Australian Coffee Growers' Manual

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Australian Coffee Growers’ Manual

by David Peasley and Jos Webber

June 2024

“To produce a great cup of coffee. It all begins with the coffee grower, who so carefully and patiently ensures that all the intrinsic flavours are captured inside the raw bean.”

Instaurator, Founder of the Australian Specialty Coffee Association

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In submitting this manual, the authors have agreed to AgriFutures Australia publishing this material in its edited form.

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Foreword

AgriFutures Australia's Emerging Industries Program has determined that the Australian coffee-growing industry is strategically positioned to expand the current high-priced export opportunities for unique Australian coffees, which are being limited by lack of supply. Domestically, 99.5% of coffee consumed is roasted from imported beans and there are significant opportunities to increase that share by import substitution. The unique story and quality of Australian-grown coffee can position the industry in these premium market segments. Key initiatives outlined in the *Australian Coffee Strategic RD&E Plan* are the creation of a consolidated system to maximise the viability of the industry and the formalisation of practices in this *Australian Coffee Growers' Manual*, incorporating new and emerging industry concepts.

This *Australian Coffee Growers' Manual* addresses the challenge of disseminating good practices and aims to equip growers with comprehensive knowledge on best practices for coffee cultivation in Australia's diverse climatic zones. The manual serves as a repository of expert knowledge and the practical experiences of industry stakeholders, presented in a user-friendly format. The dynamic nature of the manual allows for updates, ensuring it remains a relevant and valuable resource for both established and prospective growers now and into the future.

The manual addresses several key recommendations of the Strategic RD&E Plan to grow the Australian-grown coffee industry. It underscores the importance of maintaining biosecurity to protect against pests and diseases, given Australia's unique position as a region free from the most serious coffee pests. The manual also highlights the minimal use of pesticides, aligning with community expectations for a sustainable environment and allowing coffee plantations to co-exist with urban development and sensitive land uses.

Further, the manual acts as an essential resource, offering a methodical framework for site assessment tailored to the unique requirements of coffee production in terms of environmental and geographical factors. It outlines a progressive sequence of actions – from conceptualising and designing a plantation to the preparatory work, propagation and establishment – with the aim to provide growers with the knowledge to create thriving coffee plantations.

This manual has been produced as part of AgriFutures Australia's Emerging Industries Program, which focuses on new and emerging industries with high growth potential. Emerging animal and plant industries play an important part in the Australian agricultural landscape. They contribute to the national economy and are key to meeting changing global food and fibre demands. Most of AgriFutures Australia's publications are available for viewing, free download or purchase online at www.agrifutures.com.au.

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Production of this document would not have been possible without the continued financial and practical support offered to Australia's developing coffee industry by AgriFutures Australia. Research trials funded by AgriFutures and its predecessors since 1988 have been the platform upon which the industry has been able to establish and grow.

The practical experience offered by members of the Australian Grown Coffee Association has been invaluable in providing an insight into the unique growing environment of Australia's tropics and subtropics.

The information gathered has been from many scientific sources and other practical guides which have been adapted for their relevance. A short reference list is provided, but we also broadly acknowledge the wider sources of information.

The authors acknowledge the invaluable contribution of Ted Winston for his editing and scientific input based on his wide experience in the development of the Australian coffee industry and Johann Schroder for his editorial assistance.

About this manual

This manual is intended to inform growers and particularly those intending to become growers about good practices and some of the possible pitfalls of growing coffee in the tropical and subtropical climate along Australia's eastern seaboard.

It contains a collection of information, largely based on the expert knowledge of the authors and the practical experiences and contributions of growers, and others involved in the coffee growing industry. All have generously provided knowledge and resources, and allowed us the use of images taken on their plantations.

The information is presented in a practical, easy-to-follow format. For this reason, the manual has been designed as a 'dynamic' document, readily able to be amended, updated and added to.

Any knowledge and experience you might have that would benefit growers, the industry and the quality of the coffee it produces can be added to future revisions.

David Peasley and Jos Webber

Co-authors

Contents

Section 7 Coffee variety and propagation

This section outlines the process, pitfalls and management advice to produce that all-important 'right' tree once the variety is selected. The aim is to produce a healthy, 'true to type' seedling with a well-structured root system to ensure the establishment of a healthy, productive plantation.

Section 8 Establishing the plantation

This section provides a photographic sequence of successful planting techniques developed under local conditions. Recommendations on irrigation and fertilising are also included to ensure the plantation gets off to a good start.

Section 9 Nutrition

Good nutrition for coffee production involves much more than a simple recipe for applying fertilisers at a certain rate several times a year. This section explains the role of each nutrient in the coffee crop cycle, how to monitor nutrient levels, time applications and how to avoid problems affecting productivity, bean quality and tree health.

Section 10 Irrigation

The advantages and limitations of each irrigation system are presented, and information is provided on managing irrigation systems to ensure water is delivered efficiently.

Section 11 Responsible plantation management

This section provides information on environmental considerations when growing coffee, the chemicals permitted for use on coffee, responsible chemical use, and workplace health and safety.

Section 12 Pests and diseases

The coffee pests, diseases and disorders that do, or could, occur in Australia are identified, and their effect on the coffee plant or cherry and how best to combat them or prevent them from entering and infecting your coffee plantation is discussed.

Section 13 Weed control in the plantation

Information on the common broadleaf weeds and vines that occur in plantations, and guidance on their control are illustrated, and their control measures are presented.

Section 14 Pruning

Coffee flowers on new branches. This section discusses the range of pruning options to maximise production.

Section 15 Harvesting

Assessing the maturity of the cherry profile, potential yield in the plantation, and factors affecting harvester shaker performance are discussed in detail.

Section 16 Processing

Various processing methods are available. Factors that can positively or negatively affect the quality and consistency of the coffee's flavour and aroma are presented

Appendices

More detailed and technical information to expand sections 1, 2, 11 and 15 can be found in the correspondingly numbered appendices.

Glossary of terms and abbreviations

References

Executive summary

While Australia is not a major coffee-producing country, it has a unique and thriving coffee culture. Independent coffee establishments are flourishing as, increasingly, specialty coffee and sustainability come into focus in the country's coffee landscape. Over the past decade, the value of Australia's coffee imports has more than doubled, fuelled by the country's booming café industry and an ever-increasing appetite for coffee and coffee beverages. Australian-grown coffee currently supplies less than 0.5% of the domestic coffee-drinking market.

Demand for high-quality coffee is rapidly increasing due to the sophistication of the discerning Australian palate. New varieties are also being introduced to enhance the efficiency of machine harvesting, together with improved cultural management and innovative processing techniques. The coffee-growing industry is well established in the tropical tablelands of far north Queensland and in the cooler subtropics of south-east Queensland and north-east New South Wales. The potential to expand coffee growing to new production areas is emerging and the changing climate may well facilitate this expansion.

Australia is fortunate to be one of the few regions in the world free from the most serious and widespread coffee pest (coffee berry borer) and disease (coffee leaf rust). As a result, pesticides are minimally used on Australian coffee plantations, enabling our coffee to be produced using natural production systems. Community expectations for a clean, sustainable environment are satisfied and coffee plantations sit comfortably alongside urban development and other sensitive land uses. This growers' manual emphasises the vital role every coffee grower has in maintaining the biosecurity of their asset and, in so doing, helping maintain Australia's freedom from the major coffee diseases that occur in other coffee-growing regions of the world.

This manual will act as a resource to help expand the Australian-grown coffee industry to meet increasing demand for locally grown produce — targeting potential new growers, new growers, existing growers and agricultural advisers and extension officers. The manual presents basic financial and horticultural facts and figures that will help potential new growers decide whether to go the next step of becoming a coffee grower.

A checklist of climate conditions, topography and soil characteristics of a site that makes it suitable for coffee production is an important starting point. The manual presents a step-by-step guide from planning, through design, to laying out the plantation, preparing the site for planting, propagation and establishing the plantation.

Once established, programs to manage the trees to maximise their growth and productivity include irrigation, pest and weed control, and pruning. Requirements for harvesting and processing of the crop are presented.

The industry's representative body is the Australian Grown Coffee Association (http://www.agca.au/). The association brings together growers in the tropics and subtropics, harvesting and pruning contractors, wholesalers, retailers, roasters and anyone else interested in the production and or advancement of the Australian-grown coffee industry.

A strategic plan for the Australian subtropical coffee industry (2009-2010) and an *Australian Coffee Strategic RD&E Plan* (2021) were developed through consultation with stakeholders across the Australian coffee industry. These plans identify opportunities for, and barriers to, industry growth, and subsequent RD&E priorities, and can be used by industry to help drive investment and growth in the industry. Funding for the plans and this *Australian Coffee Growers' Manual* was provided by AgriFutures Australia and the Australian Grown Coffee Association.

Section 1
Is coffee growing for you?

Many financial, horticultural, labour and logistical issues are involved in the production of coffee and its viability. These are considered in this section.

The Australian coffee market

Coffee is one of the most popular beverages worldwide, and Australia is no exception. Many consumers across the country cannot imagine starting their day without their favourite brew. The pleasures of coffee were introduced to Australia by Italian immigrants during the first half of the 20th century. Our obsession gained momentum in the 1990s and has been growing ever since. Today, coffee is firmly part of the Australian lifestyle. High streets and shopping malls have more coffee outlets than any other type of retail establishment and many homes have machines and other means to make brewed – as opposed to instant – coffee.

Facts about the Australian coffee market

Coffee is now Australia's favourite hot beverage; we drink more than six billion cups of coffee each year. This equates to just over half a cup of coffee per person per day!

The coffee market is one of the fastest-growing industries in Australia.

Many consumers order coffee online and increase their consumption at home. Home-brewed coffee made up 37% of the Australia coffee market in March 2020.

As well as importers, several manufacturers and retailers across the country are focused on responding to consumers' growing preference for sustainable coffee.

The price per cup and the number of cups consumed continue to increase.

While Australia is not a major coffee-producing country, it has a unique and thriving coffee culture. Independent coffee stores are flourishing as, increasingly, specialty coffee and sustainability come into focus in the country's coffee landscape. Over the past decade, the value of Australia's coffee imports has more than doubled, fuelled by the country's booming café industry and an ever-increasing appetite for coffee and coffee beverages.

Australians have become connoisseurs of coffee, consuming more than six billion cups annually. The market has become sophisticated such that the origin and quality of the bean, the nature of the roast and the method and skill with which it is made are all relevant choice considerations.

Many consumers order their coffee online. The home-brewed coffee market made up 37% of the Australian coffee market in March 2020.

According to the Australian Bureau of Statistics:

- In 2023, Australia imported coffee and coffee substitutes to the value of $1,192 million. Of this, 51% was raw green bean, 25% was roasted coffee and 20% was instant coffee.

- Quantities of imported coffee have been steadily rising at an average annual rate in excess of 6%, and almost doubling between 2013 and 2023 (Figure 1.1).

- According to Statista (https://www.statista.com/topics/4615/coffee-market-in-australia/#topicOverview), in 2022, Australia imported 102,000 tonnes of green bean, while at the same time, 500 tonnes of green bean was grown in Australia. Locally grown coffee contributes less than 1% of Australian coffee consumption.

The growth and sophistication of the Australian coffee market, the willingness of consumers to pay well for a high-quality product, the concern over food miles and the economic attractiveness of home-grown production are favourable conditions for the continuing development of the Australian coffee-growing industry.

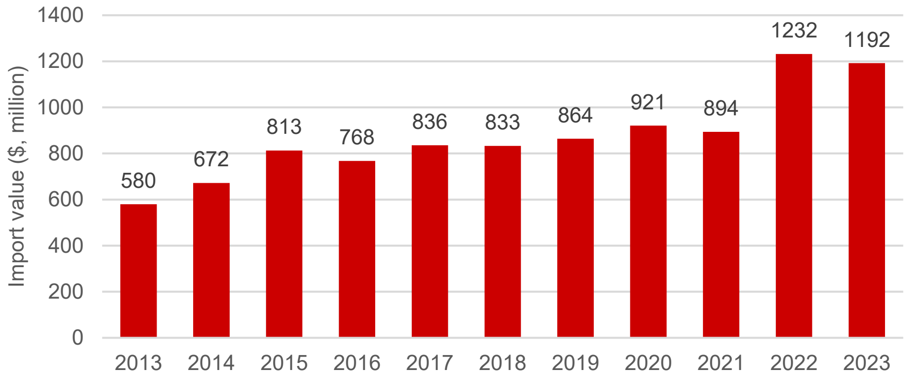


Figure 1.1: Total import value of coffee and coffee substitutes. Source: Statista (https://www.statista.com/statistics/1243644/australia-import-value-of-coffee/).

Economic and financial considerations

With the burgeoning coffee culture in Australia, there is an increasing romance associated with the prospect of growing coffee domestically. The attraction of this dynamic market is clear, but before one takes the first step of acquiring the land or purchasing a coffee plantation, it is prudent to first consider the financial, horticultural, labour and logistical issues involved. The pros and the cons of growing coffee in Australia are outlined at the end of this section (Fig. 1.9 and Fig. 1.10). This chapter introduces some of those considerations and provides facts and figures to assist in making the decision of whether coffee growing is for you.

The Australian coffee growing industry is established in northern Queensland and along the eastern seaboard of Australia's subtropics, centred on northern New South Wales (NSW). With a warming climate, it may be possible in the future to grow coffee in regions formerly considered unsuitable.

The Australian coffee industry is made up of a diverse group of growers on plantations of varying sizes. These fit into five broad categories:

1. Backyard for home consumption (10–20 trees)
2. Intercropping (bananas, macadamias, other fruit trees) and hand harvesting
3. Hand harvesting at a commercial scale (up to 2,000 trees)
4. Machine harvesting at a small scale (5,000–20,000 trees)
5. Machine harvesting at a large scale (>20,000 trees).

Motivation and considerations

Many growers entered the industry as a lifestyle choice, with the feel-good factor of growing, processing and selling their own coffee. However, the prospect of increasing returns from value-adding and the satisfaction of marketing the final roasted product has resulted in some medium-sized, part-commercial plantations, where there is additional off-farm income, moving to vertically integrated operations by processing, roasting and selling their packaged product.

This medium-sized group makes up the bulk of the industry in terms of grower numbers. In addition, there are a number of fully commercial, large plantations operating as fully integrated businesses that are involved with the entire process from tree to cup; these plantations are responsible for the bulk quantity of locally grown coffee (Table 1.1).

Table 1.1: Australian-grown coffee enterprises and their characteristics.

Property size	Small <5,000 trees 1.5 ha	Medium 5,000–20,000 trees 1.5–6 ha	Large >20,000 trees +6 ha
Property type	Lifestyle	Income-yielding	Business venture
Motivation	Tree change Personal wellbeing Environmental amenity	Passion for coffee Business development Income potential	Market potential Investment returns Extension of enterprise
Principal consideration	Lifestyle	Practical ability, time and financial management	Profitability
Labour	Self	Self and casual employees	Employees
Management	Occasional and simple	Periodic and routine	Full time and complex
Support services	Largely reliant	Partly reliant	Self-reliant
Establishment and operational costs	Minimal	Modest	Substantial
Returns	Returns are secondary to a feel-good activity	Supports desired lifestyle or supplements income	Provides adequate return on investment

Establishment costs

One of the biggest challenges facing new entrants into the industry is acquiring land that is suitable for growing coffee at a reasonable price. The cost of a property is a major upfront outlay, and subsequent sections of this manual assist in assessing the extent to which the asking price of land represents its value in terms of its potential suitability for coffee growing.

Costs in establishing a coffee plantation can vary considerably, depending on local government regulations, existing vegetation, the aspect of the land and the availability of contractors or the ability of landholders to conduct the necessary works themselves. The costs estimated in Table 1.2 are based on certain assumptions which are given for each item. **Note that economies of scale apply and not all the investment is required upfront.**

Table 1.2: Cost estimates to establish a coffee plantation.

Item	Assumption(s)	Details	Unit cost	Cost per 20,000 trees or 6 ha
Land preparation	A clean site suitable for growing coffee. This does not consider costs involved with removal of existing vegetation, drainage and major land works.	• Use of GPS navigation for accurate lay out of the plantation. • Creation of mounded rows 3.8–4 m apart. • Low-profile v-drainage of the inter-row space. • Planting of a cover crop to prevent soil erosion.	Set up cost of $1,000, then $4,000/ha with economies of scale	$25,000
Irrigation	A suitable water source exists with the necessary licences or harvestable water rights.	• Requirement is 1–4 ML per hectare per year depending on rainfall. • Pressure-compensated dripper system includes pumps, laterals and sublaterals. • Option to undertake fertigation.	$2.50 per tree	$50,000
Seedlings	Seedlings purchased/supplied by a wholesale nursery or grower and planted by a contractor.	• Planting density of 3,000 trees per hectare in rows 3.8–4 m apart; spacing between plants is 90–100 cm for small batches less than a hectare; watering-in costs are extra, if required.	$4.00 per tree	$80,000
Equipment		• Tractor of 40–45 hp (second-hand). • Ride-on mower. • Weed sprayer. • Fertiliser spreader. • Field bins × 12 (after year 4). • Shade cloth and black plastic for sun drying. • Igloo for drying.	$20,000 $15,000 $10,000 $1,000 $300 per bin $1,000 $3,000	$53,600
Total establishment costs				**$208,600**

Maintenance and growing costs

The major regular inputs into coffee production are weed control (in young plantations in particular) and establishing and maintaining a sustainably fertile soil to optimise production (Table 1.3).

Table 1.3: Annual (ongoing) expenses to maintain a coffee plantation.

Item	Assumption(s)	Details	Unit cost	Cost per 20,000 trees or 6 ha
Weed control	Cost of materials and maintenance of equipment; own time not costed.	• Mowing of the inter-row. • Control of weeds using herbicides in young plantations.	$500 per ha	$3,000
Fertilising	Soil and leaf tests form the basis of a program.	• Annual program developed. • Soil and leaf tests.	$1,000/ha $300	$6,300
Irrigation	A water licence is required (at a cost) to access water from Irrigation Area storages.	• An essential tool in managing productivity, particularly in the dry Savanah areas, but also in managing general tree health and productivity in all coffee-growing regions. • Water use is metered. • Requirement is 1–4 ML per hectare per year depending on rainfall.	$600–1000/ha	$5,000 (far north Queensland estimate)
Total maintenance and growing costs				**$14,300**

Harvesting costs

Coffee was a well-established crop in Australia in the late 1800s but died out in the 1920s because of high labour costs. The industry rekindled during the 1980s, and with the advent of machine harvesting in 1990, larger commercial plantations became established. While hand harvesting is still practised on smaller plantations, in today's labour market, it is a very expensive and impractical option on a plantation of 1,000 or more productive trees. Some larger plantations own their own harvester, while smaller plantations are harvested by a contractor using a mechanical harvester. The annual costs involved are shown in Table 1.4.

Table 1.4: Annual harvesting costs.

Item	Assumption(s)	Details	Unit cost	Cost per 20,000 trees or 6 ha
Harvest	Mechanical harvest by contractor within a 50 km radius of the home base.	• Two harvests approximately 3–4 weeks apart. • Includes freight of harvester to and from the plantation, as well as set-up costs.	$3,500 per harvester pass	$7,000 (two passes)

Processing

Processing is a critical step that can significantly affect the quality of the raw product. Where growers do not have their own processing facility, a centralised processing facility that specialises in processing for a number of growers is the ideal situation. The larger the volume to be processed, the greater the need to install (or use off-site) high-quality equipment to process, sort and grade product.

The use of an established processing centre not only avoids over-capitalising on smaller plantations, but also enables a consistent quality product to be produced. Costs involved in processing are shown in Table 1.5. **Economies of scale apply**.

Table 1.5: Costs and options for processing harvested cherry.

Item	Assumption(s)	Details	Unit cost	Cost per 20,000 trees or 6 ha
Commercial processing facility	Facility offers processing to growers on a fee-for-service basis. Should handle the product from 50,000-plus trees.	• Wet mill, dryers, dry mill, size and colour sorters, storage silos, elevators and associated equipment.	$500,000+	
On-farm processing	Plantation is up to 20,000 trees – wet mill processing.	• Washer/separator. • 1,500 kg per hour processor. • Elevators.	$9,000 $17,000 $10,000	$36,000
Outsourced processing	Cherry is harvested into field bins and wet processed, producing wet parchment/ naturals.	• Water-separation/wet processing. • Field bins and equipment to transport/load the harvested crop.	$100 per 600 kg field bin (for bins, see equipment costs)	
Freight	Contractor to transport field bins of product to/from the processing facility.	• Eight tonne payload.	$80 per hour	
Drying	Sun drying – need to have an option to dry parchment in inclement weather. One tonne requires 50 m^2 surface area (2 cm deep).	• Shade cloth. • Black plastic (50 m × 4 m). • Plastic-covered igloo may be an option.	$400 $200 $3,000	$3,600
	Mechanical drying by contractor using a compartment dryer. Each compartment takes two bins.	• Six bins in 4 tonne wet parchment yields 1 tonne dried parchment.	$1.00 per kg dried parchment	$1,200
Dry milling	Contract dry milling of parchment – minimum 100 kg (yield of green bean from parchment is 80%).	• Hulled, size sorted and bagged. • In addition, colour sorted.	$2.00 per kg $0.50 per kg	$2,500 $625

Production

Production of the first commercial crop can be expected after four years from the time seedlings are planted in the ground. Some trees will flower in the spring two years after planting, giving their first, light crop in the spring at three years.

On average, a mature plantation that is 8–10 years old will yield 250 g to 500 g green bean per tree with mechanical harvesting. Hand picking can increase the yield to 400–600 g per tree. Under optimum growing conditions, yields can be up to 700 g for machine harvesting and up to 1.5 kg for hand harvesting.

Yield is greatest at 5–8 years after planting and slowly diminishes thereafter, depending on how well the plantation is maintained and the pruning regime employed.

Rather than plant out all the available land at the outset, consider planting blocks of trees each year to enable cyclical pruning, and ultimately replacement planting, which will decrease the chance of having years without a crop.

In the subtropics, the productive life of the K7 variety grown on volcanic red soils is yet to be determined and will depend on the level of management of pruning, nutrition and water. Replanting may be cost-effective in mature plantations aged more than 15 years.

In the tropics, the productive life of the Catuai variety is 30-plus years if the plantation is well maintained and effectively pruned.

Income

The biggest variable in estimating income from growing coffee relates to yield per tree. Income is greatly influenced by the age of the trees, climatic conditions (rainfall in particular), fertility of the soil and agronomic management of the plantation. After yield, the next-most important influence on income is the quality of the raw or roasted product. Of course, high yields mean little if the quality of the raw or roasted product is not consistently high.

Income can be derived from selling raw product (green bean and occasionally parchment or naturals) or by value-adding and selling roasted bean either in the packet or in the cup. Table 1.6 shows the gross value of production that might be expected from small and larger plantations for a range of yields and prices for processed green bean.

Table 1.6: Estimate of gross income with varying yields, number of trees, and prices.

Plantation size		**5,000 trees**			**10,000 trees**			**20,000 trees**		
Yield/tree		250 g	400 g	600 g	250 g	400 g	600 g	250 g	400 g	600 g
Value of green bean/kg	$10	$13,000	$20,000	$30,000	$25,000	$40,000	$60,000	$50,000	$80,000	$120,000
	$15	$18,000	$30,000	$45,000	$37,000	$60,000	$90,000	$75,000	$120,000	$180,000
	$20	$25,000	$40,000	$60,000	$50,000	$80,000	$120,000	$100,000	$160,000	$240,000

	Unviable. Yield per hectare can be increased by closer planting, depending on the variety and the growing region. Higher values are less likely if inferior processing practices are used.		**Provide supplementary income**. Good crop management and quality controls are important to maximise yields and achieved values.		**Viable**. Higher labour and capital costs still require achievement of mid-range yields and higher values.

Value-adding options

Australian-roasted coffee typically wholesales at about $25–$30/kg and retails as a packaged product at about $40–$75/kg. Further value-adding occurs when sold as cups of coffee.

Table 1.7 enables a comparison to be made between income derived from the different products, and assumes all processing costs are included in the price per kilogram. The yield per tree has been assumed to be 400 g of green bean to enable comparisons to be made between the four products.

Table 1.7: Comparison of estimated income along the value chain (from the various coffee products derived after harvesting).

Product[1]	Price per kg	Yield per product	Yield per 100 trees	Income per 100 trees	Additional cost considerations
Parchment	$10–15	500 g	50 kg	$500–750	
Green bean	$15–20	400 g	40 kg	$600–800	Dry mill processing
Roasted bean	$40–60	320 g	32 kg	$1,280–1,920	Roasting and packaging
Coffee in the cup[2]	$400	320 g	32 kg	$12,800	Overheads and other cupped components

[1] 500 g parchment yields 400 g green bean, which yields 320 g roasted bean.

[2] 1 kg roasted bean makes 100 cups of coffee. At $4.00/cup, this equates to $400/roasted kg if sold by the cup. So, the cost of the coffee component in a cup is about $0.40

The Australian coffee-growing regions are an important international and domestic tourist destination, and are generally located in popular places to live. With increasing demand for experiential travel, there are significant opportunities for agri-tourism in the coffee industry. There is potential for visitors to have the full 'coffee experience' from the paddock to the cup in the pristine environment where coffee is grown.

There is, as yet, unrecognised potential to gain value from processing waste products. Cherry skins are a potential source of high-value sugars for biofuel, the coffee pulp is high in pectins used in the food industry, and the fibre of parchment husk can be used in food products or converted to biochar.

Calculator to help estimate income

A spreadsheet calculator to help estimate income is in the appendix to Section 1.
Disclaimer: This calculator was developed for illustrative purposes only. Users will need to input their own figures for yield, prices and costs.

Conversion ratios, figures and facts

Conversion ratios related to coffee production are shown in Table 1.8.

Table 1.8: Conversion ratios related to coffee production.

100 kg of prime red cherry	=	20 kg of dry parchment
Ratio of cherry to dry green bean	=	6 kg:1 kg
100 kg of tree dried naturals	=	33 kg dry green bean
100 kg of dry naturals	=	50 kg of dry green bean
100 kg of dry parchment	=	80 kg of dry green bean
100 kg of dry green bean	=	84 kg of roasted coffee

100 kg red cherry ➡ 20 kg parchment ➡ 16 kg green bean ➡ 13.5 kg roasted bean

- Prime red cherry has 60–65% moisture content.
- Washed, wet parchment has 50–55% moisture content after drainage.
- Green bean should be dried to 12% moisture content prior to storage.
- Green bean is best stored in a hermetic bag with a zipper (e.g. GrainPro®). The bag acts as an inner liner for jute bags and polypropylene bags. Green bean can be stored for more than a year without the risk of moisture ingress. The bag stops insect infestation and inhibits the growth of fungal contaminants without affecting the quality of the goods.
- Yield per mature tree of 1.5–4 kg of prime red cherry equals 250–600 g of dry green bean.

Environmental considerations

Environmental factors to take into account when considering whether to grow coffee are varied. They include:

- Australia is one of the few coffee-growing regions in the world free from the major diseases of coffee – coffee berry borer disease and coffee leaf rust. As a result, minimal insecticides and fungicides are sprayed on coffee in Australia. The crop lends itself to a more sustainable farming approach and/or organic production.
- Processing plants need to establish good effluent management and control using settling ponds to ensure run-off does not pollute adjacent waterways.
- Coffee can be invasive in native vegetation. Care needs to be taken to control seedlings in/near plantation perimeters, and to channel drainage away from water courses. Local government restrictions may apply.
- Unusually, rats and bats can cause problems in plantations when environmental conditions favour their predatory behaviour.
- In the increasingly urbanised environment of the Australian coffee-growing regions, coffee is a most compatible crop to grow at the urban/rural (peri-urban) interface. Its light environmental footprint fits in well with the high conservation value of these regions.

What are the pros of growing coffee in Australia?

- Demand far exceeds supply; More than 99% of coffee consumed in Australia is from imported beans.
- Australian coffee is a high-value, niche product competing in a free commercial market.
- Coffee is increasingly an integral part of the social fabric; this coupled with the movement to ‘buy local’ has the potential to deliver Australian grown coffee a marketing edge.
- Australian grown coffee has approximately 10–25% less caffeine than imported coffee.
- Coffee growing is ideally suited to the frost-free ‘terroir’ of climate, fertile soils, abundant reliable rainfall and moderate temperatures.
- None of the major coffee pests or diseases that affect coffee production elsewhere in the world are present in Australia.
- Minimal insecticides or fungicides are used in its production.
- Coffee is an environmentally sustainable crop with low food miles.
- Coffee is amenable to biological farming and organic production.
- Coffee is compatible with urban activities
- Coffee is an attractive crop in appearance
- Coffee growing can be a lifestyle choice with all aspects of production lending themselves to being contracted out; you can do as little or as much as you choose.
- For a tree crop, coffee provides a relatively quick commercial return.
- Busy times are seasonal over the harvest period – from May to August in the tropics and September to January in the subtropics.
- There are well developed and documented procedures for growing coffee – this Australian Coffee Growers’ Manual is testament to that.
- Technology for harvesting and processing has been developed and adapted for the Australian industry.
- Current growing regions have excellent supporting infrastructure and services, including agronomists, fabricators, engineers, existing contractors, and freight services.
- A vibrant industry association provides a forum for all who have an interest in Australian-grown coffee to interact, learn from each other and grow the industry.
- Coffee is a challenging yet very rewarding industry that induces passion in people – from growers to consumers.

What are the <u>cons</u> of growing coffee in Australia?

- Suitable land is expensive and there is competition from other agricultural industries for its utilisation.
- There are constraints on the topography of suitable land.
- Too few growers can lead to a lack of critical mass to support contractors.
- There is competition from cheap imported coffee.
- There is competition from imported coffees branded as 'Rainforest Alliance' or 'Fair Trade', with consumers having a poor understanding of what that branding means.
- There is brand confusion in the marketplace.
- There is no overarching regional brand in a fragmented market.
- Costs for inputs – fuel, fertiliser, electricity, labour, harvesting (multiple passes) – are high.
- There is a lack of available casual labour for peak times.
- Spring rainfall in the subtropics can be unpredictable, resulting in multiple flowerings, which translate into multiple harvests the following year.
- Without careful planning, chemical build-up in soils can lead to chemical run-off polluting rivers, land and aquatic wildlife.

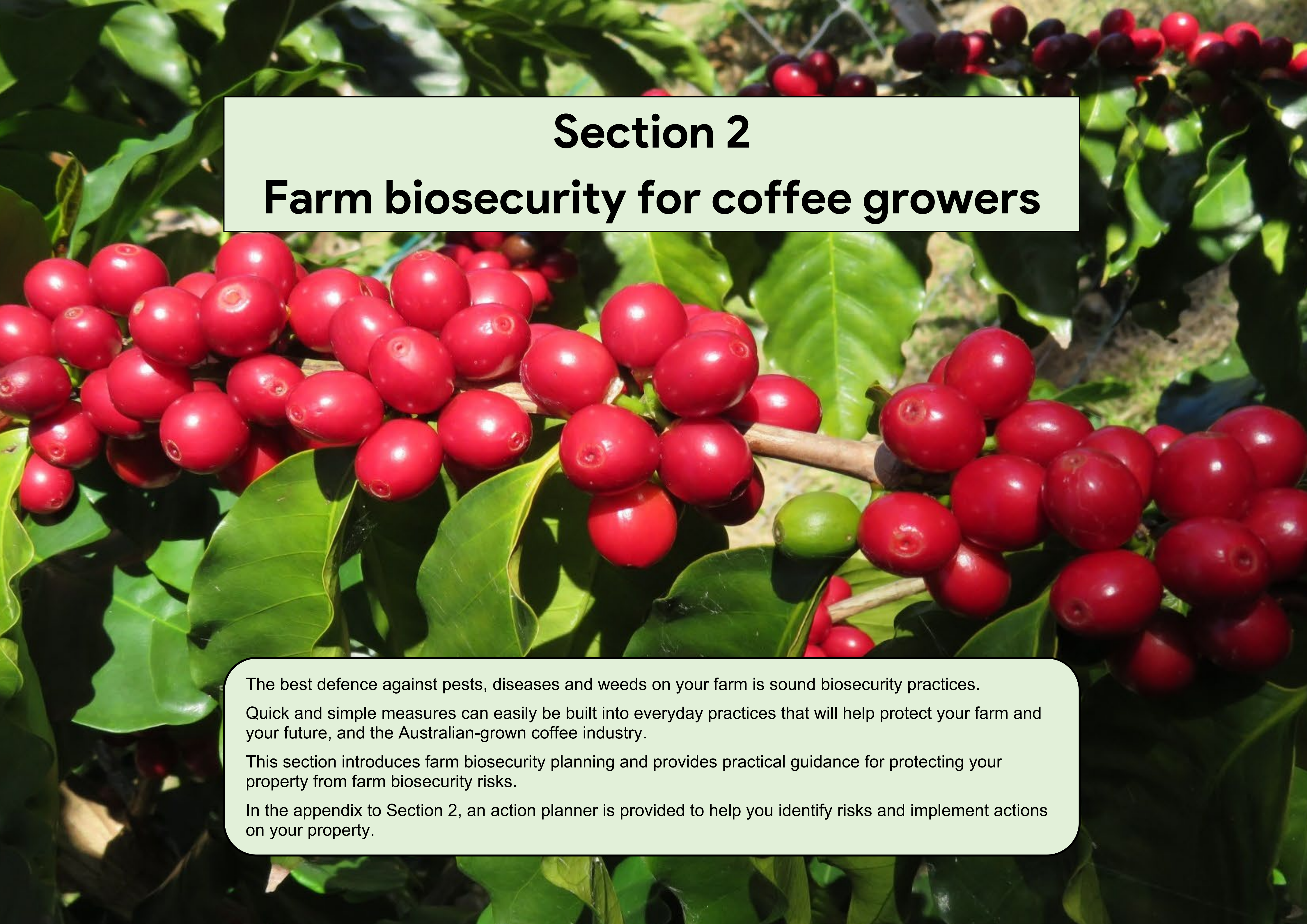
The Australian Coffee Industry Strategic RD&E Plan

The development of a Strategic Research, Development and Extension (RD&E) Plan is a crucial first step in growth for an emerging industry. The *Australian Coffee Strategic RD&E Plan* was published in 2021 as the result of extensive desktop research and stakeholder consultation across the Australian coffee industry.

This Plan clearly identifies opportunities and barriers to industry growth and subsequent RD&E priorities for the industry. It pulls together specific recommendations for future investment to support the long-term growth and competitive advantage of the Australian coffee industry. The Plan can be accessed on the AgriFutures Australia website (https://agrifutures.com.au/product/australian-coffee-strategic-rde-plan/).

Where to next?

If after reading this first section, your pulse has quickened, your interest is raised and you wish to know more about how to go about growing coffee, then the following sections of this manual cover the basics of growing coffee in Australia. For more technical information, refer to the associated appendix.



Section 2
Farm biosecurity for coffee growers

The best defence against pests, diseases and weeds on your farm is sound biosecurity practices.

Quick and simple measures can easily be built into everyday practices that will help protect your farm and your future, and the Australian-grown coffee industry.

This section introduces farm biosecurity planning and provides practical guidance for protecting your property from farm biosecurity risks.

In the appendix to Section 2, an action planner is provided to help you identify risks and implement actions on your property.

What is biosecurity and why is it important?

Australia is uniquely placed among coffee-growing countries in the world. To date, the two major diseases and pests of coffee – coffee leaf rust and coffee berry borer – do not occur in Australia.

If either of these were to arrive in Australia, their impact on the coffee industry would be devastating. It is in the interests of all involved in the industry to ensure that freedom from coffee leaf rust and coffee berry borer is maintained.

Plant biosecurity is a set of measures that protect the economy, the environment and the community from the negative impact of plant pests and diseases.

A fully functional, and effective biosecurity system is a vital part of the future profitability, productivity and sustainability of Australia's coffee-growing industry. Its building blocks are the individual enterprises that practise good industrial hygiene, expanding to a healthy regional and national biosecurity mindset.

An effective biosecurity system is necessary to preserve our freedom from the major pests and diseases that affect coffee growing in overseas markets.

As important as Australia's border integrity and national quarantine system is to prevent the incursion of exotic pests and diseases, biosecurity starts at the farm gate. It transfers along the value chain from where coffee farmers interface with contractors, roasters, wholesalers and the general public, through to importers.

The responsibility of all growers is captured in legislation in all states and territories – see opposite.

Your General Biosecurity Duty or General Biosecurity Obligation

New legislation under the *NSW Biosecurity Act 2015*, *Queensland Biosecurity Act 2014* and the *Tasmania Biosecurity Act 2019* has introduced clauses to support biosecurity management as a shared responsibility. If you are a landowner in Queensland, NSW or Tasmania, you have a responsibility to protect your industry from biosecurity risks you may come across in your day-to-day activities.

In NSW and Tasmania, the **General Biosecurity Duty** provides that as far as is reasonably practicable, biosecurity risks encountered must be prevented, eliminated or minimised. In Queensland, the **General Biosecurity Obligation** means that everyone is responsible for managing biosecurity risks under their control.

The introduction of this legislation in these states makes it more important than ever to be aware of the biosecurity risks relevant to you and your property, and to do your best to mitigate these risks.

For further information on your General Biosecurity Duty or General Biosecurity Obligation, refer to your relevant state government department website.

In states where a General Biosecurity Duty or General Biosecurity Obligation is not in effect, this principle is still followed for an unified industry approach to guard against biosecurity risks and protect individual regions.

The *Biosecurity Strategy for Victoria* (2023) outlines the collective responsibility of all stakeholders.

South Australia released a *Biosecurity Policy 2020-2023* and is updating and simplifying legislation.

In Western Australia, biosecurity is a shared responsibility and can be managed cost-effectively by means of partnerships between industry, community and government.

Biosecurity for Australian-grown coffee

Background	Problem	Management
• Australia's geographic isolation and lack of shared land borders have, in the past, provided a degree of natural protection from exotic plant pests and diseases.	• There will always be some risk of an exotic pest or disease entering Australia, whether through: – Natural dispersal (such as wind); or – Human-assisted legal movements, such international tourism, imports or mail; or – Human-assisted illegal movement of plant materials, such as smuggling; or – Changes to supply chain procedures (e.g. containerisation of produce).	• Australia's national quarantine system is designed to manage the risk of exotic plant pests and diseases from being introduced to Australia through legally imported agricultural commodities, and also aims to prevent illegal imports. • The criteria and degree of oversight by the quarantine system varies, depending on: – the reason for importing – human consumption, seed for sowing or plants for nursery stock – the origin of the product and quarantine systems in the country of origin – the volume of product imported, with increasing volumes of trade increasing the risk of import of exotic pests and diseases. • More details can be found in the appendix to Section 2.
• Exotic weeds, plant pests (insects, mites, snails) and pathogens (bacteria, viruses, fungi, nematodes) have the potential to adversely affect coffee growing and production.	• If exotic plant pests or diseases like coffee leaf rust or coffee berry borer enter and establish in Australia, they can: – Reduce crop yields and cause trade barriers (interstate). – In the worst-case scenario, it will bring about the complete failure of the local coffee growing production system.	• Biosecurity planning provides a mechanism for the Australian coffee industry, government and other relevant stakeholders to: – Actively determine pests and diseases of highest priority – Analyse the risks they pose through the pest risk analysis process – Put in place practices and procedures that would rapidly detect an incursion – Minimise the impact of exotic pests or disease incursions – Reduce the chance of pests and diseases becoming established. • Effective industry biosecurity planning relies on all stakeholders, including government agencies, industry and the public. • Through this planning process, the coffee industry will have the capacity to minimise the risks posed by pests and diseases, and respond effectively to any threats.

Actions growers can take on farm to improve biosecurity

Farm biosecurity measures can be used to minimise the spread of exotic pests and diseases before their presence is known or after they are identified. This, therefore, can greatly increase the likelihood they can be eradicated. Good farm biosecurity practices can also assist in control of endemic pests, minimising their impact. Biosecurity measures to consider are described below.

Background	Problem	Management
Warning signs		
• Warning signs tell visitors to your property that you have biosecurity measures in place to minimise the spread of pests and diseases.	• Visitors or contractors may be unaware of the biosecurity measures in place and could inadvertently introduce a pest or disease to your property.	• Place warning and information signs on key property entrance and exit gates (where practical) to inform visitors of the biosecurity practices in place and to remind personnel that farm biosecurity is a priority. Of note: – Signs should also include up-to-date contact details for people to gain further information. Visitors to the area may not be aware of relevant biosecurity protocols. – All people entering the property should have a clear view of signs – Signs should contain simple messages (e.g. do not enter the property without prior approval, use wash-down facilities for cleaning vehicles and machinery). An example biosecurity sign is shown below. 

Background	Problem	Management
Movement of people		
• People can carry pests, particularly on boots and clothing. • Knowing who has entered your property allows possible sources of diseases, pests or weeds to be tracked.	• Fungal spores, nematodes, bacteria and viruses cannot be seen and can be easily carried onto a property, along with insects and weed seeds. These can be transported in dust, soil or mud, or on boots, gloves or other clothing (even hats) that has been worn on another farm. • Movement of people between farms and between regions can potentially spread these pests. • International visitors from coffee-growing regions could introduce pests and diseases on the clothing and footwear.	• While it is not always practical to stop these movements on and off your farm, a number of measures can be used to reduce the risk of pest spread by people. Possible strategies are: – Use signs to alert visitors that biosecurity measures need to be undertaken and to report directly to the house or office on arrival. – Keep a visitor register, including contact details, times/dates of entry and exit, and key work undertaken on the site. – Ensure all visitors and employees are aware of the importance of keeping footwear and clothing (including hats) free from loose dirt and plant matter before entering or leaving the property. – Supply footwear or footbaths (with a scrubbing brush) containing a strong cleansing solution to avoid the spread of soil, mud and pathogens between areas. – Limit the number of vehicle access points to your property. – Display biosecurity signs, with clear instructions and contact details, at all vehicle access points. – Clearly sign and lock restricted access areas. – Provide a designated parking area at the front of the property. – Transport visitors, contractors, employees and government officials using vehicles based permanently on the property. – Undertake biosecurity/quarantine training for employees and other personnel. – Be aware if your visitors have recently arrived from overseas. • See the appendix to Section 2 for further details.

Background	Problem	Management
Harvest handling and managing the movement of vehicles and farm equipment (including clothing, tools and footwear)		
• Movement of machinery and equipment between regions and farms poses a high risk of introducing exotic and established pests and diseases of coffee.	• Shared vehicles (including cars and farm equipment such as harvesters, harvest bins and tractors) can carry soil and soilborne pathogens (especially when muddy). • Plant debris may contain weed seeds or pests (including pathogens or insects). • If they not cleaned properly, vehicles and farm equipment (such as hand tools) can carry pests and diseases from one part of the farm to another, between farms, and even between growing regions.	• This risk can be reduced by ensuring plant material and soil that may harbour pests is removed before people, machinery and equipment are moved to other properties or regions. – Find out where these items have been prior to allowing them to enter your farm. – Visually inspect machinery and equipment (e.g. harvesters, harvest bins, trucks and any other equipment) for signs of soil or plant material before it comes onto the property. – Clean soil, plant or other debris from equipment or vehicles (especially equipment used on crops directly) prior to entering the property, and deny access to any equipment that does not meet your standards. Clean hedge pruners and harvesters with a chlorine or other sanitiser before allowing onto the property. – Use high-pressure wash-down facilities (ideally with a concrete or tarmac pad for cleaning vehicles and equipment), not allowing wash-down run-off to enter the farm or irrigation sources. – Restrict movements of vehicles and people (where possible) between sites/properties during high-risk periods. This may include avoiding moving vehicles and machinery, particularly when roads are wet and muddy. – Consider assigning certain equipment (including clothing, tools and footwear) to be used in pest-infected areas only. This means that the equipment used in infected properties or areas is not reused in clean areas, and vice versa.

Background	Problem	Management
Record keeping		
• Produce identification and tracing systems will assist in tracing consignments to their source if they are found to be contaminated with an exotic pest or disease. • Besides records of farm inputs and outputs for coffee, records of other inputs and outputs should also be kept. • An exotic pest or disease can enter or leave your farm on a range of items, including but not limited to soil amendments, chemicals, mulch, equipment and produce packaging.	• Pests or diseases can spread quickly and get out of control if they go undetected. • In the event of an exotic plant pest incursion, valuable time can be lost trying to determine the source of the pest or disease and the extent to which it has spread. • Bad or no record keeping can significantly impair tracing processes and increase the chances of further spread of the disease or pest.	• Regular inspections of trees, leaves and fruit for anything unusual, including the presence of disease and pests, should be undertaken and recorded (diary, photographs). • If a suspicious pest or disease is found on your property, report it to the Exotic Plant Pest Hotline by calling 1800 084 881. • Consignments should be clearly marked with the grower's name or code, and a batch identification mark (date or other code). • Growers should maintain a record of the source and destination of each batch and identify separate growing areas on a property map. • Growers should also maintain records of all key inputs to the farm that may carry pests or diseases – i.e. bulk soil movements, soil amendments, mulches, equipment, used packaging (pre-used pallets), reused hessian bags, etc. • Maintain effective pest monitoring and management programs. This includes keeping records of the management of established pests and diseases, and the control measures used. • Cover harvested crops/produce to prevent plant material (especially potential 'seed' material) from blowing off during transit to processing or packing facilities or markets. • Up-to-date advice on movement restrictions must be sought before moving coffee plant material and products. This can be obtained from the domestic quarantine website (http://www.interstatequarantine.org.au/), or enquiries can be made to your local state or territory agriculture agency: – New South Wales Department of Primary Industries (https://www.dpi.nsw.gov.au/biosecurity/plant) – Queensland Department of Agriculture and Fisheries (https://www.daf.qld.gov.au/business-priorities/biosecurity/plant)

Background	Problem	Management
Movement of imported green bean		
• There are many roasters in coffee-growing regions that use imported green bean in their business.	• Imported green bean that is brought into coffee-growing regions or onto coffee plantations for roasting poses a serious threat of introducing exotic pests and diseases. Diseases can be introduced via: – the green bean (e.g. coffee berry borer) – the hessian sacks (coffee leaf rust).	• Where this occurs, biosecurity measures need to be put in place to ensure there is no risk of contamination of local plantations. Measures that should be taken include: – Knowledge of the origin of the green bean and any associated sanitary certification. – Personal hygiene relating to clothing and footwear. – Clear separation and hygiene protocols of green bean and packaging at receival and storage to prevent contamination of local plantations or product. – Do not take hessian sacks from other areas onto local farms. Effective disposal of hessian sacks ensures they cannot be a source of pest and disease spread.
• There is an increasing trend for coffee roasters to ”return to origin” and visit the overseas plantations whose green bean they use for roasting.	• Some roasters bring samples of green bean back for roasting. • Trade samples must weigh 5 kg or less. • Green bean samples might appear clean. However, the major diseases cannot be detected with the naked eye and can be carried on green bean or packaging.	• An import permit is NOT required for these small quantities of green bean on the condition **they are only used for roasting**. • Green bean imported for roasting must NEVER be used as seed to grow coffee plants. • If you want to import green bean seed for planting, you must follow the conditions in the Australian Biosecurity Import Conditions (BICON) database (https://bicon.agriculture.gov.au/). • After visiting a coffee plantation overseas, when you return to Australia, declare that you have been on a farm. • Declare to importing authorities any green bean you are bringing in for any purposes. • Each consignment must be packed in clean and new packaging. • All consignments must be inspected by importing authorities upon arrival to ensure that they are free of contamination and/or infestation by extraneous materials.
Visiting overseas farms/orchards – what to watch out for when you return		
• When Australian growers visit production regions and farms overseas that may have pests not present in Australia, care must be taken not to inadvertently introduce these pests into Australia.	• Clothing (including hats) and footwear used during the visit may carry bacterial and fungal spores, and should be thoroughly laundered in warm water before being taken to local sites. • Similarly, personal hygiene should be given extra care, e.g. washing hair and hands.	• Prior to returning, thoroughly wash all clothing and footwear used during the visit, as well as your hands, body and hair. • Any visits to farms (including orchards) should be declared on re-entry documentation as required. • Do not take green beans or packaging (particularly hessian sacks) derived from overseas countries into orchards.

Reporting suspect pests

Any unusual plant pest should be reported immediately to the relevant state/territory agriculture agency through the **Exotic Plant Pest Hotline (1800 084 881).** Early reporting enhances the chance of effective control and eradication.

Reporting an exotic plant pest carries serious implications and should be done only via the Exotic Plant Pest Hotline.

Careless use of information, particularly if a pest has not been confirmed, can result in extreme stress for individuals and communities, and possibly damaging and unwarranted trade restrictions.

Some coffee pests are notifiable under each state or territory's quarantine legislation. Each state's list of notifiable pests is subject to change over time, so contacting your local state/territory agricultural agency will ensure information is up to date.

Landowners and consultants have a legal obligation to notify the relevant state/territory agriculture agency of the presence of those pests within a defined timeframe. Timeframes for reporting notifiable pests as defined in state/territory legislation are:

- New South Wales – 24 hours
- Northern Territory – 24 hours
- Queensland – 24 hours
- South Australia – immediately
- Tasmania – as soon as possible
- Victoria – without delay
- Western Australia – 24 hours

Suspect material should not generally be moved or collected without seeking advice from the relevant state/territory agriculture agency, as incorrect handling of samples could spread the pest or render the samples unsuitable for diagnostic purposes.

State/territory agriculture officers will usually be responsible for sampling and identifying pests.

EXOTIC PLANT PEST HOTLINE

1800 084 881

Farm biosecurity checklist

Use this checklist to do a quick biosecurity assessment of your property, and refer to other sections of this document for further detail on each point.

Issue	Yes/No	Issue	Yes/No
1. Do you have information signs placed at the entry gate to demonstrate your hygiene/biosecurity measures?		8. Do you ensure that you and your staff are adequately trained in the correct use of pesticides?	
2. Do you maintain secure boundary fences?		9. Do you provide biosecurity training and awareness for your staff?	
3. Do you provide movement controls (people and vehicles) and wash-down areas/footbaths to prevent spread of pests onto your property?		10. Do you use quality assurance and/or best management practice systems?	
4. Do you have designated parking for visitors?		11. Have you sought advice from an expert in developing and implementing your farm's biosecurity plan.	
5. Do you provide on-property transport for visitors?		12. Have you been to an overseas farm, orchard or suspect area? Wash your clothes, hat, boots and hair, and declare your international visit to quarantine!	
6. Do you check whether visiting machinery has been cleaned correctly prior to entering your property?		13. Are you familiar with the coffee pests and diseases already present in Australia, and their symptoms, detection methods and management?	
7. Do you use healthy planting material and source your seed from a trusted supplier?		14. Do you frequently check your crop for exotic and established pests and diseases and record the results?	

Development of an on farm biosecurity plan tailored to the needs of an individual operation is a good way to integrate best practice biosecurity with day-to-day operations. Check out the Farm Biosecurity Action Planner on the Farm Biosecurity website (http://www.farmbiosecurity.com.au/planner/). Further information related to farm biosecurity can also be found on the website.

The AgriFutures Australia report *Biosecurity Plan for the Australian Coffee Industry* (https://agrifutures.com.au/product/biosecurity-plan-for-the-australian-coffee-industry) contains information about further exotic coffee pests and diseases.

Coffee leaf rust is caused by a fungus *Hemileia vastatrix*:

- It is the most damaging disease of coffee, causing average crop losses in excess of 30%.
- The disease is present in almost every coffee-producing region in the world except Australia and Hawaii.
- As a leaf disease, it affects the photosynthetic capacity, which in turn affects the coffee quality.
- Extreme defoliation changes the normal development of the plant over the years, with declining yields.
- Because of the economic losses and the ability of the fungus to overcome resistance in cultivars, coffee leaf rust continues to pose a serious threat to coffee growing worldwide.
- This is a disease the Australian-grown coffee industry must exclude.

The **coffee berry borer**, *Hypothenemus hampei*, is the most serious pest of coffee globally:

- The pest has not been found in Australia; it is present in Hawaii and as close as Papua New Guinea.
- It is spread by the movement of infected green bean in the international coffee trade.
- It is a small black beetle, 1.5 mm long. All immature life stages take place inside the coffee cherry.
- The insect causes damage by boring into and depositing eggs into the cherry. Larvae emerge and feed on the seed of the cherry, destroying it.
- It is difficult to control by spraying as much of its life cycle takes place in the cherry.
- An integrated pest management approach is the best strategy to reduce borer populations. Trying to eliminate ripe cherries being left on the tree or falling on the ground, together with the use of parasitic wasps that attack the borers, is considered the best strategy.

Department of Primary Industries

Importing green bean

Know the risks to Australian coffee growers

australian grown coffee ASSOCIATION

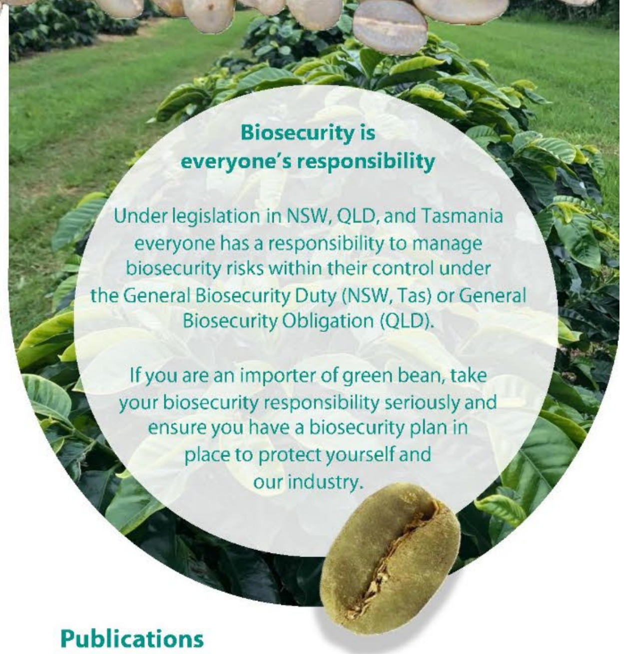
www.dpi.nsw.gov.au

Top exotic coffee pests

Coffee berry borer
Hypothenemus hampei

Coffee leaf rust
Hemileia vastatrix

Coffee berry disease
Colletotrichum kahawae



Biosecurity is everyone's responsibility

Under legislation in NSW, QLD, and Tasmania everyone has a responsibility to manage biosecurity risks within their control under the General Biosecurity Duty (NSW, Tas) or General Biosecurity Obligation (QLD).

If you are an importer of green bean, take your biosecurity responsibility seriously and ensure you have a biosecurity plan in place to protect yourself and our industry.

Publications

Australian Coffee Grower's Manual

More information

www.farmbiosecurity.com.au

www.dpi.nsw.gov.au/biosecurity/plant

www.astca.org

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Department of Primary Industries

AgriFutures Australia

Nearly all coffee roasted in Australia is imported from countries that have pests and diseases that we don't have and don't want in Australia. You can help us keep it that way!

What's the risk?

Australian coffee growing regions are currently free from many pests and diseases that affect international coffee growers, including the worst three – coffee berry borer, coffee leaf rust and coffee berry disease.

It is very easy for exotic pests and diseases from overseas to hitch hike into Australia. They can be carried in on:

- imported green bean – even sample packs from trade shows
- hessian bags in which the green bean is transported
- clothing and footwear

Exotic pests are usually invisible to the naked eye. Imports, packaging and clothing that 'look' clean and healthy can still harbour pests and diseases that can easily spread.

Coffee berry borers feed and reproduce inside green coffee beans, making them hard to detect.

Rust spores are adhesive, meaning they easily stick to clothing, footwear and packaging materials for long periods of time.

Rust spores can successfully infect new plants even after a week or more of sitting dormant on unwashed clothing or hessian bags.

Why is importing green bean so risky?

Live insects and disease spores can survive on fresh green bean and hitch hike on packaging such as hessian bags to be transported to Australia.

There are well established quarantine inspection procedures in place, however

- not every consignment is inspected
- microscopic disease spores and insects hidden inside beans are hard to detect
- insects and diseases can easily spread once introduced to a coffee growing area

The risk of an exotic pest or disease establishing in Australia is greatest when imported green bean is moved into coffee growing regions where it can infect our vulnerable coffee plantations.

How you can reduce the risk

When travelling to origin

- on returning to Australia declare to Customs that you have been on a farm
- declare any green bean samples you are bringing in
- launder shoes and clothes immediately when you get home

Importing green bean

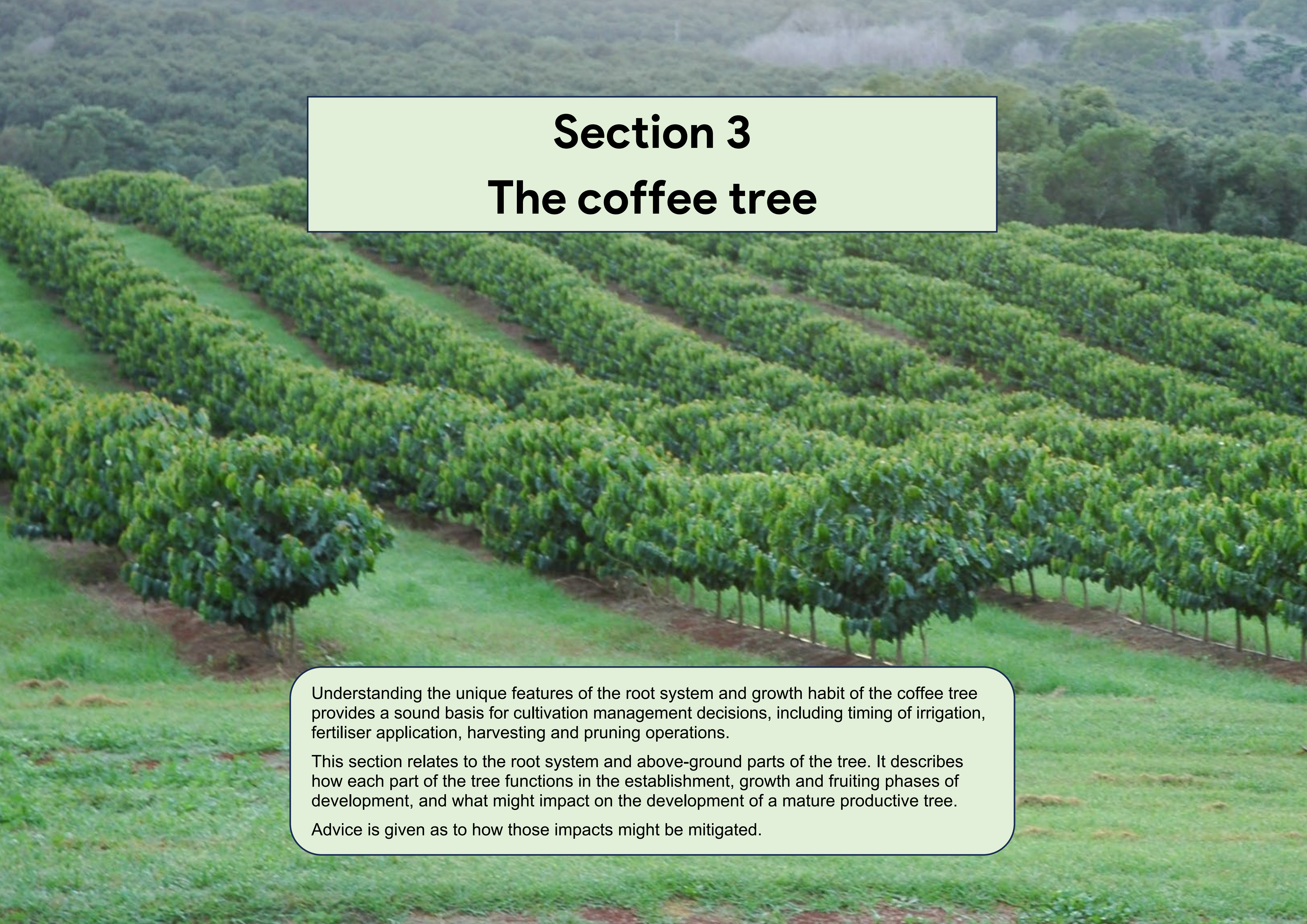
- don't bypass quarantine when importing micro-lots
- know your importers' quarantine protocols
- ask for certification that the green bean complies with quarantine requirements
- don't let imported hessian bags onto Australian coffee farms

Moving imported beans into coffee growing areas

- put in place a biosecurity plan
- separate imported beans and packaging from the plantation
- change clothing after working with imported beans and hessian bags
- dispose of hessian bags off farm
- regularly monitor for new or unusual pests or disease symptoms

EXOTIC PLANT PEST HOTLINE
1800 084 881

If you find a suspicious pest or disease in your imports or on your property, report it to the Exotic Plant Pest Hotline.



Section 3
The coffee tree

Understanding the unique features of the root system and growth habit of the coffee tree provides a sound basis for cultivation management decisions, including timing of irrigation, fertiliser application, harvesting and pruning operations.

This section relates to the root system and above-ground parts of the tree. It describes how each part of the tree functions in the establishment, growth and fruiting phases of development, and what might impact on the development of a mature productive tree.

Advice is given as to how those impacts might be mitigated.

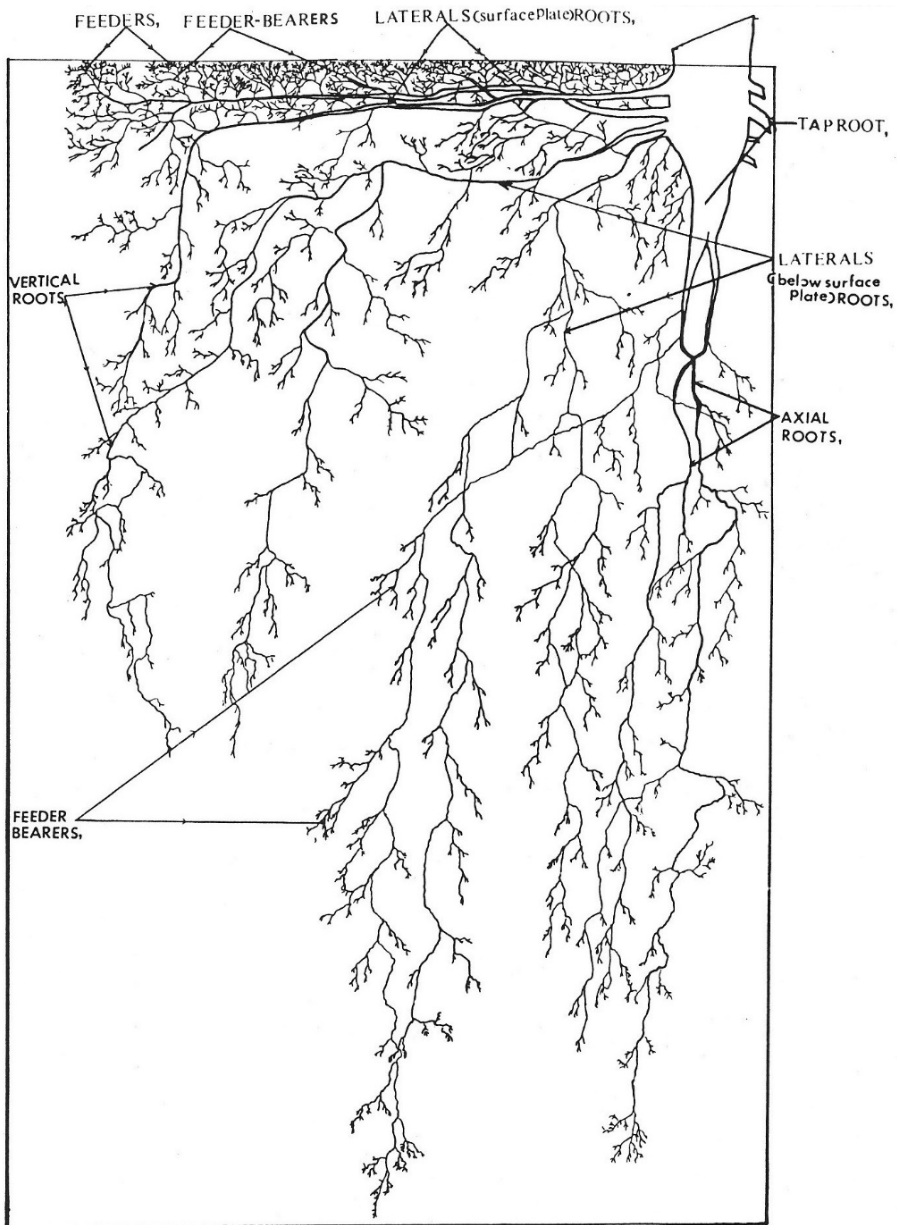


Figure 3.1: The coffee tree's root system.

The root system

While roots of the coffee tree can extend down to 3–4 metres in well-drained, dry loam soil, the greatest concentration of roots is at the 30–60 cm depth, followed by the 60–90 cm and the 0–30 cm layers.

Coffee roots are more likely to be concentrated in the surface 30 cm in poorly drained soils or in forest soils rich in humus. More than 90% of roots are also likely to be in the top 30 cm where rainfall is well spread, and/or where there is a good irrigation system, as deeper penetration of roots is not necessary.

There are five types of roots under a coffee tree:

1. Tap root is thick, often multiple and tapers abruptly at about 30–45 cm in depth. It is not like the normal tap root in other trees, which extend much deeper.
2. Axial roots – the four to eight axial roots extend deeper and run downwards from the forking of the tap root or from the lateral roots that have turned downwards. These axial roots branch in all directions and penetrate to a depth of 2.5–3 metres.
3. Lateral roots spread out horizontally from the trunk, branching parallel to the soil surface, and also become vertical, turning and continuing to grow downwards, branching in all directions like axial roots.
4. Feeder bearer roots vary in length and are generally shorter and more numerous in the surface soil.

   (These four root types with diameters above 3 mm are called the permanents and have a tough, darker outer layer.)
5. Feeder roots are white and fine, and are formed from the feeder bearers at all depths, but are also more numerous in surface soil. These fine white roots remain white and soft for at least two years.

Background	Problem	Management
The root system (Figure 3.1)		
• The tree’s axial roots can extend down 2.5–3 metres in well-drained soil.	A weak and unstable root system can be caused by: • Poor drainage or a clay layer • Soil compaction (Figure 3.3) • Rocks and rock shelf • Transplanting constricted or damaged roots.	• Check soil depth, deep rip the plant line and do not plant in poorly drained, shallow soils. • Mound tree rows to improve drainage and harvester efficiency. • Check the quality of plant stock.
• The deep, vertical (axial) roots and laterals provide the anchorage for stability.	• Seedling root systems are easily bent during transplanting into pots, and from pots to the field. • Trees with weak root systems are more susceptible to die back (from overbearing) and do not recover. • Premature ripening of cherry results in poor cupping quality.	• Ensure the main and axial roots are not bent or distorted when transplanting seedlings (see Section 8).
• The majority of lateral and feeder roots occur in the top 30 cm of soil. The tap root is short (30–45 cm).	• Trees are easily blown over (lodged) by wind and heavy rain.	• Remove/replace weak trees. • Use grass cover to protect roots from exposure through erosion.
	• The normal growth, flowering and cropping cycle is interrupted when the root system is restricted.	• Prevent water logging by providing good drainage and mounding, and do not plant in wet spots.
	• When trees are stressed by poor soil, nutrition and/or water, the roots are the first to suffer.	• Maintain high organic matter (mulching) under the tree canopy. • Test and adjust soils for compaction, water retention, organism activity, soil nutrition and pH balance. • See Sections 8 and 9 for more information.

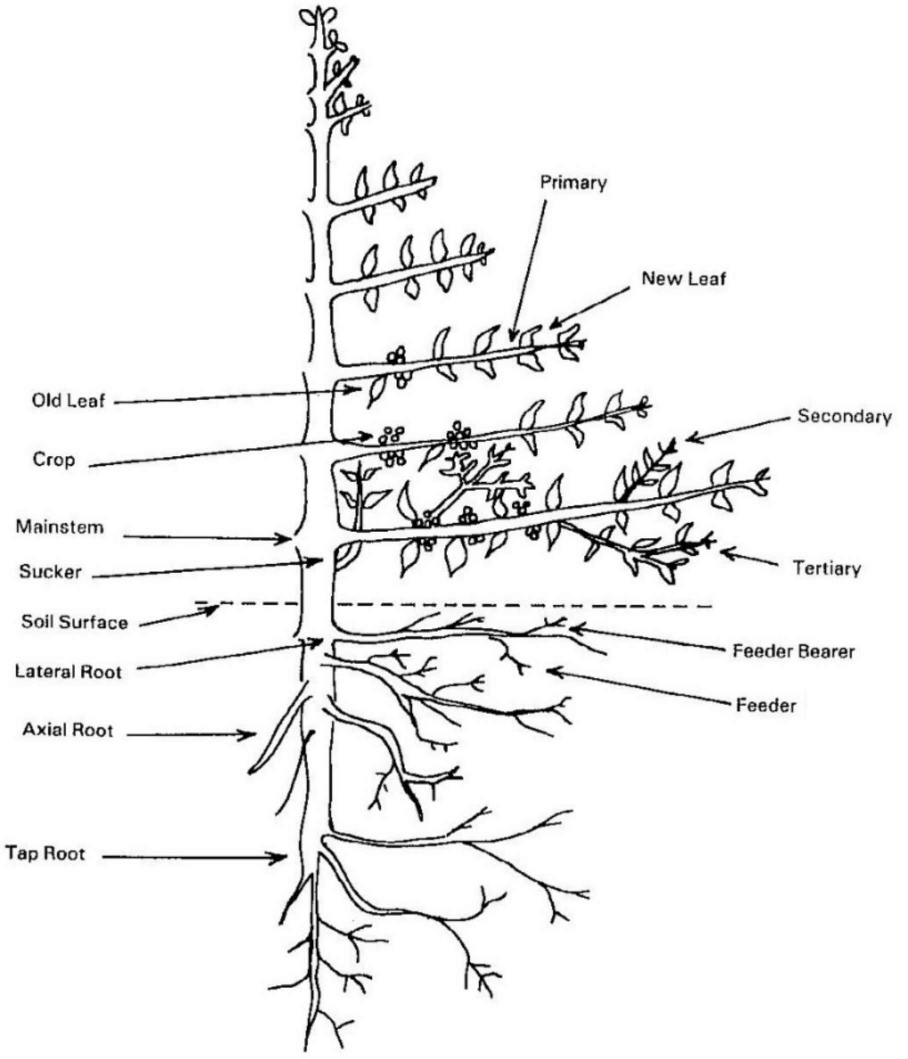


Figure 3.2: Branch hierarchy of the coffee tree.

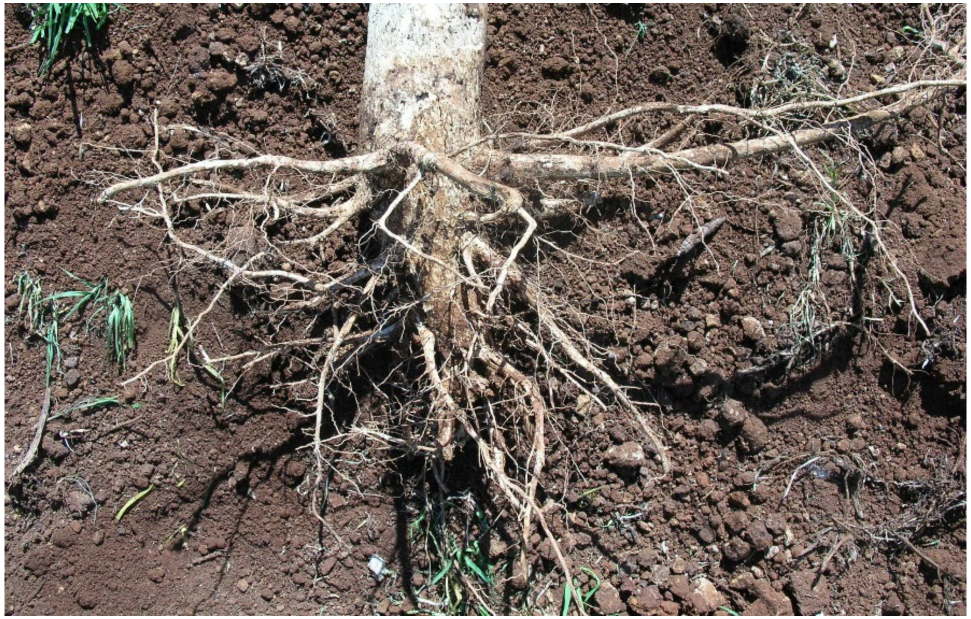


Figure 3.3: The root system has been constricted by a compacted clay layer.

Figure 3.4: The apical bud secretes hormones to prevent lower buds from shooting.

<table>
<tr><th>Background</th><th>Problem</th><th>Management</th></tr>
<tr><td colspan="3">The root system (continued)</td></tr>
<tr><td>Excessive irrigation of coffee during the establishment phase results in superficial roots being produced.</td><td>Penetration depth of the main axial roots may be reduced, resulting in poor anchorage.
The trees are also less able to withstand dry conditions and are unable to access nutrients and water effectively.</td><td>Avoid frequent, light superficial irrigations after the establishment phase (the first year after planting).
Ensure irrigation penetrates to below the root zone (see Sections 9 and 10).</td></tr>
<tr><td>Many plant hormones (auxins) that control flowering, fruit development and growth are produced in the roots.</td><td>A poor root system can result in overbearing, die back and irregular development of flowering and fruiting.</td><td>A healthy root system, good soil nutrition and water availability are essential for sustained yields and tree health (see Sections 9 and 10).</td></tr>
<tr><td>Coffee roots are the last to receive the plant foods (photosynthates) produced by the leaves.</td><td>Poor nutrition and root structure will cause rapid decline in tree health cherry productivity.</td><td>Ensure healthy leaf growth through foliar as well as ground fertilisation at critical times during periods of high nutrient take up (see Section 9).</td></tr>
<tr><td colspan="3">Main stem and branches (Figure 3.2)</td></tr>
<tr><td>The main stem (trunk) is the central axis of the tree. At the tip of the main stem is the apical bud, which controls the development of a main shoot from the main stem and all the buds below it.</td><td>If the apical bud (Figure 3.4) is damaged or removed when the tree is pruned, one or two of the lower buds in the leaf axil of the main stem will develop as suckers or secondary verticals to replace the last upright stem.</td><td>Avoid damaging the main shoot during growth of the tree until at its desired height (300–500 mm).
Remove suckers at the base of the tree and to a height of 600 mm to facilitate mechanical harvesting and focus tree growth.
Thin out other secondary verticals.</td></tr>
<tr><td>Trees such as the K7 variety typically have four types of branches:
Primary branches extend from the trunk.
Secondary, tertiary and quaternary branches extend from the preceding type.</td><td>If a primary branch is cut at the main stem, the branch will not be replaced by another as the lower buds in the leaf axils of the vertical shoots can only produce verticals or flowers.
If the horizontal primary branches are cut, they can produce more lateral branches as secondary and tertiaries or flowers, but they cannot develop into vertical shoots.</td><td>Pruning releases lateral buds from dormancy to produce new shoots.
See Section 14 relating to pruning for more information.</td></tr>
</table>

Figure 3.5: Mature green and immature bronze leaves of the K7 variety.

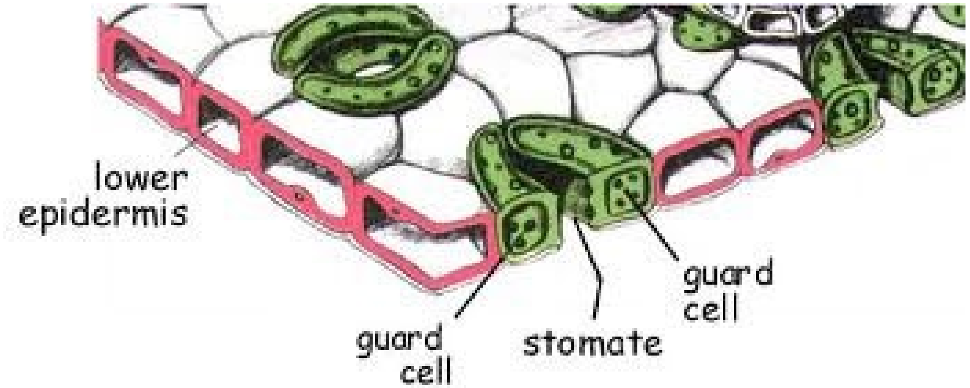


Figure 3.6: Diagram showing a stomate in the leaf.

Figure 3.7: Wavy leaf margins and drooping leaves indicate high temperatures, moisture stress and poor nutrition. This causes trees to 'shut down' and may result in leaf drop, predisposing them to die back.

Background	Problem	Management
Leaves and stomata (Figure 3.8)		
• New leaves are produced throughout the year to replace old leaves. • New leaves of some varieties (e.g. Catuai) are green, while new leaves of other varieties (e.g. K7) are bronze (Figure 3.5). • Mature leaves become dark green.	• Insufficient leaf development or leaf loss through stress reduces tree health. Beans within cherries will not properly form. • Extended dry periods will cause leaf loss. Without leaf cover, cherry is over exposed to the sun and prematurely ripens with immature beans.	• The critical time to promote leaf development through fertilisation is after harvesting and post flowering. • A sound fertiliser and irrigation regime will keep trees in full leaf.
• Stomata are tiny pores on the underside of leaves (Figure 3.6). They enable gaseous exchange in photosynthesis and respiration, regulating moisture loss and carbon dioxide concentration.	• Stomata are entry points for many fungal and other pathogens. • Extreme conditions of high temperatures and hot dry winds can cause trees to shut down and shed their leaves.	• Regularly check the undersides of leaves for signs of fungal growth. • Overhead irrigation will reduce the impact of extreme temperatures (high and low).
• Stomata open at sunrise and are fully open at a temperature of 25 °C, the optimal temperature for photosynthesis and gas exchange.	• Lack of adequate soil moisture combined with high temperatures cause the stomata to close and the tree shuts down its capacity to produce photosynthates (or plant carbohydrates) and transpire moisture. Leaves develop wavy margins and droop (Figure 3.7).	• Irrigate early in the day when high temperatures are predicted to minimise the impact.
• The surface of coffee leaves can record temperatures up to 10 °C above air temperature if their stomata cooling system is shut down.	• Exposed leaves become pale and are shed, and the tree may go into decline and develop die back.	• Spray irrigation will reduce leaf temperatures. • Plantation layout should take into account the direction of prevailing drying winds.
• The cooling ability of leaves through evaporation is lost at temperatures over 32 °C.	• Daytime temperatures, particularly in more inland locations, can exceed 32 °C for periods of a week or more. • If high temperatures occur too frequently and for extended periods, the tree's cooling mechanism (i.e. stomata) shuts down.	• Temperature regimes are a factor when considering location. • Little can be done to lessen the impact of temperature other than to grow under shade, however this will reduce yield. • High-density plantings provide self-shading within the canopy.

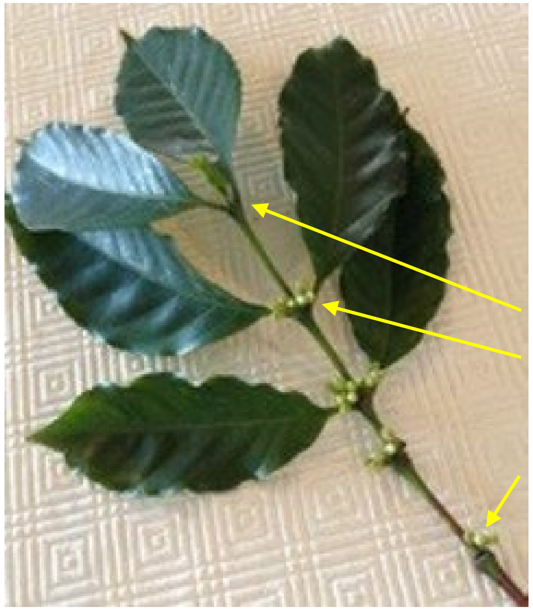


Figure 3.8:

1. Leaf axil.
2. Lateral buds at the leaf axil at the point of flowering.
3. Ring at the point where last year's growth commenced.

Figure 3.9: These 'candle' buds can become vegetative or flower buds.

Figure 3.10: Flower buds in the leaf axil.

Figure 3.11: Flower buds are triggered by rainfall or irrigation.

Background	Problem	Management
Leaves and stomata (continued)		
• At temperatures below 15 °C the stomata do not operate to their full capacity.	• Generally, this is not a problem, other than where land profiles cause pockets of cold air to be trapped. • The likelihood of frost is the principal consideration.	• Avoid planting in cold air hollows and remove vegetation that could trap cold air. • If perceived as a significant problem and other orientation considerations are not compromised, orient rows to allow cold air to pass down rather than through them.
• Stomata play a major role in maintaining the water balance within the plant.	• Internal water deficit (water stress) affects many physiological processes within the plant. • Chlorosis (yellowing) of leaves, leaf fall, sunburn of fruit, premature ripening, decrease in bean size and die back can occur.	• Maintain adequate soil moisture by monitoring soil moisture levels and irrigate according to crop load, weather conditions and stage of crop cycle (see Section 10).
Flowers and fruit growth		
• Bud development occurs in the leaf axil and is controlled by hormones from a serial bud (Figure 3.9 and Figure 3.12).	• Buds form in the spring but remain dormant until temperatures rise, and dry conditions are broken by a good rainfall (usually above 8 mm) or by heavy irrigation (Figure 3.10).	• Restrict irrigation to create an extended period of stress to break dormancy to induce flowering. • Promote growth immediately after heavy and prolonged rain by fertilising.
• A major flowering event occurs after a defined period of dry or cold stress and a significant rain or irrigation event to break dormancy. The whole plantation is awash with flowers 8–12 days after the rain trigger (Figure 3.11). • Temperature triggers the flowers to open. After two days, the flowers wither and the floral parts, except the ovaries (developing fruit), drop away.	• A single flowering is an ideal occurrence (Figure 3.13 and Figure 3.17). • However, intermittent rainfall in spring in the subtropics triggers multiple flowerings, making single-pass harvesting in this region impossible. • ‘Star’ or infertile flowers can result from excessively high temperatures in the tropics.	• Flower production can be stimulated by heavy irrigation once the flower buds have reached the ‘candle’ or swollen stage. • Overhead irrigation can reduce ‘star’ flowering during hot weather.
• Multiple flowering events happen if a series of spring rains occurs (Figures 3.15 and 3.16).	• As many as 6–8 flowering events can occur over a three-month period in the subtropics and in the higher-rainfall areas in the tropics. • The early flowerings can coincide with the final harvest.	• It is preferable to complete the harvest after a small flowering event to remove the crop and promote the later development of buds and flowers.

Figure 3.12: Plant hormones control the production of flowers from a serial bud. Until triggered by these hormones, the buds are flat and triangular in shape, and their fate as a vegetative shoot or flower is not yet determined.

Figure 3.13: Right and below: Flower clusters occur at each node and can set up to 30 fruits (cherries) at the node.

Background	Problem	Management
Flowers and fruit growth (continued)		
• Harvesting after flowering.	• Mature cherries held on the tree will hinder the development of next year's buds. • Harvesting flowering trees will hinder flowers from setting. • If harvesting is delayed, the cherry will rapidly ripen and be shed as the tree focuses on next year.	• Harvesting before flowering is the aim. • If the opportunity is missed and a major flowering occurs, further harvesting should be delayed at least a week to allow flowers to set. • Machine harvesting should be delicate or even abandoned, i.e. sacrificing the last of the crop.
• From 6–9 weeks after flowering, pinheads slowly develop (Figure 3.14). The pinhead then swells and the endosperm (the starchy tissue of the seed) forms. Full size is reached at week 20.	• Trees will shed those pinheads that it is unable to carry through to maturity.	• Undertake a fertilisation regime to match the nutrient requirements of the tree in line with pinhead growth.
• Seven months after flowering, the seed develops fully as dry matter is formed. Its structure and size are virtually complete. It then only needs to ripen.	• During this period, the young green cherries are most susceptible to damage through fungal attack, leaf loss and die back.	• Regularly check the wellbeing of trees. • Maintain good nutrition and irrigation to avoid Cercospora spot.
• A long ripening period over 3–4 months occurs in subtropical conditions. The timing and ripening period depend on factors such as altitude, topography, shading, tree health and distance from the sea. • Under dry tropical conditions, fruit development and fruit maturity occurs at a faster rate than in the subtropics.	• Starting to harvest too early can be costly in crop loss of immature cherry. • Cherries are also more difficult to remove early in the season. • Unseasonal rainfall can initiate multiple flowerings, making multiple harvesting passes necessary (Figure 3.15 and Figure 3.16).	• Monitor cherry maturity before harvesting (see Section 15 for details). • Attend to other tasks, check harvesting equipment and arrangements, and be patient. • Delay harvest until the critical maturity point is reached.
• Early ripening cherry.	• Early selective machine harvesting is difficult as cherries are harder to remove. • Harvesting costs are higher and unwanted immature green cherry is harvested.	• Hand pick or allow early-ripening cherry to mature to naturals as the remainder of the crop fully ripens.
• Under cooler conditions of the higher-altitude areas of the tropics, the timing of flowering, fruit development and maturity is similar to the subtropics.	• There is a greater chance of a harvesting/flowering conflict inland in the subtropics and in the higher-altitude areas of the tropics due to the cooler growing conditions and more frequent rainfall.	• Check cherry maturity over the plantation to assess timing and the number of harvester passes required.

Figure 3.14: Pinhead early fruit development.

Figure 3.15: Multiple flowering events result in size variation of green cherry.

Figure 3.16: Multiple flowering events result in different stages of ripening of cherry.

Figure 3.17: Synchronised cherry maturity from a synchronised flowering event.

Background	Problem	Management
Flowers and fruit growth (continued)		
• The coffee tree is unable to shed excess fruits. • The trees are committed to filling all the beans that are formed after the fruit expansion stage.	• Where plant food is limited, seeds do not fully develop. They compromise the quality of the harvest and have no value as coffee. • Poor pollination, nutrition or water management can result in a high percentage of poorly developed seed. • These poorly developed seeds are lighter in weight and need to be removed from the crop during processing.	• Cherry with undeveloped seed needs to be separated from viable seed: – separating from prime cherry is by floating them off from fully ripened cherry. – separating from fully ripened cherry is by hulling, with most being hollow or small, and thus discarded. • Those that remain need to be removed by size sorting.
• Seeds have priority for nutrients, drawing plant food away from the branches. • With a heavy crop and particularly when nutrients are limited, growth of leaves and shoots is restricted. • Coffee trees will drop their leaves instead of fruit.	• Die back will be evident. • Cherry ripens prematurely through die back. It will have poor liquoring quality and bean size. • Yellowing (chlorosis) and leaf fall will occur at fruiting nodes heavily populated with cherry.	• Ensure that adequate nutrition and water are provided according to crop load and climatic conditions (see Section 9 and Section 10). • Use an integrated approach incorporating a balance of slow-release natural mineral fertilisers to provide a more controlled release of nutrients rather than relying entirely on synthetic high-analysis fertilisers, which can promote troughs and spurts of growth.

Section 4
Growing coffee in Australia

The coffee-growing industry is well established in the tropical tablelands of far north Queensland and in the cooler subtropics of south-east Queensland and north-east New South Wales.

Traditionally, altitude has been the main criterion for growing high-quality coffee, however research and experience has demonstrated that altitude itself is less important than the interaction of soil, altitude, latitude, aspect and slope, and their combined effect on temperature and light. These factors make up the ‘terroir’ of the region where coffee is grown.

The potential to expand coffee growing to new production areas is emerging and changing climate may well facilitate this expansion.

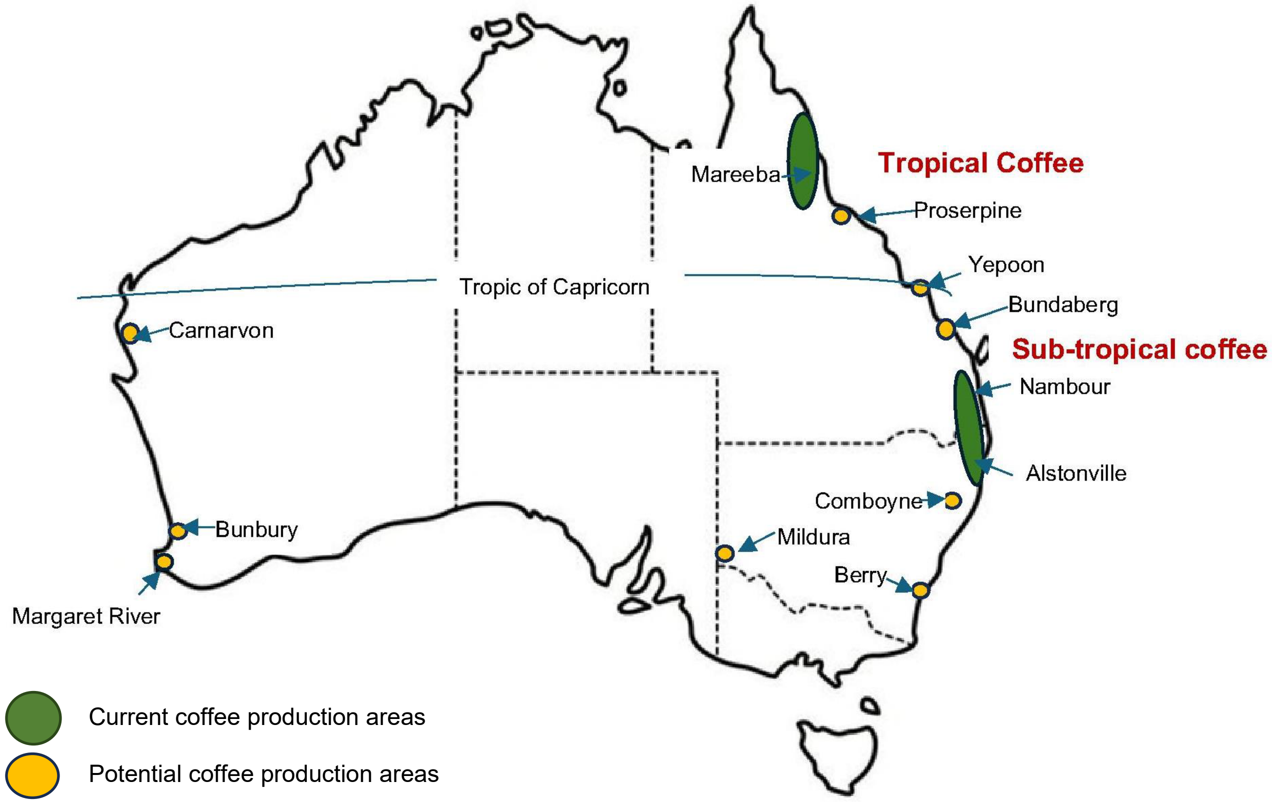


Figure 4.1: Coffee growing in Australia.

Figure 4.2: In the Tablelands of tropical far north Queensland, the climate, large areas of flat land and adequate water for irrigation are suitable for efficient machine harvesting.

Figure 4.3: In subtropical growing areas, milder temperatures and regular rainfall contribute to slower development and maturity period of the coffee cherry. These conditions extend the harvesting period.

Alstonville (sub-tropical)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature													
Mean max temp. (°C)	27.2	26.7	25.9	23.9	21.2	19.0	18.6	20.0	22.4	24.1	25.3	26.9	23.4
Mean min temp. (°C)	19.5	19.4	18.3	15.9	13.3	10.9	9.9	10.6	12.8	14.8	16.6	18.5	15.0
Rainfall													
Mean rainfall (mm)	177.8	224.9	260.6	196.7	182.4	164.6	94.3	74.8	55.6	109.2	132.7	153	1825

Mareeba (tropical)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature													
Mean max temp (°C)	31.2	30.7	29.9	28.6	26.9	25.5	25.1	26.4	28.7	30.8	31.8	32.1	29.0
Mean min temp (°C)	21.4	21.4	20.7	19.2	16.9	15.4	14.1	14.0	15.5	17.5	19.2	20.8	18.0
Rainfall													
Mean rainfall (mm)	235.3	221.4	149.2	47.8	14.6	10.5	9.7	6.8	5.9	15.4	35.4	120.0	863.4

Figure 4.4: Long-term temperature and rainfall figures for the subtropics and tropics

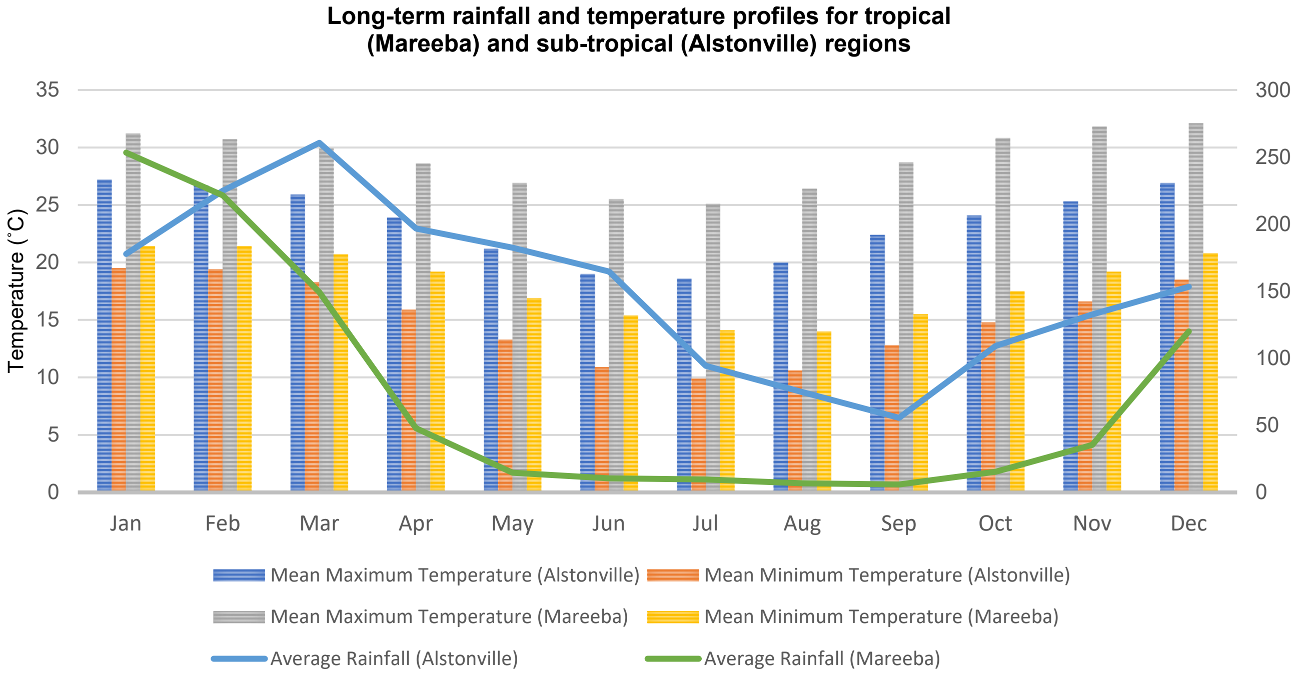
Temperature, soil, light and water are the four essentials for vibrant plant growth.

Locational characteristics that influence growth include latitude, altitude, aspect, slope and exposure to wind.

Temperature, soil, light and water, as well as other locational aspects, are each generally considered here,.

Current and potential coffee growing areas in Australia are in Figure 4.1, Figure 4.2 and Figure 4.3.

However, you are advised to refer in detail to the geological and climatic references and records for your region, and to seek out local knowledge to capitalise on more subtle variations.



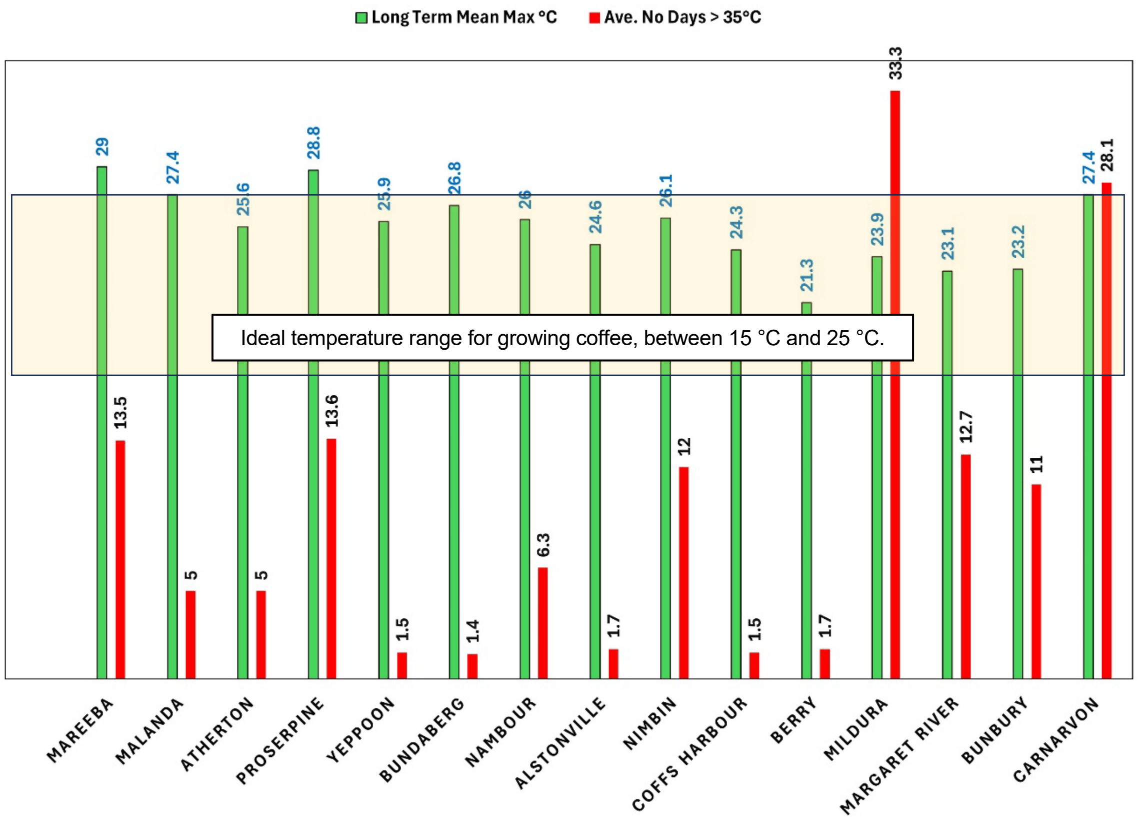


Figure 4.5: Long-term temperature data for existing and potential coffee-growing regions.

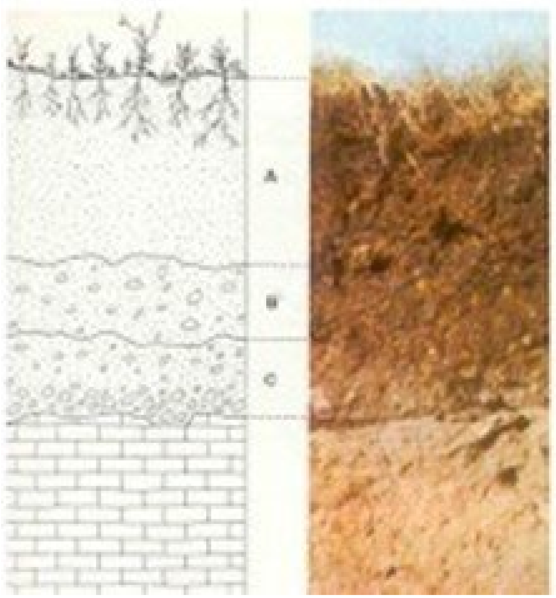
Figure 4.6: High temperatures above 33 °C for prolonged periods, and dry soil conditions cause wilting, and leaf loss.

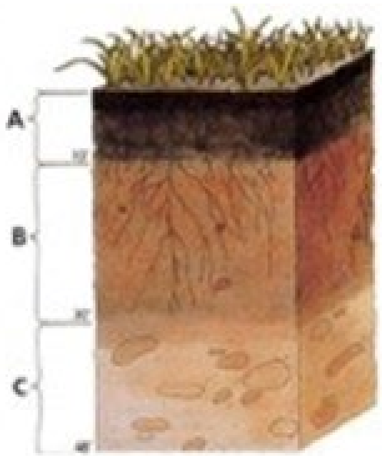
Figure 4.7: The big frost blast in Brazil in 2022 caused massive losses. Fortunately, in plantations in Australia, such damage, to date, has been rare. Avoiding frost risk areas is the first step in selecting a suitable location.

Temperature

Ambient temperature is the most limiting climatic factor for coffee growing. Coffee originated as an under-storey tree, it developed in rainforest where there was consistent shade and mild/moderate temperature variation. However, it has now been shown coffee provides higher yield under full sun with temperature mitigation from high density planting and adequate nutrition and irrigation.

Background	Problem	Management
High temperatures		
• Optimum temperatures for coffee are between 15–25 °C. • Figure 4.4 shows mean maximum and minimum temperatures for the subtropical (Alstonville) and tropical (Mareeba) coffee-producing regions. The long-term temperature ranges for existing and potential growing regions and the ideal temperature range for coffee are presented in Figure 4.5.	• Prolonged exposure to high temperatures (over 30 °C) accelerates leaf loss and induces a general decline in health and reduced bean size (Figure 4.6). • Temperatures above the optimum force rapid growth, early bearing, over-bearing on young wood, alternate bearing, early exhaustion of photosynthesis and dieback. • Hot bare soil can inhibit feeder root activity and hasten the onset of dieback.	• Select a suitable site (see also Section 5). • Select a variety with proven tolerance to high temperature. • Maintain irrigation and ground cover.
Low temperatures		
• Low temperature is the major constraint to commercial coffee growing in the subtropics and lower-lying land in tropical tablelands.	• Frosts kill coffee trees (Figure 4.7). • Even short periods below 0 °C will defoliate trees and destroy cherry. • Growth is restricted below 7 °C and young trees are injured below 3 °C. • Severe cold will ringbark the trees just above ground level.	• Check weather records to identify frost-prone areas and seek local advice to identify adverse micro-climate pockets of cold air. • Remove or thin out vegetation on lower slopes and mound planting rows to drain cold air. • Good ground cover (mulch or cover crop) serves to insulate from weather extremes. Keeping soil moist will also afford some protection if the frost is only mild. • Mechanical means, such as wind turbines, can be used to dissipate cold air.
Wide temperature variations		
• Wide ranges in temperature between night and day occur, particularly away from the coast. • If combined with a southerly cold change, the temperature change can be as much as 20 °C.	• Distorted yellow (chlorotic) new growth known as 'hot-cold' syndrome occurs when night temperatures suddenly drop. • Effect may be limited in duration and trees will produce healthy growth when temperatures moderate.	• Select a suitable site (see also Section 5). • Check weather records for regular diurnal day/night temperature variations. If they are prevalent, avoid exposed slopes or areas at risk of cold air pooling. • Do not force growth by over fertilising; healthy growth will resume when temperatures moderate.
Soil temperatures		
• Surface soil temperature can vary widely in a day, however this variation is less apparent at 15 cm below the surface. Under coffee bushes where the soil is protected from direct exposure, the temperature range is much less, varying only by 5 °C.	• Bare soil exacerbates soil temperature variation. • Frost damage is greatest in dry soils. • Hot bare soil can inhibit feeder root activity and hasten the onset of dieback.	• Strategies to reduce soil temperature extremes include maintaining good soil moisture, applying mulch and ground cover, and mounding planting rows.





Zone A: Organic activity, nutrient feeding

Zone B: Moisture and mineral absorption

Zone C: Trace elements absorption

Figure 4.8: Take trial bores and analyse the soil profile in terms of the structure of organic content and mineral composition to understand the 'terroir' with which you have to work.

For more information, see:

Malcolm, D. T., Nagel, B. K. A., Sinclair, I. and Heiner, I. J. (1999). *Soils and Agricultural Land Suitability of the Atherton Tablelands, North Queensland*. Queensland Department of Natural Resources.

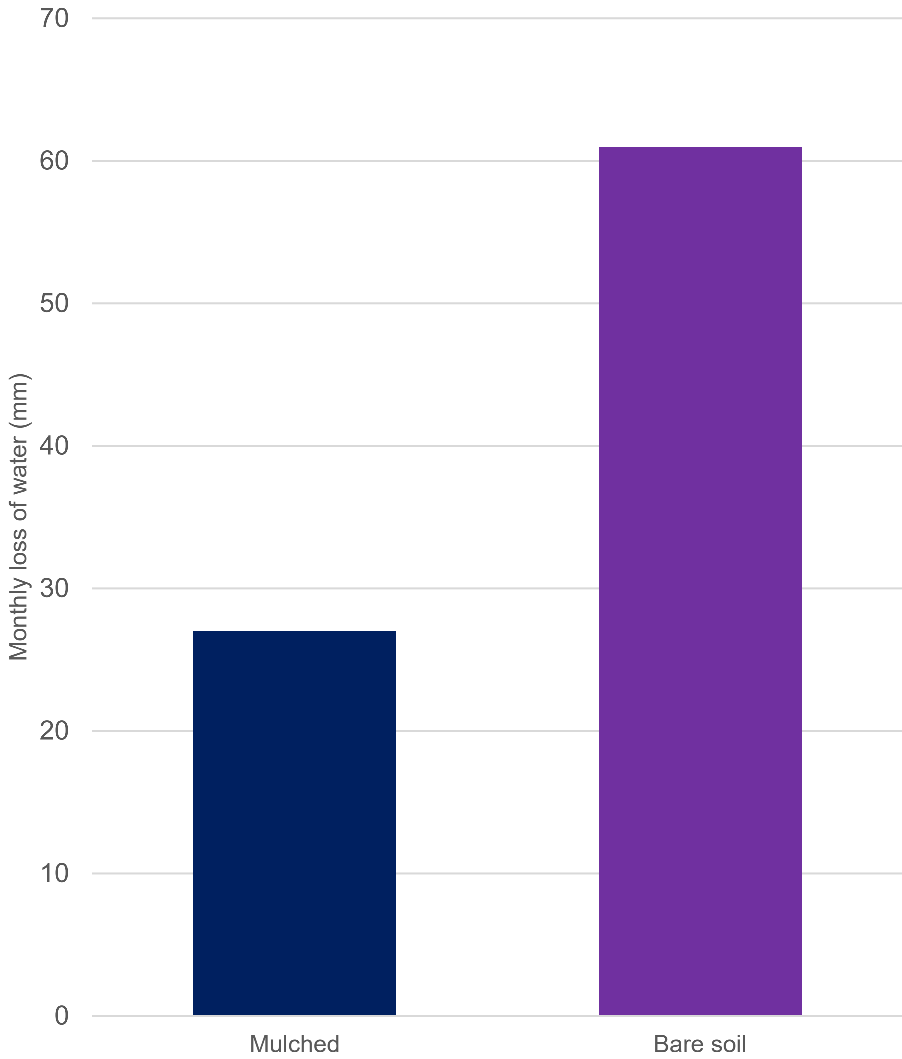


Figure 4.9: Example of the monthly loss of water by evaporation.

Soil

Coffee tree roots have a high oxygen demand and are easily drowned. Even occasional flooding for only a few days can severely damage the root system and render the trees uneconomic. Good drainage, natural fertility, high organic matter and capacity to hold sufficient moisture to supply the demands of the root system at all depths are ideal.

Background	Problem	Management
Soil type		
• Coffee can be grown in many soil types provided they are slightly acidic (pH 5–6). • A minimum depth of 1.5 metres of free drainage with medium texture and good aeration are considered best for commercial production.	• Acidity can increase through clearing, exposure and past agricultural practices. • Areas of rock shelf, clay layers, natural spring and 'pug' soils impede drainage, causing low oxygen supply to roots. • Areas of sandy soil are not suitable for coffee production due to excessive leaching of moisture and nutrients within the effective root zone.	• Select a suitable site (see also Section 5). • Take trial bores across the property to check the soil profile and depth prior to planting (Figure 4.8).
Mineral composition		
• Research has shown that the cupping quality of coffee is influenced by the nutrient and mineral composition of the soil. The balance of phosphorous, nitrogen, magnesium and potassium, together with trace elements, is of primary importance. • Natural mineral fertilisers with added biological activators and added silicon allow for slow release of nutrients and disease resistance.	• There are variations in the chemical soil composition from location to location, and even within plantations. • This may result in variation in flavour profiles. • Biennial bearing and dieback can occur due to inadequate soil nutrition and moisture. • The challenge is to present an overall consistency of the region's distinctiveness while maintaining the individuality of coffee from each plantation.	• Most acidic soils will need applications of dolomite or lime and enhancement of minor elements to maintain perfect growing conditions and the soil pH. • While quality can be influenced with applied nutrients, the contribution to flavour of trace elements is an important aspect of 'terroir'. • Research is currently underway to better understand the factors contributing to the various regions' distinctive coffee flavour and productivity.
Organic matter		
• Soils with a high organic content are desirable as they assist uptake of applied fertilisers, are less prone to erosion and offer better water and nutrient retention (Figure 4.9). • Organic matter provides a more even distribution of slow-release nutrients than synthetic fertilisers alone. • Some regions in their natural state are relatively high in organic matter (for example the subtropics, 18-20%). Other regions require the addition of organic matter to maintain high productivity and plant health.	• Land clearing, exposure and past agricultural practices could have reduced organic content to as low as 2–3%. • In the granite sands of far north Queensland, the soils are naturally lower in organic matter.	• Build up a good cover of under-canopy mulch to enhance organic matter in easily impoverished soils. • The practice of intercropping (for example planting coffee between macadamia and other tropical tree crops) to provide shade and weather protection, as well as organic mulch from decomposing leaf litter, is currently being investigated in the subtropics, mindful of interference with mechanical harvesting operations.

Figure 4.10: Left and above: These trees growing in full sunlight have had inadequate water and nutrition, with resultant loss of leaf and dieback.

Figure 4.11: This tree cannot support the heavy crop. Nutrients are being moved to the crop at the expense of the yellowing (chlorotic) leaves.

Environmental considerations

Apart from being necessary for photosynthesis, light intensity and day length control the behaviour of various internal growth regulators, including those controlling flower bud development. High-density plantings within rows create mutual shade provided by the coffee tree canopies, reducing light intensity and lowering leaf temperatures, as well as efficiently trapping solar energy. Avoid planting on steep slopes or areas exposed to strong wind.

Background	Problem	Management
Sun-to-shade ratio		
• Coffee is a shade-loving, mid-storey tropical rainforest plant. However, under-canopy production is not commercially realistic and management practices have been adapted to enable high productivity under full sun. • In the tropics, exposure to full sun can increase production provided the problem of water and nutrient stress is effectively managed.	• Exposure to full sunlight increases leaf transpiration (water loss) and evaporation from the soil, leading to water stress and suppressed photosynthesis, particularly in the tropics. • In the subtropics, the lower angle of the sun, particularly during the ripening period in winter, increases the uneven ripening of cherry on each side of the trees running in an east-west direction. Issued associated with this include: – uneven ripening increases harvesting costs as additional passes are required – the weaker winter sun reduces photosynthesis, which stresses trees and slows flowering.	• The less-harsh subtropical sun can be an advantage as it prolongs the ripening period, the disadvantage being uneven ripening from one side of the tree to the other. To negate this problem, avoid planting rows in an east-west direction. • Wider-spaced rows would allow greater light penetration to lower branches but at the cost of reducing the number of trees planted on the land available. • In the tropics, high-density planting creates mutual shade to mitigate the negative effects of full sun exposure.
Full sun or excessive shade?		
• In full sun, evaporation and nutrient up-take are greater. Shade is not required for high productivity or quality.	• In full sun, trees are prone to overbearing and dieback of laterals; branches and eventually the whole tree could die if nutrient or water stressed (Figures 4.10 and 4.11). • A biennial bearing cycle can result if trees become significantly stressed because of nutrient depletion. • Excessive shading can cause low yields and also difficulty with machine harvesting (under canopy).	• During extended dry spells, particularly during the ripening period, ensure adequate nutrition and water. • In the tropics, high-density planting creates mutual shade to mitigate the negative effects of full sun exposure. • Avoid planting near the canopies of adjacent trees. While intercropping can provide wind protection and soil enrichment, there may be issues with excessive shading and loss of nutrients to adjacent trees.
Exposure to strong wind		
• Sustained exposure to strong wind increases soil moisture requirement, retards growth, reduces leaf coverage and damages branches, leaves and flowers.	• Low yields, tree damage and reduced harvesting efficiency.	• Avoid planting on sites exposed to strong wind or that are in cyclone-prone coastal areas. • Protection from southerly and westerly winds is essential. • Use natural barriers (ridges, interplanting) and external and internal windbreaks to minimise damage.
Steep slopes		
• Steep sloping land has a poor moisture-holding capability, which is conducive to soil moisture stress.	• Low yields, poor harvesting efficiency on steep slopes above 15%.	• Avoid planting on steep slopes. • Orientate rows up and down the slope. • If steeper slopes must be planted on, ensure adequate irrigation.

Figure 4.12: Self-pollinating flowers last no more than three days.

Synchronisation of flowering can be achieved in the tropics by withholding water for 3–4 weeks. The stress brings on the flower buds, which are then ‘forced’ to open by heavy irrigation.

In the subtropics, this is more difficult to achieve as rain showers usually occur through the spring, preventing a period of water-deprivation stress, and then showers initiate flowering.

Figure 4.15: Even-sized cherry following a single flowering.

Figure 4.13: Pin-head cherry 3–4 weeks after flowering.

Figure 4.14: Uneven-sized cherry because of multiple flowerings weeks apart.

Figure 4.16: Even-sized ripe cherry following a single flowering.

Water

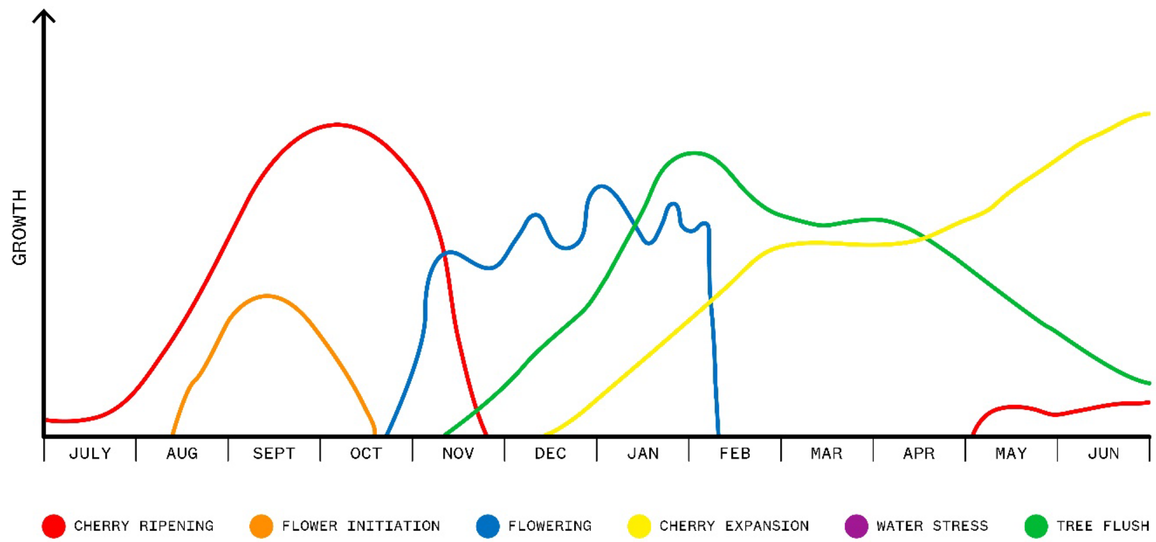
Water is intrinsically linked with the coffee growth cycle. Water controls the timing of growth phases such as flowering, vegetative growth and the sizing of the cherry. The tropical and subtropical growing regions have distinct differences in rainfall patterns which are to be managed accordingly. The tropical region has the advantage of more control over the growth phases due to the distinct dry season.

Background	Problem	Management
Rainfall (wet to dry season)		
• Flower buds are initiated during winter dry periods and will not flower until triggered by rainfall/irrigation. How rainfall is distributed throughout the year is more important than total annual rainfall (Figure 4.12 and Figure 4.13). • In the tropical region, the wet to dry seasons are more defined, which affords the opportunity to water stress the trees to synchronise flowering. • In the subtropics, there is less definition between the wet and dry seasons, with intermittent showers during the flowering period (Figure 4.4).	• In the subtropical region, the lack of a defined 'dry' season and the prolonged maturity period for the coffee cherry results in multiple flowerings and poor breaking of dormancy of flower buds (Figure 4.14). • Starting harvest too early in the subtropics, where there have been sporadic multiple flowerings, is costly as unripe cherry is removed prematurely.	• In the tropics, when there is a defined dry season, water deprivation followed by irrigation can be used to synchronise flowering (Figure 4.15). • In the subtropical region, not much can be done to control rainfall. Management must focus on harvesting according to the maturity of the coffee on the tree at the end of the season (80-85% of cherry is red) (Figure 4.16).
Irrigation by the growth cycle		
• In the tropical region, there are two times of the year when irrigation is critical: after the period of water stress (during peak flowering) to synchronise flowering response; and during rapid cherry expansion to maximise bean size. • There is less need for irrigation in the subtropics but irrigation is still useful for fertigation to restore nutrients, maintain tree health and minimise the risks of overbearing dieback and biennial bearing. • In the subtropical region, adequate irrigation and nutrition are critical during the bean sizing period (March–April). • Irrigation is also useful after harvesting to assist stressed trees to recover.	• Rainfall during the 'dry' season can inhibit water deprivation stress and compromise flowering synchronisation. • Water stress during the second critical watering period when cherries are rapidly expanding may cause additional fruit shedding. • Lower rates of photosynthesis can result in dieback of heavy-producing branches, exhaustion of plant foods and the commencement of a biennial bearing cycle. • Yellowing of leaves and shedding of leaves will occur as the nutrients are drawn to the cherry clusters. • Small bean size. • Sporadic or minimal flowering.	• In the tropical region, maximum and synchronised flowering is achieved by subjecting trees to a period of water deprivation stress, during which time flower buds are initiated. The stress period is broken, and flowering is initiated by heavy irrigation for three days (late September–December). • In the tropics, good watering is critical after the period of water stress and is also critical during rapid cherry expansion (water during December–January) to maximise bean size. • Maintain adequate water and nutrition levels using leaf and soil analysis, particularly during the bean sizing period (January-April). • In the subtropics, nutrients must be applied prior to the onset of cold weather (April–May) as the plant cannot use nutrients during winter months. • In the subtropics, withholding irrigation after harvesting in earlier-maturing coastal areas may improve the intensity of flowering by prolonging the stress period within the plant, however this is difficult to achieve in later-maturing plantations where flowering overlaps the end of the harvest.

The coffee tree's cycle of growth – flower initiation, flowering, cherry expansion and ripening

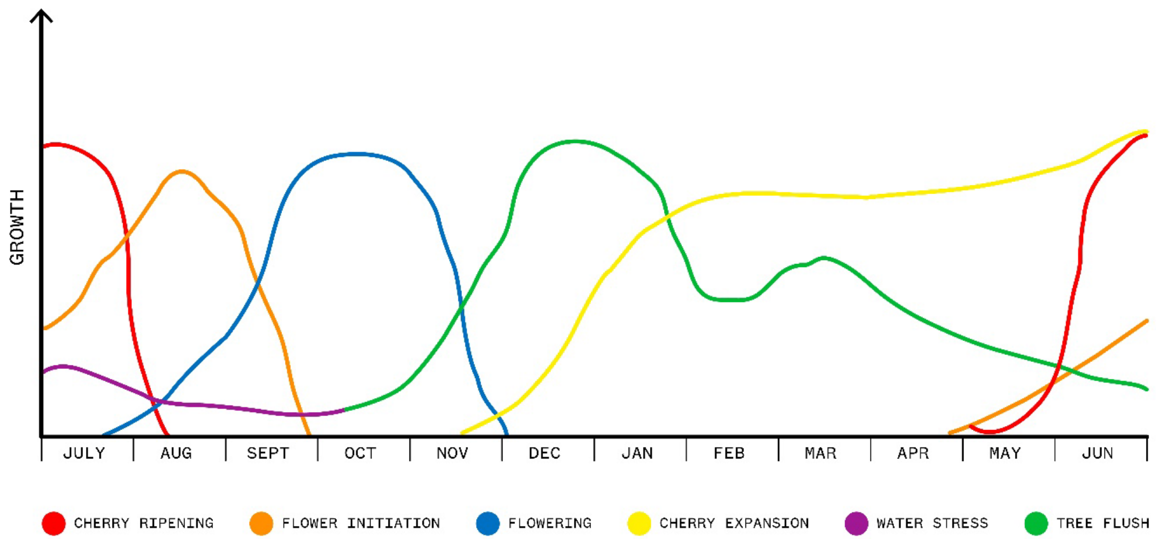
Subtropical conditions

- Slow ripening through winter months.
- Peak harvest from September–November.
- Multiple flowerings.



Tropical conditions

- Ripens through late summer/autumn.
- Peak harvest in June/July.
- Water stress through winter/spring.
- Synchronised compact flowering.



Section 5
Selecting a suitable site

Plantation sites need to be carefully selected as machine harvesting will not be successful in all areas. Protection from cold or persistent winds and access to adequate water for irrigation are essential.

This section provides a checklist of what to consider when selecting a site for commercial coffee production.

Checklist for land suitable to grow coffee

These issues are discussed in more detail on page 5.3.

Issue	Yes/No
1. Large enough area of suitable land and volume of production	
2. Long rows	
3. Flat or gentle sloping land	
4. Frost-free land	
5. North- to east-facing aspect	
6. Protection from prevailing winds	
7. Adequate reliable rainfall	
8. Slopes that allow rows to run north to south	
9. Adequate water storage	
10. Soil with sufficient depth	
11. Environmental considerations	
12. Proximity to processing facility	
13. Access to reliable services	
14. Reliable transport	

Agricultural land use maps for each region and local government area are available from:

- Queensland Government: https://www.qld.gov.au/environment/land/management/mapping/statewide-monitoring/qlump
- NSW Department of Primary Industries: https://www.dpi.nsw.gov.au/agriculture/lup/agricultural-mapping
- WA Department of Primary Industries and Regional Development: https://catalogue.data.wa.gov.au/dataset/soil-landscape-mapping-western-australia-attributed-by-wa-soil-group

Soils landscape series maps are available for each local government area and show the soil types. They describe characteristics of slope, soil depth, erosion risk and drainage limitations. They are available from:

- NSW Department of Environment and Heritage: https://www.environment.nsw.gov.au/topics/land-and-soil/information/espade
- Queensland Government: https://www.qld.gov.au/environment/land/management/soil/soil-data

These maps, in combination with the agricultural land suitability maps, are a good starting point when looking for suitable land for coffee growing.

Aerial or satellite photos

High-resolution aerial photography with a matching scale topographical overlay is available for most potential coffee-growing areas. Satellite imagery is also available from a variety of sources, including local and state government departments and private geographical imagery service providers.

These images with topographic map overlay (with contour intervals of five metres) allow potential coffee-growing land to be identified for slope, aspect and the plantable area available, as well as other features, including waterways, rock outcrops and protected areas.

Background	Problem	Management
• A large enough area is required for cost-effective harvesting and processing.	Small areas are unable to take advantage of economies of scale and produce sufficient volume of production to justify the high capital costs of harvesting and processing.	• A minimum of 30–40 acres of planted coffee is required to justify the purchase of a harvester and processing facilities. • Alternatively, smaller areas can be viable if harvesting is contracted and processing is done through a shared or central facility.
• Land for coffee growing should be frost-free.	• Coffee will not grow in frost-prone land and is severely setback by extended periods of cold weather (Figure 5.2).	• Check local maps and local knowledge on frost history of the property and avoid frost-prone land. • If frost risk is minimal, running rows down the slope and clearing breaks at the bottom of the slope through bushland will assist in draining cold air and prevent it pooling and creating frost. • Mounding of tree rows will also assist in draining cold air away from the tree.
• Land for coffee growing should be well drained.	• Coffee will not tolerate wet soil. Prolonged wet soil will kill plants.	• Select sites that are well draining and do not remain wet. • Mound coffee to assist in draining water.
• Land for coffee growing should slope less than 15% down rows and have a side slope less than 5% (Figure 5.3).	• Harvesting efficiency decreases on steep slopes above 15% and damage to the harvester shaker fingers increases on side slopes over 5%. • Operator safety is at risk on steeper slopes, particularly in wet slippery conditions.	• Select gently sloping land for tree rows. • Avoid an excessive side slope greater than 5-6% to minimise damage to trees and increase harvester efficiency.
• Orientation of planting rows must be suitable for optimal tree development.	• Slopes that allow rows to run north to south enable even ripening of coffee cherry on each side of the tree rows. This is more relevant in the subtropical areas.	• A compromise layout having regard to the ideal harvesting arrangement and optimum ripening will be required.
• Trees must be protected from cold and persistent winds.	• Cold and persistent winds will damage trees and reduce yields significantly. • Young trees are easily blown down or inclined at an angle, leading to root damage and profuse suckering. • Bark at soil level can become chaffed, leading to disease entry or ring barking.	• Avoid sites exposed to strong prevailing winds. • Get professional advice on the placement and appropriate height and effectiveness of planting windbreaks. • Windbreaks should not impede cold air drainage from the coffee planting as this can increase frost risk.

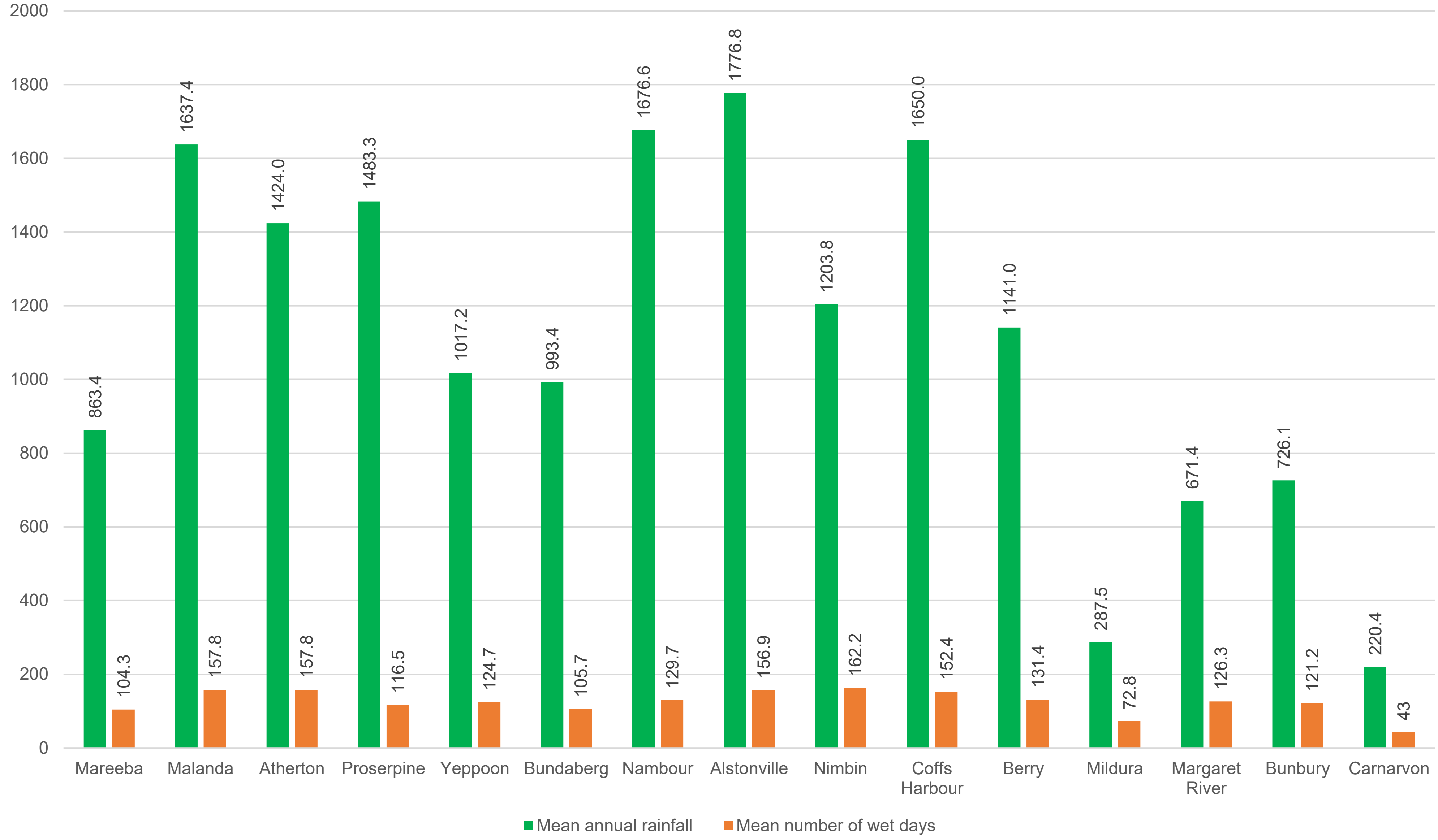


Figure 5.1: Long-term mean rainfall data for existing and potential coffee-growing areas.

Background	Problem	Management
• Adequate reliable rainfall or irrigation after flowering and during the bean sizing period is essential to maintain productivity. • See also pages 4.2 and 4.11.	• In the tropics, inadequate rainfall or irrigation after flowering (October) and during the bean sizing period (December–February) will reduce bean size and the trees' ability to mobilise nutrients to maintain summer and autumn flush growth (Figure 5.1). • In the subtropics, bean sizes and productivity will be reduced if rainfall or irrigation is inadequate after flowering (November–December) and during the bean sizing period (March–April) (Figure 5.1). • Over-cropping and dieback are likely if trees are stressed by inadequate water and nutrition during the period of rapid growth and bean sizing.	• Wetter areas in the tropics (coastal) and elevated southern areas of the Atherton Tablelands should be avoided if one-pass harvesting is planned. • Supplementary irrigation is strongly recommended to meet demand for moisture during critical times of growth and bean sizing. • Check with local authorities on entitlements for on-farm storage, accessing water supplies and water trading (Figure 5.4). • About four megalitres per hectare of irrigation water is required in the subtropics (See the 2003 publication *Best Management Guidelines for Irrigation of Coffee in the Sub-Tropics*).
• Poor-draining or heavy clay soils are unsuitable for coffee growing. Four to five days of inundation can kill coffee roots. • Soils should have good structure, high organic matter, cation exchange capacity and biological activity.	• Heavy, shallow or compacted soils will restrict root development and the capacity of the tree to access adequate nutrients and soil moisture. • Trees planted in these soils are prone to lodging (being blown over if carrying a heavy crop). • Waterlogging will kill coffee trees.	• Check soil maps for the area and understand the attributes and limitations described for the soil types present. • Undertake a soil test for the physical, chemical and biological components. • Soils should be free draining to a depth of at least one metre.
• Environmental impacts when processing coffee should be considered.	• Disposal of waste from processing is of major concern close to waterways and urban and environmentally sensitive areas. • Organic waste products have a high biological oxygen demand, which can pollute waterways. • Strict local and state regulations prevent disposal of waste into watercourses.	• Consider using an existing processing facility with approved waste disposal capacity or investigate alternative processing systems that have low or nil water requirement. • Holding ponds and reed filtration systems are used in some areas to reduce the pollutants and prevent wastewater from leaving the property. • High-tech bio digester systems are also available.

Figure 5.2: Three-year-old K7 trees killed by frost at the ends of rows in the gully where cold air accumulates.

Figure 5.3: Steep slopes and uneven topography are not suitable for machine harvesting.

Background	Problem	Management
• Close proximity to processing facility.	• Transporting unprocessed cherry long distances is uneconomical and can lead to quality problems caused by uncontrolled fermentation and contamination.	• Harvested cherry should be pulped or cool stored within a few hours to minimise quality problems if the fully washed or semi-washed processing systems are used. • Proximity to processing is not as important with the natural or raisin-processing systems.
• Access to reliable services.	• Mechanical harvesting and processing are highly technical operations that require specific expertise and prompt response to breakdowns or problems. • Mechanical, electrical, hydraulic, transport and spare part services are critical during the harvest and processing period. • Irrigation and agronomic services for trouble shooting and management support are required.	• Locating the enterprise close to these services is necessary if the harvester and/or processing facility is to be located on the property. • Using contractors for both harvesting and processing will reduce the need to locate close to services.

Figure 5.4: Tinaroo Dam in the dry tropics of far north Queensland provides irrigation for the entire Tablelands region.

Section 6
Preparing the site for planting

Time spent planning and preparing the layout of the plantation well before planting time will produce dividends in later years by achieving yields of optimum quantity and quality.

Operational costs are reduced through facilitating efficient farm operations, reducing the potential for soil erosion and damage to farm machinery.

Building a healthy soil environment in which the coffee root system can become established and be maintained is essential for sustained tree health and productivity.

Figure 6.1: Heavy-duty equipment, though more expensive, is more cost effective as the job gets done better and quicker.

Site preparation timeline – tropics

Dry season					Wet season						Dry season					Wet season							Dry	
Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**
Clear land Design plan	Layout mounds		Rip plant rows Weed spray planting rows Install irrigation Lay mulch		Apply pre-planting nutrients Plant ground cover				Control weeds Mow inter-rows				Harden off plants Weed spray Rip again	Planting Water in Add thick layer of mulch		Water when needed Plant smother grass/ground cover Control weeds Apply nutrients and build up mulch								

Site preparation timeline – subtropics

	Spring			Summer			Autumn			Winter			Spring			Summer			Autumn			Winter		
Aug	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**
Clear land Design plan		Layout mounds		Rip plant rows Weed spray planting rows Install irrigation Lay mulch				Apply pre-planting nutrients Plant ground cover			Control weeds Mow inter-rows		Harden off plants Weed spray Rip again		Planting Water in Add thick layer of mulch		Water when needed Plant smother grass/ground cover Control weeds Apply nutrients and build up mulch							

Figure 6.2: Mounded rows spaced 3.8 m apart and running down the hill, suitable for the tall varieties to avoid row-to-row shading.

Figure 6.3: Rows of semi-dwarf varieties can be as close as three metres apart. There is less shading row to row from the shorter trees.

Background	Problem	Management
Clearing the land		
• Heavy-duty equipment, though more expensive, is more cost effective as the job gets done better and quicker (Figure 6.1). • A plan is needed to ensure all tasks are completed in time for planting the first seedlings. These tasks are outlined in the site preparation timelines for the tropics and subtropics. • Land clearing should start at least 12 months before planting if tree clearing is required.	• Regulations apply to tree clearing and clearing land within the buffer areas of watercourses. • Pushing timber into gullies may interfere with natural drainage and run-off for watercourses. • Old stumps, rocks, sticks and uneven terrain will reduce the efficiency of cultivation operations, mowing and harvesting, etc.	• Check with local and state government agencies on regulations relating to tree clearing and protection of watercourses. Professional advice may be required on the location of headlands, surface drains, grassed waterways, access roads and dams, etc. • Use existing tree belts and natural topography to provide protection from wind. • Remove old stumps to reduce the risk of infecting the coffee trees with Fusarium or Armillaria wood rots.
Planning the plantation layout		
• Plan for the optimal long-term outcome of a healthy and productive plantation.	• If the whole plantation consisted of trees of the same age, there would be a risk of a diminishing crop over the years. • Complete loss of crop could result from pruning or replacement of all the trees at the same time.	• Divide the plantation into blocks. • Instead of planting out all the available land at the outset, consider planting blocks of trees each year to enable cyclical pruning, and ultimately cyclical replacement planting. This will decrease the chances of years without a crop.
Marking out the rows		
• Locating the rows in the best direction to suit the topography is critical to the success of harvesting, irrigation efficiency and even ripening of the cherry.	• Locating rows to suit the slope alone may not be the optimal direction for sunlight penetration, even cherry ripening and irrigation efficiency.	• Compromises will often have to be made because of the topography on most properties; however, maintaining the predominant north-south row orientation should be the major consideration when locating rows. • Operational efficiencies can be gained by adjusting the block designs to suit machine harvesting operations and the pruning rotation program.
• Row spacing will vary according to the growth habit of a particular variety (Figure 6.2 and Figure 6.3).	• Tall, vigorous varieties such as K7 will readily shade out the inner row and reduce light to the adjoining rows if planted too close.	• Semi-dwarf varieties such as Catuai can be planted closer at 3.5–3.75 metres apart. Taller varieties, such as K7, can be planted at 3.8–4.0 metres apart.
• Row spacing depends on the space required to operate inter-row machinery.	• Adequate space needs to be created for machinery to pass through without damaging trees, crops and equipment, and to turn around at the end of rows.	• The canopy of a healthy and mature K7 tree extends to approximately one metre from the main stem. Consider what machinery is to be used and in addition what extra space is necessary for damage-free operation. • Make provision for a headland width of 10 metres to allow the harvester to turn easily.

Figure 6.4: The ‘winged keel’ implement uplifts the soil, shattering compacted layers without disturbing the soil surface.

Figure 6.5: A well-prepared site with mounded rows; groundcover yet to be established; irrigation pipes laid out.

Background	Problem	Management
Preparing the soil		
• Coffee requires deep, well-drained soils for good root structure, optimum growth and sustained productivity.	• Compacted clay pans, clay layers or impermeable rock shelf will impede root development.	• Break up compacted cultivation pans or clay layers along the planting row using a single ripping tyne, which efficiently loosens well-structured deep soils.
• Soil within the plant line needs to be sufficiently broken up and have a friable nature for bedding-in plants and to facilitate root development.	• In heavily compacted soils, clay pans and clay layers, a single tyne fails to provide the width of lateral disturbance or shatter required. A width of 150 mm and a depth of 450 mm is desirable.	• Double or triple offset ripping provides sufficient lateral disturbance of any restricted layers. However, extra time and costs are involved. • Re-compaction of previously worked ground can occur.
• Incorporating organic matter.	• Where fresh organic material is left on the soil surface, the rippers tend to 'ball up' or gather grass, making it difficult to retain an even surface and consistent depth of rip.	• Prepare planting rows well in advance by hard slashing vegetation and, if necessary, applying a herbicide. • Rip when soils are dry (see also below). • Multi-gang rippers deal better in such situations but are difficult to operate.
• A 'winged keel' implement designed by CSIRO (Figure 6.4), when fitted to a single ripper, maximises lateral shatter and minimises the disturbance of the natural soil horizons. It minimises the inversion or turning over of the soil profile.	• The 'winged keel' implement overcomes problems of compacted soil and vegetation balling up.	• The operation creates a basic friable soil to a depth of 360 mm for root penetration. It creates a 'bow-wave' uplift effect behind the implement. • Multiple workings of the planting bed reduce the size of clods and help break up organic matter.
• Once the soil is broken up, ripping the plant line a second time will increase its friability.	• Extra time and cost are involved in improving soil structure. • Planting in lumpy soils will reduce the percentage of the plants striking successfully.	• It is better to spend more time and money creating a good planting environment in the soil than having to replace dead plants.

Figure 6.6: As soon as the earthworks and mounding are completed, sow a quick-growing groundcover, such as Japanese millet, to minimise the loss of soil from storm or heavy rains.

Figure 6.7: Trees planted on a low-profile mound, with drip irrigation and mulch.

Background	Problem	Management
Preparing the beds for planting		
• The ideal planting bed for hand planting is a good friable mineral-rich soil with high levels of well-decomposed organic matter.	• Inadequate soil depth, low organic matter and poor soil structure will impede root development.	• Forming low-profile mounds (Figure 6.5) increases the effective root depth, improves harvester efficiency and reduces the risk of frost to the base of young trees. On sloping land, it mitigates against soil erosion.
• Allowing the soil to 'settle' and remove large air pockets will help in establishing good root development.	• Air pockets within the soil hinder root development. • Broken soil that remains lumpy will need to be broken down (heeled in) around the seedling, prolonging the process and increasing the potential to damage the plant.	• Prepare the ground well ahead of planting. • If time is constrained, additional mechanical cultivations will be required.
• Plant groundcover on newly prepared beds.	• Freshly tilled bare ground is subject to erosion.	• As soon as the earthworks and mounding are completed, sow a quick-growing groundcover, such as Japanese millet, to minimise the loss of soil from storm or heavy rains (Figure 6.6).
• Apply nutrients before planting.	• The shock that seedlings experience when transplanted needs to be compensated by providing them with a new environment that promotes their establishment.	• Incorporating a mineral-based fertiliser containing rock phosphate and natural minerals with organic manures or biological soil activators is recommended at least six months before planting. • These products provide an active biological root zone for the coffee seedling; improve the soil structure; and provide a slow and longer-lasting release of nutrients to the young plant.
• The condition of the soil.	• Nutrient imbalances, leaching and burning of roots and foliage can occur as a result of over-fertilising, using the wrong fertiliser or not adjusting the pH.	• The number of soil samples required will depend on the size of the property, the topography, the range of soil types, the depths and drainage. • Soil sampling kits are available from all agricultural service stores and suppliers. Buy the kit and follow the instructions for sampling the soil to give a true reading of the property. • Detailed instructions for collecting a soil sample for analysis can be found in Section 9.20. • Do a soil analysis and apply the required pre-plant nutrients and conditioners, such as gypsum, lime, minerals, organic matter, etc. • Avoid highly soluble fertilisers in pre-planting.

Figure 6.8: Laying electric conduit and irrigation pipes in new trenches.

Figure 6.9: Poly drip lines laid out on a mounded row free of weeds. Note the groundcover in the inter-row.

Background	Problem	Management
Irrigation		
• Providing an irrigation system enables a measured delivery of moisture and nutrients to plants (Figure 6.8, Figure 6.9 and Figure 6.10). It needs to be designed and established when planning and laying out planting rows.	• Young plants require a steady supply of moisture, particularly for the first six weeks and thereafter for the first year of growth. • Irrigation is an expensive capital cost, is susceptible to damage and requires ongoing maintenance. • Irrigation may not be required every year, but it only takes one or two dry years at critical times to start dieback and a biennial bearing cycle.	• Modern irrigation systems allow automated watering according to plant need. Typically, in the first six weeks, irrigation is likely to be necessary every other day and beyond that twice a week. • Factoring in the costs and benefits of irrigation is essential (see the 2003 publication Best Management Guidelines for Irrigation of Coffee in the Sub-Tropics). • Use qualified irrigation specialists at the planning stage to design an irrigation system to suit the particular features of microclimate, topography and planting layout.
• The provision of moisture and nutrients is most critical and labour intensive at the establishment stage.	• If an irrigation system is not installed, watering is a labour-intensive activity. • Irrigation is required immediately after planting to remove air pockets and provide direct contact of the soil with coffee plant roots.	• Immediately after planting, each plant needs to be supplied with about two litres of water. Without rain, plants will require the same amount every four days (Figure 6.7). • Irrigation is covered in more detail in Section 10.

Figure 6.10: Pressure-compensating drippers are designed to provide the same amount of water at each dripper over a wide range of pressure variations in the irrigation line. These variations may result from ground undulations, length of slope or poor design.

Figure 6.11: African sweet smother grass controls erosion and tolerates shade.

Figure 6.12: African sweet smother grass is planted using the runners or as potted plugs, which can be contract planted.

African sweet smother grass *(Dactyloctenium australe)*

Highly effective in protecting the soil from erosion, it is best planted in the late spring or early summer with the onset of the summer rainy season.

For herbicide and pesticide products registered and permitted for use on coffee plantations in New South Wales and Queensland, refer to the Australian Pesticides and Veterinary Medicines Authority website (http://www.apvma.gov.au/). More details can be found in Section 11.

Background	Problem	Management
Controlling weeds and preventing erosion		
• Cultivation is the first step in effective weed control. The emphasis is to provide a planting bed free of weeds and weed seed.	• Cultivating the soil to prepare the planting mounds results in a proliferation of invasive and aggressive broad-leafed weeds, such as farmer's friends (*Bidens pilosa*), blackberry nightshade (*Solanum nigrum*). Amaranthus spp., inkweed, fleabane, etc.	• Once these weeds germinate after cultivation, they should be sprayed before they set seed to deplete the weed seed bank in the soil. • Not allowing any seed to set once cultivation commences will enable young coffee seedlings to establish without severe competition. • Glyphosate and a range of other herbicides are permitted on pasture before coffee seedlings are planted.
• An application of a pre-emergent herbicide is desirable just prior to planting to give seedlings a good, competitive start.	• Weeds easily outcompete the young and shocked seedlings to moisture and nutrients. • Weeds that establish in inter-rows will quickly invade the cultivated ground in the plant rows.	• An option is to incorporate a pre-emergent herbicide containing the active ingredient, oxyfluorfen (Stomp®, Goal® and Cavalier® are examples of brands available. • Apply at, or immediately after, planting and repeat after three or four months. • It is critical to apply herbicides to wet ground and best if there is follow-up rain within 21 days. • Spraying the weeds that emerge after the final cultivation will give plants and groundcover a chance to establish. • It is easier to kill weeds prior to planting the coffee seedlings. • Once seedlings are planted, any herbicide spraying needs to be carefully controlled to avoid drift onto the seedlings.
• Planting a suppressive groundcover in inter-rows after mounds have been formed will help reduce weed infestation and minimise erosion.	• Mounding creates the potential for erosion and an open breeding ground for weeds. Inter-rows need to be without ruts, and be weed-free, mulch-generating environments.	• Inter-row groundcover should be quickly established and regularly cut to stop seeding and build up mulch around the new plants. • Japanese millet germinates quickly and provides temporary stability of the soil (Figure 6.6). • African sweet smother grass (*Dactyloctenium australe*) (Figure 6.11 and Figure 6.12) is highly effective in protecting the soil from erosion. It is best planted in late spring or early summer with the onset of the rainy season.
Mulching		
• Mulching can assist in suppressing weed growth and building soil fertility prior to planting.	• Not recommended for mechanical planting. Undecomposed mulch will hinder planting. It is a potential source of disease. • Live weed seeds in mulch can be a problem.	• Spread a layer of well shredded mulch, 300 mm wide along the planting rows. • Use weed-free mulch material, such as sugar cane mulch, silage, baled straw or mulch from recognised weed-free sources. • Apply well in advance of planting the seedlings.
• Vigilance against weeds gaining a foothold is required for the next two years and until plants have established a lush leaf canopy.	• Only permitted herbicides are to be used once the seedlings are planted.	• During the early months, selective hand spraying is recommended and then great skill is required when mechanically spraying.

Section 7
Coffee variety and propagation

Coffee is similar to wine in many ways, and like wine, flavour (acidity, body, etc.) is largely determined by the ‘terroir’ (topography, microclimate and soils) where it is grown, rather than the variety.

Varietal characteristics, such as tree height, shape, suitability for machine harvesting, ripening pattern, yield potential, resistance to pests and diseases and suitability to local climate and soil conditions, must all be considered when choosing a tree variety.

This section outlines the process, pitfalls and management advice to produce that all-important ‘right’ tree once the variety is selected. The aim is to produce a healthy, true-to-type seedling with a well-structured root system.

Figure 7.1: The moisture content of coffee seed is tested using a grain moisture meter. When storing seed for propagation, a moisture content of 40% will ensure maximum viability. This is a helpful tool in the nursery and the processing shed.

Figure 7.2: The colour of new leaf growth is a good indicator of 'off-types.' The K7 variety has bronze tips (left), while the green tips (right) indicate a different variety or off-type.

Figure 7.3: Coffee plants are self-pollinating.

Arabica coffee plants are self-pollinating as their flowers are hermaphrodites. By the time the flower opens, 95% of flowers have already been pollinated, so they do not require another coffee plant to produce their fruit.

Some degree of cross-pollination does occur, as coffee bushes do have a flower that produces nectar and pollen. Insects, gravity and wind play a role in pollination.

It is accepted that pollinators can increase yield by up to 10%.

It is also important to bear in mind that the flowering period is quite short, lasting about three days.

Coffee is generally propagated from seed using a variety of methods, as outlined in this section. The underlying aim in all methods is to ensure the development of a sound root structure, avoiding a bent root ('J-root').

Background	Problem	Management
• The variety you choose to grow will depend on a number of factors: – Hand or machine harvest – Need to prune – Topography, soil and climate – Resistance to disease – Availability of seed/seedlings.	• In the subtropics, K7 has proven to be a vigorous grower and requires pruning every three years after trees reach four metres in height. This can result in loss of production for up to two years, depending on the severity of pruning. • Australia is one of the only countries worldwide that is free from coffee leaf rust: – Catuai is the main variety in the tropics and is susceptible to coffee leaf rust – K7 is resistant to many strains of coffee leaf rust. Further testing for resistance against all strains is required – The newer semi-dwarf varieties that are resistant to coffee leaf rust have not had extensive field testing as of 2024.	• It is helpful to see what other varieties are growing in your area and assess how well they are doing. • Newer semi-dwarf varieties are now available in Australia that should require less pruning and that are resistant to coffee leaf rust. • Stringent biosecurity measures need to be in place to avoid introducing coffee leaf rust to plantations.
• Arabica coffee varieties are highly self-fertile (up to 95%) and most pollination occurs before the flower opens (Figure 7.3). • For practical and logistical reasons, coffee is grown from seed. • Coffee can be grown from semi-hardwood cuttings.	• Growing different varieties too close together increases the chance of cross-pollination and the problem of seedlings having different characteristics to the parent tree, i.e. 'off-types' (Figure 7.2). • The occurrence of 'off-types' is negligible in plantations of a single variety.	• Cross-pollination does not matter if all trees in the area are of the same variety and are high producers. • Most seedlings will be identical to the parent tree. • If different varieties are planted, provide adequate separation if harvesting for seed.
• Most seedlings will be the same as the parent tree.	• 'Off-types' can have a different growth habit, tree height, maturity period and cherry removal force, affecting harvestability, yield, bean size and liquoring qualities.	• Ensure seed for planting is taken from healthy, true-to-type trees where there are no 'off-types' or other varieties nearby. • Purchase seedlings from a reputable supplier.
• Seed germination is usually 95–100% with sound fresh seed that has a moisture content of 25–40% and has been dried under semi-shade and stored under low-humidity conditions.	• Poor germination will occur if unviable seed is not 'floated' off and damaged seed is not removed prior to storage. • Drying seed in direct sun will reduce germination. • Over-drying and under-drying seed will reduce germination. • Moulds will develop if seed is stored above 40% moisture.	• Seed can be planted immediately after pulping or fermented to remove mucilage. • Only plant undamaged seed that sinks in water. • Dry seed slowly in shade on mesh or racks. Drying in shade with good ventilation will take about 10–14 days to reach 25–40% moisture content. • Use a moisture meter to guide drying time if seed is to be stored for longer than a few days (Figure 7.1). • Maintain seed at 25–40% moisture content in an air-tight container.
• Storage life for seed.	• The germination percentage drops from 95% when fresh to 75% after three months in air-tight bags, dropping to 20–25% after nine months. • After 15 months, germination capacity is virtually zero.	• Seeds stored at 40% moisture can retain full germination capacity for six months if stored at 15 °C.

Figure 7.4: Seed laid out on vermiculite in a Styrofoam box.

Figure 7.5: Option 1.1 on page. 7.4 – transplanting the seedling into Hyko pots as soon as the root emerges. This eliminates the chances of J-roots.

Modern-day coffee growing involves producing a large number of consistently sized seedlings for field planting. There are practical limitations and cost efficiency considerations for the nursery, transport and for in-field handling for the different methods described.

Figure 7.6: 24-cell Hyko V150 pot filled with potting mix.

Figure 7.7: Option 1.2 on page. 7.4 – seedlings germinated and grown out in potting mix. At the 'butterfly' stage, seedlings are potted on, about four months after seed was planted.

Method		
1. Two stage – germination then potting-up	**Pros**	**Cons**
1.1 Transplant as soon as the root emerges • Germinate seeds in trays filled with vermiculite (Figure. 7.4). • Seeds can be placed close together to save space. This makes it easier to identify emerging roots. • Place seeds with the centre-cut face down and close together. • After about 28 days, start checking for early signs of germination (Figure 7.5). • When roots start to appear, pick out those seeds and transfer them to a cell in their final individual pots/cells in a pre-prepared Hyko tray (Figure 7.6, Figure 7.8 and Figure 7.17). • Do not over-fill the cells in Hyko trays and clear away potting mix between cells. **1.2 Transplant at the butterfly stage** • Germinate seed in trays filled with potting mix or a mixture of potting mix, sand and vermiculite. • Space seed approximately 1 cm apart in trays. • Orientation of the seed does not matter as seeds will orientate themselves when germinating. • Keep seeds moist by regularly watering and cover the tray with shade cloth if necessary. • Transplant when the two seed leaves (cotyledons/butterfly leaves) have fully emerged and before the true leaves start to emerge (Figure 7.7 and Figure 7.16). • If the root is too long for the pot, cut off the end of the root to suit the pot depth. • Transplant the seedlings into their final individual pots/cells. • Use a 'dibble' stick to make a hole in the potting mix to allow the root system to extend fully downward into the pot/cell. • Do not apply downward pressure on the potting mix after placing the seedling in the dibble hole – this can cause 'J-rooting'. • Do not over-fill the cells in Hyko trays and clear away potting mix between cells.	• Relatively low cost of vermiculite and germinating mix. • Size sorting occurs at the butterfly stage as they are potted up. • Excellent root formation and development as the cells are an optimum size for ideal root and stem development. • Air pruning of roots allows extended holding options (Figure 7.13). • Handling is easy as the trays are self-supporting and modular. • The 24-cell modular unit can be easily secured on the planter's belt (Figure 7.14). • Planted directly from cell into the ground. • Amenable to machine planting. **Whatever the propagation method, it is critical to avoid 'J-rooting' when potting up, transplanting or planting out in the field.** 'J-rooting' of seedlings occurs when the seedling is grown in a pot or planted in a hole where the roots are forced to the side or upward, creating a J-shaped root. The roots do not grow properly, and the seedling will not thrive or may die.	• This can be time consuming initially when the seeds are placed on vermiculite in the trays. • With the butterfly leaf transplants, placing seeds too close together can cause damaged roots when transplanting. Care must be taken to avoid 'J-rooting' when potting up. • Root formation, development and structure of the seedling can be compromised if left in the Hyko tray too long. • Excess potting mix between the cells when topping up after transplanting into the Hyko trays will encourage roots to invade adjacent cells.  **Figure 7.8: Hyko 150 cells are modular and robust for field planting. Note the orange extruder used to loosen seedlings in the cells.**

Method 3.2 (page 7.6)

Figure 7.9: Bottomless sleeve around a bottomless pot.

Figure 7.10: Sleeve and pot are suspended in a frame – viewed from above.

Figure 7.11: Sleeve and pot are suspended in a frame – viewed from side-on.

Figure 7.12: The top two sets of sleeves have been filled. Then the wooden frame containing the pots is removed, leaving the sleeves resting on the bare earth below. The third set is awaiting filling with sandy compost loam.

2. Direct seeding into their final individual pots/cells	Pros	Cons
• Direct seeds – two seeds per pot – into forestry pots in racks in a greenhouse. Planting a single seed per cell typically will result in 20% of cells without a seedling or late germination, leading to uneven growth and inefficient use of nursery space. • As seeds germinate, pots are consolidated into a new rack so that all seedlings in that rack are of a similar size. • As seedlings grow, they are spaced out, leaving every second cell in the rack open. This allows the plants to grow out with a stronger structure of lower branches more suited to withstanding wind damage. • Where there are two seedlings in a pot, the weaker seedling is removed as soon as possible to not disturb the root system of the dominant seedling.	• Relatively low cost of potting mix. • No need to transplant the seeds until planting out. • Minimal chance of 'J-root' formation. • Size sorting into racks happens as the seeds germinate. • As the seedlings get bigger, it is easy to space them out within the rack by moving every second seedling into another rack.	• Seedlings of uneven size may need size sorting prior to planting out to remove 'off types' and less-advanced seedlings. • Wasted pot space and potting mix if seed does not germinate.
3. Direct seed into plastic sleeves	**Pros**	**Cons**
3.1 Plastic planter bags. • Plant two seeds in the traditional one litre plastic planter bags.	• No need to transplant seedlings until planting out in the field.	• Seedlings in traditional plastic bags with a solid bottom can readily develop 'J-roots' as there is no possibility for air pruning of the roots, and they grow back up and around the soil ball.
3.2 Bottomless sleeves • Plastic sleeves without bottoms are suspended in a pot without a bottom (Figure 7.9). They are supported in a frame/template while sleeves are filled within the seed bed (Figure 7.10 and Figure 7.11). • Once filled, the frame and plastic pots are removed, leaving the filled sleeves sitting on the seed bed and supporting each other (Figure 7.12). • Two seeds are planted in each sleeve. • Seedlings grow out in this nursery seed bed until ready for planting in the field.	• No need to transplant into another pot so the chance of J-root formation is minimal. • Plenty of soil allows strong vigorous seedlings to develop. • Can be scaled up to grow out bulk numbers of seedlings. • Plenty of room to develop a strong vigorous root system. • Easy to size sort plants at planting time.	• High cost of growing mix unless you make your own compost mix. • Plants are heavy and need to be placed/ grown out where they do not need to be moved. • Needs appropriate trays and mechanical equipment to transport and handle the bagged plants. • A larger size hole is required for each tree.

Air pruning

The different propagation methods use different styles of pots/containers.

The base of all containers should be open to the air, with just enough framework to retain the soil. This facilitates air pruning of the roots.

Air pruning occurs when a plant's root tips encounter air instead of being enclosed in a container or wrapped in soil. They respond by sending out lateral roots in search of moisture and nutrients. These lateral roots then grow in a more fibrous and branching pattern, creating a dense network of roots.

Air pruning stops the roots from growing around in circles, which can cause the plant to become 'root-bound,' leading to decreased nutrient uptake and limited water absorption, and potential to lodge (fall over) once planted in the field. Eventually, this can lead to stunted growth and reduced overall plant health.

A strong root system helps plants absorb nutrients and moisture from the soil efficiently so they can thrive.

Roots that are confined or damaged during transplanting can affect the long-term vigour and health of the tree.

Figure 7.13: Trays of 24 Hyko 150 ml pots showing the cross rungs at the bottom of the cells that allow retention of the potting mix but also enable air pruning of roots.

Figure 7.14: Trays of 24 Hyko 'unplugged' seedlings can be carried conveniently on the hip belt frame to the field and in the field for planting.

4. Grow seedlings in raised beds and transplant bare rooted seedlings	Pros	Cons
• Seed is planted in rows in raised beds under a shade cloth. • When they are big enough to plant out into the field, they are dug out and planted bare rooted.	• Cheap and less labour intensive than the container-grown method, but not recommended under Australian conditions.	• The survival rate is low and there is a high risk of transplant shock. • Trees take longer to establish. • High danger of ‘J-root’ when transplanted. • Replanting weak or dead plants is costly.
5. Growing coffee plants from cuttings	**Pros**	**Cons**
• Seedlings from under coffee trees are transplanted into pots and allowed to grow to 40–50 cm high. • These are then pruned, and the VERTICAL semi-hardwood cuttings are used for propagation. • Rooting hormone is applied and cuttings are placed in potting mix in 8 × 5 Hyko forestry trays. • Once cuttings have taken and there is a good root structure to hold the soil ball, they are then potted on into individual pots to grow out (Figure 7.14).	• The resultant plants are guaranteed to be true to type. • It is therefore important to ensure that the source of the propagation material is the variety of choice.	• Care must be taken when potting on the cuttings to avoid damage to the roots. • High danger of ‘J-root’ when transplanted.

Figure 7.15: Vegetative propagation – young coffee plants grown from semi-hardwood vertical cuttings.

Figure 7.16: Seedlings grown out to butterfly stage and now ready to pot on into Hyko pots. Method 1.2 on page 7.4.

Figure 7.17: Germinating coffee seed in Hyko pots – soldiers become butterflies! Note that all at are at a very similar stage of growth. Method 1.1 on page 7.4.

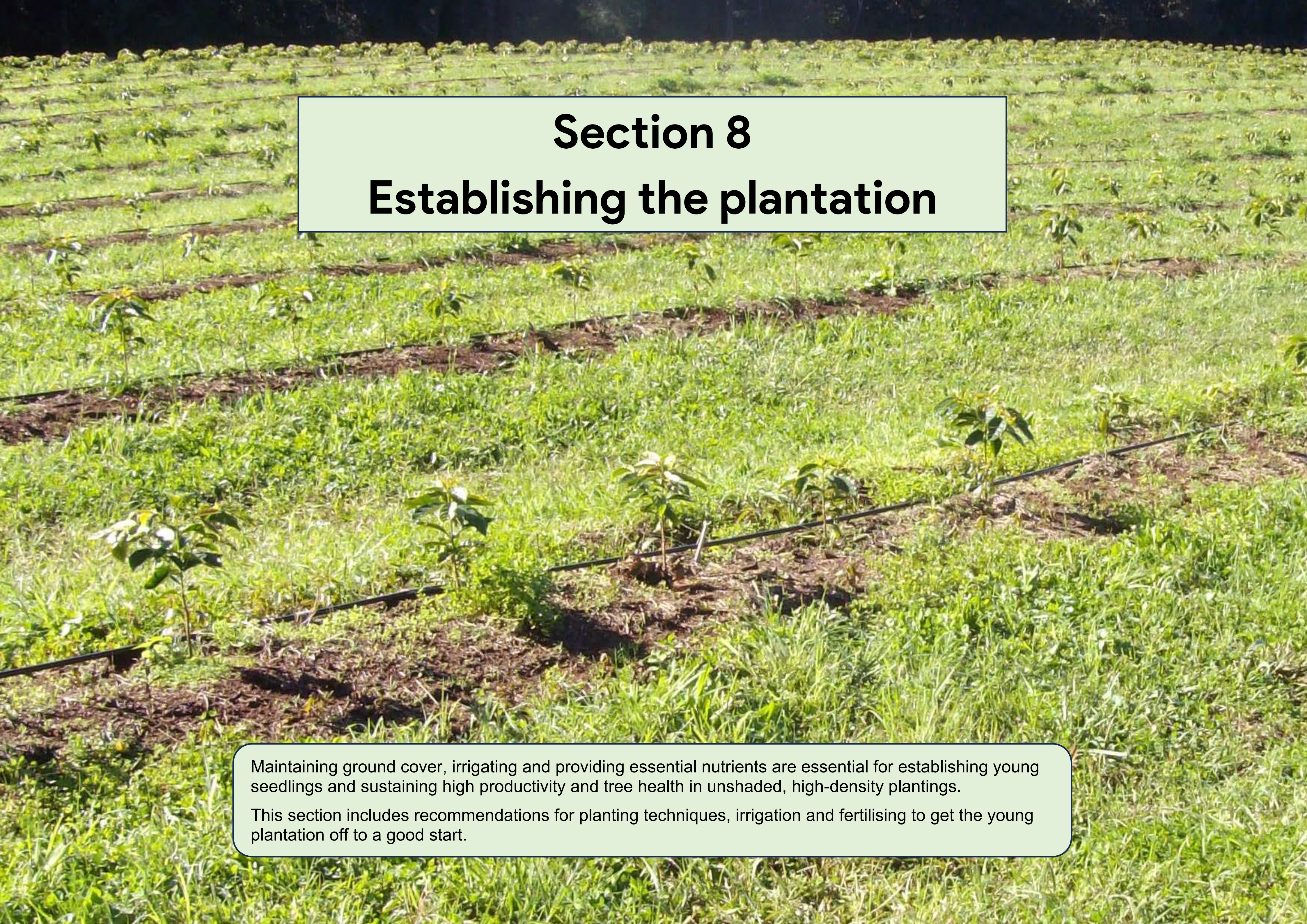
Background	Problem	Management
Germination		
• The optimum germinating temperature is 28-30 °C.	• Germination time ranges from approximately 32 days for fresh seed and up to 50 days for seed stored for eight weeks, while older seeds can take up to 70 days to germinate at the optimum temperature range. • Poor or slow germination will result when temperatures are too low, too high or too variable.	• Ensure seed is fresh and clean to maximise the germination percentage. • If in a cooler climate, use controlled bottom heated germination trays to keep the germination mix in the 28-30 °C range.
• Pre-soak seed in clean water for 24 hours.	• Unviable seeds that float can be identified and discarded.	• This can accelerate germination by up to three weeks if using seed stored for long periods. • After 3–4 weeks, the root tip appears. Select out these germinating seeds for transplanting.
• Germination mix and depth.	• Germination mix should retain moisture but not become waterlogged. • Bent or 'J-root' shape will result if the mix is too shallow, too lumpy or compacted.	• Use a soil-less mix that is free draining and free of diseases. Vermiculite alone or a mix of vermiculite and washed river sand is suitable. • No need to add fertiliser for germination as the seed has its own reserves of nutrients. • Provide 10–15 cm depth in a germination bed or tray to allow roots to grow down unimpeded before they are transplanted. • When direct seeding, cover the seed with a thin layer of potting mix so that the seed is just covered. • Keep seeds moist by regular watering and cover the tray with shade cloth if necessary.
• Sorting seedlings according to size for transplanting.	• Mixing 'leggy' or oversized and undersized seedlings together will result in uneven growth, water penetration of cells and variable nutrient requirements.	• Size sort seedlings and plant similar-sized seedlings together in each tray. • Discard 'off-types' deformed leaves and 'J-roots'.
• Nursery care and hygiene.	• Soil or waterborne pathogens can attack seeds and reduce the germination rate. • Seedlings are fragile and easily damaged, and their growth can be set back through poor care and hygiene. • Roots growing outside the germination tray or out of the base of pots or cells will be damaged, favouring the development of disease.	• Delineate a shaded and clean potting-up area within the nursery. • Discard any damaged or stunted seedlings. • Keep seedling trays elevated from the ground or benches to ensure good air flow under the tray (Figure 7.18 and Figure 7.19). This facilitates air pruning of roots below the cell and tray. • Keep potting-up benches and implements clean and apply a copper-based fungicide to work areas.

Figure 7.18: Hyko pots are filled with butterfly seedlings all at the same stage of growth. These will not need to be size sorted prior to planting out. Chances of 'J-rooting' is minimised.

Figure 7.19: Healthy seedlings in Hyko pots on racks in a shade house. Wire racks beneath the trays allow air movement and air pruning of roots, and prevents waterlogging.

Figure 7.20: These plants have been in their planting cell for too long and are root-bound. Note *Cercospora* leaf spot.

Background	Problem	Management
Nursery		
• Shading is necessary in the nursery to encourage even, healthy growth.	• Excessive shade will produce 'leggy', tall plants with weak stems. • Planting seeds too close together will also cause excessive shading. • Keeping plants in the planting cells too long will result in them becoming root-bound (Figure 7.20).	• Start with a 50% shade cloth to encourage vigorous growth. • Reduce shade during prolonged periods of cloudy weather then replace when full sun returns. • As seedlings grow, gradually remove shade until seedlings have 3–5 pairs of leaves. • Harden seedlings off by removing shade completely 2–4 weeks before planting in the field. • Plant seedlings in the field before they become root-bound.
• Irrigating seedlings to ensure even growth and freedom from disease.	• Overwatering, underwatering or uneven watering will cause stress in plants and uneven growth. • Plants tend to create an umbrella over plants inside the group and these do not get water even when sprinklers overlap. •	• Look for signs of yellowing, Cercospora leaf spot, wilting or reduced growth. • Use a portable moisture probe to check for uneven watering in the nursery (see page 8.1). • If using overhead watering, ensure sprinklers have adequate overlap in their spray pattern. • Make sure plants are spaced out so they do not shade others.
• Seedlings respond to regular applications of foliar fertiliser and slow-release granular fertiliser in the potting mix.	• Exceeding the recommended mix or application rate will cause 'burning' of foliage, particularly under high temperature and sunlight conditions. • Cercospora leaf spot will occur with poor nutrition.	• Apply recommended rates only and apply in the early morning or late in the day to avoid burning. • Ensure an even application of fertilisers to prevent Cercospora leaf spot from developing.
• Keeping plants disease-free.	• Fungus diseases such as damping off and collar rot will develop under high humidity and consistently moist conditions.	• Maintain good air circulation. • Monitor water needs using a moisture probe. • Irrigate according to need – not by the clock.
• Pest and disease control.	• Grasshoppers, caterpillars and scale may occasionally attack leaves. • Coffee green scale (*Coccus viridis*) is the main pest of coffee in the subtropics. It is attracted to weaker seedlings/trees. • Cercospora leaf spot will develop where nutrition is poor or when plants are stressed. • Fungal diseases such as Rhizoctonia and damping off will cause major losses unless controlled in the nursery and when transplanting to the plantation.	• Scale is not usually a problem if plants are vigorous. • Natural control agents such as the *Verticillium lecanii* fungus and the *Cryptolaemus* beetle larvae are very effective against scale. • If weather conditions do not favour these natural control agents, an application of a highly refined paraffinic oil, such as Biopest oil, is effective for scale. • For Cercospora leaf spot, apply a copper-based fungicide if infection is heavy, then ensure adequate nutrition through foliar sprays and slow-release fertiliser granules. • Use a registered/permitted fungicide drench in the nursery and at planting.



Section 8
Establishing the plantation

Maintaining ground cover, irrigating and providing essential nutrients are essential for establishing young seedlings and sustaining high productivity and tree health in unshaded, high-density plantings.

This section includes recommendations for planting techniques, irrigation and fertilising to get the young plantation off to a good start.

Figure 8.1: The soil within the planting row should be friable. Heavy wet soils that remain lumpy need to be further broken down.

Figure 8.2: A simple hand-held moisture probe provides a quick check of soil moisture around the roots of young seedlings.

Figure 8.3: Fine feeder root tips are sensitive to moisture stress.

Figure 8.4: Irrigation by hand or a drip system immediately after planting is essential to remove air pockets and provide direct contact of the soil with the plant's roots.

Background	Problem	Management
• The zone within which seedlings are to be planted should be friable with no clods (large lumps of compacted soil) and with all organic matter fully decomposed (Figure 8.1).	• Planting into freshly applied or sprayed-off fresh organic matter is not recommended as it impedes the planting process and tends to dry out the root system of the young seedlings. • There is the potential for decomposing organic matter to introduce pathogens (diseases) and create nutrient imbalances.	See Section 6 relating to preparation of the site.
• The soil along the planting row should be neither dry nor saturated, but moist enough to retain friability.	• Dry soils will not satisfactorily compact around the planted seedling while wet soils make planting difficult and will 'clag' to form a barrier between the seed-growing medium and the soil.	• Avoid planting when the soil is saturated. • If the soil is dry, irrigate the evening before planting.
• Fully hydrate (wet) the seedlings prior to planting (allowing sufficient time for the plant cell structure to maximise its moisture content).	• Just soaking the potting medium prior to planting will not be sufficient.	• Ideally this entails heavy watering for the 24-hour period prior to planting to allow sufficient time for the cells to take up maximum water, plus a final soaking of the potting medium just prior to planting in Seasol® or similar.
• Prior to planting, the seedlings need to be 'unplugged', i.e. loosened from the cell/pot.	• Damage to the root collar is caused by having to use excessive force to pull the seedling from the tray/pot. • Damage to the soft bark or to the root system must be avoided as it can set the tree back substantially.	• Apply pressure from the bottom of the tray using a purpose-built extruding tool (see Figure 7.8).
• Minimising transplanting shock is critical to successfully establishing early growth.	• Transplant shock sets back the health of the plant, which will remain in a weakened state until it re-establishes itself.	• A liquor polymer coating such as Envy® (a foliar coating) and Seasol® planting granules when applied prior to planting will minimise transplant shock.
• Plants should be placed in alignment into the centre of the planting row at the recommended distance for that variety and location (90–100 cm apart).	• Misaligned trees upset the harvesting process. • Yield is reduced from overcrowded trees. • Spacing that is too wide is less than optimal and results in unproductive gaps and inefficient removal of cherry from branches running along the tree row.	• Use GPS or a string line to achieve straight planting. Professional planters do this using sighting rods. • Check tree spacings with local grower practice. • The correct spacing between trees should be close enough to force branches to grow out into the inter-row where cherry removal by the harvester is most efficient.

Figure 8.5: Grasses that more readily decompose and become organic matter in the soil profile create a good mulch cover when planting rows are being established, e.g. millet.

Figure 8.6: After planting, a more durable mulch of wood chips should be spread along the planting row, but with chips kept away from the main stem.

Figure 8.7: Drip irrigation is ideal to pre-soak the planting row before and immediately after planting to minimise transplanting shock. More frequent irrigation is needed in hot sandy soil. Irrigate twice daily to start then every second day.

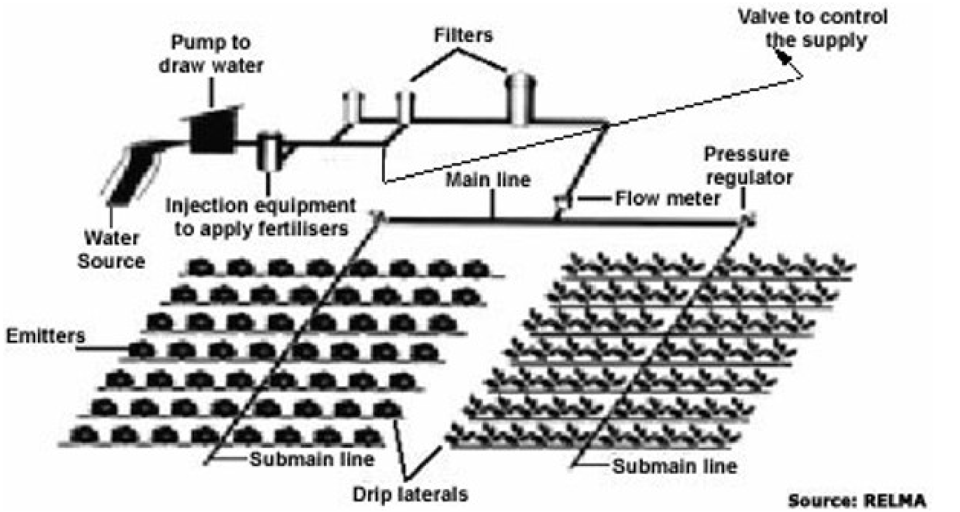


Figure 8.8: Although a high capital cost, an irrigation system is an easy and efficient means of ensuring young plants have a continuous and adequate supply of moisture and nutrients.

Background	Problem	Management
Planting		
• Plant the seedlings so that the soil covers the top of the planting mix.	• Planting too shallow will cause the roots to be exposed and the plug to dry out and be less stable, particularly on mounded rows. • Planting too deep will cause bark damage and collar rot of the cambium layer (the green tissue under the bark).	• Compact the soil around the young plant to ensure close contact of soil with the roots and to remove air pockets (Figure 8.3). • Be careful not to over-compact the soil and bend or distort the root system.
Watering		
• At the planting stage, roots are confined within the top surface of the soil which, even during the wet season, can quickly dry out.	• Newly planted seedlings are highly susceptible to water stress until roots have extended deeper into the soil. • Leaf wilt indicates inadequate moisture. • Soils vary in their capacity to hold water.	• Watering in after planting is essential (Figure 8.4). • Best results are achieved by maintaining frequent applications until the roots have established. • Then irrigate according to soil monitoring equipment. • A moisture probe (Figure 8.2) is a useful quick tool to indicate moisture level in the root zone.
Irrigation		
• Drip irrigation offers the best delivery of water to plants, providing moisture directly to the tree's roots (Figure 8.4 and Figure 8.7).	• Young plants require a steady supply of moisture, particularly for the first six weeks and thereafter for their first year of growth.	• Modern irrigation systems allow automated watering according to plant need (Figure 8.8). • Typically, in the first six weeks, irrigation is likely to be necessary every other day and beyond that twice a week.
Mulch		
• In addition to controlling erosion, mulch protects the soil and surface roots from high temperatures, reduces water loss by evaporation and prevents weeds from developing (Figure 8.5 and Figure 8.6). • Mulch is also an excellent source of organic matter. • Mulching can double the mass of secondary roots and increase primary root mass by 40%.	• Bare soil creates high soil temperatures, which restrict the development of surface and secondary roots, resulting in poor nutrient uptake and lower productivity. • Irrigation efficiency is also compromised by lower water-holding capacity. • Erosion risk is increased with bare soil. • Weeds will take advantage of nutrients fed to the young plants, and without mulch, the top layer of soil rapidly dries. • Pathogens can be transferred from mulch to the plant's main stem. • Be careful not to introduce weed seeds in mulch material brought onto the plantation.	• Apply mulch before the start of the wet season. • Check local sources of mulch material for the most cost-effective supply. Tea tree, hemp and sugar cane processing waste, straw, wood chips, compost etc. are often available close to coffee production areas at a reasonable price. • Ensure these are well decomposed and do not apply too close to the stem of the coffee seedling to avoid damaging the soft stems of young coffee seedlings.

Sequence for establishing a plantation

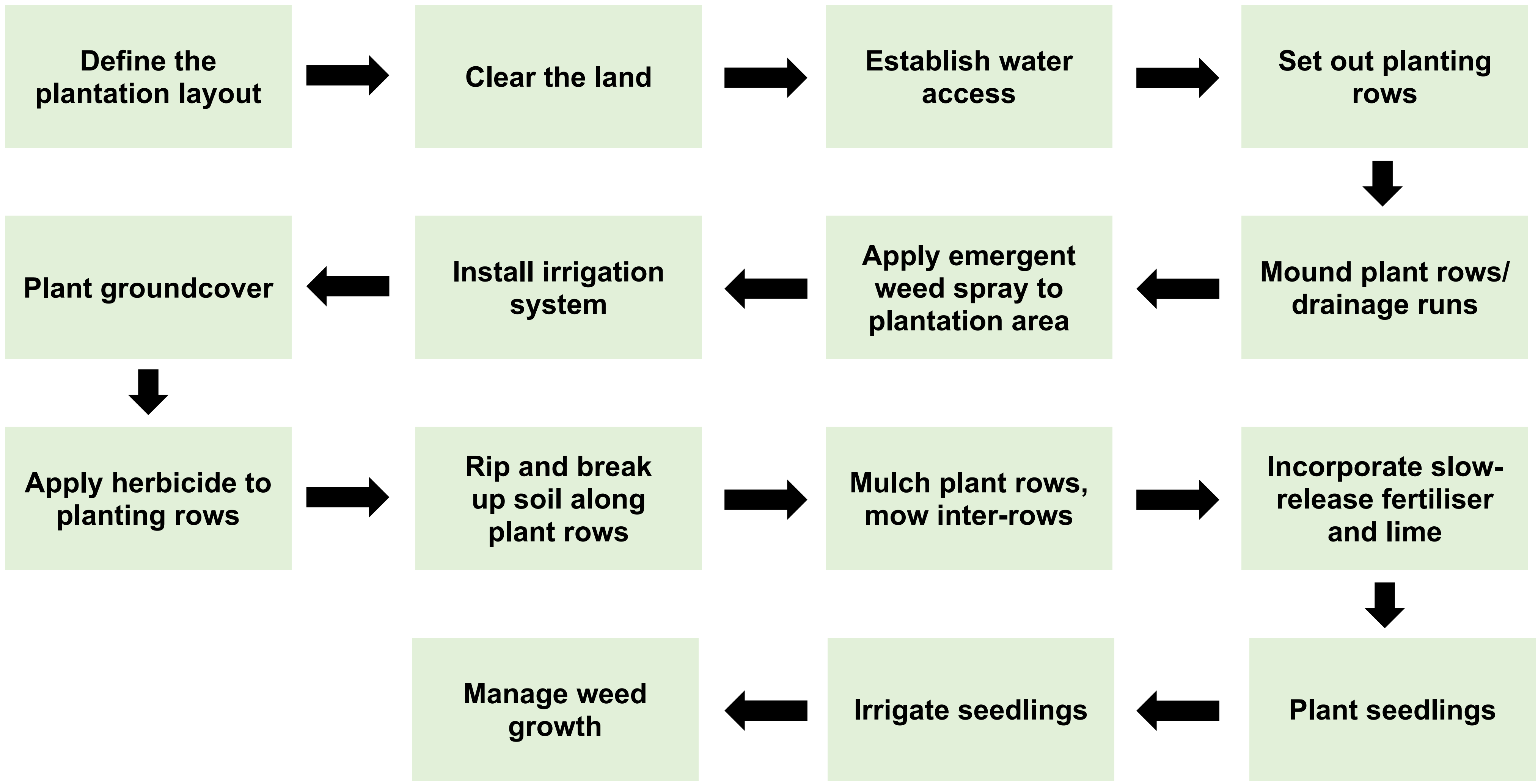
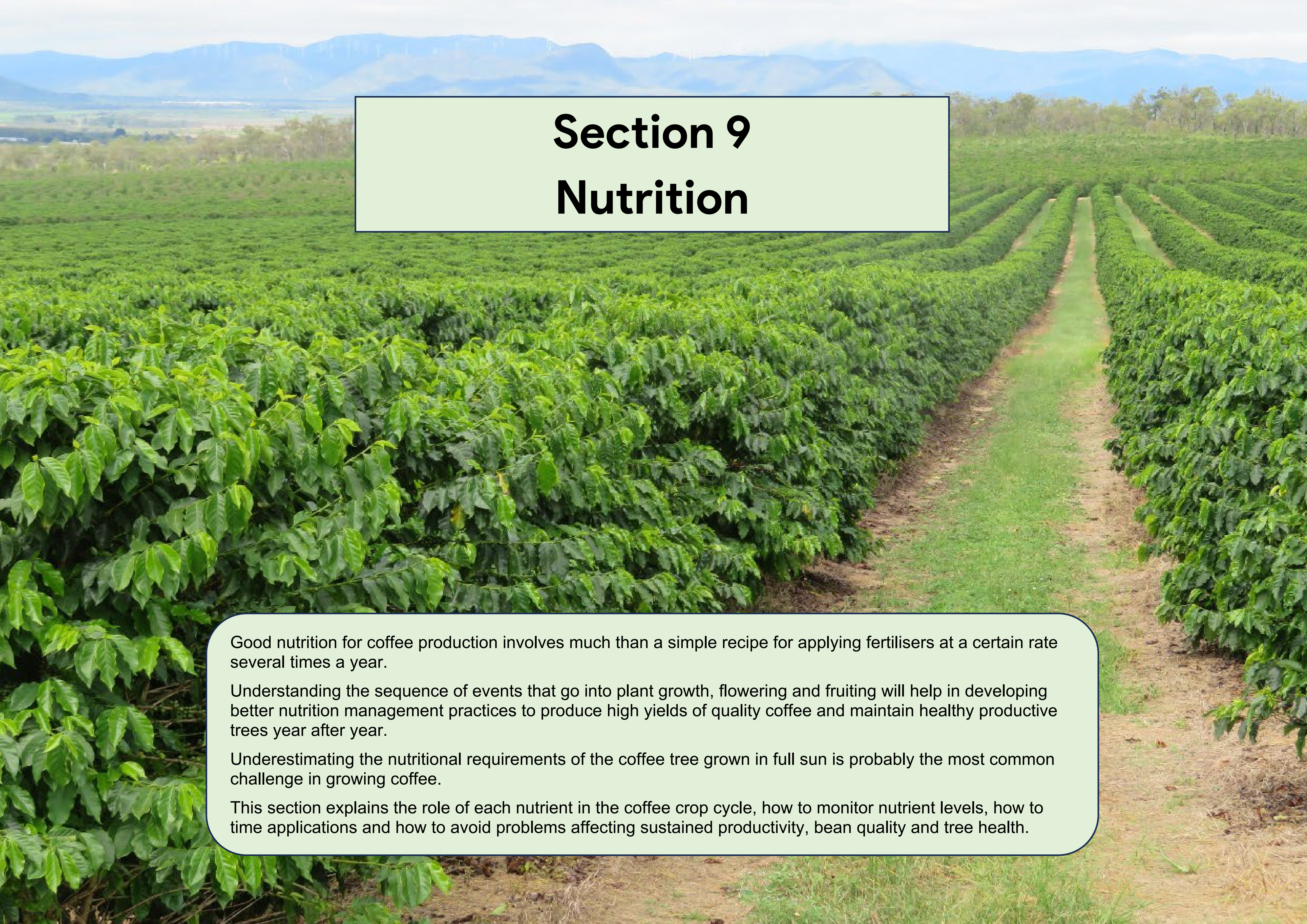


Figure 8.9: Preparation for planting with mounded rows, planted out with millet. The planting area is on top of the mound, sprayed with herbicide.

Background	Problem	Management
Weed control		
• The biggest challenge to establishing trees is weeds. • Mulch and cover crops will suppress weeds, however application of some herbicides (weed killers) is required until coffee seedlings develop a vigorous root system and leaf canopy (Figure 8.11).	• Young trees are sensitive to spray drift and their root system takes 12 months to out-compete weeds.	• Use covered sprayers and low-drift nozzles to minimise drift (Figure 8.10). • Inevitably, there will be an unsprayed zone along the line of the main stems of the trees. This must be dealt with by the careful hand application of herbicide. • Planting a row of Japanese millet besides the tree row will protect the young seedlings and help suppress weed growth (Figure 8.9).
Fertilising		
• Commence fertilising young trees six weeks after planting. • Applying nutrients through the irrigation system (fertigation) must be carefully monitored to ensure the correct dosage to each seedling. • It is important not to over-use nitrogen during the establishment phase as shoot growth can get out of balance with root growth.	• Trees need to overcome the stress of transplanting before stimulating growth. • Young roots can be burnt if they come into direct contact with solid fertiliser.	• Evenly distribute fertiliser as a band within the planting zone, avoiding close contact with the plant. • Apply in small quantities every six weeks. • Slow release, organic or natural mineral-based fertilisers will provide nutrients at a constant rate as the seedlings become established without the danger of burning or overdosing. • Use good-quality soluble fertilisers that will not settle out and block the dripper lines.

Figure 8.10: A dome sprayer head with a low drift nozzle will minimise herbicide contact and damage to the seedlings.

Figure 8.11: Young trees with light mulch and no competition from weeds or inter-row groundcover.



Section 9
Nutrition

Good nutrition for coffee production involves much than a simple recipe for applying fertilisers at a certain rate several times a year.

Understanding the sequence of events that go into plant growth, flowering and fruiting will help in developing better nutrition management practices to produce high yields of quality coffee and maintain healthy productive trees year after year.

Underestimating the nutritional requirements of the coffee tree grown in full sun is probably the most common challenge in growing coffee.

This section explains the role of each nutrient in the coffee crop cycle, how to monitor nutrient levels, how to time applications and how to avoid problems affecting sustained productivity, bean quality and tree health.

Figure 9.1: Nitrogen-deficient leaves. Yellowing (left) is initially evident in old leaves, which fall off (right).

Background	Problem	Management
Nitrogen (N)		
• Important for the formation of protein and chlorophyll, the deep green colour of plants. Chlorophyll is essential for the manufacture of carbohydrates (plant foods) through the photosynthesis process. • Needed for growth (stems, leaves, roots and fruit) as well as its influence on the flowering and bearing capacity of the coffee tree. • Will assist the tree to ripen the crop properly and at the same time produce new wood for next season's crop, provided the tree does not suffer from moisture stress. • Very mobile within the tree, i.e. can move from old to new growth. N deficiency occurs on older leaves as N moves to new leaves and fruit. • The plant requires 48% of its nutrients as nitrogen. • Has the greatest effect on yield of all the nutrients (provided they are all in balance). • Helps to combat dieback by stimulating leaf and root growth, and the manufacture of plant foods. • Mainly absorbed as nitrate (NO_3) and ammonium (NH_4). • Applied at the rate of 60–300+ kg per hectare. • Can be applied in various forms as a synthetic product such as urea, sulphate of ammonia or calcium nitrate, or potassium nitrate. Urea is the cheapest form, however in moist soils, losses to the atmosphere occur. • Leguminous cover crops, such as soybeans, lucerne, pinto peanut, lupins and clover, fix atmospheric nitrogen and convert it to a usable form for plants through bacteria-containing nodules on the plant roots. When these cover crops are harvested, nitrogen is released into the soil in a form that can be used by the coffee tree. Mulches from these crops break down readily into the ideal carbon:nitrogen (C:N) ratio for the soil. • **Optimum leaf level for N is 2.5–3%.**	• As nutrients are directed to the maturing cherries, which are the major 'sink' for nutrients, this leaves little or no reserves available for vegetative growth. Deficient leaves yellow and drop (Figure 9.1). • This limits the number of flower or fruiting buds for the following year. Nitrogen is critical in preventing dieback. • The feeder roots are the first to suffer when the plant becomes low in nutrients through overbearing or lack of fertiliser inputs. They die back, as do the vegetative branches above the ground. • Once the feeder roots die, there will be a permanent reduction in the cropping potential of the tree and despite the application of fertilisers to correct the situation, there has been such damage to the physical capacity of the roots to absorb nutrients that complete recovery is unlikely. • Dieback on bearing trees causes leaf drop (N goes to fruit) (Figure 9.1) and then cherries turn black and are poor quality. Dieback of limbs and roots leads to alternative bearing. Hard to overcome. • Deficiencies are more frequent in sun-exposed plantations, or the north or western side of tree rows where exposure is highest. • Temporary deficiencies result during dry seasons or unirrigated plantations as the topsoil dries and the 'feeder' roots in the topsoil are not functioning. • Excessive nitrogen increases caffeine content and reduces cup quality. • Adding fresh manures can create imbalances in the nutrients and problems in the uptake of some nutrients. Manures should be well decomposed. • Excess nitrogen produces dark green leaves and promotes lush succulent growth, however crops can be more susceptible to disease and fruit may fall prematurely. • Sulphate of ammonia increases soil acidity. • Excess nitrogen can also induce sulphur deficiency.	• Continuous monitoring using leaf analysis is essential to avoid future major problems that will not be obvious just by looking at the trees or roots, or by relying on soil analysis alone. • Fertiliser applications must be related to local conditions, and the results of leaf and soil analysis, in addition to yields and climatic data. • "Little and often" applications are advisable. • Maintaining heathy leaf cover provides shading to feeder roots and lowers the soil temperature. • Leaf sampling should be carried out from February to April, and again from September to December. • One soil analysis per year should be adequate. • Experienced and qualified service providers are available for analysing soil and leaf tissue and making recommendations. • The carbon:nitrogen (C:N) ratio is important for maintaining the availability of nutrients. • When applying organic material to the soil, the state of decomposition and the nitrogen content are important to ensure the C:N ratio in the soil is about 12:1.

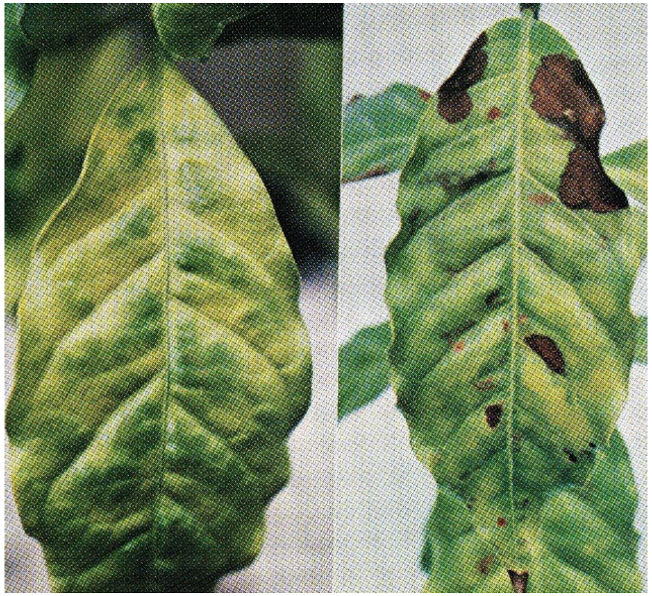


Figure 9.2 (top and bottom): Faint interveinal yellowing in older leaves, with dead spots developing in acute phosphorus deficiency.

Figure 9.3: Phosphorus is essential for the development of a healthy root system. Note the deficient plant on the left compared to the healthy root system on the right.

Background	Problem	Management
Phosphorus (P)		
• Important in metabolism, energy transfer and transport of photosynthates (sugars or other substances produced by photosynthesis). • Very mobile and stored in the tree framework and remobilised when needed. • Best response is observed in young coffee trees as it stimulates root development (Figure 9.3) and production of new growth. • Not needed in large quantities. • Necessary for the development of roots, wood and young buds. • Important at the planting stage and is applied at the bottom of the planting hole or incorporated into the planting row before planting. • Organic matter in the soil is an important reservoir for phosphorus, nitrogen and sulphur. It is best to try to maintain the phosphorus level of the soil by applying decomposed manure, compost, mulch, etc. • Now claimed to have a positive effect on bean quality, particularly acidity. • **Optimum leaf level for phosphorus is 0.15–0.2%.**	• Fixation in the soil is a serious problem with phosphorus. Immobilised phosphorus in the soil is unavailable to plants. • Where phosphorus is naturally low or strongly fixed in soils, fertiliser phosphate increases fruit set and yield. • Zinc and iron levels may be deficient where high levels of soil phosphorus occur. • Deficiency symptoms are rare. Younger leaves turn dark green while older leaves show yellowing between the veins (Figure 9.2). • More commonly, phosphorus deficiency causes reduced growing point activity, including retarded bud burst, reduced flowering, smaller leaves and reduced shoot growth.	• The best method of applying phosphorus is as a component of compound fertilisers in combination with mulch and no cultivation. Compound fertiliser should be applied to the soil surface and then covered with mulch. The fine feeder roots then grow into the decomposing mulch layer and take up the phosphorus in the presence of humus. Fixation in the soil is thereby minimised. • Phosphorus can be applied within the planting hole to assist root development, and in the nursery. • Rock phosphate or tricalcic phosphate is suggested for acidic to very acidic soils. Rates of 100–200 g per planting position are suggested. Rock phosphate dissolves slowly and gradually releases nutrients. • Single superphosphate (SSP) contains both phosphorus and sulphur, and 20% calcium. • Molybdenum superphosphate is another option and provides for long-term molybdenum supply. • Diammonium phosphate (DAP) is an excellent source of phosphorus and nitrogen for plant nutrition. It is highly soluble and dissolves quickly into the soil to release plant-available phosphate and ammonium. It is also alkaline; however, the ammonium present in DAP is gradually converted to nitrate by soil bacteria, resulting in a drop in pH. Application rates should be calculated in relation to the soil content of phosphorus and the soil pH. • Applying solid forms of phosphorus to the soil surface has limited effect and it is usually applied in a compound fertiliser or in fertigation at the rate of 50–60 kg of phosphorus per hectare per year. • Phosphorus can also be applied as a foliar spray, as a 1% aqueous solution of DAP (diammonium phosphate) or phosphoric acid, or as a complete foliar feed.

Figure 9.5: Potassium symptoms first appear on older leaves as a chlorotic band along the leaf margins.

Figure 9.4: Older leaves show symptoms of potassium deficiency while young leaves remain unaffected.

Background	Problem	Management
Potassium (K)		
• Main function is in the physiological development of the coffee tree, in particular the development and maturing of the fruit. • Represents the second-highest proportion of nutrients required by the coffee tree, at 28% of total absorption. • Potassium level required during cherry development exceeds that of nitrogen, which helps to explain why the element can become the limiting factor to crop production after a few years. • Potassium promotes vigour, boosts cell strength and increases the coffee tree's tolerance to diseases, water stress or frost stress. • Is a key driver for yield and important for respiration, photosynthesis and water regulation. • Has a crucial role in increasing cherry size and quality through its role in the movement of sugars from the leaf for accumulation in the fruit. • Is mobile in the tree and during peak periods of growth, particularly fruit fill. • Easily leached, especially in sandy soils. • Peak demand is during fruit development, but the plant uses potassium throughout the season. It is important to ensure that supplies are not limiting. • Coffee uses 150–250 kg/ha of potassium and about 80 kg of this finds its way into the cherry. • Higher rates of 300-400 kg/ha potassium in mature crops have recorded high yield responses. • Naturally high in volcanic soils and soils that are regularly mulched. • **Optimum range for leaf is 2.1–2.6%.**	• Maintaining adequate levels of nitrogen and potassium will prevent dieback and *Cercospora* leaf spot. • Can be depleted rapidly in the soil, more so than nitrogen, and can limit production. • Must be kept in balance with calcium and magnesium as high potassium levels will result in deficiency symptoms in magnesium and calcium (see photo). • Deficiencies show as interveinal chlorosis (yellowing) of older leaves. They develop brown scorches along leaf margins, and leaves curl inwards and have a ragged appearance (Figure 9.4 and Figure 9.5). • With time, the leaf blade margins die off, dry out and roll upwards. • In severe cases of potassium deficiency, dieback or complete death of the tree occurs. Cherry production also suffers, with reduced cherry size and an increased number of blind or empty cherries or 'floaters'. • Excessive potassium can be detrimental to cup quality.	• As with nitrogen, rates should be increased year on year until the trees reach maximum productivity. • Ideally, there should be about 30% more nitrogen in the leaf than potassium. It is important that potassium use is balanced to N use, but high levels of both nutrients are needed for optimum growth, and this is more important than precisely balancing the nitrogen:potassium (N:K) ratio. • Keep calcium and magnesium in balance with potassium. Use the results of leaf analysis to adjust the ratio. • When using foliar forms, split applications of 2% potassium nitrate monthly for three months have provided the best yield responses without risking crop damage. Potassium nitrate has a positive effect by raising the pH around the roots compared to sulphate and chloride forms. • Commonly applied as sulphate of potash (48% K) or muriate of potash (60% K). Sulphate of potash is preferred to muriate of potash because of the negative effects of chloride. • If required, an annual input of 150–200 kg of potassium can be applied in split applications. Lighter soils are more prone to leaching and may require higher applications.

Figure 9.6 (top and bottom): Magnesium deficiency can occur during periods of low light intensity and heavy crop loading; this causes yellowing between the veins, which remain green.

Figure 9.7: Calcium deficiency occurs in the newest growth. Young leaves turn bronze along the margins while the midrib stays green. Leaves will droop downwards, and the apical (top main) bud dies back.

Because calcium is quite immobile, deficiencies are first seen in new growth. Young leaves become irregularly chlorotic with yellowing or bronzing along their edges and extending back into the mid-leaf areas. This leaves an area with saw-like edges around the main veins.

Background	Problem	Management
Calcium (Ca)		
• Calcium is important for strong cell wall formation, and this has a major effect in strengthening plant growth and maintaining fruit quality. • It also serves as an enzyme activator and is involved in cell division, stimulating growth of roots and leaves. • Most calcium uptake occurs before flowering, but it is important that supplies are available early and right through the season to maintain healthy growth. • **Optimum leaf level for calcium is 0.7–1.3%.**	• Because calcium is quite immobile, deficiencies are first seen in new growth. Young leaves become irregularly chlorotic with yellowing or bronzing along their edges and extending back into the mid-leaf areas (Figure 9.7). This leaves an area with saw-like edges around the main veins. • The leaf margins may develop a wavy characteristic, with the leaves cupping downwards. • Under severe deficiency, leaves develop corky areas around underside veins and there is dieback of shoot tips. • Lack of calcium is most noticeable in young trees which have poorly developed root structures.	• Need moist soil for plant uptake. • Speed of uptake depends very much on the form and particle size the of product used. • Care should be taken before lime is applied to coffee trees as heavy applications can cause imbalances and calcium cations may dislodge the potassium and magnesium cations from the root zone where roots are absorbing nutrients, thus causing deficiencies. • Use of lime should be limited to correcting the acidity and reducing the toxicity effects of aluminium and manganese. • Gypsum (calcium sulphate or $CaSO_4$) or phosphogypsum can be used in heavier soils where it acts as a physical conditioner, aiding root penetration (down to two metres) and soil and moisture retention. Gypsum does not alter soil pH.
Magnesium (Mg)		
• Is a constituent of chlorophyll and is therefore important in photosynthesis. It is likely that the ‘hot-cold’ syndrome causing yellowing of new leaf growth in winter is the result of a process called ‘photo-oxidation’, whereby the plant is unable to metabolise magnesium to the growing point under cold conditions. • Magnesium is involved in the transport of phosphorus in the plant and water uptake, and is highly mobile in the tree, transferring from older to younger leaves. • Magnesium is needed throughout periods of active growth. • **Optimum leaf level for magnesium is 0.2–0.4%**.	• Magnesium deficiency shortens leaf life and is first seen on older leaves, and reduces yield. • Symptoms of magnesium deficiency are the typical interveinal chlorosis of the leaves (Figure 9.6). The mid-rib and main veins always remain green, and yellowing begins at the base of the branch and progresses towards the tip. In branches with maturing cherries, older leaves are prematurely lost.	• Where soil acidity is normal, magnesium deficiency can be corrected by foliar sprays of Epsom salts (magnesium sulphate) at 1% concentration. • Magnesium sulphate (MgSO4) can also be fertigated.
Calcium (Ca) and Magnesium (Mg)		
• Calcium and magnesium are important in the development of terminal buds and flowers. • Most productive growth comes from maintaining a high calcium:magnesium (Ca:Mg) ratio in the leaf. • **Optimum leaf Ca:Mg ratio is 3:1.**	• Calcium and magnesium deficiencies have a negative effect on bean quality.	• Calcium and magnesium must be kept in balance with potassium in the right ratio (3:1) to avoid inducing deficiencies of any of these three nutrients. • Dolomite (calcium carbonate and magnesium carbonate) can be used to increase the pH (i.e. reduce the acidity). Rates of 250–700 kg per hectare are used according to soil test results.

Boron

Figure 9.8: Abnormal growth of the shoot apex and narrowing of new leaves suggest boron deficiency.

Figure 9.9: Young leaves become mottled with necrotic spots in boron-deficient plants.

Figure 9.10: Dead, irregular leaf margins are symptoms of boron toxicity.

Sulphur

Figure 9.11: Faint diffuse interveinal yellowing occurs first on young leaves with sulphur deficiency.

Figure 9.12: Sulphur deficiency resembles nitrogen deficiency BUT leaves are spotted.

Figure 9.13: Vegetative growth is reduced when sulphur deficiency becomes advanced.

Background	Problem	Management
Boron (B)		
• Used for cell division (growth) in plants growth and pollen formation associated with carbohydrate metabolism and the synthesis of nucleic acids. • Activates the uptakes of other nutrients, especially calcium. • Essential for the development and growth of new shoots and roots, flowering, fruit set and development. • Mobile in the soil but not the plant – hence deficiencies are on the growing points. • Care must be taken to maintain **leaf levels of boron in the range of 40–100 ppm.** • High levels of boron are toxic to coffee trees.	• Deficiencies are most common during periods of dry weather when boron uptake is reduced. • Where boron is deficient, rooting, flowering and fruit set is poor. • Younger leaves turn light green and mottled with uneven edges, and are often narrow and twisted. New leaves have dead spots or tips (Figure 9.8). • The oldest leaves firstly become yellow at the tip. As the deficiency progresses, the yellow area spreads and affects about half of the leaf area. • The leaf develops a cork-like texture around the main veins. • Leaves become deformed and can appear curled, twisted and wrinkled. • The terminal growing point may die and the tree produces new sideshoots, resulting in a deformed, fan-shaped bush (Figure 9.9). • Toxicities and leaf death will occur if leaf boron levels exceed 200 ppm (Figure 9.10).	• Compared with other micronutrients, relatively low levels of boron are required (about 200 g/ha/year). • Applications to the soil are generally more effective. • Soil applications are particularly important to maintain boron levels in trees grown in highly leached tropical soils. • However, foliar sprays can provide a good, in-season, top-up response, raising leaf levels to maintain coffee production and bean quality. • Pre-harvest sprays of boron can also reduce the impact of a range of fungal diseases on the processed coffee bean. • Monitor leaf levels and use Solubor (20% B), boric acid (18% B) and sodium borate (Borax, 11–14% B) according to recommendations from leaf analysis results. • When using foliar boron, best yield increases come from applications made both before and post flowering, preferably in combination with zinc. Be careful not to overdose as easy to go from deficiency to toxicity.
Sulphur (S)		
• Important in the structure of protein and amino acids; chlorophyll synthesis and efficient utilisation of nitrogen; and good disease resistance and cherry production. • Most important during fruit maturity. • **Optimum leaf range 0.1–0.2%.**	• Sulphur deficiency results in younger leaves turning a faint yellowish green, starting as a band around the main vein (Figure 9.11). The underneath surface of the leaf is lighter than the upper surface, while the upper surface maintains a shiny appearance (Figure 9.12). Some mottling can be found near the leaf margins. • Growth slows and symptoms can be found across the whole tree (Figure 9.13).	• Sulphur is present in most fertiliser programs to prevent deficiencies occurring. • Check leaf and soil levels by leaf and soil analysis.

Zinc

Figure 9.14: Early symptoms of zinc deficiency showing interveinal chlorosis of young leaves.

Figure 9.15: Advanced symptoms of zinc deficiency show the younger leaves narrowing and chlorotic.

Iron

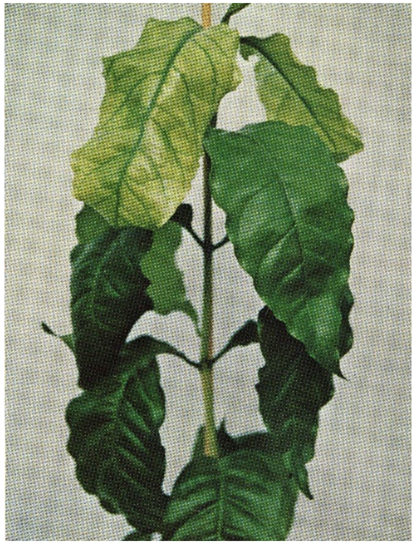


Figure 9.16: Young leaves with iron deficiency showing interveinal chlorosis.

Figure 9.17: Advanced symptoms of iron deficiency. Affected leaves show distinct interveinal chlorosis in younger leaves.

Background	Problem	Management
Zinc (Zn)		
• Important for the correct functioning of many enzyme systems, as well as the synthesis of nucleic acid and metabolism of auxin growth hormones (see 3.4). • One of the most important micronutrients in coffee production. • Contributes to the formation of chlorophyll. • **Optimum leaf level for zinc is 10–30 ppm.**	• Zinc deficiencies lead to significant yield loss. When deficient: – interveinal chlorosis (yellowing) occurs between leaf veins while veins remain green (Figure 9.14) – leaves become elongated, thin and strap-like. They lose their sheen (can be confused with glyphosate damage) (Figure 9.15) – leaf borders can become curled and the internodes between the leaves are shortened – the green leaf veins stand out from a yellow background. • Symptoms are usually more visible at the tips of the branches in new growth, and the tree is stunted and takes on a rosette habit (Figure 9.15). • Poor correlation between soil and tissue zinc readings. • High phosphorus can hinder zinc uptake. • Overuse of zinc may decrease yields.	• Coffee requires relatively low levels of zinc, about 500 g/ha/year. • Deficiencies are best corrected or prevented by using foliar sprays. • Care must be taken to ensure levels within leaf tissue are not excessive as zinc can compete and replace other cations within the plant, resulting in the loss of yield. • Target levels in leaves for optimum yields should be about 30 ppm. • Two spray applications pre- and post-flowering are recommended together with boron if appropriate. • Formulation is important. Zinc sulphate can be used, however best results come from formulated zincs, such as Zintrac™. • Foliar zinc also helps boost plant health, minimising the effects of fungal infections on the bean.
Iron (Fe)		
• Important in chlorophyll and plant enzyme formation, as well as aiding respiration processes. • Red volcanic soils are high in iron; however, iron deficiency occurs quite frequently when the iron is fixed and unavailable due to imbalances of other nutrients and pH. • Soil and tissue iron levels are poorly correlated. • A relatively large amount of iron finds its way into the bean. • **Optimum leaf level for iron is 50–150 ppm.**	• Young leaves turn pale green and then a chlorotic yellow or white (Figure 9.16). • Veins stay green unless the deficiency is particularly severe, then leaves turn almost white. Older leaves are rarely affected (Figure 9.17). • A deficiency can spoil bean quality, resulting in amber beans.	• Coffee requires adequate iron to produce strong, healthy, high-yielding trees. • High iron levels occur in red volcanic soils. However, this iron is usually unavailable due to imbalances of other nutrients and pH, and may need to be corrected. • Increasing organic matter reduces the risk of iron toxicity. • Foliar iron chelate can be applied to improve iron levels.

Figure 9.18 (left): Copper deficiency – leaves lose their colour before dead patches appear on the margins. The secondary veins of younger leaves become prominent or 'ribbed', and leaves may become distorted.

Figure 9.19 (below): Manganese deficiency – younger leaves are pale green to bright yellow. Leaves at the tip become completely yellow.

Figure 9.20 (top and bottom): Molybdenum deficiency – rarely but may be seen on strong acid soil. Older leaves are affected first. Yellow spots develop near leaf margins, leading to spots of dead tissue.

Background	Problem	Management
Copper (Cu)		
• Needed to activate several plant enzymes and regulate photosynthesis. Also aids lignin production, strengthening cell walls. • Only needed in very small amounts, but is important in maintaining growth and yield. • Use of copper-based fungicides means that copper deficiencies are rarely seen. • **Optimum leaf level for copper is 10–20 ppm.**	• Where plants are deficient in copper, shoots are weak and restricted, and may form rosettes. Leaves lose their colour before developing necrotic (dead) patches on the margins. • The secondary veins of younger leaves become prominent or ‘ribbed’ and leaves may become deformed, distorting into an ‘S’ shape (Figure 9.18). • Young plant leaves may curve downwards, starting from the bottom of the tree, creating a wilting, drooping growth habit. • Excessive soil copper will hinder development of new roots – often seen in nurseries.	• When copper fungicides are not applied, regular copper sprays at three weekly intervals may increase yield. Copper sulphate or copper chelates can be used where deficiency occurs. • Check leaf analysis level. • Normal copper fungicide applications maintain adequate leaf levels. • Watch spray run-off, especially in the nursery.
Manganese (Mn)		
• Responsible for activating many different enzyme systems. Essential for respiration, nitrogen metabolism and chlorophyll synthesis. • Catalyses the splitting of water molecules in photosynthesis with the release of oxygen. • During periods of rapid growth, e.g. at the start of the rainy season, manganese reserves in the leaf, particularly in new growth, will rapidly decline. • Good supply of manganese maintains healthy growth, minimising fungal attack and disease on the processed bean. • Acidic soils may have relatively high levels of manganese. If so, manganese can compete with and restrict uptake of other nutrients. • **Optimum leaf level for manganese is 50–100 ppm.**	• Deficiencies are worse on alkaline soils or those that have been over-limed. • Manganese is immobile in the plant. • Deficiency symptoms include the complete leaf becoming pale olive green, with a mottling or stippling between the veins. As the deficiency increases, the whole leaf yellows. This yellowing appears first at the tip of the branches, especially those in direct sunlight (Figure 9.19).	• Trace element-containing foliar sprays may be needed to maintain growth and fill fruit in alkaline soils.
Molybdenum (Mo)		
• Needed for the efficient use of nitrate and for phosphorus metabolism. • Molybdenum requirements are very low, and most soils have sufficient reserves to meet crop demand. • Molybdenum availability increases as soil pH increases (alkaline soils). • **Optimum leaf level for molybdenum is 0.15–0.20 ppm.**	• Deficiencies are rare but may be seen on strongly acidic soils. • Deficiency symptoms include bright yellow spots developing near leaf margins and between leaf veins. These areas can turn necrotic (dead). • Leaves become distorted and narrow, rolling downwards such that margins meet underneath the main vein (Figure 9.20). • Older leaves are affected first.	• Recommended sources for molybdenum are ammonium molybdate (48% Mo) and sodium molybdate (39% Mo). • Use of molybdenum super phosphate will give a longer-term supply of molybdenum. • Use according to the recommendations from leaf analysis results.

Figure 9.21: A quick, easy-to-use test for pH in the soil. This sample shows a pH between 5 and 5.5. Ideal pH for coffee is between 5 and 6. These test kits are available from retail outlets.


Figure 9.22: Take the third or four pair of leaves from the tip of an actively growing branch from the mid-height of the tree. Ignore the yet-to-mature leaf pair on the end.

Background	Problem	Management
Aluminium (Al)		
• Not essential to the coffee plant. • Growth of trees is reduced at high leaf concentrations. • Solubility is very low in neutral and alkaline soils, and increases markedly in acidic soils below pH 4.5.	• Usually a problem in high-rainfall areas and soils are naturally high in aluminium. • The first sign of excessive aluminium on plants is limited root growth. Root tips and lateral roots become thicker and brown; frequently, phosphorus uptake and translocation to upper plants parts is affected. • Toxicity symptoms are similar to those for phosphorus.	• Maintain high organic matter, calcium and magnesium to suppress aluminium uptake. • Maintaining pH above 5.5 keeps aluminium unavailable to plant roots, thereby avoiding toxicity.
Chlorine/chloride (Cl)		
• Not a problem under high-rainfall conditions. • Salt laden winds close to the coast can cause leaf burn.	• Excessive levels of chloride cause leaf burn, leaf fall, root damage, poor growth and yield, resulting in poor uptake of essential nutrients. • Toxicity symptoms become more acute as moisture becomes more limiting.	• Avoid the use of fertiliser containing chloride, e.g. use potassium sulphate instead of muriate of potash. • Chloride can be reduced in the soil profile by improved drainage, leaching irrigations, use of fertilisers free from chloride and avoidance of spray irrigation. • Leaching irrigations need to be heavy and frequent. Light, frequent irrigations wet the surface layer of the soil only, leading to an accumulation of chloride in this layer, aggravating the problem.

Monitoring nutrients in soil and leaf

Nutrient deficiency symptoms can be useful in detecting major problems; however, regular monitoring of leaves and soil and adjusting the fertiliser program should prevent major visual symptoms from occurring.

Leaf tissue analysis

- Helps monitor crop needs throughout key periods of the growth cycle – particularly helpful when using fertigation.
- Should also be used to diagnose or confirm nutrient deficiencies, particularly where visual symptoms are confusing or not visible, or where multiple nutrient deficiencies occur.
- It is important to ensure that tissue analysis follows standard procedures.
- Pre-flowering is the preferred sampling time, but more frequent sampling is desirable (e.g. at harvest) to check and adjust the nutrient status during periods of active growth.

Soil testing

- Can be used to measure pH, organic matter content and cation exchange capacity (CEC), thereby indicating nutrient availability and the nutrient retention characteristics of the soil.
- Can be used to assess levels of soil potassium and phosphorus, and to indicate the cationic imbalances, e.g. K:Mg:Ca ratios. However, it is not a good indicator of nitrogen requirements.
- Soil and leaf nutrient levels are often poorly correlated.
- Easy-to-use test kits are available for testing soil acidity (Figure 21).

Leaf analysis

Leaf sampling procedure

1. Take the third or fourth pair of leaves from the tip of an actively growing main branch. Sample leaves from bearing or non-bearing branches, but not a mixture of the two. Select from the mid-height of the tree. Only take leaves that are free from insect or physical damage and disease. Do not count soft leaves (Figure 9.22).
2. Take four pairs of leaves from each sample tree and sample at least 15 trees over the sample area or block. There should be at least 60 leaf pairs in the sample.
3. Place the sample leaves in a clean paper bag and label the bag so the block/area is clearly identified.
4. Take sample bags to the analytical laboratory. Do not keep the samples for more than 24 hours before they are analysed.

Table 9.1 shows the optimum leaf nutrient levels for unshaded coffee (Reuter and Robinson, 1986).

Table 9.1. Optimum leaf nutrient levels for unshaded coffee.

Nutrient	Deficiency	Normal	Excess
Nitrogen %	<2	2.5–3.0	>3.5
Phosphorus %	<0.1	0.15–0.2	>0.2
Potassium %	<1.2	1.5–2.6	>2.6
Sulphur %	<0.05	0.1–0.2	>0.25
Calcium %	<0.5	0.7–1.3	>1.5
Magnesium %	<0.15	0.2–0.4	>0.5
Iron (ppm)	<50	50–150	>220
Manganese (ppm)	<20	50–100	>400
Copper (ppm)	<3	10–20	>25
Zinc (ppm)	<7	10–30	>20
Boron (ppm)	<30	40–100	>100
Molybdenum	<0.10	0.15–0.20	<0.30

Leaf analysis results for coffee

Element or category	Your level	Acceptable range	Deficient	Acceptable	Excessive or toxic
Nitrogen (N)	2.29%	2.5–3.0%			
Phosphorus (P)	0.13%	0.15–0.2%			
Potassium (K)	2.4%	2.1–2.6%			
Sulphur (S)	0.18%	0.12–0.3%			
Calcium (Ca)	1.07%	0.75–1.5%			
Magnesium (Mg)	0.25%	0.25–0.4%			
Copper (Cu)	94 ppm	16–20 ppm			
Zinc (Zn)	4 ppm	15–30ppm			
Manganese (Mn)	67 ppm	50–100 ppm			
Iron (Fe)	107 ppm	70–200 ppm			
Boron (B)	60.1 ppm	20–100 ppm			
Molybdenum (Mo)		0.15–0.20 ppm			
Silicon (Si)	206 ppm	N/A	N/A		
Carbon (C)	47.30%	N/A	N/A		

Figure 9.23. Example laboratory report for a coffee plantation.

Levels at the extremes of the acceptable range may be a cause for concern.

Copper levels can be affected by copper sprays. Refer to soil test figures for interpretation.

Ideal levels for analysis are derived from the following sources:

- Reuter, D. and Robinson, J. B. (1997). *Plant Analysis – An Interpretation Manual*. Second edition. CSIRO Australia.
- Winston, E. Op de Laak, J., Marsh, T., Lempke, H. and Chapman, K. (2005). *Arabica coffee manual for Lao-PDR.* Food and Agriculture Organisation of the United Nations.

Soil sampling procedure

To standardise procedures between farms, years and personnel involved, the following practices are suggested:

- DO NOT sample after fertiliser application. Scrape away fertiliser/lime etc.
- Areas of different tree size, age, soil types, fertiliser or other major differences should be treated as separate samples.
- Remove surface litter, i.e. leaves, etc., prior to sampling. Do not scrape away soil.
- Take samples to depth of 15 cm with soil auger or a spade (Figure 9.24).
- Place soil in a CLEAN bucket.
- Sample from a minimum of 20 sites per block.
- Thoroughly mix all soil. Break up clods to ensure even mixing.
- Sub-sample to reduce volume for sample bags (500 g sample is needed).
- Label all bags and laboratory sheets.
- Keep auger clean between sites.

The objective of sampling is to get an average of soil in the block, i.e. a representative sample, not the best nor the worst.

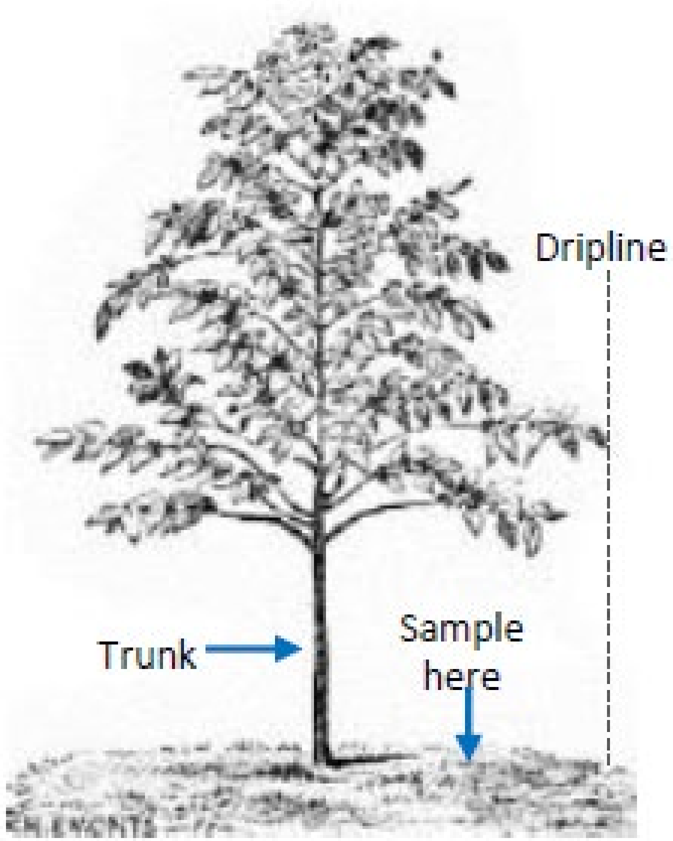


Figure 9.24: Soil should be sampled from the mid-point between the dripline (widest point of the branches) and the trunk of the tree.

Soil analysis report for coffee (red volcanic soil)

Albrecht category	Your level	Ideal level	Nutrient status		
			Low	Medium	High
CEC	15.81	10.00			
pH level (1:5 water)	6.20	6.3			
Organic matter	10.13%	4–10%			
Conductivity (1:5 water)	0.12	0.1–0.2			
Ca:Mg ratio	3.28:1	5.67:1			
Nitrate (N) (Morgan)	21.0 ppm	10–20 ppm			
Ammonium nitrate (Morgan)[\$]	20.4 ppm	10–20 ppm			
Phosphorus (Mehrlich III)[\$]	98 ppm	50–70 ppm			
Calcium (Mehrlich III)[\$]	2196 ppm	2443 ppm			
Magnesium (Mehrlich III)[\$]	401 ppm	259 ppm			
Potassium (Mehrlich III)[\$]	493 ppm	280–491 ppm			
Sodium (Mehrlich III)[\$]	31 ppm	21–62 ppm			
Sulphur (Mehrlich III)[\$]	14 ppm	30–50 ppm			
Aluminium (Mehrlich III)[\$]	8 ppm	<8 ppm			
Silicon ($CaCl_2$)	25 ppm	>100 ppm			
Boron (Hot $CaCl_2$)	1.19 ppm	1–3 ppm			
Iron (DTPA)	111 ppm	40–200 ppm			
Manganese (DTPA)	12 ppm	30–100 ppm			
Copper (DTPA)	9.0 ppm	2–7 ppm			
Zinc (DTPA)	6.3 ppm	5–10 ppm			
Molybdenum (Nitric acid)[\$]	N/A	0.5–2 ppm			
Cobalt (Nitric acid)[\$]	N/A	2–40 ppm			
Selenium (Nitric acid)[\$]	N/A	0.6–2 ppm			
Texture	Clay loam				
Colour	Red				
Base saturation					
Calcium	61.10%	68%			
Magnesium	18.61%	12.00%			
Potassium	7.04%	4.00–7.00%			
Sodium	0.75%	0.50–1.50%			
Aluminium	0.50%	0.50%			
Hydrogen	12.00%	10.00%			

[\$] Analytical method

Figure 9.25: Example laboratory report for a soil sample.

Cation exchange capacity (CEC) is the capacity of soil particles (clay and humus) to attract cations (hydrogen, calcium, magnesium, potassium and sodium), and the subsequent exchange of one ion for another.

It influences soil's capacity to hold onto essential nutrients and provides a buffer against soil acidification.

CEC is like a big sponge from which the plants take up potassium, calcium, magnesium and sodium, and thus you need to maintain a good balance between these.

Soils with a low CEC are more likely to develop deficiencies.

CEC of soil differs with the percentage of humus and with the percentage and composition of clay:

- Soils with a higher clay fraction tend to have a higher CEC.
- Organic matter has a high CEC (250–400).
- Sandy soils have a very low CEC.

Figure 9.26: Overhead irrigation is used for delivering nutrients; increasing humidity and cooling coffee trees prior to and during hot weather in the dry tropics, keeping stomates open to cool the canopy; and frost protection.

Figure 9.28: Nutrient mixes for fertigation are mixed and pumped through the drip irrigation system.

Figure 9.27: Drip fertigation and mulching are ideal to establish young coffee plants.

Fertilising – application strategies

Application strategies need to consider significant nutrient losses that occur, particularly in high-rainfall, tropical plantations, because of surface run-off, leaching and volatilisation.

- All macronutrients – except for phosphorus and some micronutrients – can be leached. Phosphorus, for example, can be lost due to surface run-off.
- Nitrogen volatilisation is a significant problem and losses of up to 50% have been measured. In the tropics, it is assumed that more than half of the applied nitrogen and 25% of the potassium and magnesium can be lost through the process.
- Trials show that 60–85% of the total applied sodium, calcium and magnesium fertiliser can be lost on soils with a low CEC. Thus, it is common practice to apply small but frequent amounts of fertiliser and to use mulches wherever possible to supplement applied nutrients.
- As a result of the very high nutrient losses that occur in coffee plantations, the fertiliser rates required and commonly used are much higher than those suggested by theoretical calculation.

1 Basal fertiliser

Especially phosphorus and lime can be added to the planting hole when establishing the crop. They are also widely used in the coffee tree nursery. In high-alkaline soils, gypsum is recommended instead of lime.

2 Side-dressed fertilisers

These are commonly placed underneath the tree around the drip line or outer edge of the canopy, where finer root hairs are normally concentrated. It is important to keep fertiliser (and poorly composted mulches) at least 10 cm away from the tree stem to avoid damage. Not very effective if used with drip lines in dry weather.

3 Foliar application

This is used to address an immediate nutritional need or where soil conditions restrict the availability of specific nutrients (Figure 26).The use of adjuvants will improve the efficiency of foliar sprays onto the waxy coffee leaf. Cherries are relatively sensitive to foliar sprays, so it is important to ensure correct formulations are used to minimise the risk of damage. Where feasible, apply to soft flushes for better penetration/uptake.

4 Fertigation

Fertigation is the application of soluble fertiliser through an irrigation system (Figure 9.28). Drip irrigation is highly suitable for fertigation and in warm subtropical areas, fertigation is virtually a must, especially in the dry tropics when using drip irrigation (Figure 9.27).

Fertigation is generally used to supply the crop's nitrogen, phosphorus and potassium needs. Although soluble forms of calcium, magnesium and sulphur are available, they are much more expensive, not always compatible with mixes and often best applied as a foliar spray or ground application (Figure 9.26).

Applying nutrients through an irrigation system can:

- Increase fertiliser efficiency because the nutrients and water are applied together, making the nutrients immediately available to the plants in the active root zones.
- Decrease labour and energy costs by making use of the water distribution system to distribute the fertiliser instead of the tractor.
- Add flexibility in your fertilising program to apply those nutrients needed at various times during the crop cycle.
- Minimise losses through fertiliser leaching, run-off and volatilisation.

Which fertilisers to use in fertigation

General considerations for fertigation include:

- Irrigation lines need to be charged with water prior to adding the fertiliser to the line. The ends of the lines need to be flushed occasionally.
- The selection of products to be used in fertigation include:
  - the salt must be completely soluble in water and must not contain insoluble additives, such as insoluble sulphates or phosphates
  - sodium, chloride, ammonium and organic nitrogen or elements not required for plant growth should be minimised under normal use
  - the salt must not react with other components in the same mix to produce insoluble salts, and should not radically alter the pH of the irrigation water
  - the fertiliser must be economical; there is no point using expensive fertiliser salts when a cheaper source is perfectly adequate.

Nitrogen (N) for fertigation

Your irrigation water quality and the frequency of fertigation and placement of nutrient in the root zone will determine selection of the nitrogen source. Potassium and calcium nitrate are relatively soluble and cause only slight shift in pH of the water and soil.

Water quality and soil conditions should be considered when selecting a nitrogen fertiliser source to use in your irrigation system.

Nitrogen in ammonium form at low fertiliser application rates will absorb into the clay particles, and only move a minimal distance from the source of application. Ammonium nitrate application will also result in some loss to the atmosphere due to ammonium volatilisation, especially if the soil pH is above 7.

Urea is not strongly absorbed by the soil and will move deeper below the surface than ammonium salts. After the hydrolysis of urea to ammonium carbonate, the ammonium ions react with and are fixed by the soil. Flexibility of urea placement is achieved through water management.

Nitrate will move with the water along the wetted front. When too much water is applied, the N will leach below the root zone. As a result, efficiency of nitrate application will be improved by applying fertiliser throughout the growing season. The ability to manage the water application with your irrigation system should minimise leaching of applied nitrate.

Recommended sources:

- Calcium nitrate (15.5% N). Commercial calcium nitrate also forms 1% ammonium-N in solution and supplies 20% calcium.
- Potassium nitrate (13% N) also supplies 36.5% potassium.
- Urea (46% N). Use only low-biuret products. Urea does not form ions in solution, so it does not affect EC, but plant roots react just as they do for any salt.
- Diammonium phosphate (DAP) and monoammonium phosphate (MAP). Both will also supply phosphorus.

Phosphorus (P) for fertigation

The pH and calcium and magnesium content of your irrigation water will have a great bearing on whether you will inject phosphorus through your irrigation system.

Inorganic phosphorus is precipitated and strongly absorbed in most soils, especially volcanic soil. If applied on the soil surface, it will not normally move more than 20–30 mm with rainfall or irrigation.

The possibility of precipitation of insoluble phosphates is extremely high when phosphorus fertiliser is added to irrigation water high in calcium and magnesium. This can be overcome by acidifying the water to reduce the pH below 6.5, which should keep the calcium and magnesium salts in solution while the phosphate fertiliser is being applied.

There appears to be little benefit from applying P fertilisers continuously during the growing season.

Recommended sources:

- Mono-potassium phosphate (23% P) also supplies 28% potassium (but no N).
- MAP (22% P and 10% N) and DAP (20% P and 18% N).

Potassium (K) for fertigation

Common potassium fertilisers are readily soluble in water. However, care should be taken when mixing potassium with other fertilisers. This can cause problems; for example, a mixture of calcium nitrate and potassium sulphate could yield insoluble calcium sulphate, which can block the irrigation lines.

Although many soils generally contain large amounts of potassium, it is not all available:

- Unavailable potassium accounts for 90% of the total.
- Slowly accountable potassium accounts for 8%.
- Readily available potassium accounts for 2%.

Most potassium is held close to the surface in the organic matter. Availability and uptake of potassium largely depends on soil moisture conditions. Repeated small or continuous applications of potassium through the irrigation system allow the fertiliser to be available at rates that are effective and economical. This is important since potassium is more readily exhausted than many other nutrients. Potassium content in the leaves can be almost twice as high when potassium is added through frequent fertigation.

Recommended sources:

- Potassium nitrate (37% K).
- Mono-potassium phosphate (25% K).
- Potassium sulphate (40% K) also adds sulphur (17%).
- Potassium chloride (52% K) is not recommended in large doses.

Magnesium (Mg) for fertigation

Recommended sources

- Magnesium sulphate (10% Mg) also adds sulphur. It is highly soluble.

Sulphur (S) for fertigation

Recommended sources

- Magnesium sulphate (13% S).
- Potassium sulphate (18% S).

Manganese (Mn) for fertigation

Recommended sources

- Manganese sulphate (24-32% Mn).
- Manganese chelate (10% Mn).

Zinc (Zn) for fertigation

Recommended sources

- Zinc sulphate (23% Zn).
- Zinc chelate (10% Zn).
- Do not mix with boron.

Molybdenum (Mo) for fertigation

Recommended sources

- Ammonium molybdate (48% Mo).
- Sodium molybdate (39% Mo).

Calcium (Ca) for fertigation

Recommended sources

- Calcium nitrate (20% Ca).
- Calcium chloride (36% Ca). Limited use due to chloride content.
- Calcium chelates (There are a couple of liquid ones such as Stoller).

Iron (Fe) for fertigation

Recommended sources

- Iron EDTA (6-14% Fe). Readily soluble and stable from of iron.
- Iron EPTA. Using different chelating agents, the iron can be protected in solutions at higher pH level.

Boron (B) for fertigation

Recommended sources

- Boric acid (18% B). Use quickly before boron precipitates.
- Sodium borate (Borax) (11-14% B).
- Solubor (20% B).
- Do not mix with zinc sulphate.

Copper (Cu) for fertigation

Recommended sources

- Copper sulphate (25% Cu).
- Copper chelate (10% Cu).

Background	Problem	Management
Incompatibility and precipitation		
• Some soluble fertilisers are unsuitable for use with other soluble fertilisers because of the risk of precipitants being formed that may clog lines and emitters. • Precipitation can also be the result of water quality; for example, hard water with high levels of calcium or bore water containing dissolved iron will encourage precipitation.	• This problem is most likely to occur when calcium-containing fertilisers are added, mixed or present with fertilisers containing phosphate or sulphate. • Never mix sulphate (SO_4) and nitrate (NO_3) fertilisers.	• Avoid clogging by injecting the fertilisers containing phosphorus and sulphur in one irrigation, and injecting fertilisers containing calcium in the next. • Thoroughly rinse the equipment and irrigation lines between these irrigations.
Soil acidification		
• Soil acidification can also occur under poor irrigation management or leaching. Nitrification initially acidifies the soil, but plant uptake alkalises it to some extent. • The risk is also much greater on acid soils than alkaline, and this is why it is important to know the soil pH when choosing a fertiliser.	• Long-term use of ammonium-based fertilisers could increase the rate of soil acidification. This risk is greater with fertigation using drip irrigation, because the total nutrient requirements of the plant must be supplied to a relatively small volume of soil. • Uptake of ammonium by plant roots results in net acidification of the root zone. • If, however, the nitrate produced from ammonium by soil bacteria is leached from the root zone by rainfall or excess irrigation before the plant can take it up, the soil remains acid.	• In acidic soils, fertilisers such as calcium nitrate should form a significant part of the total nitrogen supply. • Monitor the pH of the wetted volume of soil to pick up any changes, particularly if the soil was already acidic when the fertigation program began. A soil pH of 5.5–6.0 is best for coffee trees. Preventing soil acidification with dolomite or lime is easier than correcting subsoil acidity caused by ammonium-based fertilisers. • The amount of nutrients to apply to a coffee plantation is normally defined in terms of kg/ha. Calculations need to be made back from kg/ha to estimate how much soluble fertiliser to supply for a given area. These calculations must consider the solubility of the fertiliser in the solution, the size of the tank and the length of the injection period.

Figure 9.29: Mulch keeps the soil cool and encourages the development of feeder roots, which supply 80%-plus of the nutrients to the coffee plant. Mulch breaks down to humus, which provides nutrients in a readily available form to the coffee feeder roots.

Humus and humates

- Humus is the result of the decomposition of organic matter in the soil. When combined with the clay particles of the soil, it increases aggregation and improves soil structure. This leads to better water retention capacity and reduced water run-off and soil erosion.
- Humates are the humic acid molecules in the humus that hold most of the nutrients from applied fertilisers.
- These humates are classified into three distinct categories: humic acid, fulvic acid and humin. Each category is separated based on their solubility in water as a function of pH.
- Humic substances are recognised as having many beneficial impacts on both soil and plant growth.

Background	Problem	Management
Mulching and organic matter		
• In its natural environment, coffee grows in a bed of forest litter. Its surface root system is adapted to function most efficiently under such conditions. In commercial plantations, we attempt to simulate these conditions by keeping the bare soil permanently covered with a layer of organic mulch material, which increases yield, helps conserve soil and reduces weed competition. • Organic matter encourages the activity of microfauna (earthworms, etc.), which contribute to better soil porosity and facilitate the transformation of organic elements into nutrients. • Organic matter improves the soil capacity to buffer pH variations. This is important when high inputs of nitrogen fertilisers acidify the soil. This leads to aluminium toxicity, which impedes root growth and nutrient assimilation. • Organic matter improves the activity of microorganisms. • Humates are breakdown products of humus (see the box on the previous page). • Nitrogen incorporated into the soil via root, leaf and branch decomposition or leguminous mulches can reduce the dependence of synthetic nutrients in coffee plantations. • Heat generated during fermentation of coffee pulp prior to its use as mulch can eliminate the spread of pests and diseases, and avoid nitrogen stress. • The availability of plant nutrients is increased and mulching limits the excessive uptake of manganese, which may build up rapidly in acid soils. • Mulch reduces soil temperature and encourages the development of surface feeder roots, which are the main suppliers of nutrients to coffee trees (Figure 9.29).	• When the humus is leached away, the soil becomes compacted, and its aeration is reduced, resulting in reduced nutrient uptake by the coffee roots. • Root absorption of nutrients can be reduced to 30–50% in soils with low organic matter. • Deterioration of soil conditions can increase the plant’s sensitivity to nematodes and diseases. • Soil acidity also reduces microbial activity. • Mulch can harbour pests that attack the coffee stem, particularly in young coffee. • The frost hazard is increased on a dry mulched surface. • Most mulch materials are inflammable and require precautions to prevent mulch catching fire. • Mulching can be a costly exercise and is labour or capital intensive depending on the source and type of mulch. • The availability of low-cost mulch material is a constraint. • Introducing weed seeds is a common problem. • Materials with a high carbon:nitrogen ratio, (i.e. cereal straw and grasses) tend to lock up nitrogen when applied to the root zone and additional nitrogen might be required. • Unless additional nitrogen is applied, excessive mulching can deplete nutrients available to the coffee tree. • Bare soil can become excessively hot, destroying vital feeder roots.	• Leguminous mulches (soyabean, lucerne, etc.), have a low carbon:nitrogen ratio and are ideal, particularly on newly established coffee. • Compost formed from processed coffee waste, soil and plant waste can be used after it has been fermented for three to four months to destroy weed seeds and diseases, and to complement fertiliser applications. • Mature, not fresh, farmyard manure is used in mixed-farming regions at the rate of 20–30 tonnes per hectare.

The role of specific nutrients – summary

	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Mo	Zn
Flowering and cherry set	↑	↑					↑					↑
Bean size	↑	↑					↑					↑
Yield	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑		↑
Disease incidence	↓		↓	↓		↓	↓	↓		↓		↓
Cup quality			↑	↑								
Caffeine content					↑	↑						

Increase ↑

Reduction ↓

Explanatory note: Excess nitrogen has a negative effect on cup quality, increasing caffeine content (may not be desirable in some Australian coffees).

Figure 9.30: The beneficial effects of nutrients applied at the correct level on a range of coffee production parameters.

Summary of nutrients influencing yield and quality

Yield

- **Nitrogen** and **potassium** are essential for strong vegetative growth, filling cherry and high yields.
- **Phosphorus** for early growth and rooting, as well as bean fill.
- **Calcium** for good root and leaf growth, strengthening the tree structure, tolerance to leaf and fungal diseases. Required right through cherry fill period.
- **Magnesium** and **sulphur** for increasing yield. Required throughout the season.
- **Zinc** and **boron** are important for flowering to improve cherry set and yield.
- If any micronutrient is limiting, this will restrict plant growth and productive leaf area, and reduce crop yield.

Quality

- **Nitrogen** needed for good growth but too much at later stages of crop maturity can compromise the cherry size.
- High levels of **potassium** are needed during cherry set and cherry fill to maximise sugar accumulation in the cherry and eventual bean size.
- **Calcium** maintains cherry quality and improves tolerance to cherry diseases.
- **Potassium** and **calcium** are linked to improved cup quality.
- **Magnesium** and **sulphur** have been shown to improve caffeine content (may not be desirable for some Australian coffees).
- Most micronutrients improve healthy growth and minimise disease pressure.

Vegetative growth to pre-flowering

Nutrient effects

- **Nitrogen** and **potassium** – to reactivate and promote early growth of new plant tissues.
- **Calcium** – to boost root and leaf growth to provide a platform for high yields.
- **Magnesium** – to fuel energy transfer in the developing tissues.
- **Sulphur** – to maximise growth through protein formation.
- **Boron** and **zinc** – to maximise flowering and strong cherry set.

Cherry expansion

Nutrient effects

- **Nitrogen** and **potassium** – to maintain tree growth and bean fill during this critical phase.
- **Calcium** – to maximise supplies in the cherry, and hence improve cherry integrity, as it expands.
- **Micronutrients** – where needed to maintain growth.

Post-flowering to cherry formation

Nutrient effects

- **Nitrogen** and **potassium** – to maintain plant growth and maximise cherry strength.
- **Calcium** – to maximise strong growth of heathy tissues.
- **Magnesium** – to boost chlorophyll activity and N-uptake.
- **Micronutrients** – to maintain growth and maximise cherry set.

Cherry maturity

Nutrient effects

- **Nitrogen** – in reduced amounts to maintain growth and cherry fill.
- **Potassium** – for good sugar-to-starch conversion and to maximise cherry weight.
- **Calcium** – for strong cherry integrity.

Figure 9.31: Nutrient requirements at key growth stages.

Natural mineral fertilisers

Natural mineral fertilisers with biological activators are a recent innovation in nutrition and soil health. Containing rock phosphate and a range of naturally derived minerals from basalt, granite, etc., these fertilisers are certified to suit organic or biologically sustainable farming and should be trialled as part of the fertiliser program.

At this stage, they are not meant to replace compound fertilisers. They are to be applied as a once-a-year application to increase the long-term availability and the balance of nutrients, as well as increasing the biological activity of microbes and other beneficials, such as earthworms.

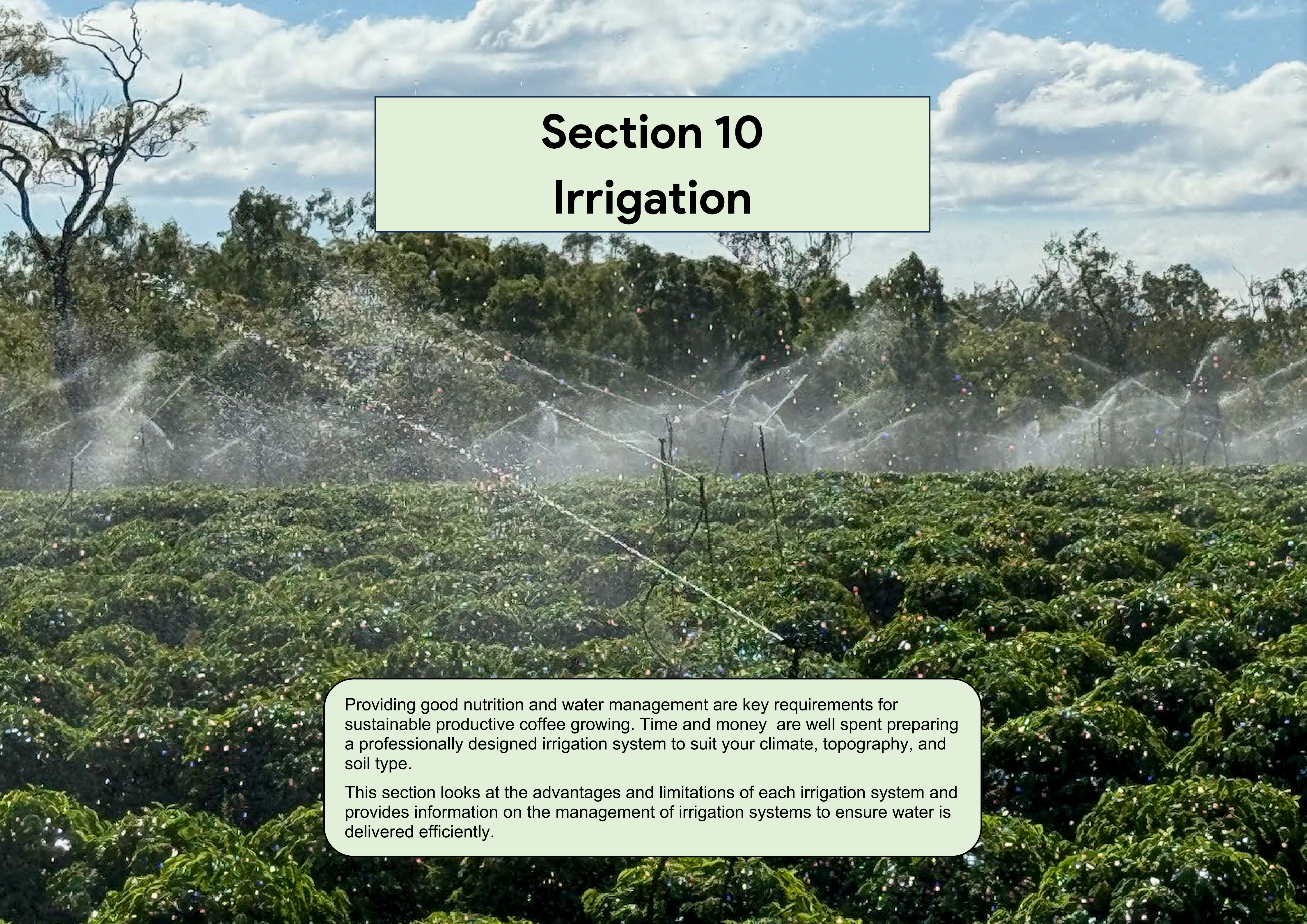
Microbes play a vital role in decomposition and recycling of energy and nutrients held within organic matter. They provide a sustained release of essential nutrients to the plant roots when they are required.

Biological farming tips

Ag-lime	• 2.5t/ha. • Best to incorporate in soil if possible or put on when soil is moist. • Major effect on CEC. • Maintain levels with rock/mineral fertilisers.
Boron	• No ready store. • Best way to supply ongoing is with compost. • Stabilised boron granules: 5-10 kg granules for every 100 kg granular fertiliser. • Do not exceed 12 kg/ha banded or 25 kg/ha broadcast.
Chicken litter	• 2.5–5 m^3/ha – roughly 3% N. • Apply four times a year – would give 130 kg N/ha.
Compost	• Spread 0.5–1 mm thick or 5-10 m^3/ha, or 5 t/ha. • Can add lime each time you turn to a max of 5 kg/$m^{3.}$ • C:N ratio >30 does not favour bacteria. • C:N ratio <30 favours bacteria – more cellulose than lignin.
Foliar	Every 4–6 weeks apply: • 7 L fish emulsion/3 L kelp per 1000 L. – can add biological products to this mixture – 2% urea, soluble K_2SO_4 + 5 L molasses. • Dave's concoction: – 100 L water – 1 L molasses – 500 ml fish emulsion – 500 ml seaweed/kelp – 10 L worm leachate. • Urea/humate – urea at 20 kg/ha – humate at 10 L/ha.
Gypsum or $CaSO_4$	• If need to use – make sure it is MINED gypsum (pH neutral). • By-product gypsum has pH of 3.
Humate	• Soluble humate granules: – add 1 kg granules to a bucket to make up to 10 L – agitate vigorously – 10-15% of humates are insoluble – let sit overnight – siphon off the soluble fraction from the top avoiding sediment – sludge can be added to compost. • Foliar: 2-10 L/ha. • Fertigation: 30 L/ha. • Watering can: 200 ml/10 L.
Metal dust	• Cheapest way to rejuvenate the soil. • The finer the material, the greater the surface area and more likely to be nutritionally available sooner than coarser: – quarries usually have smallest scree 7–8 mm – order size 5 or Fox's dust. • In compost – max 5 kg/m^3. • Rate: 500 kg/ha on plantation.

Phosphorus	• Fe in red soil binds soluble P. • Superphosphate rapidly bound and unavailable in soil; works well first season but thereafter poor response. • ROCK phosphate gives best results (see separate section).
Program	• Compost: 5–10 m^3/ha, December–February • Lime: 2.5 t/ha if pH below 4.5 • Gypsum: 2.5 t/ha if pH above 7. • Rock P: 250 kg/ha, anytime (with lime) • Chicken litter: 5 m^3/ha, late winter and then early spring • Foliar: As a top up every 4–6 weeks
Rock dusts	• REACTIVE rock phosphate has 25% silica (non-reactive, 50% Si); P more available with less Si. • Soft rock phosphate is good. • Is alkaline with low solubility. • Colloidal clay-based calcium phosphate – does not lock up. Slow release with prolonged availability. • 19% Ca, 8% P N, Si, S, C and TE. • High in silicon, 20%. • Good spread of trace minerals (**Fe, K, Mg**, S, Mn, ZN, Cu). • Rate: 250 kg/ha.
Seasol	• Not a fertiliser but a good growth promoter/stress reducer. • Cannot mix in a tank with Ca or P. • Can mix with urea. • Application rate: 5 L/ha monthly or 2.5 L/ha fortnightly. • Soak prior to transplanting: 1:250. • As a foliar spray for: – pick me up: 1:250 – maintenance: 1:500.

Section 10
Irrigation



Providing good nutrition and water management are key requirements for sustainable productive coffee growing. Time and money are well spent preparing a professionally designed irrigation system to suit your climate, topography, and soil type.

This section looks at the advantages and limitations of each irrigation system and provides information on the management of irrigation systems to ensure water is delivered efficiently.

Figure 10.1: Pressure-compensating drippers are designed to provide the same amount of water at each dripper over a wide range of pressure variations in the irrigation line. These variations may result from ground undulations, length of slope or poor design.

Figure 10.2: Moisture probes can be set for full point and refill point from a range of soil depths to assist in irrigation scheduling.

Figure 10.3: Overhead spray irrigation provides cooling to the leaf canopy during extremely hot weather and should be used in combination with drip irrigation for optimum efficiency of water use. It is also useful for applying nutrients through the leaf and for frost protection.

Irrigation for coffee

While the coastal subtropical growing regions have an annual rainfall considered adequate for coffee growing, irrigation is still necessary for the establishment of young trees, sustained high productivity, bean quality and tree health to prevent dieback.

In the dry, hotter savannah region of tropical north Queensland, irrigation has a dual role. It is used to apply nutrients as well as provide water to the trees. Water also takes on a unique role when it is used to trigger flowering. This single large flowering event facilitates machine harvesting by concentrating cherry maturity to enable one-pass harvesting.

Drip irrigation is preferred over overhead irrigation for most plantations because of the efficiency of water use and the capacity to directly apply water to add nutrients via fertigation to the surface feeder roots, which drive productivity and tree health.

Strategic use of overhead irrigation has a place, however, in areas where higher temperatures (above 30 °C), cause the leaf cooling system (the stomates) to shut down. When exposed to longer periods of higher temperatures and low humidity, coffee trees lose their capacity to use water and nutrients, reducing productivity and predisposing trees to overcropping and dieback. There may also be opportunities to use overhead irrigation to prevent damage in frost-prone areas.

Background	Problem	Management
Overhead spray irrigation		
• Overhead spray irrigation increases the humidity within the tree canopy and keeps stomates open to cool the leaves and prevent shut down of transpiration and leaf activity required for uptake of nutrients and water during hot dry conditions (Figure 10.3). • Can effectively deliver nutrients to the trees via foliar application of nutrients.	Relying totally on overhead spray irrigation can result in: • Increased risk of erosion with overwatering. • High evaporation losses. • Increased weed competition. • Higher water requirement than drip irrigation. • Higher operational power requirements than drip irrigation. • May increase risk of fungal diseases on leaves and ripe berries during high-humidity periods. • Risk of leaf scorch if water has high saline content when applied during hot weather. • More difficult to control the infiltration rate and target depth than drip irrigation. • Water is wasted on non-target soil and plants. • Risk of topsoil compaction, soil capping and surface run-off. • Crop protection sprays may be readily removed from the leaves. • If overhead sprinklers are within the row, they need to be removed for machine harvesting. • If overhead sprinklers are in a separate row, you sacrifice a row of trees. • Lateral move irrigation is slow to cover an area if needed quickly.	• Use strategically, in combination with drip irrigation, prior to high temperature and dry periods to increase humidity and reduce temperatures within the tree canopy (Figure 10.3). • Regulate application rates to avoid over-watering, soil compaction and surface run-off. • Check water quality to avoid scorch damage to leaves during hot weather. • Operate to avoid the hottest part of the day. • Apply crop protection sprays after irrigating, if necessary. • Keep weeds slashed or under control to minimise evaporation/transpiration losses.

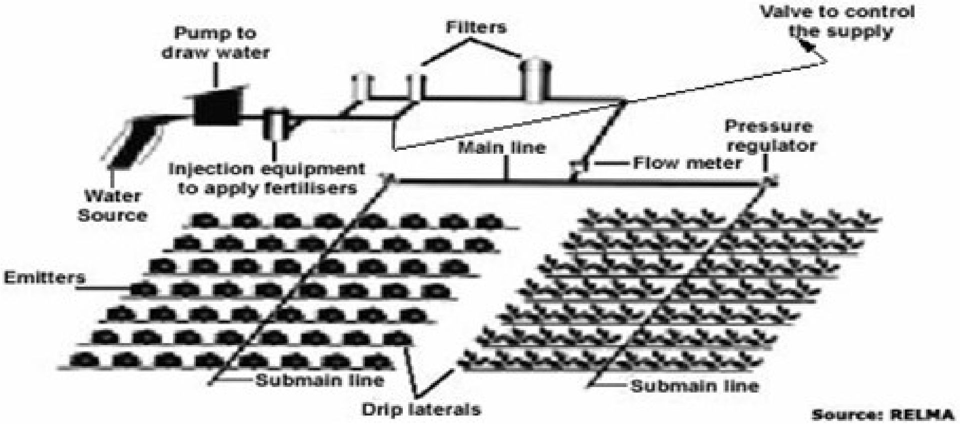


Figure 10.4: The architecture of a typical drip irrigation system.

Figure 10.5: Designing and installing a drip irrigation system is a job for a professional. This will ensure the correct amount of water is delivered to every coffee tree and the system can be monitored and serviced regularly.

Designing an irrigation system

- This is definitely a job for the professional irrigation design specialist (Figure 10.4 and Figure 10.5).
- Experience proves that getting technical design advice at the start is money well spent in cost savings and realising production potential.
- Each site is different, and all factors need to be accounted for before the system is installed.
- Variables include:
  - topography
  - the amount of water available – water licence and harvestable entitlement as well as storage capacity during peak demand
  - soil type – water-holding capacity, infiltration rate, variations in drainage rate through the profile, variation in soil type over the plantation area
  - length of rows as determined by slope, topography, the harvesting requirements for turning, unloading and harvester efficiency
  - soil moisture monitoring equipment – easy to use, durable, accurate
  - Potential to expand – allow for changing water requirements for extending the planting later and to meet maximum crop water demand.

Background	Problem	Management
Drip irrigation		
• Drip irrigation is well suited to coffee growing as it requires less water and water is applied directly to the roots, avoiding losses from evaporation, evapotranspiration, and leaching. • Drip irrigation puts water directly over or near the roots, so well-designed systems can boast a distribution uniformity of 90–95%. • The system can be operated frequently, avoiding water stress and allowing the water requirements of trees under heavy crop loads to be met. • Maximises the use of restricted water supply. • Eliminates surface drainage and potential environmental damage. • Fertilisers can be applied in the irrigation water to the active root zone, providing more efficient uptake and use of nutrients. Fertigation allows easier and more precise use of fertilisers. • Slashing and herbicide costs are lower than with overhead irrigation. • Operating costs are lower than other systems due to higher water distribution efficiency. • Convenient to operate and easily automated to take advantage of off-peak power. • Allows access to plantations during irrigation, providing more flexibility in mowing, harvesting and spraying. • Unaffected by windy conditions that would reduce the effectiveness of overhead or spray application systems. • Can open up more marginal land for irrigated horticulture, such as sandy soils, as water and nutrients are supplied directly to the plant's root zone. • Pressure-compensating drippers ensure even output of water regardless of slope (Figure 10.1).	• On sandy soil, the wetting pattern is narrower and it is difficult to cover the entire root zone . • Uneven watering can result if pressure-compensating drippers are not installed on sloping land. • Attention to design and maintenance are required as drip systems have a low tolerance to breakdowns. • The system must be properly maintained with regular cleaning and flushing to prevent permanent damage. • Tape drip systems are more susceptible to blockage and deterioration than poly pipe. • If there is a breakdown or poor irrigation scheduling, the onset of water stress in the plant can occur more readily and be more severe than with full-cover spray systems. • Drip irrigation cannot reduce the effect of high temperatures within the canopy of the tree as stomates in the leaf (which keep the plant cool) shut down if temperatures exceed 30 °C. • The most common problems with drip irrigation are blocking of the emitters due to fine dirt, algae and iron or calcium build-up. • Unsecured drip lines can move from their target position and these trees suffer from insufficient water and fertiliser. • Dripper lines are vulnerable to damage from mowers, harvesting machinery, vermin and birds.	• On sandy soils, to ensure adequate watering, two lines may be necessary, or the addition of mulch will aid in the lateral spread of the water. • Scheduling and monitoring drip irrigation is more important than with overhead spray systems. • Scheduling tools (in-line pressure and output) must be frequently monitored and continuously logged. • Getting the design right in the first place should result in trees receiving the correct amount of water at the right time. • Avoid relying on weather-based irrigation scheduling systems as the value of rainfall is quite often over-estimated. **Measure what is going on in the soil as the basis for irrigation scheduling.** Soil moisture sensors are preferred to measure available moisture within the root zone (Figure 10.2). • Water should be distributed in a uniform pattern to each tree to form a continuous wet strip along the entire tree row. This wetted strip is usually not visible on the soil surface but is present 30-40 cm below the surface where most of the fibrous feeder roots of the coffee tree are. • Regular monitoring of dripper output and maintenance is required to flush irrigation lines and chlorinate, or phosphoric acid inject if required (Figure 10.6).  **Figure 10.6: Monitoring dripper output.**

Maintaining an efficient irrigation system

Maintaining an efficient irrigation system is particularly important for drip irrigation, where it is difficult to identify problems early. The most common problems with drip irrigation are:

- Emitter plugging
- Deterioration of dripper components
- Mismanagement of system pressures.

Regular maintenance and monitoring are the best way to identify and avoid problems before tree growth and yield suffer.

Over time, system performance will decline to some degree in all drip systems, and it is important to minimise this decline.

Systems that are regularly flushed and chlorinated, have adequate filtration, and are initially well designed can maintain an excellent level of performance over time.

To gain the maximum benefit from drip irrigation systems, there are three main areas of drip system maintenance:

- Flushing
- Chlorination – cleaning the system using chlorine or acid
- Monitoring system performance.

Figure 10.7: Flushing the lateral.

Drip system maintenance

Flushing

Even with a good filtration system, sediment will still accumulate in the pipework and laterals, so it is a good idea to regularly flush filters, mains, submains and laterals (Figure 10.7).

Chlorination

This is used to reduce blockages due to organic matter. Chlorine is an oxidising agent that kills bacteria, algae and other organic matter, and prevents new growth.

Also used to prevent the growth of certain bacteria in iron-rich water that cause iron to precipitate and form a red sludge that attaches to pipes and blocks emitters.

Acid injection

While chlorine is used to manage organic deposits in drip systems, acids can be injected to control mineral deposits, such as calcium and iron, which can precipitate out in the drip system.

Drip system monitoring

Distribution uniformity (DU) is a measure of how evenly water is being delivered within an irrigation system. Poor uniformity can lead to over-watering and under-watering within the same block.

To determine whether irrigation is being applied evenly and within manufacturer's specifications, two measurements can be used to calculate dripper performance:

1. Dripper discharge
2. Operating pressure.

Detailed instructions on flushing, chlorination, hydrogen peroxide and acid injection, as well as monitoring the performance of and managing the irrigation system, are available at https://www.dpi.nsw.gov.au/agriculture/water/irrigation/systems

Section 11
Responsible plantation management

Many aspects of growing coffee commercially may impact the surrounding environment and require responsible management.

Coffee growing has less impact on the environment than many other forms of agricultural production because of its relative pest and disease-free status. Consequently, spraying and noise impacts are minimal.

Disposal of waste from processing is an environmental issue that needs to be addressed to minimise the impact of wastewater and organic contaminants.

This section provides information on some of the environmental considerations when growing coffee, the chemicals permitted for use on coffee, responsible chemical use, and workplace health and safety.

Agricultural chemicals should be used in accordance with label or permit instructions.

All chemicals, including fuels and oils, must be stored, handled, applied and disposed of in a manner that minimises environmental impacts.

Environmental management system (EMS)

An environmental management system (EMS) is a systematic approach to managing the impacts a business has on the environment. An EMS does not dictate levels of environmental performance. However, a minimum requirement is that it enables a business to comply with legislative requirements concerning the environment. It should also build on existing activities, such as industry best management practices, industry codes of practice, quality assurance, food safety schemes and workplace health and safety considerations.

An EMS has a number of steps:

1. An environmental risk analysis to identify, assess and prioritise potential environmental impacts.
2. Setting environmental objectives and targets.
3. Developing an environmental management program to meet these objectives and targets.
4. Monitoring, measuring and recording environmental performance to check that objectives and targets are being met.
5. Reviewing the system at regular intervals and improving the system as needed.

The EMS is based on the 'plan, do, check, review' management cycle to continuously improve the environmental performance of a business.

An EMS is not a product you buy off the shelf but a **process** that helps you to improve your business's environmental performance.

Monitoring is the basis of sound decision making

Management decisions require a sound basis for action to ensure the desired result is achieved in a cost-effective way. Monitoring and recording data will be necessary for scheduling irrigation, adjusting the fertiliser program, controlling pests and diseases, rainfall events and flowering dates, estimating the crop and assessing its maturity prior to harvesting. See the appendix to Section 11 for more details.

Factors that impact on the environment

Many aspects of growing coffee commercially may impact the surrounding environment and need careful management. Coffee growing has less impact on the environment than many other forms of agricultural production because of its relative pest and disease-free status. Consequently, chemical spraying and associated noise impacts are minimal.

Disposal of waste from processing is an environmental issue, particularly minimising the impact of wastewater and organic contaminants on the environment.

Aspects of coffee growing that may impact on the environment are stated below, along with the associated section of the manual that includes further detail on managing potential environmental impacts.

Land degradation:

- Site selection (Sections 5 and 6)
- Plantation layout (Section 6)
- Erosion control measures (Section 6)
- Use of mulch (Sections 8, 9 and 13).

Responsible chemical use (this Section 11):

- Judicious use of fertilisers and pesticides
- Spray drift.

Waste disposal (Sections 11 and 16):

- Water quality.

Biodiversity management:

- Flora and fauna zones, including windbreaks
- Vegetation alongside watercourses.

Minimising carbon footprint:

- Use of solar energy to power equipment and vehicles
- use of recyclable/biodegradable containers and packaging.

Strategies to avoid land degradation

Manage water flow in the plantation

- Surface water management diverts water from entering the plantation, reducing volume and velocity.
- Identifying site topography to include strategic shallow V-drains to stop volume build-up will reduce erosion.
- In planting preparation, especially if soil is cultivated or if planting mounds are made from soil excavated adjacent to the row, a gutter effect will be susceptible to erosion.

A preferred run-off control system has the following elements:

- Establish mounded tree rows and associated grassed drains running directly downhill. This is best done at establishment of the plantation.
- Do not plant trees in natural drainage ways or immediately next to them, and remove those plantings where they exist.
- Convey run-off across the slope at regular intervals, downslope via diversion drains discharging into natural water courses or formed grassed waterways.
- Establish good ground cover in the inter-row areas and drains.
- Run drains down slope and in the inter-row area.
- The inter-row area will be broad and shallow with regular diversion points and have good groundcover, as shown in Section 6.
- Where erosion is evident, such as eroded gullies, contact the local land management agency.

Mulch

- Mulch is designed to protect the soil from erosion and moisture loss. It needs to be coarse to resist rapid breakdown and allow good aeration.
- Mulch is most useful with plants up to two years old because older plantations become self-mulching.
- Mulch can also act as a good weed suppressant.
- Use side-throw mowers to throw grass clippings under the trees.

Maintaining and managing groundcover in the plantation

- Groundcovers provide protection against loss of soil because they slow down run-off water after rain and allow water to infiltrate into the soil.
- Plant roots in the ground are highly resistant to erosion and support soil structure, nutrient cycling and soil biology. The roots of ‘green’ groundcovers help bind the soil particles and can provide protection against concentrated ‘stream flow’ in heavy rain, which can dislodge soil and make it susceptible to erosion and soil structure decline.
- Increasing soil organic matter improves soil structure and fertility by increasing the soil’s ability to hold nutrients and moisture, and provides a more stable soil temperature throughout the year.
- Vigorous groundcovers provide a buffering effect against compaction by machinery.
- Once groundcover is established and maintained, the plantation is resilient to erosion and other degradation impacts. This provides good conditions for plant growth and creates a suitable habitat for soil organisms to maintain and improve soil structure, and to hold and cycle nutrients efficiently.
- As the inter-row becomes shaded, low light-tolerant species can maintain groundcover.
- Plantation canopy management is essential to enable light penetration to the plantation for groundcover growth.

Vegetative groundcovers

- Establish grass in inter-row areas to control erosion.
- Use low light-tolerant species such as smothergrass, as canopy shading reduces light infiltration under the tree. Smothergrass will grow in high light and shaded conditions.
- In drainage lines, use grass species with above-ground runners or stolons, such as Kikuyu or couch, because they are ‘ground hugging’ and give good cover and can spread.
- If using herbicide, use knockdown rather than systemic chemicals to leave the root system alive to hold the soil.

Understanding land degradation

Why is soil erosion important to me as a coffee farmer?

- High-rainfall events are typical, so proactive measures are needed.
- The topsoil has the best soil structure, contains the most nutrients, and has the highest level of soil biology and root density. As such it needs to be protected and conserved for coffee productivity.
- Topsoil erosion may be incremental, with only millimetres being removed in one event, but over time the healthiest part of the productive capacity is removed.
- Loss of valuable topsoil and topsoil organic matter due to past management practices, i.e. clearing, cultivation and erosion, results in declining soil fertility.
- Trees with roots exposed by erosion generally produce smaller beans of lower quality.
- Leaching rainfall conditions and the use of certain nitrogenous fertilisers can decrease the soil pH and cause associated toxicities (aluminium toxicity) and deficiencies (lack of calcium and magnesium), and reduced soil microbial activity.
- Breakdown of soil structure can be caused by machinery operations, particularly when the soil is wet, and with high-intensity rainfall.
- This is a pollution event for the waterways receiving this turbid, nutrient-laden material.

Land degradation includes soil erosion, soil structural decline, reduced fertility and increasing acidity. The soils of the coffee-growing regions have a variable history of soil erosion and other degradation problems due to prior and ongoing use. High rainfall increases the potential for erosion and nutrient leaching from the soil. Soil type has a major effect on the amount of soil loss:

- Sandy surface soils, for example, are generally more prone to erosion than clay soils. This is a particular problem in the dry tropics.
- Of equal importance is the physical condition of the topsoil. Soil that has been cultivated to a fine tilth when preparing planting sites is more susceptible to erosion damage than an undisturbed soil.
- Soils least likely to erode are those that are cultivated as little as possible and protected by a mulch or standing cover crop.

Gully erosion

Where the soil surface is bare and the topography is steep, soil erosion losses can be dramatic:

- Sloping land should be provided with soil conservation structures, such as diversion drains, U-drains and grassed interrow strips, to control soil loss before it becomes a problem
- Water needs to be diverted away from crop areas at regular intervals to reduce the concentration and erosive potential of run-off.

Mass movement including landslip

Steep slopes, high rainfall and a lack of deep-rooted vegetation greatly increase the risk of landslips. Where landslips occur, a range of rehabilitation measures can be used These include:

- Locating diversion banks or drains above slip areas to intercept and divert run-off water away from the slip and into more stable areas
- Re-shaping, when ponding occurs at the back of the slip, to remove water from this vulnerable area
- Using drainage pipes to intercept and remove subsurface water flows
- Maintaining a good grass cover and using trees wherever possible to stabilise and ‘dry out’ the slip area.

Off-site effects of land degradation

The off-site or downstream effects of land degradation are costs borne by the landholder at the erosion source and by the community. Transported soil material contains fertilisers and chemicals that can have serious environmental consequences some distance from the soil erosion source. Land degradation caused by erosion within a catchment can lead to:

- Sedimentation of culverts, drainage lines and watercourses, which increases flooding risks and drainage costs
- Deterioration of water quality
- Reduced water storage capacity of dams
- Pollution of the ocean, dams, creeks and rivers by soil, agricultural chemicals and fertilisers.

To maintain and improve soil health in the plantation, plan for the long term and integrate best practices for erosion control, soil organic matter management, water and nutrient management, and pest and disease management.

Figure 11.1: Every two tonnes of cherry processed results in approximately one tonne of coffee pulp.

Figure 11.2: Composted pulp and husk ready for spreading on the plantation.

Figure 11.3: Distributing the husk from hulling of the parchment.

Wastewater management

There are two ways by which coffee can be processed: the dry (natural) processing method and the wet (fermented and washed) processing method. (See **Section 16** for more details). In the wet method, the coffee cherry is subjected to mechanical and biological operations to separate the bean or seed from the skin, the mucilaginous pulp and the parchment. The skin and most of the pulp is separated in the pulpers. This fraction represents about 40% of the weight of the fresh fruit, and together with the wastewater generated needs managing to avoid pollution problems.

Background	Problem	Management
• The wet processing system uses a large volume of water – an estimated 15–20 L to produce 1 kg of green bean. • For every two tonnes of cherry that is processed, one tonne of coffee pulp is generated (Figure 11.1).	• Wet processing generates a high volume of polluted effluent that is generally made of a high concentration of organic matter and suspended solids, and is highly acidic. • If there is no recycling of water, then the on-farm water supply itself will be depleted.	• Care must be taken that this wastewater is not discharged into nearby streams or waterways. • An aerobic lake system (aerobic lagoons) can facilitate recycling of wastewater back into production plants.
• Coffee processing by-product is made up of 43% pulp, 12% mucilage and 6% parchment. • The effluent produced by coffee processing plants is coloured containing different macromolecules, such as polyphenols (e.g. melanoidins) and caffeine.	• Toxic chemicals like caffeine tannins, phenolic and alkaloids are tough to degrade using conventional biological treatment processes and are accountable for the wasterwater's dark brown colour. • Microbial processes break down the organic substances released into water bodies slowly, using up the oxygen from the water. • As demand for oxygen needed to break down organic waste in wastewater begins to exceed supply, a decrease in oxygen slowly creates anaerobic conditions.	• Controlled anaerobic digestion has been applied with different degrees of success to the treatment of liquid and solid wastes from coffee processing.
• Wastewater is rich in fermentable sugars and organic matter. • Coffee pulp is a source of nutrients: 0.5% of composted pulp is nitrogen, 0.15% is phosphorus, and 0.5% is potassium.	• This high organic matter makes it an ideal substrate for microbial processes to produce value-added products.	• Organic fertiliser – the pulp, left in piles for 3–12 months, turns into rich, black humus that can be used for composting (Figure 11.2). • Another way of composting is to mix coffee husk (Figure 11.3) with cattle manure, leaving the mixture in pits or heaps. • Coffee pulp is used as planting soil for mushroom production. After having fermented for two days, the pulp is pasteurised, drained, dried and mixed with mushroom spores. • Production of biofuels by transforming by-products and coffee residues into second-generation biofuels, which can be bioethanol, biogas and biodiesel by fermentation or anaerobic digestion.

Responsible chemical use

The use of chemicals is regulated to minimise risks to health, the environment and trade. Agricultural and veterinary chemical products must be used responsibly and safely, according to the label directions.

Agricultural chemicals can be potentially dangerous to humans, flora and fauna and ecosystems.

Pesticides can have serious effects on natural ecosystems if they move off-site via water, air or soil. Of particular concern is the effect of pesticide residues on sensitive neighbouring or downstream ecosystems, such as wetlands, freshwater and marine habitats, and national parks and reserves.

Spray drift is a potential source of friction between farmers and their neighbours:

- Spray drift can also cause damage to native wildlife and vegetation
- Liability for damage, illness or injury caused by spray drift is also becoming a serious issue.

Chemicals other than pesticides are widely used for cleaning and sanitising around growing and production sites, and for treating water. Care needs to be taken to ensure these chemicals do not enter waterways and drains or accidentally spill onto soil and vegetation.

You must:

- Only use registered agricultural and veterinary chemical products for the purpose for which they are registered
- Follow instructions on the product label.

Appropriately choosing and using chemicals protects against:

- Loss of markets due to chemical residues in produce
- Health and safety impacts
- Environmental impacts.

Consider rotational use of chemicals with different modes of action to minimise selection for resistance

Before using chemicals, ask yourself:

- Have I correctly identified the insect, weed or disease?
- Is chemical control necessary? Are there other methods of control?
- What's nearby? Are there neighbouring crops, bodies of water or sensitive areas, such as schools?
- What are my intended markets for the produce? Are there additional restrictions on chemicals that can be used?
- Are the weather conditions and stage of the pest infestation appropriate for the application?
- Do I have the correct equipment (including personal protective equipment; PPE) to apply the product?

Protocols, codes of practice and guidelines

In overseas coffee-producing countries, there is an increasing trend to attain accreditation for environment, social and agronomic high standards because of the higher price premiums paid for certified product.

According to the University of Florida, "certified coffees take one or more aspects of sustainability into account. This means the coffee [is] grown in a healthy environment, is economically viable for farmers, promotes fairness among farmers and workers, or all three aspects."

Certification schemes include:

- **Bird-friendly** – grown under the shade of other plants. Purpose is to protect migrating birds.
- **Organic** – to be labelled as such, it needs to be **certified** as organic.
- **Fairtrade** – looks at the livelihood of coffee farming from the fair treatment of workers to increased visibility in the market. It is meant to improve the lives of marginalised coffee planters around the world.
- **Rainforest Alliance** – based on sustainability, fair wages and environmental responsibility.

Protocols, codes of practice and best practice guidelines differ from a process standard such as ISO 14001 in that they do prescribe a certain level of environmental performance that the business should strive to achieve.

Codes of practice/guidelines relevant to the Australian-grown coffee industry are:

- ChemCERT https://www.chemcert.com.au/
- Farmcare www.growcom.com.au
- Freshcare https://www.freshcare.com.au/
- Organic Certification Ltd https://aco.net.au/
- Horticulture for Tomorrow www.horticulturefortomorrow.com.au
- Workplace Health and Safety https://www.safeworkaustralia.gov.au/doc/ guide-managing-risks-machinery-rural-workplaces

Figure 11.4: Cryptolaemus larvae feeding on coffee green scale.

Figure 11.5: Coffee berry borer being parasitised by the fungus *Beauvaria brassiana*. This fungus occurs in Australia and would be an important control measure should CBB ever occur here.

Integrated pest management

Pesticides are only one strategy for controlling pest insects, diseases and weeds. Consider the use of integrated pest management (IPM).

- Training in recognition of the pests and diseases that can attack your crops, their symptoms of attack and life cycles.
- Regular monitoring of crops for pests, diseases and weeds.
- Only using pesticides if pest numbers exceed threshold levels, and consider using:
  - environmentally friendly pesticides, such as oils, soaps and biological control agents, such as bacillus formulations
  - narrow-spectrum pesticides instead of broad-spectrum pesticides
  - spot applications of pesticide instead of blanket sprays
  - strategic application when the pest or disease is most vulnerable
  - resistance-minimisation strategies.
- Practising good hygiene to limit disease.
- Having an all-year-round weed management program in place, both in and around the growing area. Weeds can harbour pests and diseases, and act as a constant source of reinfestation (although weeds may also be a refuge for natural predators).
- Maintaining good soil health, including an open, well-aerated structure, high organic matter levels and a diverse and active soil biology, which in turn promotes healthy crops that are more resistant to disease and pests.
- Encouraging natural predators (Figure 11.4 and Figure 11.5).

Further information about IPM is available from state government departments of agriculture/primary industries.

Chemicals authorised for use in coffee production

The Australian Pesticides and Veterinary Medicines Authority (APVMA) is the Australian Government regulator of agricultural and veterinary (agvet) chemical products. For an agvet chemical product to legally be manufactured, imported, supplied, sold or **used** in Australia, it must be registered by the APVMA.

The registration process involves scientifically evaluating the safety and efficacy (effectiveness) of a product to protect Australia's trade and the health and safety of people, animals and the environment. Consider using an experienced agronomist to advise on pesticide application.

An up-to-date list of chemicals **registered** for use on coffee (Table 11.1) can be accessed at https://portal.apvma.gov.au/pubcris; in the search field enter "Coffee" or the active or commercial name of the chemical for which you are interested to get more details.

The APVMA also administers a **permits** scheme that allows for the legal use of chemicals in certain ways that are contrary to the label instructions, or in certain circumstances allows for the limited use of an unregistered chemical product. Permits are issued to individuals or organisations and have an expiry date.

Details of current (and expired permits) for use on coffee (Table 11.2) can be accessed at https://portal.apvma.gov.au/permits; in the search field, enter "Coffee".

Changes to permits and registrations occur from time to time, and it is the responsibility of the user to keep up to date with these changes.

Disclaimer: The authors of this manual give no warranties, expressed or implied, regarding the accuracy, completeness or fitness for a particular purpose of any information provided in this manual. Sole responsibility and risk associated with the use of the data, irrespective of the purpose to which that use is applied, must be accepted by the user.

Table 11.1: Chemicals registered for use on coffee as of 30 June 2024.

Trade name(s)	Active	Class	Pest
Govern, Goal, Cavalier, Point , Raystar, Oxifen, Crossbar and more	Oxyfluorfen	Herbicide – pre-emergent	Various weeds and grasses.
Conquest Chlorpyrifos, David Gray Chlorpyrifos	Chlorpyrifos	Insecticide	Mealy bug
SpinoSec 240, Kobus 480, Surefire Preserve, Entrust	Spinosad	Insecticide	Avocado leafroller
Yates Success, Succes Neo Jenvelva	Spinoteram	Insecticide	Avocado leafroller
OZCrop Methoxyfen, Surefire Enigma, Methoxycrop 240, Prodigy and more	Methoxyfenozide	Insecticide	Post-harvest fumigant for stored grain etc.
Fumaphos, Fumagard,Pestphos and more	Phosphine / Aluminium phosphide	Insecticide	Numerous beetles, moths, weevils in stored coffee bean

Table 11.2: Chemicals not registered but authorised for use on coffee under permits as of 30 June 2024.

Trade name	Active	Class	Pest	Expiry date	Permit holder	Permit No
Basta plus other registered products	Glufosinate	Herbicide	Various grasses and weeds	31/01/2025	ASTCA	PER93725
Entrust Organic Qallcova	Spinosad	Insecticide	Fall Armyworm	31/07/2025	Horticulture Innovation	PER89870
Zolo 430 plus other registered products	Tebuconazole	Fungicide	Cercospera leaf spot	30/06/2027	ASTCA	PER92002
SCORE Foliar plus other registered products	Difenoconazole	Fungicide	Cercospera leaf spot	30/06/2027	ASTCA	PER92001

All chemical users must record:

- The full name and contact details, including address and telephone number of:
  - the person who used the product
  - the owner or occupier of the land on which the product was used
  - anyone who was responsible for organising, overseeing or directly supervising the chemical use.
- The qualifications of the user and anyone responsible for organising or directly supervising the chemical use.
- Sufficient particulars to identify the product(s) used. Typically, this would include:
  - the registered trade name of the product as found on the label
  - the name of the manufacturer of the chemical
  - the name and amount of the active constituent of the chemical
  - the batch number, in the event of a possible product recall.
- Details identifying the exact location of the land treated, including:
  - the Real Property Description Number found on the rates notice for the property
  - a farm map detailing paddock names or numbers
  - use of global positioning system (GPS) devices may also be helpful in determining and recording the exact location of the land treated.
- The date or dates of the chemical application.
- The equipment and methods used to apply the product (e.g. boom sprayer, handgun, type of nozzle).
- Details of weather conditions (temperature, relative humidity, wind speed and direction, cloud cover, amount of any rain) before, during and after the product was used, and the times the observations were made.
- The rate at which the product was used (e.g. per hectare) or enough information to calculate the rate; for example, the quantity, concentration, total spray volume and total area with respect to the chemical application.
- A description of the type of crop treated or a situation in which the chemical was used (e.g. roadsides, fallow).

Minimising spray drift

Managing spray drift should be included in property management plans. Specific spray plans can be developed that include identification of sensitive areas and options for minimising spray drift into those areas.

You should also consider the following strategies:

- Read the label for any particulars relating to spray drift.
- Check the weather forecast before preparing product or starting off. Do not spray if the wind direction and speed would cause the spray to drift onto sensitive areas or neighbours. Under light wind conditions, wind direction is often variable and may result in unpredictable off-target movement.
- Avoid spraying on hot days (>30 ºC) or dry days (<40% relative humidity) as these conditions can increase the rate of evaporation of water-based sprays and may subsequently increase spray drift.
- Erect or plant barriers to catch possible spray drift and establish buffer zones between production areas and neighbours or sensitive natural areas, such as wetlands and waterways.
- Use appropriate equipment (such as correct spray nozzle size and pressure) to limit drift.

Laws relating to chemical storage and use change frequently. Check with your state authority for the most up-to-date information.

Making and keeping records

- All agricultural chemical users are responsible under state legislation for ensuring records of each chemical application are made (see previous page).
- There are additional obligations for use of prescribed herbicides in certain situations within specified **Great Barrier Reef** catchments. Information about these additional requirements can be found on the Queensland Government website (https://www.qld.gov.au/environment/agriculture/sustainable-farming/reef/reef-regulations).

Safe storage

All farm chemicals must be stored in a secure storage area that meets local regulations/legislation and label directions. It is recommended that growers obtain specific local advice as each state and, in some cases, each local government area may have requirements. In general, when storing agricultural chemicals, use the following guidelines:

- Store pesticides and chemicals away from residences and other occupied buildings, and in a lockable, weather-proof, fire-proof, well-ventilated area away from production areas, waterways, water supplies and flood-prone areas.
- Keep the storage area clear of extraneous or combustible waste materials.
- Ensure adequate lighting for a safe working environment.
- The floor should be impermeable and easy to clean, and the storage area should be able to contain spills.
- Maintain a chemical spill clean-up kit near the area (store pesticides and chemicals in their original containers).
- Store pesticides separate from fertilisers and chlorine. Store liquid pesticides and chemicals below powders. Maintain an up-to-date inventory.
- Store only enough pesticide on site to meet short/medium-term needs.
- Regularly check pesticide and chemical containers for any leakage or damage. Running water should be available.
- Chemical storage areas should be appropriately signed for the size and nature of the storage, including a ‘No smoking’ sign.
- Keep current material safety data sheets for all chemicals in use.

All states have strict regulations concerning the storage of pesticides and chemicals on farms and business sites, including occupational health and safety requirements. **Check with your local authority to ensure you conform to these regulations.**

Safe transport

- Ensure chemical containers are leak-proof and adequately secured when transporting on farm or between farms.
- Observe safe handling practices when transporting pesticides and chemicals.

Dealing with spills

- Read the label for specific conditions.
- Know how to deal with spills and have spill kits close to storage and mixing areas.
- At a minimum, spill kits should include: a shovel; dustless absorbent material, such as ‘kitty litter,’ activated charcoal, vermiculite, hydrated lime, clay or earth and dry sand (avoid using sawdust or other combustible materials); containers to hold the absorbent material or other leaking containers; and PPE.

Mixing

- Read the label to determine whether there are any restrictions on mixing product and the correct way to mix.
- Make sure to locate the mixing and washdown area away from water sources, drains and streams. The area should be constructed to contain spills for collection and disposal.
- Never leave a spray unit unattended while filling.
- As some drums are difficult to pour, use a specifically designed drum pourer to minimise spillage. Triple-rinse empty chemical containers and mixing equipment back into the vat.

Legal requirements for chemical users

- Under the NSW *Pesticides Act 1999*, anyone who uses pesticides in their job or business must be trained and hold a valid licence.
  - The term pesticides includes herbicides, insecticides, fungicides, bactericides, baits, lures and rodenticides (rat poison).
- Under the West Australian *Workplace Health and Safety (WHS) Act 2011*, anyone who uses hazardous chemicals must be trained.
- ChemCERT conducts training for individuals and businesses working with chemicals to ensure their safe transport, storage and application:
  - ChemCERT is a **Registered Training Organisation** (RTO: 90855) monitored by the Australian Skills Quality Authority (ASQA), that delivers nationally recognised accreditation across Australia. For more information, visit https://www.chemcert.com.au/.

Disposal of pesticide containers

- Under various state regulations, businesses are required to dispose of empty chemical containers safely. When purchasing, ask if used pesticide containers can be reused, returned, refilled or recycled.
- Used containers that cannot be returned or recycled should be triple rinsed or pressure rinsed immediately after emptying the container as residues are more difficult to remove when they are dry. This is done by filling the container with clean water to approximately a quarter of capacity, replacing the cap, shaking, and then adding the wastewater to the spray tank. This is repeated three times.
- Other disposal methods (e.g. pumping to sump or limed disposal pit) are not acceptable.
- Pressure rinsing is also an option and special equipment is available.
- Puncture steel containers after rinsing so that they cannot be re-used. Pass a steel rod or crowbar through the neck/pouring opening and out the base of the container.
- Do not puncture plastic 20 L containers included in reconditioning/reuse programs.
- Empty pesticide containers must be stored in a designated, secure area (preferably locked) and disposed either through a controlled approved disposal scheme or according to a documented procedure that meets state or territory regulations. Access to this area must be restricted for both people and animals.
- The **drumMUSTER** scheme operates in all states. From January 2004, only containers carrying the eligible container logo are collected under the drumMUSTER program. The drumMUSTER website contains details of collection days and locations. It also includes contact details for regional field officers. Pending disposal via drumMUSTER or other approved disposal methods, containers must be rinsed and stored in a separate secure area.

Disposal of surplus spray and washings

- Avoid leftover pesticide by carefully calculating how much is needed for the area to be sprayed.
- Do not allow leftover spray, rinsings from a spray tank or from empty pesticide or chemical containers to enter streams or drainage from the property. Make sure that any disposal method you use is safe for your chemical waste, location and circumstances, as incorrect disposal can result in prosecution.
- Disposal methods may include:
  - Storing rinsate or surplus spray in an appropriately labelled container and use to make up the next compatible spray mix
  - Diluting rinsate/surplus spray and spray onto target crop in a manner that will not exceed label rates or wash off chemical previously applied
  - Spraying leftover pesticide and washings from rinsing after spraying on to an area of ground away from where people will be and from drains, low drainage areas, waterways, and water storages (follow label guidelines)
  - Emptying into a lime-filled pit (obtain advice as to quantities of lime and appropriate sites before using this method)
  - Consider using enzyme products (new technology enzyme products are capable of almost completely breaking down organophosphate insecticides, either in the spray tank or in a holding tank, and provide a useful option for rapid chemical clean-up).
- Spray equipment should be filled and washed in an area chosen and established for that purpose. Spillages and rinsings should not be able to escape from the area. Ensure the area is well away from watercourses and dams.

Disposal of old, de-registered or unwanted concentrates

- Unwanted chemicals, such as those that are no longer registered for use, should not be stored on farm for longer than is necessary to arrange for their disposal.
- Ensure these chemicals are appropriately stored to prevent misuse. Storage in the chemical shed is recommended as long as the chemicals are clearly identified as not for use and, preferably, are segregated.
- One option for disposal of unwanted agricultural chemicals is **ChemClear**®. The program has a web-based booking system where growers can register chemicals for collection. For more details, visit www.chemclear.com.au or call 1800 008 182.
- Alternatively, a certified or approved chemical waste contractor or supply company can be used.

Consider community relations

- Disputes involving environmental nuisance (for example, issues related to the application of agricultural chemicals, noise or dust) can lead to a breakdown of good neighbourly relations.
- Having a ‘good neighbour’ policy and discussing aspects of farming with neighbours is one way to achieve this. Neighbours, particularly those from non-farming backgrounds, should be aware that primary producers make their living through agricultural activities and that these activities are an important part of the economy and food chain.
- Primary producers need to recognise that some activities can negatively impact their neighbours, and that at times it may be appropriate to adjust activities as far as reasonable to minimise the impact.

Health and safety

To help make a farm a safe workplace setting, here are a few things to consider:

- Make available and wear PPE when required and/or recommended, and keep it in good condition.
- Set a good example by consistently following safe work practices. Make it clear that anything less than safe is not acceptable.
- Talk about health and safety regularly with staff so that everyone is on the same page.
- Encourage workers to speak up if they have any health and safety concerns.
- If someone has a health and safety concern, act on it quickly.
- Ensure regular attendance at safety training sessions and appropriate certification where required.

Personal protective equipment

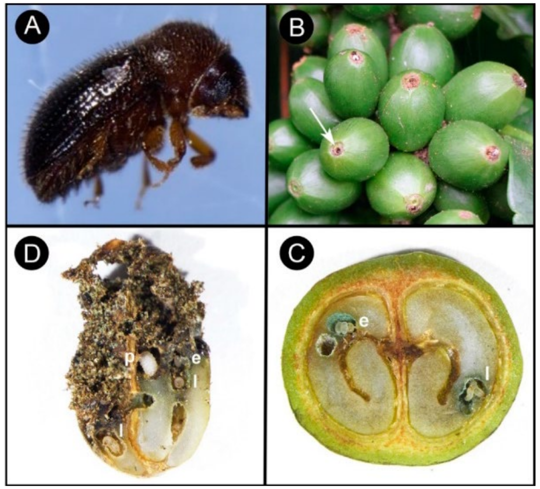
- In the horticultural sector, PPE is used for working with hazardous substances, such as crop protection products and liquid fertilisers.
- Specific PPE is required for each substance, such as gloves, spray overalls, spray masks, safety goggles and boots. Check the label for requirements.
- It’s important for all workers to wear PPE when required and/or recommended. Wearing PPE can mitigate risks and encourage safe work practices on a farm.
- PPE comes in many forms, including:
  - Hearing protective devices such as earmuffs and plugs
  - Respiratory protective equipment such as masks
  - Eye and face protection, such as safety glasses and shields
  - Safety helmets
  - Skin protection, such as gloves, gauntlets and sunscreen
  - Clothing such as high-visibility vests, life jackets and coveralls
  - Footwear such as safety boots and rubber boots.

Section 12
Pests, diseases and disorders

The good

The *Cryptolaemus* larvae actively seek out and feed on coffee green scale and mealybug.

The bad



Coffee berry borer (not present in Australia).

The ugly

Coffee leaf rust (not present in Australia).

Fortunately, Australia is free from the major coffee pests and diseases that seriously affect coffee production in other coffee-producing countries (see '**the bad**' and '**the ugly**' above). Also, we are fortunate that Australia has a range of natural biological parasitoids and predators already in our environment which are proving effective in controlling common pests, such as coffee green scale and mealy bug.

Successfully controlling our pests and diseases involves an integrated management strategy also involving chemical control, good nutrition and using our beneficial biological agents.

This section illustrates the pests, diseases and disorders in Australia, their effect on the coffee plant or cherry, and how best to combat them or prevent them from entering and infecting your coffee plantation. Keeping a watchful eye out for anything suspicious, reporting it and having it identified quickly is our best defence against major pest and disease outbreaks.

<table>
<tr><th>Pests</th><th>Problem</th><th>Management</th></tr>
<tr><td colspan="3">Coffee green scale</td></tr>
<tr>
<td>The coffee green scale, Coccus viridis, is the most important scale pest affecting coffee plants, causing serious losses in many coffee-growing regions around the world.

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<td>The coffee green scale sucks the tree sap and debilitates the plant. The green scale excretes a sweet substance called ‘honeydew’, which covers the leaves and supports the growth of a black sooty mould, which reduces photosynthesis.


The Verticillium fungus (Verticillium lecamii).</td>
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The Verticillium fungus (Verticillium lecamii) and the Cryptolaemus larva are natural control agents for the coffee green scale, and are most active during prolonged wet weather.
When scale becomes established and natural control agents are not present, spraying with a paraffinic oil (e.g., Biopest®) provides effective control by smothering the scale.
Spot spraying only the affected trees is usually sufficient, provided good coverage of the undersides of the leaves is achieved.
Keeping trees in good health and not allowing them to become stressed through poor nutrition or lack of water is another natural way of preventing infestation of scale.
Ants are always associated with scale infestations, preening and spreading the scale, and feeding on the scale’s sticky honeydew residue.
Spraying broad-spectrum insecticides to kill ants in coffee trees will soon create more problems by killing out beneficial insects that keep the scale under control.
Broad-spectrum insecticide spraying will also predispose coffee trees to being attacked by mites and other insects.
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Pests	Management
Meet our natural predator of the coffee green scale, the *Cryptolaemus* larva. 	Cryptolaemus are Australian native ladybird beetles. They and other beneficial predators can be purchased from accredited suppliers via post. Details of the 'Good Bugs' suppliers are available from www.goodbugs.org.au.  **The Cryptolaemus larvae actively seek out and feed on the coffee green scale and mealybugs.**  **Cryptolaemus controlling a severe, advanced infection of coffee green scale.**

Pests	Problem	Management
Mealybugs		
• Mealybugs (*Planococcus* spp.) feed by sucking plant sap and are potentially a serious pest of coffee, infesting tender branches, nodes, leaves, flower clusters, cherries and roots. • Mealybugs multiply in white waxy clusters, which protect the soft body of the sucking insect. 	• Like the coffee green scale, the mealybug exudes a sugary honeydew attracting the black sooty mould, which covers the leaves and affects photosynthesis. • Ants play a role in the spread of the mealybugs, feeding on the honeydew secreted by the mealybugs.  **Mealybugs infesting ripe coffee cherry, causing premature ripening.**	• Cryptolaemus larvae actively seek out and feed on mealybugs and the coffee green scale. • Trying to control mealybugs or ants with broad-spectrum insecticides is not recommended. There is a risk of interfering with the natural control mechanisms and useful predators, which are easily killed by broad-spectrum insecticide spraying. • When mealybugs become established and natural control agents are not present, spraying with a paraffinic oil (e.g., Biopest®) provides effective control by smothering the pests. • The most effective natural predator of the mealybug is the Cryptolaemus beetle and its larvae (*Cryptolaemus montrouzieri)* – the Australian native ladybird beetle. • Beneficial predator insects are extremely effective at eradicating mealybugs and decimate an infestation of the pest over a few weeks if their populations are allowed to build up.  **Cryptolaemus larvae feeding on an infestation of mealybug in a cherry cluster.**

Pests	Problem	Management
Queensland fruit fly (*Bactrocera tryoni*)		
• Adult female Queensland fruit fly lays eggs in the sweet flesh of the coffee cherry. The eggs develop into larvae or maggots, which are readily seen moving actively in the flesh of the cherry. • Cherries that have been stung or infested are usually not shiny and full, but dull and slightly flaccid.	• Queensland fruit fly is a problem for late-harvesting areas in the subtropics, where over-ripe cherry remains on the tree into the hotter months of November and December. • Penetration of the skin of the cherry and development of the larvae in the flesh allows the entry of a range of yeasts, bacteria and fungi. These can produce uncontrolled fermentation and the development of 'off' flavours in the bean. 	• There are two ways to minimise Queensland fruit fly attack: (1) harvesting before the onset of hot weather; and (2) reducing or controlling the fruit fly population in and around the plantation. • Baiting of male and female fruit flies is very effective and does not involve spraying of coffee trees. • Male attractant bait stations (such as below) can be hung on a branch. They attract the male flies from 100–200 m distance and are effective for about three months. They are a monitoring tool and do not attract the females, which do the damage. • Q-lure bait stations can be hung around the plantation to monitor the build-up of female flies. • Bait spraying should not be necessary except in extreme infestations. A weekly spot spray onto foliage of other tree types around the boundary of the plantation or on absorbent board stations will attract and kill female flies attracted to the protein bait. • Avoid spray contact with coffee trees and cherries. • Release sterile males. 

<table>
<tr><th>Diseases</th><th>Problem</th><th>Management</th></tr>
<tr><th colspan="3">Cercospera</th></tr>
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- Caused by the fungus *Cercospora coffeicoia*, Cercospera is the only significant disease affecting coffee in Australia.
- Cercospora leaf spot is common and can be found in every plantation.
- It is nearly always associated with trees in poor health or under stress.

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- It can cause severe defoliation if left unmanaged and can infect developing cherries.
- Overbearing will predispose trees to Cercospora leaf spot as nutrients are directed to developing cherries.
- Plants exposed to full sun and lacking nutrients, particularly nitrogen, are most susceptible.
- In the nursery, it is a common disease in warm, moist weather or where plants are planted too close together and air drainage is poor.
- Spores are spread during warm, wet, windy weather from fallen leaves under the trees.

Cercospora spot infection of the cherry can cause a rapid progression to the tree-dried stage (see far right column), however these cherries have not matured naturally to 'tree-dried naturals' and are inferior in quality.

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- It is generally a minor disease and is nearly always associated with trees in poor health or under stress.
- Long-distance spread from one property to another is unlikely, so any infection is likely to have come from within the plantation.
- Maintaining healthy leaf cover, good nutrition (especially with nitrogen and potassium) and good irrigation management will minimise Cercospora infection and reduce the build-up of spores within the plantation.
- Check soil and leaf nutrients levels regularly and monitor irrigation.
- A preventative spray program using fungicides, **if permitted for coffee**, can provide protection:
  - the fungicides only work BEFORE an infection period occurs
  - they DO NOT eradicate existing infections
  - Applying fungicides when the disease has already appeared not only wastes time and money, but it may also contaminate the harvested cherry if applied close to harvest.

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Diseases	Problem	Management
Fusarium wilt		
• *Fusarium solani* is a common soil and root-inhabiting fungus, causing dry root rot, and is usually confined to single trees that have been damaged or stressed. • Purplish-brown discoloration of the wood in the crown area is symptomatic of *Fusarium solani* infection. 	• This disease is not common, however when infection occurs, it often kills trees. 	• There is no control once plants are infected. • The infection is usually confined to the tree, which has been injured or stressed.
Anthracnose		
• Caused by the common fungus *Colletotrichum gloeosporioides*. • It causes death or necrosis on branches, leaves and floral buds. • Fruits can also be affected when fully ripe. • Anthracnose normally infects early-maturing fruit or weak tissue. Favourable conditions are high humidity, followed by higher temperatures. • Can be confused with Cercospora infection of the fruit. • Normally not a problem on healthy growing trees or coffee cherry.	• Causes difficulty in processing because the skin of the cherries sticks to the bean. 	• Reduce humidity in the plantation where possible by avoiding excessive overhead irrigation, controlling weeds and reducing/removing shade.

Diseases	Problem	Management
Damping off		
• Damping-off is the destruction of seedlings by pathogens. Pathogens most commonly responsible for damping off are *Pythium* species and *Rhizoctonia solani.* • These are natural soil inhabitants. 	• Seedlings in the early stage are in close contact and susceptible to soilborne diseases, such as damping off. • Large organic matter debris in the seeding germination mix is a source of inoculum. • Damage to the seedling stem close to the ground at planting provides an entry for the fungus. • Trees may not be noticeably affected immediately, but months or even a year down the track, the seedling will be seen to be not thriving and on close examination, there will be a stricture in the stem just above ground level that is cutting off flow of nutrients from the leaves.  ***Rhizoctonia solani*** **attack on Arabica coffee seeding bed.**	• Washed river sand or sterile potting media can be used for seed germination instead of soil. • Soil or sand may be treated with a fungicide or a biological control agent before planting. • Once the disease is observed, remove the affected seedlings immediately. • Care must be taken when planting seedlings to not damage the stem.

Disorders	Problem	Management
Dieback		
• The coffee cherry becomes the first 'sink' for nutrients, especially nitrogen, resulting in a weak root system, chlorosis and loss of leaves. 	• Poor nutrition and water management cause overbearing and dieback. Severe dieback results in complete loss of leaf and death of trees. 	• Continuous monitoring of the nutrient status in the soil, and in the plant through leaf and soil analysis, is essential to avoid major problems in the future. • Fertiliser applications must be related to local conditions. • Adequate nitrogen and potassium, and irrigation is essential in preventing dieback by maintaining healthy leaf growth in balance with crop load.
Hot-cold syndrome		
• High diurnal ranges in temperature (cold nights and warm days), can cause the typical 'hot-cold' syndrome, where new growth becomes distorted and yellow or chlorotic. 	• Leaf appearance may be confused with magnesium and zinc deficiency. However, this condition only occurs following cold nights and bright sunny days. • This is a temporary setback to leaf growth and is not a nutritional problem.	• Avoid applying heavy fertiliser as the plant cannot use nutrients when temperatures are too cold. • Wait until new healthy green growth appears before applying fertiliser.
Glyphosate injury		
• Glyphosate spray drift damage causes stunting, distortion and narrowing of new leaves. 	• Poor yields and susceptibility to Cercospora leaf spot can result from glyphosate injury.	• Use glyphosate according to label directions and avoid spray drift to foliage and exposed roots.

<table>
<tr><th>Biosecurity threats to Australia’s coffee industry</th><th>Problem</th><th>Management</th></tr>
<tr><td colspan="3">Coffee leaf rust (Hemileia vastatrix)</td></tr>
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Coffee leaf rust (CLR) is the most damaging coffee disease worldwide. It is caused by the fungus Hemileia vastatrix. It is present in almost every coffee-producing country. It is present in Papua New Guinea and is a potential threat due to its proximity to Australia.
Rain, wind and worker activities are the main pathways for spreading the disease inside the plant canopy and between plantations.
Transportation of planting material or contaminated goods (hessian coffee bags) are significant pathways for long-distance movement of the disease.
Disease behaviour varies depending on the cultivation system, the local weather, the varieties planted and the presence of compatible rust races.
CLR develops well at 16-28 °C with an average of 22 °C.
Plantations in cool conditions, e.g. higher altitudes and higher latitudes, are less favourable for infection.


Yellow-orange lesions form on the underside of the leaf.
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CLR causes average crop losses of 30% if no control measures are carried out, but reaching 100% when attacks are severe.


Severe defoliation caused by CLR infection in Brazil.

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Chemical control

Chemical control consists of protective fungicides that inhibit the germination of the rust fungus and systemic fungicides with curative effects to stop the infection process.
Copper-based fungicides are commonly used to protect the plants, while foliar applications of systemic fungicides, mainly the azole group (tebuconazole and difenoconazole), and Strobilurins (azoxystrobin and pyraclostrobin) are also effective but not registered for use on coffee in Australia. They would require an emergency permit to be approved for use in Australia.
A fixed calendar spray program consists of a constant number of applications throughout the year.

Breeding

Several breeding programs around the world have used the self-fertile, tetraploid hybrid between C. arabica and C. canephora, known as the Timor hybrid.
Australia’s variety selection program is evaluating several rust-resistant varieties from various coffee breeding programs through the World Coffee Research breeding program.
Varieties are being distributed for commercial evaluation following field trialling under Australian conditions.

Biological control

Increased interest in the speciality coffee market, sustainable agriculture and fungicide residues in the crop has driven interest in biological control as a field of research for the future.
However, the use of biological agents Bacillus thuringiensis, Pseudomonas spp., yeasts and chemical inducers has yet to prove practically viable under field conditions.

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<table>
<tr><th>Biosecurity threats to Australia’s coffee industry</th><th>Problem</th><th>Management</th></tr>
<tr><td colspan="3">Coffee berry borer (Hypothenemus hampei)</td></tr>
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Coffee berry borer (CBB) is the most serious pest of coffee all around the world:
It originally spread via the coffee trade from Central Africa. It has recently been found in Hawaii and in Papua New Guinea in 2017.
CBB is a small black beetle 1.55 mm long.
CBB entry holes are about 1 mm in diameter at the end of the cherry. The entry holes can be seen on green, yellow and red cherries.
CBB can spread within the plantation through infecting other cherries.
Once the borer infects a cherry, it completes its life cycle inside the cherry. When cherries are over-ripe, borers can exit and reinfect other cherries.



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Given the proximity of Papua New Guinea to Australia, there is potential risk of spread to the coffee industry in Australia.
The probable main pathways of spread into Australia are moving unprocessed (green) beans; hitchhiking on used bags, equipment, vehicles and clothing; and infested cherries and raisins (naturals).



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Exclusion

Imported green beans must be inspected by quarantine authorities. Avoid using unsterilised second-hand bags, particularly imported coffee bags.
Do not import green or unprocessed beans except through quarantine authorities.

Control spraying

CBB is difficult to control by spraying insecticides since much of its life cycle takes place deep inside the cherry.

Cultural control

The best cultural method for CBB population control is to harvest the coffee so that ripe cherries on the tree and fallen cherries on the ground are not left behind, however this is laborious, expensive and impractical.

Integrated pest management

Neither the application of chemicals nor cultural or biological methods have proven to be sufficiently effective as a single method of control. However, each has an important contribution in an IPM program.
The recommended methods include insect monitoring; using good harvesting practices; avoiding the escape of borers from the processing area; releasing biological control agents into the field; and integrating cultural controls such as harvesting every cherry left on trees and those fallen on the ground.

Biological control

Several parasitic wasps attack the CBB in its African centre of origin, as does the parasitic fungus Beauveria bassiana.
This pathogenic fungus and the parasitoids have been successfully mass produced and used in South America and Central America. Screening is underway for possible biological agents for use in Australia.
The parasitoids have been released by the millions in Colombia, and B. bassiana has been sprayed in almost all infested coffee-growing areas, where it is showing effective control of CBB in an integrated program.

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KEEPING THESE PESTS AND DISEASES OUT OF AUSTRALIA IS EVERYONE'S RESPONSIBILITY

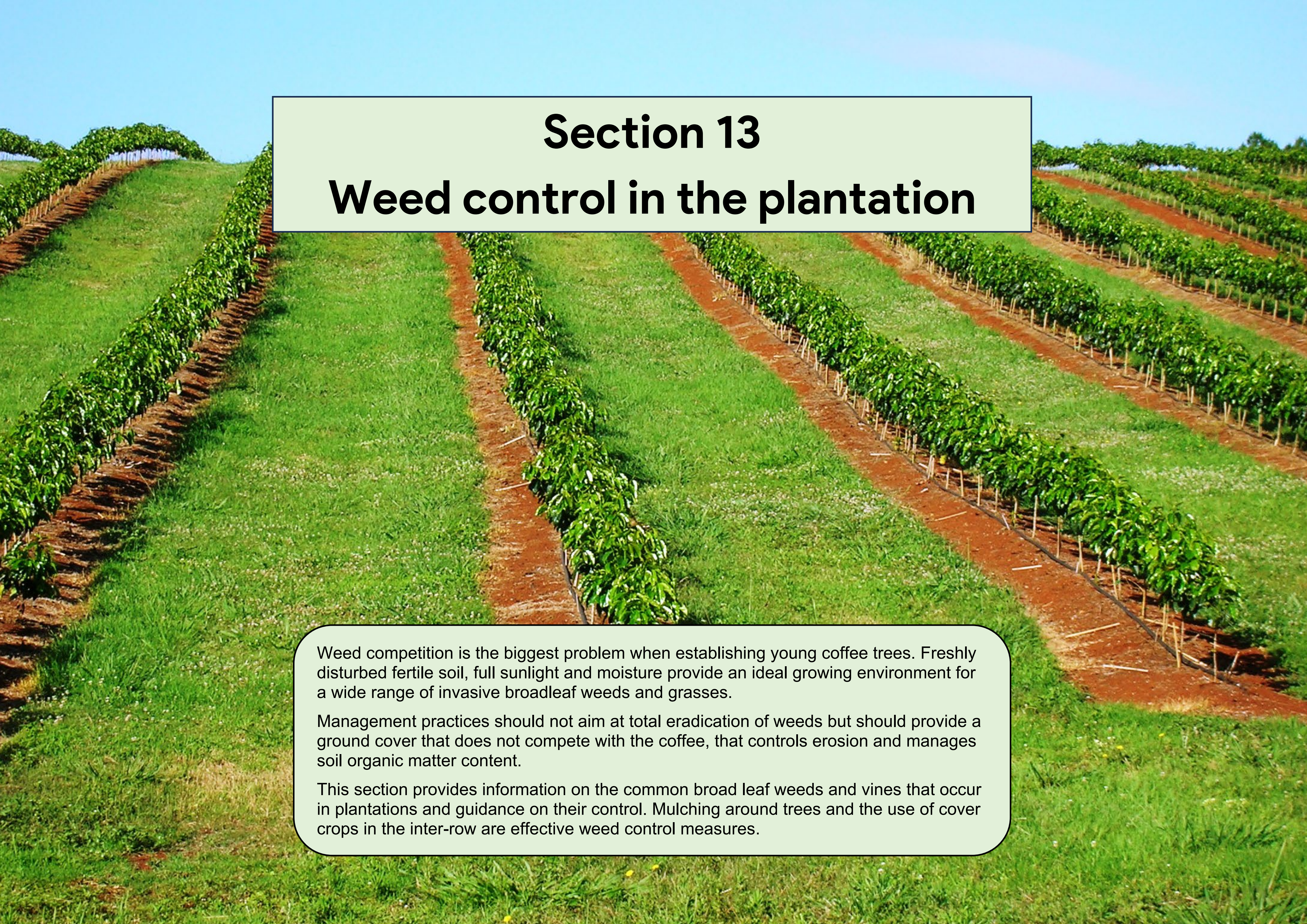
KNOW WHAT TO LOOK FOR AND REPORT ANYTHING SUSPICIOUS

MAINTAIN STRICT BIOSECURITY ON ENTRY TO YOUR PLANTATION

HAVE A BIOSECURITY PLAN FOR THESE PESTS AND DISEASES

EXOTIC PLANT PEST HOTLINE

1800 084 881



Section 13
Weed control in the plantation

Weed competition is the biggest problem when establishing young coffee trees. Freshly disturbed fertile soil, full sunlight and moisture provide an ideal growing environment for a wide range of invasive broadleaf weeds and grasses.

Management practices should not aim at total eradication of weeds but should provide a ground cover that does not compete with the coffee, that controls erosion and manages soil organic matter content.

This section provides information on the common broad leaf weeds and vines that occur in plantations and guidance on their control. Mulching around trees and the use of cover crops in the inter-row are effective weed control measures.

Figure 13.1 (above and left): Farmer's friends/ cobbler's pegs.

Figure 13.2 (above and left): Amaranth.

Background	Problem	Management
• Successful weed management starts 12 months before planting coffee when the land is prepared for planting. • In favourable growing conditions, particularly in the spring and summer, active weed growth occurs amazingly quickly. • Coffee seedlings are slow to establish over the first year in the field, competing poorly with broadleaf weeds and grasses as they establish their root system and generate the necessary plant foods for growth.	• Cultivating the soil to prepare the planting mounds results in a proliferation of invasive and aggressive broad-leafed weeds, such as farmer's friends (*Bidens pilosa*) (Figure 13.1), *Amaranthus* spp. (Figure 13.2), blackberry nightshade, (*Solanum nigrum*) (Figure 13.3), inkweed, fleabane and more. • Weed infestation can severely retard growth of the coffee seedlings, delay cropping by one or two years, result in poor tree stability and impair the structure of the root system.	• Once weeds germinate after cultivation, they should be sprayed before they set seed to deplete the potential weed seed bank in the soil. • Not allowing any seed to set once cultivation starts will enable young coffee seedlings to establish without severe ongoing competition. • As part of site preparation, spray germinating weeds with a post-emergent herbicide such as glyphosate (Roundup®) or glufosinate (Basta®), Glyphosate and a range of other weedicides are permitted on pasture before coffee seedlings are planted. • Apply a thick layer of mulch in a 50 cm wide band along the planting row.
• An application of a pre-emergent herbicide just prior to planting is desirable to give seedlings a good, uncompetitive start.	• Weeds easily beat the young and shocked seedlings to moisture and nutrients. • Weeds that establish in inter-rows will quickly invade the cultivated ground in the plant rows.	• Pre-emergent herbicides containing the active ingredient, oxyfluorfen (Stomp®, Goal® and Cavalier®) are examples of brands available. • Apply according to the label at, or immediately after, planting. • This can be repeated after 3–4 months. • It is critical to apply to wet ground and best if there is follow-up rain within 21 days. You may be required to water in the product.
• Coffee trees have a shallow, poorly developed root system, with 80% of the roots in the top 30 cm of soil. • Failure to suppress weed growth in this vital first year is the biggest problem in establishing coffee trees as they compete in the same root zone near the surface.	• Failure to control weed growth will delay cropping and predispose young trees to moisture stress, nutrient deficiency and attack by pests and diseases as their defence mechanisms are weakened. • Grasses such as kikuyu, Rhodes grass and crowsfoot will rapidly invade the planting row and restrict the growth of young trees.	• Once seedlings are planted, any herbicide spraying needs to be carefully controlled to avoid drift onto the seedlings. • Maintain spraying as the young trees establish, building up under tree mulch with side mown material from the inter-row. • Wind-free days are rare, particularly after mid-morning during the summer and autumn period of rapid weed growth – so get in while you can!

Figure 13.3: Blackberry nightshade.

Figure 13.4: Wild tobacco.

Figure 13.5: Ragweed.

Figure 13.6: Wandering Jew.

Broad leaf weeds in the plantation

Background	Problem	Management
Common broad-leaf invaders of freshly prepared ground include: • Farmer's friends or cobbler's peg (*Bidens pilosa*) (Figure 13.1) • Amaranth (*Amaranthus* spp.) (Figure 13.2) • Blackberry nightshade (*Solanum nigrum*) (Figure 13.3) • Wild tobacco (*Solanum mauritianum*) Figure 13.4) • Ragweed (*Ambrosia artemisiifolia*) (Figure 13.5) • Wandering Jew (*Tradescantia* spp.) (Figure 13.6) • Fleabane *(Conyza bonariensis)* (Figure 13.7*)* • Inkweed (*Phytolacca* spp.).	• Broad-leafed weeds are aggressive competitors for water, nutrients and light. • Coffee leaves close to the ground will absorb drift or spray. Then the herbicide can be translocated to the growing parts of the tree, and rows if a systemic herbicide is used (e.g. glyphosate). • Contact herbicides will cause burning of lower leaves contacted by the spray, but damage is localised.	• Spray when weeds are young. Allowing these weeds to become well established before spraying is a costly mistake in terms of effectiveness and product required to control when established. • Use a shielded dome sprayer to minimise the chance of spraydrift to young seedlings.

Figure 13.7: Fleabane

Spray when weeds are young. Allowing these weeds to become well established before spraying is a costly mistake in terms of effectiveness and product required to control when established.

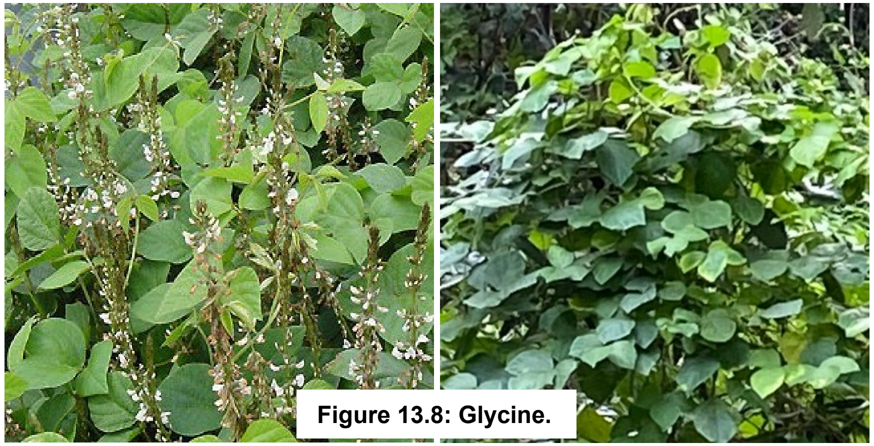


Figure 13.8: Glycine.

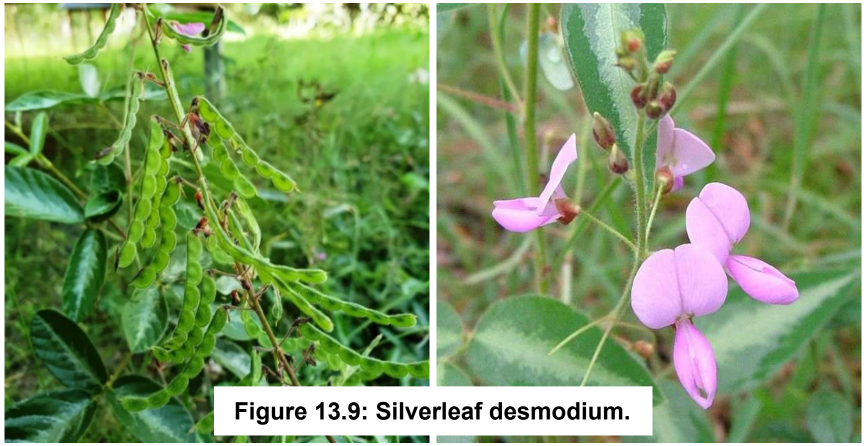


Figure 13.9: Silverleaf desmodium.

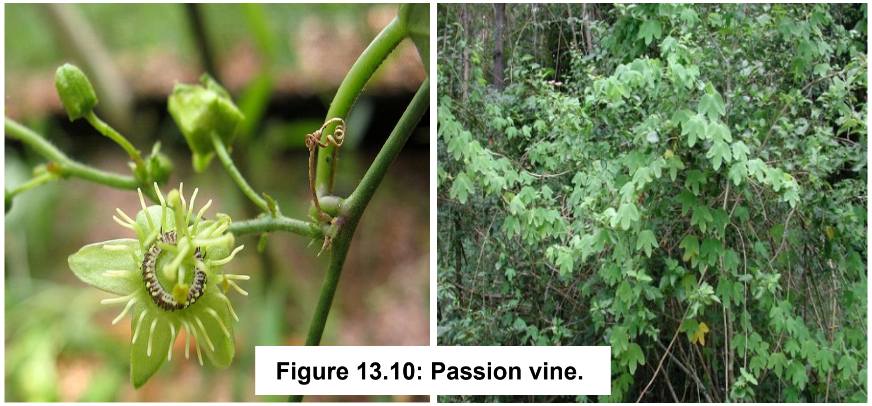


Figure 13.10: Passion vine.

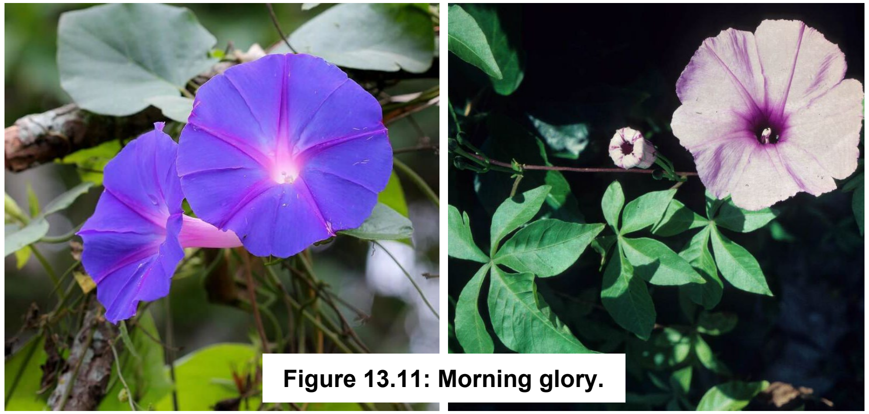


Figure 13.11: Morning glory.

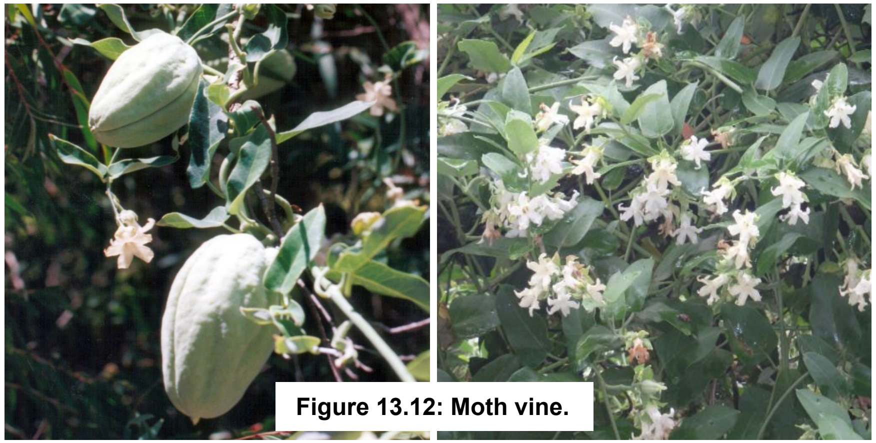


Figure 13.12: Moth vine.

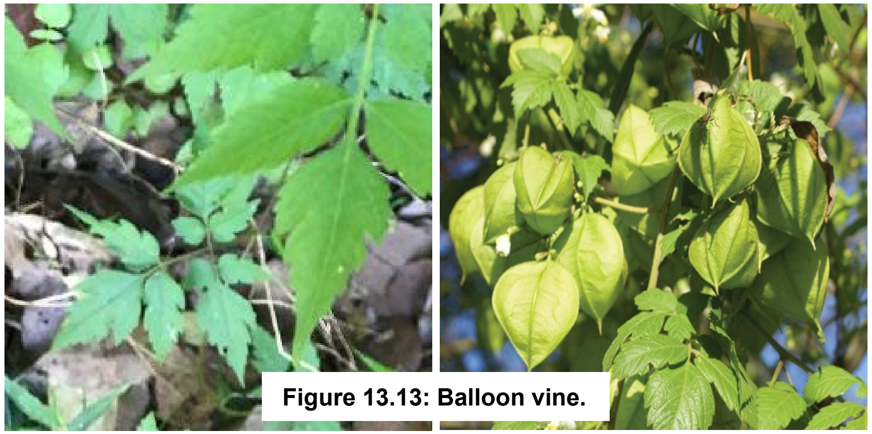


Figure 13.13: Balloon vine.

Vines in the plantation

Background	Problem	Management
Common legume vine weeds that are early invaders of freshly disturbed soil include: • Glycene *(Neonotonia wightii)* (Figure 13.8) • Silverleaf desmodium *(Desmodium uncinatum)* (Figure 13.9) • Passionfruit vine *(Passiflora* spp.*)* (Figure 13.10) • Morning glory *(Ipomea* spp.*)* (Figure 13.11) • Moth vine *(Arujia sericifera)* (Figure 13.12) • Balloon vine *(Cardiospermum grandiflorum)* (Figure 13.13) • Siratro *(Macroptilium atopurpureum)* (Figure 13.14) • Bell vine *(Ipomea plebeia)* (Figure 13.15).	• They quickly establish, suffocating trees, and will impede efficient harvesting if not removed.	• If vine growth becomes established in the trees, the stems need to be severed at the base and growth ripped out by hand. • If they cannot be ripped out by hand, then the cut surface remaining in the ground needs to be painted with a concentrated solution of herbicide (50%).



Figure 13.14 (three left images): Siratro.

Figure 13.15: Bell vine

Figure 13.16: Mulch around recently planted seedlings will minimise weed competition and retain moisture for the shallow roots of the new plant.

Figure 13.17: Straw mulch minimises weed competition and reduces the need for herbicides. It also improves the environment for surface root growth and soil microbes.

Mulching

Background	Problem	Management
• Weeds will out-compete young coffee trees that are slow to establish due to their poorly developed root system and slow growth rates in their first year. • Mulching can assist in suppressing weed growth and building soil fertility prior to planting.	• Not recommended for mechanical planting. Undecomposed mulch will hinder planting and is a potential source of disease. • Live weed seeds in mulch can be a problem.	• Apply well in advance of planting the seedlings. • Or, once seedlings are planted, spread a layer of well-shredded mulch, 300 mm wide and 50-100 mm deep along the planting rows (Figure 13.16). • Use weed-free mulch material such as sugar cane mulch, silage, baled straw or mulch from recognised weed-free sources (Figure 13.17).
• Vigilance against weeds gaining a foothold is required for the next two years and until plants have established a lush leaf canopy. There are restrictions on which herbicides can be used.	• Only permitted herbicides can be used once the seedlings are planted.	• During the early months selective hand spraying is recommended. Great skill is required when mechanically spraying to avoid spray drift impacting young seedlings. • A sprayer shielded under a dome minimises the risk of overspray on young trees Figure 13.18).

Benefits of mulching

Mulch provides the young coffee tree with the best conditions to develop a strong healthy root system and plant vigour through:

- Potentially reducing weed infestation and evaporation losses and enhancing the percolation and retention rate of soil.
- Regulating the temperature of the soil and plant roots.
- Retaining soil moisture.
- Minimising nutrient losses.
- Protecting the soil from wind and water erosion.
- Reducing compaction of soil, which can severely affect the roots of crops, which consequently reduces the growth and development of plants.
- Increasing organic matter in the soil.
- Encouraging biological activity.

Figure 13.18: A sprayer shielded under a dome minimises the risk of overspray on young coffee trees.

Figure 13.19 (above three images): Smother grass (*Dactyloctenium australe*) suppresses weeds and other grasses, does not compete with coffee trees, controls erosion and tolerates shady conditions. Its low growing habit reduces mowing and weedicide costs significantly. Sweet smother grass is planted from runners in summer.

Figure 13.20 (three images left and right): Pinto peanut (*Arachis pintoi*) is effective in controlling erosion, is shade tolerant and fixes nitrogen in the soil. It is established from runners in spring. Also, can be sown by seed, but the seed must be fresh.

Inter-row

Background	Problem	Management
• A priority after planting is to establish an inter-row ground cover that provides mulch, suppresses weeds and does not invade the plant row to compete with the trees.	• Rapidly growing tall grasses are great for suppressing inter-row weed growth. • They act as a source of mulch but will quickly invade the plant row and out-compete seedlings.	• In the establishment phase, the generation of mulch is of foremost importance to retain soil moisture and suppress weeds in the plant row. • Initially, sowing non-invasive tall-growing grasses such as Japanese millet, some types of sorghum and oats may be suitable.
• Making the transition from tall mulch-producing grasses to non-competitive groundcover that will provide long-term suppression of weeds.	• Mowing and spraying are significant management costs.	• Sweet smother grass (*Dactyloctenium australe*) provides a highly effective, low-growing groundcover: – plant as runners in early to mid-summer in moist soil – smother grass will rapidly spread and suppress most weeds and provides excellent erosion control. It does not compete with the coffee trees and grows well under shade, without climbing into the trees like kikuyu grass does. • Pinto peanut (*Arachis pintoi*) is effective in controlling erosion, is shade-tolerant and fixes nitrogen in the soil: – It is established from runners in spring. • Brachiaria, or signal grass, is commonly used in north Queensland – from seed.

Figure 13.21: A sward of pinto peanut giving excellent cover in the inter-row.

Benefits of cover crops

Soil improvement

- Reduced surface crusting.
- Improved soil structure both from the break-up of existing hardpans by roots and reduced compaction from traffic.
- Increased organic matter.
- Higher levels of soil micro-organisms and earthworms.
- Addition of nitrogen where legumes are used.
- Increased levels of soil nutrients when organic matter decays.
- Increased water infiltration and drainage.
- Reduced erosion, particularly on sloping land.
- Better access to the plantation following rain or irrigation.

Improved plantation environment

- Increased humidity and cooler soil surface temperatures where the cover crop is growing.
- Lower soil temperatures and evaporation losses, where a thick dead mulch is left on the surface in summer.
- Reduced sunburn damage to coffee trees in some situations.
- Wind protection in young plantations.

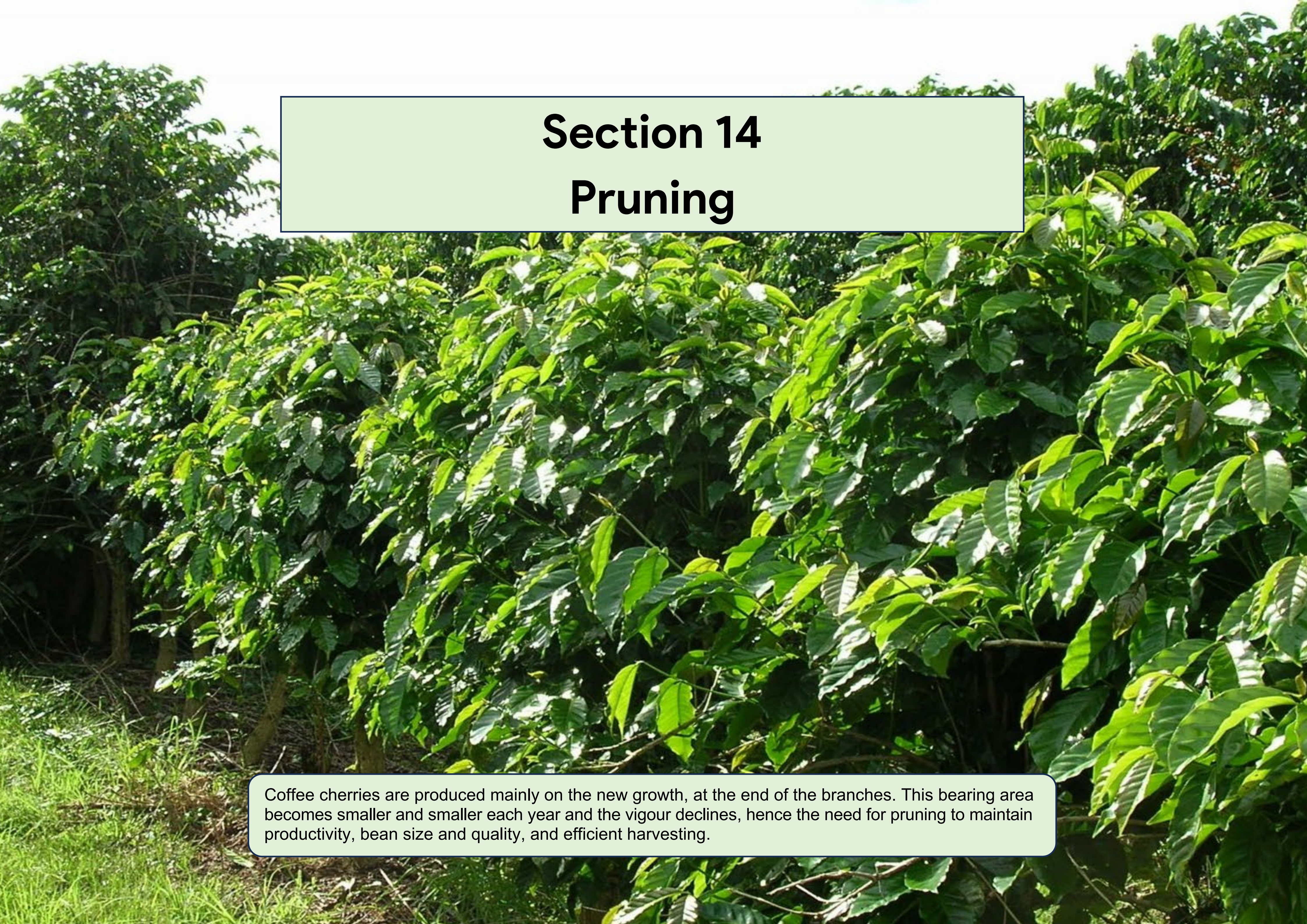
Weed and pest control

- Suppression of weeds both while the cover crop is growing and during summer if it is left as a surface mulch.
- Provision of a more favourable environment for the build-up of beneficial predators of insect pests of vines by creating a better microclimate, shelter, food and reduced dust.

Cover crops

Background	Problem	Management
• There is increasing interest in using different cover crop species and mixes of cover crops to improve soil health and productivity in the Australian horticulture industry. **Cover crop terminology** **Cover crop** refers to any plant population that has been established in the inter-row area (irrespective of species and management). **Sward** (alternatively sod) refers to groundcover, whether grass, legume or other plant species. Swards can be annual or perennial, volunteer, or sown species. **Biomass** is the total sward availability at any given time, measured in kg/ha. **Green manure** refers to an annual cover crop, re-sown each autumn and grown for maximum spring biomass production. This bulk matter can be mown, and/or incorporated at an appropriate time. **Annual regenerating sward** consists of plant species that set seed in spring, prior to ageing, and then regenerate from this seed the following autumn. Examples include annual medics and subclovers. **Perennial swards** are perennial species such as sweet smother grass, pinto peanut, perennial ryegrass, fescues, cocksfoot, lucerne, white clover and strawberry clover. Swards of these species persist over summer and can provide year-round green growth. **Beneficial insect swards** are used to provide a continuous bloom over spring and summer, and are a haven for a range of insect species. They may provide a source of nourishment for beneficial species, such as ladybirds, lacewings and parasitic wasps. **Seeding rate** refers to the weight of seed distributed over a sown hectare.	• Availability of tillage, seeding and mowing equipment. • Cover crop competition for water and nutrients (particularly for those that grow in spring and summer). • Possible need for increased irrigation and fertiliser. • Requirement for insecticides to control pasture pests, e.g. redlegged earth mite. • They negatively impact on coffee productivity by competing for water and nutrients. • Growth onto the tree rows, e.g. by running (medic clover) or lodging (vetch or field pea) and interference with water distribution from under-canopy sprinklers and microjets. • They may allow build-up of undesirable weed species in the plantation.	A range of factors must be considered when choosing a cover crop, including: • Climate – particularly the annual distribution of rain over the season. • Topography – the need to control erosion on a sloping site. • Soil characteristics – depth, texture, pH, salinity or waterlogging. • Irrigation system – there are specific requirements for drip irrigation (establishment under potentially dry conditions) and furrow irrigation (small seeds can be washed away). • Choice of cover crop may vary within a plantation, e.g. for different topography or soil types. • Time of maturity (seed set) and senescence (when it hays off). Timing may be important in relation to budburst and frost control – particularly in frost-prone areas. • Biomass production and sward height. A high sward may be required to mow and throw under the trees, or a low sward for minimal mowing. • Persistence of the mulch into the following autumn. • Use of a legume to supply soil nitrogen. • Ability to suppress weeds. • Possible requirement to suppress tree vigour. • Resistance of the cover crop to pests and diseases.

Section 14
Pruning



Coffee cherries are produced mainly on the new growth, at the end of the branches. This bearing area becomes smaller and smaller each year and the vigour declines, hence the need for pruning to maintain productivity, bean size and quality, and efficient harvesting.

Why pruning is necessary

- Keep trees in a manageable shape and size for efficient machine harvesting and machinery access between rows.
- Remove dead or unproductive stems and branches.
- Encourage new growth of stems and branches to provide crop-bearing wood.
- Coffee cherries are produced mainly on the new growth, at the end of the branches. This bearing area becomes smaller and smaller each year and the vigour declines.
- Open up the foliage canopy to light and air. Dense canopies encourage pests and diseases, while heavy shading inhibits flower bud initiation.
- Regulate the crop in heavy bearing years and even out the biennial bearing cycle, thereby reducing the risk of dieback.
- Improve yields and fruit (bean) quality. If left unpruned, yields and bean size decreases.
- Increase the efficiency of cherry removal and harvester selectivity in removing ripe cherry and leaving immature greens on the tree.
- Minimise damage to shaker fingers and reduce blockages and overloads of sticks and leaves on the harvester elevator and waste clearance mechanism.

Planning a pruning strategy

- Maintaining an income stream is important for cash flow, so it is not advisable to prune the whole plantation in the one year, unless it is practical and financially feasible to do so.
- By staggering the pruning over 6–8 years, production levels can be maintained at a reasonably uniform level.
- **Block pruning** (pruning all the trees in a block) offers significant advantages over pruning alternate or every third row in a rotation program. Pruning all the trees in each block allows for more efficient management of irrigation, fertilising, harvesting and weed control.
- **Low stumping** (30–45 cm above the ground) has major disadvantages, including uncontrolled suckering and profusion of regrowth. If trees are in an exhausted state, they may not recover from stumping. Hand thinning of sucker uprights is also very labour intensive. Stumping also delays cropping for up to two years and because the canopy is removed entirely, controlling weeds is a major management issue (Figure. 14.4).
- **Knee-height stumping** (50–60 cm) is preferred for machine harvesting as there is less suckering and damage from the harvester, as this is above the height of the fishplates (Figure14.1, Figure 14.2, Figure 14.3).

Background	Problem	Management
Fundamentals of pruning coffee		
• Coffee flowers and bears fruit on new growth. • Pruning encourages new growth of stems and branches to provide crop-bearing wood. • Three to four years after planting, the single main stem reaches full height and generates the primary branches from which the secondary and tertiary branches develop. • Regulate the crop in heavy bearing years and even out the biennial bearing cycle, thereby reducing the risk of dieback. • Pruning: – improves yields and bean quality – increases efficiency of cherry removal and harvester selectivity in removing ripe cherry and leaving immature greens on the tree – minimises damage to shaker fingers – reduces blockages and overloads of sticks and leaves on the harvester elevator and waste clearance mechanism. • There are four basic tree management systems to choose from to suit machine harvesting: – hedging – capping – stumping – replanting.	• Because coffee cherries are produced mainly on the new growth at the end of the branches, this bearing area becomes smaller and smaller each year and the vigour declines. • A few years later, the growth of the tree slows down and there are virtually no new primary branches produced. • If left unpruned, the tree enters a long period of reduced vigour and slow leaf and shoot development. If left unpruned, yields and bean size decrease. • Most of the growth and flowering then occurs at the top of the trees while the rest of the tree becomes sparse and unproductive – particularly in full sunlight. • Traditional pruning systems were developed to suit hand harvesting and consisted of multiple stems, which do not suit machine harvesting. • Stump pruning too low (less than 40 cm) encourages excessive suckering, which interferes with the harvester fish plates and the harvester damages the regrowth. • Pruning during wet weather can create infection sites for bacteria and fungi. • If trees are in an exhausted state, they may not recover from stumping, and a preferred option may be to replant.	• Where contractors are used, pruning equipment needs to be checked for cleanliness prior to entering the plantation. • Prune in dry weather if possible. • Pruning should be carried out immediately after harvest following a heavy cropping year, provided trees are in good health. This will minimise yield losses as the trees would generally be entering a light cropping year. • Remove dead or unproductive stems and branches. • Keep trees in a manageable shape and size for efficient machine harvesting and machinery access between rows (Figure 14.5, Figure 14.6, Figure 14.7). • Open the foliage canopy to light and air. Dense canopies encourage pests and diseases while heavy shading inhibits flower bud initiation. • Prune to a single stem system at least to the top of the fishplates of the harvester – about 45 cm. • For tall varieties: – hedging (top and/or sides) and topping (1.3–1.8 m) is the preferred pruning system – annual capping of new growth after harvest keeps trees within ideal height for machine harvesting – stumping to 50 cm is an effective option, however it is labour intensive as it is important to remove sucker growth to maintain a single stem. • Stumping at knee height (50–60 cm) is recommended for semi-dwarf varieties (Figure 14.1, Figure 14.2, Figure 14.3): – the regrowth occurs above the fish plate height and no damage occurs to the tree – recovery rates to full productivity occurs within two years with good nutrition and water management – annual capping of the new growth after harvest.

Figure 14.1: Semi-dwarf trees pruned eight months previously to knee height.

Figure 14.3: 20 months after pruning in the same plantation.

Figure 14.2: Heavy crop set in these trees 20 months after pruning.

Figure 14.4: (above) A tree stumped to less than 50 cm generates vigorous sucker growth. (right) This is unsuitable for machine harvesting unless suckers are removed, which is very labour intensive. It is an option for smaller plantations where hand harvesting is feasible.

Figure 14.5: A multi-purpose hedger, with circular saw blades on a rotating arm, can be used to prune the tops and sides of taller varieties.

Figure 14.6: A pair of circular blades mounted at the top and back of the harvester is used to 'cap' the trees after the last pass each harvest season. This maintains trees at optimal harvestable height.

Figure 14.7: This tree shredder is used to shred trees to knee height. Remaining side shoots are also cut off, leaving a stump that will regenerate and bear a crop after two years. The prunings are shredded into pieces less than 30 cm, which readily break down and do not interfere with any cultural operations. Best done a block at a time every 6–8 years.

Section 15
Harvesting

Harvesting strategies differ between the subtropics and hot, drier tropical growing areas, and each requires a different strategy to achieve the maximum yield of quality coffee.

This section describes ways to assess the maturity of the cherry profile, yield in the plantation, and the factors affecting harvester shaker performance.

Multiple passes are necessary in the subtropics, where synchronised flowering and maturity of the cherry is difficult to achieve.

In the dry tropical tablelands of far north Queensland, one-pass harvesting is possible as the maturity of the cherry can be concentrated by irrigation to control the flowering.

Green – immature, held tightly, not desirable in harvest. More than 1% in the processed dry green bean is unacceptable. These cherries should be left on the tree for the next harvester pass.

Coloured – mid-colour and not fully mature. Ideally, these should be left on the tree for the next harvesting pass.

Prime – full and shiny red cherry is removed more easily than immature green and coloured cherry. The ideal maturity stage for producing high-quality plunger coffee with good acidity.

Past-prime purple – darker, duller cherry losing moisture. Its quality characteristics are showing good potential for the fuller-bodied espresso coffee.

Naturals – purple/black, dehydrated, tree-dried cherry. Previously rejected as lower quality, however the fuller-bodied taste is showing exciting potential for the espresso market and for blending.

Deciding when to harvest

Knowing the potential size of the next harvest is helpful in early planning of field management operations, processing, financial planning and marketing. Various methods of estimating yield have been tried both in Australia and overseas. Details can be found on pages 15.3 and 15.4.

Figure 15.2: The five maturity stages of coffee ripening – green, coloured, prime (red), past-prime purple and tree-dried naturals.

Figure 15.3: Harvesting at the right stage of ripeness results in minimum amount of green (immature) and semi-ripe (coloured) cherry.

Ripe cherry is removed easier than immature cherry!

Setting the shaker frequency, speed of travel and pressure on the coffee tree can be achieved by understanding the relationship between maturity stage of the cherry and the fruit removal force.

A more detailed discussion on the use of a pull force meter and interpretation of results is in the appendix to Section 15.

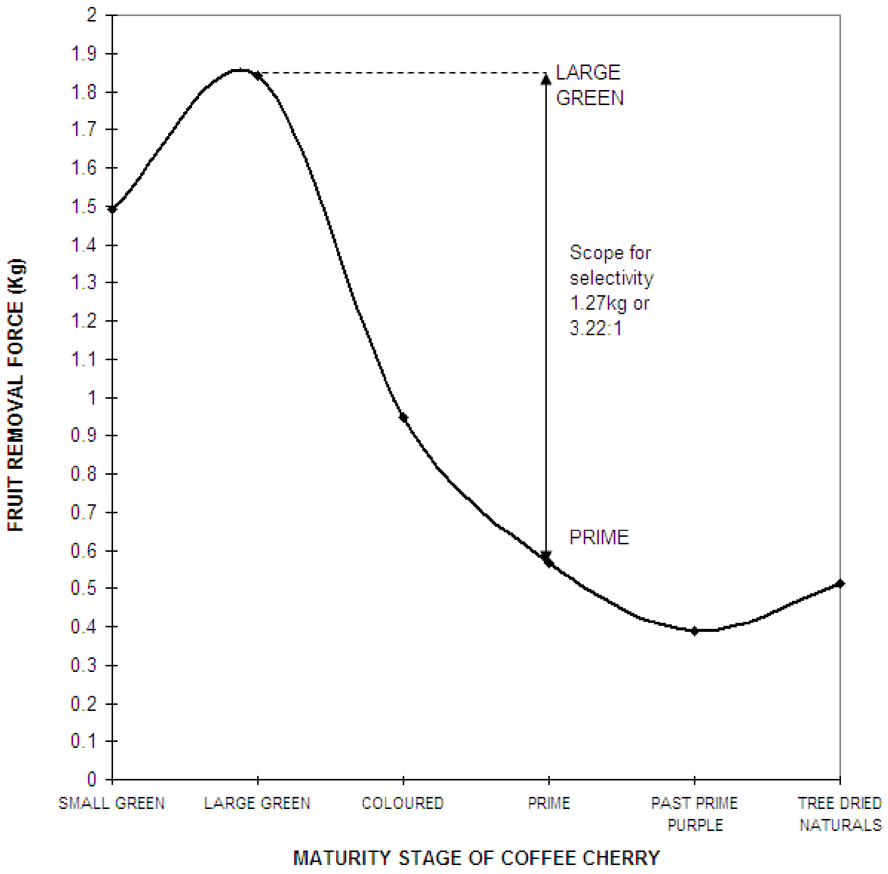


Figure 15.4: Relationship between maturity stage of coffee cherry and fruit removal force.

Figure 15.5: Maximum harvesting efficiency is achieved when the ratio of the pull-force required to remove the ripe and unripe cherry is as wide as possible.

How to do a maturity profile

Step 1. Collect all the cherry from the sample tree – this is the bulk sample.

Figure 15.6

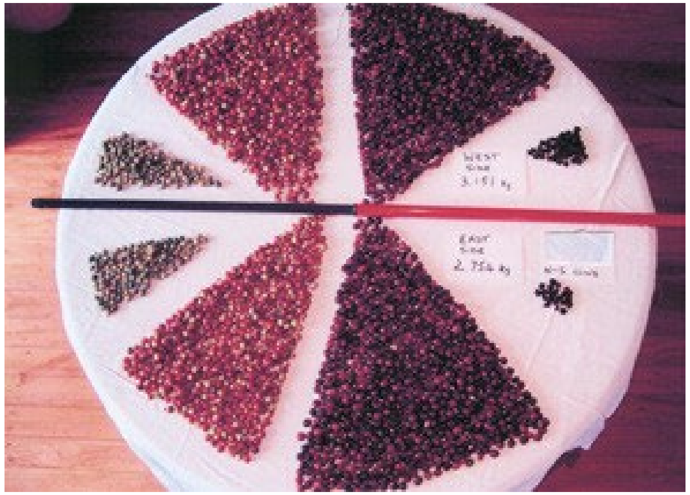


Figure 15.8: This maturity profile wheel from a different sample tree shows it is ready to harvest – more than 90% prime, past prime purple and naturals.

Step 2. Divide up the maturity stages into a maturity profile wheel.

Figure 15.7

Step 3. Calculate the area of each sector of the wheel from Step 2. This profile shows that 50% of the cherry on the tree is not ready for harvest (green 35%, coloured 15%) *and* 50% is ready for harvesting (prime plus past-prime purple 40%, naturals 10%). Harvesting should not commence until there is at least 75–80% ripe cherry (prime, past-prime purple *and* naturals).

Estimating yield

The following methodology, presented as Figure 15.9, has been developed to provide a sound statistical basis for estimating yield. It can be used when assessing the maturity profile of cherry on the trees and deciding when harvesting should commence – **here's how to do it!**

1. A quick drive through all blocks, every five rows, looking at rows each side, will give a general picture of the crop load, variation within the plantation, from zero, low, medium and high-yielding trees.
2. It will then be easy to select individual trees that are typical of these four crop load categories – zero (0), low (L), medium (M), high (H).
3. Strip pick every cherry from one selected tree in each category (a low, a medium and a high-yielding tree) onto hessian or shade cloth laid underneath the tree. Remove leaves and twigs and weigh the cherry from each sample tree. This will provide an actual yield figure for each yield category.
4. From the record sheet, add up the total number of ratings for each category, calculate the percentage of trees in each yield category (Z, L, M and H). For example – 66 trees were rated as Z, L, M or H in a block of 3,400 trees (about 1 ha).
5. To calculate the total yield: Using the total tree count for the block (3,400), calculate the number of trees in each yield category and multiply this figure by the average yield for that category.
6. To calculate the average cherry yield per tree, divide the total yield (21,268) by the number of trees (3,400). Equals 6.25 kg/tree.
7. 6.25 kg cherry equates with 1 kg green bean. A total yield projection of 3,400 trees × 1 kg = 3,400 kg dry green bean.

Remember:

- These estimates are **for the available cherry on tree – or the maximum yield possible from the block.**
- **Losses of about 30–40%** (70–60% recovery) can be expected due to cherry dropping to the ground through wind or rain, cherry left on trees after harvesting at the end of the season, and losses to the ground during harvesting.

Yield category	Weight of cherry picked	% of total sample
Zero	0	0.0%
Low	1	9%
Medium	3.5	32%
High	6.5	59%
Total	11	100%

Yield category	No. of sample trees in category	% of total sample	Total no. of trees per category
Zero	0	0.0%	0
Low	1	1.5%	51
Medium	10	15.2%	517
High	55	83.3%	2832
Total	**66**	**100%**	**3400**

Yield category	Total no. of trees per category	Cherry yield per tree	Total cherry yield
Zero	0	0	0
Low	51	1	51
Medium	517	3.5	1,809
High	2832	6.5	18,408
Total	**3400**	**11**	**21,268**

Yield per tree: 21,268 ÷ 3,400 = 6.25 kg cherry

(approx 1 kg dry green bean equivalent)

Figure 15.10: Front view of the original harvester built in the 1980s that is still operating in the dry tropics of far north Queensland.

Figure 15.11: The flat leaf and twig extraction rollers at the rear of the machine allow efficient removal of waste and prevent costly blockages and damage to the machine.

Principles of machine harvesting

- The coffee harvester is a large self-propelled three- or four-wheel machine that straddles the rows of coffee trees.
- Within the harvester frame are two vertical cylinders or shaker heads which carry hundreds of fibreglass resin rods or fingers (40-50 cm in length). The fingers are inserted into the two vertical cylinders and arranged to fully surround the shaker cylinders.
- To achieve the shaking action required to dislodge the coffee cherry, off-set weights are attached to the top of each cylinder. These rotate to give the vibration required.
- The fingers vibrate and rotate through the coffee trees as the harvester moves forward along the row.
- The speed of travel by the harvester along the row is determined by the crop load, the degree of synchronisation of ripening, and the pull-force of the ripe cherry.
- The coffee cherries are dislodged from the branches by the action of the fingers and are caught on a catching frame of spring-loaded fishplates. The fishplates expand and contract around the base of the tree. They deflect the cherry into a bucket conveyor, which transports the cherry into storage bins on the harvester.
- The bins are emptied at the end of the rows and the cherry is transported to the processing facility.

Slope constraints

- Coffee harvesters were designed to operate on fairly flat land. However, the incorporation of self-levelling devices enables operation on a side slope of 6–8%. Side-to-side slope adjustments keep the tree row centred and upright between the two shaker heads of the harvester.
- The harvester can operate travelling up rows that slope as much as 15%. For greater slopes, the harvester must operate downhill.

Background	Problem	Management
Adjusting the harvester		
• The spring-loaded fishplates surround the trunk of the tree and deflect fallen cherry onto the conveyors (Figure 15.14). • Crop lifters harvest low-hanging branches (Figure 15.13). • The shaker mechanism can be adjusted to the desired frequency and amplitude of vibration. Shaker pressure loading is also adjustable for each side of the tree and up and down the tree (Figure 15.12).	• Multiple stems at the base of the tree prevent the fishplates from closing around the base of the tree, providing a gap for cherry to fall to the ground. • There can be significant losses of coffee cherry through the collection and conveyor mechanism of the harvester.	• Remove secondary vertical shoots of coffee trees below the height of the harvester fishplates (30-40 cm) to allow the fishplates to close completely around the trunk (Figure 15.15). • Technology, such as preloading shaker finger pressure, layer harvesting, adjustable selective vibration to allow ‘on demand’ variations in shaker harmonics of the shaker heads, will improve the efficiency of ripe fruit removal without excessive removal of unripe cherry.

Figure 15.12: The vibration frequency, pressure loading, and amplitude of the harvester’s shaker fingers can be adjusted to improve the efficiency of cherry removal.

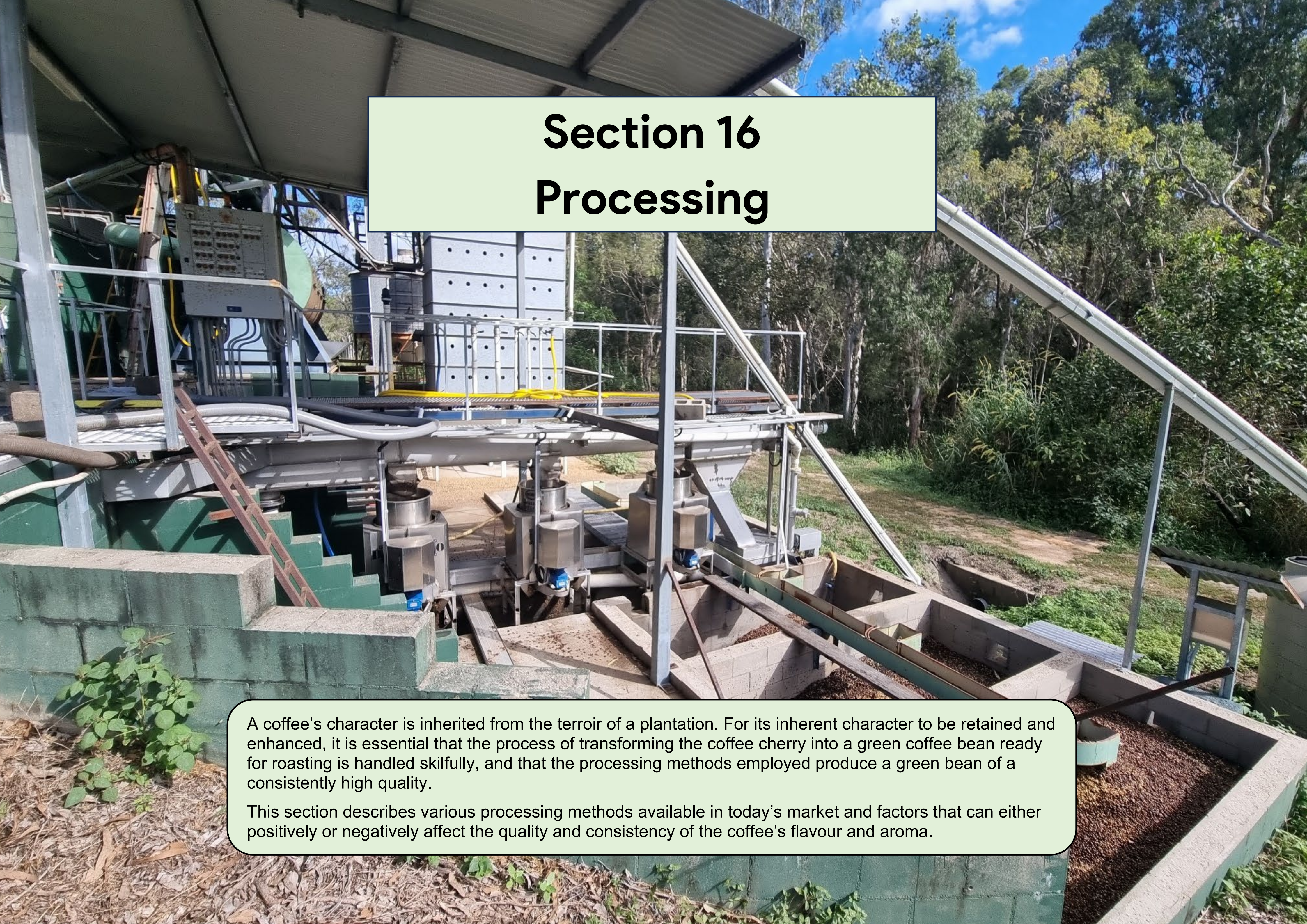
Figure 15.13: Harvesting low-hanging branches is achieved with the use of crop lifters in the front of the machine.

Figure 15.14: Spring-loaded fishplates wrap around the base of the coffee tree and deflect the cherry into the collection conveyors each side of the fishplates.

Figure 15.15: This rear view of the harvester shows how harvested cherry is conveyed through the harvesting bin on the side of the machine. Leaves and twigs are blown out of the rear of the machine.

Factors affecting harvester performance

Background	Problem	Management
Vibration frequency		
• The machine harvester can be set to give an aggressive or light agitation to remove cherry. • Depending on the timing and completeness of the initial harvest, an assessment needs to be made as to the benefit of undertaking subsequent passes to remove residual and later-ripening cherry. • As the cherry matures from green to coloured (yellow/ orange), to the red of prime cherry, and then to purple and onto the tree-dried 'natural' stage, the force holding the cherry to the branch reduces.	• An aggressive setting on the shakers will optimise the volume harvested. However, this will increase the percentage of green cherry in the pick and lessen the need for subsequent passes. • A light setting will optimise the quality and consistency of ripeness but require subsequent passes.	• The key to achieving the maximum percentage of ripe (desirable) cherry and minimising the immature cherry (undesirable) in the harvester bin is to harvest when the ratio of the pull-forces between the ripe and unripe is as wide as possible (Figure 15.4). • The harvester operator has scope for achieving selective harvesting by adjusting the controls on the harvester to maximise the recovery of ripe cherry.
Tree size and structure		
• Tall varieties such as K7 are well suited to machine harvesting because of their open branching and long inter-node length between cherry clusters. This allows more efficient transfer of vibration from shakers to the cherries. • Semi-dwarf varieties such as Catuai are also suitable and can remain at a lower height longer than tall varieties. They may be harder to remove in the first harvest, with more cherries close to the main trunk, making them more difficult to shake off. • Access to harvesting of lower branches can be a problem in semi-dwarf varieties. Mounding of planted row beds increases harvesting efficiency of lower branches.	• Tall varieties must be kept pruned to below the head of the shaker frame. This requires a strategic pruning program to sustain productivity. • Harvester efficiency is reduced and substantial damage to shaker rods and tree branches occurs if trees are allowed to grow above 2.8–3 m. • Multiple stems or upright main branches, arising from the base of the tree, cause significant problems for the shaker fingers and the collection system, as they keep the 'catching fishplates' open and let dislodged cherry fall to the ground. • Vibration efficiency is dampened by the thicker mass of older multiple vertical stems, and damage to shaker fingers occurs more frequently.	• Secondary vertical shoots emerging at the base of the main vertical should be removed. • On stumped trees, regularly rub off all but a single vertical, then once firmly established, maintain a single stem with direct herbicide spraying at the base of the stump. • Semi-dwarf varieties can be maintained at a harvestable height by pruning. • Maintaining a single stem to at least of height of 30–40 cm above the ground is essential for achieving a high recovery rate of cherry. • Other requirements, such as productivity, harvestability, pest and disease resistance, and cupping quality must be included in the criteria for selecting new varieties.
Number of harvests		
• Two or three harvester passes are usually required in the subtropics. • In the dry tropics, two harvests are often required, despite the concentrated ripening period. • The number of harvests required varies from year to year, and with climatic conditions and crop load.	• Removing the crop in one harvester pass using aggressive settings on the harvester shakers can result in lost productivity, tree damage and reduced bean quality.	• Timing of additional passes late in the harvesting cycle must be assessed. A point is reached when there is insufficient value in the remaining crop to justify further passes that could remove the developing flower buds. • A series of passes smooths the flow of product through the processing plant. In addition to evaluating the costs of harvesting and returns from additional crop, there is also benefit in cleaning the tree of cherry as it promotes its readiness to begin the next production cycle.



Section 16
Processing

A coffee's character is inherited from the terroir of a plantation. For its inherent character to be retained and enhanced, it is essential that the process of transforming the coffee cherry into a green coffee bean ready for roasting is handled skilfully, and that the processing methods employed produce a green bean of a consistently high quality.

This section describes various processing methods available in today's market and factors that can either positively or negatively affect the quality and consistency of the coffee's flavour and aroma.

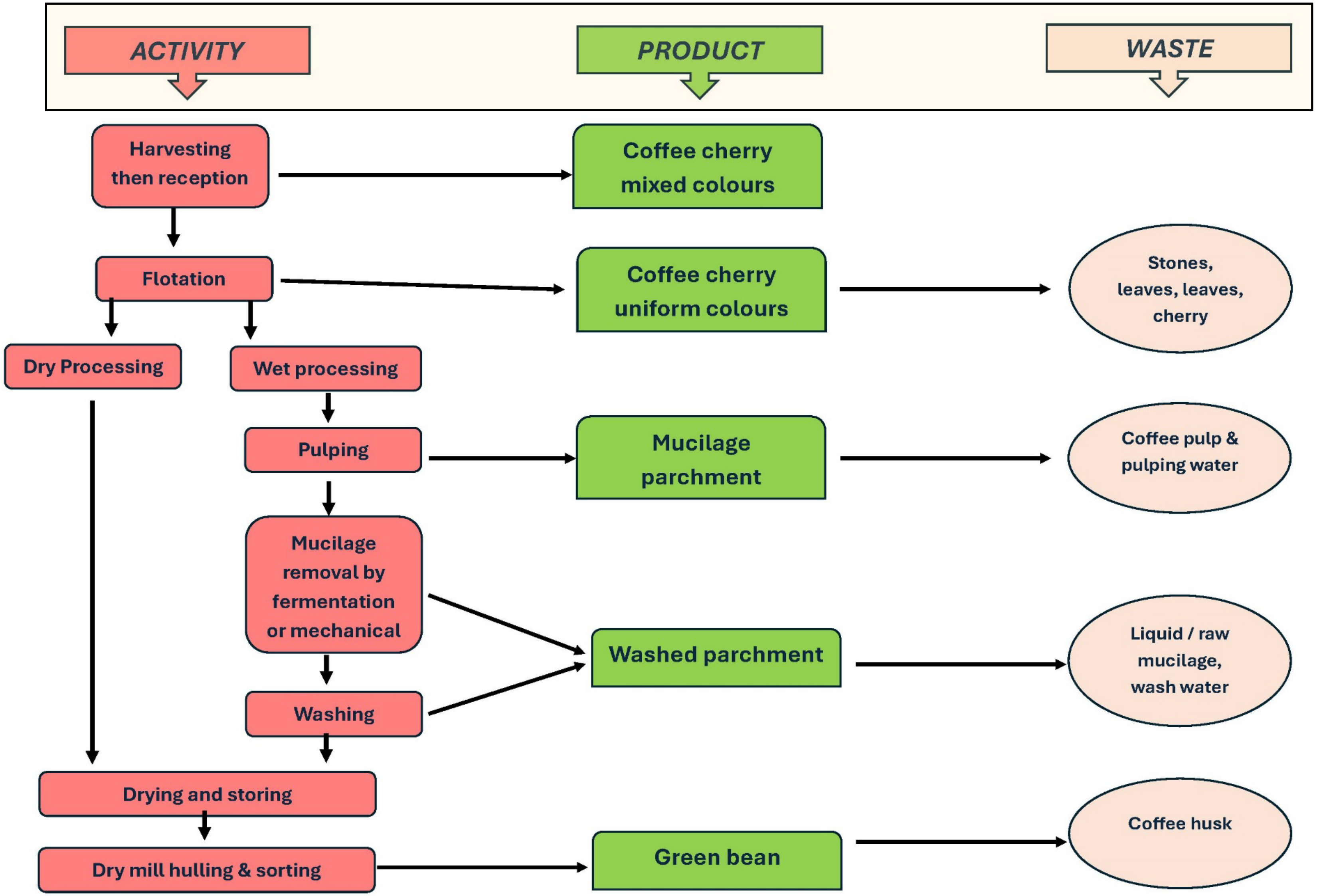


Figure 16.1: Stages of coffee processing

Background	Problem	Management
• Cherry begins to deteriorate the moment it leaves the tree. • A build-up of heat occurs through fermentation.	• Fermentation will cause decomposition of cherry skins and beans will absorb ‘off’ flavours, seriously reducing the quality of the coffee.	• Harvest in cool conditions. • Cherry held on the plantation should be stored in the shade, then delivered for processing within four hours of harvesting. • Deterioration of cherry can be slowed if stored in a cool, airy environment.
• Transporting cherry from the plantation to the processing plant needs to be well managed.	• Poor preparation and implementation of this operation will reduce time efficiency, increasing cost and will possibly affect the quality of the product. • A steady flow of supply to the plant needs to be achieved.	• Preparation and planning are key: – have the equipment to move the product serviced and ready. – have sufficient containers and space to store the volume of the expected harvest. – identify collection and delivery points and the routes between them. – include a back-up plan for critical operations.
• The scale and design of processing plants range from complex factories to on-plantation plants and stand-alone machines with improvised equipment.	• Plant and equipment need to be of adequate size to cope with expected volume. • A processing plant is a significant capital investment, requires operator expertise, has high maintenance costs and stands unused most of the time.	• Assess the scale (capacity) and the sort of equipment required to efficiently handle crop volumes. • Consider the extent to which processes are to be undertaken (see diagram). • Compare with the costs and benefits of off-site, factory processing.
• Processing is divided into wet and dry methods with a separate plant for each part (Figure 16.1). Once the product has a moisture content of less than 20%, it is in a stable and transportable condition. • More details are on pages 16.4 and 16.6.	• There are operational advantages in having the convenience of an on-plantation wet processing plant. Dry processing is less critical.	• Assess the cost, transportation and third-party dependency of off-site processing against the potential cost of self-owned capital equipment. • Consistency and quality of product is easier to achieve in fully equipped, factory-scale dry processing mills.
• Processing plants need to be protected from the weather and have adequate water supply, waste disposal provision and three phase electricity.	• Unless these are already available, the set-up costs for these requirements is considerable.	• If on-plantation processing is desired, the availability of these aspects needs to be considered at the plantation feasibility assessment stage. • Alternatively, assess the availability and convenience of using existing processing plants elsewhere.
• The efficiency of processing depends on the smooth and steady flow of product through it.	• Without the continuous supply of product, processing will be inefficient. • A delay in processing will adversely affect the quality of the product.	• To ensure smooth and continuous throughput, delay commencement of processing until adequate supply is held. • Ensure reception areas have capacity and capability to ensure continuous feed.

	Green	Coloured	Prime red	Past-prime purple	Tree-dried
					
Skins	Solid light and dark green skin	Yellow, orange and light red skins	Bright red turgid skins with fresh lustre	Soft skins, sweet sticky mucilage beginning to dehydrate	Wrinkled dark brown/black tight skins fully dehydrated and fermented
Skin/bean separation	Substantially impossible	Usually possible to separate skins from beans	Easily separated	Easily separated if dehydration is not too far progressed	Hulling when dry to remove skin and parchment (husk) or repassing while wet after initial processing
Mucilage	Undeveloped	Partly developed, bitter taste	Juicy and sweet taste	Sticky and intense sweetness	Leathery with molasses/ caramel aroma
Beans	Immature	Developed	Fully mature	Fully mature	Fully mature
Quality	Only use for caffeine extraction	Low oil content. Second-grade product reducing flavour quality	High-grade product if green cherry removed	High-grade product if processed carefully	Quality product requiring special processing
Processing methods	Generally discarded	Can be discarded by hand sorting or use of a colour sorting machine Fully washed Semi washed	Fully washed Semi washed Fermentation	Fully washed Semi washed Fermentation	Naturals Raisin Repass

Figure 16.2: Summary of the properties of the various stage of coffee cherry ripening.

<table>
<tr><th>Fully washed wet processing</th><th>Comment</th></tr>
<tr><td>

- Unripe cherry, leaves, twigs and other unwanted material are removed from the crop. This can be done by hand, passing down a conveyor belt, or mechanically, using a shaker table, which removes additional unwanted material.
- Over-ripened and fully ripened cherries float in water and are separated in floatation tanks (Figure 16.3) from unripe, coloured, prime red and past-prime cherry, which sink (see above).
- Floated product (known as naturals) is collected and spread out to dry, while cherry that sinks is conveyed to a pulping machine (Figure 16.4), which mechanically removes the fleshy pulp.
- Pulped parchment is soaked for up to 72 hours until the parchment has lost its slimy feel and is rough to touch.
- The parchment is either dried in an unwashed state or washed clean of the fermented water and then dried either mechanically or on drying beds by the sun.

</td><td>

- This processing method has been the typical processing method employed in the subtropics on smaller-scale operations. It is also used on large operations in the tropics. Relatively cheap and unsophisticated equipment is involved.
- A moderate supply of clean, fresh water is required for float tanks to promote a flow of product through the pulper, for fermentation and for washing. The water used for fermentation is highly acidic and should be discharged into holding ponds to break down before being assessed for release into water courses.
- Fermentation is the most critical stage of the process:
  - over-fermentation can result in ‘stinker beans’, which cause ‘off’ flavours and are a serious defect
  - if under-fermented, the parchment retains a coating that will continue to react when laid out to dry and can develop moulds that infuse adverse flavours into the beans
  - fermentation is carried out in batches and the size of the tanks used is a constraint on volumes that can be dealt with at any one time
  - the rate at which the mucilage breaks down varies depending on the amount of sugars in the mucilage, the ambient temperature and the humidity
  - pectolytic enzymes can be used to accelerate the removal of mucilage
  - maintaining consistency of product between each tank and batch is more difficult than with product that flows through a semi-washed process.
- During fermentation, the parchment needs to be regularly stirred and felt for sliminess. As soon as the parchment feels rough, fermentation is complete, and beans should be removed from the fermentation soup.
- Expert tasters favour coffee produced by this method. If practised correctly, resultant beans will have a uniform dark green colour and produce coffees with good acidity and sweetness.

</td></tr>
</table>

Figure 16.3: Receival – the harvester dumps the cherry crop directly into the receival tank prior to pulping.

Figure 16.4: Large processing plant with three in-line stainless steel pulpers in the background. Waste pulp collecting in tank.

Figure 16.5: Wet parchment ready for drying.

Figure 16.6: Compact in-line processing set-up for smaller operations. Receival is on the right, then passes through leaf shaker, flotation tank, pulper and demucilager.

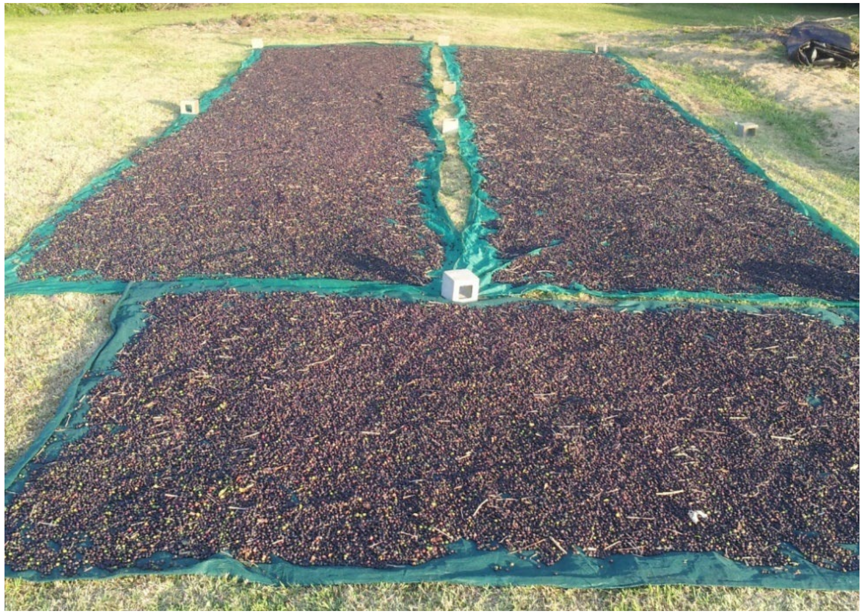
Semi-washed wet processing	Comment
• This process is the same as the fully washed method described above but eliminates the fermentation stage. • After flotation, the product can be passed through a green bean separator: – here, the desired cherry with bean is forced through a size grid and falls down to the collection tray, which leads the fruit to the pulper. The hard green skinned cherry is retained within the revolving drum and collected at a separate outlet – the wanted product then proceeds to a pulper; this removes the residual skin and flesh from the bean seed (parchment) – the wet and slimy parchment is conveyed to a demucilaging machine; this washes and scrubs off the sticky mucilage (Figure 16.5). • When washed and scrubbed, the clean parchment is sent for drying.	• This semi-washed process has become a 'standard' production method in major coffee-growing regions where water supply is limited. • It has also become the normal method of production within the Australian subtropical and tropical regions for medium (Figure 16.6) and large-scale plantations where machine harvesting produces large volumes of product that must be speedily processed. • There is a high capital cost in purchasing and housing the equipment required. • Machinery is likely to require a three-phase electricity supply. • A steady throughput of product is required for machinery to function efficiently and satisfactorily. • The rate of conveying product from one stage to the next needs to be continuously monitored. • Continuous supervision of processing equipment by a skilled machinery operator is essential to ensure the trouble-free performance and optimum quality of product that is being handled. • This process produces a clean consistent product, with beans having a good uniform green/grey colour.
Natural processing	**Comment**
• Sometimes referred to as raisin processing. • This process involves those cherries that are separated from prime cherry as floaters at the floatation stage. • Initially considered waste, this product is now regarded worthy of processing and used for blending to contribute to the complexity of coffee in the cup. • The floaters are immediately taken from flotation tanks and spread out on drying mats or loaded into dryers before they rehydrate. • The beans in their skin must be turned at least twice a day until touch dry and kept dry until fully dried to at least 20% moisture content before storing.	• As the product is primarily cherry that has completed ripening on the tree, the content is fully fermented, and the mucilage is fully infused. • If harvested when dry and separated by size (the dehydrated cherry being smaller), the moisture content may be low enough for immediate storage. • The most critical stage of this easy processing method is achieving a touch dry condition and maintaining it so until ready for storage. • Because up to 50% of the total harvest may be naturals, a considerable area is required to spread out the naturals if they are to be sun dried. • The coffee produced is not of a style favoured by expert tasters but has more intense flavours, is full-bodied with low acidity and is more suited for espresso coffees or for blending with wet processed coffee to increase complexity.
Other methods	**Comment**
• In recent years, the importance of controlling coffee fermentation in the final quality of the beverage has been recognised.	• Fermentation is influenced by the coffee fruit treatment, availability of oxygen, water addition, and starter culture utilisation. Each type of coffee fermentation protocol can influence the coffee beverage. There is a migration from the use of processes in open environments to closed environments with controlled anaerobic conditions.

Figure 16.7: Horizontal rotary driers can dry parchment or naturals.

Sun drying on shade cloth is an option for smaller plantations.

Figure 16.8 (left): Sun drying parchment.

Figure 16.9 (right): Sun drying naturals.



<table>
<tr><th>Drying</th><th>Comment</th></tr>
<tr><td>Drying processed coffee beans is required to stabilise an otherwise unstable product. Quality can easily be lost by drying that is too slow, too fast or otherwise inappropriate.
The success of the drying cycle depends on the distribution of moisture in the final product. The cells of beans contain up to 60% moisture, which is contained as free water within the cell structure. During the drying cycle, the free moisture must evaporate from the bean at a consistent rate over time.
Drying of parchment beans is a two-stage process:
the first stage (also called ‘skin drying’) may take 6–12 hours, during which time the internal moisture will be reduced to 20-25%
in the second stage (‘final drying’), the moisture content is slowly reduced from 20–25% to 10–12% over 8–24 hours.</td><td>Depending on the processing method employed, the whole fruit, the naturals or the beans may be dried. The drying process can be a source of many downstream quality issues if not managed properly.
If the drying temperatures are too high, the rate of moisture evaporation from the complex grid of coffee cells happens in an uncontrolled manner and the distribution of free moisture in the finished product is not uniform.
Moist pockets with more than 13% moisture will develop inside the cell structure. These wet pockets make the green bean unstable during storage and shipping.
In the worst-case scenario, moulds can develop and these can accelerate quality degradation, resulting in ‘off’ flavour taints, such as TCA.</td></tr>
<tr><td>For smaller producers, coffee can be dried naturally in the open on a patio, on a raised bed or on shade cloth (Figure 16.8 and Figure 16.9).
Solar (tunnel) dryers can be installed around the drying beds, which serve not only to trap the solar energy to dry the beans, but also to protect the drying beans from rain.</td><td>Natural sun drying offers the benefit of a relatively low investment in equipment.
This method facilitates an even and gradual drying process, provided that the product is turned frequently and that the mass of parchment beans is not packed too deep – preferably no deeper than 6 cm.
Condensation must be controlled when the drying beans are covered, especially at night when temperatures drop.
Freshly processed beans transpire rapidly, and the moisture must be allowed to escape. If covered by a plastic tarp, it must be positioned such that there is sufficient free space above the beans to allow air movement and evacuation of the moist air.</td></tr>
<tr><td>On larger plantations, coffee is usually dried mechanically. This drying technique uses advanced technology to carefully regulate temperature, air flow and humidity, ensuring a consistent and predictable drying process.
There are three common types of mechanical dryers used in coffee processing:
static bed or silo dryers, where hot air is forced through a bed of coffee.
contra-flow or vertical dryers, where the coffee is cycled from bottom to top and allowed to flow downward through a stream of hot air.
horizontal dryers, where the hot air is introduced through a central shaft and forced outward through a rotating, perforated horizontal cylinder from which hot air is forced through the bed of coffee (Figure 16.7).
Mechanical drying generally requires a combustible energy source to generate the heat required to dry the beans.</td><td>Mechanical drying equipment is a major capital investment.
Performance of the horizontal drum dryer is particularly sensitive to load and an under-loaded dryer works poorly since the hot air leaves with little contact with the coffee.
Rotation speed is not normally adjustable so the critical control parameters for the operator comprise the initial moisture content of the product, the loading (as near to design capacity as possible), the inlet temperature and the air flow.
The limits for the temperature during the drying process are important. The temperature should not be more than 45 °C.</td></tr>
</table>

Figure 16.10: Typically, a dry mill is undercover and has a receival station, a huller to remove the parchment and a polisher to remove remaining parchment, which is then size-graded through a series of sieves before passing over a densimetric table to sort out defective beans.

Figure 16.11: Colour sorting is an important step in coffee processing that involves removing beans with colour defects from the stream of green coffee beans. These defects can be caused by insect damage, disease or other factors, and can affect the flavour and quality of the final coffee product.

Dry mill processing	Comment
While every step in processing plays an important role in coffee's flavour, what happens at a dry mill is arguably one of the most important. It is here that the beans go through final cleaning, polishing, sorting and grading – steps that ensure the quality of the final product. 1. The first process is **hulling**, to remove the parchment husk of wet processed beans or the skin and husk of dry processed beans (Figure 16.10): • This is done by a machine that rasps the covering away from the bean. • Hullers can be fitted with magnets to take out any metallic impurities and a destoner, where the vibrations separate small stones from the green bean. 2. The second process is **polishing**, to remove any remaining parchment and the thin silver skin using a polisher or by passing through the huller again. 3. **Size grading** is done through a vertical series of sieves, each with a progressively smaller hole diameter. The hulled green bean is passed through these sieves and in the process is sorted by size. 4. During grading by **weight** (density), beans are passed over a fluid bed vibrating densimetric table. It is set at an angle and uses the gravity created by the angle combined with vibration and blowing air to sort the beans by density: • This separates high-quality, dense coffee beans, which move to the top, from less-dense beans that move to the bottom. 5. The final step in the sorting process, **grading by colour**, is to remove discoloured beans by passing the beans through a colour sorting machine: • This machine is equipped with a high-speed camera that scans the beans for colour defects (Figure 16.11). • When a defect is detected, the machine uses a jet of air to remove the off-coloured bean from the stream. • This process is efficient and can sort large quantities of coffee beans quickly. • Operators set the parameters of the machine to differentiate the colours based on client requirements and individual characteristics of a batch of coffee.	• Dry mills are an expensive capital cost and are unlikely to be cost effective for other than the largest operations. • Their operation requires skilled operators. • The dried parchment is stable and can be stored, allowing hulling to be undertaken on as-needs basis through the year, providing green bean for roasting that is fresher than green bean hulled in overseas countries and then transported to Australia for roasting. • Dry mills are established in the region and have the capacity to handle product from the region's plantations. • The market requires beans to be sorted to certain internationally recognised sizes, such as 14s (14/64ths of an inch), 16s, and 18s, etc. Peaberries (a single bean formed in the cherry) is a separate marketable category. • The cost of dry mill processing depends on the volume and quality of the product supplied to the factory and the extent to which processing and grading is required. Economies of scale apply. • As a rule of thumb, the cost of full dry mill processing and grading is in the order of $2.00/kg, depending on volume. • For there to be confidence in the quality, consistency and availability of supply of Australian-grown coffee, growers are encouraged to market product that has been well processed and graded.

Figure 16.12: Climate-controlled storage room with product stored in one tonne bags, 20 kg hessian sacs and collapsable bins.

Figure 16.14: GrainPro® resealable polyethylene bags can be used as liners in hessian bags to maintain green bean freshness, by keeping air and moisture out.

Figure 16.13: Collapsable plastic storage bins save on storage space.

Storage	Comment
• Coffee is best stored either as parchment or naturals. • Once the parchment is hulled and the green bean is exposed, it is more susceptible to adverse environmental influences. • The environment must be dry and not subject to wide variations in temperature: – a climate-controlled storage area at 20 °C and 40% humidity is ideal. • To prevent coffee taking on taints and flavours from the environment, the store should be secure, clean, well aired and not contain any volatile products (Figure 16.13). • Storage can be in bulk containers (bags or bins) or in more manageable sacks (Figure 16.12). • Green bean can be stored in hermetic resealable plastic bags, e.g. GrainPro® (Figure 16.14): – these are made from multi-layer recyclable polyethylene material with sufficient low permeability to prevent air and moisture from getting in. • Coffee is not of general interest to pests, but pest control is required in stores as vermin tend to chew holes in sacking and build nests.	• Handling requirements and storage space will determine the type and size of storage. • Coffee can be stored as parchment without physical deterioration for many years: – storing coffee is a cost and delays cash flow, and extends the risk of spoiling. – however, as a commodity in a rising market, stored coffee is an investment and a diminishing resource. – whether or not the cupping quality of coffee improves or deteriorates over time is debatable; however, there is clearly a deterioration in the appearance of the green bean, which takes on a paler straw-like hue. • Once parchment or naturals are hulled, the green bean is normally stored and marketed in 20 kg hessian sacks: – however, without the protective husk, the green bean is directly exposed to the atmosphere and is better protected in sealed plastic sacks (Figure 16.4). • There is little to be gained, and much to potentially be lost, in storing green bean for extended periods before roasting.

Appendix to Section 1: Is coffee growing for you?

Calculator to help estimate income – cross-reference with page 4 in Section 1

Set up a spreadsheet using the information in columns B and C. Enter your information into the yellow input cells C7 to C10. Set up the formulae in cells C12 to C23.
Disclaimer: This calculator was developed for illustrative purposes only. User(s) will need to input their own figures for yield, prices and costs.

A	B	C	D	E
6	**Inputs**		**Calculation**	**Notes/guide**
7	Number of trees	10,000		For K7, average is 1,000–1,200 trees per acre
8	Green bean yield per tree (250–800 g)	350		Average yield is 350–450 g per tree, max 800 g in a bumper crop (green bean, not cherry)
9	Green bean price per kilogram	19		Typical range for Australian green bean is $14–22; premium pricing is $30-plus
10	Roasted bean price per kilogram	49		Retail $40–60; sell to café $32–35; premium retail $79–99-plus
11	**Outputs**			
12	Processed green bean for sale (kg)	3,500	= C7 × C8 / 1000	Number of trees × yield per tree in grams
13	Roasted bean for sale (kg)	2,800	= C12 × 0.8	80% of the green bean output
14	Green bean revenue	$66,500	= C12 × C9	Kilogram × price per kilogram
15	Roasted bean revenue	$137,200	= C13 × C10	Kilogram × price per kilogram
16	Hybrid revenue (60% green, 40% roasted)	$94,780	= C14 × 0.6 + C15 × 0.4	60% of output sold as processed green bean and 40% sold as roasted
17	Green bean costs	$17,500	= C12 × 5	For farms up to 15,000 trees, costs range from $3–7 per kg; $5 per kg used here; change formula if you prefer another figure
18	Roasted bean costs	$28,000	= C13 × 10	Ranges from $8–12 per kg; $10 per kg used here; change formula if you prefer another figure
19	Hybrid costs (60% green, 40% roasted)	$21,700	= C17 × 0.6 + C18 × 0.4	60% of processed green bean costs PLUS 40% of roasted bean costs
20	**Margins**			
21	Green bean margin	$49,000	= C14 – C17	Excludes mortgage, rates, time, marketing, website, etc.
22	Roasted bean margin	$109,200	= C15 – C18	Excludes mortgage, rates, time, marketing, website, etc.
23	Hybrid margin (sell 60% green, 40% roast)	$73,080.0	= C16 – C19	Excludes mortgage, rates, time, marketing, website, etc.

Appendix to Section 2: Farm biosecurity for coffee growers

Contents

Preparing an on-farm biosecurity plan

The best defence against pests, diseases and weeds on your farm is to implement sound biosecurity practices. Quick and simple measures can easily be built into everyday practices that will help protect your farm and your future.

The purpose of this farm biosecurity planner is to help you identify important biosecurity risks on your farm and provide guidance on how to address them. By developing an action plan, you will be able to identify and prioritise biosecurity practices relevant to your property. Many of the identified risks require continuous monitoring and vigilance.

Biosecurity essentials

When devising a plan for your farm, these biosecurity essentials are a good place to start. The essentials are:

- Farm inputs
- Farm outputs
- People, vehicles and equipment
- Production practices
- Weeds
- Train, plan and record.

The actual management practices you choose to use will vary depending on the parameters of your property(s):

- Good practices need not be expensive, but they do need to be easy to follow and attended to regularly.
- Initially, they may take up a little of your time but will become habit in time and are invaluable in the face of a biosecurity event.
- If you build your plan around daily, monthly or yearly farm routines, then biosecurity should become a regular habit.

Priorities

After you have ranked your priorities, assess which ones you can achieve in the short and long term. Go back to the plan periodically and check progress towards your goals.

As a guide, short-term activities can:

- Be planned and implemented within 12 months
- Help your business comply with regulatory requirements
- Be financially feasible in the short term
- Fit in with the time commitments of your enterprise.

Long-term activities:

- Are planned and implemented over more than one year
- Need additional financial, personnel or resources that are not currently available
- Enhance the quality of service, aesthetics or administrative procedures.

Property map

Having a map of your property can be helpful to identify key features to factor into your planned biosecurity practices, such as:

- Known pest, disease or weed problem areas
- Entry and exit points
- Main roadways or parking areas and how close they are to production areas
- The best places to locate biosecurity zones, wash stations or check points.

How to use this action planner

Risk assessment is an important element of biosecurity management. Risks identified in this planner and their associated actions are comprehensive suggestions covering a variety of scenarios. It is unlikely that all actions in this planner will apply to your property.

Go through the action planner and identify which risks are applicable to you and your property. Think about the suggested actions as examples to then develop your own personalised actions best suited to your property. It is advisable to also plan to reassess your property and processes at relevant timepoints to your property, activities and emerging environmental risks.

Risk assessment matrix

Risk assessment is about identifying a hazard, considering what could happen (consequence) and what the chances of this occurring are (likelihood). This is a practical approach to ensure that you apply your resources to where they will achieve an outcome, without wasting time and money (Figure A2.1).

Use this risk assessment matrix to determine the level of risk an activity is likely to pose to your property and production. The risk assessment can be helpful in prioritising which biosecurity practices to implement first. For more details, see this Animal Health Australia risk assessment fact sheet (https://www.farmbiosecurity.com.au/wp-content/uploads/2019/11/Risk-Assessment-Fact-Sheet.pdf).

		Likelihood of occurrence		
		Unlikely Could happen sometimes	**Likely** Could happen most times	**Very likely** Could happen every time
Impact to property, production and/or surrounding area if occurs	**Minor** May have little impact	Low risk	Medium risk	Medium risk
	Moderate Will have some impact	Low risk	Medium risk	**High risk**
	Major Will have great impact	Medium risk	**High risk**	**High risk**

Modified from: Badgery-Parker, J. (2009). *Keep it CLEAN: Reducing costs and losses in the management of pests and diseases in the greenhouse*. NSW Department of Primary Industries. https://www.farmbiosecurity.com.au/wp-content/uploads/2019/03/Keep-it-clean-booklet.pdf

Figure A2.1: Risk matrix.

Risk assessment can help determine:

- How severe the risk is
- Whether any existing control measures are effective
- What action you can take to control the risk
- How urgently action needs to be taken (Figure A2.2).

Level of risk rating	Response
Minor	Ongoing monitoring
Moderate	Active management
Major	Urgent intervention

Figure A2.2: Risk response table.

Farm inputs

Almost anything moved onto your property can be a potential source of a biosecurity risk (e.g. plant pests, diseases, weed seeds, planting material, chemical and organic soil amendments etc). Water sources and feral animals that enter the property can also be sources of biosecurity risk.

Farm input	Potential risk	Action(s) to take	Action	Done?
New plants or propagation material 	New plants and propagation material introduced to your property could be carrying unwanted diseases and pests.	• Make sure plant material is sourced from a reputable supplier, preferably with a health status guarantee. • Isolate new planting material away from healthy plants for 3–6 weeks until you are sure they are pest and disease-free. • Regularly check newly planted stock for signs of pests and diseases. • If pest or disease occurrence is identified, treat before they become established.		
Water sources 	Water is a potential carrier of unwanted pests. It can carry weed seeds and soil, or waterborne pests, such as fungi, bacteria and nematodes. Many pest and disease-causing organisms can survive for a long time in water sources until they find a host.	• Inspect water inlets and storages for rubbish, weeds or pests that could cause contamination. • Consider the implications of recycled water. • Prevent algal blooms by aerating or treating water that is stored in dams and is high in nutrients.		
Fertiliser 	Organic fertilisers (manure) can be the source of weeds, nematodes, pests and diseases if not properly prepared.	• Ensure that organic fertilisers are thoroughly composted to destroy weed seeds, pests and disease-causing organisms. • Maintain a record of the source of organic fertilisers, the application dates and where applied.		

Farm outputs

Responsibility for biosecurity doesn't end when your produce leaves the farm gate. The biosecurity measures you put in place support not only protection of your own property, but also biosecurity in your region and potentially the Australian coffee industry.

Farm output	Potential risk	Action(s) to take	Action	Done?
Moving plant products off the property 	There are two aspects to consider here: • Biosecurity – parts of plants separated from the crop can still spread diseases and pests from your property and threaten the region. • Product integrity – documentation to verify the management history that applies to the product supplied.	• Ensure plant products are free of pests and diseases, that your records are up to date, and that the transport vehicle is cleaned down before and after transportation. • Keep records of product applications, such as date applied, items used, and the fields/areas applied to. • Provide copies of paperwork, such as Interstate Certification Assurances, where required.		
Product packing 	Soil and plant material adhering to harvested crops can carry insect pests and disease-causing organisms. If this product is transported to a new region without proper precautions, there is a risk of pest and disease spread.	• Remove as much excess plant material and soil as possible from harvested crops. • Minimise post-harvest contamination. • If chemical treatments have been applied to the crop, a 'spray diary' record should accompany each consignment.		
Product transport 	Transport vehicles and containers can contain chemical residues, insect pests, diseases, weed seeds and soil or other contaminants from previous deliveries. Contamination may result where containers have not been adequately cleaned out after carrying another commodity, such as treated fertiliser.	• Ensure all transport vehicles and containers are adequately cleaned, before loading of plant products and other farm inputs, such as fertiliser.		

People

If it can move, it can carry plant diseases, pests and weeds. For this reason, people, vehicles and equipment pose a high biosecurity risk and should be managed.

People	Potential risk	Action(s) to take	Action	Done?
Property access 	Multiple entry points to your property make it difficult to control visitor access and manage high-risk visitors, such as those who visit multiple properties each day.	• Limit the number of access points to your property (lock unused gates). • Use signs to direct visitors to a designated parking or reception area. • Access to production areas (fields, sheds, etc.) should be limited to a restricted range of personnel only. • Keep a visitors' log with contact details, dates and times, and purpose of entry.		
Signage 	Never assume that people know what to do when they arrive at your property. Without signage, visitors and staff may be unaware of the biosecurity procedures enforced on your property.	• Erect signs to instruct visitors and staff. Use clear instructions and provide relevant contact details, such as a phone number.		
Visitor risk assessment 	Visitors can unknowingly carry diseases, pests and weeds on their clothes and personal items. The risk is greater if they have been in contact with other crops or have recently been interstate or overseas.	• Have a script of risk assessment questions ready to ask and instructions to be given to visitors. • If required, provide the visitor with cleaning equipment or a change of clothing or footwear to reduce the risk. • If you cannot reduce the risk, refuse entry to high-risk visitors.		

People	Potential risk	Action(s) to take	Action	Done?
Field days or walks 	Holding field days or walks on a property introduces risks from a wider region, with people potentially carrying pest, disease or weed material from their properties, on their vehicles, shoes or clothing.	If you are holding a field day on your property, make sure you: • Provide a designated parking area away from production areas • Use signage to direct visitors to a sign-in area with a visitor register • Put in place general hygiene measures, such as foot baths, to minimise risk • Limit contact with production areas and use only main roadways and tracks • Record visitor contact details.		

Vehicles, equipment and machinery

Diseases, pests and weeds can enter a farm and be spread by equipment and vehicles, either directly or in plant material or soil. It is important to maintain equipment hygiene and ensure all vehicles that visit your property are clean and well maintained.

Vehicles and equipment	Potential risk	Action(s) to take	Action	Done?
Equipment hygiene 	Tools and equipment can carry diseases, pests and weeds seeds. Risk of disease spread is higher when equipment is borrowed, loaned or bought second-hand from other properties. Cultivation machinery and equipment can transfer insect pests and diseases to subsequently managed crops.	• Clean and disinfect tools and equipment before and after use on crops. • Clean and disinfect second-hand, borrowed, loaned or contractors' equipment before and after use. • Ensure no soil, plant material (including weed seeds) or pests are left on or in machinery or transport equipment by removing any contaminants and disinfecting.		
Dedicated equipment 	Practically, it may be best to have dedicated tools, clothing and footwear for use on crops affected by pests or diseases. This equipment should never be used in clean areas of your property.	• Have dedicated tools, clothing and footwear available for use in production areas affected by pests or diseases. • Always work with sick plants last (work from clean to dirty).		
Vehicle entry points 	Multiple, unsecured entry points to your property make it difficult to control access and manage high-risk visitors. These could include utility providers or agronomists who visit multiple properties every day.	• Encourage visitors to enter the property via one or two routes only. • Use signs to inform visitors about property access points.		

Vehicles and equipment	Potential risk	Action(s) to take	Action	Done?
Vehicle hygiene and washes 	All parts of a vehicle can carry disease-causing organisms, pests and weed seeds.	• Provide a bunded wash area for vehicles that need to enter production areas for wastewater management. • If possible, use a high-pressure wash-down (or blow down) facility located well away from crops for cleaning vehicles. • For best protection, disinfect after washing.		
Vehicle movement and parking 	All parts of a vehicle can carry disease-causing organisms, pests and weed seeds. By restricting parking and vehicle movements on the property, it is easier to control and monitor the spread of diseases, pests and weeds.	• Minimise the number of vehicles you allow onto the property and restrict them to designated visitor parking areas. • Not all vehicles need to access production areas. Where possible, have designated vehicles that are for use on-farm or use your own farm vehicles to transport visitors around the property. • Monitor areas around parking facilities for signs of diseases, pests and weeds.		
Roads and tracks 	There is an increased risk of introducing diseases, pests and weeds when vehicles travel off, or divert from, established roads and tracks.	• Have farm maps on hand to give to visitors and farm workers. • Require visitors to stay on established roads or tracks. • Check areas next to roads and tracks for signs of diseases, pests and weeds, and treat weeds before they set seed or become established.		

Production practices

Good on-farm hygiene reduces the risk of spreading pests and diseases. Implement simple hygiene practices for water, product packaging, storage facilities, waste materials and plant propagation activities.

Production practices	Potential risk	Action(s) to take	Action	Done?
Water management 	The management of water supplies is important for the maintenance of healthy plants. If water sources become contaminated, they can spread pests throughout production areas.	• Where possible, use drip irrigation for recycled water to avoid aerosol formation. • Prevent algal blooms by aerating or treating water that is high in nutrients and is stored in dams.		
Plant waste 	Plant material can still harbour pests and diseases even after it is removed from the growing plant.	• Collect all plant waste that shows signs of pests or diseases, and dispose of it by deep burial or burning, well away from water sources and production areas. • For cuttings or healthy waste plant material, use a dedicated waste management facility or compost it thoroughly.		
Monitoring and surveillance 	Early detection of pests and diseases, gives you the best chance to prevent pests or diseases from establishing on your property, and ongoing additional expenses for their control. Early detection also increases the chance of eradicating a new pest or disease. Recording the absence of pests or diseases is just as important as recording their presence.	• Regularly monitor your crops. • Become familiar with the pests and diseases commonly found in your region so you will know if you see something different. • Monitor for new weeds along roadsides and fence lines along the perimeter of your farm. • Display posters showing common pests and diseases to help staff with identification. • Consider developing an emergency management plan to assist in the event of a new outbreak (e.g. coffee berry borer).		

Production practices	Potential risk	Action(s) to take	Action	Done?
Monitoring frequency 	There is a significant risk that pests and disease can enter your property if you do not monitor the plantation regularly.	• Establish a routine to regularly monitor activity and plant health in the plantation. • Increase the frequency of inspections of crops during periods of higher risk such as known disease outbreaks, increased insect and wildlife activity or growing periods for weeds. • Treat pests, diseases and weeds in a timely manner.		
Agricultural chemicals 	Chemical residues on plant products can result in rejection from international and domestic markets, and can pose a risk to human health.	• Only use products permitted in Australia for use on coffee or within appropriate timeframes prior to planting. • Follow the instructions on the label and observe any withholding periods after treatments. • Where necessary, seek training in appropriate use of agricultural chemicals. • Engage the services of an experienced agronomist, if required.		
Resistance to chemicals 	Inappropriate use of chemicals can cause insects, diseases or weeds to become resistant, making control difficult. This can cause more widespread and ongoing biosecurity problems.	• Rotate chemistry (note the active ingredient on the label, not the trade name) and adopt other resistance management practices to reduce the development of resistance in weeds, insects and pathogens. • Engage the services of an experienced agronomist, if required. • Assess the use of integrated pest management options.		

Weeds

Weeds are a widespread nuisance but can also cause harm to your business, so they need to be actively controlled.

Weeds	Potential risk	Action(s) to take	Action	Done?
Weeds 	Weed species are significant biosecurity problems, as well as being alternative hosts of some agricultural and horticultural pests. You may have a legal obligation to control certain weeds in your region. Check your state requirements or ask your local council to find out.	• Establish a weed management plan for your property, including plans for eradicating, containing or managing current weeds on your property, and preventing the introduction of new species. • Control weeds along dirt tracks and roads, and next to vehicle parking or cleaning areas. • Look for outbreaks of weeds, especially after drought, fire and flood or new land clearing.		
Property and land disturbance 	Property and land disturbance through excavation activities, fire, flood or storms provide an opportunity for pests and weeds to become established.	• Control weeds in fields after flooding, drought or fire. • Inspect any areas that have recently been landscaped (e.g. new roads or dams) or affected by land destruction (e.g. fences), and treat weeds before they have a chance to set seed and become established.		

Train, plan and record

Ensure staff are well trained and that you can trace farm inputs (including plants) and where they have come from, and where outputs went. Keep accurate records of purchases, sales and movement of products entering or leaving the property.

Train, plan and record	Potential risk	Action(s) to take	Action	Done?
Biosecurity planning 	A lack of a biosecurity plan puts your plantation at risk in the face of an unplanned threat.	• Devise a biosecurity plan for your property, prioritise actions and update the implementation table as you achieve goals. • Identify areas that are considered to have both a major impact and are very likely (high risk), and address these first. See the risk assessment matrix on page App 2.3.		
Record keeping 	A property owner or manager should be able to 'trace back' and 'trace forward' if there is a disease, pest or weed incursion on their property. Keeping a record of problem areas (e.g. weeds, diseases) can also help with farm management.	• Keep records of purchases and sales, health certificates and declarations, and pest and disease monitoring activities. • Keep a record of problems encountered and where they are to help you manage your property to minimise the risk of spread. • Keep a record of agricultural chemical (herbicide/fungicide/ insecticide) and organic fertiliser applications: date, active ingredient and block(s) treated.		
Vendor declaration statements 	Simple visual inspection of plant material on arrival to your property may not be enough to know they are healthy.	• Purchase planting material and other inputs from accredited nurseries or suppliers. • Request history and supporting paperwork where applicable, such as high-health accreditation or certificates.		

Train, plan and record	Potential risk	Action(s) to take	Action	Done?
Staff training 	Everyone working on the property (including friends and family) may not know how easily diseases, pests and weeds can spread, and how to prevent this from happening.	• Inform staff of the biosecurity standards required on site. • Provide biosecurity training or information sessions for staff. • Have posters to remind staff of the importance of farm biosecurity.		
Monitoring and surveillance 	Active monitoring and surveillance can provide early warning of potential or emerging problems with pests and diseases. Monitoring data can be used to support continued access to domestic and international markets. Recording the absence of pests or diseases is just as important as recording their presence.	• Keep a record of all crop monitoring activities, even if you don’t see anything unusual.		
Suspect diseases, pests and weeds 	You have a responsibility to report unusual diseases, pests or weeds to an agronomist, state agriculture or primary industries department, or the Exotic Plant Pest Hotline.	• Know who to call if your suspect you have an emergency disease or plant pest. Keep details of state agriculture or primary industries departments, agronomists or the Exotic Plant Pest Hotline at hand.		

Import conditions for coffee

The Australian Government's Department of Agriculture Fisheries and Forestry (DAFF) is responsible for developing biosecurity (sanitary and phytosanitary) risk management policy and reviewing existing quarantine measures for the importation of live animals and plants, and animal and plant products. In particular, DAFF:

- Undertakes import risk analyses to determine which products may enter Australia and under what quarantine conditions.
- Consults with industry and the community, conducting research and developing policy and procedures to protect Australia's animal and plant health status and natural environment.
- Assists Australia's export market program by negotiating other countries' import requirements for Australian animals and plants. Further information can be found at www.agriculture.gov.au.

The **Australian Biosecurity Import Conditions (BICON) database**, which can be accessed at www.agriculture.gov.au/bicon, contains the current Australian import conditions for more than 20,000 foreign plants, animal, mineral and biological products, and is the first point of access to information about Australian import requirements for a range of commodities.

It can be used to determine whether a commodity intended for import to Australia requires a quarantine **import** permit and/or treatment, or whether there are any other quarantine prerequisites.

For **export** conditions, see the **Manual of Importing Country Requirements (MICoR) database** at http://www.agriculture.gov.au/biosecurity-trade/export/micor.

Specific import conditions are provided for the various import scenarios likely for coffee (from BICON on the DAFF website). To access the import conditions associated with each of the scenarios, go to www.agriculture.gov.au/import/bicon, type in 'coffee' and '*Coffea*', and click through to the relevant scenario.

Risk assessment of imported goods is an ongoing process, and it is important to access the most up-to-date information direct from the BICON website.

Further resources

Exotic Plant Pest Hotline: 1800 084 881

Farm Biosecurity website: www.farmbiosecurity.com.au

Plant Health Australia website: www.planthealthaustralia.com.au

New South Wales Plant Biosecurity: https://www.dpi.nsw.gov.au/biosecurity/plant

Queensland Plant Biosecurity: https://www.daf.qld.gov.au/business-priorities/biosecurity/plant

Contacts

New South Wales Plant Biosecurity

Plant Biosecurity and Product Integrity | Biosecurity & Food Safety

NSW Department of Primary Industries.

Phone: 1800 084 881

Report a plant biosecurity pest or disease at https://forms.bfs.dpi.nsw.gov.au/forms/9247.

Queensland Plant Biosecurity

Plant Biosecurity and Product Integrity

Department of Agriculture and Fisheries

Phone: 13 25 23

Report a plant biosecurity pest or disease at https://www.daf.qld.gov.au/contact/report-a-biosecurity-pest-or-disease.

Appendix to Section 11: Monitoring in the plantation

Monitoring is the basis of sound decision making

Management decisions require a sound basis for action to ensure the desired result is achieved in a cost-effective way.

Software packages are available for horticultural crops, including avocados (Avoman) and macadamias (Macman) to help in recording data and deciding whether and what action is required.

Monitoring and recording data will be necessary for scheduling irrigation, adjusting the fertiliser program, controlling pests and diseases, rainfall events and flowering dates, estimating the crop and assessing its maturity prior to harvesting.

Monitoring activities that should be undertaken include:

1. **Irrigation monitoring** and scheduling can now be managed from the computer in real-time measurements of soil moisture at a range of soil depths and a range of monitoring points (see Section 8 for details).

2. **Environmental monitoring** should be on farm and have computer-based recording programs (see Section 8 for details).

3. **Plant and soil nutrient levels** are measured regularly using leaf and soil analyses from reputable accredited laboratories in the region. Fertiliser programs are adjusted according to their results to avoid negative yield and quality effects before they are visible (see Section 9 for details).

4. **Monitoring pests and diseases** is a relatively simple operation with very few problem areas at this stage. However, chance favours the prepared mind, and keeping a watchful eye out for anything out of the ordinary could save major costs if problems are dealt with at an early stage. Recording beneficial insects or parasites is also useful in maintaining the balance of health in favour of the coffee crop (see Section 11 for details). Refer to the pest and disease monitoring sheet on the next page.

5. **Essential tools for effective monitoring** are:

   - Hand lens with 10x or 20x magnification
   - Notebook
   - Monitoring chart
   - Coloured tape to mark affected trees/rows
   - Plastic bags and marking pen for sample collection and identification
   - A sharp pocketknife (with a method for disinfecting between collection).

   These monitoring tools should be kept in the vehicle used for field operations **<u>and used</u>** to learn, observe, record and identify.

6. **Monitoring the developing crop**. A field diary or notebook should be used to record:

   - significant flowering events in each block of trees
   - whether they are light, medium or heavy
   - at the position on the tree where flowering is most intense.

   This will be useful later in the season when it comes time to estimate the crop and decide when to harvest.

7. **Estimating the crop.** See the appendix to Section 15.

Pest and disease monitoring sheet

Block: …………………………………………………………		Date: ……………………………..							
		Pest or disease				Beneficial			Comment
Row no.	**Tree tag colour**	Cercospora spot	Coffee green scale	Mealy bug	Other	Predator	Parasite	Other	

Appendix to Section 15: Harvesting

Monitoring is the basis of sound decision making. Management decisions require a sound basis for action to ensure the desired result is achieved in a cost-effective way. This appendix provides some practical suggestions to assist you in estimating crop and assessing maturity prior to commencing harvest.

Estimating the crop

- This will require a clipboard and record sheet of tabulated ruled squares (see the yield estimate record sheet) to record individual tree yield estimates.
- Sample every 10th tree in every fifth row.
- Score them as zero, low, medium or high for each sample tree in the monitoring grid.

Refer to Figure 15.9 on page 15.4.

Yield estimate record sheet

Block no. .... **Date:** ....

Tree number	1	10	20	30	40	50	60	70	80	90	etc.
Row 1	L	L	Z	M	M	M	H	H	H	M	
Row 5	M	M	M	M	M	H	H	H	H	H	
Row 10											
Row 15											
Row 20											
Row 25											
Row 30											
Row 35											
Row 40											
Row 45											
etc.											

Key to crop load: Z = Zero; L = Low; M = Medium; H = High

When to start harvesting

Assessing when to start harvesting will be more soundly based if the **fruit removal force** and **maturity profile strip pick technique** are used.

Fruit removal force

A tabulated record sheet (right) is adequate to record fruit removal force data.

Using the pull force meter

- As the coffee cherry matures from green to coloured (yellow-orange), to the red of prime cherry, and then to purple and onto the tree-dried 'natural' stage, the force holding the cherry to the tree reduces.
- **The key to achieving the maximum percentage of ripe (desirable) cherry and minimising immature cherry (undesirable) in the harvester bin is to harvest when the ratio of the pull-forces between the ripe and unripe is as wide as possible.**
- The harvester operator then has greater scope for achieving selective harvesting and adjusting the controls on the harvester to maximise the recovery of ripe cherry.
- Test 10 cherries in each of the maturity profiles, record the results in the sheet opposite and calculate the averages for each stage.

A typical summary of pull-force tests conducted is presented below.

	Small green	Large green	Coloured	Prime	Past-prime purple	Tree-dried naturals
Force (kg)	1.490	1.841	0.947	0.568	0.390	0.513

Analysis of this data shows the ratio between the large green cherry (which we do not want to harvest) and the prime cherry is 3.22:1. This means it takes 3.22 times the force to remove the green than the prime cherry. This wide ratio provides the potential for achieving selective harvesting. **Note**: The ratio is even greater for past-prime purples and the naturals.

The coloured maturity stage has a fruit removal force between the prime and the green cherry. The ratio between large green and coloured is 1.93:1, and the ratio between coloured and prime is 1.66:1. Obviously, coloured cherry presents the greatest challenge to selective harvesting. The quality characteristics of coloured cherry are of upmost importance in deciding what percentage of this maturity stage is acceptable in the final product.

Fruit removal force recording sheet

Plantation identification:……………………………………..……………………………

Block no.: ……………………………………………………………………………………

Variety: ………………………………………………………………….……………………

Tree age: ………………………………………………………………...……………………

Time of testing: ………………………………………………………………………………

Temperature and weather conditions: ……………………………………………………

Date: …………………………………………………………………………………………

Green	Coloured	Prime	Past-prime purple	Naturals

Example fruit removal force record sheet

NAME: Joe and Jane Blow
VARIETY: K7
TREE AGE: 3 years
TIME: 5.30 – 6.30pm
TEMP: 17°C
DATE: 30 September 2002

K7 IRRIGATED	SMALL GREEN	LARGE GREEN	COLOURED	PRIME	PAST PRIME (PURPLE)	OVERRIPE (MBUNI)
	5.0+	2.40	3.50	1.45	0.60	0.45
	2.40	1.20	3.00	0.80	1.30	0.10
1 tree	3.20	4.80	3.75	1.20	1.30	1.10
	2.10	2.10	2.40	2.10	0.70	1.00
	3.50	3.50	3.20	2.00	1.20	0.20
	3.00	3.25	1.90	1.80	0.70	0.20
	1.60	3.30	2.00	1.75	1.40	1.30
	3.00	3.60	2.50	1.70	1.50	0.40
	2.40	3.60	2.00	1.70	1.10	0.60
	2.40	3.50	2.90	1.60	1.30	1.40
AVERAGE	2.86	3.125	2.715	1.61	1.11	0.675
	3.30	3.95	3.50	1.30	1.20	1.00
East side	3.95	2.40	2.00	1.30	0.90	0.40
	1.30	4.75	1.60	1.20	1.30	0.90
Random	3.60	4.80	2.60	1.70	0.50	0.50
	2.40	3.80	2.90	1.30	0.90	0.20
	2.10	3.30	2.30	0.75	1.50	0.70
	3.60	3.40	3.25	2.30	1.50	0.60
	3.20	5.00+	3.40	1.45	0.65	0.50
	1.80	2.75	3.00	1.70	1.50	0.70
	2.25	3.10	2.70	1.20	1.20	0.70
AVERAGE	2.75	3.725	2.725	1.42	1.07	0.620
	2.00	3.50	2.00	0.80	0.60	0.10
West side	2.70	2.50	3.00	1.60	0.90	0.90
	1.50	3.20	2.70	1.50	0.50	0.20
Random	1.30	3.80	2.20	1.20	1.50	0.40
	2.90	4.00	1.80	1.50	1.80	0.20
	1.60	3.50	1.70	2.00	1.40	0.70
	2.90	3.30	3.00	1.90	1.50	1.00
	2.60	2.90	2.75	2.00	1.60	0.10
	2.60	4.00	2.30	1.50	0.50	0.30
	2.40	3.30	2.50	2.10	0.60	0.40
AVERAGE	2.25	3.40	2.395	1.61	1.09	0.43
One tree	**2.860**	**3.125**	**2.715**	**1.610**	**1.110**	**0.675**
Random east side of row	**2.750**	**3.725**	**2.725**	**1.420**	**1.070**	**0.620**
Random west side of row	**2.250**	**3.400**	**2.395**	**1.610**	**1.090**	**0.430**
AVERAGE	**2.600**	**3.417**	**2.612**	**1.547**	**1.090**	**0.575**

Coffee cherry maturity profile

A photographic record of the separated five maturity stages of cherry from a typical sample tree is shown in Figure A15.1. A sector wheel is sufficient to estimate the desirable from immature cherry. **Refer to Section 15.3 for detailed instructions.**

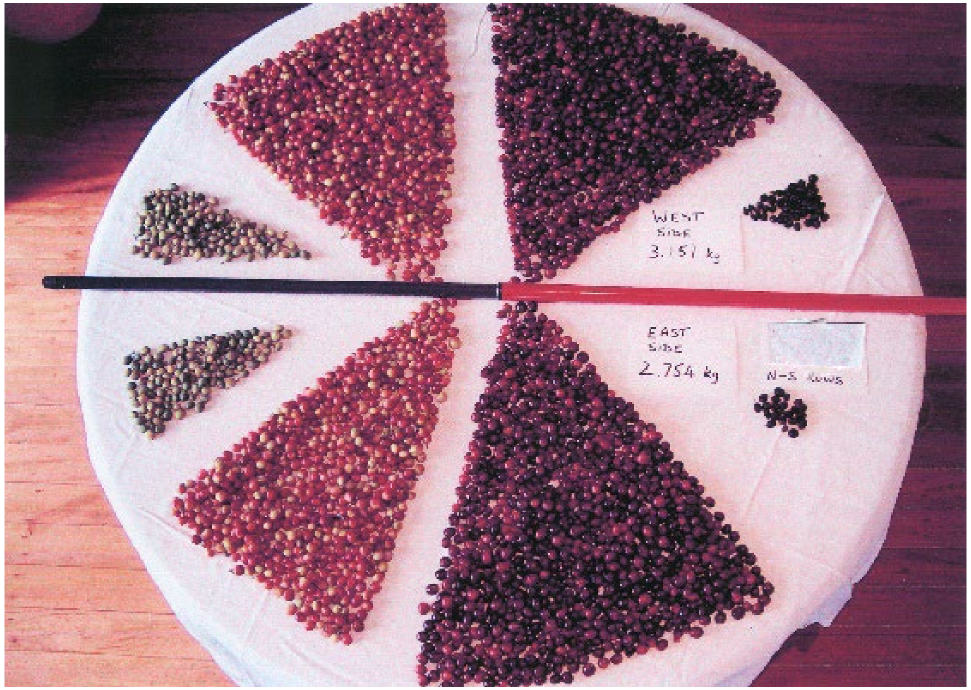


Figure A15.1: This maturity profile wheel from a sample tree shows it is ready to harvest – more than 90% prime, past-prime purple and naturals.

Glossary of coffee terms

Terms related to coffee production

Active ingredients (a.i.)	The biologically active portion of a pesticide formulation.
Acidity	In **soil,** acidity is measured by pH; pH 7 is neutral. Coffee trees prefer a pH of 5–6, slightly acidic. In **coffee we drink**, acidity provides positive taste characteristics of ‘brightness’, giving coffee its structure and sweetness.
Alternate host	A plant or animal that is host to pests or diseases that affect cultivated crops or farm livestock.
Altitude	Traditionally, high-quality Arabica coffees are grown at higher altitudes (above 1000 m) in the tropics, however equivalent cooler growing conditions at lower altitudes outside the tropics can produce similar results.
Apical dominance	Dominance exerted by an apical bud that prevents the development of lower buds.
Arabica	*Coffea arabica* is the most widely grown coffee species in the world, producing 75% of world production. Arabica varieties exhibit a huge range of qualities in aroma, body, sweetness and acidity. All of the world’s ‘speciality’ coffees are arabicas.
Auxin	Growth hormones that promote the elongation of shoots and roots in all plants.
Available water	Amount of water that plants can extract from the soil as long as moisture tension remains below the permanent wilting point (about 4.2 = 15 atm.). Coffee trees are adversely affected by moisture stress at lower moisture tension than 15 atm.
Beneficial insects	Insects that feed on, or destroy, pest species.
Berry	Common name for the coffee fruit. The correct botanical name is a ‘cherry’ or a ‘drupe’.
Biocontrol, biological control	The control of crop pests by the introduction of natural predators, parasites or other living organisms without harmful side-effects on the crop plants.
Biodiversity	Number of species, the variety and the variability of living populations of organisms within specific environments.
Body	In tasting terms, body is how big and heavy the coffee feels in your mouth. Body and ‘mouthfeel’ are the initial tasting descriptions for coffee.
Bourbon	The bourbon coffee variety is well known in the world of speciality coffee for producing a distinct and sweet cup profile. Bourbon varieties and mutations are spread around the world.
Carbon:nitrogen ratio (C:N ratio)	The ratio of the weight of organic carbon (C) to the weight to nitrogen (N) in a soil or in organic material.
Cation	A positively charged ion that moves to the cathode in an electrolysed solution, or more broadly, any positively charged ion (e.g. calcium, magnesium).
Cation exchange capacity (CEC)	The sum total of exchangeable cations that a soil can absorb. Also called ‘total exchange capacity’ or ‘cation adsorption capacity’. Like the anion-exchange capacity, it is expressed in milliequivalents per 100 g of soil.
Chlorosis	Yellowing of the foliage of a plant.

Climate change (coffee context)	Increasing temperatures due to climate change are forcing the higher-altitude coffee production areas to even higher altitudes, limiting the potential productive area for top-quality coffees. Growing coffee in cooler climates at lower altitudes in higher latitudes outside the tropics may be how the industry expands in the future.
Coffee leaf rust (CLR)	A fungus and the most devastating disease of coffee worldwide.
Cotyledon	The first leaf or leaves of the embryo in seed plants.
Cover crop or living mulch	Crop grown as groundcover to protect the soil and reduce erosion, provide additional soil nitrogen, and improve soil structure by adding organic matter.
Cultural control	Use of cultural practices (mulching, pruning, tilling, etc.) to provide conditions that are unfavourable to insect pests, and that improve crop resistance to disease.
Dieback	Symptoms that begin with the appearance of necrotic tissues in the young shoots or branches of a plant, spreading to older tissues, ultimately affecting the main stem and finally causing the death of the plant.
Dormancy	A period during which the plant or a seed is inactive, typically due to physiological and environmental reasons.
Endemic	Restricted or peculiar to a site or region.
Endocarp	The outer covering of the coffee bean, otherwise known as ‘parchment’.
Estate, plantation	Land on which the coffee is grown and all the infrastructure which surrounds the coffee growing and processing business. Ownership can be individual, corporate or cooperative.
Evapotranspiration	Total loss of water from a cropped area, including transpiration loss through the stomata of the leaves of the plants and evaporation loss from the soil.
Field capacity	The amount of water the soil retains after free drainage from a saturated soil.
Foliar application	Spraying leaves and the canopy with agrochemicals to control pests or diseases, or to feed plants.
Fungicide	A natural or chemical substance that has the property of killing fungi.
Genome	The complete set of genes on the chromosomes carried by a plant, an organism or a virus.
Green	Unroasted coffee is called ‘green bean’ or ‘raw bean’. The dry parchment and silverskin have been removed after drying to produce green bean. World coffee trade is in green bean.
Herbicide	A chemical compound for eliminating undesirable plants that can either be applied to the plants or to the soil.
High grown	Arabica coffees grown at high altitudes, above 1000 m (approximately). These coffees are usually superior to those grown at low altitudes. The term ‘high grown’ also figures in many grade descriptions.
Host plant	A plant on which a particular insect, disease or fungus feeds, develops and reproduces during part of its life.
Humid tropics	Regions where the mean annual temperature in the lowlands is above 24°C and where the annual rainfall exceeds or equals the potential evaporative return of water to the atmosphere. They include all lowland areas where annual rainfall is more than 1500 mm.
Immature	Unripe.
Infection	The penetration of an undesirable organism into a host plant.
Infiltration rate	The rate at which water enters soil under controlled conditions.

Inputs	Items purchased to carry out farming operations. Inputs include fertilisers, pesticides, herbicides, seeds and fuel.
Integrated pest management (IPM)	An integrated approach to controlling pests or diseases in which chemical, cultural, biological and any other methods of control are combined.
Intensive cultivation practices	Involves the use of high levels of inputs of agrochemicals, irrigation, mechanisation and other modern technologies. Costs are high so profitability depends on high yields.
Intercropping	The growing of different crops in mixed stands (as opposed to monoculture).
Internode	Portion of a plant stem or branch between two successive nodes.
Interveinal	Spaces between the veins of leaves.
Leaching	The removal of soluble constituents of the soil, including plant nutrients, by water moving downwards through the soil by percolation.
Leguminous	Species that belong to the family Leguminosae, including herbs, shrubs and trees, all of which bear nitrogen-fixing nodules on their roots.
Mealy bugs *(Planococcus* spp.*)*	Sap-sucking insects that feed on a wide range of plants. They are a large and diverse groups of insects, closely related to scale insects and aphids. Many species are pests of horticultural crops and ornamental plants. Their name is derived from the mealy secretion of waxy filaments they produce as a protective barrier. They feed by inserting their mouthparts directly into the plant, sucking up nutrients from the sap.
Mechanical drying	A mechanical dryer is a big rotating drum to which heat is applied. Temperature control and drying time to the required moisture content is critical to avoid compromising the quality of the coffee.
Microclimate	The climate in a very small area or in a particular habitat.
Monocropping	Cultivation practice that consists of growing a single crop in a specific area.
Mucilage	The sweet flesh of the coffee fruit that sticks to the parchment skin of the bean when the skins are removed during pulping.
Mulching	The practice of spreading fresh or decayed plant material on the surface of the soil with a view to decreasing weed growth, reducing evaporation losses from the soil surface and ultimately increasing soil organic matter levels.
Multiple stem	Coffee tree with more than one stem developed through selective pruning. Not desirable for machine harvesting.
Natural process	Natural processing (or dry processed coffee) is the oldest processing method. Coffee cherry is harvested and dried with the fruit and skin intact. Drying can take a long time, requiring continual raking and turning to prevent mould development.
Nitrogen fixation	The conversion of atmospheric nitrogen gas to ammonia, nitrates and other compounds that contain nitrogen by means of nitrogen-fixing bacteria, photosynthetic bacteria and algae.
Nutrient recycling	Nutrients are recycled in the natural world – a living plant takes nutrients from the soil, dies and decays, and nutrients are recycled through the next generation.
Organic matter	Carbohydrate materials originally produced as a result of photosynthesis and the combination of gaseous carbon dioxide with water. Examples are plant litter (roots, stubble, leaves, mulch) and animal manures.
Origin	Where coffee comes from. Single-origin can be from a single country; however, speciality roasters use the term to describe a specific variety of coffee plant from a single farm.

Orthotropic	Vertical shoot.
Pathogen	An undesirable organism that penetrates a host plant and causes a disease.
Pectolytic enzyme	Breaks down pectins in the mucilage and speeds up the processing. Reduces the normal fermentation process time from 24 hours down to seven hours depending on temperature.
Peri-urban	Agricultural land abutting residential areas on the outskirts of towns.
Pest	Any organism that attacks a plant or an animal. Pests include fungi, viruses, bacteria, insects, nematodes, ants, mammals and all other microflora and fauna.
pH	Indicates the degree of acidity or alkalinity. A neutral pH is 7; below 7 is acidic and above 7 is alkaline.
Phenotype	The outward appearance of an organism.
Phloem	Soft tissues of the plant through which nutrients and sap are conducted.
Photosynthesis	Synthesis by plants and some bacteria of sugars from atmospheric carbon dioxide and water vapour. Photosynthesis takes place in chlorophyll-containing cells when they are exposed to sunlight.
Phytotoxic	Toxic to plants.
Plagiotropic growth.	Tendency to grow horizontally or obliquely from the trunk or the tap root (branches or lateral roots).
Predator insect	An insect that feeds on other insects. Unlike parasites, its movements are autonomous, so predators do not depend solely on an individual host.
Provenance	Place of origin.
Primary branch	A lateral branch arising directly from a vertical stem.
Pruning	Cultivation practice that consists of removing wood from a plant to increase the fruit-bearing branches or to shape it.
Refractometer	A hand-held instrument used widely to measure the total soluble solids (TSS) or sugar content in a liquid using the principle of light refraction.
Relative humidity (RH)	The ratio (%) of water vapour in the atmosphere to the amount required to saturate it at the same temperature.
Resistance	The power of an organism to overcome the effects of a pathogen or any other specific damaging factor.
Ripe	When the coffee cherry is mature and at its most vibrant red, before it starts to go purple.
Scale insects (*Coccus viridis*)	A group of sedentary bugs that feed on plants, including coffee green scale These pests can be readily controlled by natural predators, including parasitic wasps and the *Verticilluim* fungus.
Screen	Frame with a perforated metal plate or wire mesh with openings of different sizes, used to grade coffee beans by size.
Secondary branch	A branch arising directly from a primary branch.
Seedling	Plant grown from a seed.
Selective harvesting	Consists of hand picking or mechanical separation of ripe cherries only.
Shoot	Young, vertical stem formation. New above-ground plant growth.
Single stem	Coffee tree maintained on one stem only.
Soil texture	Defined by the proportion of particle sizes – sand, silt and clay – in the soil.

Species	A group of interbreeding individuals having some common characteristics not normally able to interbreed with other such groups. Species are subdivided into subspecies, races and varieties.
Stem	The upright branch of a tree that bears leaves and flowers.
Stoma	Minute orifice in the epidermis of plant tissues, mainly located underneath the leaves, through which gaseous interchange takes place, particularly water vapour and carbon dioxide. Plural is 'stomata'.
Stripping	Removing all the coffee cherries present on the branch, irrespective of their degree of ripeness.
Stumping	Cutting a tree back, leaving only the stump.
Sucker	Vertical shoot arising from the stem, the root, the axil or a branch.
Susceptibility	Vulnerable to a given disease (sensitivity).
Sustainable agriculture	Agricultural production system that enables the farmer to maintain productivity at levels that are economically viable, ecologically sound and culturally acceptable in the long term. Under such a system, resources are managed efficiently with minimal damage to the environment and human health.
Systemic pesticide	Pesticide that enters the plant tissues before being fatally ingested by the pest.
Tap root	Main root that grows downwards from the radical and generates lateral roots.
Tensiometer	A device for measuring the suction force required to extract water from soil.
Terroir	A term of French origin used in wine, coffee and tea to denote special characteristics that geography bestows upon particular varieties.
Tipping	Pruning the ends of primary branches or stems.
Topping, capping	Cutting off the terminal end of an upright stem.
Trimming	Reducing a tree or a plant to a neat, orderly shape by pruning or clipping.
Understory	Vegetation that grows under the shade of taller plants.
Wilting point	Point at which plants are unable to absorb any more soil moisture.
Xylem	The lignified part of the water-conducting tissue of plants.

Terms related to green and roasted coffee

Aged coffee	Coffee from previous crops stored in special warehouses for long periods. Ageing reduces acidity and increases body.
Arabica coffee	Coffee of the botanical species *Coffea arabica.*
Arabusta coffee	Hybrid cross of *Coffea arabica* and *Coffea canephora.*
Bean	Endosperm or seed of the coffee fruit.
Bean in parchment	Coffee bean enclosed in its parchment.
Bean sizes: flat beans	Screened through round holes of different sizes, ranging from size 13 to 20: very large (size 20), extra large (size 19), large (size 18), bold (size 17), good (size 16), medium (size 15), small (size 14–13). The numbers indicate the diameter of the sieve holes in 64ths of an inch, i.e. size 17 = 17/64ths of an inch.
Blend	A mixture of two or more coffee varieties producing a recognisable and reproducible quality of coffee liquor.
Bold	A large to very large, well-formed and even coffee bean.
Caffeine	An alkaloidal compound present in coffee tissues but more concentrated in the bean (average 1.5%).
Caffeol, coffee oil	The volatile, oily substance developed in the coffee bean during roasting.
Centre cut	Cleft or groove on the flat side of the bean.
Clean coffee	A well-graded coffee, free of defects.
Cleaning	Removal of foreign matter, fragments of coffee and defective beans from green coffee.
Coffee bean	Commercial term used for the dried seed of the coffee tree.
Coffee cherry	The fresh fruit of the coffee tree. Sometimes also referred to as a coffee berry.
Colour	From blue harvesting and conditions of storage and transport – green to yellow-green and brown depending on origin, species, age, method of processing and fruit maturity.
Defect	Any impairment of the coffee bean that could cause deterioration in quality.
DGB	Dry green bean.
Dried coffee cherry	Also known as coffee in pod or husk coffee.
Dry fermenting	After pulping, the coffee is fermented without water.
Drying of coffee cherry	Drying coffee cherries to reduce their moisture content, remove their husks and condition them for storage.
Drying of parchment coffee	Drying parchment coffee to reduce its moisture content to condition it for storage and further hulling.
Dry processing	Treatment of coffee cherries whereby they are dried under the sun or mechanically. This process produces husk coffee. Drying is usually followed by the mechanical removal of the husk. The result is ‘natural’ or ‘unwashed’ green coffee.
Fermentation	Biological treatment that consists of degrading the mucilage, which still adheres to pulped coffee.
Foreign matter	Any mineral, animal or vegetable matter that does not come from the coffee cherry (stones, sticks, clods, metallic residues, etc.).
Grinding	Mechanical operation that fragments roasted coffee beans and produces ground coffee.
Ground coffee	Roasted coffee that has undergone grinding.

Honey process	Pulped natural or honey process is a method in which the fresh coffee cherries are de-pulped but allowed to dry without washing. Some of the fruit is still there, but not nearly as much as in the natural process.
Hull	Dried parchment (endocarp) of the coffee fruit.
Hulling or dehulling	The mechanical removal of the dried endocarp (parchment) from parchment coffee to produce green coffee.
Husk	Assembled external envelopes of the dried coffee fruit.
Husking or dehusking	The mechanical removal of the husks from dry coffee cherries.
Pales	A term used to describe discoloured beans. They can come from old stocks, from immature beans or from coffee afflicted by drought. Amber beans often cause pales in the roast.
Peaberry coffees	Beans are graded through oval-shaped screens; peaberry coffee beans are sized 9–13.
Polishing	The mechanical removal of the silverskin from green coffee.
Pulp	Part of the coffee cherry that is eliminated during pulping and fermentation. It is composed of the skin and part of the mucilage.
Pulping	Operation that consists of removing the pulp and part of the mucilage by mechanical means. Part of the mucilage generally remains adhering to the parchment.
Roasting	The use of heat to generate fundamental chemical and physical modifications in the structure and composition of green coffee beans, to darken the bean and develop its characteristic flavour.
Robusta coffee	Coffee of the botanical species *Coffea canephora* var. Robusta.
Silverskin	Dried seed coat of the coffee bean. It is usually silver or copper coloured.
TCA (Rio flavour defect)	The Rio defect is a coffee ‘off-flavour’ associated with unpleasant medicinal, phenolic and iodine-like notes. 2,4,6-Trichloroanisole (TCA) is the main marker of this alteration.
Washed-and-cleaned coffee	Dry-processed green coffee from which the silverskin has been removed by mechanical means and using water.
Washing	The use of water to remove the degraded mucilage from the parchment.
Wet-processed coffee	Green coffee that is wet processed is known as washed or semi-washed coffee. Washed coffee is green coffee from which the mucilage has been totally removed and semi-washed is green coffee where most of the mucilage still adheres to the parchment.

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