

Vegetable Growing Manual

A guide to vegetable growing in the semi-arid tropics of the Top End of the Northern Territory



Published March 2012
by the Northern Territory Department of Resources.

(Print) ISBN 978-0-9872563-1-7

(Online) ISBN 978-0-9872563-0-0

General enquiries about this publication should be directed to:

Plant Industries Division
Department of Primary Industry and Resources
GPO Box 3000, Darwin NT 0801
Phone: (08) 8999 2323
Facsimile: (08) 8999 2010
Email: horticulture@nt.gov.au

DISCLAIMER

While all care has been taken to ensure that information contained in this Vegetable growing manual is true and correct at the time of publication, changes in circumstances after the time of publication may impact on the accuracy of its information.

The Northern Territory of Australia gives no warranty or assurance, and makes no representation as to the accuracy of any information or advice contained in the Vegetable growing manual, or that it is suitable for your intended use.

You should not rely upon information in this publication for the purpose of making any serious, business or investment decisions without obtaining independent and/or professional advice in relation to your particular situation.

The Northern Territory of Australia disclaims any liability or responsibility or duty of care towards any person for loss or damage caused by any use of or reliance on the information contained in this of publication.



Contents

INTRODUCTION	3
PLANNING TO GROW VEGETABLES COMMERCIALY	4
Farm planning	4
What to grow	5
Where to grow	5
Budgeting	6
Skills and training	6
SOIL PREPARATION	7
Green manure cropping	7
Crop type	10
LAND PREPARATION	11
Ripping.....	11
Cultivation	12
PLANTING	13
Raised beds	13
Plastic mulch	14
Paper mulch	16
Drip line.....	17
Planting on plastic mulch	17
NUTRITION.....	18
Management strategies	18
Soil test	18
Basal fertiliser	20
Fertigation.....	21
Leaf analysis for nutrient monitoring	24
IRRIGATION	25
Irrigation management.....	25
System design.....	25
Watering schedule	25
Soil moisture monitoring	26

Contents

PEST AND DISEASE CONTROL	28
Crop monitoring.....	28
Correct identification of insects and plant diseases	28
Methods of control.....	28
Integrated Pest Management.....	30
CHEMICAL USE AND RESIDUES	31
Read the Label.....	31
The Maximum Residue Limit (MRL).....	31
Residue Testing of NT Produce	32
HARVEST AND POST-HARVEST	33
Maturity and quality	33
Harvesting and handling.....	33
Temperature	34
Air flow	35
Humidity.....	35
Ethylene.....	36
Packaging.....	36
Asian vegetable packaging	36
Post-harvest disease	37
Coolrooms	37
Interstate Certification assurance (ICA).....	38
Quality Assurance	38
Summary points	38
TRANSPORT AND MARKETS	39
Road Transport	39
Air Freight	39
Supply Chain	40
The grower	40
The freight forwarder	40
The trucking company	40
An unloader	40
The agent	40



Introduction

This vegetable growing manual is a consolidation of twenty years of research, development and general experience of various NT Government officers in growing vegetables.

The manual covers enterprise planning, maintaining soil structure, growing a crop, managing pests and disease, and cooling and handling vegetables after harvest. There are many variables which impact the viability of a vegetable producing enterprise, and we hope that by highlighting the major points, growers will be challenged to think them through and search out more information.

Specific information on crop growth, pest and disease control can be obtained through Agnotes or by contacting Department of Resources (DoR).

Contributors:

- Kevin Blackburn
- Mark Traynor
- Greg Owens
- Chris Wicks
- Matt Darcey
- Melinda Gosbee
- Liz Easton
- Graeme Patch
- Stuart Smith
- Colin Martin
- Chelsea Moore



Planning to grow vegetables commercially

Planning is the key to success in any horticultural enterprise. The key to planning is to gather data relevant to economic success, i.e. markets, transport, cost of inputs and likely returns from outputs. These form the basis of the business plan. Time spent researching an investment can save time and money in the long run. Simply planting a crop in the hope that it will make money is a recipe for disaster. The need to be market focused is critical in profitable farming. Budgeting and managing a small business are also integral parts of running a successful vegetable farm.

Farm planning

Introduction

A farm plan is important and provides a basis to setting up a budget. This plan will show the physical layout of a farm plus what and where to grow for the season. Adjustments may be needed from one season to the next to make improvements and seize new opportunities or technologies. Successful farm planning and budgeting often results from decisions based on the grower's own farm records.



Minimising traffic is important on a farm.

Vehicular access

A road plan that allows adequate access and turning space for all equipment and vehicles is essential. Continuous traffic compacts the soil, so it is best to decide on heavy traffic areas and stick to them. Provide adequate turning room and spray access for tractors.

Soil types and wet areas

Avoid planting on seasonally wet areas and identify any poor or good soil types.

Farm hygiene

The outbreak and spread of soil borne diseases like *Fusarium* is often caused by infected soil being transported by human and vehicle traffic. Put the shed near the front gate of the property so that visiting vehicles will stop there, not drive all the way through the farm. Airborne disease and insect contamination can come from old crops. Always plant new crops upwind from old crops to avoid contamination.

Scheduling

If planting a number of plots of the same vegetable over the season, try to make them the same size as this simplifies calculation of fertiliser and water requirements. Planting should be scheduled for harvest continuity over the desired production period.

Crop rotations and green manure

Crop rotations should be included in the farm plan. Planting the same crop on the same land continuously may allow buildup of nematodes and soil disease. Changing from, for example, a leafy crop to beans then cucurbits, and planting a green manure crop in between can significantly reduce pest and disease. It is important to include green manure crops in the rotation every wet season.

Windbreaks

Windbreaks reduce wind damage and spray drift to crops and need to be incorporated into the farm layout. These can be natural (rocks or trees), or artificial (constructed from shade cloth). An ideal windbreak species for vegetable production is bana grass (*Pennisetum purpureum* x *Pennisetum typhoides*). It grows quickly to about 3 m in height, and can be readily removed. This grass should be planted perpendicular to the prevailing wind, about a tractor width from the vegetables (2 m). As a rule of



Growing carrots is an option for the Katherine region.



thumb, a wind break protects an area approximately 10 times its height. So bana grass 3 m tall will effectively protect about 30 m of crop. Natural stands of bush left uncleared may also be used for windbreaks and buffer zones.

Incompatible companions

Planting vegetables between rows of fruit trees is generally not recommended. There are two main drawbacks; first, chemicals registered for the fruit trees may not be registered for the vegetables, and will increase the chances of detecting unregistered chemicals on the crop, or vice versa. The second reason is that the trees will be accessing irrigation and fertiliser applied to the vegetables, which will make the tree crop more difficult to manage, particularly if they require a drought period.

What to grow

In deciding what crops to grow, consideration must be given to things like:

- Market value of the product
- Cost of production
- Ease of production/skill levels
- Marketability
- Transport of produce
- Infrastructure requirements
- Time to harvest
- Suitability of crop to environment.

Sources of information include markets, the Northern Territory Horticultural Association, Northern Territory Government, rural suppliers and other industry members. Discussions with intended wholesalers or customers are essential in determining the time of harvest, quality, volume, packaging and transport. Price and throughput information may also be available on the web at a charge (www.ausmarket.com.au).

The risk of crop failure should also be considered. Growing more than one commodity reduces risk of crop failure. Schedule the time of harvests of several plantings of the one crop or several crops so that the work load is spread evenly.

Where to grow

Some of the factors affecting where-to-grow include cost of land, soil type, water availability and quality, cool room and packing facilities, labour availability, transport options and activities on adjoining properties. There are some advantages in growing in districts close to other producers in terms of sharing equipment etc., however, wind borne diseases and pests can make close neighbours with poor farm hygiene difficult to get along with.



Budgeting

A grower needs to be fully aware of the costs and estimated profits involved before they start. What will the costs be? How much income is expected over the life of the crop? What will peak debt get to before income is received? Can debt be serviced until income flow covers costs?

One of the most useful things in planning to grow vegetables commercially is budget preparation. It can be done simply by estimating what inputs are needed to grow the crop, (checking prices with input suppliers or rural merchandisers) and estimating returns from the produce picked (obtain average prices from the markets or other growers). Remember that first time growers usually have poorer quality and less yield compared to experienced growers.

Some of the costs to consider include: planting material, irrigation, mulch, fertiliser, trellising, herbicides, insecticides, fungicides, fuel, electricity, machinery purchase or hire, packing cartons/crates, labour, transport, repairs and commission on sales.

Basic infrastructure is also an expense. Is a coolroom, tractor, spray equipment, even a shed or road needed? These larger costs need to be adequately financed. Alternatively, there may be options available such as contract spraying or slashing, hiring of equipment or sharing coolrooms.

It is important to consider a scenario where returns are 10, 20 or 30% lower than expected.

This could be due to price drops, crop failures or reduced yields, problems with markets, or even ill health or personal matters. Plans should include contingencies to have enough resources available.

Insurance for product damaged in transport should be considered. A tight arrangement with an agent for advice of price and damaged product is necessary. It is important to be paid promptly after delivery. Good records of all transactions are necessary. Some markets have systems where agents lodge a bond with the market authority to help pay their bills if they go broke, so investigate all possibilities.

Once all costs have been identified, it is important to compare the total against income. Is the amount left worth weeks or months of hard work?

Skills and training

Have a good look at personal skills and abilities. Is the expertise available to successfully grow and harvest a crop? What are the sources of information? Who can be learned from? It may be beneficial to spend some time working for an experienced producer or consider planting a small trial crop.

Some types of training are also necessary. Chemcert courses are compulsory for the use of dangerous poisons (Schedule 7). Approved supplier or other food safety programs such as Freshcare may or may not be essential depending on the intended market.

Soil preparation

Green manure cropping

Green manure crops are grown specifically to be incorporated into the soil to improve soil health. Green manure crops play an important role in vegetable production systems in the Northern Territory.

The major benefits of green manure crops are:

- Maintenance and improvement of soil structure in light textured tropical soils. Under constant cropping and tillage, local soils can suffer severe structural damage, weed invasion, surface sealing and crusting, compaction, and water and wind erosion in as little time as three years.
- Increases in soil water holding capacity.
- Increases the cation exchange capacity (CEC) which will decrease the leaching of nutrients through the soil profile. Positive charged cations like potassium and calcium will be 'held' by the incorporated organic matter.
- Lower soil temperatures with a related increase in soil micro-flora.

Green manure crops, like this sorghum crop, are an essential part of a vegetable growing system in the Top End of the Northern Territory.

- Control of root knot nematodes through the inability of the green-manure crops (grasses) to host root knot nematodes and their ability to smother weeds that are alternative hosts. It is now considered that the breakdown of organic matter is also important, as nematophagous (nematode destroying) fungi proliferate as organic matter decomposes. Leguminous green manure crops are generally susceptible to root knot nematodes and should not be used where susceptible vegetable crops are to follow.
- Even small increases in soil organic matter can mean that there is a large increase in soil microbiological activity. The increased biological activity can reduce the severity of soil borne diseases and the losses caused by them.
- Forage sorghums and millets have deep, extensive root systems which allow them to scavenge for plant nutrients leached below the root zone of vegetable crops. These nutrients are recycled and brought to the surface again when the green manure crop is incorporated and broken down in the soil.
- A well established green manure crop will protect the soil against water erosion from high intensity monsoon rain.
- Dense green manure crops will smother weeds, including possible nematode hosts.



Management of green manure crops

The use of green manure crops, grown during the wet season is important to maintain and improve soil structure.

In tropical soils, soil structure is, arguably, a more important constraint to optimum crop production than plant nutrition. The most widespread soils in the Darwin area with horticultural potential are deep red lateritic kandosols with a high percentage of ironstone gravel in parts of their profile. The soils are relatively deep and are free-draining; all have low clay and organic matter contents, a very low cation exchange capacity and a low moisture holding ability. These soils have very low levels of available plant nutrients and “lock up” or immobilise applied phosphorus. They are highly fragile soils, lacking in structure and quickly break down under cultivation.

Sowing

The critical issue with green manure cropping is ensuring good crop establishment under rain-fed conditions. Weeds should be killed prior to sowing, either by cultivation or herbicides. Extra cultivation may be necessary to prepare a well aerated seed bed.

Green manure crops are sown into moist soil when early monsoon rain is imminent, usually about mid to late December.



Green manure over the wet season is important to maintain soil health, seen here on a cucumber farm under cover.



A precision seed drill is an ideal way to plant a green manure crop.

A small spreader on the back of a four wheel motorbike is a quick and easy way to spread green manure seed on a prepared paddock.



The timing of planting is important and everything must be ready when conditions appear favorable. Follow up rain falls after seed germination is desirable so that moisture stress does not affect seedling emergence or establishment. Early season rainfall can be erratic and a two week drought following good planting moisture will burn off developing seedlings. Therefore even though early wet season storms are useful for seedbed cultivation, it is better to wait for the first monsoon before planting to ensure there will be follow up rains for seed germination and plant growth.

A sowing rate of 20 kg/ha is recommended for forage sorghums sown with a seed drill, (the preferred method), or 30 kg/ha when mixing the seed with fertiliser and distributing it with a fertiliser spreader. Both methods require careful calibration to obtain uniform seed and fertiliser distribution. The use of a seed drill saves on seed costs due to lower sowing rates and assists in producing good crop establishment because the seed is sown at uniform depth. The use of press wheels, chains, mesh or rollers behind the drill to provide good seed/soil contact is also recommended.

If the seed is mixed with the fertiliser, careful attention must be paid to agitating the mix to prevent the seed separating out. In addition, some fertilizers, such as diammonium phosphate (DAP), burn seed and should not be mixed with seed. Starter fertilizer such as granulated mono-ammonium phosphate (MAP), ‘single’, or ‘triple super’ can be safely mixed with seed. Harrowing after broadcasting incorporates seed into the top 25 mm of soil.



Incorporation at the right stage is critical for green manure crops.

Fertiliser

Fertiliser rates for the green manure crop will depend on the cropping history of the soil to be planted.

On virgin soils, which are very low in all available plant nutrients, approximately 200 kg/ha of a suitable NPK blended fertiliser such as 14-14-12, or similar is required at sowing.

High yielding green manure crops of 20 t/ha dry matter will require around 20 kg/ha phosphorus, 100 kg/ha nitrogen and 75 kg/ha potassium. Fertiliser requirements should be based around soil analysis results from your agronomist.

Crops should also be slashed two or three times with an application of urea at 50 kg/ha after each slashing to promote new vigorous growth.

Slashing and Incorporation

A green manure crop, whether a millet or a forage sorghum, should be slashed when the first flowers appear. At this stage, vegetative growth has slowed and the roots are at maximum depth. The initial cut should leave 150–200 mm of standing stubble to allow rapid re-growth of the crop. Usually, 2 or 3 cuts are achievable over the wet season. How many cuts also depends on the flowering characteristics of the green manure crop. Bigger crops will require larger slashing machinery.

Seed production can cause a weed problem in subsequent crops therefore more slashing may be necessary to prevent seed set.

NOTE: If growers only slash at the end of the season there can be problems cutting and incorporating the green manure crop because of the width and woodiness that develops in the crop with age.



Slashing becomes difficult if green manure crops are left too long after flowering.

The timing of the final cut is important so that it is early enough to ensure that there is adequate soil moisture remaining for three to four weeks for the breakdown of the incorporated organic matter before cropping commences. The crop will not decompose effectively in dry soil. It is preferable to slash the crop twice, or to use a mulcher to chop it up into smaller pieces for easier breakdown. Leave for one to two weeks to dry out and slash again to cut the re-growth, as low as possible, before soil incorporation. Alternatively, a herbicide such as glyphosate may be used to stop re-growth.

If the area is not to be used for that season the slashed organic matter can be left on the soil surface where it will protect the soil from wind and water erosion and high temperatures during the dry season. This area can be replanted again to a new green manure crop at the start of the following monsoon.

Strips of the green manure crop can be left standing within a vegetable crop as a temporary windbreak in areas prone to wind damage.

A rotary mulcher will break up heavy green manure crops and is particularly useful on millet crops where large tiller clumps occur. Although rotary hoes cause soil structural damage to light textured soils, they can be carefully used at a shallow setting and low speed to break up heavy stubble or millet clumps.

Soil incorporation of the chopped up green manure crop is then carried out using offset disc harrows. The plant material must be sufficiently broken up to allow easy trash burial with the disc harrows. This operation can be carried out during March to ensure that sufficient rain will be available to break down the organic matter over a three to four week period.

Incorporating 25–50 kg/ha of urea can assist in the breakdown of the buried organic matter.

Crop type

There are three main classes of summer forage crop: forage sorghums, forage millets and forage legumes. Of these, the hybrid forage sorghums offer the best prospects under local conditions although millets are used but are more difficult to manage.

Table 1 shows the advantages and disadvantages of common types of green manure under different conditions.



Offset discs can be used to incorporate green manure crops. Keep use to a minimum as they can cause hardpans.

Table 1: Characteristics of green manure crops for the Top End

Green manure	Land suitability	Sowing rate kg/ha	Planting and establishment	Advantages	Disadvantages	Potential dry matter yields t/ha
Forage Sorghum	Grow on most soils	20	Seed size suits most drills. Easy to broadcast.	Late seeding and easy to grow	Will develop thick stalks at low density	Up to 20 t/ha
Millets	Cannot tolerate water logged soils	8–12	Small seed needs moist seedbed for successful germination. Easy to broadcast, may need special small seed drill	Tolerant of dry conditions after establishment	Goes to seed before Forage Sorghum Must be cut to prevent thick stems	Up to 20 t/ha
Legume species	Not suited for rotation with most vegetable crops	Depends on species	Mostly quite easy to establish	Bacteria on roots fix nitrogen	Can't be used in rotation with nematode susceptible crops	5–7.5 t/ha

Land preparation

Ripping

Deep ripping or sub-soiling is cultivation with a long and deep tyne(s) that is used to break up compacted layers in the soil profile. The benefits of deep ripping are improved root penetration and plant growth, and improved drainage (especially during the wet season).

The nature of the sandy red earth soils common to the Darwin rural area is that any form of cultivation with conventional implements, and rotary hoes in particular, will lead to a compacted layer (hard pan) in the soil profile. The use of heavy equipment in clearing land of trees and scrub, stacking trees into windrows for burning, stick raking and stump removal all contribute to the development of hard pans. Undisturbed soils can also have a degree of sub-surface compaction which requires ripping to break it up.

Ripping may need heavy equipment to break up tough hard pans.



Ripping soils should be avoided when the soil is too dry or wet, as this destroys any existing soil structure. It is too dry in this picture.

Deep ripping to break up soil hardpans is required at two times:

- Following completion of the clearing operations and before planting a green manure crop, fields should be deep ripped to allow the soil to drain freely during the wet season. If virgin land is used for vegetable cropping before planting a green manure crop, it is important to ensure that there is minimum disturbance to the virgin soil and that the cultivation operation is carried out on moist and not dry soil to minimize structural damage.
- The operations involved in incorporating the green manure crop into the soil generally result in soil compaction problems, especially the use of rotary hoes and disc implements. These implements can form a hardpan about 20 cm below the soil surface. The soil should be ripped using a chisel plough while soil is moist but not plastic (like dough), and as close to planting time as possible. This would normally be about three or four weeks after incorporation of the green manure, when it has decomposed.



Ripping is best done when the soil is moist, as shown above.



The Wallace Plough is a five tyned implement designed to break up hard layers in the soil.

Cultivation

The general principle to follow in working soils is to cultivate as little as possible, never cultivate them when too dry or too wet, and wherever possible, use tyned implements to minimise soil disturbance.

NT soils are largely poorly structures and low in organic matter. Inordinate levels of tillage has been shown to contribute to soil structural damage, surface sealing and crusting, compaction, increased surface runoff and water erosion. Any or all of these factors can lead to loss of crop production, increase the risk of soil erosion, and reduce the sustainability and profitability of the farming system.

Primary cultivation should commence with chisel ploughing to a minimum depth of 30 cm. These are heavy-duty implements that require substantial power to operate efficiently. Special types of chisel ploughs such as the Wallace Plough or the Ausplow are designed to lift and fracture compacted soil layers, allowing the soil to fall back in place without any inversion or sideways displacement. A five shank or five tyned chisel plough would require a 50 kW power source, a seven shank plough would require 70 kW and a nine pointer would need at least 90 kW of tractor drawbar power.



The weight of the 200 litre drum of water on top of the Wallace plough helps force the rippers into the ground.

Secondary cultivation can be carried out using a range of implements depending on the condition of the soil and the amount of trash present. Spring tyned cultivators can work well when there is minimal trash present. They develop a seedbed into a good tilth and also level out an uneven piece of ground. Importantly do not overwork the soil and create surface sealing. Offset disc harrows are also used for secondary tillage when there is still a lot of trash present in the soil although their use should be kept to a minimum. These implements have a bad reputation for creating hard pans.

Specialist implements such as disc hillers and bed shapers are used after secondary tillage to construct raised vegetable beds.



A spring tyned cultivator is used to work up soil with minimal disturbance.

Planting

Raised Beds

Some form of raised bed should be used in all vegetable crops, even if plastic mulch is not used. Using raised beds reduces risk of waterlogging. They also provide an additional volume of loose and friable soil to assist root development and plant establishment.

Raised bed construction

Even though raised beds will tend to shed water, it is important that the area be deep ripped before bed construction to allow percolation through the soil profile. The soil should be worked to a good tilth, as large clods cause difficulty in laying plastic evenly. The presence of large clods of soil is an indication of working soil when it is too wet.

Plastic mulch raised beds should be around a height in the centre of 75 to 100 mm after compression with a bed shaper. The following steps are taken in raised bed construction:

- Use single or ganged discs on a toolbar to throw up soil into the middle of the bed. Quite a lot of soil is required to fill out the bed with the shaper.

Adjustable ganged discs for hilling up of beds.



Large farms use equipment that construct and shape multiple beds.

- To properly construct beds a bed shaper, is essential. A shaper is made to suit the width of the exposed plastic on top of the ground (900 mm exposed with 1200 mm wide plastic) and flattens out and tapers the top of the hill into an even slope. Wings on the sides of the shaper collect soil and pack it firmly under the sloping top of the implement to form a firm bed. Bed shaper attachments can be mounted on mulch layers to carry out two basic operations in one pass. One of the main reasons for constructing a well shaped and firm bed is to have the plastic mulch stretched firmly with no movement or air pockets underneath the mulch. A firm bed also prevents the soil from slumping during crop growth.
- Basal fertiliser is spread evenly over the bed either before or after the bed is shaped depending on the condition of the soil. It is recommended to shape the bed in one direction, apply the fertiliser and then incorporate it on the second run in the opposite direction. The shaper mixes the fertiliser in the top 25–30 mm of soil as it rolls and presses the soil down to firm the bed.



The bed shaper can also incorporate the basal fertiliser.



This simple bed shaper works well.

Plastic Mulch

Laying plastic

It is important that mulch laying machines are correctly adjusted so that plastic mulch is stretched tightly over bed by the press or packing wheels and the following discs cover the edges of the plastic with soil to keep it in place. The operational speed of the implement is critical to obtain the desired results. Plastic mulch should be laid down in the heat of the day and the rolls of plastic should be left out in the full sun to heat up before laying to get the best tension over the raised bed.

Loose, poorly tensioned mulch results in excessive flapping in the wind that can damage the young seedling emerging from the hole in the plastic sheet. Any space between the soil and the plastic can harbour all types of pests including mice, grasshoppers, ants, and crickets. These pests can damage seedlings and chew holes in irrigation tape.



A single bed plastic mulch layer.



These finished beds ready for plastic mulch.

Wetting Pattern

One function of plastic mulch is to develop an adequate horizontal wetting pattern for effective root growth in crops. Roots proliferate in moist soil, which ideally should extend right across the bed underneath plastic mulch. The zone of major root concentration with rockmelons, which is similar to other vegetable types, occurs in the top 0–30 cm of soil (70–80% of total roots) with a very high concentration of roots in the top 10 cm.

Failure to use plastic mulch on NT soils can result in elongated wetting fronts with very little horizontal wetting of the mound. This wetting pattern restricts the development of surface feeder roots and severely reduces the total root area. Trials with a range of vegetables indicate a significant yield increase can be expected by using plastic mulch with drip irrigation, and that the fruit quality of crops like melons and pumpkins is improved. Trials on bitter melon and okra with and without plastic mulch and fertiliser injection have shown significant yield increases can be achieved with plastic mulch compared to bare ground. The yield increase with okra was 43% and as high as 136% with bitter melon. Experiments with buried drip tape were not successful with sandy soils but have been more effective with the heavier clay loams.

Weed control

Plastic mulch also provides a very effective method of weed control. Very few herbicides are suitable for cucurbits although there are a number of selective herbicides for other vegetables. If grass weeds emerge from the planting hole in the plastic, they can be sprayed with a selective grass herbicide while the vegetable seedlings are still small.

To check on relevant herbicide registration visit the APVMA website at www.apvma.gov.au or consult your local agronomist.

Soil Temperatures

The colour of plastic mulch used greatly affects soil temperature. In hot weather, early or late in the dry season, high temperatures under black plastic may inhibit seed germination. White plastic is preferable if planting late in the dry season.

A comparison between the soil temperatures under black and white mulches is shown in Table 2.

Table 2: Soil temperature under plastic mulch at 25 mm at 3pm (Darwin rural)

	Black Plastic	White Plastic
May / June	33° C	30° C
Sept / Oct	44° C	38° C

White plastic should be used in very hot conditions.



Plastic mulch has been found to increase bitter melon yields by over 100%.



A crop of shallots grown with hay mulch and overhead sprinklers. Some crops are not suited to plastic mulch.

Crops and plastic mulch

Plastic mulch is generally used on high value crops including cucumber, pumpkin, rockmelon, watermelon, zucchini, tomato, capsicum, button squash, snake beans, bitter melon, sweet basil, okra, chilli, lebanese cucumber and eggplant. Other trellised crops that are widely spaced (2–3 m apart) such as luffas and gourds are better suited for use of hay mulch around the base of the plants, with a short radius sprinkler on each plant.

Crops such as taro, yam bean, shallots, chives, some herbs and leaf vegetables are generally not suited to using plastic mulch and are best irrigated by drippers or small overhead sprinklers.



*Zucchinis perform well using plastic mulch.
INSET: Capsicums growing on plastic mulch.*

Mulch removal

Plastic mulch can be removed using tractor mounted forks with the lift arms positioned just under the buried edge of the plastic. This will lift and bundle the mulch successfully. Another effective method is to use a toolbar mounted with ripper shanks and wide 'Alabama' sweeps so that the inside sweeps insert under and lift the buried plastic mulch.

Specialised machinery has also been developed to remove plastic mulch and the drip tape.

Research into biodegradable plastic mulches conducted in the Katherine area has found a product that is robust enough to last the life of the crop and will degrade naturally without the need to remove it.



Laying paper mulch.

Paper mulch

Trials comparing paper and plastic mulch showed:

- Paper mulch was difficult to lay at the correct tension without tearing, as it does not stretch like plastic.
- Durability of paper mulch was poor compared to plastic. Persistent winds resulted in some lifting and tearing of the paper. Once the plants had covered most of the bed, the paper was protected from wind damage.

Extensive lateral water movement across the bed under plastic mulch is well known and results in good root development and distribution. Soil under paper mulch tends to saturate for a short distance either side of the dripline. This is fine for early growth but as the plants mature, the wetted bed surface area remains confined, as does root distribution.

NT trials showed breakdown of wet paper at 8 weeks which got progressively worse. By 10 weeks the wetted strip along the dripline was nearly rotted away. Paper left in the field at the end of the trial was effectively incorporated into the soil. The plastic mulch had to be lifted and removed. Paper was significantly more expensive and heavier than plastic.

Tomatoes growing on paper mulch.





The position of the dripline can be seen if the plastic is stretched correctly.

Drip line

Drip lines generally have numbered specifications i.e. the wall thickness (the higher the number the thicker the wall), emitter spacing, and the flow rate (bigger holes mean bigger flow rates).

The drip line is laid out at the same time as the plastic mulch from a reel situated forward of the plastic roll so that it sits on the surface of the soil, underneath the plastic and close to the centre of the bed. It is important that the dripline is not in the centre of the bed where it may be damaged when planting holes are made in the plastic.

As an example, a high flow, heavy duty drip line is used with a 200 mm emitter spacing, discharging 5 litres per metre per hour. Get specific expert advice to meet your irrigation needs.

Planting on plastic mulch

Large commercial operations have mulch laying machines that cut or burn a hole in the mulch and plant the seed or seedling in one operation. Some growers use planters such as air-seeders or plug-mix planters that cut the hole in the plastic and plant the seed in separate operations. Small growers can use a sharp tin on a handle to easily cut a hole on tightly laid mulch at the correct spacing and then sow seed by hand. Hand sowing of seed has special advantages when using expensive hybrid seed and usually ensures that there are no missing plants that often occur with mechanical planters.

It is important to prevent damage to the dripline when cutting holes in the plastic mulch, by placing it to one side of the centre-line of the bed. If the plastic has been stretched correctly it is very easy to see the dripline under the taut plastic.



Trellised bitter melon growing on plastic mulch.

If using seed instead of plants, the soil should be moistened to ensure good germination. Over-watering of the plants early in growth is a common and serious problem of irrigation management. Light irrigations are all that is required as the seed germinates and begins growing. As plants grow, irrigation duration and frequency should be increased. Seedlings can be used to replant misses in the field as replanting field misses with seed results in too big a difference in maturity of plants. The germinating seedlings need to be protected from a number of possible pests and diseases e.g. ants, cutworms and damping off fungi etc.

Small seeded crops like tomatoes should not be direct seeded. Seedlings need to be grown to a suitable size in a protected nursery before planting. With cucurbit crops such as melons and pumpkins which have a runner habit, strong winds can force the plants over to one side of the slippery plastic bed and in some cases break the main stem through twisting. The use of wind breaks is an important consideration in areas prone to the effects of strong winds.

Planting a second crop into plastic mulch after the first one is finished has never been very successful in the NT. It is considered that soil compaction under the plastic, as well as the difficulty of getting basal fertiliser into the bed are two of the problems that result in poor establishment and poor plant performance.

Nutrition

Management strategies

The sandy red earths of the Top End require a long-term strategy of management to bring them to the stage of optimum nutrition. To do this the following methods should be employed.

- Annual green manure crops to build up soil organic matter and gradually improve the cation exchange capacity (CEC) and water holding capacity of the soil.
- Check pH annually and use agricultural lime for pH correction.
- The use of gypsum as an additional source of calcium.
- Testing your soil for available nutrients to develop a fertiliser program.

Soil test

A laboratory soil test is the only way to get an indication of the status of your soil. It is an invaluable guide to fertiliser requirements provided that correct sampling procedures have been followed. Agricultural suppliers or NT Government officers can advise on soil testing procedures. Soil tests and results interpretation are commercially available from local agricultural suppliers. Although soil tests alone do not provide the complete answer to fertiliser rate and type, they are useful in reducing the guesswork involved and give the grower a basis for decision making on fertiliser use. Plants vary in their nutrient requirements, so it is impossible to publish absolute, quantitative standards of soil nutrient levels to apply for every crop. As well, factors other than nutrient quantity, such as pH, irrigation, soil aeration, soil type, soil depth, microbial activity, and temperature affect the availability of nutrients for plant uptake.

pH

The measurement of soil pH is an important component of soil analyses, and is a measure of the acidity or alkalinity of the soil solution. Plants are sensitive to pH because of the major influence it has on the availability of nutrients required for plant growth (see diagram, below). Most vegetable crops prefer a pH from 6.5 to 7.0, which is mildly acid to neutral, for optimum nutrient availability and growth. Soil pH can be raised by the addition of agricultural lime or dolomite as most soils in the Darwin region are mildly to strongly acid.

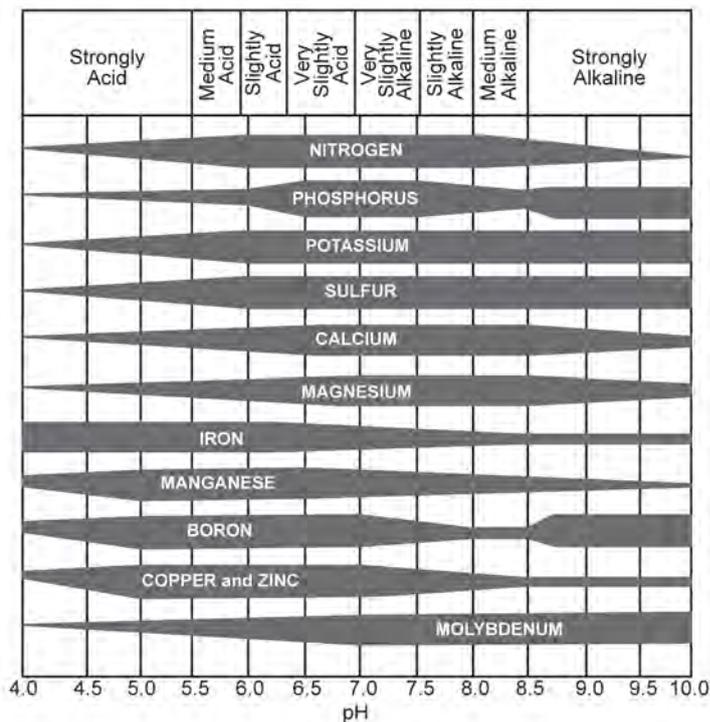


Figure 1: Influence of pH on soil nutrient availability.

Once the pH of the soil is known, the correct product to increase the pH can be chosen. Lime is used if magnesium is adequate. If magnesium is low, dolomite is used both to increase pH and as a source of magnesium. If the pH is suitable, magnesium adequate and calcium low, gypsum can supply the required calcium without affecting pH. This is shown in Table 3.

Table 3: Choice of calcium product with pH.

pH	Ca ppm	Mg ppm	Product
below 6.5	below 600	below 90	Dolomite
below 6.5	below 600	above 150	Aglime
below 6.5	above 1000	above 150	Aglime
above 6.5	below 600	below 90	Gypsum & MgSO ⁴
above 6.5	below 600	above 150	Gypsum

If accessing local bulk supplies check the analysis to be sure of that you get the required product.

Table 4: Typical analysis of agricultural lime and dolomite.

	Neutralising value	Kg/ha required to raise soil pH by 0.1 pH unit	% Ca	% Mg
Lime	78%	240–300	30.3	0.11
Dolomite	60%	400	17.4	9.4

Table 5: Estimates of lime and dolomite application rates with changing pH.

pH change	Lime	Dolomite
5.0 to 6.5	3.6 t/ha	6 t/ha
5.5 to 6.5	2.4 t/ha	4 t/ha
6.0 to 6.5	1.2 t/ha	2 t/ha

Balance Ca:Mg levels

Once the pH is satisfactory, calcium (Ca) levels in the soil may need to be adjusted. Plants need adequate calcium to maintain correct growth and quality. Also, calcium may need to be added to obtain the correct calcium to magnesium (Ca:Mg) ratio. A serious problem with most Top End farms is that the underground water or bore water used for irrigation is derived from dolomite and usually carries high levels of magnesium (Mg).

The ratio of calcium (Ca) to magnesium (Mg) should be between 3:1 and 5:1. A typical result from the analyses of a local soil would have a Ca to Mg ratio of between 0.5:1 to 2:1 which is very low and highly imbalanced and means that quite a lot of calcium has to be applied to the soil to raise the calcium levels. High Mg can also interfere with the uptake of other cations such as potassium and zinc.

- If the Ca:Mg ratio is below 2:1, Mg may induce Ca deficiency, even though the Ca level in the soil may be adequate.
- If the Ca:Mg ratio is above 20:1, then Mg deficiency could occur.
- Generally, the minimum soil Ca:Mg ratio should be 3:1, a good level being 5:1.

Calcium can be added to balance the Cation Exchange Capacity (CEC). The CEC value indicates the capacity of the soil to hold on to cations and to make them available to the plant. Soils with high amounts of clay or organic matter have high CECs of up to 20 milliequivalents per 100gm (meq/100g) and can hold more exchangeable cations. The CEC of local sandy soils is usually less than 5 meq/100 g which is quite low. Low CEC means that fertiliser cations (Ca, Mg, K, NH₄) can easily be lost through over irrigation or heavy rain. The proportion of CEC made up by different cations is also important. Applying calcium will help displace undesirable cations from the exchange complex such as sodium or aluminium.

Table 6: Guide to optimum levels of cations as a proportion of CEC.

Cation	Proportion of CEC
Calcium (Ca)	65–80 %
Magnesium (Mg)	10–15 %
Potassium (K)	1–5 %
Sodium (Na)	below 5 %
Hydrogen (H)	below 5 %
Aluminium (Al)	below 5 %

Sources of Calcium

As discussed, lime is used to correct pH in acid soils for vegetable production to raise pH to about 6.5. Pure calcium carbonate (lime) has a standard neutralising value of 100 for its ability to neutralise acidity. Other products are rated against this standard - most lime material should have a neutralising value of at least 80 (which means 80% of the strength of pure calcium carbonate). Limestone is extremely insoluble and needs to be finely ground to react quickly in the soil to produce the desired effect. It is important to incorporate finely ground limestone into the soil as Ca is insoluble and needs to be mixed in the plant root zone.

Gypsum (calcium sulphate) can provide the additional calcium needed for the crop and can be applied to the bed at planting. Gypsum from quarried sources does not alter the pH of the soil and is more soluble than agricultural lime. The calcium content varies but is usually about 20% Ca while sulphur is about 15%.

Calcium nitrate is a highly soluble compound that is used to increase the calcium supply for crop growth, particularly in the later growth stages. A solution of calcium nitrate can be injected into irrigation water. Calcium chloride can be used in some situations where high nitrate levels are an issue, however care must be taken with chlorine sensitive crops. Calcium thiosulphate and calcium chelates with mannitol are also being used as a readily available calcium source on some farms, without the drawback of possible chloride toxicity.

Long term effects

It is very difficult to achieve long term changes in soil pH and CEC in sandy soils of the Darwin region. Very rapid breakdown of organic matter and massive leaching due to monsoonal rain means that soil tends to return to near its natural pH. The nutritional capacity of soil should be retested every year prior to planting of vegetable crops.

Basal fertiliser

Basal fertiliser is essential for early seedling growth and cannot be omitted or substituted by fertigation. In NT soils, care should be taken to prevent the washing of basal fertiliser below the root zone of plants by over-watering beds when wetting up the soil prior to planting. It is important to wet up with small irrigations at short intervals to keep the wetted area immediately around the young developing roots rather than wash the basal fertiliser out of the root zone.

Virgin soils

The nutrient status of Top End sandy red earths in their virgin state is poor. pH levels range from 5.0 to 5.5, and most nutrients are in the very low to undetectable range with the exception of calcium and magnesium which are derived from the parent material but are only present in low amounts. In strongly acidic soils, the presence of high levels of iron and aluminium can form insoluble compounds with phosphorus and reduce its availability to plants. A liming program to manage pH is very important in minimizing phosphorus fixation. Phosphorus availability is greatest at pH range of 6 to 7. It is preferable to apply phosphorus in a band to reduce contact with the soil therefore minimize fixing.

The basal fertiliser needs to be incorporated into the top of the beds. If planning to use plastic mulch, the operation of the bed-shaper will incorporate the fertiliser into the first 2 to 3 cm of the soil.

Basal fertiliser rates are calculated on a kg / ha of bed area and result in a rate per metre of bed. This calculation does not include the area between beds. Local Darwin soils have very low clay and organic matter contents meaning their cation exchange and water holding capacities will be low. As a general rule based on experience and crop response. Table 7 shows baseline basal fertiliser for vegetables grown in sandy soils in the Darwin region. The remainder of the nutrients are supplied during the life of the crop.

Soils high on organic matter are good for growing vegetables.



Table 7: Basal fertiliser for vegetables grown in sandy soils around Darwin.

		N (kg)	P (kg)	K (kg)	Ca (kg)
Total major nutrients (kg/ha):		70	120	60	1095
Applied as					
NPK 14-14-12	500 kg/ha	70	70	60	
Single super phosphate 0-8.8-0	570 kg/ha		50		95
Agricultural lime @ 30% Ca	2000 kg/ha				600
Gypsum @ 20% Ca	2000 kg/ha				400

These rates should be applied to the bed area only, not broadcast over the entire area. It is important to note that as the pH of the soil changes, less lime will be required to correct pH but more gypsum might be needed to maintain calcium levels.

Previously cropped soils

Soil analysis are essential for previously cropped soils. Carry this out after the green manure crop has been incorporated, and well before planting. Most modern laboratories complete their analysis in five working days. As a benchmark, the soil nutrient requirements in Table 8 would be considered adequate for a vegetable crop.

Table 8: Target soil analysis ranges for growing vegetables.

Nutrient	Symbol	Level (mg/kg or parts per million (ppm))
Phosphorus	P	50–70
Potassium	K	110–150
Calcium	Ca	900–1000
Magnesium	Mg	90–120
Zinc	Zn	1–3
Boron	B	0.1–0.6
Manganese	Mn	20–50
Iron	Fe	20–50

Nitrogen is an important element for plant growth, however, soil nitrogen levels are not considered as the element is highly mobile and soil levels vary dramatically due to irrigation or rainfall intensity. Even so, the level of nitrogen in NT soils is typically very low, - a function of low organic matter levels.



A fertigation unit and valve manifold.

The levels in Table 8 (in mg/kg) are a guide to aim for when making decisions on fertiliser requirements. The P content of the soil is probably the most important factor to monitor as it can take three to four years to reach the desired level due to fixation in the soil.

As pH is stabilized at around 6.5, and phosphorus levels in the soil increase over time, less phosphorus fertiliser will be required.

The following calculations show how to convert the required ppm (mg/kg) increase to kg/ha of nutrient over one hectare to 15 cm soil depth for nutrients that are reported as weight of nutrient per unit weight of soil.

Soil sampled to 15 cm depth
Assume bulk density of 1.3 gm / cm³
Therefore 1 m³ of soil weighs 1300 kg

Soil volume per hectare to 15 cm depth
10 000 m² × 0.15 cm depth = 1500 m³

Therefore the top 15 cm of soil over one hectare weighs
1500 m³ × 1300 kg = 1 950 000 kg

Hence 1 mg / kg of a nutrient is equivalent to 1.95 kg / ha.

To raise the level of a given nutrient by 1 ppm (mg / kg) in the top 15 cm of a soil with a bulk density of 1.3 gm / cm³ a total of 1.95 kg / ha of that nutrient is required.

Fertigation

Fertigation is the practice of applying fertiliser through the irrigation system mostly through drip irrigation. If using plastic mulch, it is the only way to supply enough nutrients to the crop.

Fertigation has many advantages, which include:

- The technique allows for a regular flow of plant nutrients by applying a little nutrient often. It is simpler and more convenient than side-dressing applications and saves on labour costs.
- There is greater flexibility in timing nutrient supply so that the plant requirements can be supplied at the correct phase of growth.
- There is improved availability of nutrients for uptake by the roots as the solution is placed directly in the wetted root zone.
- The potential for root burn is reduced as the nutrients are applied in dilute solutions or at low concentrations.

Fertigation occurs during a normal irrigation cycle. The irrigation cycle or total irrigation time consists of the pre-wet or pressure build up, the injection time (where fertiliser is injected into the irrigation water) and the flush time. The total irrigation time is determined by the water requirements of the crop and can be indicated by the use of soil moisture monitoring equipment.

The injection time

The injection time depends on the injection rate of the pump and the volume of solution to be injected. It must be equal or greater than the time it takes for water to go from the injection point to the last emitter. This information can be obtained by injecting a water soluble dye like potassium permanganate at the injection point and timing its movement through the system. The purple colouration of the dye in the water can be detected at the furthest emitter. In small irrigation systems this time is usually less than 30 minutes but in larger systems can be over an hour. The injection time must fit into the irrigation cycle. If it cannot then more frequent injections are required.

The Flush time

When fertiliser injection is completed, the irrigation system is allowed to run for a specified time to flush out any fertiliser residues. This is called the flush time. Like the injection time, the flush time is the time it takes for the water to go from the injection point to the last emitter on the furthest dripline of the area being injected. Fertigation should be done at the end of the irrigation because additional watering after the flush time will leach the fertiliser out of the root zone of the plants.

As an example, a system with 400 m of dripline covering an area of 0.06 ha had an injection rate of 1 Litre per minute. The crop was fertigated twice a week. All the nutrients for one injection could be dissolved in 20 L water. By injecting dye into the system the flush time was found to be 20 minutes, so an injection time of 20 minutes was equal to the flush time and the minimum time allowed to guarantee an even distribution of nutrients.

Fertiliser injection

There are a number of successful methods of injecting fertilisers. The system most suited to relatively small scale growers using drip irrigation systems is the pressure differential venturi. The venturi is a device that causes a rapid reduction in water pressure causing suction which draws fertiliser solution into the irrigation line. It is simple in design with no moving parts, inexpensive, easy to install and requires little maintenance. The main disadvantage with venturi injectors is the relatively large pressure loss (up to 200 kpa) in the main line required for them to operate efficiently. As a result, venturis are mostly used with drip irrigation where there is a large pressure difference between the main line and the drip system. Venturi systems are difficult to automate and injections need to be done manually.

Some practical considerations of fertigation

- The use of a suitable in-line ring filter is considered essential so that fertiliser particles do not block dripline orifices.
- It is important to use fertiliser of high solubility so that a minimum amount of water and injection time is required.
- Weekly nutrient rates should be split into at least 2 or preferably 3 injections per week if carried out manually, but automatic daily injections would be ideal.
- Flush driplines out immediately after injection by irrigating for the flush time as determined by the dye test
- The minimum injection time must be equal to or greater than the flush time to ensure nutrient is spread evenly through the crop.
- A non-return valve should be installed to prevent back-flow of chemicals which may contaminate the water supply.

Compatibility of different elements:

- When mixed together in the fertigation tank, compatibility problems may occur with some fertilisers. Calcium compounds cannot be mixed with any sulphate or phosphate products otherwise insoluble precipitates will be formed that will block driplines.
- Boron compounds should be injected on their own or insoluble precipitates can result.
- As a general rule trace elements should be injected separately. If you remain unsure of the compatibilities of some ingredients then consult your agricultural supplier.
- Algal growth in the dripline can cause blockages of the emitters and is more likely to be a problem when pumping from surface water sources rather than from underground water. Incomplete flushing of the irrigation system after fertiliser injection can cause this algal growth. Low rates of sodium hypochlorite injection at regular intervals will keep driplines free of algae.
- Calculations for injected fertilisers should be based on the type of crop. With running crops like melons or pumpkins where the whole area is covered by leaf, calculations are made on a kg / ha basis, eg: 15 rows at 40 m length, 2 m row spacing.

Total area = $15 \times 2 \times 40 = 1200 \text{ m}^2 = 0.12 \text{ ha}$.
This is the same with trellised crops, which would cover the whole area if they were laid horizontally on the ground.

- For low growing vegetable crops that don't spread out past the bed, the injected area should be calculated on the crop area only.

Scheduling nutrient application using fertigation

- Soil immobile nutrients such as phosphorus, zinc, magnesium, iron and copper must be placed within easy reach of developing roots, either as a basal dressing or in irrigation water; being not very mobile in soil water they stay where they are put so, if dissolved in irrigation water, it is important that the root zone only is irrigated.
- Nitrogen, potassium and sulphur are relatively mobile in soil water and the demand for these nutrients is high during vigorous early growth. The main objective is to supply these nutrients as the plant requires them for its rapid growth phase. Nitrogen applications should be reduced as the fruit development phase commences, because high nitrogen levels in the plant late in fruit development can be detrimental to quality at harvest due to excessive vegetative growth and less sugar in fruit.
- In the fruiting or reproductive period the most important nutrients are calcium and boron, and to a lesser extent, potassium. The effectiveness of plant immobile nutrients, e.g. calcium and boron, increase with several small applications rather than one large application.
- The most critical issue in the early growth phase is precise irrigation. If over-watering occurs nutrients are washed away from the young developing roots. As the plants get older, and their root systems become more extensive, they may reach the leached nutrients (especially nitrogen) which can then cause an imbalance, leading to a reduction in fruit quality.
- For crops with a short harvest period, such as rockmelons, 70–80% of the total injected nitrogen required needs to be applied from about week 2 to week 6. This could be done by growing a large plant quickly with plenty of flowers and obtain a good fruit set before cutting the nitrogen back and applying calcium to the young developing fruit.

Vegetable nutritional requirements for use in fertigation

The formulas:

- Crops of short harvest duration such as rockmelons, watermelons and honeydews, where harvest periods generally do not exceed 2–3 weeks, are based on the following assumptions.

Approximately 65 kg/ha of nitrogen is injected for the life of the crop with 80% applied before fruit set (phase 1) and 20% after fruit set (phase 2). The injected potassium for phase 1 growth is calculated using a N:K ratio of 3:2 and phase 2 is the reverse at 2:3.

Phase 1 before fruit set
(applied from week 2 to week 6)

52 N - 20 P - 35 K (in kg/ha) [using 96 kg potassium nitrate (KNO_3), 91 kg mono ammonium phosphate (MAP) and 62 kg urea applied in equal increments]

Phase 2 after fruit set until a week before first harvest.

13 N - 0 P - 20 K - 16 Ca (in kg/ha) [using 48 kg potassium sulphate (K_2SO_4), and 82 kg calcium nitrate $\text{Ca}(\text{NO}_3)_2$ applied in equal increments]

- A different strategy is applied with crops with an extended harvest period such as button squash, zucchini, cucumbers, bitter melon, okra, snake beans etc.

Phase 1 before fruit set
(applied weekly from week 2)

25 N - 5 P - 18 K (in kg/ha) [using 49 kg potassium nitrate (KNO_3), 23 kg mono ammonium phosphate (MAP) and 34 kg urea applied in equal increments]

Phase 2 after fruit set until the end of harvest
(applied weekly)

12 N - 5 P - 18 K - 5 Ca (in kg/ha) [using 49 kg potassium nitrate (KNO_3), 23 kg mono ammonium phosphate (MAP) and 26 kg $\text{Ca}(\text{NO}_3)_2$ applied in equal increments]. Phase 2 injections are made into two solutions so that calcium nitrate does not come into contact with the mono ammonium phosphate, or else precipitation of calcium phosphate will occur. Phosphorus is included at a maintenance rate to replace that removed by the crop.

Customized premixed formulations of soluble fertiliser are available from most major rural suppliers, which are tailored for each crop stage.

Trace Elements

Trace elements are essential to the normal functioning of plant metabolisms. Trace elements should be injected into irrigation water several times throughout the life of the crop to prevent any deficiency from occurring rather than waiting for symptoms to show in the crop, especially if those elements are low in soil. Compatibility problems may arise if the trace elements are incorporated into the major formulae and it is best to inject them separately. Formulations of trace element mixes can be purchased that have all the elements all in soluble form in one drum. These are convenient and effective. Additional boron and calcium may be required during fruit development but it is important that it is not overdone as many crops are sensitive to boron and toxicity can occur. A dry ash leaf test is the best way of identifying any trace element deficiency.

Leaf analysis for nutrient monitoring

Any vegetable production venture should include a nutrient monitoring program, especially if you are dealing with a new crop, a different soil type or a change to a different climate. This allows you to check any suspected nutrient deficiency. Samples of the plant for monitoring can be the whole leaf, which is oven dried and ground for analysis or just the leaf petioles from which the sap is tested. The analyses should be conducted by an accredited laboratory and can be arranged by your local agricultural supplier or consultant. It is important to keep accurate records to correlate nutrient input with test results and crop performance, to develop a fertiliser program to suit your particular situation.



At least 20–30 leaf petioles are needed for sap analysis.

Petiole Sap Testing

The analysis of petiole sap is a rapid method of checking the nutrient status of your vegetable crop. While analysis of oven dried and ground leaf material could take a week or more for a result, a sap analysis report should only take a day or two. Sap testing should be a regular program to determine trends throughout the life of the crop rather than a one-off analysis. Because petiole sap is generally collected from the terminal growth, the test may not accurately register the more immobile nutrients which tend to remain in the older leaves of the plant, although they will reflect current supply. However, sap testing works well for the major nutrients (NPK).

Field sap testing kits are available but their accuracy has been questionable in the past and they only test for one nutrient at a time. Guides for nutrient “adequacy” levels and interpretation of results are available through various publications or talk to your local consultant or qualified agronomist at rural supply outlets.



A simple manifold set up with a venturi injector, pressure gauges and a valve causing the required pressure drop.

Irrigation

Irrigation management

Good irrigation management of vegetable crops is essential to a successful and profitable harvest. Under watering causes stress with subsequent poor growth and reduced yield. Over watering can lead to root and stem diseases and leaches fertiliser away from plant roots. An efficient irrigation system saves time and money and increases yields.

If fertiliser is applied in the irrigation water, precise control is necessary to ensure delivery of fertiliser to and not flushing nutrients beyond the root zone. With fertigation the nutrients travel with the water into the soil and mobile nutrients like nitrogen and potassium are easily leached away by over irrigating.

Good irrigation management relies on:

- System design
- Irrigation schedules that suit the crop
- Soil moisture monitoring to ensure application volumes and frequency match crop needs and soil water characteristics.

System design

It is firstly important to select the correct pipe diameters and lengths for mains, sub-mains and laterals to deliver sufficient water to the end of the lines. This information, along with pump capacity and filtration requirements, is available from your local irrigation supplier or consultant. It is also advisable to install an automatic irrigation controller to ensure that watering is not overlooked or forgotten.

The next step of system design is to determine the best method of irrigating the intended crop. The system must have the capacity to meet maximum crop demand without wasting water, irrespective of whether you use drip tape, single drippers or mini-sprinklers. It is equally important that all the root zone is wetted. This is impossible to achieve with a single dripper at the base of the plant, especially on sandy soils. Multiple drippers or drip tape combined with a mulch cover of plastic or hay mulch will provide more lateral water movement and a larger wetted area.

Mini-sprinklers are effective on widely spaced trellised crops (2–3 m apart) such as luffas and gourds, but closely planted row crops such as melons, pumpkins, squash or okra should have a continuous wetted area along the bed using drippers or tape.



Mini-sprinklers are used here in a long melon crop in the Darwin River area. Note the hay mulch around each plant.

Watering schedule

A watering schedule determines when and how much water to give a crop. The main objective is to provide plants with sufficient water to avoid stress that cause yield and / or quality reductions. These decisions are based on the water demands of the crop, the water holding capacity of the soil and the root zone volume (i.e. the crop available water content of soil in the root zone).

The basic rule for watering vegetable crops is to apply small amounts early when the plants are small and gradually increase this as the plants grow and root systems develop. The best way to determine the correctness of the schedule is to monitor the moisture content of the soil. Schedules can also be based on evapotranspiration adjusted with a crop coefficient.

Strong dry winds can have a dramatic effect on crop water demand as plants rapidly lose water through their leaves. Effective windbreaks lessen this problem but additional water is required during hot windy conditions.

Table 9 can be used as a guide for irrigation scheduling on vegetables that are relatively heavy users of water, based on experience on the common sandy soils around Darwin using plastic mulch and drip tape (3.5 L/min/hr). It can be seen that as the crops grow, the application of water gets heavier.

Table 9: Example irrigation schedule for a vegetable crop in the Darwin rural area.

Week	10 am watering	1 pm watering	3 pm watering	Total daily water
1–2	15 min.		15 min.	30 min.
3–4	15 min.	15 min.	30 min.	60 min.
5–6	30 min.	30 min.	60 min.	120 min.
7–8	30 min.	60 min.	60 min.	150 min.
8–10	60 min.	60 min.	60 min.	180 min.

The total water requirement for the day should be divided into at least two applications with a major portion applied during the hottest part of the day when plants need it the most (between 1 and 4 pm).

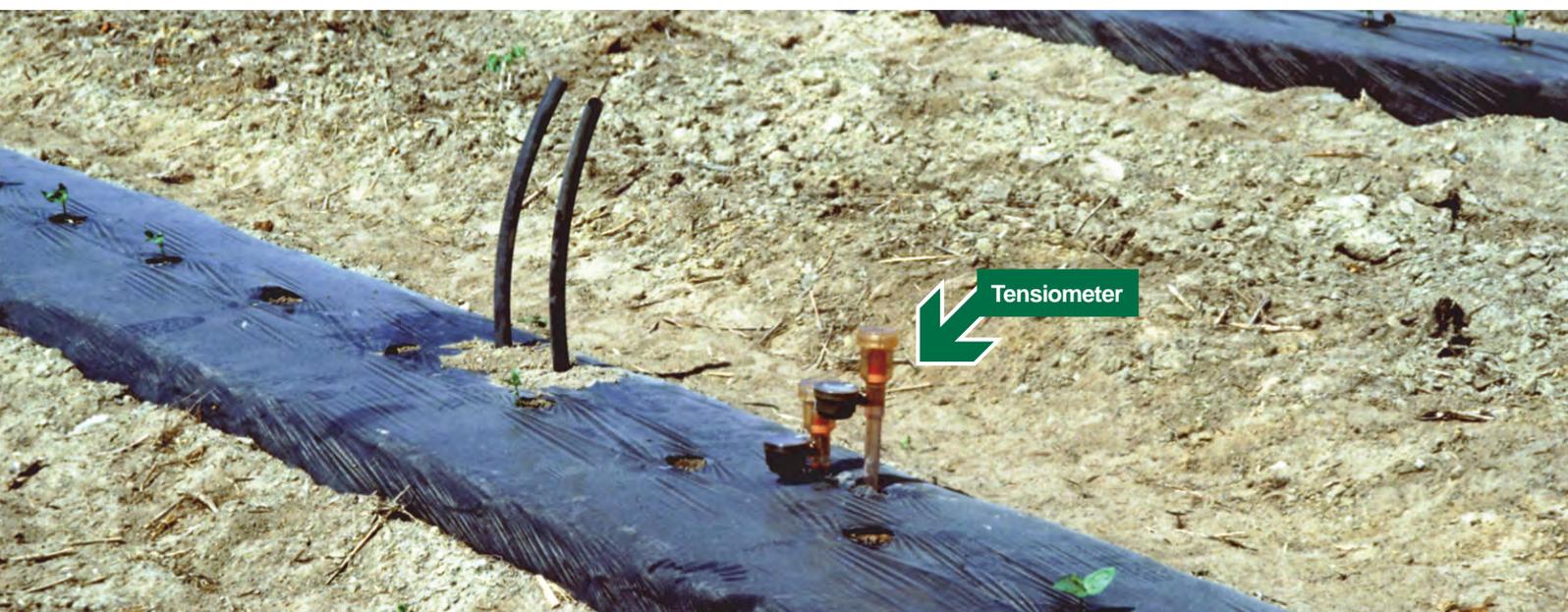
The amount of water the soil can hold depends on your soil type. Soils with a high clay or organic matter content hold more water than sandy soils. Increasing organic matter content by annual green manure cropping will gradually increase the water holding capacity of your soil.

It has been found that under plastic mulch most vegetable roots are found in the first 0–20 cm of soil depth (70–80% of total roots). This means that when irrigating a vegetable crop, water that goes deeper than 20 cm is probably past the root zone and wasted.

Soil moisture monitoring

One way to ensure that you are not over or under watering is to monitor changes in the amount of water in the root zone. This can be as simple as digging down into the root zone of plants and feeling for moisture and visually tracking where the water has travelled. At the other extreme there are sophisticated and expensive monitoring tools like capacitance probes to measure and store volumetric soil water content data. These are mainly used in high value crops planted over large areas (e.g. rockmelons). One simple way of monitoring the soil moisture in your vegetable crop is to use tensiometers.

Tensiometers are plastic tubes filled with water with a porous ceramic tip on the soil end, and an airtight seal on the other. The ceramic tip is inserted into the ground at the depth where soil moisture is to be monitored. Water can move freely in or out of the porous tip. As the soil dries, water moves from the tube into the surrounding soil. Because the top of the tube is air tight, as the water leaves the tube through the ceramic tip, suction develops in the tensiometer which can be measured. When the soil is re-moistened, water travels from the soil through the porous cup into the tensiometer thereby reducing the suction. The amount of suction is therefore an indicator of the moisture content of the soil.



Tensiometers are cost effective and can increase the accuracy of your irrigation management.



Tensiometers placed at two different levels in a rockmelon crop.

Tensiometers measure how difficult it is for plant roots to extract water from the soil. A high reading on the gauge indicates a dry soil from which the plant has more difficulty in extracting water.

There are two types of tensiometers available. One design (for example Irrrometer® or Jet-fill®) has the soil tension gauge attached to the top of the tube. Another design (Soil Spec®) requires a portable electronic gauge equipped with a needle that penetrates the rubber bung at the top of the tube to measure the vacuum. Gauge readings are usually in kilopascals (kPa) of suction, which is the difference between atmospheric pressure and the pressure in the tensiometer.

Tensiometers are usually placed in pairs for effective irrigation monitoring with one at 20 cm in the zone of maximum root concentration and one at 40 cm at the bottom of the root zone.

The shallow tensiometer measures the soil moisture status in the active root zone. When the shallow tensiometer reads 20–25 kPa the soil around the roots is drying out and irrigation should be applied. If readings are graphed over a period of time, it is possible to predict and plan for a future watering by extrapolating the rate of drying from the graph. After watering, the reading from the shallow tensiometer will drop as soil is remoistened.



Two types of tensiometers – the Irrrometer® on the left and the Soil spec® on the right.

The deeper tensiometer indicates when water has penetrated to depth and watering should stop, that is, when the reading drops to 15 kPa, irrigation should stop. If irrigation is continued, the wetting front will percolate lower than the root zone, possibly leaching nutrients.

Tensiometers are useful if the information from them is recorded. No more than 30 minutes, every day would be needed to monitor a medium-sized farm's irrigation. As experience is gained using tensiometers an understanding of the water movement and water retention characteristics of the soil is developed. This will increase the yield and quality of the vegetables grown.

Pest and Disease Control

Crop monitoring

Monitoring vegetable crops for pests or disease from planting onwards is essential. Infestations usually start in a small area of the crop or in adjacent weeds and if not noticed will quickly spread. Monitoring crops once or twice a week on a random basis (2 or 3 places in each row) gives growers early warning of an infestation making control easier and cheaper. However, growers need to know what to look for.

Correct identification of insects and plant diseases

Some insects are pests, others are harmless and some are beneficial because they attack other insects. Correct identification of a pest or disease is vital for effective control as some insecticides and fungicides control only specific pests and diseases. Spraying the wrong chemical may not be effective and result in a waste of time and money. NT Government entomologists and plant pathologists can correctly identify insects and plant diseases and recommend the most effective control strategies.



Poor insect management will lead to an explosion of insect problems, for example, this taro plantation in the Humpty Doo area was devastated by cluster caterpillar (*Spodoptera* spp.)



Fusarium resistant basil is now used in the Darwin Rural area.

Methods of control

Cultural Control

This method involves cultural practices that lower pest and disease levels. Examples are given below:

- **Crop rotations** and **time of planting** strategies to avoid periods of peak pest or disease.
- Cultivating **cover crops** and incorporating **organic matter** to improve soil structure and reduces nematode populations.
- Using **raised beds** for good **drainage** to prevent fungal diseases such as *Pythium* sp.
- **Destroying old crops** after harvest and **controlling weed areas** to stop pests, diseases and mosaic viruses to survive and multiply
- Use of **disease or virus resistant varieties** or rootstocks such as the *Fusarium* tolerant basil variety (Nufar F1), bacterial wilt resistant rootstock (wild malay eggplant) for tomato and the *Fusarium* resistant rootstock (Iron cowpea) for snakebeans.
- **Traps and baiting systems** to lure and destroy pests such as fruit flies and termites.
- Provide **correct water and nutrient management** to vegetable crops. Over watering can cause bacterial and fungal problems and excessive nitrogen can make plants more attractive to pests and diseases.
- Using trap crops that attract pests away from commercial crops
- Cultivating plants that breed beneficial insects.



Snake bean grafted on Fusarium resistant rootstock (Iron cowpea).

*TOP RIGHT INSET: Baiting systems are an effective way to manage termites (*Mastotermes darwiniensis*).*

Chemical Control

This method involves application pesticides or fungicides directly to the crop and is the most common method of crop protection. These applications may be preventative or applied in response to pest or disease outbreaks. Pests and diseases can quickly build up resistance to the continued use of one type of chemical making them less effective therefore rotating chemicals from different chemical groups makes resistance less likely and gives better control. Chemical companies try to avoid resistance build up to preserve the efficacy of their products by stipulating that the use of their chemicals are restricted or used in a rotation program. Frequent use of broad spectrum pesticides should be avoided as they may destroy beneficial insects.

If spraying equipment is not adequate or not correctly calibrated, the chances of obtaining control will be very low. It is necessary that the correct amount of chemical reach the target area which in the case of most pests and diseases is both sides of the leaves. The spray needs to penetrate through the entire leaf canopy and high operating pressures help to achieve this. Incorrect calibration of spray equipment can result in poor control if too little is applied while too much is a waste of chemical and may lead to harmful residues.

Correct types of nozzles play an important part in achieving good coverage with the required droplet size. Nozzle technology is changing all the time, so it is a good idea to talk with your supplier about the best nozzles to use for your application.



Sampling honey dew melon for disease in the Darwin rural area.

Chemical spraying, in general, should be done in the early morning or evening when there is little wind and when bees and other natural pollinators are not foraging.

Maintaining a spray diary is an important part of your pest and disease management. Records allow you to refer back to what actually worked and what did not. Information you should record include the following:

- The crop type and age.
- The name of the pest or disease and the level of infestation.
- The chemical name and rate applied.
- The time and date of spraying.
- The level of success in controlling the pest or disease.

There is growing public awareness of the dangers of toxic chemicals to the user, the consumer and the environment so directions on the label must be observed. Through education and certification programs, vegetable growers are becoming more responsible for the safe and correct use of chemicals on their farms. It is appropriate for all growers to have a current ChemCert certificate. National Farm Chemical User Training Programs are run regularly in most areas.



Getting the right droplet size is important for effective chemical application.

Biological Control

Biological control occurs when predatory or parasitic insects and pathogens help control pests and disease. This includes pathogens these may occur naturally or can be introduced into a crop. Biological control is an essential component of integrated pest management. Prominent features of biological control are methods used to increase biodiversity and the number of beneficial organisms. Cultural practices such as green manuring and mulching can increase the diversity of soil microorganisms including root-knot nematode suppressive fungi. Chemical fertilizers, herbicides and pesticides can reduce the diversity of beneficial organisms in the soil.

Several useful predators and parasites of pests are produced commercially. Ladybirds, lacewings, predatory mites and parasitic wasps are all sold. The Australasian Biological Control Association (www.goodbugs.org.au) provides links to the current producers of bio-control products.

Biopesticides are formulations of entomophagous fungi (fungi that feed on insects), bacteria or viruses. These agents are targeted at a specific insect pest, and require understanding of the method of action for the best effect. The endotoxins of the bacteria *Bacillus thuringiensis* are stomach poisons for several caterpillar species. They are most effective when used for young caterpillars. The infected insects cease feeding, become still and die after a few days. Another example, *Nucleopolyhedrosis* virus (Gemstar®, Vivus®) targets *Helicoverpa armigera* (corn earworm or heliothis).



Baiting is an effective management tool for fruit fly.

Integrated Pest Management (IPM)

The key ingredients of IPM are effective monitoring of pest and disease levels and the use of specific controls, that preserve biodiversity and beneficial organisms. Successful IPM programs aim to keep pests and diseases below economically damaging levels without necessarily eradicating them completely.

Chemical Use and Residues

Read the Label

Agricultural chemicals used to control pests can benefit productivity. However excessive or inappropriate use of chemicals may harm crops, contaminate produce or the environment, put markets at risk and endanger health.

Traces of chemicals or residues found in produce can result from a number of sources

- direct application of chemical
- post-harvest application of chemical
- indirect application e.g. spraydrift
- environmental contamination (e.g. residues in contaminating crops/soil).

If a chemical is used there is some chance that residue will end up in the produce or on the surface of the produce.

The product label contains the vital information for safe and effective use of that chemical. There should be no problems with residues if the grower uses the chemicals:

- at the correct rate
- with the recommended application method
- on the crops and problems listed on the label
- within the withholding period
- in the correct environmental conditions, especially with regard to wind and drift.

It is important to observe the withholding period as quoted on the label. The withholding period for an agricultural chemical is the minimum recommended interval that should elapse between the last use of a chemical product on a crop and the harvesting, cutting or grazing of that crop. This waiting time before picking is essential to allow the level of residues to drop to or below the minimum residue limit (MRL). The purpose of withholding periods is to avoid unacceptable levels of agricultural chemicals and their metabolites in raw agricultural commodities and food for humans and animals.

The use of agricultural and veterinary chemicals is controlled in the Northern Territory under the *Agricultural and Veterinary Chemicals (Control of Use) Act (2010)*.

The purposes of this Act are:

- a) to impose controls relating to the possession, sale, use and application of chemical products, and the manufacture, sale and use of fertilisers and stockfoods, that ensure sustainable agriculture by protecting:
 - i) the health of the general public and the users of those substances;
 - ii) the environment;
 - iii) the health and welfare of animals; and
 - iv) domestic and export trade in agricultural produce; and
- b) to promote the harmonisation of legislation in Australia controlling the use of chemical products by regulating the possession and use of those products in accordance with labels and permits under the Agvet Code.

The controls referred to in subsection (a) above include the following:

- a) the prohibition and regulation of the possession and use of chemical products, including the prescription and supply of chemical products by veterinarians and pharmacists;
- b) the regulation of ground and aerial spraying and the use of S7 chemical products;
- c) the declaration of chemical control areas and agricultural emergencies;
- d) the management of land and agricultural produce contaminated by chemicals.

The Maximum Residue Limit (MRL)

The maximum residue limit (MRL) is the maximum concentration limit for an agricultural chemical in produce, resulting from the registered use of that chemical. These levels are set by the Australian Pesticides and Veterinary Medicines Authority (APVMA) with regard to the maximum label use pattern (i.e. good agricultural practice) plus other factors including acceptable dietary exposure and the rate of breakdown of the chemical in the produce.



Chemical services branch of the Northern Territory Government regularly check produce from the Top End for chemical residues.

These MRLs are included in the Australian Food Standards Code adopted by various state laws and the MRL becomes the maximum concentration of a chemical residue (resulting from the registered use of an agricultural or veterinary chemical product) that is legally permitted in a food or agricultural commodity.

MRLs are trade standards set for all types of raw food commodities where the use of an agricultural chemical is required for efficient practice. These are listed in an Australian Pesticides and Veterinary Medicines Authority publication “The MRL Standard” and are specified for each individual chemical in milligram per kilogram of the individual crop or produce type.

Products must only be used on crops listed on the label. It is a violation where an unregistered chemical residue is found in produce.

If produce contains chemical residues above the MRL then there is:

- a risk the produce may be unsafe to eat.
- a certainty that the produce will be seized and withdrawn from sale
- a risk that the grower’s authorisation for chemical use will be withdrawn (e.g. S7 chemicals)
- a risk that legal action would be taken against the grower
- a risk that markets could be lost along with the reputation of NT produce.

However, residue levels in produce should not exceed the MRL through normal label use if withholding periods are strictly adhered to.

Residue Testing in NT Produce

It is important to have an industry promoted as supplying healthy clean produce with public confidence in that produce. Testing for chemical residues is important means to find out how effectively we are achieving this goal.

NT Government officers conduct residue-testing programs for tropical vegetables. NT Government officers will follow up on any samples with residue levels above the MRL (and also those above half MRL) to investigate the cause and to give growers advice on best practice or alternative pest control measures. Test results may also identify areas where no suitable registered product is available and further research or a permit is required.

Growers should maintain records of residue test results (and of course chemical use) for future farm planning and market access considerations. The data from these testing programs is available to the individual growers for their quality assurance records.

Harvest and Post-harvest



Bitter melon can over-mature quickly in transport if some fruit in the box is already ripe.

Maturity and quality

Quality is about delivering what the customer wants in terms of consistency of product, reliability of supply, size and shape, and price.

Many problems with vegetables after harvest can be traced back to their maturity at harvest. If they were over mature, then problems with breakdown, disease and temperature are more likely. Knowing the stage of maturity that the customer wants that will cope with the handling chain from field to customer will preserve quality.

Assuming the product is what the market wants at the right maturity stage, maintaining the quality of vegetables after harvest relies on the management of four things – temperature, air flow, water loss and ethylene. They are related, and changes in one aspect will have effects on another.



Dents caused by the stems of other cucumbers.

Torn ends caused by careless harvesting are usually out of specification and allow diseases to enter the open wound.

Harvesting and handling

Vegetables should not be harvested in the hottest part of the day. High temperatures cause moisture loss through evaporation, they also make the pulp more susceptible to bruising. Once vegetables are picked they need to be kept cool by at least keeping them in the shade during harvest, but preferably by someone taking them back immediately to the cool room. Leaving vegetables in the sun increases their temperature, dehydrates them and speeds up ripening and decay. Care needs to be taken when harvesting vegetables as they are easily damaged.

Rough handling can result in wounds, bruises and abrasions on the vegetables that reduce the quality of the product and the price. Do not throw vegetables into containers, they can fall onto the stems of other vegetables and receive dents or punctures.

Vegetables such as cucumbers and okra should be cut from the plant instead of broken off. Breaking can cause the skin at the tip to tear off, making the vegetables unacceptable to the market. Any open wounds or damaged regions can act as entry points for fungal pathogens or bacteria.

Other common causes of field damage can be reduced using simple methods. Wear gloves when handling produce. This will reduce scratches and abrasions caused by fingernails. Reduce the amount of dirt and twigs that get into crates in the field by keeping them off the ground and out of contact with the soil. Dirt and twigs rub against the skin of the vegetables and cause scratches and abrasions.

In summary:

- Harvest in the cooler parts of the day, not the hottest
- Keep the harvested vegetables in the shade not the sun, or take immediately to a cool room after harvest
- Do not throw the produce into containers
- Harvest fruit vegetables (e.g. cucumber) with a knife - do not tear them off vines
- Wear gloves to reduce abrasions
- Keep crates off the ground and eliminate dirt and twigs from crates to reduce abrasions.

Temperature

Once vegetables are picked, the most important thing to maintain the quality and maximise shelf life, is to remove heat. For most vegetables, this means bringing the temperature down to between 8°C and 10°C, but it is important to identify the correct temperature for your type of produce.

Table of recommended post harvest storage temperatures:

	Product	Temperature		Product	Temperature
	Bitter Melon	5°C		Okra	10°C
	Capsicum	7–13°C		Pumpkin	10–13°C
	Cucumber	10–13°C		Taro	14–16°C
	Eggplant	10–12°C		Snake Bean	5–10°C
	Lettuce	0°C		Tomato (ripe green)	13–21°C
	Onion	0°C		Zucchini	5–10°C

It is essential to get the vegetables into a cool-room as soon as possible after harvest to start cooling. It is also important to pre-cool vegetables before packing. Vegetables put into boxes and liners while they are still warm take longer to cool and are more likely to have problems.



Typical cool room in the NT.

Air flow

Temperature is managed by manipulating the flow of air around the produce. The best way to speed up cooling of the vegetables is to increase the flow of cool air around them. This can be done in several ways:

- Leave space around containers – don't stack them against walls or in large piles until they are cool;
- Make sure the containers have ventilation holes to allow air flow;
- Use a forced air cooling fan. This drags cool air through the produce;
- Measure the temperature of the vegetables in the centre of the box before packing, as sometimes they will feel cool to touch but can still be warm; and
- Don't pack the vegetables in plastic bags until they are cool. Plastic bags restrict air flow.

Once the product has reached the desired temperature, the management of air flow changes to keep warm air out of the produce. To keep the product cool while packing:

- Pack in a coolroom, or at least in the cooler parts of the day;
- Minimise the amount of time that vegetables spend out of the coolroom;



Incorrectly stacked boxes or boxes filled with the wrong product can be disastrous at the market end.

- Minimise the flow of warm air around cooled boxes by stacking them on pallets and covering with a tarp or blanket to minimise air flow, particularly if they are to be transported on open trucks;
- Don't put produce in hot areas eg: in the sun, or on hot parts of the vehicle floor eg: above the exhaust. Put something such as cardboard between the vegetables and hot areas or stack them on a pallet. Reflective insulating material can also help if you are travelling in the sun; and
- Transport produce in the cooler parts of the day.

Vegetables are still alive after they are packed. They respire, or breathe, and produce heat and ethylene and lose water. Cooling reduces the speed at which all of these things take place, and is the most important factor in maximising their shelf life.

Humidity

Reducing water loss from produce is a major factor in extending shelf like, so managing humidity is important. To manage humidity, reduce the flow of dry air around the vegetables.

Vegetables should be stored in a high humidity coolroom, where humidity is 95%. Most cooling systems are low humidity, 60–70%, which can dry produce. Designing a high humidity coolroom is the best way to ensure high humidity. However, humidity can be increased by installing a humidifier, which introduces water vapour into the room. Keeping the floor wet can also help.

Ethylene

Ethylene is a gas which fruit and vegetables produce as they ripen. Ethylene can also accelerate ripening of NT vegetables, the largest producer of ethylene is bitter melon. One bitter melon in a box can produce enough ethylene to accelerate ripening of all other fruit in the box.

The best way to stop ethylene being a problem is to make sure it is not there in the first place! Pack only good quality bitter melon – no overripe or damaged fruit. Damaged fruit produce ethylene.

To minimise the risk – think about the air flow. Plastic bags stop air flow and will increase ethylene build up in a carton therefore paper packaging may be a better option. Ventilation will reduce the build up if there is a problem.

Packaging

Cartons need to be strong enough to maintain its strength even when stacked at the bottom of the pallet. Cartons lose strength when wet or when humidity is high. Make sure boxes are packed correctly. Over filling boxes causes damage to vegetables, and under filling allows them to move inside the box which may cause abrasion during transport.

The type of bag, if one is used depends on the type of vegetable you are packaging, and the risk they may warm up during transport.

Asian vegetable packaging

Asian vegetables can be grouped into three types. These have similar characteristics and therefore similar packaging requirements.

High respiration rate and water loss

Snake beans, basil and okra. Because these vegetables lose water, they are packed in plastic bags. However, these vegetables produce excessive heat from respiration after they are packed, so the risk of heating is high. If temperature control is adequate and there is little chance that the product will heat up, then plastic bags will be satisfactory. If temperature control is variable, then increasing the airflow by using plastic bags with holes may be a good compromise.

High ethylene production

Bitter melon. Plastic bags hold ethylene in, and are not recommended. Use paper or plastic bags with holes.

Less Sensitive - Luffa, sinqua, hairy melons, other melons and eggplant. These vegetables tend to last well. Cooling still helps in maintaining quality, but water loss is low because these vegetables have thick skins. Plastic packaging is rarely needed.

Characteristics of packaging commonly used for vegetables:

Packaging	Air flow	Water loss	Chance of Temperature Increase	Chance of Ethylene Build-up
Plastic bags	Low	Low	High	High
Plastic bags with holes	Medium	Medium	Medium	Low
Paper	High	High	Low	Low
Gas exchange bag	Low	Low	High	Medium



Eggplant does not need plastic wrapping for transport and sale.



Cucumbers need plastic wrapping or water loss will make them shrivel.



Post-harvest Disease

The most common causes of disease or rots during transport are high temperature and poor quality product. High temperatures cause vegetables to break down which allow rots to develop. If vegetables are packed that already have disease, then disease will further develop during transport. Packing good quality vegetables and ensuring proper temperature control will reduce the incidence of disease.



Coolrooms

A coolroom is one of the more expensive capital items needed for vegetable production. When designing or choosing a coolroom, there are many things to consider:

- Site
- Insulation
- Door
- Daily load of produce
- Daily heat load
- Dimensions
- Refrigeration capacity
- Humidity
- Cooling coils and air movement
- Defrosting
- Temperature control
- Temperature measurement.

The most important things to consider are

‘How much produce is expected to be

(a) picked in one day and

(b) stored in the room?’

For example, beans need to be picked daily but may only be shipped every three or four days. The refrigeration needs to be able to remove the heat from the freshly picked products and also have room to store previous day’s harvest. Having a coolroom that is too small will make it difficult to maintain vegetable quality.

Interstate Certification Assurance (ICA)

Interstate Certification Assurance (ICA) is a system of plant health certification based on quality management principles. Under ICA a business can be accredited to issue Plant Health Certificates for its produce and therefore send them for sale in other states that require these certificates. To be accredited a business must be able to demonstrate it has effective in-house procedures in place that ensure produce consigned to intra or interstate markets meets specified Quarantine requirements. This provides an alternative to traditional plant health certification involving NT Government inspectors.

Quality Assurance

Quality assurance (QA) began to be accepted in Australia for vegetable production in the 90s as clients and agents became more concerned about food safety. QA systems cover food safety requirements, customer requirements (eg for quality or packaging), and legislative requirements, eg quarantine treatments.

If a good QA plan is written for a farm, it can be a valuable management tool to maintain quality and safety of not only the product but can also ensure staff safety and business operational efficiency.

Hazard Analysis and Critical Control Points (HACCP) is an internationally recognised method to identify, evaluate and control hazards to food products. It is the basis for most quality assurance plans. It is mostly based on food safety issues, although food quality issues can also be written into the plan.

The most important part about implementing a quality assurance system is to find out what customers require. Implementing a complex scheme when a simple one would be enough is a waste of time and resources. Also, evaluation of scheme cost is important. Most require third party auditing which can be expensive. For more information on QA schemes, it is best to contact your local Horticultural association to find out what is available.



- The quality of the vegetables in the market depends on the quality of the vegetables that you pack. Poor quality at packing will only get worse during transport; Pack the best.
- Vegetables need to get cool quickly and stay there.
- Temperature, humidity and ethylene can be managed by manipulating air flow.
- Packaging depends on the type of vegetable you are producing, and the risk that the temperature will increase within the packaging.

Transport and Markets

Road transport

Problems associated with transporting vegetables long distances by road are relatively common. In the NT, this is due to several factors:

- Multiple products in the load
- Multiple producers with consignments in the load
- Different standards of cooling and packing for all product in the load.

Other issues which can be a problem include:

- Loading/mechanical damage
- Refrigeration faults.

Open and honest communication is the only way to ensure that the quality of vegetables is maintained. Growers are ultimately responsible. It is important to talk to the those who transport the crop.

Air Freight

Air freight is another transport option for fresh produce. Again, it is wise to discuss freight options with transport companies as there may be combinations of price and flight times which suit the product being sent. Flight schedules change seasonally, and sometimes on short notice. Cultivating a good relationship with the freight company is helpful to keep up to date with any possible changes.

Packaging for air freight is different than for trucking. Cardboard cartons are designed to have maximum strength when they are palletised, however air freighted cartons are often loaded individually which can cause damage. Depending on the volume of product and the relationship with the company, other handling options such as packing an airfreight container (AV) on property may be possible.

Refrigerated trucks are an important link in the cool chain



Loading vegetables for Southern markets

Supply Chain

There are several people involved in the handling of vegetables from growing to market. Each party should have a formal written agreement with the next in the handling chain, stating conditions of trade and when the grower is to be notified of problems. A checklist of suggested list of items follows:

The grower

- delivers vegetables cooled below an agreed temperature
- uses packaging which will withstand the journey and promote air flow for cooling
- packs vegetables of right maturity
- measures temperature when it leaves the farm, and when it arrives at the freight forwarder.
- Puts a date code and clear identification of grower on each carton
- Organises Interstate Certification Assurance documents, where necessary.

The freight forwarder

- should measure and record temperature in the presence of the grower, and give a copy to the grower
- should have enough coolroom space to handle the vegetables
- keeps vegetables within an agreed temperature range
- cools vegetables to an agreed temperature, if the vegetables are not precooled
- stacks pallets to minimise crushing
- uses direct transport options where ever possible
- notes forklift or other mechanical damage

The trucking company

- keeps vegetables within an agreed temperature range and proves this with temperature recorders
- reaches markets at the agreed time
- ensures no loss of quality if produce is transferred to other trucks
- insures against incidents such as a roll over or fridge breakdown
- determines liability in the event of other problems which would prevent delivery, eg flood.



An unloader

- records temperature as the product comes off the truck, if it is arranged.

The agent

- reports to the grower on the quality, volume and arrival time of product.
- reports to the grower on price received.
- keeps the vegetables in a coolroom to maximise their shelf life.

This can be verified by an independent quality inspector, who is paid by either the agent, the freight forwarder or the grower to report on quality. Contact numbers are available from your local association. The inspector can also authorise a waste certificate, when your product is considered unsuitable for sale. It is wise to consult the freight forwarder and agent for all the information they require on the waste certificate for you to claim compensation if possible.

Further Information

A wide range of fact sheets, growing notes, information booklets and information sheets relating to vegetable production in the Northern Territory can be found at www.horticulture.nt.gov.au

Department of Primary Industry and Resources
Plant Industries Division
GPO Box 3000
Darwin NT 0801

General Enquiries

Telephone: 08 8999 2357
Facsimile: 08 8999 2049
Email: horticulture@nt.gov.au

Plant Pathology

Telephone: 08 8999 2261
Facsimile: 08 8999 2312
Email: plant.pathology@nt.gov.au

Entomology

Telephone: 08 8999 2258
Facsimile: 08 8999 2312
Email: insectinfo@nt.gov.au

Chemical Services

Telephone: 08 8999 2344
Facsimile: 08 8999 2111

A guide to vegetable growing
in the semi-arid tropics of the
Top End of the Northern Territory



Produced by the
Northern Territory Government

Department of Primary Industry
and Resources
GPO Box 3000, Darwin NT 0801