Pre-harvest effects on lettuce quality

Integrated Crop Protection

PROTECTING CROPS

Lettuce is an important horticultural crop in Australia, with an annual production over 160 million tonnes and a total gross value of $140 million. Lettuce is regularly purchased by 80% of consumers in Australia.

There are four main types of lettuce:

- ***Crisphead*** often referred to as Iceberg or simply head lettuce, with dense rosette and crispy texture
- ***Butterhead*** another heading type with smaller tender leaves and delicate avour
- ***Cos*** also known as Romaine, with elongated, crispy-textured leaves
- ***Loose leaf*** or bunching, with large variation in leaf size, shape, colour, and texture

One of the outstanding qualities of Iceberg lettuce is its high density, giving it more robust handling, transport and storage capacity and longer shelf-life than the other types. It is widely used as a key ingredient for tossed salads and on sandwiches at home by consumers, and by restaurants, by quick-service restaurants and also sold as pre-washed ready-to-eat leaf premixed with other vegetables in the form of salad bags retailed at supermarkets and greengrocers.

By contrast, Butterhead types of lettuce are more fragile than Crisphead, more easily bruised, and susceptible to leaf breakage and wilting.

Key quality issues

A recent consumer study showed that quality and freshness are the most important triggers to consumer purchase of green leaf vegetables in Australia.

Shelf-life is a critical issue in lettuce, as it relates directly to freshness, a quality that consumers value highly in their buying decisions. It is the length of time a product can maintain the appearance, safety and nutritional value that appeals to the consumer.

The key quality attributes for whole and fresh-cut lettuce are moisture loss, shrivelling, colour (browning, bleaching of the green colour), off-odours, and off-flavour formation, breakdown and microbiological contamination.

Crop management

Matching growing region with optimal production window

Lettuce crops should be grown under environmental conditions within the optimal range for the crop. This will result in the highest yields, and the best quality. The optimum germination and growing temperature for lettuce are shown in Table 1.

Night temperature is also important, so if the minimum night temperature exceeds 15°C, quality is adversely affected.

Seed germination is strongly influenced by temperature. There is high-temperature dormancy of lettuce seed above 27°C, which is a limitation for direct-seeded lettuce. The time taken from sowing to emergence is strongly affected by temperature. For example, the time from sowing to germination at 0°C = 49 days, and at 5°C = 15 days. Long germination periods increase the risk of soil-borne disease affecting the emerging seedlings.

The Salinas Valley, California, is widely regarded as the best lettuce-growing region in the world for summer lettuce production. The daily maximum and minimum temperatures between April and November in the Salinas Valley are shown in Figure 1, and these are within the optimum temperature range shown in Table 1.

Table 1. Temperature limits for the growth of head lettuce

	GERMINATION TEMPERATURE (°C)	GROWTH TEMPERATURE (°C)	NOTES
Minimum	2.2	7	
Optimum range	18 - 21	12 - 21	Max night temp. = 15°C
Maximum	27	24	

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This project has been funded by Horticulture Innovation Australia Limited using the vegetable levy and funds from the Australian Government.

Salinas Valley growers do not try to extend this optimum production window, but instead move production to Arizona for winter. (**Note:** the months in Figure 1 are shifted by six months to give the southern hemisphere equivalent).

In Gatton, SE Qld, the optimal growing temperature for lettuce is from early May to early September for transplanted lettuce (Figure 2). In a sequential planting study carried out by AHR, the highest yield and the longest shelf-life were found to correspond with this May to September production window for the Gatton region.

Lettuce is a crop where choosing the optimal growing time and location will give you the highest yield *and* the best quality – there is no trade off!

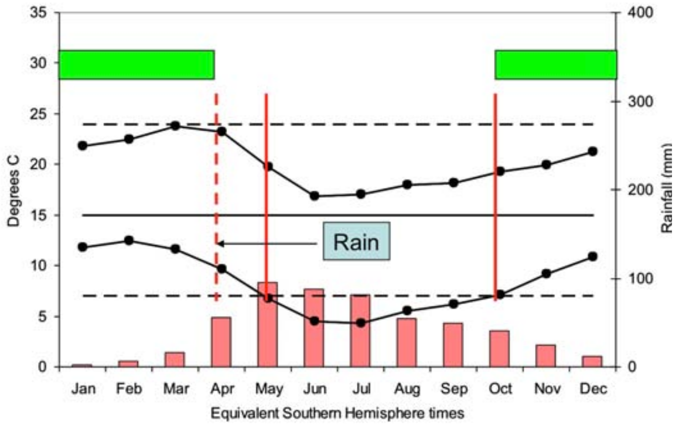

Figure 1. Average temperature (lines with black dots) and rainfall (bars) data for the Salinas Valley, California. Optimum temperature ranges for lettuce production are shown as horizontal lines. The green bars indicate the optimal production time for head lettuce. Note: the months are shifted by six months to give the southern hemisphere equivalent.

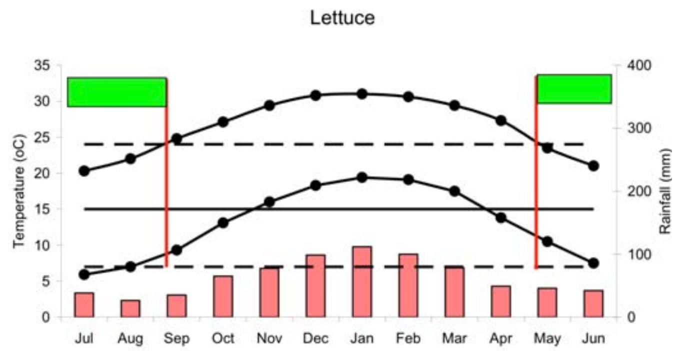

Figure 2. Average temperature (lines with black dots) and rainfall (bars) for Gatton, SE Qld. Optimum temperature ranges for lettuce production are shown as horizontal lines. The green bars indicate the optimal production time for head lettuce.

Developing a crop planting scheduling: Matching varieties to region and time of year

The other important factor with lettuce is matching lettuce variety types to the correct production "slots" within each region and season.

AHR[1] has developed a series of five lettuce variety groups for Iceberg and five variety groups for Cos lettuce. These groups are shown in Table 2.

An example planting schedule for winter Iceberg lettuce production in SE Qld is shown in Figure 3, and an all-year-round production for Iceberg lettuce in southern Australia is shown in Figure 4. A more detailed guide is available on the AHR website (www.ahr.com.au) or by following this link.

Table 2. Iceberg and Cos lettuce variety types

	ICEBERG LETTUCE TYPES	COS LETTUCE TYPES
Heat	*Summer Vanguard* (Heat tolerant)	*Paris Island Cos-PIC* (Warm season)
Main season	*Salinas* (Main Season)	*Paris Island Cos-PIC* (Traditional cool season)
Intermediate	*Salinas x Vanguard* (Intermediate)	*Slow Closing* (Intermediate)
Cool season	*El Toro* (Cool Season)	*3/4 Cos* (Slow bolting)
Cold tolerant	*Winter Vanguard* (Frost tolerant)	*Mini Cos* (Compact)

Current lettuce varieties

For information on current lettuce varieties within these groups, contact Australian vegetable seed companies. The web contacts are listed below:

Rijk Zwaan www.rijkzwaan.com.au

Monsanto Seed www.monsanto.com.au

South Pacific Seeds www.spssales.com.au

Terranova Seeds www.terranovaseeds.com.au

HM Clause Pacific pacificenquiries@hmclause.com

Nunhem Seeds nunhems.customerservice.au@bayer.com

Syngenta Seeds www3.syngenta.com/country/au/en/keycrops/vegetables/Pages/seeds.aspx

Lefroy Valley Seeds www.lefroyvalley.com

Fairbanks Seeds www.fairbanks.com.au

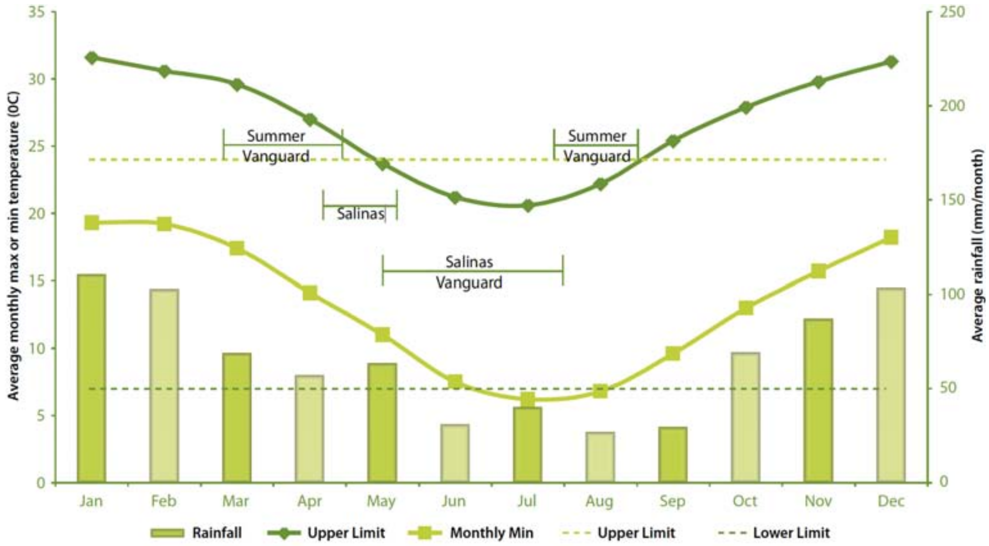

Figure 3. Winter Iceberg lettuce planting sequence for Gatton, SE Qld.

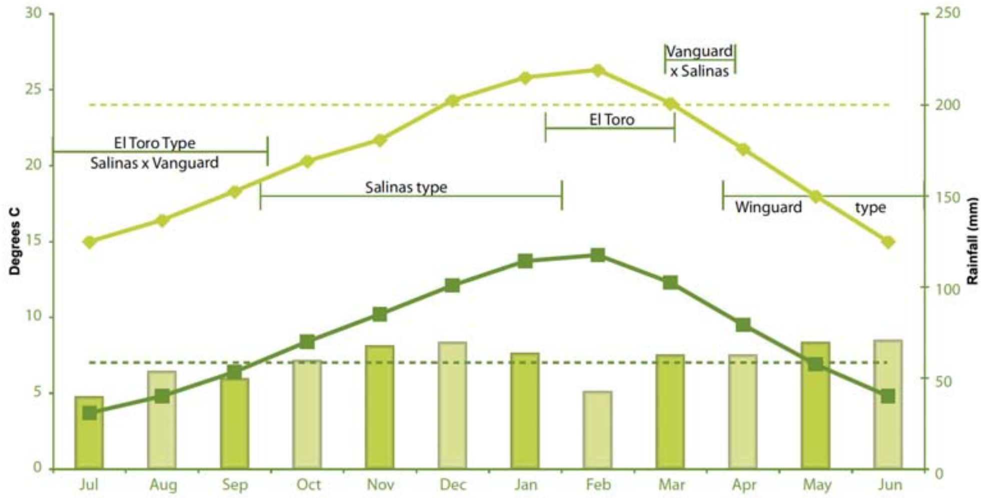

Figure 4. Summer Iceberg lettuce planting sequence for southern Australia.

Mineral nutrition

Lettuce quality (especially colour and visual appearance) and shelf-life are enhanced by a balanced supply of nutrients, especially the macronutrients nitrogen, phosphorus and potassium. This applies to both field and under protected cropping.

Higher rates of nitrogen generally result in reduced shelf-life (especially very high rates), greener and softer leaves at/after harvest, and increased nitrate content than lower rates.

Optimum nutrition can assist in control of diseases that reduce quality, for example avoiding excessive nitrogen (N) fertilisation or ensuring that the nutrient solution concentration is not excessive, as well as choosing N forms that can favour plant resistance to fungal diseases such as downy mildew and anthracnose. Calcium nitrate is better than sulphate of ammonia or urea.

Balanced nutrition: Field

Nitrogen can be applied to lettuce at high rates of 75–150 kg N per ha without any adverse effect on quality provided it is balanced by potassium (K) and especially phosphorus (P).

In a Florida study, 225kg N/ha was applied to Iceberg lettuce, and resulted in high yield and good quality, provided it was applied with more than 100 kg/ha of phosphorus. Interestingly, potassium does not appear to play any direct role in lettuce quality.

Calcium nitrate is preferred to ammonia nitrogen or urea for yield and shelf-life, however, and a mix of nitrate and ammonium is also acceptable, while nitrification inhibitors can also be used successfully to slow nitrate availability to the plant.

Nitrate accumulation in the leaves of lettuce is a health issue. Very high rates of nitrogen in the range 250-300 kg/ha N can result in high levels of nitrate irrespective of the form of N in the fertiliser. In general, the nitrate forms of N, including calcium nitrate, can cause nitrate accumulation on the leaves more readily than the ammonium or urea forms of N.

The pre-plant NPK application rates should be determined using a pre-plant soil test, and then side-dressing rates adjusted according to leaf tissue nutrient levels, and with experience. Typical NPK fertiliser rates for Iceberg and Cos lettuce are shown in Table 3.

Table 3. Typical NPK rates for Iceberg and Cos lettuce

NITROGEN (KG/HA)	PHOSPHORUS (KG/HA)	POTASSIUM (KG/HA)	NOTES
Pre-plant basal application			
40-80	40-60	0-50	Adjust as per soil test result
Side-dressings or fertigation (total amount)			
35 – 70	0	0-25	Apply as two side dressings at week 2 and week 4 after transplanting, or weekly via fertigation

Balanced nutrition: Protected cropping

The situation with greenhouse-grown lettuce and quality is unclear. Several studies have shown that, depending on cultivar, increased N in the potting mix or nutrient solution can result in shorter shelf-life, greener and softer leaves, and higher leaf nitrate content. In contrast, some studies have shown that varying EC from 1.4 to 2.4 dS/m, or increasing the level of calcium in the nutrient solution has no impact on shelf-life, external appearance, texture, vitamin C and phenolics.

Impact of nutrition on disease

The source of nitrogen can affect the plants' susceptibility to disease. In Australia, calcium nitrate applied to Iceberg and Cos lettuce seedlings grown in four commercial locations in Victoria reduced the incidence of downy mildew (*Bremia lactucae*) and anthracnose (*Microdochium panattonianum*). The application of ammonium nitrogen increased susceptibility to these diseases.

High rates of nitrate and total nitrogen can increase susceptibility to Septoria leaf spot (*Septoria lactucae*). High rates of nitrate can also favour the fungal diseases *Botrytis cinerea* and *Sclerotinia sclerotiorum*.

Management of nitrate in the nutrient solution for leafy vegetables is limited, since nitrate is the predominant form of N in the nutrient solution. However, ensuring that the nutrient solution concentration is not excessive is a beneficia practice.

Tip burn management

Tipburn is an important physiological disorder of lettuce associated with the lack of mobility of calcium (Ca) in the heads or developing heart tissues, resulting in browning of leaf margins on young leaves in the head.

In the field, tipburn is associated with high crop-growth rates, and so cultural practices that prevent excessive growth rates (e.g. balancing nitrogen supply to the plants, avoiding excessive nitrogen, correct choice of variety, or growing at cooler times of the year) are likely to be effective strategies for reducing the incidence of tipburn. High humidity near harvest can also trigger tipburn. Foliar sprays of calcium, or injecting calcium through the trickle irrigation system are not effective at controlling tipburn.

In contrast, under protected cultivation and hydroponics, frequent foliar applications of calcium chloride solution as low as 90 mg/L to Cos lettuce soil-grown in the greenhouse in Canada decreased the number of leaves and percentage leaf area with tipburn, and increased Ca content in young leaves. Likewise, a foliar application of a calcium nitrate solution at 2.5 mg/L twice a week was effective in controlling tipburn in Cos lettuce soiless-grown in Greece.

Using EC to increase shelf-life in hydroponic lettuce

In baby Cos lettuce grown in hydroponics, increasing the EC of the nutrient solution from 2.8 to 3.8 or 4.8 dS/m resulted in firme leaves, better colour and less decay from bacteria and fungi after storage at 5°C for nine days after harvest.

In a study with Lollo Rosso lettuce, watering babyleaf lettuce plants from below with 2.9 g/L sodium chloride solution compared to tap water resulted in leaves with two days longer shelf-life, less breakdown, bruising and discolouration in storage. The leaves were slightly smaller and better able to withstand damage during processing.

Figure 5. Floating row covers.

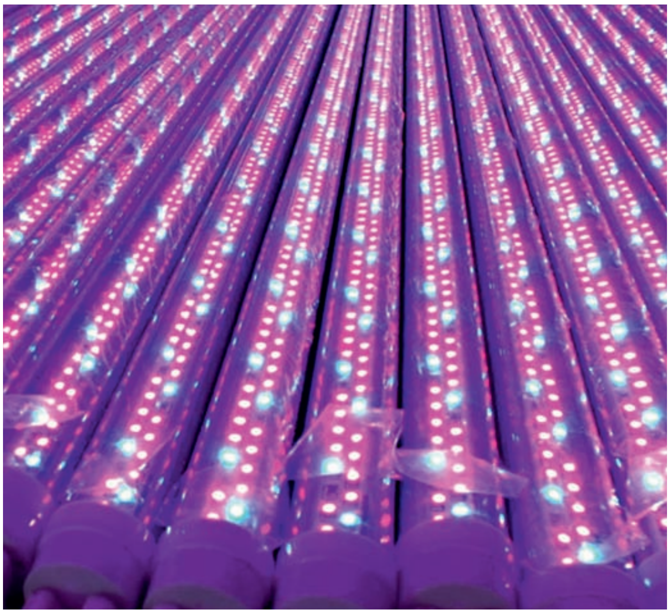

Figure 6: LED lights.

Deficit irrigation

Maintaining lettuce free of water stress, from sowing to harvest, is a good irrigation management strategy. There is some evidence, however, that drip irrigation can result in a 1–2-day increase in shelf-life for Iceberg and Cos lettuce as compared to overhead irrigation.

Sprinkler irrigation is useful for helping plants to establish well, but after that drip irrigation allows better control of soil moisture, and also avoids wetting the foliage, which helps reduce foliar disease.

There is some recent evidence that applying a mild water stress to Cos lettuce crops of 15% below full irrigation can reduce cut-edge browning and increase the phenolic content of the leaves.

Applying mild water stress seven days before harvest combined with drip irrigation can also reduce microbial breakdown of Iceberg lettuce in storage. In general, excessive irrigation and overhead sprinkler irrigation, both increase microbial breakdown of harvested lettuce in storage, e.g. processed fresh-cut lettuce.

Floating row covers

A study of babyleaf lettuce grown in south Queensland, showed the use of floatin crop covers (Figure 5) could reduce insect contamination of lettuce, and reduce customer complaints. The covers could reduce insect infestation by up to 90%, exclude windblown foreign bodies, and would have little impact on general quality, strength, and shelf-life compared to standard unprotected growth.

Light

Light-emitting diode (LED) technology (Figure 6) has made it feasible to regulate light environments and thus provide ideal light quality, intensity and photoperiod, especially in protected facilities, opening exciting new opportunities for increasing phytochemical content in vegetables.

In a study in Taiwan, hydroponically grown Butterhead lettuce under red, blue, and white LED lights resulted in better growth, faster development, improved nutrition, appearance, and eating qualities (i.e. sweetness and crispness). Pre-harvest exposure of hydroponically grown lettuce to red and blue LED light for 48 hours can reduce nitrate accumulation by more than 50% and increase soluble sugar content more than tenfold.

For more information contact Dr Roberto Marques, NSW DPI roberto.marques@dpi.nsw.gov.au or Dr Gordon Rogers (AHR) gordon@ahr.com.au

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