessing the effect of a shading net, and a partially covering plastic film, on the development of "Kensington Pride" mango fruit skin-color, its final quality, and the plants' photosynthetic activity**. A new method of measuring mango skin-color on different sides of the fruit is proposed. No difference was observed with regard to the observed parameters between the plants cultivated under the two different protection systems and those growing in the open air. It can, therefore, be stated that **such cultivation techniques do not alter the development of the mango fruit and its appearance, nor the plant's photosynthetic activity.**
Xu WT, Wang SB, Wu HX, Gao YY, Yao QS, Luo C, Zhan RL, Ma XW. 2019. Effects of rain cover cultivation on ecophysiology-factors, yield and fruit quality in mango. In: He X, Pan J, Luo C, editors. Vol. 1244. [place unknown]; p. 137–142.	Coastal South China Renong 1	The advantages of the rain cover cultivation over open field were evaluated in order to explore the mango efficient cultivation mode in the coastal rainy region of South China. The **'Renong 1' mango trees were treated with rain covers from first blooming until harvest.** The results suggest that rain covers modified the microenvironment of the canopy in mango and **promoted bisexual flower rate and yield of mango while they had no negative effects on the internal quality of fruits and improved the storability of mango fruit**. Therefore, rain-shelter cultivation could be a promising practice for mango production in the rainy region of South China.

Authors, Title, Journal, Volume	Main country	Summary
Hormaza JI. 2025. Mango production under Mediterranean climates. Acta Hortic [Internet]. [accessed 2025 Aug 25] (1415):19–24.	Spain	Although most of the mango production worldwide is concentrated in countries with tropical and subtropical climates**, mango cultivation in Mediterranean climates has increased in the last few years, facing some adaptation problems**. These challenges are mainly due to excessively low temperatures during the winter and spring months. Research-driven advances have resulted in successful solutions that have been adopted by mango growers to obtain high yields and high-quality mangos under these conditions, such as high-density plantings, cultivation in trellises, control of flowering or greenhouse cultivation. **Choosing cultivation sites with minimal occurrences of temperatures below 10°C in winter and above 40°C in summer is crucial.** Edaphic conditions and wind exposure should also be considered. Greenhouse cultivation, increasingly practiced in Spain, helps mitigate climatic constraints, reduce irrigation needs, improve quality and yield and extend the harvesting season. Greenhouses offer a controlled environment that can protect mangoes from extreme temperatures and frosts. **In the greenhouse, utilizing trellis systems, such as espalier, palmette, and cordon, has proven successful in Australia** (Mahmud et al., 2023) **and is now being adopted in Spain, Portugal and Sicily (Italy).** Delaying flowering to align with optimal temperatures for pollen germination, tube growth, fertilization, and fruit set can help mitigate the impact of suboptimal temperatures on pollen germination, tube growth, fertilization and fruit set. preventing early flowering in young mango trees is crucial to avoid depleting carbohydrate reserves, which can weaken and prematurely age the trees. This issue is exacerbated by cold temperatures during winter, that can even occur in nurseries. To mitigate this problem, **nurseries in Mediterranean climates should be established in warmer locations or using heated greenhouses. Planting seedlings of polyembryonic rootstocks in the field and grafting them two years later, once they are well established, is an alternative approach, but managing this method can be particularly difficult in high-density plantings**, as it requires more careful and labour-intensive practices to ensure the seedlings are properly established and ready for grafting.
Zul H, HMH Muhamad, Wam, Mahfuzah WI, Shaidatul, Mohd, AR, Mohd, FAF. 2014. Evaluation of growth, yield and fruit quality of harumanis mango under greenhouse and open field conditions.-All Databases [Internet]. [accessed 2025 Aug 25].	MARDI Sintok, Kedah, Malaysia.	Studies were conducted to evaluate the growth, yield, and fruit quality of mango (Mangifera indica) cv. Harumanis **trees grown under greenhouse and open field conditions** at MARDI Sintok, Kedah, Malaysia. A total of 48 trees were selected for the experiment and treated with paclobutrazol (PBZ) to induce flowering. Vegetative and reproductive growth parameters were measured, followed by a quality assessment of harvested fruits. **The results indicated that greenhouse cultivation led to earlier flowering and fruiting compared to open field conditions**. Fruit quality from greenhouse-grown trees was comparable to that of open field-grown trees. Future studies are recommended to explore the use of pollination agents and IoT systems to enhance yield and fruit quality in greenhouse conditions.

13.3 Dragon Fruit

"The 'Costa Rica' (7.54 kg/plant) white-fleshed pitaya cultivar, and 'Malaysia Red' (8.44 kg/plant) red-fleshed cultivar had the highest fruit yields" in a tunnel type-greenhouse structure (4.5 m of side height, 7 m of mid-height) (Oziyc et al 2024).

Shade nets "reduced incoming solar radiation by ~40–70%, lowered the canopy temperature by 3–7 °C. Shading reduced sunburn by > 96%, as well as disease incidence and severity. It enhanced new sprouts by 28–84%, total chlorophyll (28–79%), and NDVI, while reducing canopy temperature. White and black 50% shading also increased flower bud production by 33% and 27%, respectively, compared with open and reduced flower bud drop. Under these two shades, yield increment was observed by 67% and 53% compared to open. However, shading reduced total soluble solids... White and black 50% shading are more suitable for preventing heat stress damage in dragon fruit in hot and dry semi-arid climates for sustainable yield and fruit quality" (Patil et al 2024).

16 mesh net houses in subtropical Taiwan "may be useful for white-fleshed pitaya cultivation during its natural reproductive period" (Chien & Chang 2019).

Authors, Title, Journal, Volume	Main country	Summary
Belbase P, Jayachandran K, Balaji Bhaskar MS. 2025. Assessment of Soil and Plant Nutrient Status, Spectral Reflectance, and Growth Performance of Various Dragon Fruit (Pitaya) Species Cultivated Under High Tunnel Systems. Soil Systems. 9(3):75.	U.S.A. White, red and yellow	Although high tunnels are being used to produce specialized crops, little is known about how pitaya growth, physiology and nutrient uptake change throughout the production period. This study aims to evaluate the impact of high tunnels and varying rates of vermicompost on three varieties of pitaya, White Pitaya (WP), Yellow Pitaya (YP), and Red Pitaya (RP), to assess the soil and plant nutrient dynamics, spectral reflectance changes and plant growth. Soil nutrients showed a higher concentration of Na and K grown inside the high tunnels in all three pitaya species due to the increased concentration of soluble salts. Spectral reflectance analysis showed that RP and WP had higher reflectance in the visible and NIR region compared to YP due to their higher plant biomass and canopy cover. **This study emphasizes the importance of environmental conditions, nutrition strategies, and plant physiology in the different pitaya plant species. The results suggest that high tunnels with appropriate vermicompost can enhance pitaya growth and development.**
Oziyci HR, Unlu M, Altinkaya L, Tekin A, Gubbuk H. 2024. Comparative Analysis for Quality Traits of Pitaya Varieties in Protected Cultivation. APPLIED FRUIT SCIENCE. 66(1):173–181.	Antalya/Türkiye 'Costa Rica' (7.54 kg/plant) white-fleshed pitaya cultivar, and 'Malaysia Red' (8.44 kg/plant)	The study explored the potential **of eight new pitaya cultivars for protected cultivation in subtropical climate conditions, comparing yield and fruit characteristics. Two white-fleshed and six red-fleshed cultivars were planted in the study.** The physico-chemical properties (pH, total acidity, glucose and fructose amounts, fruit weight, fruit diameter, fruit length, plant yield, color, total phenolic content, total monomeric anthocyanins, antioxidant activity, glucose and fructose amounts) of the fruits were analyzed using principal component analysis. **The 'Costa Rica' (7.54 kg/plant) white-fleshed pitaya cultivar, and 'Malaysia Red' (8.44 kg/plant) red-fleshed cultivar had the highest fruit yields…..** 'Thai Red' (8.19 mg cyanidin-3-glucoside—Cy3G/100 mL) and 'Malaysia Red' (5.57 mg Cy3G/100 mL) …..Overall, the study revealed new pitaya cultivars that are adaptive for protected cultivation with varying fruit characteristics. The experiment was carried out a tunnel type-greenhouse structure (4.5 m of side height, 7 m of mid-height) in 3-year-old plants through 2020–2021 in Antalya/Türkiye (altitude 21 m, latitude 36°55'32"N, longitude 30°51'46"E). The plantation used a trellis system with a single pole and a ring.
Mitra S, editor. 2024. Dragon fruit: botany, production and uses. [place unknown].		The book has 13 chapters covering a range of topics including dragon fruit physiology, **cultivation techniques**, production technology, postharvest management and processing methods, offering valuable insights for researchers, growers and industry professionals alike.

Authors, Title, Journal, Volume	Main country	Summary
Dinh-Ha Tran, Yen C-R, Chen Y-KH. 2015. Effects of bagging on fruit characteristics and physical fruit protection in red pitaya (Hylocereus spp.). Biological Agriculture & Horticulture. 31(3):158–166.	Southern Taiwan	The most important role of fruit bagging was to effectively protect fruits from physiological factors such as cracking, bird damage and blemish, which led to the significant decrease of the total **damaged and defective fruits (13.7-33.3%), as compared with non-bagged control (66.7-72.6%).**
Gübbük H, Balkıc R, Altınkaya L. 2024. Greenhouse Cultivation. In: Mitra S, editor. Botany, Production and Uses [Internet]. GB: CABI; [accessed 2025 Aug 11]; p. 221–235.	Various	In subtropical climates, the cultivation of tropical fruit species in greenhouses is an important option, as plants can grow with less water and meet production deficits and export opportunities. Dragon fruit is considered an important fruit crop to grow in plastic greenhouses. Countries such as China, Turkey, Israel and Spain are growing dragon fruit in greenhouses using technologies developed to suit the requirements for successful cultivation. **This chapter discusses the types of greenhouses used for cultivation, suitable varieties to grow and the management practices that should be followed.**
Patil A, Kakade VD, Kalalbandi BM, Morade AS, Chavan SB, Salunkhe VN, Nangare DD, Basavaraj PS, Jinger D, Reddy KS. 2024. Mitigating heat stress in dragon fruit in semi-arid climates: the strategic role of shade nets in enhancing fruit yield and quality. Environ Dev Sustain [Internet]. [accessed 2025 Aug 11].	Baramati, India	To **manage heat stress and prevent sunburn, green-, white-, and black-coloured shade nets with 35% and 50% shade factors were employed in three dragon fruit genotypes.** Overall, **shading reduced incoming solar radiation by -40–70%, lowered the canopy temperature by 3–7 °C. Shading reduced sunburn by > 96%, as well as disease incidence and severity. It enhanced new sprouts by 28–84%, total chlorophyll (28–79%), and NDVI, while reducing canopy temperature. White and black 50% shading also increased flower bud production by 33% and 27%, respectively, compared with open and reduced flower bud drop. Under these two shades, yield increment was observed by 67% and 53% compared to open. However, shading reduced total soluble solids**. White 50% shading enhanced total phenols and flavonoids, while white 35% shading enhanced vitamin C in fruit pulp compared to control. Overall, our findings indicate that **white and black 50% shading are more suitable for preventing heat stress damage in dragon fruit in hot and dry semi-arid climates for sustainable yield and fruit quality.**
Tomaz de Oliveira MM, Albano-Machado FG, Penha DM, Pinho MM, Natale W, Alcantara de Miranda MR, Herbster Moura CF, Alves RE, de Medeiros Correa MC. 2021. Shade improves growth, photosynthetic performance, production and postharvest quality in red pitahaya (Hylocereus costaricensis). Scientia Horticulturae. 286.	Fortaleza, Ceará, Brazil red pitahaya	This investigation aimed to evaluate shading as a strategy for coping with high solar radiation in red pitahaya (*Hylocereus costaricensis*), through a long-term field experiment. To this end, we studied growth, physiological performance, productivity and postharvest quality of red pitahaya grown under four shade levels, namely, 35, 50, 65 and 80%, compared to plants under full sunlight (control). Red pitahaya showed superior performance under shading compared to the control, especially plants under about 35% shade. …..Shaded plants showed improved yields along with production precocity, as seen through comparison with the local cultivation under full sunlight. In the second year, a maximum estimated yield of 18.7 t ha^{-1} was observed under about 35% shade, which is a production increase of 70% vs plants under full sunlight (10.9 t ha^{-1}). Shading improved fruit quality through increased fresh weight, pulp yield, pulp firmness and reddish pulp coloring, indicating the accumulation of betalain pigments. Our findings support shading as a valuable strategy for coping with stress induced by extremely high solar radiation in field plantations, thus providing increased productivity by preventing bleaching and death of *Hylocereus*, especially in drylands.

Authors, Title, Journal, Volume	Main country	Summary
Chien Y-C, Chang J-C. 2019. Net houses effects on microclimate, production, and plant protection of white-fleshed pitaya. Hortscience. 54(4):692–700.	Taiwan	To evaluate the comprehensive response of commercial cultivation of the **white-fleshed pitaya** (*Hylocereus undatus* 'VN White') **under net house in Taiwan,** experiments were conducted during the natural reproductive period (from June to Sept. 2016) with fruits grown within net houses (**either 16 or 24 mesh insect-proof netting, without fruit bagging) or in an open field (the control, without netting, with fruit bagging).** The effects of netting on microclimate, phenological period, flowering (floral bud emergence) of current and noncurrent cladodes (shoots) (2- to 3-year-old), fruit quality, market acceptability, pests and diseases control, and level of sunburn were investigated. Indoor solar radiation in the 16 and 24 mesh net houses were 78.12% and 75.03%, respectively, and the sunlight intensities [photosynthetic photon flux density (*PPFD*), $\mu mol \cdot m^{-2} \cdot s^{-1}$] were 76.03% and 73.00%, respectively, that of control. The maximum daily temperature for the 16 and 24 mesh net houses was greater than that of the control. However, there were no significant differences in daily average temperature, minimum temperature, or relative humidity (RH). The first flowering cycle (12 June 2016) and last flowering cycle (11 Sept. 2016) in both net houses were the same as those in the control. **The accumulative flowering of current cladodes was unaffected by net covering, but that of noncurrent-year cladodes in both net houses was lower than that in the control.** Although the L* and C* values of fruit color in the 16 and 24 mesh net houses were lower than those in the control, the fruits still had commercial value. **The average fruit weight of the 16 mesh net house was significantly greater than that of the control.** Average total soluble solid (TSS) content, TSS content at the fruit center, and titratable acidity were unaffected. In addition, the 16 mesh net house blocked some large pests without exacerbating disease or sunburn. **Our findings suggest that 16 mesh net houses may be useful for white-fleshed pitaya cultivation during its natural reproductive period in subtropical Taiwan**.
Chien Y-H, Chu Y-C, Hsu Y-H, Chang J-C. 2024. Synergistic effect of net-houses and light sources on the enhancement of off-season flowering waves and production of 'Da Hong' red-fleshed pitaya. Scientia Horticulturae [Internet]. [accessed 2025 Aug 27] 329:112982.	Taiwan Da Hong red fleshed	To meet the increasing demand for year-round production of 'Da Hong' **red-fleshed pitaya (*Hylocereus polyrhizus*)**, which is limited by its natural flowering season in the summer and has been a dominant cultivar in Taiwan, China and East-SouthEast Asia owing to its self-compatibility and excellent fruit quality, extending the off-season cultivation period has become a crucial endeavor. This study aimed to **assess the effects of net-houses and light sources on off-season (spring and winter) fruit quality yield of 'Da Hong' red-fleshed pitaya in Taiwan.** Mature six-year-old plants were cultivated either in net-houses or open fields (OFs), with night-breaking achieved using artificial lighting: either 100 W incandescent bulbs (IBs) or 23 W compact fluorescent energy-saving bulbs (CFBs). The study was conducted during spring and winter in 2017–2018, with flowering rate and fruit production evaluated. Floral bud emergence in the net-house+IB and net-house+CFB groups preceded that in other treatments by at least 2 weeks during spring, with net-house+IB exhibiting the highest frequency of flowering waves (four in spring and three in winter**). Across all treatments, night-breaking via artificial lighting in spring markedly increased yield, with IBs and CFBs producing similar outcomes. Quality-wise, OF cultivation surpassed net-house cultivation in spring, whereas net-house cultivation, particularly with IBs, proved more effective during winter**. In summary, net-house cultivation offers several advantages for off-season production, including earlier peak flowering in spring, increased flowering cycles in both spring and winter, and higher flowering rates during winter. **Overall, these results may help enhance and stabilize off-season 'Da Hong' red-fleshed pitaya cultivation. Moreover, the significance of our study has the potential to revolutionize the flowering physiology, the strategy to enhance year-round production and the advancement of agricultural sustainability in pitaya.**

13.4 Pineapple

Shading at 30 d after flower fading and at height of 0 cm was suggested in ‘Golden’ pineapple production in China (Weifeng et al 2020).

In “the summer, the use of screens with 50 % of shading provided average gains of 22 and 39 % of total and commercial mass of crowned [Smooth Cayenne variety] fruits per plant and gains of 22 and 40 % of total and commercial yield per hectare, respectively. The gradual increase in shading intensity resulted in a decrease in the qualitative attributes of the fruits, when compared to covering the fruits with newspaper. Screens with up to 50 % of shading can replace newspaper when covering the fruits to avoid scalding” (de Araujo 2021).

In Tawan, Kuan et al (2017) found that “Fruitage percentage significantly decreased to 83.3% in fields covered with double layer of 50% shading net. Without any covering material as check, fruit stalk cracking was high, up to 22.2% after 2 weeks of red heart stage, and average fruit stalk cracking was even higher, up to 50% when near flowering. This study has shown fruit stalk cracking can be effectively improved by the use of both mono layer of white polyethylene fibers and double layer of 50% shading net, with the incidence of only 8.6% and 10.0%, respectively”.

In Goa, India pineapples were successfully “grown inside polyhouse to utilize the additional spaces with fertigation and flower induction with a 50 ml solution of ethephon 25 ppm + urea 2% + sodium carbonate 0.04% with a B: C ratio of 1.15” (Maneesha et al 2025).

Martinez-Conde et al 2024 recommends “early installation of shade netting 45 days after planting decreases the growth and yield of pineapple; thus, the use of shade netting at this age is not recommended. Regarding fertilization, the combination of 50% chemical fertilization with organic fertilization showed similar growth and yield values compared to 100% conventional chemical fertilization under both shade net conditions”.

Weifeng et al 2020 showed that “the incidence of sunburn of pineapple fruits increased with the delay of the shading time, and no differences were found among three heights at 30 d after flower fading. When pineapple plants were shaded at 30 d after flower fading and at height of 0 cm, pineapple fruits showed good external qualities, including larger fruit size, less fruit eyes, less fruit shape index, larger fruit hardness, higher edible rate and good internal qualities, including higher soluble solid content, higher soluble sugar content and lower total acidity. Shading at 30 d after flower fading and at height of 0 cm was suggested in pineapple production.”

Zhao et al (2020) discovered that the “prevention to sunscald effect of blue sunshade net performed the best, followed by green and black sunshade net … The pineapple covering with blue sunshade net after 60 d of lower fading could gain high yield and good quality..”

Authors, Title, Journal, Volume	Main country	Summary
Zhao W-F, Ma Z-L, Zhang X-Y, Cha L-G, Liu S-H, Yang W-X. 2020. Effects of color and covering time of sunshade net on yield and quality of Ananas comosus. Guizhou Agricultural Sciences. 48(4):123–126.	Yunnan China	For the sake of providing the technical basis for cultivation of pineapple with good quality and high yield in Yunnan, a field experiment was conducted to **explore the effects of different color (black, green and blue) and covering time (covering after 60 d, 45 d, 30 d of pineapple flower fading) of sunshade net on sunscald rate, yield and quality of pine apple**. Results: **The prevention to sunscald effect of blue sunshade net performed the best, followed by green and black sunshade net.** The covering time had obvious effects on appearance characters and quality of pineapple. The pineapple covering with blue sunshade net after 60 d of flower fading was featured with large longitudinal and transverse diameter, medium fruitlet number, suitable shape index, high fruit hardness, high Vc content, low total acid, high soluble sugar content, good comprehensive traits of appearance and quality and high yield. **The pineapple covering with blue sunshade net after 60 d of lower fading could gain high yield and good quality.**
Weifeng Z, Weixiu Y, Zhiling M, Xiaoyan Z, Liguo C, Shenghui L, Yanfang Z. 2020. Effects of time and height of shading on yield and quality of pineapple. In: IOP Conference Series: Earth and Environmental Science [Internet]. Vol. 512. [place unknown]: IOP Publishing; [accessed 2025 Aug 12]; p. 012101.	Golden	Effects of time and height of shading on the sunburn rate, yield and quality of pineapples were investigated in order to provide a theoretical basis for high-quality pineapple production. Golden pineapple was used as the material, and three shading times (30 d, 45 d, and 60 d after flower-fading), and the heights of 0 cm, 20 cm, and 40 cm (the distance from the top of the plant) were set. Golden pineapple's internal and external fruit qualities were measured**. The results showed that the incidence of sunburn of pineapple fruits increased with the delay of the shading time, and no differences were found among three heights at 30 d after flower fading. When pineapple plants were shaded at 30 d after flower fading and at height of 0 cm, pineapple fruits showed good external qualities, including larger fruit size, less fruit eyes, less fruit shape index, larger fruit hardness, higher edible rate and good internal qualities, including higher soluble solid content, higher soluble sugar content and lower total acidity. Shading at 30 d after flower fading and at height of 0 cm was suggested in pineapple production.**
Martínez-Conde J, Palacios-Torres RE, Ramírez-Seañez AR, Amador-Mendoza A, Reyes-Osornio M, Yam-Tzec JA, Gutiérrez-Hernández JO, Hernández-Hernández H. 2024. Impact of the combination of chemical and organic fertilization on the growth and yield of pineapple under two shade net conditions. Agronomy 14(5):1027.		The use of organic sources presents itself as a viable alternative to mitigate the excessive reliance on chemical fertilizers in agricultural practices. However, in the realm of pineapple cultivation, research exploring the synergy between chemical and organic fertilizers remains scarce. In this context, the objective of this research was to evaluate the impact of the combination of chemical and organic fertilizers on the growth and yield of the MD-2 pineapple cultivar under two shade net conditions (installed 45 and 250 days after planting). **The experiment was conducted in a split-plot design, with the main plot being the shade net conditions and the sub-plots the five fertilization treatments, which were applied 18 times via drip irrigation (control, 100% chemical fertilization, 50% reduced chemical fertilization, organic fertilization, and a combination of 50% chemical fertilization with organic fertilization).** The results showed that the **early installation of shade netting 45 days after planting decreases the growth and yield of pineapple; thus, the use of shade netting at this age is not recommended. Regarding fertilization, the combination of 50% chemical fertilization with organic fertilization showed similar growth and yield values compared to 100% conventional chemical fertilization under both shade net conditions**. Furthermore, this combination presented similar nitrate and potassium values in the plant and did not negatively affect malic acid content. Therefore, the use of organic fertilizers in pineapple cultivation is a promising strategy to reduce the excessive use of chemical fertilizers, and it could also improve soil fertility.
Maneesha SR, Gupta MJ. 2025. Prospects of pineapple cultivation under polyhouse in coastal zones of India. Bangladesh Journal of Botany. 54(2):293–300.	Goa, India	The growth and development of pineapple plants and it's response to different flower induction chemicals inside polyhouse microclimatic conditions were studied in hot-humid coastal conditions during 2017-18 at ICAR-CCARI, Goa. The existing naturally ventilated double-span polyhouse was structurally modified to accommodate heavy rainfall, and the additional space created on both sides was utilized to grow pineapple plants with fertigation and flower induction treatment. The day temperature (37.00-42.50 degrees C) and night temperature (12.16-22.87 degrees C) inside the polyhouse were higher than the ambient conditions throughout the growing period of the crop (31.94-34.16 degrees C and 19.65-24.46 degrees C, respectively). The relative humidity inside the polyhouse ranged from 50.75-97.85%, whereas in ambient conditions, it was 37.75-91.90%. Among the different flower induction treatments, the ethephon 25 ppm+urea 2% + sodium carbonate 0.04% treatment was the most effective with the earliest flowering (33.33 days), which was 15.11 days ahead of the control (48.44 days). **Pineapple can be successfully grown inside an existing polyhouse to utilize the additional spaces with fertigation and flower induction with a 50 ml solution of ethephon 25 ppm + urea 2% + sodium carbonate 0.04% with a B: C ratio of 1.15**.

Authors, Title, Journal, Volume	Main country	Summary
Kuan ChingShan KC, Tang ChiaHui TC, Lee TanCha LT. 2017. Effects of covering materials on plant temperatures and fruit stalk cracking rates of “Tainung No. 17” pineapples. Journal of the Taiwan Society for Horticultural Science. 63(3):147–158.	Taiwan, 'Tainung No. 17'	Different covering materials are utilized to study their impacts on plant temperature cooling, fruitage percentage and fruit stalk cracking of 'Tainung No. 17' pineapple. Therefore, data carefully collected and recorded in this research include hourly average temperature, relative humidity, wind speed and solar radiation in pineapple orchard during experimental period. **Fruitage percentage significantly decreased to 83.3% only in fields covered with double layer of 50% shading net. Without any covering material as check, fruit stalk cracking was high, up to 22.2% after 2 weeks of red heart stage, and average fruit stalk cracking was even higher, up to 50% when near flowering. This study has shown fruit stalk cracking can be effectively improved by the use of both mono layer of white polyethylene fibers and double layer of 50% shading net, with the incidence of only 8.6% and 10.0%, respectively.** The temperatures on the surface of check are higher than that of the air and materials covered plants. Besides, thermography images were taken and the minimum fruit stalk temperature of plants without any covering material was 30.6°C As result, mono layer of white polyethylene fibers and double layer of 50% shading net were both lower than that of the former with the minimum temperature of 28.5°C and 29.9°C, respectively.
Farahani F. 2013. Growth, flowering and fruiting in vitro pineapple (Ananas comosus L.) in greenhouse conditions. African Journal of Biotechnology [Internet]. [accessed 2025 Aug 12] 12(15).	Tehran City, Iran	The experiment was carried out in a greenhouse, located in Tehran city, Iran. The objectives of this study was to evaluate the effects of fertilizer and acidic soil on the foliar and radicular growth of micropropagated plantlets of the pineapple cv. Merr (*Ananas comosus* L.). **We evaluated the growth of that genotype in five different ages of acclimatizing: 1, 2, 3, 4, 5 and 6 months in greenhouse. The hardening of plantlets increased length of shoot, leaf length and leaf number and slip production, accelerated flowering and fruit maturity, caused uniform flowering and fruit ripening, and had no effect on sucker development. When hardening plantlets were at least 60 to 70 cm tall and 10 to 12 months old, an inflorescence bud was observed to form in the center of the leaves. Flowers (light red in color) opened row by row over a period of about two weeks. When fruits were about six months old, about four months after flowering has occurred, these changes were observed. The color of the shell changed from green to rich gold. When the fruit was golden half way up, it could be picked and eaten**. The color change of the shell occurred first at the bottom of the fruit and moved upwards. During this change, the fruit became sweeter and the color of the flesh changed from white to yellow.
de Araujo HS, do Curmo SA, Belmiro dos Santos NC, Nakada Freitas PG, Purquerio LFV. 2021. Effect of shading screens on the production and quality of “Smooth Cayenne” pineapple. Pesquisa Agropecuaria Tropical. 51.	Smooth Cayenne	In pineapple cultivation, it is common to cover the fruit with newspaper, in order to avoid scalding caused by sunburn. However, the scarcity of material and the large labor force required have led to the search of control alternatives. **This study aimed to evaluate the use of shading screens in the production and quality of 'Smooth Cayenne' pineapple.** A randomized blocks experimental design was used, with **five treatments (fruits covered with newspaper and plants covered with screens with 35, 40, 50 and 80 % of shading), four replicates and two seasons (summer and winter**). In **the summer, the use of screens with 50 % of shading provided average gains of 22 and 39 % of total and commercial mass of crowned fruits per plant and gains of 22 and 40 % of total and commercial yield per hectare, respectively. The gradual increase in shading intensity resulted in a decrease in the qualitative attributes of the fruits, when compared to covering the fruits with newspaper. Screens with up to 50 % of shading can replace newspaper when covering the fruits to avoid scalding.**
Kishore K, Rupa TR, Samant D. 2021. Influence of shade intensity on growth, biomass allocation, yield and quality of pineapple in mango-based intercropping system. Scientia Horticulturae. 278:109868.	Eastern tropical region of India	Fruit tree-based intercropping system is commonly practiced in India; however, optimization of light environment for intercrops is essentially required to enhance their productivity. Influence of three shade intensities were examined on growth, biomass allocation pattern, leaf chlorophyll content, nutrient uptake, fruit yield and quality of pineapple in mango-based intercropping system. Sunburn intensity significantly reduced under LE2 and LE3. Path analysis studies indicated that plant biomass was that most important predictor for fruit yield in pineapple. Our findings demonstrate that in eastern tropical region of India pineapple may be cultivated as an intercrop with ~50 % shade intensity since the performance of crop is significantly affected under monoculture system.

Authors, Title, Journal, Volume	Main country	Summary
Weifeng Z, Weixiu Y, Zhiling M, Xiaoyan Z, Liguo C, Shenghui L, Yanfang Z. 2020. Effects of time and height of shading on yield and quality of pineapple. In: IOP Conference Series: Earth and Environmental Science [Internet]. Vol. 512. [place unknown]: IOP Publishing; [accessed 2025 Aug 12]; p. 012101.	Modern Tropical Agricultural Scientific Research and Teaching Base of Yunnan Agricultural University (Pu'er City, Yunnan Province) 'Golden'	Effects of time and height of shading on the sunburn rate, yield and quality of pineapples were investigated in order to provide a theoretical basis for high-quality pineapple production. **Golden pineapple was used as the material, and three shading times (30 d, 45 d, and 60 d after flower-fading), and the heights of 0 cm, 20 cm, and 40 cm (the distance from the top of the plant) were set**. Golden pineapple's internal and external fruit qualities were measured. The results showed that the incidence of sunburn of pineapple fruits increased with the delay of the shading time, and no differences were found among three heights at 30 d after flower fading. When pineapple plants were shaded at 30 d after flower fading and at height of 0 cm, pineapple fruits showed good external qualities, including larger fruit size, less fruit eyes, less fruit shape index, larger fruit hardness, higher edible rate and good internal qualities, including higher soluble solid content, higher soluble sugar content and lower total acidity. **Shading at 30 d after flower fading and at height of 0 cm was suggested in pineapple production.**
Tavares JP, Silva MT. 1995. Greenhouse-produced pineapple in the Azores (Portugal). In: II International Pineapple Symposium 425 [Internet]. [place unknown]; [accessed 2025 Aug 12]; p. 97–108.	Azores Islands (belonging to Portugal, located in the middle of the Atlantic Ocean)	Studies were undertaken by the authors with other locally available mulches such as wood chips and sawdust, pumice stone, black gravel and sand, besides branches of *P. undulatum*, *Criptomeria japonica* (L.f.) D. Don, and *Banksia integrifolia* Lef., on the sole basis of the knowledge on traditional techniques and with the support of the Laboratório Químico Rebelo da Silva and the Centro de Pedologia Tropical (both in Lisbon). Tested beds contained from bottom to top three layers of organic matter (woody plant chips, *leiva* soil, and sawdust) alternating with three layers of soil. Branches of *P. undulatum* resulted the best mulch because of their physical and chemical characteristics. Other studied alternatives were mineral materials between layers of chips and/or chips + sawdust from *P. undulatum* branches, with or without fertilizer ; black gravel appeared preferable to pumice stone and sand because richer in P, Ca, Mg, Fe and Ti, and absorbing more heat.
Martínez-Conde J, Palacios-Torres RE, Ramírez-Seañez AR, Amador-Mendoza A, Reyes-Osornio M, Yam-Tzec JA, Gutiérrez-Hernández JO, Hernández-Hernández H. 2024. Impact of the Combination of Chemical and Organic Fertilization on the Growth and Yield of Pineapple under Two Shade Net Conditions. Agronomy. 14(5):1027.		The use of organic sources presents itself as a viable alternative to mitigate the excessive reliance on chemical fertilizers in agricultural practices. However, in the realm of pineapple cultivation, research exploring the synergy between chemical and organic fertilizers remains scarce. In this context, the objective of this research was to evaluate the impact of the combination of chemical and organic fertilizers on the growth and yield of the MD-2 pineapple cultivar under two shade net conditions (installed 45 and 250 days after planting). The experiment was conducted in a split-plot design, with the main plot being the shade net conditions and the sub-plots the five fertilization treatments, which were applied 18 times via drip irrigation (control, 100% chemical fertilization, 50% reduced chemical fertilization, organic fertilization, and a combination of 50% chemical fertilization with organic fertilization). **The results showed that the early installation of shade netting 45 days after planting decreases the growth and yield of pineapple; thus, the use of shade netting at this age is not recommended.** Regarding **fertilization, the combination of 50% chemical fertilization with organic fertilization showed similar growth and yield values compared to 100% conventional chemical fertilization under both shade net conditions**. Furthermore, this combination presented similar nitrate and potassium values in the plant and did not negatively affect malic acid content. Therefore, the use of organic fertilizers in pineapple cultivation is a promising strategy to reduce the excessive use of chemical fertilizers, and it could also improve soil fertility.

13.5 Banana

Shade net cultivation improved plant growth," accelerated flowering and fruit ripening, and increased fruit size, weight, and yield" (Saboki & Jafari 2025) and "number of leaves, pseudostem circumference and pseudostem height were found to be higher under greenhouse conditions than those in open field cultivation" (Gubuk et al 2018). Subhasi et al (2016) surveyed 100 banana producers and found that "gross output in greenhouse banana production is approximately two-fold higher than open field production and it is determined 6547.50 TL $acres^{-1}$, and 3253.75 TL $acres^{-1}$, respectively".

Screen houses contain knitted or woven screens and air temperature and net radiation were similar between the two types, but mean air velocity was 18% higher and the specific humidity 8% lower than under the woven screen and flowering and fruit yield were the same but water use efficiency under the woven type, was better (Pirkner et al 2014)

Choudhury et al (2023) found poly net houses were most beneficial. Net covers resulted in higher temperatures, but lower relative humidity and soil records were higher moisture (in Turkey) (Altinkaya & Gubbuk 2020).

"'Williams', 'MA13' and 'CV 902' were more productive than 'Grand Nain' in greenhouse conditions" in Turkey (Gubuk et al 2020).

Nearly a third of bananas ('Grande Naine' and 'Gruesa') grown in the Canary Island are grown under cover. "The **FPE cover** (clear polythene cover) presented better optical and thermic characteristics, such as low UV transmission and high (>75%) photosynthetic ally active radiation (PAR), and greater durability compared with previous covers utilised in CI under similar environmental conditions. The characteristics of M20 and M16 (monofilament mesh)were found very similar, while MB (rafia mesh) reduced considerable PAR values (40-45%), which translated into an undesirable longer cycle length" (Cabrera et al 2012).

Authors, Title, Journal, Volume	Main country	Summary
Saboki E, Jafari A. 2025. Impact of shade net cultivation on banana yield and quality. Discov Plants. 2(1):248.	southern Sistan and Baluchestan Iran Dwarf Cavendish	This study, conducted from 2021 to 2023 in southern Sistan and Baluchestan, Iran, investigated the potential of shade net cultivation to mitigate environmental stress and enhance Dwarf Cavendish banana productivity. **A comparative treatment of shade net and open-field cultivation methods for Dwarf Cavendish bananas was conducted to examine the growth and yield of both mother plants and their first-generation ratoon crops. Shade net cultivation notably improved plant growth, accelerated flowering and fruit ripening, and increased fruit size, weight, and yield.** Specifically, the yields increased by 27.6 and 30.7% for the mother plants and first-generation ratoons, respectively. Shade nets also reduced heat and wind stress and eliminated fruit sunburn. These results demonstrate that net shade cultivation can enhance banana yield and quality under typical subtropical climatic conditions.
Pirkner M, Tanny J, Shapira O, Teitel M, Cohen S, Shahak Y, Israeli Y. 2014. The effect of screen type on crop micro-climate, reference evapotranspiration and yield of a screenhouse banana plantation. Scientia Horticulturae. 180:32–39.	Northern Israel	Most **banana screenhouses are currently equipped with transparent screens, with a nominal shading of 8–15%.** Two types of screens are widely used, **woven or knitted**….We have investigated four types of screens based on different shading levels (8%, 10% or 13%) and different screen textures (woven or knitted). A large commercial banana plantation in Northern Israel was covered with patches of the four different screen types,….The results showed that both the **net radiation and air temperature were similar under these two screens**. Nevertheless, under the knitted screen the horizontal **mean air velocity was 18% higher and the specific humidity 8% lower than under the woven screen.** Leaf lamina tearing (typical wind damage) and estimated reference evapotranspiration were higher under the knitted screen; the latter mainly during the fall–winter season. However, the horticultural measures of **flowering and fruit yield characteristics were the same under all four screen types,** with results typical of screenhouse banana plantations in this region. Hence, the results suggest a potential increase in **water use efficiency under the woven** as compared to the knitted screen.
Choudhury S, Islam N, Shaon AR, Hossain J. 2023. Evaluation of different high tunnel protection methods for quality banana production in Bangladesh. Journal of Plant Sciences and Crop Protection. 6(1):102.	Bangladesh	High tunnels can provide several benefits to horticultural crops, including…. Present study was carried out to assess the effect of **different type of high tunnels on banana growth, yield, and fruit quality characteristics**. **Net houses, poly net houses, UV poly shed houses, and open field (control)** conditions are among the experimental treatments. The results revealed that the plants produced in the poly net house condition had maximum pseudo stem height (171.00cm), stem girth (68.66 cm), chlorophyll content (57.63), number of fruits (140), number of hands (9.66), individual fruit weight (125.00) and pulp: peel ratio (3.35) of bananas as compared to the other treatments. Quality parameters like total soluble solid (21.78°Brix), ascorbic acid (10.24 mg/100g), total sugar (25.44%), and reducing sugar (15.75%) were higher in fruits grown in poly net house. The study revealed that the poly net house is the best growing environment for bananas in terms of growth, yield, and quality attributes.
Bahadur L, Anmol DS, Singh SK. 2020. A review on successful protected cultivation of banana (Musa). Plant arch. 20:1570–1573.	Punjab region of Pakistan	In Punjab, banana cultivation is restricted to certain area due to frost injury and adverse climatic conditions during winter seasons and the yield is adversely affected and most of the time whole crop remain damaged. **Prolonged prevalence of low temperature during winter prevents the emergence of inflorescence through the pseudostem top due to rosetting of inflorescence**. Under such conditions protected cultivation of banana has been advocated. Overall vegetative growth like plant height, number of leaves and stem circumference have been reported better under protected conditions which might be due to crop favorable environmental conditions like adequate relative humidity, lower maximum temperature, lower light irradiance, lower evapotranspiration, higher maximum temperature and lower wind speed usually prevailed under net house protection.

Authors, Title, Journal, Volume	Main country	Summary
Subași OS, Secer A, Yașar B, EmeksIz F, Uysal O. 2016. Production cost and profitability of banana in Turkey. Mediterranean Agricultural Sciences. 29(2):73–78.	Mersin and Antalya , Turkey	This study is carried out in Mersin and Antalya provinces where banana intensively growing in Turkey. It is aimed to reveal production costs and profitability of banana in 2010. In this research, data gathered from **100 banana producers by questionnaires in 2 provinces**. It is determined that average production size is 15.53 acres, and banana production size is 8.48 acres which have share 54.82% in total production area. In the study area**, yield per acres determined 5238 kg in greenhouses and 2819 kg in open field**. **Gross output in greenhouse banana production is approximately two-fold higher than open field production and it is determined 6547.50 TL acres^{-1}, and 3253.75 TL acres^{-1}, respectively**. There are significant differences in terms of absolute profit and relative profit. Absolute profit in greenhouses and open field 2263.33 TL, 202.44 TL, and relative profit are calculated 152.83% and 106.63%, respectively.
Gubbuk H, Bakry F, Guven D, Taskiran O, Mathieu Y. 2020. Agronomic evaluation of new Cavendish banana cultivars for growing in different protected cultivation areas in Turkey. In: VanDenBergh I, Gubbuk H, Lehrer K, editors. Vol. 1272. [place unknown]; p. 27–32. https://doi.org/10.17660/ActaHortic.2020.1272.4	Turkey 'Williams', 'MA13', 'CV 902', 'Grand Nain'	'Williams' had on average the highest pseudostem circumference and height but also the highest bunch weight (50.27 kg). The bunch weight of ' MA13' and 'CV 902' was 47.65 and 42.66 kg, respectively, whereas the control ('Grand Nain') and 'Jobo' had a lower bunch weight. **'Williams', 'MA13' and 'CV 902' were more productive than 'Grand Nain' in greenhouse conditions**. In addition, no somaclonal variations were observed in any of the three experimental locations. These results suggest that the new selections have potential to provide higher yields in Turkey in protected cultivation, providing higher returns to growers, compared to local selections.
Pathak PK, Mitra SK. 2014. Assessment of Low Cost Perforated Polythene Cover as Non-Chemical Approach to Control Scarring Beetle and Quality Banana Production. In: Chomchalow N, Chantrasmi V, Sukhvibul N, editors. Vol. 1024. [place unknown]; p. 283–285.	West Bengal, India	Investigation was carried out in North 24 Pargana district of West Bengal, India to standardize the suitability of perforated polythene cover against scarring beetle of 'Grande Naine' banana. Polythene cover of different perforations (15 and 20%) was tried. The results revealed that bunch covering with polythene completely controlled the incidence of scarring beetle irrespective of the percentage of perforation. The results also showed that bunches covered with 20% perforated polythene bag significantly increased yield (44.23 t ha(-1)), fruit weight (111.29 g),bunch weight (15.91 kg) and benefit cost ratio (2.64). Bunches covered with 15% perforated polythene showed the maximum TSS: acid ratio of fruit (67.77) compared with 41.07 in control. An increase in temperature and relative humidity and decrease in light transmission was recorded inside the polythene cover. It is suggested to use bunch covering with 20% perforation polythene to control scarring beetle infestation and quality banana production.
Gubbuk H, Gunes E, Guven D. 2018. Comparison of open-field and protected banana cultivation for some morphological and yield features under subtropical conditions. In: VanDenBergh I, Risede J, Johnson V, editors. Vol. 1196. [place unknown]; p. 173–177.	Turkey	Banana production in Turkey is located well beyond subtropical banana production zones. However, banana is the only tropical fruit produced commercially in both open-field and greenhouse conditions. Recently the area under greenhouse production has started to expand, partly because production costs are covered by harvesting fruit in same year as planting. This popularity has also led to improved greenhouse technology being used for banana production. In **this research, the effects of open-field and greenhouse production systems on some of the morphological (number of leaves, pseudostem circumference, pseudostem height, bunch stalk circumference), phenological features (fruit maturation length), and yield components (number of hands, number of fingers per bunch) were determined.** In addition, the effects of production systems on physicochemical features of banana were investigated. Similar cultural measures were applied in both cultivation systems except for bunch covering. Among the morphological features, **number of leaves, pseudostem circumference and pseudostem height were found to be higher under greenhouse conditions than those in open field cultivation**. Fruit maturation length was shorter in greenhouse-produced banana by about 25 days, compared to that observed in open-field cultivation. Yield components were also found to be better in greenhouse-produced banana as compared with open field production, with average bunch weight of 40 kg in greenhouse-produced banana versus 27 kg in banana produced under open-field conditions. Physical fruit parameters were found to be better for greenhouse-produced fruits compared to those observed in open-produced fruits while soluble solids contents did not differ in both production conditions. The results of this research clearly showed that some yield and fruit quality components were found to be superior when produced in a greenhouse production system compared to that observed in open field production system and no wind damage, naturally, was observed in greenhouse.

Authors, Title, Journal, Volume	Main country	Summary
Altinkaya L, Gubbuk H. 2020. Comparison of open-field and net-covered banana production in subtropical conditions. In: VanDenBergh I, Gubbuk H, Lehrer K, editors. Vol. 1272. [place unknown]; p. 39–43.	Gazipasa province, Antalya, Turkey	Plastic sheeting is the most common covering material used for protected cultivation, but it intercepts rain-water. **The objective of this study was to evaluate banana production in both open-field and net-covered systems, where special plastic netting provides a viable alternative to standard plastic sheeting**. The experiment was conducted in Gazipasa province, Antalya during 2015 and 2016. The cultivar 'Dwarf Cavendish' was used as planting material. Galvanized iron frames and insect-proof mesh were used for construction and covering material, respectively. During the growing period, climate data (minimum, average and maximum temperature, relative humidity and soil moisture), leaf chlorophyll content, light intensity values (photometric, quantum and pyranometric), wind damage and yield were evaluated in both the open-field and net-covered systems. Results showed that **while temperature values were higher under the net-covered system, the relative humidity was lower in some months compared to open-field conditions. On the contrary, soil moisture records were higher in the net-covered system than those recorded for open fields**. Chlorophyll content was higher in the net-covered system, while the means of light intensity values were detected to be lower in the net system compared to that measured in the open field. Very little wind damage was observed in the net-covered system, compared with significant wind damage in the open field. Yield was higher in the net-covered system with 44.9 vs. 40.2 t ha-1 recorded in the open field.
Cabrera Cabrera J, Galan Sauco V. 2012. Evaluation of Different Covers Used in Greenhouse Cultivation of Cavendish Bananas (Musa acuminata Colla AAA) in the Canary Islands. In: Wuensche J, Albrigo L, Gubbuk H, Reinhardt D, Staver C, VanDenBergh I, editors. Vol. 928. [place unknown]; p. 31–39.	Canary Islands, 'Grande Naine' and 'Gruesa'	From the 9,113 ha devoted to banana cultivation in the Canary Islands (CI) in 2008**, 3,160 were under protected cultivation**. Several types of covers with different thermic and optical characteristics are utilised in banana cultivation. The influence of 4 different covers [1) FPE, a clear polyethylene thermic cover of 860 gauges, a three-layer film, that sandwiches an expanded polymer layer with gas micro bubbles between two plain polymer layers, marketed commercially as Celloclim 4S (R), 2) M20, a monofilament mesh (20x10 threads cm(-2)), 3) M16, another monofilament mesh 16x10 threads cm(-2) and 4) MB, a raffia mesh, marketed by Polysack (R) as white net 50%] on growth, development and yield of the two most widely grown cultivars in CI 'Grande Naine' and 'Gruesa' were evaluated in field trials. The optical properties of these covers were also studied. **The FPE cover presented better optical and thermic characteristics, such as low UV transmission and high (>75%) photosynthetic ally active radiation (PAR), and greater durability compared with previous covers utilised in CI under similar environmental conditions. The characteristics of M20 and M16 were found very similar, while MB reduced considerable PAR values (40-45%), which translated into an undesirable longer cycle length.**
Arunachalam V. 2022. Advances in Banana (Musa acuminata, M. balbisiana Colla) Production Technologies for the Coastal Ecosystems. In: Transforming Coastal Zone for Sustainable Food and Income Security [Internet]. [place unknown]: Springer, Cham; [accessed 2025 Aug 27]; p. 181–187.	India *Musa acuminata, M. balbisiana* Colla)	Banana (*Musa acuminata, M. balbisiana* Colla) forms a major component in coastal agroecosystems in tropical and subtropical zones. The major banana-growing countries and territories are analysed with respect to the area in the coastal zones. This chapter reviews the latest research work across the globe on banana in coastal agroecosystems. The constraints and opportunities for banana production in coastal ecosystems with reference to suitable cultivars, agroforestry systems, **poly-house cultivation, biotic and abiotic stress factors are described in brief.** Grand Nain and other Cavendish cultivars are found suitable at the coastal locations. Dwarf banana cultivars are found to perform well in agroforestry systems. The chapter also highlights the strategies for handling various challenges in the banana crop. **Research on the protected cultivation of banana in the subtropical coastal zone is emphasized to augment banana production to meet the local requirements**. Wind, salinity, potassium deficiency and shade are the major constraints in the cultivation of banana in coastal ecology. The impact of salinity stress in banana cultivation and the reduction in fruit yield due to salinity is discussed. A new rapid method for measuring foliar sodium, potassium contents is highlighted. The climate change vulnerability is also experienced in the banana crop which can shift the banana growing areas. The predicted increase in air temperature in future and possible impacts on banana crop and shifts in the suitable area under cultivation, simple strategies to mitigate the impacts are discussed which **include high-density planting to provide mutual shade, increasing the banana area under agroforestry systems especially under coconut, arecanut, coffee, cocoa and Inga tree crops**.

13.6 Blueberry

“According to fruit yield and quality, all three cultivars ('Duke', 'Aurora', and 'Brigitta') benefit from the hail net over the high tunnel, while 'Duke' and 'Brigitta' also benefit in particular from the hail net combined with growth in pots” (Smrke et al 2021). Yield and production improved for *Vaccinium virgatum* Ait (li & Bi 2013).

Anti hail covers are important for blueberries – “The 'Emerald' cultivar demonstrated an overall positive response to the net application, with measured traits either remaining unaltered or showing improvement in comparison to field growth. The 'Snowchaser' cultivar displayed enhanced firmness when grown under cover, which is a favorable outcome” (Smrke et al 2023; Morales et al).

Covers tested by Perriera et al (20230) included “standard polyethylene was used from bud break to harvest, a white reflective net from fruit set to harvest, and a silver reflective net throughout the year”.

El-Horri et al (2025) showed that cover film colour can have an effect too “Red film in enhancing plant biomass and Red and Blue films in improving fruit yield and maintaining nutraceutical postharvest quality in blueberry fruit.”

Authors, Title, Journal, Volume	Main country	Summary
O’Callaghan L. New Zealand blueberry production on the rise. Fruitnet	New Zealand	Northland blueberry growers have reported a strong season with production surging nearly 60 per cent to 300 tonnes this season. Low chill cultivars
Tartanus M, Malusa E, Sas D, Labanowska B. 2018. Integrated control of Lecanium scale (Parthenolecanium sp.) on highbush blueberry in open field and protected crops. Journal of Plant Protection Research. 58(3):297–303.	Poland	The increased cultivation of highbush blueberry in Poland has been paralleled with enhanced damage to this crop by different pests and diseases, including soft scales. We have carried out trials to assess methods for controlling soft scales of the genus Parthenolecanium in highbush blueberry grown in open fields or under a plastic tunnel, with an approach based on integrated pest management (IPM) principles. The reduction of Lecanium scale population using alternative products, with mechanical mechanisms of action, was similar to that achieved with treatments of different formulations of neonicotinyl-based pesticides; sometimes they were even more effective on protected crops. Control programs on plantations with a large population of Lecanium scales based on the application of these alternative products in spring and at harvest time and chemical compounds in autumn resulted in a very high efficacy and are considered the most suitable strategies to assure yields without residues and a reduced impact on the environment.
Smrke T, Veberic R, Hudina M, Zitko V, Ferlan M, Jakopic J. 2021. Fruit Quality and Yield of Three Highbush Blueberry (Vaccinium corymbosum L.) Cultivars Grown in Two Planting Systems under Different Protected Environments. HORTICULTURAE. 7(12).	'Duke', 'Aurora', and 'Brigitta'	Here, 'Duke', 'Aurora', and 'Brigitta' blueberry cultivars were planted under the protective environments of a **high tunnel and black hail net, each using ridge and pot planting systems**. The high tunnel increased the maximal air temperature on average by 7.2 degrees C compared to the hail net. For all three cultivars, harvest began 6 to 18 days earlier under the high tunnel than under the hail net; however, lower yields and individual phenolics contents were obtained for the fruit. In 'Aurora' and 'Brigitta', environmental conditions under the high tunnel also reduced plant volume and fruit sugar/organic acid ratio. Growing blueberry plants in 60 L pots had no negative effects on plant volume and fruit ripening time, yield, firmness, color, and chemical composition….. Here, we can conclude that optimal highbush blueberry production of 'Duke', 'Aurora', and 'Brigitta' under the climate conditions of the study provides earlier ripening times under the high tunnel. However, **according to fruit yield and quality, all three cultivars benefit from the hail net over the high tunnel, while 'Duke' and 'Brigitta' also benefit in particular from the hail net combined with growth in pots.**

Authors, Title, Journal, Volume	Main country	Summary
Smrke T, Vodnik D, Veberic R, Sircelj H, Lenarcic D, Jakopic J. 2023. Growing highbush blueberries (Vaccinium corymbosum L.) in a protected environment-How much does a microclimate matter? SOUTH AFRICAN JOURNAL OF BOTANY. 160:260–272.	South Africa, Duke	Significance was also observed between high-tunnel and hail-net conditions. Individual and total phenolic concentrations in the leaves did not significantly change during the daytime, but significantly higher values were detected under the hail net. Our results indicate that, regarding photosynthetic pigments and phenolics, modified microclimatic conditions, i.e**. elevated air temperature and reduced light quantity under different types of protected environments strongly affect the physiological status of highbush blueberry 'Duke' plants and the chemical composition of leaves.**
Morales L, Gollan A, Bello F, Rivadeneira MF, Vazquez D, Tripodi KEJ. 2025. Anti-hail covers causes changes in the quality and biochemistry in two blueberry (Vaccinium corymbosum L.) cultivars. TECHNOLOGY IN HORTICULTURE. 5.	NE Argentina 'Emerald' and 'Snowchaser'	Given the increased frequency of hailstorms that pose a threat to blueberry fruit and bushes, the utilization of anti-hail covers has become prevalent in Argentina's North-Eastern region. However, this practice may alter the orchard microclimate, potentially affecting fruit quality. The impact of these covers on the biochemical composition and agronomic attributes of two extensively cultivated blueberry cultivars, **'Emerald' and 'Snowchaser' was investigated**. The early phenological stages exhibited a delay of several days in fruit under cover, which could potentially postpone the onset of the commercialization period.…**The 'Emerald' cultivar demonstrated an overall positive response to the net application, with measured traits either remaining unaltered or showing improvement in comparison to field growth. The 'Snowchaser' cultivar displayed enhanced firmness when grown under cover, which is a favorable outcome**. In this variety, the increase in the levels of raffinose, a stress-related sugar, may indicate a divergence from 'Emerald' with regard to stress sensing. Both varieties demonstrated resistance to decay in the postharvest period, with an increased SS/TA ratio and firmness resulting from the use of covers. Despite some varietal differences, this study supports the efficacy of anti-hail covers in safeguarding blueberries without compromising overall crop health and fruit quality. This outcome is relevant since it validates this practice for two blueberry varieties of commercial importance, thereby reducing the potential loss of fruit and bush damage.
Li T, Bi G. 2019. Container Production of Southern Highbush Blueberries Using High Tunnels. HORTSCIENCE. 54(2):267–274.	Mississippi state, rabbiteye blueberries (Vaccinium virgatum Ait.),	Blueberry production in Mississippi (MS) is mainly rabbiteye blueberries (Vaccinium virgatum Ait.), which ripen in late May to June. Growing early-ripening southern highbush blueberries (SHBs) (Vaccinium corymbosum L.) presents an opportunity for early fruit production and increased market price for locally produced blueberries, yet faces the challenge of spring frost damage. One-year-old liners of 10 SHB cultivars were transplanted into 15-gallon plastic containers and placed in a high tunnel in Apr. 2015. Blueberry plants were fertilized with either a conventional or an organic fertilizer at comparable rates. Plants were evaluated for berry yield, timing of first berry harvest and peak harvest, single berry weight, and soluble solid content during the 2016 and 2017 growing seasons. The high tunnel increased monthly maximum temperature by 3.2 to 10.4 degrees C, monthly average temperature by 0.7 to 4.2 degrees C, and minimum monthly temperature for up to 3.0 degrees C compared with outdoor environment. ….. **Total berry yield per plant ranged from 921 g to 2136 g in 2016 and from 1222 g to 2480 g in 2017. …... Container production of SHB cultivars in a high tunnel produced total berry yield equivalent to 6458 kg/ha in 2016 to 7500 kg/ha in 2017, advanced blueberry production by 4 to 5 weeks**, and therefore may serve as a potential production system for early fruiting blueberries in Mississippi.
A. Duarte-Sierra, D.K. Jha. 2023. Effectiveness of plastic pallet covers to shift the marketing period of fresh wild blueberries. Acta Horticulturae.(No. 1364):359–368.	Quebec, Canada	Wild blueberry (Vaccinium angustifolium Ait.) is one of the main crops in the horticultural sector in Quebec (QC) as well as in other Canadian provinces. This study compared the efficiency of preserving wild blueberries for 25 d using plastic proprietary pallet covers versus uncovered fruit. The blueberries were harvested from farms near Normandin, QC, and precooled with forced air at 6°C in a commercial packing house located near the fields. The fruit were then distributed on pallets of approximately 50 kg of fruit each. Five factors were used on the experimental design: 1) pallet shrouds (no cover, polyethylene, PrimePro and LifeSpan); 2) temperature (0 and 4°C); 3) type of fruit (unsorted or sorted); 4) CO_2 injection (0, 10, 20%); and 5) the addition of a SO_2-generating patch (not preset, or present). ….. Response variables included weight loss (%), external color (hue°), size (mm), and total soluble solids (TSS) content of fruit. Uncovered pallets lost weight significantly ($p=0.0033$) compared to the covered pallets stored at either 0 or 4°C. Regardless of the temperature, berries showed a more intense blue-purple color at high CO_2 concentrations compared to non-exposed berries ($p=0.02914$). Furthermore, the size was not affected by either temperature or type of cover. Nonetheless, CO_2 concentration was significantly ($p=0.0406$) different among treatments. Finally, the absence of a plastic cover significantly elevated ($p=0.0288$) the TSS content of the fruit. **Overall, the use of the pallet shrouds improved fruit preservation and quality of berries.**

Authors, Title, Journal, Volume	Main country	Summary
Ogden, A.B. and van Iersel, M.W., 2009. Southern highbush blueberry production in high tunnels: Temperatures, development, yield, and fruit quality during the establishment years. HortScience, 44(7), pp.1850-1856.	Georgia “Emerald” and “Jewel”	Growers interested in producing early, high-quality, southern high bush blueberries (*Vaccinium corymbosum L.*) in high tunnels face a lack of information regarding appropriate cultural methods. We sought to elucidate the optimal date to close high tunnels to hasten vegetative and reproductive growth of organic southern high bush blueberry cultivars Emerald and Jewel grown in Georgia. The three dates selected to close the high tunnels were 15 Dec., 2 Jan., and 16 Jan. High tunnels raised soil and daytime air temperatures during winter months, but the tunnels did not retain heat at night and did not provide freeze protection without the use of propane heaters. The high tunnel microclimate advanced both vegetative and reproductive growth compared with outdoor plants. Averaged over the 2-year study, the 15 Dec. tunnel closure advanced flower initiation by 38 days for ‘Emerald’ and 39 days for ‘Jewel’ compared with outdoor control plants. Synchronization of flowering of the two cultivars was poor in 2007 when ‘Emerald’ flowered much earlier than ‘Jewel’ and much better in 2008. In 2007, flower and fruit development of ‘Jewel’ were faster than that of ‘Emerald’ with Jewel going from the appearance of individual flowers to ripe fruit in 80 days as compared with 105days for ‘Emerald’. Total yield was strongly correlated with fruit set (r= 0.94). ‘Emerald’ fruit contained higher concentrations of soluble solids and anthocyanins than ‘Jewel’ fruit, and anthocyanin concentrations increased throughout the harvest period. No fruit matured in 2008 as a result of freeze damage. The biggest obstacle for high tunnel production of southern highbush blueberries appears to be preventing freeze damage and assuring pollination. Cost-effective freeze protection and ways to promote good fruit set will be critical to successful production of early southern highbush blueberries in high tunnels.
Smrke T, Veberic R, Hudina M, Jakopic J. 2022. Pot and Ridge Production of Three Highbush Blueberry (Vaccinium corymbosum L.) Cultivars under High Tunnels. AGRICULTURE-BASEL. 12(4).	University of Ljubljana (Slovenia; latitude, 46°05′ N; longitude, 14°47′ E; altitude, 295 m a.s.l.) 'Duke', 'Aurora', and 'Brigitta',	In recent years, new approaches to intensive blueberry (Vaccinium corymbosum L.) production have become necessary, in terms of protected environments and planting systems. These are designed to avoid numerous production difficulties, such as market saturation, damage from hailstorms, bird attacks, and spring frosts, and specific soil property requirements. Use of high tunnels and planting in a custom substrate (e.g., pots, along ridges) have gained interest among growers in recent years. As in our previous study, we determined the performance of three blueberry cultivars, 'Duke', 'Aurora', and 'Brigitta', when planted in pots and along a ridge under a high tunnel. Substrate water content was maintained at the same level for the pots and the ridge, although the substrate temperature fluctuations were greater for pots. Plant growth in pots was significantly lower for 'Duke' and 'Aurora' compared to the ridge. Additionally, for 'Aurora', the fruit yield was significantly lower for pots (103.4 g/plant), compared to the ridge (315.2 g/plant), although the opposite was seen for 'Brigitta' (122.4 vs. 93.5 g/plant, respectively). Individual sugar and organic acid contents mostly coincided with total contents, with lower total sugars for 'Duke' and higher total organic acids for 'Aurora' and 'Brigitta' for pots. For 'Duke' and 'Brigitta' fruit, the contents of some individual phenolics showed significant differences between treatments for phenolic acids and flavanols. **These data show that growth in pots can be a useful planting method for the blueberry cultivars 'Duke' and 'Brigitta', and high yields and good fruit quality can be attained by following correct technological measures.**
Pereira M, Mota M, Oliveira PB. 2023. Extending blueberry production season with different covering materials. Percival D, Polashock J, Retamales J, editors. Acta Horticulturae.(1357):69–78.	Grândola (Alentejo) Southwest Portugal	To extend the blueberry production season, several types of tunnel covers were tested in Grândola (Alentejo), standard polyethylene to anticipate production and two different nets to delay production. **Standard polyethylene was used from bud break to harvest, a white reflective net from fruit set to harvest, and a silver reflective net throughout the year**. The control group had no tunnel cover. These different covers were applied to five cultivars, ‘Alix Blue’, ‘Gupton’, ‘Star’, ‘Legacy’ and ‘Sky Blue’. In 5 plants of each cultivar and cover, phenological stages using an adapted BBCH scale, total number of fruits and total fruit weight plant[1], average fruit weight, °Brix, average fruit dry matter and new shoot growth were evaluated and radiation under the covers (PAR, PFD and the fraction of PAR in total light) was measured using a ceptometer and a spectroradiometer. Results obtained evidenced that average fruit weight and new shoot growth were not significantly affected by the tunnel cover and that all parameters were negatively affected by the permanent silver net, while the white net provided best results for total number (152 fruits) and total weight of fruit (363 g). The polyethylene cover increased mostly fruit dry matter (18.2%). Total PAR, PFD, and fraction of PAR in light was mostly reduced by the white net (51, 54% and less 1.3% points, respectively), but all the covers showed negative outcomes when compared to the control. Polyethylene was responsible for earlier flowering when compared to a white net (4 days), earlier fruit set (7 days), and an earlier start of fruit ripening (10 days). **An adequate combination of cultivars and covers (white net applied to ‘Sky Blue') may prolong harvest season up to two weeks.**

Authors, Title, Journal, Volume	Main country	Summary
El-Horri H, Bartolini S, Remorini D, Ceccanti C, Florio M, D'Asaro L, Jain G, Massai R, Landi M, Guidi L. 2025. Light down-conversion technology improves vegetative growth, berry production, and postharvest quality in tunnel-cultivated blueberry. Agronomy. 15(7).		This study examined three innovative 'light-converting films' that convert green light (-23%) into red light (+8%; Red film), ultraviolet light (-80%) into blue light (+9%; Blue film), and green light (-5.7%) into red light (+4%; Pink film) but also ultraviolet light (-76%) into blue light (+5.6%; Pink film). These films were used for growing blueberry plants under cover under controlled tunnel conditions (27.3 11.7°C, 51.9 21.6% RH)…… **The results suggest the importance of Red film in enhancing plant biomass and Red and Blue films in improving fruit yield and maintaining nutraceutical postharvest quality in blueberry fruit.**

13.7 Kiwifruit

Authors, Title, Journal, Volume	Main country	Summary
Shi C, Luo J, Wang X, Lu Z, Zhang J. Comparative study on protected cultivation and open cultivation of "Hongyang" kiwifruit.-All Databases [Internet]. [accessed 2025 Aug 25].	Jiangsu-Zhejiang-Shanghai region	In order to explore a suitable pattern of planting 'Hongyang' kiwifruit in Jiangsu-Zhejiang-Shanghai region and realize the mass production of kiwifruit, the **3-year-old 'Hongyang' kiwifruit** from the Chongming Standardization Production Demonstration Base of Fruit Trees was used as a test material, and in different cultivation conditions the effects of such environmental factors as temperature, humidity and light intensity on the kiwifruit's survival rate, growth quantity, disease resistance, and fruit yield and quality were comparatively analyzed. The results showed that the **diseased plant rate of bacterial canker was 0% in protected cultivation but 23.5% in open cultivation; Compared with open cultivation, the kiwifruit leaf disease incidence in protected cultivation decreased by 71.3%, and the rate of sun burn fruits in protected cultivation decreased by 86.8%.** Because protected cultivation improved the microenvironment of 'Hongyang' kiwifruit growth, the fruit yield and the weight per fruit increased by 126% and 19.1% respectively. The after-ripening fruits of protected cultivation were 18.2% in soluble solid content and 160 mg/100 g in vitamin C content, being respectively 3.4% and 25% higher than those of open cultivation, tasting very sweet and less sour and also effectively improving fruit peel brightness. From the above results it was concluded that protected cultivation could effectively improve the fruit yield and quality of 'Hongyang' kiwifruit.
Calderón-Orellana A, Silva DI, Bastías RM, Bambach N, Aburto F. 2021. Late-season plastic covering delays the occurrence of severe water stress and improves intrinsic water use efficiency and fruit quality in kiwifruit vines. Agricultural Water Management [Internet]. [accessed 2025 Aug 25] 249:106795.	San Nicolás, Chile	Kiwifruit is widely recognized as a fruit crop sensitive to water stress due to low stomatal regulation. Unfortunately, many of the most important kiwifruit producing areas have been affected by increasing water scarcity due to climate change. Protected cultivation may be used in kiwifruit vines not only to mitigate water stress and potential reductions in fruit quality but also to increase intrinsic water use efficiency. At **the beginning of fruit maturation, two environmental conditions (uncovered and covered with a transparent plastic covering) were assessed in mature kiwifruit plants (*Actinidia deliciosa* Chev. cv. Hayward) subjected to conventional and deficit irrigation regimes in San Nicolás, Chile, for two consecutive seasons**. The results showed that covered plants under deficit irrigation required twice the time to exhibit severe water stress levels (~−1.3 MPa) than plants under open-field conditions. Despite changes in solar radiation quantity and quality due to the transparent plastic covering, differences in rates of water stress occurrence between cover treatments in deficit-irrigated vines were not explained by differences in soil desiccation or stomatal conductance. **The delay in severe water stress onset led to considerable water savings and caused no reductions in either yield or fruit quality, which increased water productivity between 21% and 71%. Fruit from covered plants subjected to deficit irrigation exhibited higher firmness at greater maturity (>7.0 Brix).** The increase in water productivity in severely water-stressed kiwifruit vines, when using late-season plastic canopy cover, confirms that protected cultivation can be an excellent tool to reduce the impact of limited irrigation in many kiwifruit producing areas affected by water scarcity.
Vendrame N, Reyes F, Dichio B, Xiloyannis C, Pitacco A. 2023. Characterization of microclimate and turbulent fluxes at a Mediterranean kiwi orchard covered with hail-protection net. In: 2023 IEEE International Workshop on Metrology for Agriculture and Forestry (MetroAgriFor) [Internet]. [place unknown]; [accessed 2025 Aug 27]; p. 222–226.	Bernaldasouthern Italy).	Screens and covers are increasingly used to protect crops from pests and extreme meteorological events. Their use affects plant microclimate and physiological responses as well, but this is only partly understood, particularly when considering the interaction among the cover and the training system. This **study focuses on the microclimatic effects of the use of a hail protection net and an horizontal (pergola) kiwifruit canopy. The system splits the orchard environment in three distinct layers, determining a shaded understory, a space comprised between the canopy and the net, and the atmosphere above the net**. To accent the effects, we considered a high-water demanding crop – kiwifruit, in an environment characterized by high evaporative demand (Bernalda, southern Italy).Three full eddy covariance and radiative balance equipment were used to assess fluxes (carbon dioxide, water vapor, and sensible heat) in the three layers and monitor meteorological variables (air temperature and relative humidity, wind, upward and downward short and long wave radiation, carbon dioxide and water vapor concentrations). Data from a typical clear-sky summer day are considered in this paper. While the net strongly reduced wind speed, it had a modest impact on all other variables. Conversely, the tick canopy layer had a major impact on all variables, determining a highly shaded, cooler and more humid understory, with very light wind. **Nevertheless, the combination of high relative humidity and presence of the net was able to reduce the net loss of longwave radiation from the canopy during night, mitigating its cooling under these conditions**. The reduction in wind speed and the increase in incoming longwave radiation around the crop, observed at night time, indicate potential valuable mechanisms that may be exploited to decrease water needs and prevent late frosts in the context of climate change, where extreme climatic events are more frequent and crop water requirements continue to increase.

13.8 Turmeric and Ginger

Shannon et al (2019) found that shade increased turmeric "plant height, leaf size, and fresh weight of rhizomes, but an apparent increase in rhizome dry weight was not significant. Shade decreased curcumin concentration and yield in mother rhizomes but had little effect on curcumin concentration in lateral rhizomes. An apparent increase in curcumin yield in lateral rhizomes with shade was not significant. Significant differences among varieties were observed for rhizome yield and curcumin concentration and yield."

Silaru et al (2024) found that for turmeric, "Greenhouse condition was found to be the best environment followed by field condition for fresh rhizome yield and essential oil content, whereas field condition was best for dry recovery, oleoresin and curcuminoids content".

For ginger, ZihFeng et al (2000) found that "compared with the controls, ginger cultivated in the tunnel germinated earlier, had higher growth rates, and produced higher dry matter yield. Yields were highest in the tunnel with plastic mulching".

Authors, Title, Journal, Volume	Main country	Summary
Silaru R, Duraisamy P, Kotha Madduri Y, Sounderarajan A, Veeraraghavan S, Kuntagodu Subraya K. 2024. Deciphering the genotypic superiority of turmeric (*Curcuma longa* L.) for yield and quality traits under three contrasting production systems. Journal of Applied Research on Medicinal and Aromatic Plants [Internet]. [accessed 2025 Aug 27] 43:100592.		Turmeric (Curcuma longa L.) is a high-value spice and medicinal crop in the family Zingiberaceae. Growth, yield, and quality are influenced by geographical factors, production conditions, and climatic factors such as temperature, relative humidity, rainfall, and light. Breeding for controlled environments requires a focus on specific plant traits, like rapid growth, adaptability to low light conditions, and manipulation of plant size. Genotypes with maximum genetic plasticity are ideal for these conditions. The cultivation of turmeric must accelerate to meet demands for a increased yield and quality while minimizing environmental impact, achievable through controlled-environment production systems. Our study aims to identify superior turmeric genotypes for high yield and quality under controlled production systems, including vertical structures and greenhouse conditions. Results showed significant variation among 21 genotypes across three different production systems in terms of yield, dry recovery, oleoresin, essential oil, and curcuminoids. CIM Pitambar (185.76), Acc. 849 (176.50), Acc. 214 (149.50), and IISR Pragati (148.74) demonstrated superior fresh rhizome yield per clump under vertical structures. IISR Pragati performed well in both under greenhouse (959.08 g) and field condition (635.95 g). High recovery of cured turmeric was recorded in Acc. 14 (23.20 %) under vertical structures, Chhattisgarh Haldi 2 (25.60 %) under greenhouse and Uttar Rangini (23.14 %) under field conditions. Waigon Turmeric outperformed all other genotypes for oleoresin and essential oil contents and was found to be significantly higher across the production systems. **The curcuminoids varied significantly and ranged from 0.12 % to 6.65 % across three production systems. Waigon Turmeric (2.13 %) was found to be superior for vertical structures, IISR Pragati (3.62 %) for greenhouse and IISR Prathiba (6.18 %) for field conditions. Greenhouse condition was found to be the best environment followed by field condition for fresh rhizome yield and essential oil content, whereas field condition was best for dry recovery, oleoresin and curcuminoids content.** Our findings suggested that yield and quality are affected by the environments, and yield was found to be best in the greenhouse and quality traits performed best in field conditions.

Authors, Title, Journal, Volume	Main country	Summary
Flores S, Retana-Cordero M, Fisher PR, Freyre R, Gómez C. 2021. Effect of photoperiod, propagative material, and production period on greenhouse-grown ginger and turmeric plants [Internet]. [accessed 2025 Aug 27].	USA	The objectives were to 1) compare growth and yield of different ginger (*Zingiber officinale*) and turmeric (*Curcuma longa*) propagules grown under two photoperiods (Expt. 1); and 2) **evaluate whether their growing season could be extended with night interruption lighting (NI) during the winter (Expt.** 2). In Expt. 1, propagules included 1) micropropagated tissue culture (TC) transplants, 2) second-generation rhizomes harvested from TC transplants (2GR), and 3) seed rhizomes (R). Plants received natural short days (SDs) or NI providing a total photon flux density (TPFD) of 1.3 $\mu mol \cdot m^{-2} \cdot s^{-1}$. Providing NI increased number of new tillers or leaves per plant, rhizome yield (i.e., rhizome fresh weight), and dry mass partitioning to rhizomes in both species. There was no clear trend on SPAD index in response to photoperiod or propagative material. Although TC-derived plants produced more tillers or leaves per plant, 2GR ginger and R turmeric produced a higher rhizome yield. In Expt. 2, seed rhizomes of ginger and turmeric were grown under five treatments with different photoperiods and/or production periods: 1) 20 weeks with NI (20NI), 2) 24 weeks with NI (24NI), 3) 28 weeks with NI (28NI), 4) 14 weeks with NI + 10 weeks under natural SDs (24NISD), and 5) 14 weeks with NI + 14 weeks under natural SDs (28NISD). NI provided a TPFD of 4.5 $\mu mol \cdot m^{-2} \cdot s^{-1}$. **Lengthening the production period and providing NI increased rhizome yield and crude fiber** content in both species. SPAD index decreased when plants were exposed to natural SDs at the end of the production period (NISD treatments). Results demonstrate the potential to overcome winter dormancy of ginger and turmeric plants with NI, enabling higher rhizome yield under natural SDs.
Cui ZhiFeng CZ, Ai XiZhen AX, Zhao YuZhu (et al.) ZY (et al.). 2000. Yield effect of ginger in plastic house. China Vegetables.(No. 3):14–16.	Plastic tunnels	The effect of growing ginger in a plastic tunnel with or without plastic film mulch was examined**. Findings indicated that compared with the controls, ginger cultivated in the tunnel germinated earlier, had higher growth rates, and produced higher dry matter yield. Yields were highest in the tunnel with plastic mulching**.
Shaikh AA, Kulkarni KV, Bagade SV. 2017. Effect of growing situations on ginger (Zingiber officinale Rosc.) production. Trends in Biosciences. 10(14):2531–2533.	Shadenet vs poly	Growing of ginger under **shadenet situation favourably influenced all the growth contributing characters viz. plant height, number of functional leaves plant-1 and the leaf area (dm2) plant-1 at all the** growth stages as compared to polyhouse and open situations. All the yield contributing characters viz., fresh and dry weight of rhizome plant-1 (g) were also favorably influenced with growing of ginger under shadenet condition as compared to polyhouse and open condition.
Shannon DA, van Santen E, Salmasi SZ, Murray TJ, Duong LT, Greenfield JT, Gonzales T, Foshee W. 2019. Shade, establishment method, and varietal effects on rhizome yield and curcumin content in turmeric in Alabama. Crop Science [Internet]. [accessed 2025 Aug 27] 59(6):2701–2710.	Alabama USA	Growing interest in curcumin from turmeric (Curcuma longa L.) for medical and health purposes has led to interest in turmeric cultivation in the United States. The warm growing season in Alabama is short relative to tropical environments where the plant is normally grown, and research on cultural practices is lacking. **A split-split-plot experiment was performed in Alabama to assess the effects of shade (40% shade vs. no shade), establishment method (early establishment in greenhouse over heat vs. direct seeding), and variety on rhizome yield and curcumin content.** Canonical discriminant analysis revealed distinctive trends based on varietal differences, establishment methods, and presence or absence of shade. Extending the growing season by early establishment in the greenhouse increased rhizome and curcumin yield, as well as curcumin concentration in lateral rhizomes. **Shade increased plant height, leaf size, and fresh weight of rhizomes, but an apparent increase in rhizome dry weight was not significant. Shade decreased curcumin concentration and yield in mother rhizomes but had little effect on curcumin concentration in lateral rhizomes. An apparent increase in curcumin yield in lateral rhizomes with shade was not significant. Significant differences among varieties were observed for rhizome yield and curcumin concentration and yield.** Cultivation of turmeric in Alabama is feasible by extending the growing season and selection of short-season varieties high in curcumin.

13.9 Coffee

Authors, Title, Journal, Volume	Main country	Summary
Lin BB. 2007. Agroforestry management as an adaptive strategy against potential microclimate extremes in coffee agriculture. Agricultural and Forest Meteorology [Internet]. [accessed 2025 Aug 26] 144(1):85–94.	Soconusco region of Chiapas, Mexico.	Current climate change patterns may cause more extreme and variable climates in the future, threatening agricultural productivity in many areas of the world. Because many smallholder, rural farmers depend on subsistence, rainfed agriculture, priorities should be focused on coping mechanisms that protect these farmers from future vulnerabilities. This paper examines one possible adaptive strategy for coffee agriculture. A high (60–80%), medium (35–65%), and low (10–30%) shade coffee site were chosen in the Soconusco region of Chiapas, Mexico. Microclimate and soil moisture data were collected to examine the ability of shade tree cover in an agroforestry system to protect crop plants against extremes in microclimate and soil moisture fluctuation. **Site and site by time effects were analyzed using linear mixed models to compare mean differences of microclimate measurements (temperature, relative humidity, and solar radiation) by site as well as by time of the day.** Although there were not large differences in seasonal means for these factors, site by time effects show that temperature, humidity, and solar radiation fluctuations increase significantly as shade cover decreases. Soil data showed significantly larger fluctuations in soil moisture gain and loss in the low shade site respective of patterns of precipitation. **Overall, the amount of shade cover was directly related to the mitigation of variability in microclimate and soil moisture for the crop of interest. The use of agroforestry systems is an economically feasible way to protect crop plants from extremes in microclimate and soil moisture and should be considered a potential adaptive strategy for farmers in areas that will suffer from extremes in climate.**
Shannon DA, van Santen E, Salmasi SZ, Murray TJ, Duong LT, Greenfield JT, Gonzales T, Foshee W. 2019. Shade, Establishment Method, and Varietal Effects on Rhizome Yield and Curcumin Content in Turmeric in Alabama. Crop Science [Internet]. [accessed 2025 Aug 27] 59(6):2701-2710	Alabama USA	Growing interest in curcumin from turmeric (*Curcuma longa* L.) for medical and health purposes has led to interest in turmeric cultivation in the United States. The warm growing season in Alabama is short relative to tropical environments where the plant is normally grown, and research on cultural practices is lacking. **A split-split-plot experiment was performed in Alabama to assess the effects of shade (40% shade vs. no shade), establishment method (early establishment in greenhouse over heat vs. direct seeding), and variety on rhizome yield and curcumin content**. Canonical discriminant analysis revealed distinctive trends based on varietal differences, establishment methods, and presence or absence of shade. Extending the growing season by early establishment in the greenhouse increased rhizome and curcumin yield, as well as curcumin concentration in lateral rhizomes. **Shade increased plant height, leaf size, and fresh weight of rhizomes, but an apparent increase in rhizome dry weight was not significant. Shade decreased curcumin concentration and yield in mother rhizomes but had little effect on curcumin concentration in lateral rhizomes.** An apparent increase in curcumin yield in lateral rhizomes with shade was not significant. Significant differences among varieties were observed for rhizome yield and curcumin concentration and yield. Cultivation of turmeric in Alabama is feasible by extending the growing season and selection of short-season varieties high in curcumin.
Silaru R, Duraisamy P, Kotha Madduri Y, Sounderarajan A, Veeraraghavan S, Kuntagodu Subraya K. 2024. Deciphering the genotypic superiority of turmeric (*Curcuma longa* L.) for yield and quality traits under three contrasting production systems. Journal of Applied Research on Medicinal and Aromatic Plants [Internet]. [accessed 2025 Aug 27] 43:100592.	Kerala, India,	Turmeric (Curcuma longa L.) is a high-value spice and medicinal crop in the family Zingiberaceae. Growth, yield, and quality are influenced by geographical factors, production conditions, and climatic factors such as temperature, relative humidity, rainfall, and light. **Breeding for controlled environments requires a focus on specific plant traits, like rapid growth, adaptability to low light conditions, and manipulation of plant size.** Genotypes with maximum genetic plasticity are ideal for these conditions. The cultivation of turmeric must accelerate to meet demands for a increased yield and quality while minimizing environmental impact, achievable through controlled-environment production systems. Our study aims to identify superior turmeric genotypes for high yield and quality under controlled production systems, including vertical structures and greenhouse conditions. Results showed significant variation among 21 genotypes across three different production systems in terms of yield, dry recovery, oleoresin, essential oil, and curcuminoids. CIM Pitambar (185.76), Acc. 849 (176.50), Acc. 214 (149.50), and IISR Pragati (148.74) demonstrated superior fresh rhizome yield per clump under vertical structures. **IISR Pragati performed well in both under greenhouse (959.08 g) and field condition (635.95 g). High recovery of cured turmeric was recorded in Acc. 14 (23.20 %) under vertical structures, Chhattisgarh Haldi 2 (25.60 %) under greenhouse and Uttar Rangini (23.14 %) under field conditions. Waigon Turmeric outperformed all other genotypes for oleoresin and essential oil contents and was found to be significantly higher across the production systems.** The curcuminoids varied significantly and ranged from 0.12 % to 6.65 % across three production systems. Waigon Turmeric (2.13 %) was found to be superior for vertical structures, IISR Pragati (3.62 %) for greenhouse and IISR Prathiba (6.18 %) for field conditions. Greenhouse condition was found to be the best environment followed by field condition for fresh rhizome yield and essential oil content, whereas field condition was best for dry recovery, oleoresin and curcuminoids content. Our findings suggested that yield and quality are affected by the environments, and yield was found to be best in the greenhouse and quality traits performed best in field conditions.

13.10 Mandarin

Authors, Title, Journal, Volume	Main country	Summary
Roets NJR, Ngwamba IF, Tesfay SZ, Ngcobo MEK. 2020. The effect of a low-density white shade net on physiology, phenology and production of mandarin (*Citrus reticulata* ‘Nadorcott’). Acta Hortic	South Africa	A number of South African mandarin producers cover orchards with shade nets to protect their crop against occasional hail. However, **shade nets also affect the light environment and microclimate of the orchard covered. This subsequently affects the tree physiology, growth, production and fruit quality. The aim of this study was to determine the effect of a low-density, white shade on the physiology, vegetative growth and yield of 'Nadorcott' mandarin**. The **shade net did not have a marked effect on orchard air temperatures, but relative humidity was significantly increased** while photosynthetic active radiation (PAR) was significantly decreased. These changes in orchard light and humidity conditions had a significant effect on tree physiology. **Trees covered by the shade net had increased stomatal conductance and rates of transpiration and photosynthesis. V**egetative vigour was further increased by the shade net for both years. This was possibly as a result of shade avoidance responses that were triggered by the lower light levels under the shade net. **The effect of the shade net on yield was inconclusive** because 'Nadorcott' mandarin is an alternate bearer. The large differences in yield obtained between the two years as a result of alternate bearing gives insufficient information on the effect that the shade net might have on yield. Fruit size was also significantly increased under the shade net.

13.11 Vanilla

Authors, Title, Journal, Volume	Main country	Summary
We have achieved year-round flowering with the boost of the greenhouse system. 2025. [accessed 2025 Aug 27]. https://www.hortidaily.com/article/9755963/we-have-achieved-year-round-flowering-with-the-boost-of-the-greenhouse-system/	Ecuador *Vanilla odorata*, *Vanilla Karen-Christianae*, *Vanilla pompona, Vanilla cribbiana*	All year flowering using a greenhouse system – Morona Ecuador "We have achieved year-round flowering with the boost of the greenhouse system" growing *Vanilla odorata*, *Vanilla Karen-Christianae*, *Vanilla pompona, Vanilla cribbiana* **“While more than 70% of the flowers can be lost with the traditional system, in the greenhouse the percentage of usable blossom reaches 99%...** "Each plant can produce up to 800 grams per year. When green, the price is USD 35 per kilo, but if you go through the whole process of production, curing and drying, prices rise to very attractive levels: *odorata* can reach USD 350/kg and *tahitensis* USD 180-200/kg," they say.”

13.12 Mitigations for having under cover systems

Covering crops can protect against rain (Pechan et al 2023), drought and retaining soil moisture (Altinkaya & Gubbuk 2020) and nutrients (Belbase et al 2025), radiation (Cabrera et al 2021), rising ozone levels (Zhang et al 2025), pest control when banana bunches are covered with 20% perforated polythene (Pathak et al 2014). Yield improvements and shorter growth periods under certain cover conditions can be achieved too, as reported for various fruits above.

Authors, Title, Journal, Volume	Main country	Summary
Pathak PK, Mitra SK. 2014. Assessment of low cost perforated polythene cover as non-chemical approach to control scarring beetle and quality banana production. In: Chomchalow N, Chantrasmi V, Sukhvibul N, editors. International Symposium on Tropical and Subtropical Fruits. Vol. 1024. Leuven 1: Int Soc Horticultural Science; p. 283–285.	India Grande Naine	Investigation was carried out in North 24 Pargana district of West Bengal, India to standardize the suitability of perforated polythene cover against scarring beetle of 'Grande Naine' banana. **Polythene cover of different perforations (15 and 20%) was tried**. The results revealed that **bunch covering with polythene completely controlled the incidence of scarring beetle irrespective of the percentage of perforation.** The results also showed that **bunches covered with 20% perforated polythene bag significantly increased yield (44.23 t ha(-1)), fruit weight (111.29 g),bunch weight (15.91 kg) and benefit cost ratio (2.64**). Bunches covered with 15% perforated polythene showed the maximum TSS: acid ratio of fruit (67.77) compared with 41.07 in control. An increase in temperature and relative humidity and decrease in light transmission was recorded inside the polythene cover. It is suggested to use bunch covering with 20% perforation polythene to control scarring beetle infestation and quality banana production.
Zhang J, Huang Y, Tong X, Wu H, Ran H, Fan W, Li Y, Dong S, Zhou S, Liu J, et al. 2025. Unexpected benefits of agricultural greenhouses in mitigating ozone pollution on crop yields in China. Atmospheric Environment [Internet]. [accessed 2025 Aug 26] 360:121438.	China- ozone mitigation	Ozone (O_3) is a major photochemical pollutant that harms crops and reduces yields. While its impact on open-field crops is well-documented, research on O_3 levels in agricultural greenhouses is limited. This study provides the first real-time measurements of O_3 concentrations inside and outside a lettuce-growing tunnel greenhouse in Kunming, China, revealing an average indoor/outdoor (I/O) O_3 ratio of 0.55 ± 0.15. We assessed Accumulated Ozone exposure over a Threshold of 40 ppb (AOT40) and relative yield losses (RYLs) for lettuce as an example, estimating the benefits of greenhouse cultivation across China. In ten major greenhouse farming regions, outdoor O_3 levels consistently exceeded the AOT40 threshold, while indoor levels remained mostly below it. Over five lettuce growing seasons (1.5 months each) from March to October, with I/O ratios of 1.0, 0.70, 0.55, and 0.40, AOT40 values were 7.21 ± 2.71, 2.16 ± 1.15, 0.67 ± 0.46, and 0.03 ± 0.05 ppm h, respectively. Corresponding RYLs were −0.08 ± 0.03, −0.02 ± 0.01, −0.01 ± 0.00, and −0.00 ± 0.00. Greenhouses prevented a 6–8 % yield reduction by lowering internal O_3 levels. This mitigation translated into an economic benefit of 4.9–6.5 billion USD, equivalent to 103.2–147.6 USD per person for China's 55 million greenhouse farmers in 2019, or 3.4–4.6 % of annual greenhouse vegetable production benefits, assuming planting lettuce. This single-crop approximation introduced merely 8.3 % ± 0.7 % overestimation versus Monte Carlo simulations with 17-crop combinations (2–16 species). Our findings show that greenhouses significantly reduce O_3-induced crop damage and offer substantial economic advantages. **With rising O_3 levels and the rapid growth of facility agriculture globally, this study underscores the importance of adopting greenhouse cultivation practices.**

Authors, Title, Journal, Volume	Main country	Summary
Pechan PM, Bohle H, Obster F. 2023. Reducing vulnerability of fruit orchards to climate change. Agricultural Systems [Internet]. [accessed 2025 Aug 27] 210:103713.	Chile, Tunisia	Farmers are forced to undertake adaptive measures to protect their crops against climate change impacts. Fruit trees present farmers with unique adaptive challenges. In pursuit to expand the knowledge base on climate change effects on crops in underreported regions, we present herein data from Chile and Tunisia on the vulnerability of cherry and peach orchards to climate change and on possible measures to counter its impact. OBJECTIVES: We aimed to ascertain a) the extent to which fruit farming biophysical operations in Chile and Tunisia are vulnerable to climate change impacts, b) whether the vulnerability can be reduced through agronomic, technological or financial adaptive measures and, c) how to overcome challenges that may prevent implementation of these measures. METHODS: **The study is based on face-to-face interviews with 801 peach and cherry farmers in Tunisia and Chile and three focus meetings with farm representatives**. RESULTS AND CONCLUSIONS: Fruit farmers have used and **are planning to use a number of agricultural, technological, and financial tools to reduce the vulnerability of their crops to climate change. Agronomical measures are focused on planting varieties with higher drought and disease resistance as well as lower winter chill requirements. Technological measures focus on installing nets reflects farmer regional experiences with crop hail damage and rain at the fruit maturing stage.** Planned improvements in irrigation reflect anticipated future problems with water availability and drought. The decision not to implement adaptive measures is mainly linked to economic barriers. Specific actions are proposed to overcome these and other measure implementation barriers. SIGNIFICANCE: The self-reported **experiences of fruit farmers provide valuable insight into the effectiveness of various climate change adaptive measures, which often differ from scientific expectations or recommendations**. For example, farmers are not overly concerned about fulfilling winter chill requirements, they are also not well informed about all available climate change adaptive tools. In addition, many adaptive measures are not implemented due to administrative or financial barriers. To help address this, regionally-led cooperation be-tween farmers, policy makers, industry, and scientists is needed to identify and overcome these barriers, allowing for the successful implementation of appropriate adaptive measures.

<table>
<tr><th>Authors, Title, Journal, Volume</th><th>Main country</th><th>Summary</th></tr>
<tr><td>Renwick, A, Lyne, M, Rutherford, P, Guenther, M, McIntyre, T, Wreford, A. Future land use in New Zealand and how we fund it [Internet]. Lincoln: Lincoln University.</td><td></td><td>2 Projected changes in crop suitability under two emissions scenarios (low and very high)
P. 100 Low emissions scenarios vs High emissions
<table>
<tr><td>Kiwifruit</td><td>• Reductions in suitability are expected for many parts of the upper North Island and around East Cape.
• Northland is the most affected, but also some reduction in the Bay of Plenty.
• The Central and Lower North Island and the South Island see improvements in suitability.
• The majority of change is expected to occur by mid-century</td><td>• By mid-century changes are on par with the low GHG concentration pathway.
• By the end of the century:
– More places around the North Island (upper and coastal areas) see reduced suitability.
– The South Island and Central North Island see increases in suitability that are substantial in many locations.</td></tr>
<tr><td>Blueberry</td><td>• Most of the North Island is expected to have a slight reduction in suitability.
• The Central North Island and the South Island will see improved suitability for blueberry production.
• Suitability in Waikato and Bay of Plenty will remain high, as it is in many locations in both islands of the country. Thus footprints are unlikely to be significantly affected, with the possible exception of Northland where lower-chill varieties of blueberry would be required.
• Most changes in suitability will occur by mid-century.</td><td>• By mid-century, the changes to the suitability will be on a par with the low GHG concentration pathway.
• By late-century, there is a notable increase in area of land with highest suitability scores.
• This results from improvements in the Central North Island and the South Island (Canterbury, parts of Otago and Southland).
• There is, however, a further worsening for most of the North Island.
• The blueberry footprint could become more dispersed, especially in the South Island</td></tr>
</table>
p.101
<table>
<tr><td>Avocado</td><td>• A modest increase in suitability is expected for most of the country by mid century.
• Some marginal areas come into scope.
• Little further increase in suitability by the end of the century.
• Areas with the highest suitability for avocado will continue to be predominantly in the Northland region.
• Some change in land use from other crops to avocado could be expected in Northland.
• Overall, the areas of higher suitability will expand, particularly in Taranaki, Bay of Plenty, Hawke's Bay and Waikato regions</td><td>• A modest increase in suitability is expected by mid-century for most of the country.
• Some areas in Taranaki, Bay of Plenty, Hawke's Bay, Waikato, Wairarapa and Manawatu regions come into scope.
• Further improvements are expected to occur by late-century.
• Further and significant land use change to avocado could be expected as warming temperatures disadvantage crops requiring winter chill</td></tr>
</table></td></tr>
<tr><td>Kirkland, WT, Hadfield, SM, Forbes, RN, Orsman, WJ. 1980. Agricultural regional planning report No. 1 Horticultural development in Northland. Palmerston North: Ministry of Agriculture and Fisheries.</td><td></td><td>Impacts of increased horticultural production in Northland need to consider factors such as additional “handling, processing and storage facilities” p. 13.</td></tr>
</table>

13.13 Workforce impacts

In NZ, semi-automation on farms can attract and help retain workers (Lowe 2023).

Authors, Title, Journal, Volume	Summary
Lowe, RA. The impact of semi-automated tools and machines on the attraction and retention of the New Zealand fruit industry workforce [Masters] [Internet]. Hamilton: The University of Waikato; [accessed 2025 Aug 28].	Semi-automation is being implemented by agricultural sectors globally in a bid to reap the many benefits of the automated world and alleviate labour crises. There is a lack of data on the impact of semi-automation on the New Zealand fruit industry workforce, particularly regarding attraction and retention. This thesis addresses the gap by exploring both the impact of semi-automation on attraction and retention, and how it is perceived by the on-orchard workforce within the New Zealand fruit industry. The research questions for this study are (1) what is the impact of semi-automation on the attraction of New Zealand fruit industry on-orchard workforce? (2) what is the impact of semi-automation on the retention of the New Zealand fruit industry on-orchard workforce? (3) how does the New Zealand fruit industry on-orchard workforce perceive semi-automation? Purposive (non-probabilistic) sampling was used to select 20 participants from **5 stakeholder/employee groups across seven New Zealand fruit sectors.** Semi-structured interviews were conducted and analysed using the General Inductive Approach. Four major themes emerged: (1) attraction and retention to the fruit industry, (2) the presence of semi-automation, (3) the impact of semi-automation, and (4) perception toward semi-automation. **The findings show that where semi-automation is applied and supported, it positively impacts attraction and retention to the industry through a widened labour pool, improved health and safety, better working conditions and improved efficiency of tasks and information. This research provides a useful resource for Human Resource Management that captures current industry realities and recommendations for responding to the agricultural revolution.**

<table>
<tr><th>Authors, Title, Journal, Volume</th><th>Summary</th></tr>
<tr><td>Bell, K, Poehler, E, Song, Z, Barker, A. 2024. Workforce implications of large-scale land-use change in Aotearoa New Zealand [Internet]. [accessed 2025 Aug 28].</td><td>Many stakeholders across the research sector, central and local government, and Iwi Māori believe that diversifying land uses can help to achieve environmental and economic goals in Aotearoa New Zealand. This paper investigates how the workforce might constrain this process by developing a simulation model to examine the effect of land-use change on the labour market for regions in Aotearoa New Zealand. The model uses assumptions about workforce demand, population growth, the shortage reduction rate, and the labour supply elasticity to dynamically project changes in workforce size, wage rates, and workforce shortages in the food and fibre sector, at the regional scale. The ‘Business as usual’ scenario forecasts an average real wage growth of 12.7% and an average workforce expansion of 8.4% by the end of the simulation period in 2052. Additionally, it predicts an average peak regional workforce shortage of 8.3%. As a case study, we analyse the Northland region, simulating a regional push for horticulture developments beyond business-as-usual via investment in regional water storage projects. In our most expansive scenario, we simulate a real wage increase of 29.5%, a workforce increase of 43.2%, and a 14.9% peak shortage. In addition to the main scenario where the workforce increases due to higher wages, we analyse two alternative strategies to increase the workforce in response to this increased demand: growing the workforce via population growth and freeing up workers through converting pastoral land into forestry. Success for both strategies would require large deviations from status quo expectations. The results highlight that building a larger workforce will be a significant barrier to the ambition of labour-intensive land-use change, requiring a combination of strategies if land-use goals are to be met.

“absence of significant literature on understanding how the workforce presents a barrier to industry expansion” p 3

Table, p 4

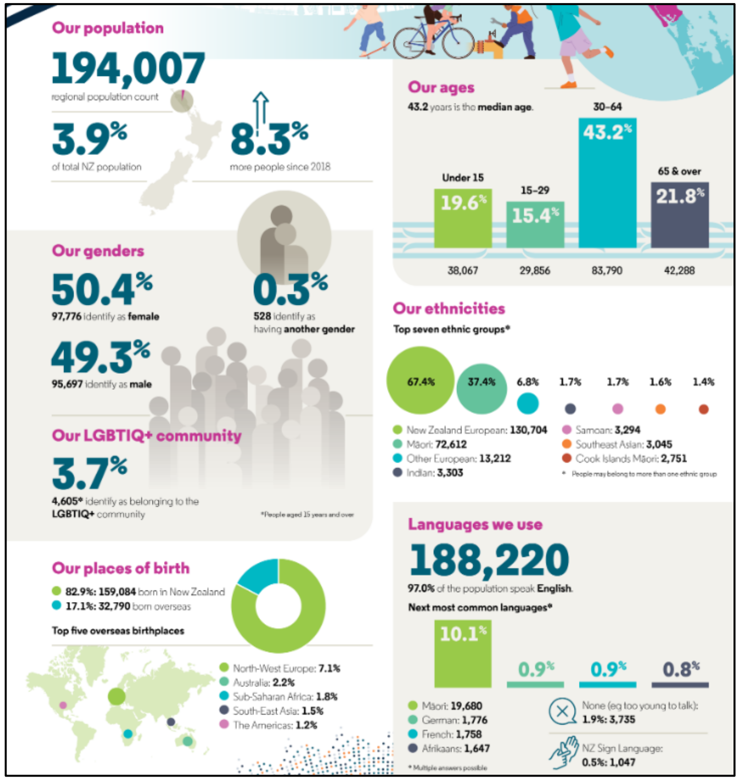
Table 1: Regional workforce forecasts results for BAU scenario from Song et al. (2023)
<table>
<tr><th>Region</th><th>Current workforce demand (2022)</th><th>Future projected demand (2032)</th><th>Percentage change</th></tr>
<tr><td>Northland</td><td>16,919</td><td>18,073</td><td>6.82%</td></tr>
<tr><td>Auckland</td><td>62,901</td><td>65,126</td><td>3.54%</td></tr>
</table>
Conclusion: In Northland
“Building a larger workforce will be a significant barrier to the ambition of labour-intensive land-use change, requiring significant wage increases, population growth, or land conversion to forestry to be feasible. While our analysis suggests that large-scale land use change is unlikely to be feasible, if it is to occur, it will require clear investment signals, including clear policy support for enabling conditions that the private market does not provide.” P.26</td></tr>
<tr><td>Kirkland, WT, Hadfield, SM, Forbes, RN, Orsman, WJ. 1980. Agricultural regional planning report No. 1 Horticultural development in Northland. Palmerston North: Ministry of Agriculture and Fisheries.</td><td></td></tr>
</table>

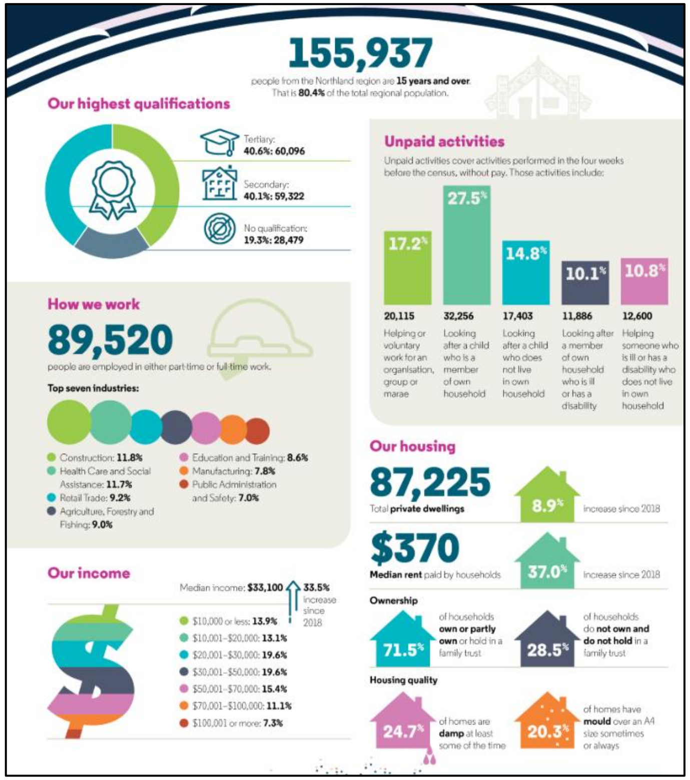
Authors, Title, Journal, Volume	Summary
Legun K, Burch KA, Klerkx L. 2023. Can a robot be an expert? The social meaning of skill and its expression through the prospect of autonomous AgTech. Agric Hum Values [Internet]. [accessed 2025 Aug 29] 40(2):501–517.	Automation on the farm: “While much work has described the value of intuition in supporting sound decision-making, and there is much work on the value of embodied knowledge in navigating decision-making in complex ecological systems, one significant aspect of these performances of knowledge are that the attribution of responsibility is very clear. As our research participants noted their desire for the accurate reporting of data from sensors, or greater accuracy in the performance of tasks, or the combination of the two (i.e., more precise decisions and their autonomous performance), we were left wondering who would be responsible for any socially or environmentally undesirable outcomes. In some cases, our participants noted that their expert position would remain, but could be conducted at an increasing distance. In some cases, narratives around the reduction in risk seemed to skirt dangerously closely to a desire to shirk responsibility. When responsibility involves making yield and quality targets, this is one thing, but when it is about ongoing patterns of fertiliser or chemical applications, we take pause. Is it us, now, in projects like our own, who will have to take responsibility for the decisions and learning processes built into these machines? Or those who own the intellectual property and commercialise these technologies? Or are those who benefit financially from the reduced dependence on labour those who will be responsible? **As humans and decision-making robotics become more entangled within agricultural settings, and the social and environmental pressure on good agricultural practices increases in the face of climate change, we need to be vigilant to ensure that those who should be responsible are aware of their responsibility and active in taking it.”**
Fox M. 2024. Gumboots on the ground approach to role-value in the food and fibre sector.	Key themes identified in a Kellogg study based on KPI and manager/worker job description requirements and what KPIs and skills were important for the workforce: “… themes based on various Food & Fibre Sectors orchard manager counterparts. These themes include production and yield, operation efficiency, financial reporting, quality and safety standards, team leadership, sustainability and environments, communication and investor management, innovation and adaptability.” P 23.
Dominati, E, Dodd, M. Review of western farming philosophies and how to learn from Mātauranga Māori to develop trans-cultural farming systems [Internet]. [place unknown]; [accessed 2025 Aug 29].	In Table 1 p 23, “thirteen principles of agro-ecology, as described by Wezel et al. (2020) are listed and we comment on the links to similar principles from Te Ao Māori, and discuss **how Te Ao Māori can operationalise the integration of these principles for a farm system.”** These include, recycling, input reduction, soil health, animal health, biodiversity, synergy, economic diversifications, co-creation of knowledge, social value and diets fairness, connectivity, participation and land and natural resource governance.
O’Connor M, Burch KA, Gounder S. 2025. Anticolonial co-design: a methodology for including agricultural workers in the development of new AgTech. Kōtuitui: New Zealand Journal of Social Sciences Online [Internet]. [accessed 2025 Aug 29] 20(4):678–698.	Example of a collaborative codesign of AgTech between designers and end users of the tech. “How workers will be affected by new AgTech will depend on how labour is valued and organised within situated farming operations (Legun and Burch 2021; Prause 2021; Legun et al. 2022), how technologies are designed (Burch and Legun 2021; Gugganig et al. 2023), and how data is managed (Taiuru et al. 2023). In this paper, we focus on the question of technology design and how researchers can strategically design anticolonial methodologies to support them in doing their best to not contribute to ongoing processes of colonialism which have often become the default in research taking place in settler colonial contexts”
Goulart Nogueira Da Silva R. 2023. Efficiency evaluation of an automated mango harvesting unit. [thesis] [Internet]. [place unknown]: CQUniversity; [accessed 2025 Aug 29].	An Australia study on the development of automated mango harvesting tech: “In the competition for available harvest labour, the mango industry fares poorly compared to other fruit industries due to: (i) **release of a caustic sap on detachment of the fruit that can burn the fruit or human skin**; (ii) harvest during tropical summers when temperatures can exceed 40°C, (iii) a **large and heavy fruit, which increases ergonomic hazards associated with repetitive picking motions;** and (iv) location of much of the growing regions in relatively remote regions of Australia.”

Google Scholar Search:

New Zealand AND (undercover OR shelter OR greenhouse OR screenhouse OR screen OR polythene OR tunnel) AND (workforce OR labourer* or farmer* OR “Human impact”) AND (orchard*) (first 20 pages of results)

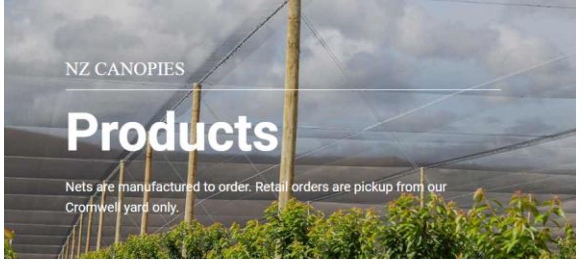
Stats NZ Northland demographics from 2023 census: A growing region with an increase of 8.3% since 2018.
(Our region: Northland | Stats NZ. [accessed 2025 Aug 29]. https://www.stats.govt.nz/infographics/detailed-regional-infographics-from-2023census/our-region-northland/





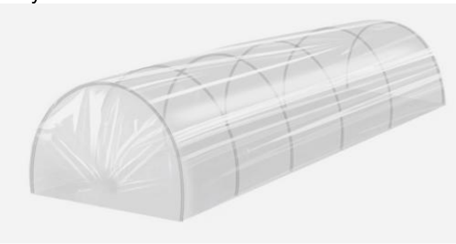
13.14 Commercially available protected cropping systems in New Zealand

Suppliers / Protective cropping / rain shelter designs for tree crops - Source of Northland suppliers from : Exhibitor-Category-Listing-as-at-19.11.21.pdf

Type	Company	Link
Custom canopy covers – nets/shade cloth 	NZ Canopies (South Island)	Crop Protection Net Systems from NZ Canopies
Textiles- nets 	**PGG Wrightson Whangarei** 38 Finlayson Street, Vinetown 0110 09 470 2521 whangareistore@pggwrightson.co.nz	Horticultural Textiles | Shop Online | PGG Wrightson
Ships nationwide 	Morrifield Greenhouses- tunnel houses (Invercargill)	NZ-Made Tunnelhouses for Sale in NZ | Morrifield Greenhouses

Type	Company	Link
Orchard components	Hortivate (Motueka)	Products - Hortivate
The **Cravo retractable roof system** comes in a variety of shapes and sizes from a Canadian company who've been making them for forty plus years… "It's a steel and wire structure with retractable plastic covers driven by motors. The roof and the walls have eight motors apiece all able to be independently operated with computer software from your phone." They set their parameters based on temperature, windspeed and humidity and the software does the rest. 	Used by Clyde orchards	Retractable roof bears fruit at orchard - Clyde Orchards

Type	Company	Link
Italian Valente anti rain nets  and Chilean Wayki open/close covering technology 	Used by Blenheim cherry grower	Innovating for the perfect cherry, every time | Horticulture New Zealand — Ahumāra Kai Aotearoa Caythorpe Family Estate - Marlborough - Hortivate
Caggiati B. 2024. LeaderBrand opens large-scale greenhouse project in Tairāwhiti. Fruitnet [Internet]. [accessed 2025 Aug 26]. https://www.fruitnet.com/produce-plus/leaderbrand-opens-large-scale-greenhouse-project-in-tairwhiti/260096.article	LeaderBrand covered houses for vegetables (with help from the Provincial Growth Fund)	https://www.fruitnet.com/produce-plus/leaderbrand-opens-large-scale-greenhouse-project-in-tairwhiti/260096.article New Zealand: Growers have crops "undercover" to counter adverse weather conditions
O'Callaghan L. 2022. Hi-tech New Zealand strawberries on the horizon. Fruitnet [Internet]. [accessed 2025 Aug 26].	26 Seasons' indoor hydroponic system for strawberries recycles water, and uses mobile vertical racks and pulsing light, so it doesn't require the pesticides or herbicides that are usually an essential part of large-scale strawberry production	https://www.fruitnet.com/produce-plus/hi-tech-new-zealand-strawberries-on-the-horizon/247882.article
	Giltrap - machinery	Giltrap / Quality NZ Farm Machinery | Seed, Feed, Spread or Carry
	Norwood, Whangarei Ltd	Home | Norwood
	Smart Shelters (for animals, but adaptable?)	Farm Sheds & Shelters | Rural Sheds | Smart Shelters
	Agriline- equipment - Dargaville	Contact | Agriline | Agricultural Machinery Importer in New Zealand

Type	Company	Link
Poly Cover- Gubba 	Rosedale Auckland	Poly Cover |Shop Now | Gubba
	Orchard cover Based in Te Puke	Crop Net Protection Service in New Zealand | Orchard Cover

<table>
<tr><th>Type</th><th>Company</th><th>Link</th></tr>
<tr><td>Quiedan - Developed in the Californian and European berry fields to protect valuable crops from rough weather, covered canopies are delivering growers a financial bonus through higher yields, better fruit quality, and improved pest and disease management. Today, covered canopies, also known as high tunnels, are widely used around the world to drive orchard productivity and improve financial returns. A leading developer of high-strength covered canopy systems has been Californian-based Quiedan.
</td><td>For berries, kiwifruit

(Can’t find location based)</td><td>TUNNEL HOUSES | Quiedan NZ

Can supply the complete Quiedan kit for fast and easy construction, including framing, fittings and covers.

You can install your Quiedan canopy using a small team, or we can help arrange a contract installer.</td></tr>
</table>

13.15 Horticultural plant suppliers - Northland

Type	Advice on growing	Supplier
Bananas: Cavendish, hybrid (Goldfinger, Mona Lis, High Noon and Bonanza, Ladyfinger (Rajapuri))	Your Backyard Fruit Bowl – Bananas Growing bananas in New Zealand's South Island and 4 banana varieties to try - Banana Growers of NZ | Facebook Geoff Mansell Kotare farm near Whangarei- "hey need a sheltered spot to grow as the large leaves, which are the carbohydrate factories for the fruit, are easily torn in the wind resulting in smaller fruit. But he has even found a variety that can be used as a windbreak." New Zealand growers aim to make a dent in the imported banana market | RNZ News Country Calendar: Going bananas for subtropicals | The Post	Plants | Kotare Subtropicals Cavendish Banana Plant | Kotare Subtropicals Misi Luki Banana Plant | Kotare Subtropicals Mona Lisa Banana Plant | Kotare Subtropicals Avondale market, Auckland Subtropical Fruiting Plants | Subtropica | New Zealand Gisborne Banana – flyingdragonnursery Waipapa Exotica NZ Plants | Blue Java Banana - Cold Tolerant and Hardy Online Exotica NZ Plants | High Noon Banana - Dessert Banana Online Exotica NZ Plants | Banana - Misi Luki Online Exotica NZ Plants |Sweetheart FHIA 03- Banana- Dessert Banana and Hardy Online Exotica NZ Plants | Ducasse / Pisang Awak - Banana - Delicious Sugar Banana and Dwarfing Variety Online Exotica NZ Plants | Banana - Goldfinger - Honduran Cold Hardy and Prolific Online https://exoticanz.com/collections/exotic-plants/products/banana-hamoa-sweet-and-large-fruit Online Exotica NZ Plants | Banana - Mysore Online Exotica NZ Plants | Banana - Bonanza Excellent Tasting and Cold Tolerant Online Exotica NZ Plants | Banana -Rajapuri- Banana - Creamy, Sweet Tasting Fruit and Dwarfing Online Exotica NZ Plants | Banana - Double Mahoi - Double Bunches of Delicious Creamy Banana Online
Pineapples - Queen, Red and Cayenne	Te-Tai-Tokerau-Northland-Pineapple-growing-opportunities-community-scan-2024.pdf	Pineapples | Kotare Subtropicals Queen Pineapple Plant | Kotare Subtropicals; Red Pineapple Plant | Kotare Subtropicals Subtropical Fruiting Plants | Subtropica | New Zealand Gisborne Red Pineapple plants for sale New Zealand / Buy Online NZ – Exotica NZ Online Exotica NZ Plants | Queen Pineapple Online
Turmeric (*Curcuma longa*), ginger (*Zingiber officinale, Alpinia galanga or Thai*),		Kotare Subtropicals Turmeric Plant | Kotare Subtropicals White Ginger Plant Kouikai, Bank peninsula Subtropical Fruiting Plants | Subtropica | New Zealand Gisborne (ginger and turmeric) Galangal - Thai Ginger (Established Plant) – Exotica NZ online

Type	Advice on growing	Supplier
Pawpaw (Asmina triloba)		Kotare Subtropicals 934602_dd2b1d1bb48740419e5ec0bc6e474935.pdf Subtropical Fruiting Plants | Subtropica | New Zealand Gisborne Papayas – flyingdragonnursery Waipapa
Dragon Fruit – White and Red (Selenicereus setaceus)	Exotica NZ Plants | White Dragon Fruit - Rooted in Pot	Kotare Subtropicals 934602_dd2b1d1bb48740419e5ec0bc6e474935.pdf Banana – flyingdragonnursery Waipapa Exotica NZ Plants | Red Dragon Fruit - Rooted in Pot Online Exotica NZ Plants | White Dragon Fruit - Rooted in Pot Online
Coffee	The first commercial grower was Icuras Coffee overlooking Doubtless Bay. After trials they say they found just the Bourbon Pointu (Arabica var Laurina), proved to be consistent enough with between 60 to 90% beanset. As rainfall has dropped considerably there in recent years they have now started irrigating.	Coffee - 1.9l | Soft Fruit Plants | Kings Plant Barn | NZ Garden Centres, Shop Online, Cafes The Plant Company, Napier Buy Coffea arabica Plants | Free Shipping Over $150 Planting up the farm in subtropical Northland - Dairy Country
Subtropical plants and equipment	Bens Garden | Facebook Kataia	

14 Appendix 2. Plant Variety Rights (PVRs) fact sheet

What Plant Variety Rights (PVRs) are

A PVR is a form of intellectual property protection that gives plant breeders the exclusive right to sell, reproduce, or commercialise new plant varieties they have developed. These rights help breeders recover the time and money spent creating new and improved plants.

Why PVRs exist

The PVR system encourages innovation in plant breeding by rewarding breeders who create plants with better qualities – such as higher yield, improved taste, or disease resistance. This benefits:

- Farmers, who can grow better crops, and
- Consumers, who get more choice and better quality products (e.g. the famous Zespri™ SunGold™ Kiwifruit).

By providing legal protection, breeders are motivated to invest in developing new varieties.

What protection a PVR gives

With a PVR, the owner has the **exclusive right** to:

- Sell or offer for sale the plant's seeds, spores, or cuttings
- Produce the plant for sale

For some plants (like fruit trees or ornamental plants), the right also covers the commercial production of their fruit, flowers, or other products.

Exceptions – What you can do without permission

You do not need the owner's permission to:

- Grow or use the variety for non-commercial purposes (e.g. in a home garden)
- Use it for breeding new varieties (called the "breeder's exemption")
- Use the harvested material for food or other non-reproductive purposes (e.g. sunflower seeds for eating)

How long protection lasts

- 20 years for most plants
- 23 years for "woody plants" (e.g. trees, roses, grape vines), since they take longer to grow and reproduce

How a plant qualifies for a PVR

A variety must be:

1. New – not sold for more than 12 months in New Zealand (or 4–6 years overseas)
2. Distinct – clearly different from other varieties
3. Uniform – plants of the same generation look and behave consistently
4. Stable – characteristics remain the same across generations

The breeder must also provide a unique name (denomination) for the variety.

How to apply

Applications go to the Plant Variety Rights Office (PVRO) under IPONZ (Intellectual Property Office of New Zealand) Apply for Plant Variety Rights | Intellectual Property Office of New Zealand

- The plant is tested to confirm it meets all requirements, which can take several years.
- If approved, the Commissioner of Plant Variety Rights grants the PVR.
- IPONZ keeps a public register of all granted PVRs.

Since PVRs only apply within one country, breeders must apply separately in each country where they want protection. However, countries that are part of the UPOV convention (like New Zealand) use similar standards, so test results from one country may be accepted by another.

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