Pre-harvest effects on the quality of babyleaf spinach

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One of the key issues with babyleaf spinach is how to deliver this popular leafy vegetable to consumers in good condition. For this to happen, growers must first produce high quality spinach, and this quality must be maintained throughout the supply chain until it's used by the consumer.

It doesn't matter how good the supply-chain handling methods are if the quality of spinach in the field has been affected by adverse growing conditions.

Factors such as growth rate, growing location, weather conditions, variety, nutrition and diseases can all significantly reduce the potential shelf-life of a spinach crop. On the other hand, good growing conditions and management can deliver an optimum product that can easily survive the supply chain in tip-top condition.

One way to think of quality is that it is like a bank account. Good growing conditions and techniques add to the amount of shelf-life "in the bank". Once the crop is harvested, the quality declines – it's being "withdrawn" from the quality bank. Good postharvest handling practices can slow the rate of quality decline, but it can never increase quality!

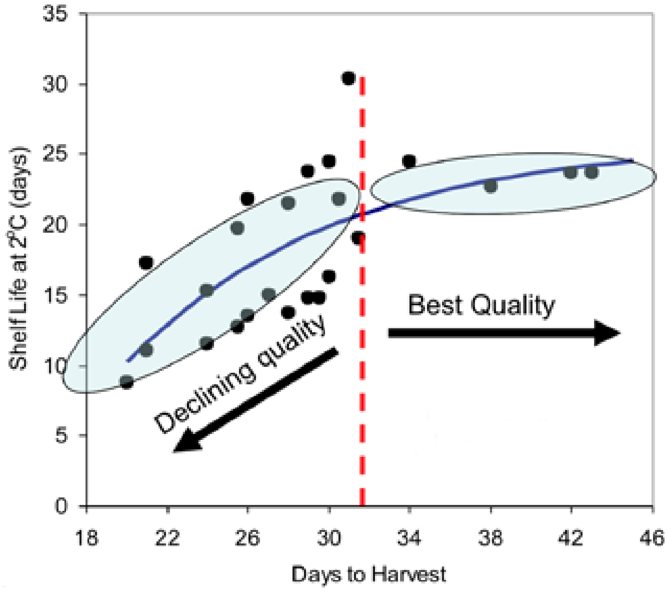

Figure 1. Shelf-life at 2°C of babyleaf spinach (three varieties combined) with the days to harvest.

If your crop has only five days' shelf-life in the bank at harvest, it is very unlikely to reach the consumer in good shape. If your crop has 15 days' shelf-life in the bank at harvest, the chance of it reaching consumer in good condition is high, and everyone's happy.

Spinach has a long potential shelf-life if grown and stored under ideal conditions. In AHR trials, good quality spinach could be stored for over 21 days at 5°C, was still in good condition.

So, what are some of the things you can do to produce long-lasting, high-quality spinach for which your customer will keep coming back?

Crop management

You should aim to grow babyleaf spinach in the optimal production window for your region

The three most significant preharvest factors that affect spinach postharvest quality and shelf-life are:

- Growth rate of the crop
- Variety
- Minimum night temperature during the growing period

Growth rate of the crop

The shelf-life of babyleaf spinach is strongly affected by the growth rate of the crop. This was confirmed by an extensive series of field trials in Australia over three growing locations in Queensland, NSW and Victoria involving monthly plantings of three variety types one month apart over 12 months.

The best quality and longest shelf-life can be achieved when the ***growing period from sowing to harvest exceeds 32 days***. Shelf-life is reduced by about half a day for each day below 32 days. Growing the crop for longer than 32 days has no effect on shelf-life (Figure 1).

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The length of the growing period is determined by ***growing temperature*** and ***variety type***. The optimum growing temperature for spinach is shown in Table 1.

The minimum temperature for seed germination is 2°C with a maximum germination temperature of 30°C and an optimum range of 7°C to 24°C. Once established, young plants can withstand temperatures as low as 9°C. High-temperature dormancy can be induced when the soil temperature exceeds 30°C.

Once established, spinach will grow from 5° to 24°C and growth is most rapid at 15° to 18°C. The plants can withstand frosts down to –9°C without significant injury. Freezing weather however harms small seedlings and plants approaching maturity more than mid-growth stages, when the crop will tolerate subfreezing temperatures for weeks.

Table 1. Optimum temperatures for germination and growth of babyleaf spinach

TEMPERATURE	GERMINATION (°C)	GROWTH (°C)	SELECTION LIMITS
Minimum	2	5	Min = 2
Optimum Range	7–24	14–24[2] 15–18 fastest growth	Max. night = 15
Maximum	30[1]	32	Max = 30

[1] Soil temperature above 30°C for germination is a limiting factor.

[2] 14–24°C growth for maximum quality and greater than 20°C can reduce growth rate due to higher plant respiration.

The table above can be used with monthly average minimum and maximum temperatures across Australia to determine optimum planting window for babyleaf spinach. Once the growing region is known, the planting window can be determined using average temperature data.

Variety

Selecting the variety you plant at a particular time of the year for your location is the other way to change the growth rate of a crop. The three groups of babyleaf spinach varieties in relation to growth rates are:

- Fast growing
- Intermediate
- Slow growing

In warm-growing areas or at warm times of the year, choose slow growing varieties. In cool areas, faster growing varieties can be used. For information on current babyleaf spinach 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

Determining a planting schedule

It is possible to predict how many days it will take from sowing to harvest by calculating growing degree days (GDD) for a spinach crop. This approach has been used successfully for many vegetable crops in Australia and internationally.

Growing degree days for a particular region can be calculated using historical average temperature for your growing region. This data is available from the Bureau of Meteorology.

You should start with the harvest date(s) required. Then, using the formula below, calculate the number of days that would be required from planting to harvest to give the number of degree days required for the variety type you are growing. The number of growing degree days from planting to harvest for each variety type is given in Table 2.

The formula for calculating growing degree days is:

growing degree days = (Tmax +Tmin)/2 - Tbase

where:
Tmax = the daily maximum air temperature °C
Tmin = the daily minimum air temperature °C
Tbase = the GDD base temperature for the crop being monitored

For spinach, the base temperature = 0°C. If the measured Tmax ever exceeds 27°C, then 27°C should be used in place of the actual maximum (high temperature cut-off).

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Table 2. Spinach Growing Degree day requirement

VARIETY TYPE	GROWING DEGREE DAYS (SEEDING TO HARVEST)	BASE TEMPERATURE (°C)	HIGH TEMPERATURE CUT-OFF (°C)
Slow growing	552	0	27
Intermediate	530	0	27
Fast growing	515	0	27

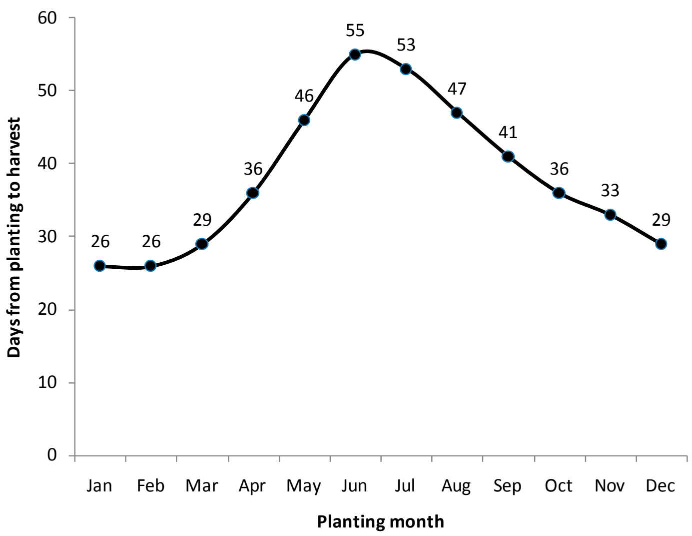

Figure 2. The predicted number of days from planting to harvest for intermediate growth rate spinach, in Bairnsdale, Victoria assuming the plants were seeded on the first day of the month indicated. The data labels are the number of predicted days from planting to harvest.

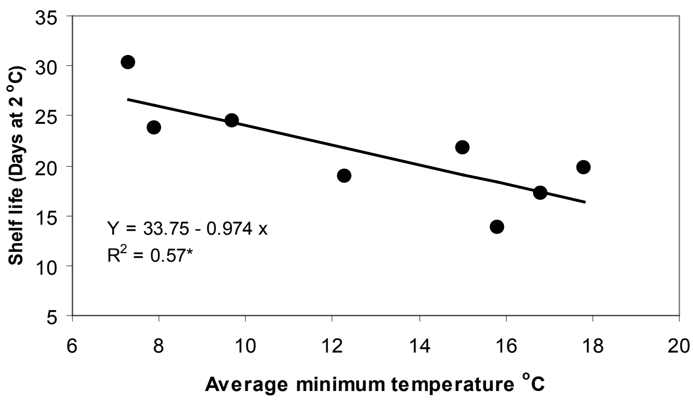

Figure 3. Shelf-life at 2°C of babyleaf spinach (mean of three varieties) and average minimum temperature during the growing season.

Growing degree day example

The number of days from sowing to harvest will change over the year, according to temperature. Figure 2 shows the predicted number of days from sowing to harvest for an intermediate growth rate variety grown in Bairnsdale, Victoria.

Night temperature

As the average minimum temperature falls below 15°C, the shelf-life of spinach increases (Figure 3). During cooler nights, the respiration rate of the leaves is lower, reducing the rate that stored carbohydrate is used to support leaf respiration. More carbohydrate in the leaves can be used in producing stronger leaves that will last longer in storage, leading to a longer shelf-life.

Other factors that can affect quality

Crop nutrition

The topic of mineral nutrition in relation to babyleaf spinach has not been comprehensively reported in the scientific literature. However, general studies report little effect of nitrogen (N) rate on the shelf-life of spinach.

The higher levels of applied nitrogen (especially as nitrate) increase the content of nitrate and oxalate in the leaves under field or greenhouse conditions.

There is some evidence that application of silicon can enhance visual quality and shelf-life, as well as reduce the nitrate content of the leaves, suggesting it is an area that warrants further investigation.

Typical fertiliser program for babyleaf spinach

The data presented here is a summary of the current best practice on babyleaf spinach nutrition.

A typical fertiliser program would be a basal granular NPKS fertiliser such as Nitrophoska™ (12:5.2:14.1:8 N:P:K:S) or equivalent applied preplant, then supplemental nitrogen and sulphur applied at planting. About 30% of the nitrogen and 100% of the phosphorus (P) and potassium (K) should be applied before planting. Apply the balance of the nitrogen requirement at planting as a soluble granular fertiliser containing sulphur.

The crop nutrient status can be guided by leaf tissue levels (Table 3).

Use dry ash tissue analyses (not sap) to help you to adjust fertiliser rates for subsequent plantings, and also to calculate your actual crop nutrient removal figures.

Table 3. Babyleaf spinach optimum leaf tissue nutrient levels for the whole leaf blade plus petiole 30 days from sowing[1]

NUTRIENT	OPTIMUM LEAF TISSUE LEVEL	
Nitrogen (N)	4.2-5.2	%
Phosphorus (P)	0.48-0.58	%
Potassium (K)	3.8-5.3	%
Calcium (Ca)	0.6-1.2	%
Magnesium (Mg)	1.6-1.8	%
Boron (B)	40-60	mg/kg (ppm)
Copper (Cu)	5-7	mg/kg (ppm)
Iron (Fe)	200-250	mg/kg (ppm)
Manganese (Mn)	50-100	mg/kg (ppm)
Molybdenum (Mo)	0.1-1.0	mg/kg (ppm)
Zinc (Zn)	50-75	mg/kg (ppm)
Sodium (Na)	Less than 0.75	%
Chloride (Cl)	Less than 1.0	%

Nutrient removal by the crop

Another way to estimate the amount of nutrient that a crop will need is to calculate the amount of nutrient that is removed by the crop when it is harvested. This can be calculated by multiplying the crop yield by the percentage of each nutrient in the leaf. Some typical crop removal figures for spinach are shown in Table 4, but remember, the actual figure will vary according to your yield and the tissue analysis.

Note: The crop removal approach is only approximate and does not account for inefficiencies in nutrient availability to the crop, leaching losses, nitrification additions of N, etc., but it does provide a rough guide. It is a good idea to add 15–20% to the crop removal figures if you are using them to calculate fertiliser rates.

Calculate nutrient uptake as follows:

Nutrient uptake (kg nutrient/ha) =
yield (t/ha) x **nutrient content** (%) x 0.4

(Note: this assumes a 4% dry matter content, based on AHR babyleaf research).

This formula will work for N, P, K, Ca or Mg. Use your leaf test report to get the nutrient concentrations and use your actual harvested yield for the crop.

Table 4. Spinach nutrient removal estimates for a typical 1.25 – 1.5 kg/m yielding crop.

Crop removal (kg/ha)	Nitrogen (N)	Phosphorus (P)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)
	43–53	5–6	39–54	7–13	16–19

Water management

The key message with spinach is to keep the crop well watered and do not stress at any stage during growth. It is important to avoid overwatering to the point where the soil remains saturated as this encourages the development of water mould diseases such as Pythium and Phytophthora.

Deficit irrigation, i.e. irrigating to supply less water than the plant needs has been tested in separate trials in Texas and in China. Supplying the crop with either 50% or 75% of the water the crop needed resulted in lower yield, increased leaf yellowing, and the accumulation of nitrate and oxalic acid.

Planting density

In a field trial with babyleaf spinach (cultivar Whale - RZ) grown in summer at Stanthorpe, south-east Queensland, increasing plant density from 300 to 600 and 900 plants/m^2 reduced shelf-life from 23 to 20 and 16 days, respectively, as well as increasing fresh weight yield and resulting in smaller leaves in correlated trials in other locations.

The trial highlighted the required compromise between plant density, yield and shelf-life. In addition, the study also suggested that higher plant densities appear to be correlated with a higher incidence of Sclerotinia leaf spot, a damaging disease of babyleaf spinach.

Increasing plant density by reducing within-row spacing from 25 to 15 cm of spinach plants grown in Texas reduced leaf area and leaf dry weight, but had little effect on leaf thickness or leaf number. The potential impact of those leaf changes on shelf-life was not assessed in that study.

Harvesting

The crop should be harvested using a purpose built spinach harvester (Photo 1) when the crop is at the stage of development required by the customer. A common harvest specification for babyleaf spinach in Australia would be: leaf length 10–12 cm with the petioles (leaf stems) less than 4cm long. Leaf width 4–6 cm.

Normal practice would be to harvest the crop in the morning, remove field heat as soon as possible, and consign to the processor or the market.

[1] *Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida.* G. Hochmuth, D. Maynard, C. Vavrina, E. Hanlon, and E. Simonne (HS964)

Photo 1. Harvesting babyleaf spinach with a purpose-built harvester.

There has been some research suggesting harvesting later in the day can help with shelf-life. In a glasshouse trial at Sydney, spinach harvested at 6 pm had a 2–3 day longer shelf-life when bagged and stored at 4°C, as well as better visual quality than harvested at 9 am or noon, which was associated with higher starch levels in the leaves. In the UK, field-grown babyleaf rocket harvested at 10 pm had a 6-day longer shelf-life when processed, bagged, and cold-stored at 3.5°C compared to harvesting at 10 am. The difference was due to increased cell elasticity and leaf-sugar content.

Silicon and quality

Silicon (Si) is a non-metallic element that can mitigate the effects of various types of stresses.

Plant available silicon can increase the plant's resistance to pathogens and insects by activating systemic acquired resistance (SAR) and promoting the formation of *phytoliths* which damage the mouthparts of insect pests.

Silicon can also help the plant fight so called abiotic stress, e.g. chemical stresses such as nutrient toxicity or deficiency and salinity. It can also help the plant deal with water stress (too much or too little), sunburn and frost damage.

Photo 2. Floating row covers.

Some of the reported effects of silicon in relation to leafy vegetable crops include:

- Prolonged shelf-life and increased yield in corn salad
- Reduced nitrate uptake and nitrate content in leafy vegetables
- Enhanced visual quality (i.e. retained more green and reduced browning) in Iceberg lettuce in long term storage (20 days at 5°C)

The mineral Si is also an essential element for humans and a component of the diet found mainly in plant-based foods. There is growing scientific evidence that silicon plays an essential role in bone formation and maintenance, and that higher intake of bioavailable silicon is associated with increased bone mineral density. A recent study showed that the addition of silicon (at 50 or 100 mg/L, as potassium metasilicate) to the nutrient solution of hydroponic-grown fresh-cut leafy vegetables including tatsoi, mizuna, basil, chicory, and swiss chard, increased both silicon content and bioaccessible silicon in the leaves, with no impact on yield or leaf colour. The use of silicon in this way offers a potential added-value opportunity as a *bio-fortified* product.

Floating row covers

A study of babyleaf lettuce grown in south Queensland, showed the use of floating crop covers may be used to reduce insect contamination of lettuce, and reduce customer complaints. The covers can reduce insect infestation by up to 90%, exclude wind-blown foreign bodies, and has little impact on general quality, strength, and shelf-life compared to standard unprotected growth.

Floating row covers can reduce yield, and also shelf-life. However, the lighter fleece-type row covers have only a minimal effect on yield and quality, but reduce insect levels in babyleaf spinach crops by an impressive 80%.

An interesting potential side benefit of the fleece type covers is an increase in temperature under the net of between 3–6°C which could have significant positive benefits in allowing earlier production in cool season, and in frost protection. Refer separate factsheet "Blankets for Vegetables" (www.soilwealth.com.au)

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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