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Lettuce – best management production practice to meet the market requirements of consistent product quality and shelf life

R Dimsey, C Murdoch, et al
Natural Resources and Environment, Victoria

Project Number: VG98082

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Final report for the project VG 98082
(September 2001)

Rob Dimsey, Craig Murdoch *et al*

Natural Resources and Environment
Bairnsdale, Victoria

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Final report for the project VG 98082

By: Rob Dimsey, Craig Murdoch, Lavinia Zirnsak, Stephanie Andreata, Tegan Rennick, Julie Sippo Slobodan Vujovic and Paul Pierce

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Scope of the Report

This report presents the key findings and a summary of the work conducted in Victoria from July 1998 to June 2001 by the Lettuce Best Management Project team. The results and summary presented are as complete as possible but more detail is presented in the seasonal milestone reports which report on the trial design and results in greater detail. Copies of these more detailed reports can be obtained from the authors.

Project Team

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1. Media Summary

This project aims to address quality issues related to the production of summer lettuce crops in southern Victoria. The major issue identified by the industry was the incidence of tipburn and its impact on quality and shelf life of whole and minimally processed lettuce. Other quality issues included the incidence and impact of pests and diseases. The trials have:

- Monitored current practices in relation to irrigation, nutrient management and environmental conditions and assessed the impact of these on the incidence of tipburn and plant growth.
- Assessed the role of cultivar selection on tipburn and other quality issues.
- Monitored pest and disease issues.

Key outcomes and conclusions:

- Confirmed the relationship between rapid crop growth rate, falling sap-calcium concentrations and an increased incidence of tipburn.
- Of all treatments, cultivar selection resulted in the greatest reduction in tipburn.
- Early harvesting will greatly reduce tipburn severity.
- Foliar calcium supplement sprays did not significantly affect sap calcium concentrations in the plant or reduce tipburn.
- In both summer and winter plantings, the concentration of sap calcium was low in plants throughout their growth and declined as plants matured.
- Leaf sap calcium was not influenced by soil calcium levels.
- Growth rate had a key effect on the incidence of tipburn and was affected by cultivar, nitrogen, water and climate.
- Irrigation in some regions can be improved and will help manage poor water quality and improve product quality.
- Reducing fertiliser application following a previous crop did not restrict growth rate or yield.
- Scentry traps are an effective monitoring tool for *Helicoverpa spp.*

Recommendations for Future R & D

- Develop improved nutrient and management systems for lettuce production to reduce and tailor nutrient input to crop needs.
- Improved management of *Helicoverpa spp* and in particular *H armigera*, which is a major threat by adapting integrated pest management systems.

Key practical applications of the project that can be implemented include:

- To maximise water and nutrient uptake by the crop, make sure adequate water is provided overnight.
- Iceberg and Cos lettuce types must be managed separately in discrete irrigation blocks over the summer growing season.
- Cultivar selection has a significant impact on tipburn and breeding programs should include tipburn resistance.
- Scouting and montoring for *Helicoverpa* pests is critical for control of this pest.
- Foliar calcium application does not increase sap calcium or reduce tipburn.

2. Technical Summary

The main focus of this project has been to identify management practices which can reduce the incidence of tipburn in lettuce crops. Tipburn is the major quality issue associated with summer lettuce production in southern Victoria and threatens both the production of whole lettuce for the fresh market and minimally processed salad mixes. . It is generally accepted that tipburn may not be completely eliminated but its occurrence can be reduced through improved management practices. The project is focussed on Iceberg and Cos lettuce, the two main types produced in Victoria.
The trials have:

- Monitored current practices in relation to irrigation and nutrient management and assessed the impact of these and the environment on the incidence of tipburn and nutrient levels within the plant.
- Assessed the impact of cultivar variation on tipburn and other quality issues.
- Assessed impact on plant nutritional status and effect on tipburn of nutrient management techniques such as foliar application of calcium and managing fertiliser application.
- Monitored pest and disease issues.

The first year aimed to, monitor current crop practices including the nutrient status of the plants and irrigation practices and assess the impact on the incidence of tipburn and other quality issues. Replicated trials were used to assess cultivar response to tipburn and other pest and diseases.

The second year of the project established replicated trials to assess foliar applications of calcium and their effectiveness in increasing concentration of calcium in leaf sap and the impact on tipburn. Monitoring continued with an emphasis on sequential plantings and the impact of climate. Replicated cultivar trials evaluated a wider genetic selection of cultivars.

With a lack of response to foliar fertilisers the third season established replicated trials to evaluate the impacts of of reducing fertiliser application on growth rates, calcium absorption and tipburn. Four treatments were evaluated which included: no fertiliser application, grower practice, calcium nitrate only, and potassium only. Cultivar trials focused on fewer cultivars and assessing changes in tipburn approaching harvest.

Monitoring for *Heliothis spp* was also carried out over the three years to assess whether *H punctigera* or *H armigera* were causing pest problems. Cultivars were also assessed for susceptibility to pest and disease and impact on shelf life.

Key findings and outcomes:

- Confirmed the relationship between rapid crop growth rate, falling sap-calcium concentrations and an increased incidence of tipburn.
- Of all treatments the impact of cultivars on leaf sap calcium within the plant was the most significant.
- Incidence of tipburn varied with cultivars as was the critical issue of harvest time.
- Foliar calcium application was not beneficial for it did not significantly affect calcium levels within the plant and did not reduce tipburn.

- Leaf sap calcium levels were low within plants throughout their growth and declined as plants matured in both summer and winter.
- Sap-calcium concentrations recommended for lettuce may be unattainable and should be reviewed.
- Leaf sap calcium was not influenced by soil calcium levels.
- Growth rate had a key effect on the incidence of tipburn and is affected by nitrogen, water and climate.
- Irrigation in some regions can be improved and will help manage poor water quality and improve product quality.
- Excess amounts of nutrients are available to the crop from residual crops and application.
- Reducing fertiliser application following another crop did not restrict growth rate or yield.
- There is potential to manage nutrient applications to reduce inputs and improve quality and reduce tipburn without yield loss.
- Scentry traps are an effective monitoring tool for *Helicoverpa spp.*

Recommendations for future work

- The results in the final season have indicated the potential to develop improved sustainable lettuce production practices by better targeting and managing nutrient application. There is potential to reduce nutrient application, use more sustainable practices and maintain yield, quality and reduce tipburn. The use of nitrate/calcium ratios to as an indicator of tipburn should also be evaluated to identify which might lead to the onset of tipburn.

- *H armigera* has also been identified as a major pest and due to its resistance to a range of chemical groups requires an integrated strategy for management and new chemistry to be assessed for integrated pest control in lettuce.

3. Introduction

Victoria produces around 37% percent of the national lettuce production, which in 1995/96 was valued at $69 million. The major production regions in Victoria are Werribee, Cranbourne and Bairnsdale with more scattered production in the north west of the state. Crisphead varieties are the major types supplied to export and fresh domestic markets. Market opportunities for open headed and fancy lettuce are expanding and Cos lettuce are becoming an increasingly important product.

In September 1997 a meeting of lettuce growers, representing the major production areas, identified production issues of priority to the industry. These were: tipburn in summer lettuce, storage rots and disease management. Discussion with other sectors of industry such as processors and salad mix producers confirmed these quality management issues are central to consistent, cost effective production. Tipburn is a major issue for any minimally processed or cut product as storage life and quality is dramatically reduced. It is less of an issue for fresh lettuce but nevertheless causes significant crop loss and adverse consumer reaction from time to time.

The aim of the project was to address the quality issues in lettuce production relating to the following:

- Yield and quality loss associated with the nutritional disorder tipburn.
- Crop nutrition and production practices to produce consistent product with improved shelf life and quality.
- Management of significant field diseases, primarily the fungal disease anthracnose. Subsequently new registrations and low disease pressure meant that anthracnose was not a major issue during this project whereas Heliothis had become a major issue, causing some significant crop loss and preliminary monitoring work was carried out.

A steering committee comprising growers, processors, seed and chemical company representatives and field advisors was formed to oversee the project and provide feedback and advice to the project team.

The lettuce types targeted for the work are crisphead (iceberg) and cos, the former because it is the largest single type of lettuce grown and the latter because of its increasing importance and high susceptibility to tipburn. It was recognised that the proposed work will not cure the problem of tipburn but is aimed at improving management to reduce the incidence and impact. Trial work was carried out at three sites: Somerville, Werribee and Lindenow and Boisdale in East Gippsland representing the key production areas in southern Victoria.

The aim of this first seasons work was to monitor the crops and identify critical areas to be addressed in the subsequent seasons. Current crop practices including nutrition and irrigation were monitored and the impact on the incidence of tipburn, pests and diseases and other quality issues were assessed. The impact of cultivars on the incidence of tipburn was also evaluated and some monitoring of *heliothis* was carried out.

The potential for raising calcium levels in crops by using supplemental applications and the impact on tipburn was evaluated. Regular monitoring of different crop growth stages was also carried out. The cultivar trials evaluated a wider genetic selection of cultivars. In addition, the role of cultivar on post harvest storage life was also evaluated as part of a separate sub project.

Due to the inability of foliar calcium supplements to raise the sap-Calcium concentration to within desirable limits the focus changed, to evaluate the effect of changing fertiliser inputs on plant growth rate and tipburn. Cultivar trials focused on selected lines and looked more closely at changes approaching harvest.

The project has identified a number of key issues and while tipburn may not be eliminated there are management options that can reduce the likelihood of tipburn occurring and there are key factors that affect tipburn. The project has also identified a number of other issues with implications for improved management of lettuce production. Calcium, which is recognised as a major nutrient affecting tipburn although it would appear that factors which influence growth rate and the ability of the plant to take up calcium are the critical issue. These include weather, nutrient levels, irrigation and the effective management of these interactions to provide some control of growth rate and impact on tipburn.

Cultivars provide a promising opportunity for reducing tipburn in "summer' lettuce by selecting more tipburn tolerant cultivars. In summer Cos lettuce requires specific management. Early harvesting and ensuring adequate irrigation to optimise the movement of water and sap-nutrients to developing leaves enclosed in the lettuce heart are also critical. Watering should also be carried out at night to improve the supply of calcium to the "heart" leaves and minimise the impact of poor water quality.

Attempts to manipulate the concentrations of major leaf-sap nutrients through foliar and fertiliser application have been ineffective except for "luxury" accumulation of nitrate close to harvest. It appears that concentrations of non-nitrogen nutrients are regulated throughout development and were not influenced by higher nutrient availability. There is no strong evidence of any value in using calcium foliar sprays and there was no benefit in reduction of tipburn.

The use of pheromone traps for *Heliothis spp* provided an indication of periods of high pest pressure and when crops should be scouted more closely. Scentry® traps were more effective than Pot traps in monitoring for *Heliothis spp*.

The project results have also indicated that often too much fertiliser is applied and that there are opportunities to reduce fertiliser application based on soil test results and previous cropping without any loss of yield or reduction in quality. This may even improve quality, as excess nitrogen will contribute to increased incidence of tipburn. This combined with better scheduling and more even irrigation will have important implications for sustainable production and requires further work. Extension of this information to industry is also a priority.

The other major issue that has arisen for the industry is control of *Helicoverpa armigera*. The use of traps as a monitoring tool has been demonstrated but the development of effective control strategies combining biological pesticides, new chemistry and beneficials and the potential to use them in an integrated strategy needs to be developed.
(Note: For more detailed results and soil test results see the annual trial reports)

4. Materials and Methods

General Summary

The materials and methods has been broken down into the various activities carried out over the period of the project and within each of these the materials and methods for each year are described.

Trials and monitoring were carried out in 4 sites over the three year period of the project:

- Somerville
- Werribee
- Lindenow and Boisdale

These sites were chosen as being representative of lettuce production in southern Victoria taking into account variation in soil types and climate and are the main areas where summer lettuce is produced in Victoria.

Irrigation Practices

The three sites chosen all used overhead irrigation with fixed sprinklers but frequency of irrigations varied due to the different soil types.

Somerville -	Irrigations nearly daily, applied at night on a sandy soil.
Werribee -	Irrigations around twice a week, usually applied in the afternoon, on a red clay soil
Lindenow -	Irrigations more variable, around three times each week depending on rainfall and usually applied early morning on a rich loam soil.

5. Crop Monitoring

5.1. Year 1 – 1998/99

5.1.1. Materials and Methods

The aim of the first year monitoring program was to assess current nutrition, irrigation practices and correlate with tipburn on affected crops with a view to determing the key issues involved to address in subsequent years trials. The sap monitoring used a commercial sap testing service and moisture monitoring equipment to monitor the soil moisture levels.

In year one, two plantings times were monitored, a December and a February planting. The trials evaluated commercial crops of both Cos and Iceberg. This involved some destructive sampling of plants (approximately 160 - 200 plants over the duration of the crop). Crops were planted and treated with the growers usual practices.

Soil Moisture Monitoring

The proposed soil moisture monitoring protocol needed to be capable of continuously monitoring changes in soil water availability beneath the actively growing lettuce crop. The soil-water monitoring equipment had to be capable of assessing water availability in the plant root zone, for lettuce, this zone is in the top 15 cm of soil. The Aquaflex soil monitoring system, backed up with tensiometers, provided the required capability. Soil compaction measurements and water application volume will also be measured to take into account field variability.

Point monitoring systems are suspect, in that they only represent soil moisture measurements at a single point. Each Aquaflex sensor interrogates a soil volume of approximately 5.5 litres, (STREAT Instruments). The aquaflex system was backed up by traditional tensiometers which will be read twice weekly to use as a conventional method of measurement. Changes in soil moisture over the life of the lettuce crop were monitored at each location using a 4-channel Aquaflex system, (STREAT Instruments, N.Z.).

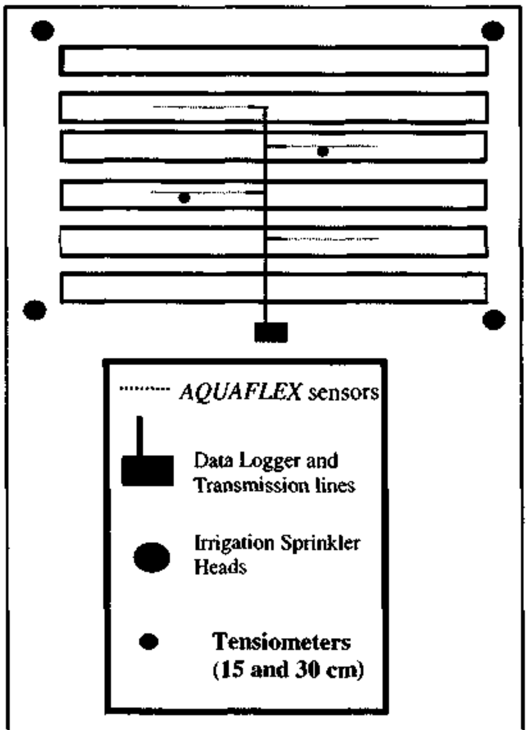


Fig 1. Layout of *AQUAFLEX* sensors and *SOILSPEC* tensiometers

One, 3-metre sensor strip was buried in each of four raised beds across the irrigation bay at a depth of 15cm. (fig. 2). This was found to be near the base of the main root mass of the mature crop. The data from all four sensors were averaged to provide an estimate of changes in soil water content beneath the lettuce crop at each site.

The manually recorded Aquaflex sensor data was supplemented with readings of soil water tension using Soilspec tensiometers. The tensiometers were installed at 15 and 30-cm depths, beside two of the four Aquaflex sensors at each location, (fig

1.). The tensiometers provide a reference point for the Aquaflex data, which is expressed in dimensionless Aquaflex units. A linear correlation between the Aquaflex and Tensiometer has already been established by Krake, 1998. Discrepancies between the two systems may be affected by the inherent variation in soil moisture across an irrigation bay and the small 'sphere of influence' (point source) of two single point tensiometers compared with multiple 3m Aquaflex ribbon sensors.

Plant Nutrition Monitoring

Plant Sap testing were carried out twice weekly with samples sent to SERVE-AG to carry out the analysis. The crop was sampled according to SERVE-AG recommendations where the youngest fully expanded leaf (usually the tallest leaf) from 15-20 representative plants are combined. Nitrate, phosphorus, potassium, calcium, magnesium, zinc, sodium and boron were measured for the crop at each site at twice weekly intervals. Soil nutrient levels were sampled pre- sowing and at the end of the crop.

Sampling commenced in the 3rd week after transplanting for a crop expected to require 7 weeks to mature and in the 4th week for an 8 week crop. To support the sap testing results dry leaf tissue analysis will be carried out every second sampling to establish correlation between the two methods and conventional standards for leaf tissue analysis.

Water quality is an issue at Werribee and was monitored at both Werribee and Cranbourne sites.

At each site the crop monitored was grown using the growers standard cultural practices.

Fertiliser Applications:

Lindenow - Super potash was used prior to planting for this was new ground.
At planting, Rustica (12:15:14) was used.
Side dressing of Calcium nitrate 28 days after transplanting.

Werribee - Calcium nitrate was applied at transplanting.
Side dressing of Rustica applied 14 days after transplanting.

Somerville - At transplanting Rustica was applied.
Side dressing of Calcium nitrate was applied 28 days after transplanting.

Samples of Iceberg and Cos were collected twice weekly from the same planting as the soil moisture monitoring study excluding the areas where the Aquaflex was laid. Twenty iceberg and twenty cos plants, were harvested at approximately the same time, early in the morning. Composite samples of the youngest fully expanded leaf (YFEL), was collected from 20 plants and for leaf sap analysis.

Similar samples of the next outermost leaf (YFEL +1) from 20 iceberg and 20 cos plants were collected, dried at 60°C and forwarded to State Chemistry Laboratories for dry tissue analysis.

Crop Growth Measurements

On the same sample of plants taken for tissue analysis crop growth measurements were taken to assess crop growth rates and the incidence of disorders, notably tipburn. Measurements included:

-Total weight above ground
-Trimmed head weight
-Core length, and width
-Number of leaves
-Size of youngest fully expanded leaf, (YFEL)
-Assessment of the incidence and severity of Tipburn and other conditions.

5.1.2. Results

<u>Lettuce Crop Growth Rates</u>

<u>Planting 1 (November 1998)</u>

There were large differences in crop growth rate and fertiliser strategies at the three locations, (fig. 2). Differences in soil type and local weather conditions largely determine crop growth rate. Vegetable growers operating in open fields are largely unable to influence the effects of local weather conditions on crop growth rate. Tipburn was first noticed in iceberg lettuce about one week prior to harvest.

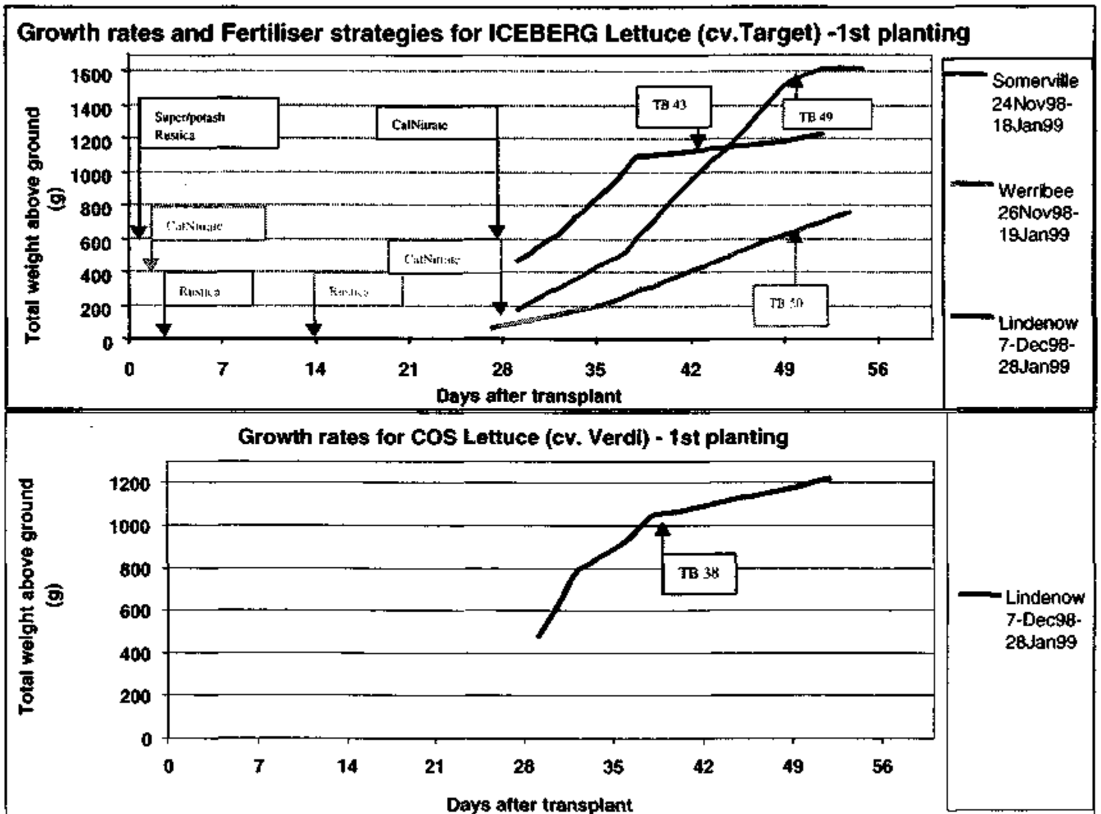


Fig 2. Growth rates and fertiliser strategies for the production of mid-summer lettuce at three Victorian locations,

* *refers to the days after planting when tipburn was first noticed in the crop.*

Planting 2 (February – 1999)

Tipburn is usually a less common problem later in summer when temperatures moderate and growth rates are not as high. However, at Lindenow, symptoms of tipburn were observed in Iceberg lettuce, 52 days after transplanting into new ground. In this instance, the development of tipburn was preceded by a week of very high growth rate where the total plant weight above ground doubled from 400 to 800 grams, (fig 3). This rapid growth rate followed a week of warmer weather and a side dressing with a significant increase in nitrate levels at day 36.

Transient shortages of essential elements during periods of rapid growth may have triggered the development of tipburn in this crop. The growth rate of iceberg lettuce grown at Somerville and Werribee was more uniform and symptoms of tipburn were not evident. Cos lettuce grown at Lindenow also developed Tipburn as the crop growth rate increased following slow growth until day 45. The growth rates for cos lettuce growing at Somerville and Werribee were more consistent and no symptoms of tipburn were observed.

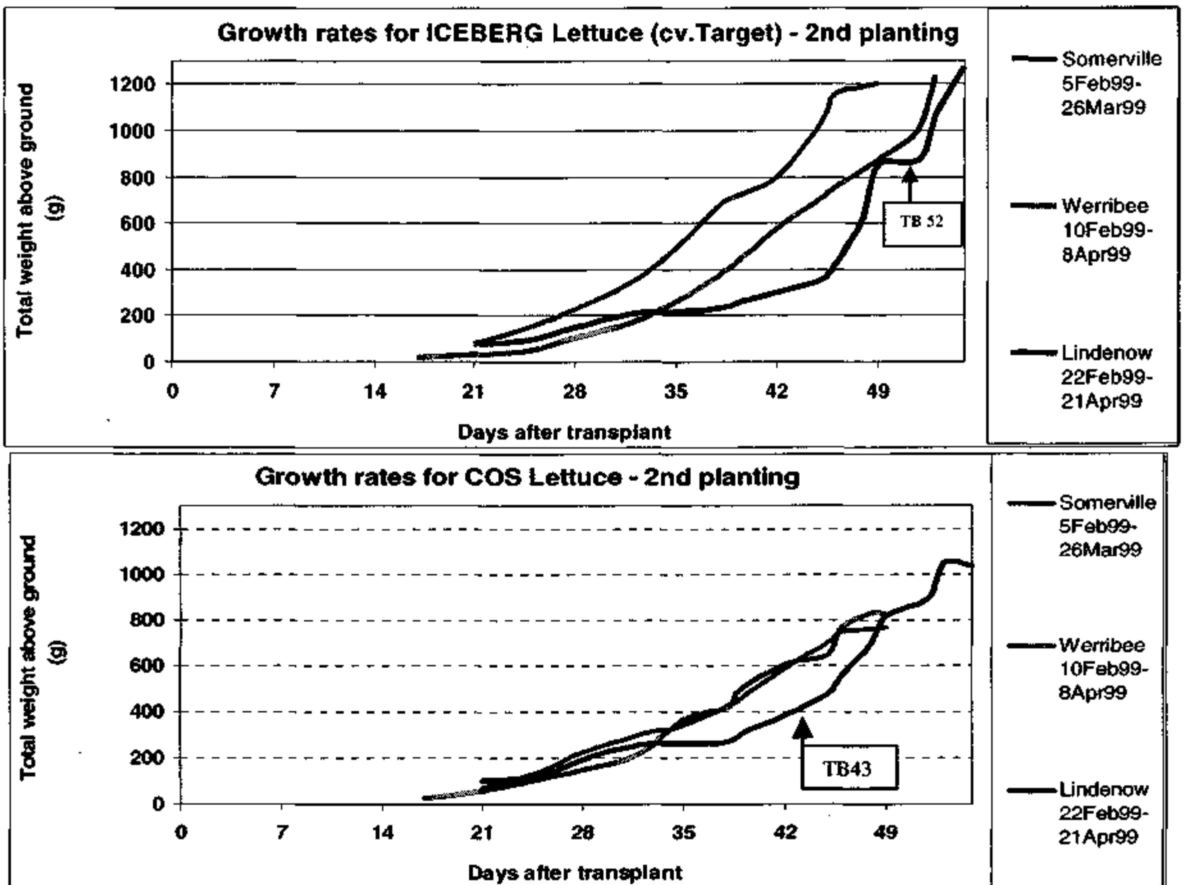


Fig 3. Crop growth rates for late summer lettuce grown at three Victorian locations.

Leaf Sap Analysis

Nitrate

Nitrogen in the form of calcium nitrate is applied to lettuce crops to boost growth and improve the green colour of the leaves. Base levels of nitrate in the soil at planting are largely depleted within four weeks and supplemental nitrate may be applied, especially on sandier soils, where leaching may be more pronounced.

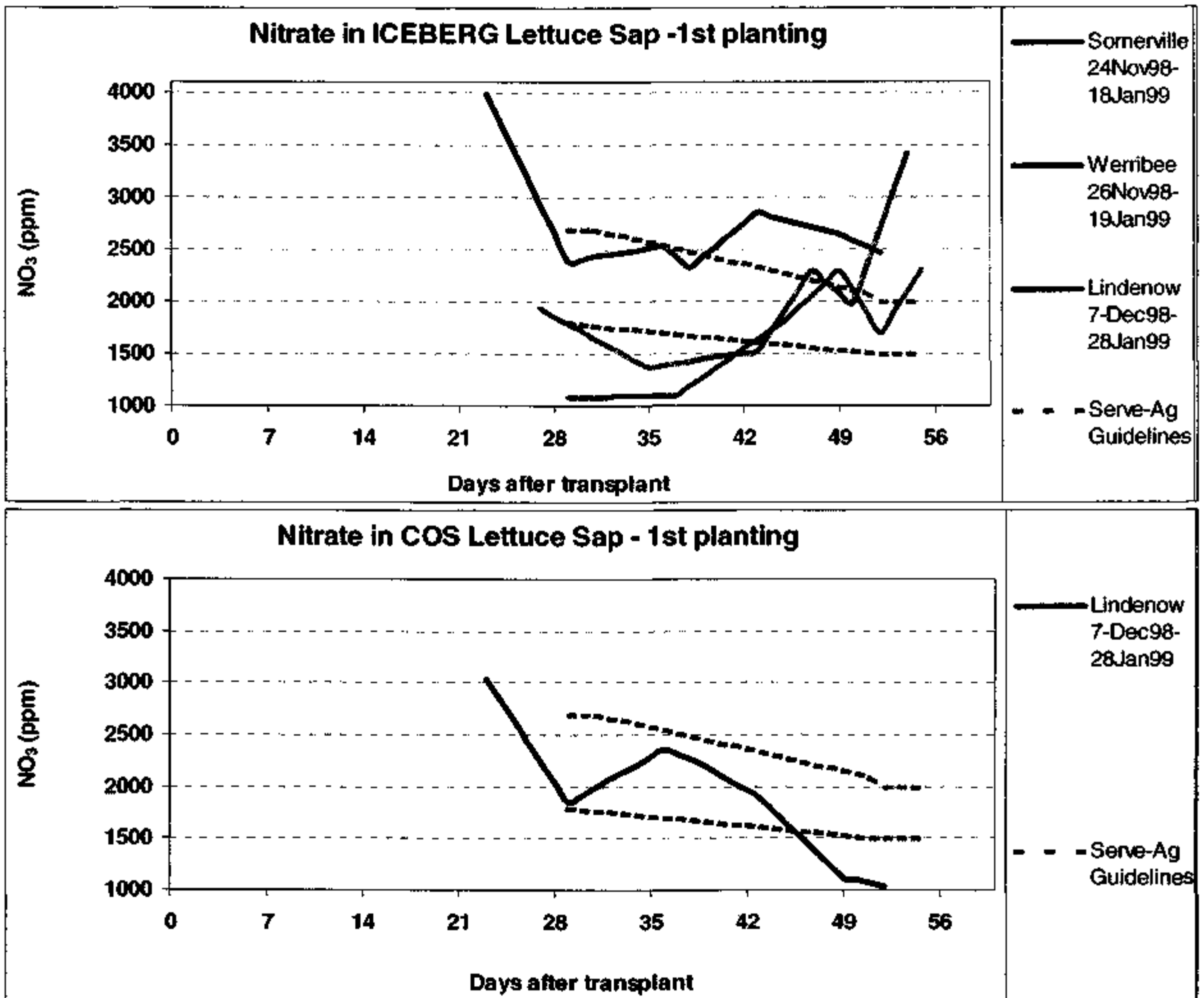


Fig 4. Concentration of nitrate in the sap of lettuce leaves collected from mid-summer plantings at three Victorian locations..

The more demanding growing conditions experienced during mid-summer may have made it difficult to control the crop nitrate concentration at harvest, (fig 4). The late-summer crops grew more uniformly and the nitrate concentrations in the crops at harvest were closer to the desirable limits. The effect of other variables may be seen in the second planting, (fig 4). The second iceberg crop at Lindenow grown on new ground, had very high concentrations of nitrate during the period of low growth rate near day 35 and relatively cooler temperatures. At Werribee, irrigation ceased at day 35 and nitrate levels declined and until the autumn rainfall following day 42. The nitrate concentration in iceberg lettuce grown at Somerville and all cos crops, was largely within desirable limits.

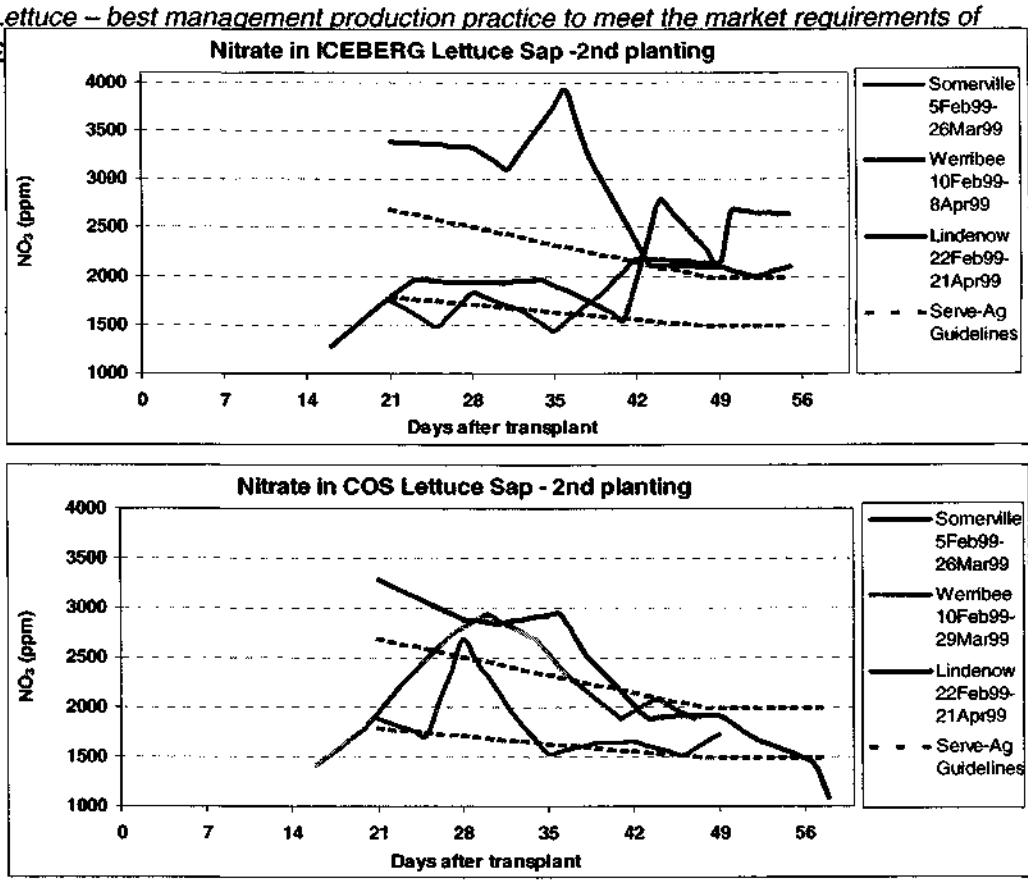


Fig 5. Concentration of nitrate in the sap of lettuce leaves collected from late-summer plantings at three Victorian locations.

Potassium

During mid-summer, the concentration of Potassium in iceberg and cos lettuce leaves may be deficient near crop maturity but is largely within desirable limits until early hearting, (fig 5).

Unlike phosphorus, the amount of available Potassium in the soil decreases over the life of the crop. A top dressing was applied (Rustica, 12:15:14) within two weeks of transplant. Despite this practise, Both the sap and soil concentrations of Potassium decline over the life of the crop. Although no direct deficiency symptoms were observed, the low sap Potassium may have been an avoidable stress factor. The lettuce crop response to Potassium was not established.

The potassium concentration in iceberg and cos planted in February, displays a similar pattern to the mid-summer planting, (fig 6). The pronounced fall in leaf sap potassium at from day 35 at Werribee followed by a recovery from day 42 corresponds with a prolonged dry period following the last irrigation which was broken by autumn rains. A similar fall was observed with cos lettuce at Werribee although no recovery followed.

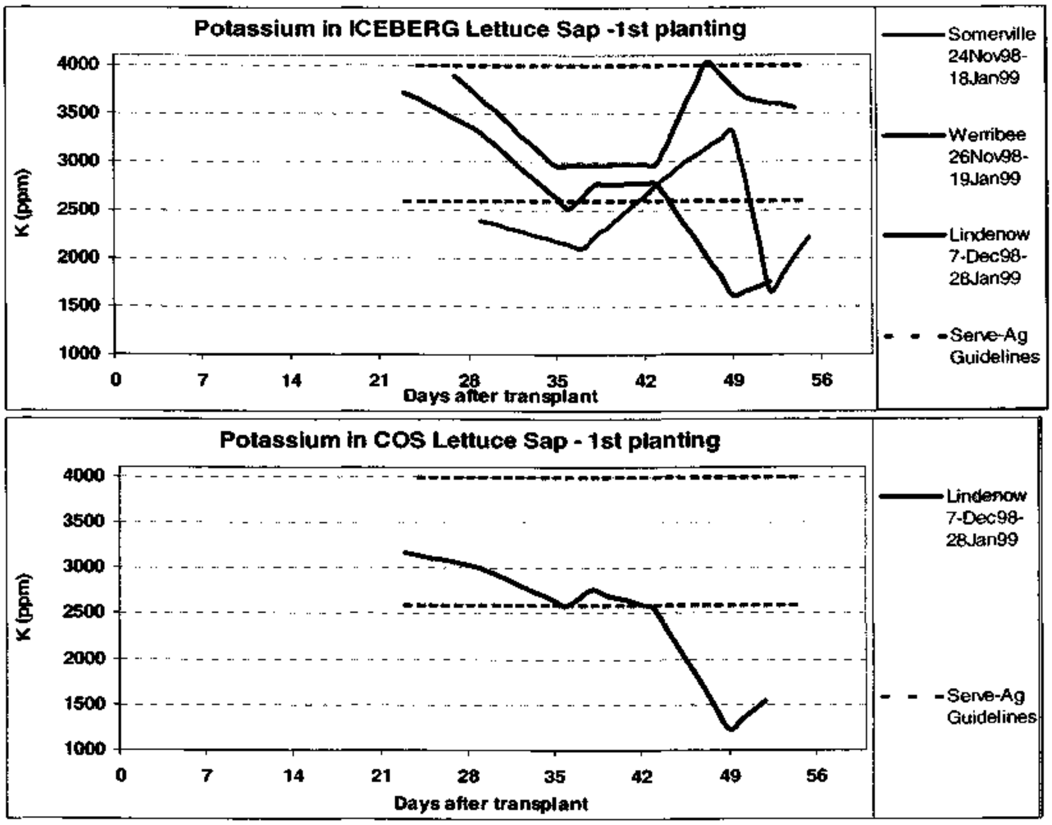


Fig 6. Concentration of Potassium in the sap of lettuce leaves collected from mid-summer plantings at three Victorian locations.

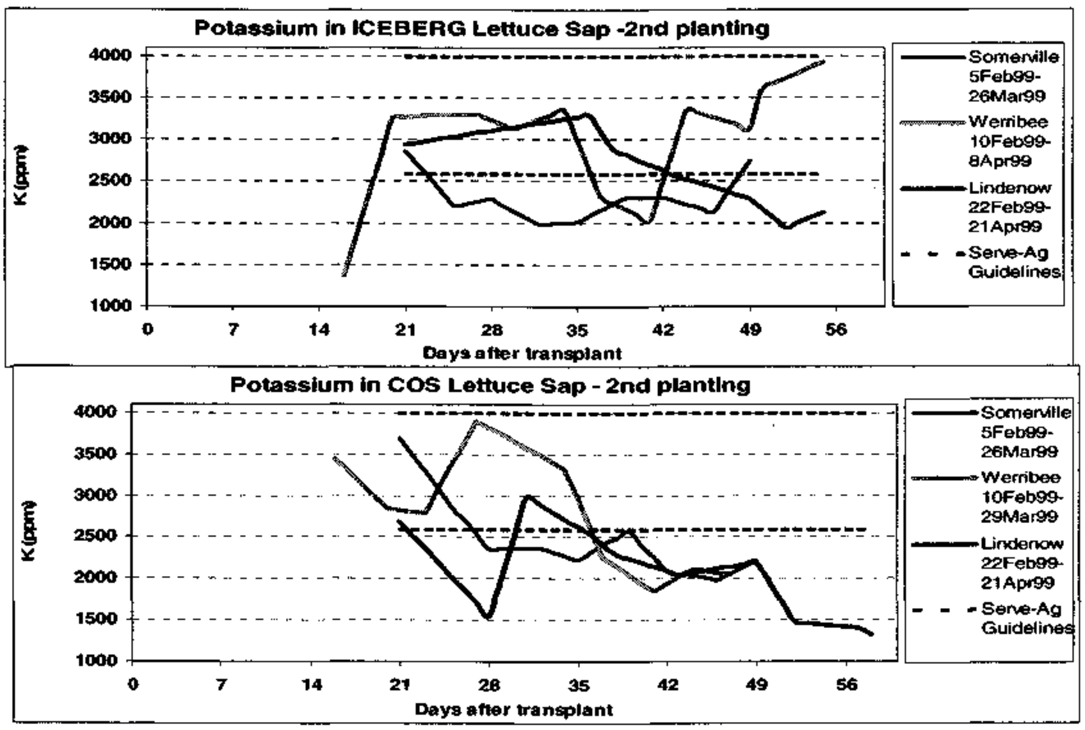


Fig 7. Concentration of Potassium in the *sap of lettuce leaves collected from late-summer plantings at three Victorian locations..*

Calcium

Tipburn in lettuce is recognised as a calcium deficiency disorder, (Saure, 1998). The leaf sap analysis confirmed that calcium was well below desirable limits for most of the life of the crop, (fig. 8). In the first planting of Iceberg lettuce at Somerville and Werribee, sap calcium appears to recover after day 42, although it was noted that after hearting the same wrapper leaf continued to be sampled and may not reflect the condition of inner leaves. At Lindenow, no recovery in calcium concentration of the leaf sap was observed in either iceberg or cos lettuce crops.

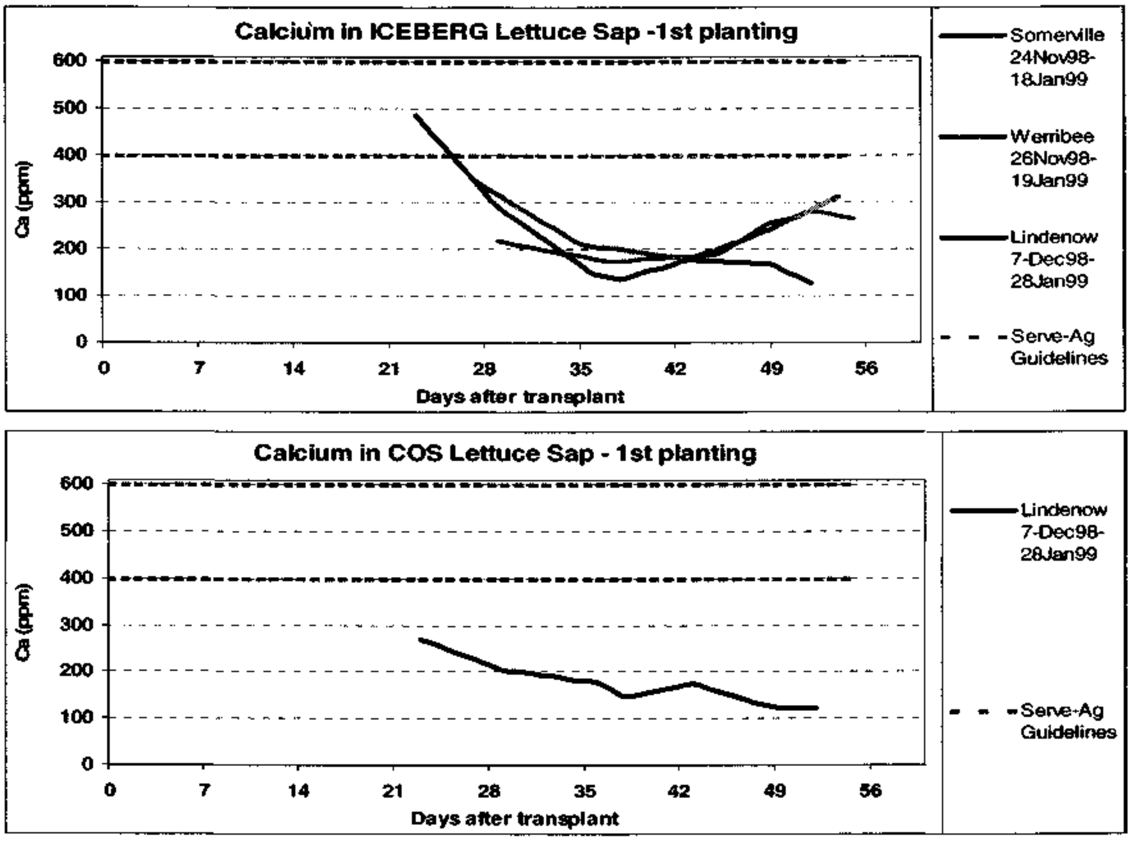


Fig. 8. Concentration of Calcium in the sap of lettuce leaves collected from late-summer plantings at three Victorian locations..

In the late-summer plantings, the concentration of leaf-sap calcium was again very low at all three locations but symptoms of tipburn were only observed at Lindenow, (fig 9). Like the first planting, some recovery in leaf-sap calcium was observed in iceberg crops at Somerville and Werribee although this may have been an artefact of continued sampling the same wrapper leaf. At Lindenow, where symptoms of tipburn were observed, there was no recovery in leaf-sap calcium. The absence of tipburn symptoms in crops at Somerville and Werribee, despite low leaf-sap calcium, suggests that additional crop growth factors were involved. Increasing the leaf-sap calcium concentration may help reduce the risk of developing tipburn.

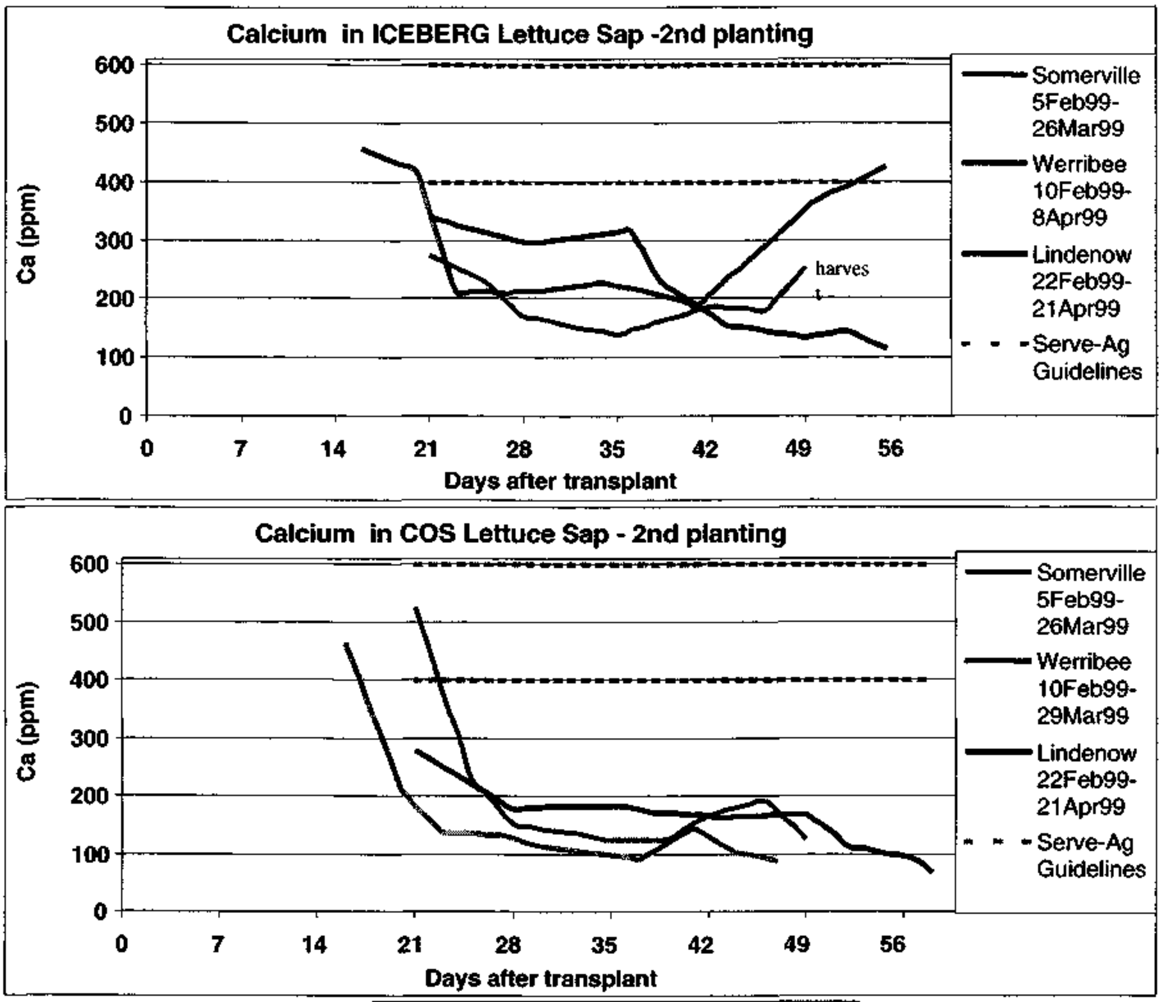


Fig 9. Concentration of Calcium in the sap of lettuce leaves collected from late-summer plantings at three Victorian locations.

Irrigation

Irrigation is one of the major tools available to vegetable growers for adjusting the growing environment for open field crops. The sandy soil at Somerville was free draining and required more frequent, (often daily), watering. Irrigations were mainly scheduled during the night enabling plant-water recharge under conditions of lower evapotranspiration. Changes in soil water over both plantings are shown in figure 10, which includes a closer consideration of conditions during the fortnight preceding signs of tipburn. With night watering, the soil moisture did not begin to fall until after 9am the following day. The grower was able to maintain soil moisture in a narrow range between 15 and 16 Aquaflex units corresponding with a soil water tension between 0 and 10kPa.

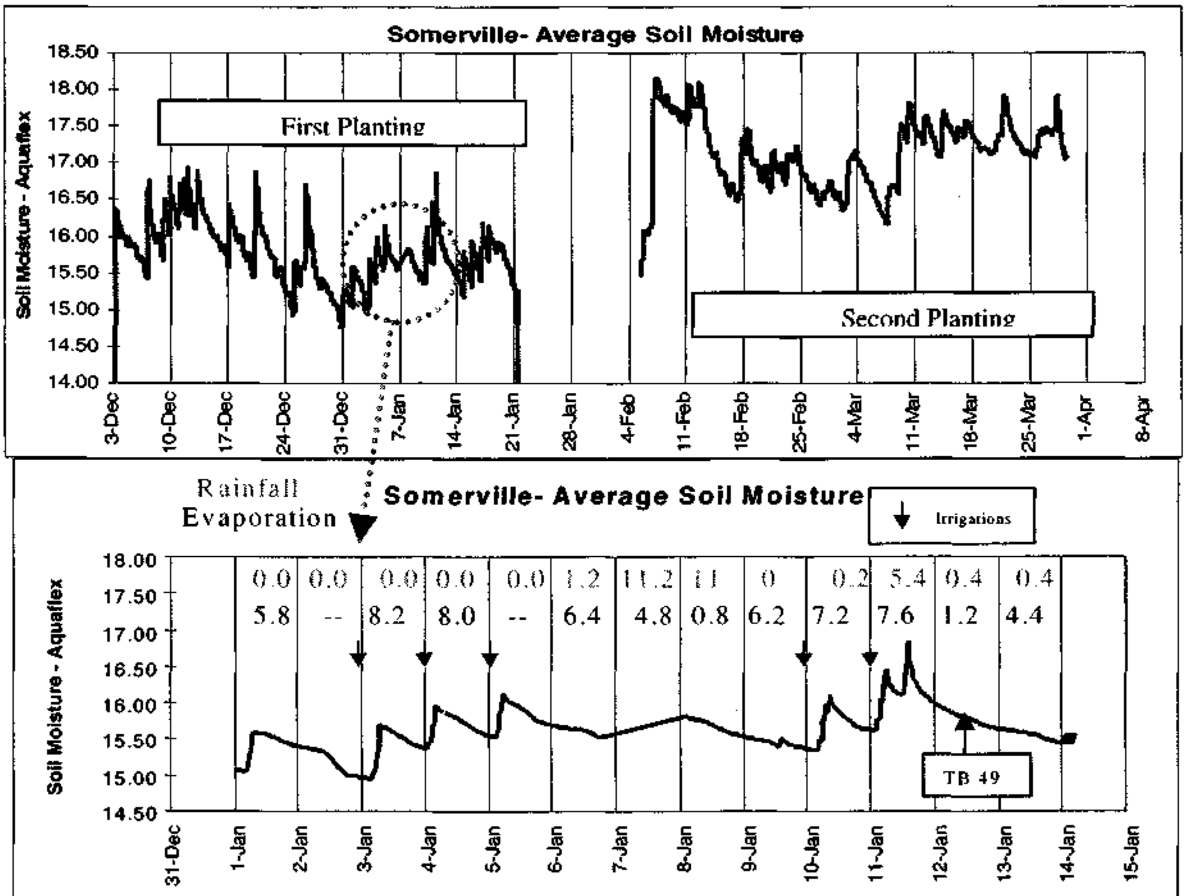


Fig. 10 Changes in soil moisture beneath an actively growing lettuce crop at Somerville during summer 1998-1999

*** Daily average rainfall and evaporation figures provided by Bureau of Meteorology at Cranbourne are a guide only and are <u>not</u> specific to the Somerville site**

A different irrigation strategy was used at Werribee where the red clay soils held water for a longer period. Irrigations were scheduled every third or fourth day, usually in the afternoon, maintaining the soil water tension between 0 and 30kPa during the fortnight preceding the development of tipburn, (fig 11). During the second planting, irrigation ceased early in March. The soil water tension fell to 70kPa in mid-March before the autumn rain fell. It should be noted that the late-summer lettuce crops could tolerate this water stress without bolting.

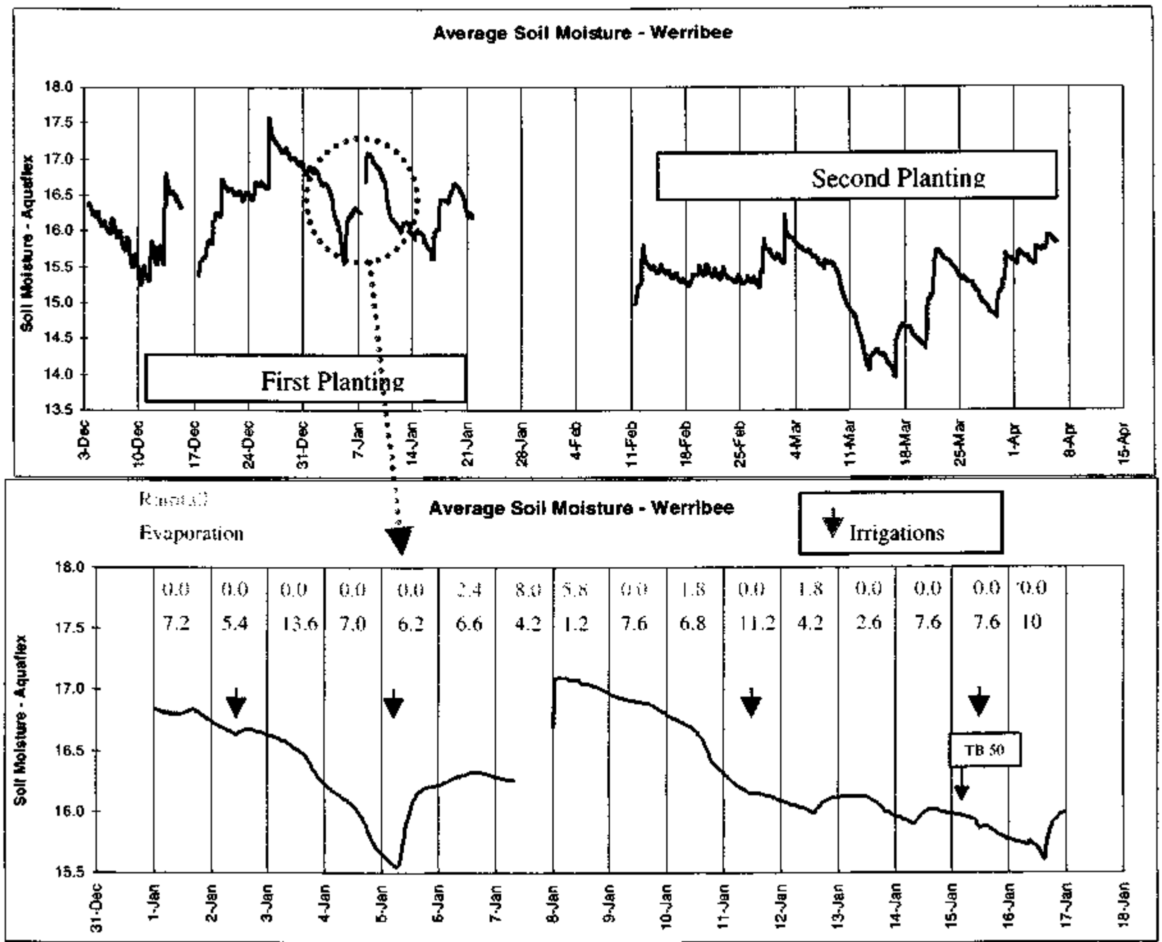


Fig 11. Changes in soil moisture beneath an actively growing lettuce crop at Werribee during summer 1998-1999

The black clay-loam river flats at Lindenow have good water holding capacity. Weekly irrigations were considered adequate during March and April 1999, (fig 12). During the fortnight preceding the first sighting of tipburn in the crop, the soil water tension varied between 0 and 86kPa. The first signs of tipburn were preceded by a week of warm weather and application of a nitrate side dressing to a sluggish crop. The weekly irrigation due around April 6, was cancelled because of imminent rain. It is conceivable that the irrigation late on April 11 provided the last requirement for rapid growth and precipitated the symptoms of Tipburn on April 15.

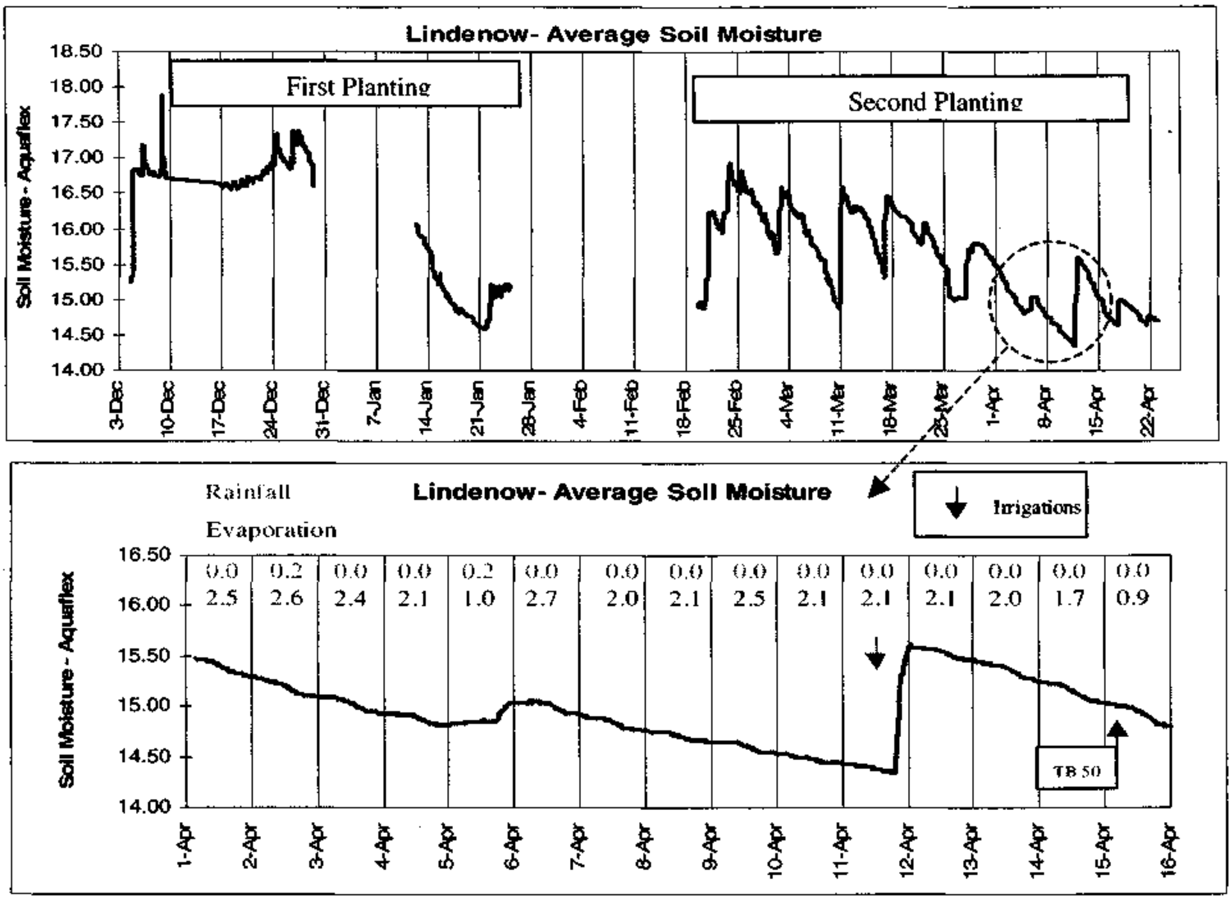


Fig 12. Changes in soil moisture beneath an actively growing lettuce crop at Lindenow during summer 1998-1999

5.2. Year 2 1999/00

5.2.1. Materials and Method

Multiple Crop and Climatic Monitoring for Incidence of Tipburn

One of the lessons learnt last season was the importance of building a comprehensive picture of crop dynamics including nutrients in the plant and soil, crop growth rates, irrigation and changes in crop quality (tipburn, downy mildew, grubs, big vein etc).

Growers have reported that sometimes *"Tipburn doesn't just occur prior to harvest but can also occur on plantings at a range of growth stages simultaneously."*, (project steering committee meeting minutes, 14/5/99).

This study involved twice weekly inspection of several plantings (sequential crops), noting the occurrence and severity of diseases and disorders. Weather was monitored at each site to enable correlation of climatic conditions with the incidence of tipburn.

Weekly crop measurements were supplemented with twice -weekly crop monitoring of different aged plantings. Crop monitoring during the Dec-Jan tipburn period, was carried out to identify the effects of leaf-sap calcium, irrigation and weather conditions on the incidence of tipburn and other quality issues.

Assessment plots containing 200 adjacent plants were marked in weekly commercial plantings at Somerville and Werribee in November 1999 and again from January 2000. Plots were scouted each week and the number of plants affected by tipburn was recorded. The account was not comprehensive as not all plantings were followed through to harvest.

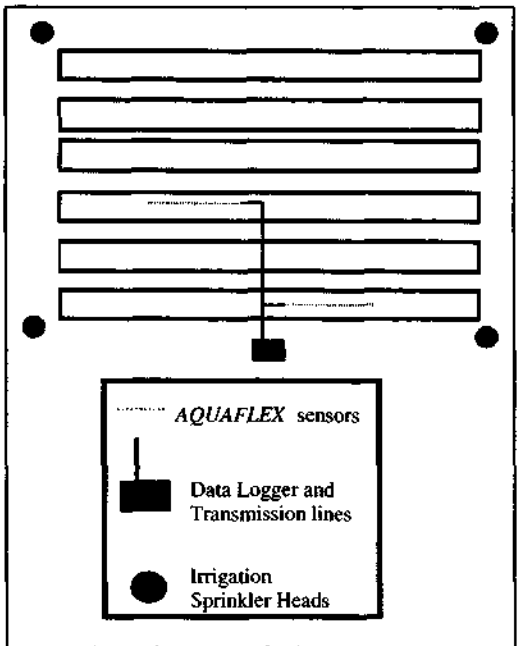


Figure 13. Layout of *AQUAFLEX* sensors across the irrigation bay.

Soil Moisture Monitoring

Changes in soil moisture over the life of the lettuce crop were monitored at each location using the TDR based Aquaflex system, (Krake, 1998). Soil moisture was monitored using one, 3 metre sensor strip buried in each of two raised beds across the irrigation bay at a depth of 10cm directly beneath the transplants, (figure 13). These changes were made from last season to improve the response time and hence better reflect water stress conditions experienced by the crop.

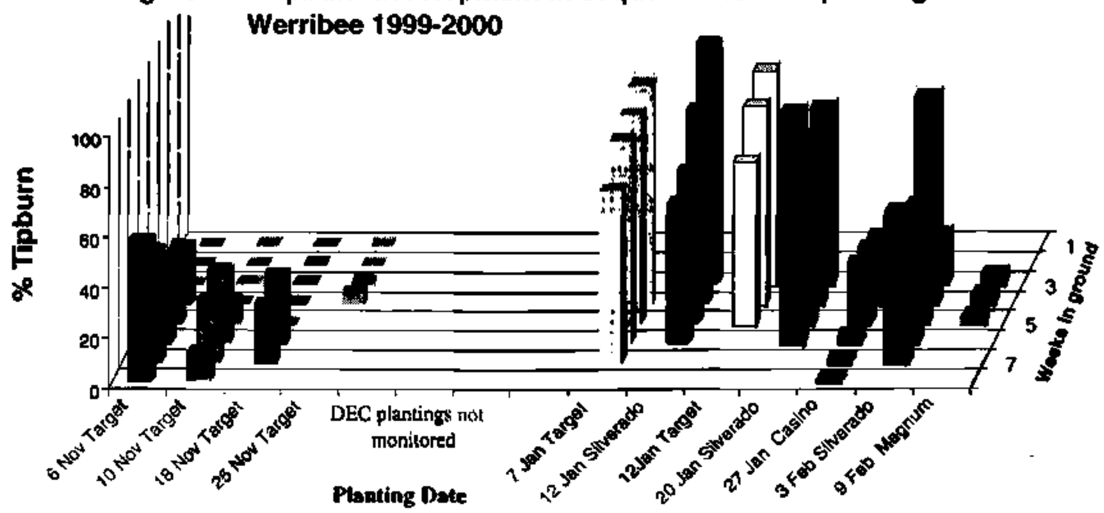
Pest and Disease

Helicoverpa grubs caused substantial damage to lettuce crops last season. The project steering committee encouraged the project team to deliver timely information on moth trap counts and egg lays to growers. Moth counts of *H. puntigera* and *H. armigera* were routinely collected from Scentry® pheromone traps each week. During periods of high moth pressure, trap counts were determined twice weekly and lettuce crops will be scouted for egg lays. Growers were advised promptly, (see technology transfer).

5.2.2. Results

Sequential Plantings

Figure 14. Tipburn development in sequential lettuce plantings Werribee 1999-2000

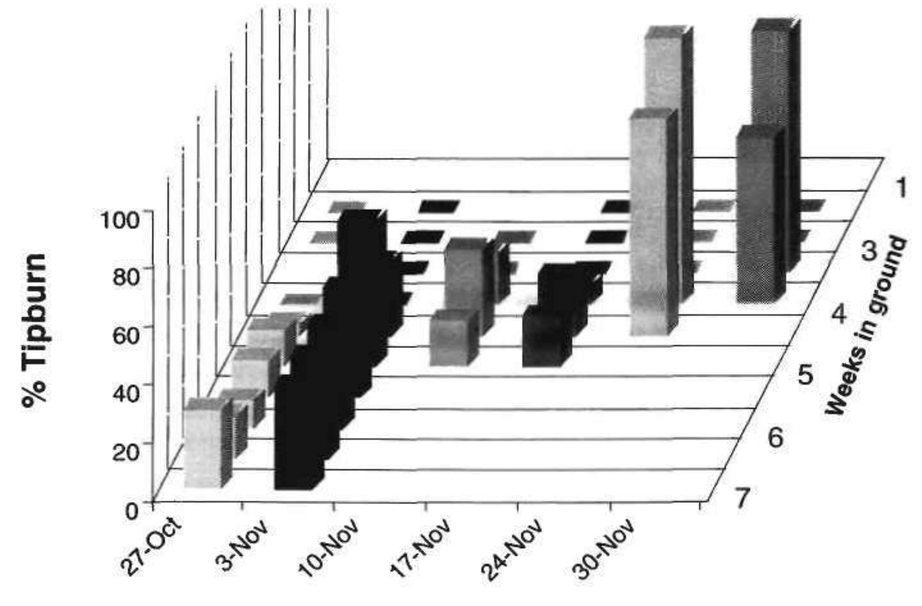


At Werribee, (figure 14), only iceberg lettuce was grown and cultivar changed with some plantings. Several features of tipburn development in iceberg lettuce were noted:

1. Some plantings developed less tipburn than others.
2. Tipburn developed more rapidly, extensively and earlier in January plantings.
3. The onset of tipburn coincided with heart formation which varied with cultivar and season.
4. Cultivars varied in their sensitivity to tipburn throughout the season.
5. Better management practices are more critical in January planted crops.

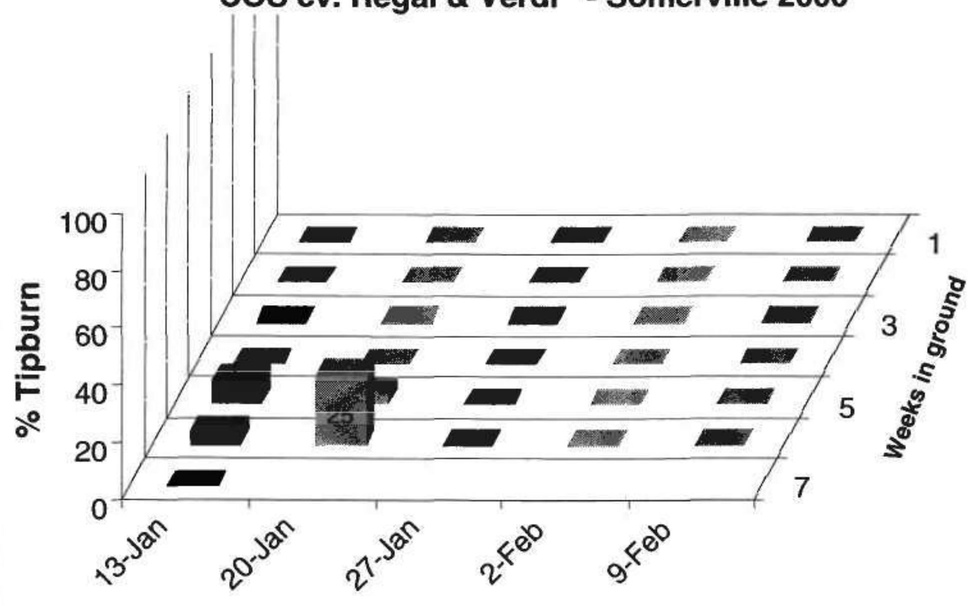
At Werribee, the earlier onset of tipburn in mid-summer plantings may help explain growers observations of tipburn occurring simultaneously in plantings at a range of growth stages.

Figure 15. Tipburn development in sequential lettuce plantings cv. Target - Somerville 1999



At Somerville, iceberg lettuce was studied through 1999 and cos lettuce in 2000. The iceberg cultivar "Target" was used exclusively throughout the summer of 1999 at Somerville, (figure 15). At Somerville, tipburn developed earlier and was more extensive in late November plantings.

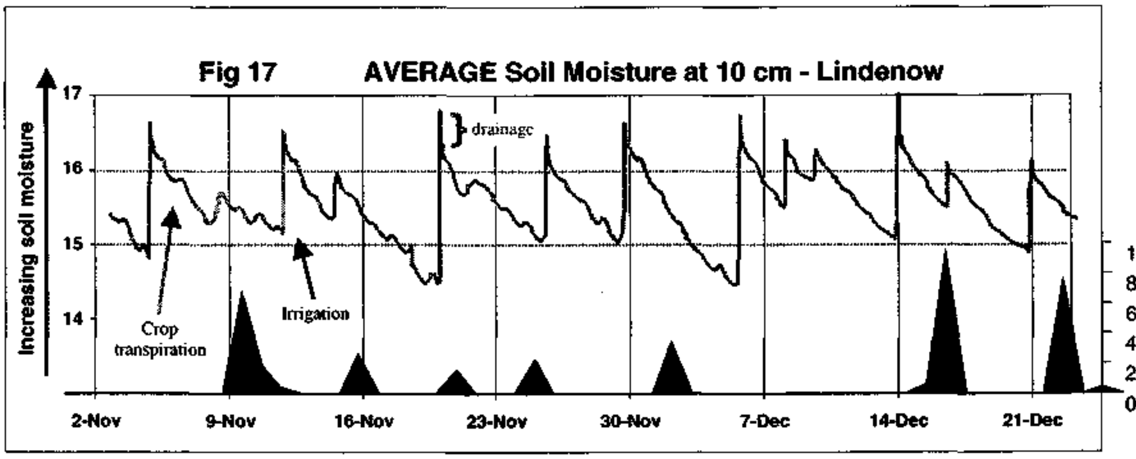
Figure 16. Tipburn development in sequential lettuce plantings COS cv. Regal & Verdi - Somerville 2000



The development and extent of tipburn in cos lettuce was studied only at Somerville during the January 2000 plantings (figure 16). In summer cos at Somerville is grown in a separate area with heavier soil and using a different irrigation strategy lettuce and is not intercropped with Iceberg lettuce. These strategies appear to have reduced the incidence of summer tipburn in cos.

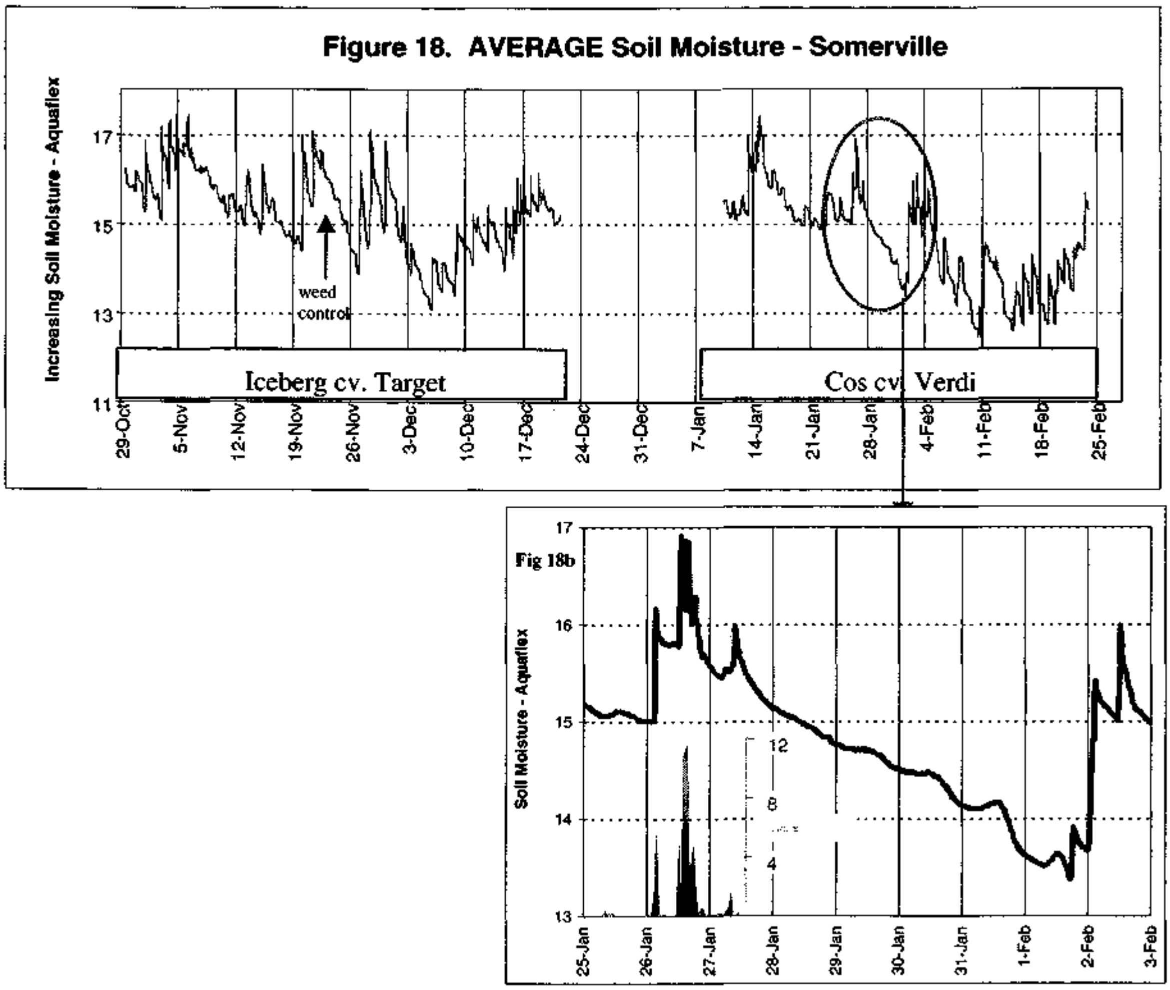
Irrigation

The lettuce crop Lindenow was grown on black clay-loam river flats and were usually watered every 5-7 days (figure 17). This record shows changes in soil moisture 10cm below the soil surface as well as rainfall. The irrigation events appear as sharp spikes which are followed by a gradual depletion in soil water due to uptake and evapotranspiration through the crop. Rainfall of 6mm on the 10th November slowed the decline in soil moisture and extended the time between irrigations to 8 days. Irrigation usually saturated the top 10cm of soil and we can see the rapid drainage which follows. This water may still be available to the crop through those roots below 10cm.

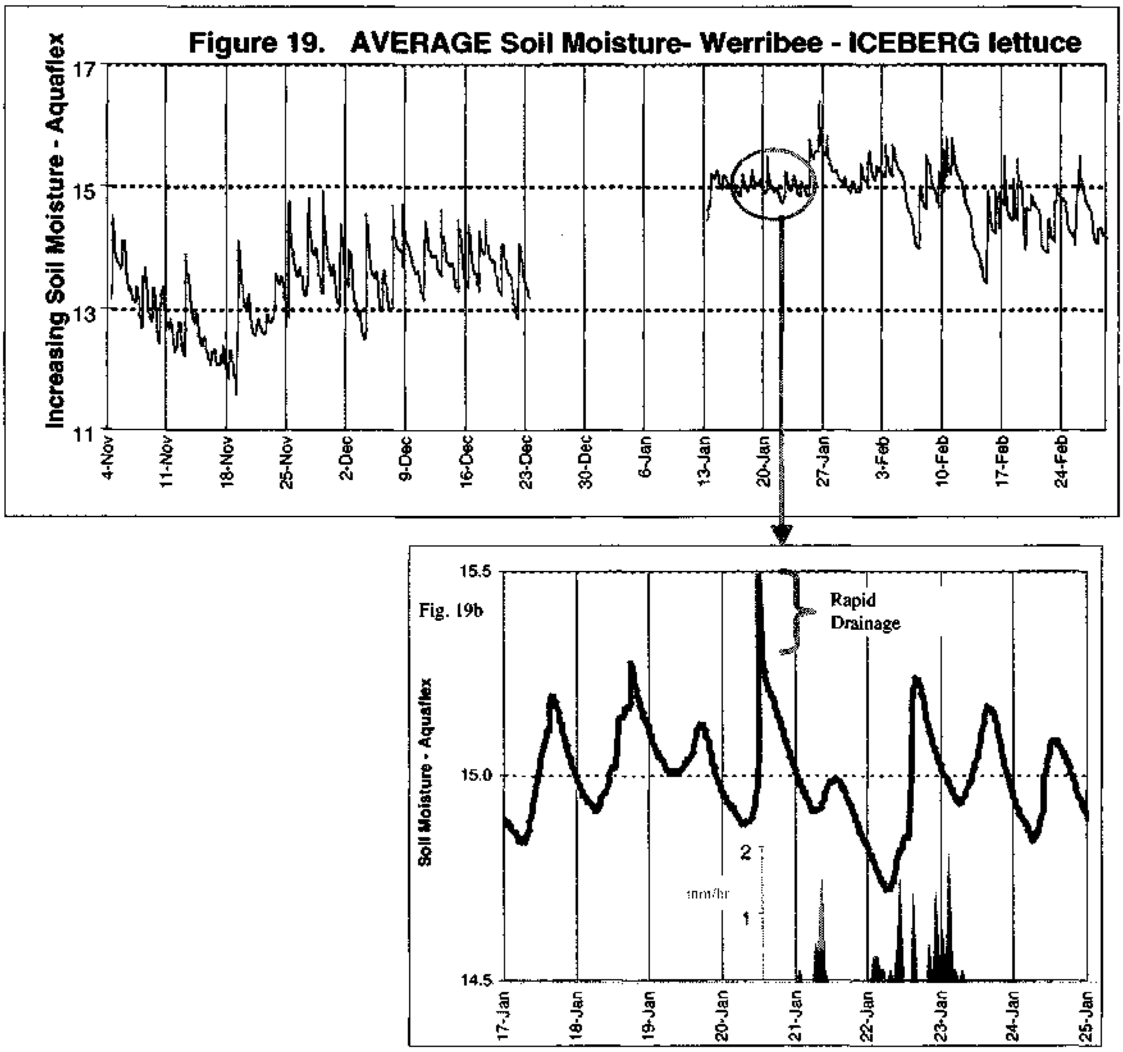


The sandy soil at Somerville was free draining and required more frequent, (often daily), watering. Irrigations were mainly scheduled during the night enabling plant-water recharge under conditions of lower evapotranspiration. Changes in soil water over both plantings are shown in figure 18. Irrigation was withheld late in November as part of the growers weed control strategy.

On the afternoon the 26th January, 44mm rain fell at Somerville. Half this rain fell between 1-3pm and irrigation was withheld till the 2 February, (fig 18b). It is useful to note that this intense rainfall saturated the soil to at least 10 cm and quickly drained to ~16 units (field capacity). Soil moisture conditions at 10cm returned to the pre-storm value within 24 hours. Drainage deeper in the soil profile may still have been directly available to deeper plant roots as no adverse affects were observed in the crop. Given the intensity and duration of the rainfall (average 12mm/hr for 2 hours) it is likely that substantial surface runoff would also have occurred.



At Werribee, crop irrigation was improved compared with the 1998-99 season. More regular, shorter duration waterings maintained a narrow range of soil moisture, (figure 19). While better irrigation practice may reduce crop water stress, good irrigation practice alone could not prevent tipburn. It has been suggested that non-damaging mild stresses may improve the crops tolerance to tipburn, (Saure, 1998). The benefit of smaller more frequent watering on soil moisture at 10cm is shown in figure 19b. Smaller irrigations on the 17^{th}, 18^{th} and 19^{th} of January 2000, produced more gradual increases in soil moisture at 10cm. In contrast, the heavier irrigation on 20^{th} January, caused a sharp increase in soil moisture at 10cm, much of the additional irrigation water quickly drained below 10cm within 12 hours. Although this water could still be accessed by roots deeper in the soil, most lettuce roots are within the top 10cm of soil and this is where most nutrient uptake occurs. Irrigation management practices were improved to use limited water resources more efficiently.



5.3. Discussion

Tipburn in lettuce is recognised as a physiological condition that affects developing leaves. In the first year tipburn occurred in all crops in the first planting but during the second planting, when growth rates were generally lower, tipburn only occurred in the Lindenow crops.

Low concentrations of calcium were evident in leaf sap and dry tissue samples throughout most of the growing period. This is consistent with existing explanations of tipburn as a calcium deficiency disorder. The concentrations of potassium in leaf sap also fell below desirable levels especially in cos lettuce, near maturity and low leaf sap potassium may also weaken resistance to downy mildew. The concentrations of other nutrients were generally within acceptable limits except for low phosphorus in crops grown on new ground at Lindenow. When calcium is applied, it is usually as a sidedressing with nitrogen ie, as calcium nitrate. This will have some effect on the crop growth rate, which may not be beneficial to the uptake and distribution of calcium. Other means of applying calcium need to be evaluated.

Tipburn was a more consistent problem during the January harvest compared with the April harvest at all locations. Low calcium, potassium and increased water stress in the crop harvested in April, did not result in tipburn at two of the three study sites. This suggests that nutrition and water supply are only part of the tipburn story. The humidity, temperature and rainfall all play an important part in determining the crop growth rate, which impacts on the incidence of tipburn. When the crop is growing less vigorously, there is a lower risk of developing tipburn.

Irrigation frequencies varied at the three sites principally due to the differing soil types and the consequent requirements for soil moisture management. Soil moisture at all sites was generally maintained within a desirable range and large fluctuations in soil moisture levels were avoided. This should be beneficial and reduce the potential incidence of tipburn.

The timing of water applications however also varied and this could negatively impact on tipburn incidence as well as being less desirable when water quality is an issue such as in Werribee. Irrigation at night would improve the supply of calcium to developing leaves within the heart, which could lower the incidence of tipburn. The impact of poor water quality will also be reduced which would be particularly beneficial for growers in the Werribee area where the incidence of high sodium levels is an issue.

In year 2 the changes in growth rates and nutrient levels within plants were consistent with the previous seasons results and consolidated the previous years work. The first onset of tipburn coincided with heart formation and varied with cultivar and planting date.

The sequential monitoring trials indicated an earlier onset of tipburn in mid-summer plantings may help explain growers observations of tipburn occurring simultaneously in plantings at a range of growth stages and tipburn developed more rapidly, extensively and earlier in January plantings. The exposure to additional heat in January produced smaller plants with more tipburn and indicated that better management practices are more critical in January planted crops.

It is important not to delay harvesting the crop as the tipburn severity continues to increase, as does the risk of damage from grubs and soft rots. The variable results with cos lettuce at the different locations indicate that it requires specific management to reduce incidence of tipburn. There appears to be a higher incidence of tipburn in crops where cos and iceberg lettuce are intercropped.

Irrigation practices were consistent but particularly in Werribee management was improved in comparison to the previous season.

6. Cultivar Evaluation

6.1. Year 1 – 1998/99

6.1.1. Materials and Method

The aim of the trial was to evaluate the performance of a number of different cultivars of cos and iceberg lettuce in relation to the incidence of tipburn (susceptibility/tolerance), yield and regional suitability. As part of the overall monitoring of the trials disease incidence such as, anthracnose and others, were also monitored.

Trials were be placed at the same sites as the monitoring trials for soil water and crop nutrient management. The purpose of the cultivar trials was not to evaluate a large range of cultivars which would simply be duplicating the efforts of seed companies, but to evaluate the comparable performance of the main existing and new (eg DMR (downy mildew resistant type).

Cultivars evaluated:

Yates:	
Iceberg	Target, Magnum, Rhapsody
Cos	Ideal, LE 094, Nero
Rijk Zwaan:	
Iceberg:	Iglo, Remus, Adal
Cos	Donatus
SPS:	
Iceberg:	Silverado, Diamond
Cos	Regal
Hendersons:	
Iceberg:	Mercury, Charger, Buffalo
Cos	Verdi

The trials were observation trials with 2 replicates to give 30 plots. The two replicates will also allow the results to be analysed. The plots will be grown according to the commercial practices applied to the rest of the crop at the trial site. The crops will be assessed weekly at the same time as the monitoring is carried out at the main water and nutrient monitoring trial. Assessment will include disease and tipburn incidence.

The plots will be 3 metres long at the commercial plant spacing used by the participating grower which should provide a minimum of 21 plants per plot. Assessments will be based on the incidence of tipburn, disease and product quality including yield at harvest, head weight and size.

Trials were planted at Somerville, Werribee and Lindenow, on two occasions:

Somerville -	November 24 1998 and February 5 1999.
Werribee -	November 26 1998 and February 10 1999.
Lindenow -	December 7 1998 and February 22 1999.

A selection of commercially available lettuce seeds, were raised by a commercial seedling company. The seedlings were transplanted to grower prepared seed beds by hand. At the three trial sites, fifteen cultivars were evaluated, nine iceberg and six cos.

Twenty-five plants of each cultivar were planted in each plot in four rows on each plot. A randomised block design, with two replicates was used. Due to a germination failure with cv. *Mercury*, this cultivar was replaced in the second planting by *Yates 034*.

Plants were spaced at 35cm centres along two raised beds. At harvest, a random sub-sample of five plants of each cultivar was collected for assessment.

Several measurements were made of individual plants including:

-Total weight above ground (fresh weight, g)
-Trimmed head weight (g)
-Core length, and width (cm)
-Number of leaves
-Size of youngest fully expanded leaf, (YFEL)
-Incidence and severity of Tipburn or other conditions.

There was insufficient data to consider ranking the lettuce cultivar performance statistically for each location. The constraints of small numbers of samples and replicates, were redressed by combining the observations from the three locations and the two harvest dates to provide a valid overall comparison. The statistical analysis used a generalised linear mixed model which incorporated a logistic transformation of proportions into the form log (p/(1-p)). Standard errors of differences between pairs of means were calculated on the transformed data. The observed differences between the means of pairs of cultivars were then compared with the least significant difference calculated by the model.

6.1.2. Results

A comparison of the rates of tipburn amongst lettuce cultivars indicated that some cultivars may have a lower overall incidence of tipburn than do others, (fig 20).

The Iceberg cultivar *Silverado* appeared the most promising having the lowest incidence of tipburn on five of the six plantings, (the exception being the second planting at Lindenow). Overall, *Silverado* performed significantly better ($P<0.05$), than the other iceberg cultivars *Adal, Charger, Iglo, Magnum, Mercury, Rhapsody* and *Target*. The cultivar *Silverado* also performed better than *Buffalo* and *Diamond* ($p< 0.10$). There was insufficient data to make any meaningful conclusions regarding the performance of the cultivar *Yates 034*.

The cos lettuce, cultivar, *Nero*, was compared with each of the other cos cultivars for the first planting. *Nero* appeared the most promising cultivar, achieving the lowest incidence of tipburn. Nero displayed a significantly lower ($P<0.05$), incidence of tipburn than the cos cultivars; Ideal, *Verdi, LE094,* or *Regal.* The apparent differences in performance between *Nero* and *Remus* were not significant at $P=0.05$.

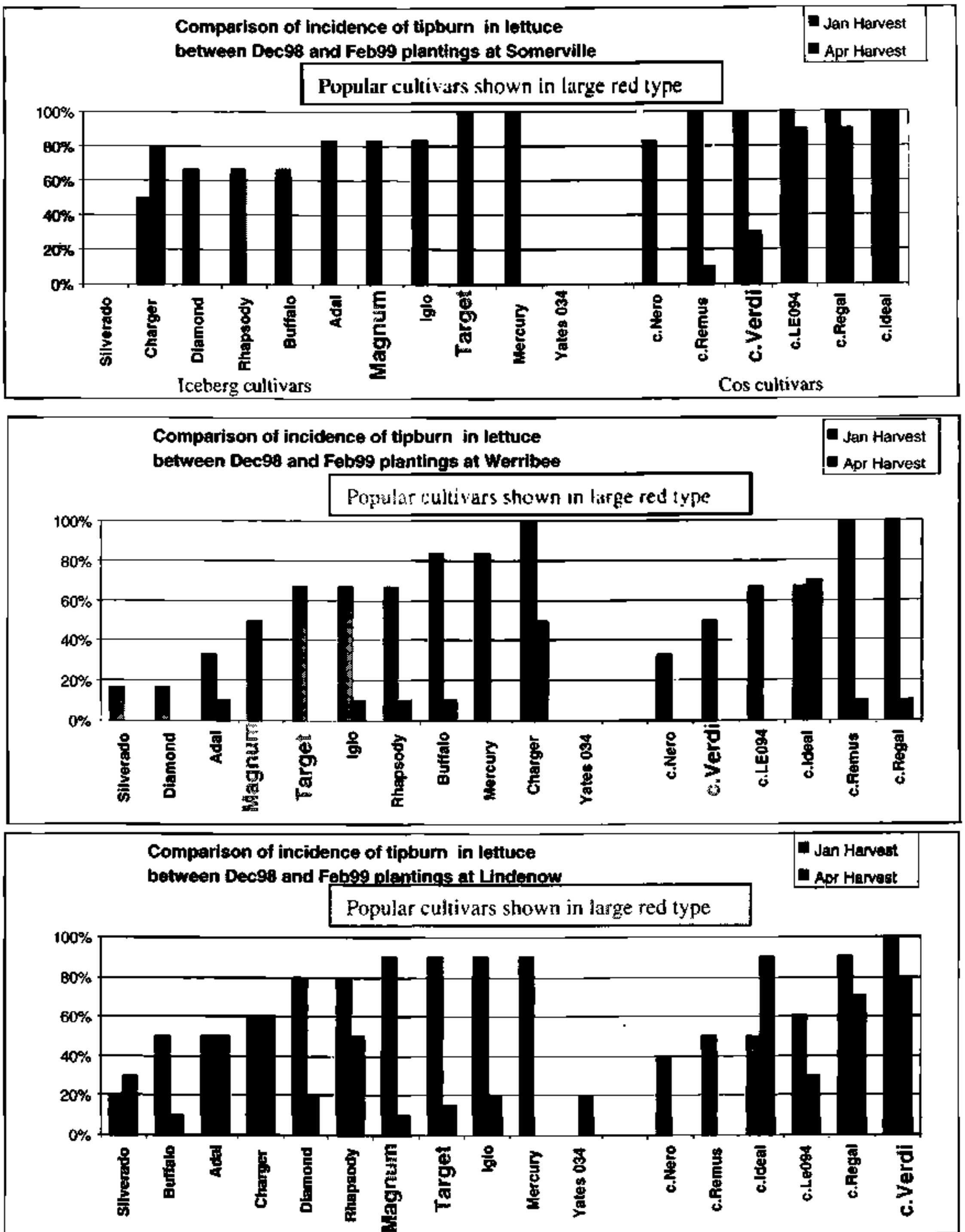


Fig 20. A comparison of tipburn incidence for 17 selected Iceberg and Cos lettuce cultivars grown at three Victorian locations during mid and late-summer 1998-1999.

6.2. Year 2 – 1999/00

6.2.1. Materials and Methods

Building on the first seasons findings, the second season evaluated fewer cultivars but from a more diverse genetic stock including salinas, desert and empire lines. These lettuce "types" vary in growth rates and plant structure. The aim will be to determine if these lettuce types consistently vary in their susceptibility to tipburn.

These trials will again be run through the key period for the incidence of tipburn. Fewer cultivars will mean that there can be more replicates and more statistically reliable results can be obtained. Cultivars were determined in conjunction with advice from the seed companies. Fourteen (14) cultivars, were raised by a commercial seedling company and hand transplanted to grower prepared seed beds, separated from the calcium supplement study.

Cultivars were planted late in January 2000 so that the trials were conducted during the peak tipburn season at single properties in each of the three, summer lettuce growing regions in Victoria.

Somerville:	Lat 38° 14' S	Lon 145° 12' E
Werribee:	Lat 37° 58' S	Lon 144° 41' E
Boisdale (East Gippsland):	Lat 37° 54' S	Lon 147° 00' E

At each trial site, 4 plots of each cultivar (each of approximately 50 plants), were grown on prepared raised beds using a randomised block design. As an improvement on the cultivar study of last year, a different randomised sequence was used at each site.

Plants were spaced on 35cm centres with 3 or 4 rows to each raised bed. On the morning of harvest, all plants were assessed for tipburn incidence. This physical inspection worked well with cos lettuce as it was possible to physically open each heart and identify both internal and external tipburn. With iceberg lettuce, it was not possible to inspect the heart leaves without destroying the plant so only visible external tipburn was assessed.

At each trial site, all cultivars were evaluated and harvested on the same day. It is possible that some early maturing cultivars were past their peak condition at these harvest dates. In addition, 20 plants from each plot were harvested and stored under controlled conditions for shelf-life evaluation.

Cutivars for Tipburn Assessment:

South Pacific Seeds

- Silverado (Salinas type used last season)
- Ponderosa (not a DMR variety but corky root resistant)
- Cos Lionheart ((3/4 size)

Henderson Seeds

- Cos Verdi

Rijk Zwaan

Claudette (suitable for spring, summer and autumn harvest)
Toronto (slow bolting and strong against internal tipburn, mildew resistant and LMV tolerant – suitable for spring summer and autumn)
Cos Donatus
Cos Rhonda (baby- slow bolting, can be grown year round)

Yates

Target
Raider (desert type with some resistance to tipburn)
Casino (salinas type which will be widely grown in Werribee this year following perceived resistance to tipburn last season)
Cos Nero (slower growing)

Lefroy Valley

Kingsway
Cos Cosmic

6.2.2. Results - 1999/00

A comparison of the rates of tipburn amongst selected lettuce cultivars confirmed last seasons findings that some cultivars have a lower incidence of tipburn than do others. For each trial site, those cultivars with a significantly reduced incidence of tipburn are marked with an asterisk. All iceberg cultivars performed well at Somerville with tipburn incidence less than 20%. At Boisdale, tipburn was more extensive, (>40%) with the cultivars Kingsway, Toronto, Casino and Ponderosa performing better than other cultivars. As the trials were only assessed at a single date, it is possible that some early maturing cultivars were not in peak condition at harvest and better performance could be expected with an earlier harvest date.

Observations at Boisdale support this view with some cultivars deteriorating markedly in the week prior to assessment.

Unfortunately the iceberg cultivars planted at Werribee were accidentally harvested before assessment although some iceberg cultivars were compared in the sequential planting study.
With cos lettuce, the cultivars Verdi, Donatus and Cosmic, achieved the lowest incidence of tipburn at all three locations. The apparent differences in performance between these three cos cultivars were not statistically significant.

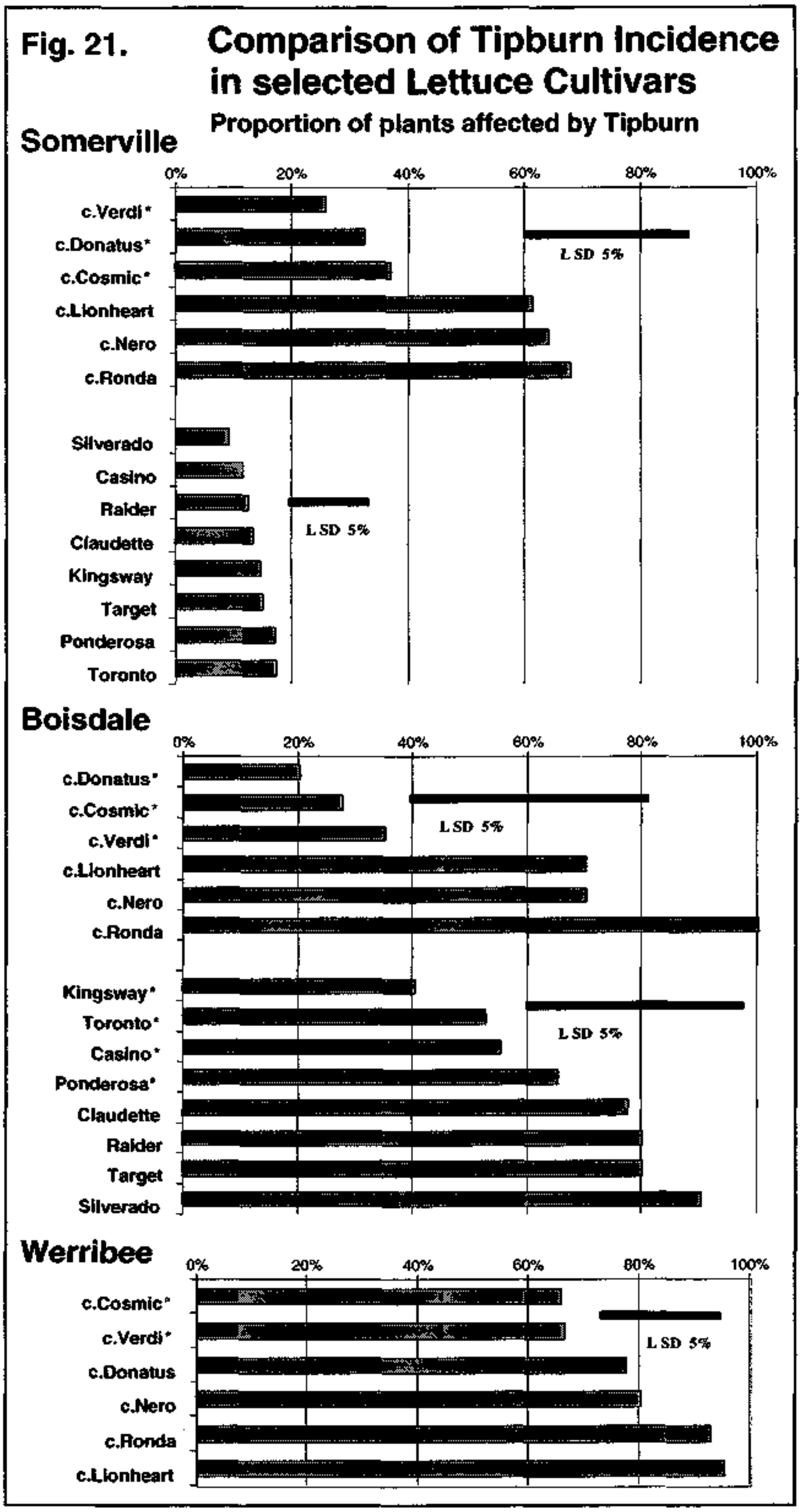


Fig. 21.
Comparison of Tipburn Incidence in selected Lettuce Cultivars
Proportion of plants affected by Tipburn
Somerville
0%
20%
40%
60%
80%
100%
c.Verdi*
c.Donatus*
c.Cosmic*
c.Lionheart
c.Nero
c.Ronda
LSD 5%
Silverado
Casino
Raider
Claudette
Kingsway
Target
Ponderosa
Toronto
LSD 5%
Boisdale
0%
20%
40%
60%
80%
100%
c.Donatus*
c.Cosmic*
c.Verdi*
c.Lionheart
c.Nero
c.Ronda
LSD 5%
Kingsway*
Toronto*
Casino*
Ponderosa*
Claudette
Raider
Target
Silverado
LSD 5%
Werribee
0%
20%
40%
60%
80%
100%
c.Cosmic*
c.Verdi*
c.Donatus
c.Nero
c.Ronda
c.Lionheart
LSD 5%

6.3. Year 3 – 2000/01

6.3.1. Materials and Method

Over the previous two seasons we evaluated a number of commercial and newer cultivars and identified differences in tipburn tolerance. A reduced number of selected cultivars were evaluated for their resistance to field diseases and disorders under existing grower management systems. The focus was on changes in the incidence of tipburn approaching harvest. Tipburn can occur rapidly near harvest and last season it was observed that there were changes between cultivars in the relative levels of tipburn during the few days preceding harvest.

Crops were monitored closely during the two weeks leading up to harvest and changes in sap calcium levels will be established. The trials were conducted at all 3 sites during January to Febuary 2001. Cultivar evaluation focused on lettuce types selected by the grower and included field evaluation for market acceptability by members of the project steering committee.

The Grower steering committee have commented that when considering the promotion of alternate varieties with improved tipburn tolerance, the market appearance of lettuce types must not be overlooked. It was decided that this season, each Grower would select trial cultivars appropriate to their production system.

The early February trial plantings at Lindenow were abandoned following severe growth setbacks caused by water restrictions.

Cultivars:

Yates	- Target, Raider and Casino
South Pacific Seeds	- Silverado, Sheeba, Lionheart (cos)
Rijk Zwaan	- Toronto
Henderson Seeds	- Verdi (cos)
Lefroy Valley	- Cosmic

Werribee Iceberg Cultivar Trials

Five iceberg cultivars, Sheeba, Casino, Raider, Silverado and Toronto were evaluated in a single planting on the red clay loam soils at Werribee from 18 January 2001

Lindenow Cos Cultivar Trials

The Cos cultivars Cosmic, Lionheart and Verdi are popular summer varieties in East Gippsland. Trials of these cultivars were planted at Lindenow on 10 January 2001.

6.3.2. Results
Iceberg Cultivar Trials

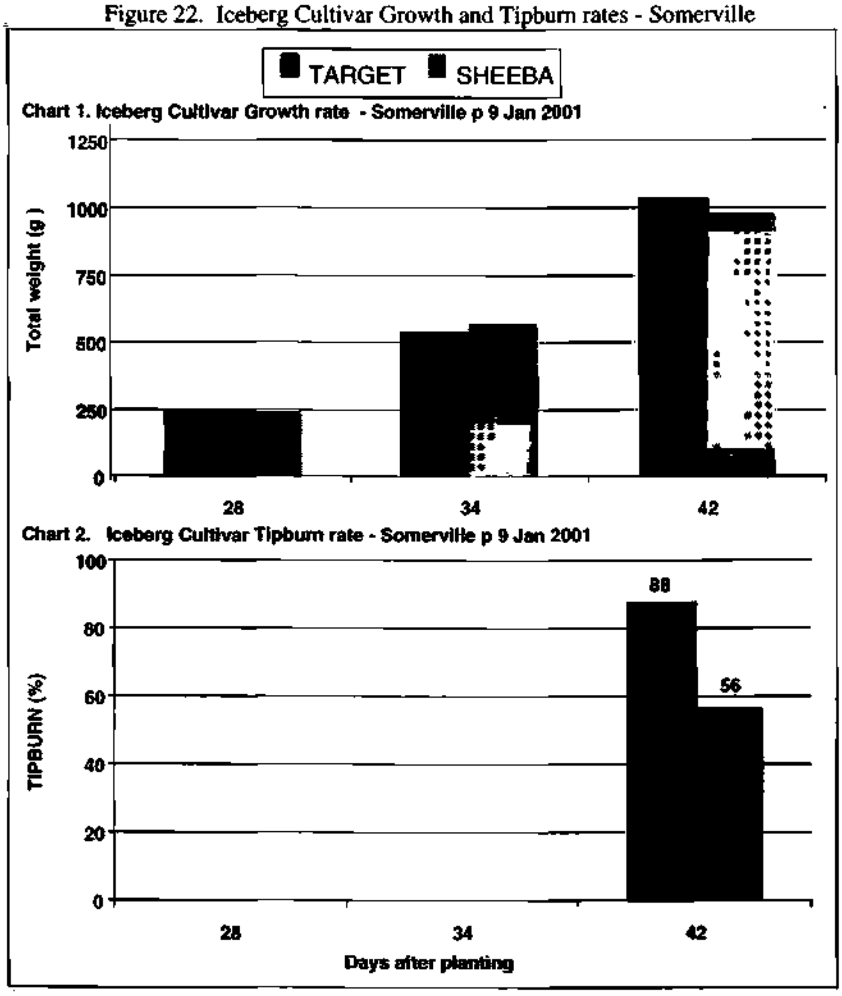
Crops were monitored closely during the two weeks leading up to harvest and changes in sap calcium concentrations were established.

Growth and Tipburn rates
Iceberg cultivars Target and Sheeba are popular summer varieties on sandy soils and growers have developed fertiliser and irrigation practices that best suit these varieties.

We did not observe any significant difference in growth rate or harvestable yield of the two varieties (figure 22, chart 1).

Cultivar Sheeba was generally more tipburn tolerant than Target (figure 22, chart 2). The incidence of tipburn in Sheeba was nearly 1/3 less than was observed in cv. Target which suggests that Sheeba would be better suited to mid-summer growing conditions. Sheeba has a lower growing habit than cv. Target and may have a higher risk of developing Sclerotinia root rot or Botrytis than varieties with a more upright habit under unsuitable conditions.

Figure 22. Iceberg Cultivar Growth and Tipburn rates - Somerville

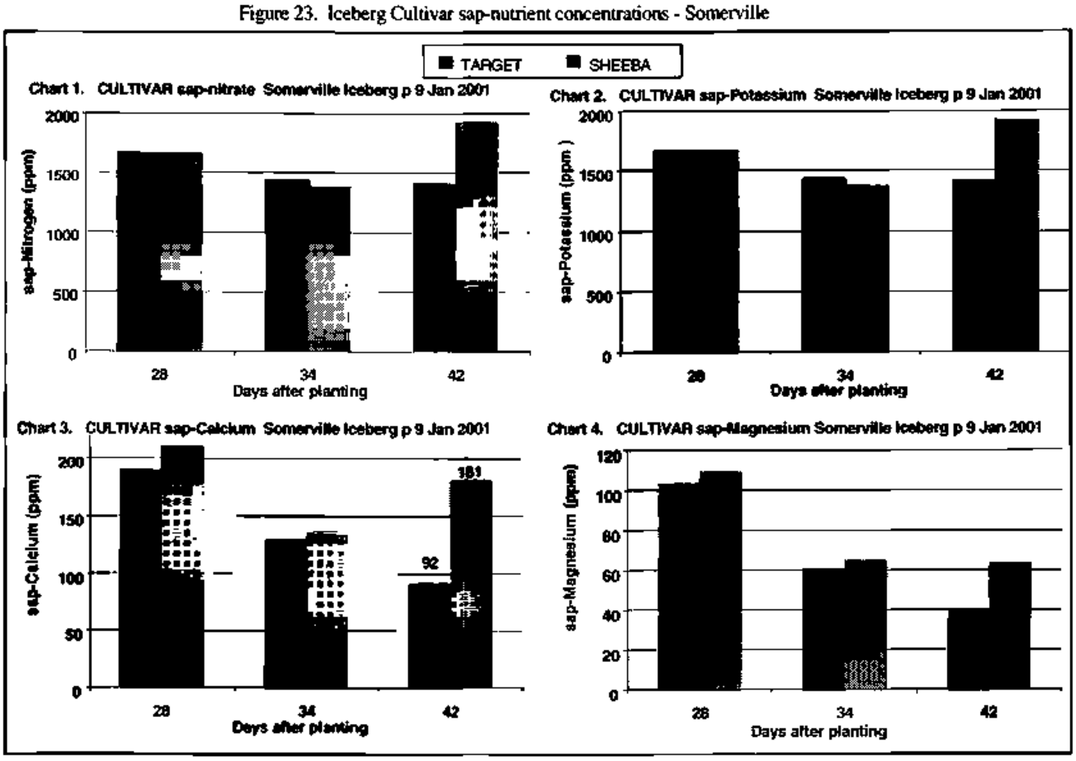


Leaf-sap nutrients

Cox etal. (1976) suggested that root development and root to shoot ratio are likely to play an important role in nutrient uptake and tipburn development in field grown lettuce. A tipburn sensitive cultivar was shown to have less root development than a more resistant variety. Other published research has shown a considerable portion of the lettuce root system dies back just prior to the onset of flowering (ie, harvest) (Rowse, 1974). Differences in cultivar tipburn sensitivity may be related to changes in root length or vigour close to harvest.

The sap analysis results for the Somerville cultivar study are shown in figure 23.

Figure 23. Iceberg Cultivar sap-nutrient concentrations - Somerville



While the growth patterns of both varieties were indistinguishable, Sheeba generally had higher concentrations of leaf-sap nitrogen, potassium, calcium and magnesium at harvest.

The root system in Sheeba is clearly more effective than Target close to harvest. Leaf-sap calcium in Sheeba was one of the highest values recorded near harvest and twice that found in Target. This may help account for the significantly lower incidence of tipburn in Sheeba.

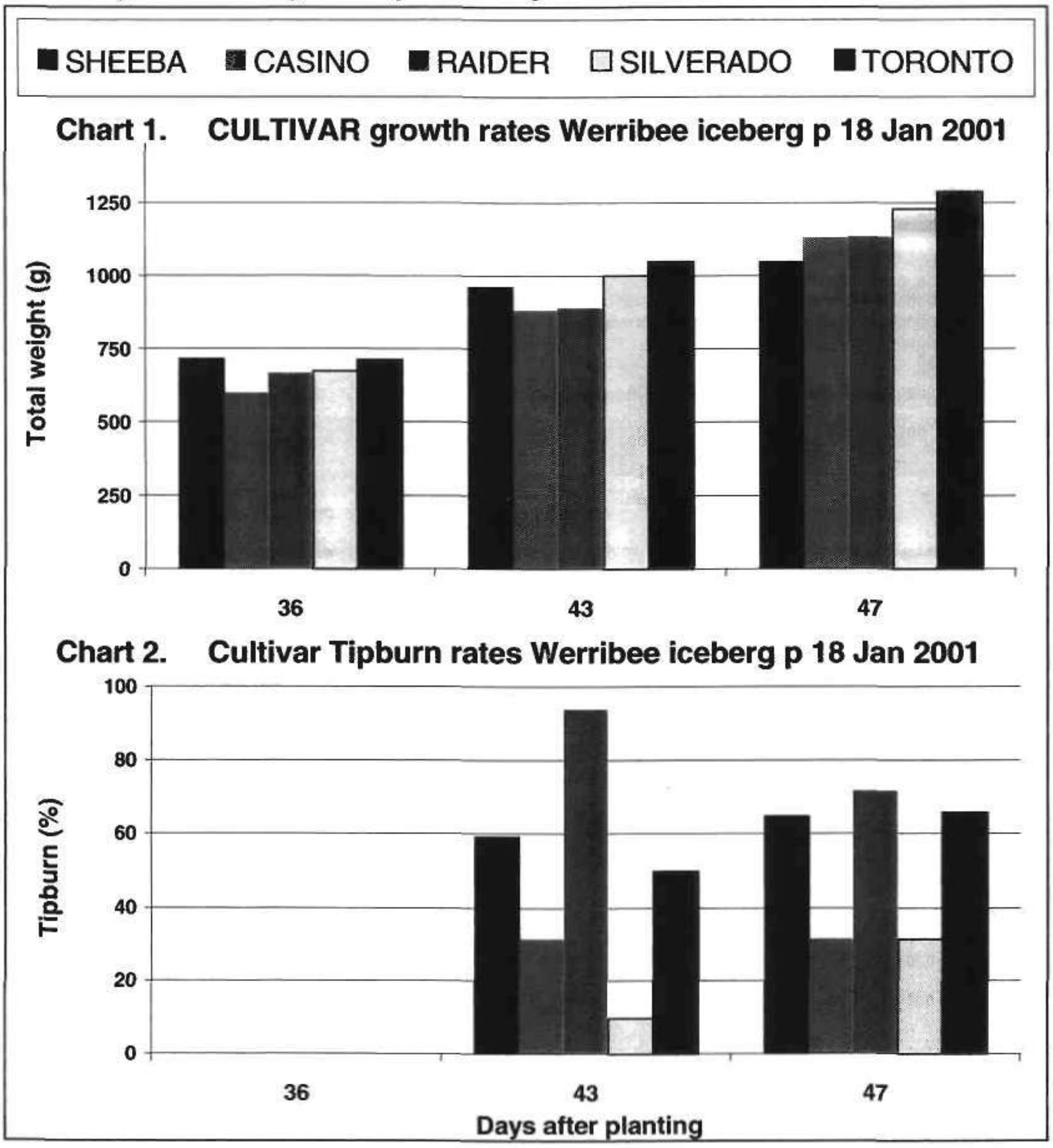
Our work with calcium supplements over the past two years failed to generate such dramatic changes in leaf-sap calcium as can be achieved by changing cultivars.

Werribee iceberg variety trials

Growth and Tipburn rates

Five iceberg cultivars, Sheeba, Casino, Raider, Silverado and Toronto were evaluated in a single planting on the red clay loam soils at Werribee from 18 January 2001 (figure 24).

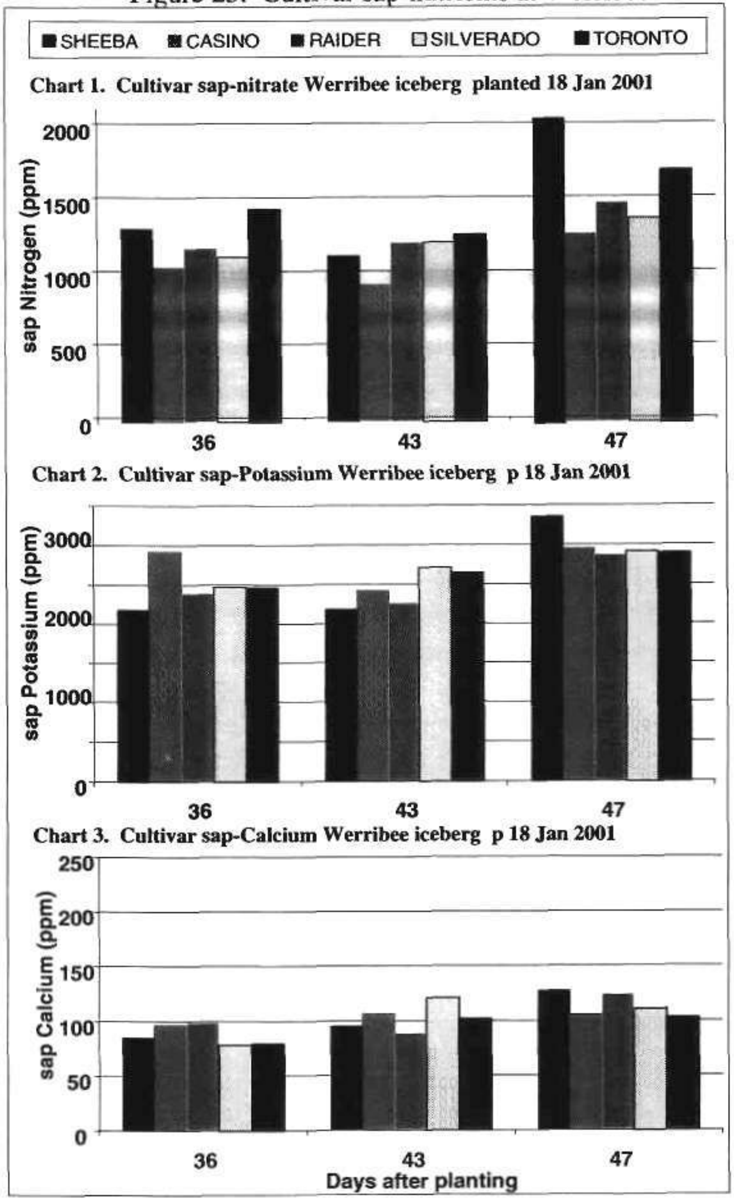
Figure 24 .Iceberg cultivar growth and tipburn rates at Werribee



The largest varieties at harvest were Toronto and Silverado (figure 24, chart 1). Sheeba established quickly but growth fell behind the other cultivars in the final 3-4 days before harvest.

Varieties Silverado and Casino generally had the lowest incidence of tipburn in the week up to and including harvest (figure 24, chart 2). These two varieties also had the highest sap-calcium at day 43 (see figure 25, chart 3). The incidence of tipburn in Casino did not change during the 4 days prior to harvest providing the grower with a wider harvest "window". Other varieties generally developed more tipburn in the last days before harvest. The exception was Raider, which appeared to recover from severe tipburn in the last few days before harvest. Raider is a very successful processing variety used extensively in Queensland but performed poorly in this January planting at Werribee. The grower reported that Raider performed much better in the February plantings.

Figure 25. Cultivar sap-nutrients at Werribee



Leaf-sap nutrients

The sap analysis results for the cultivar trials at Werribee are shown in figure 25. Throughout this cultivar trial, the grower applied fertiliser to the crop by fertigation through the overhead sprinkler system.

Although the concentration of leaf-sap nitrate was less than 'desirable' the growth rate and yield were not visibly affected (figure 25, chart 1). As we observed at Somerville, Sheeba generally had the highest concentrations of leaf-sap nitrogen, potassium and calcium at harvest. The cultivar Sheeba generally had greater concentrations of sap-nutrient than many other cultivars close to harvest.

Leaf-sap potassium in all cultivars was also marginally below desirable limits, (2500-4000 ppm) until harvest, (figure 25, chart 2).

This was the first season the grower used fertigation and sap analysis suggests the crop may benefit from a minor application of nitrate and potassium.

The higher concentrations of leaf-sap calcium at day 43 in cultivars Silverdo and Casino (figure 25, chart 3) corresponds well with the lower incidence of tipburn in these varieties in the few days up to and including harvest.

The apparent recovery of Raider from severe tipburn in the last few days before harvest may also be linked to the increase in leaf-sap calcium observed during this period.

Cos Trials

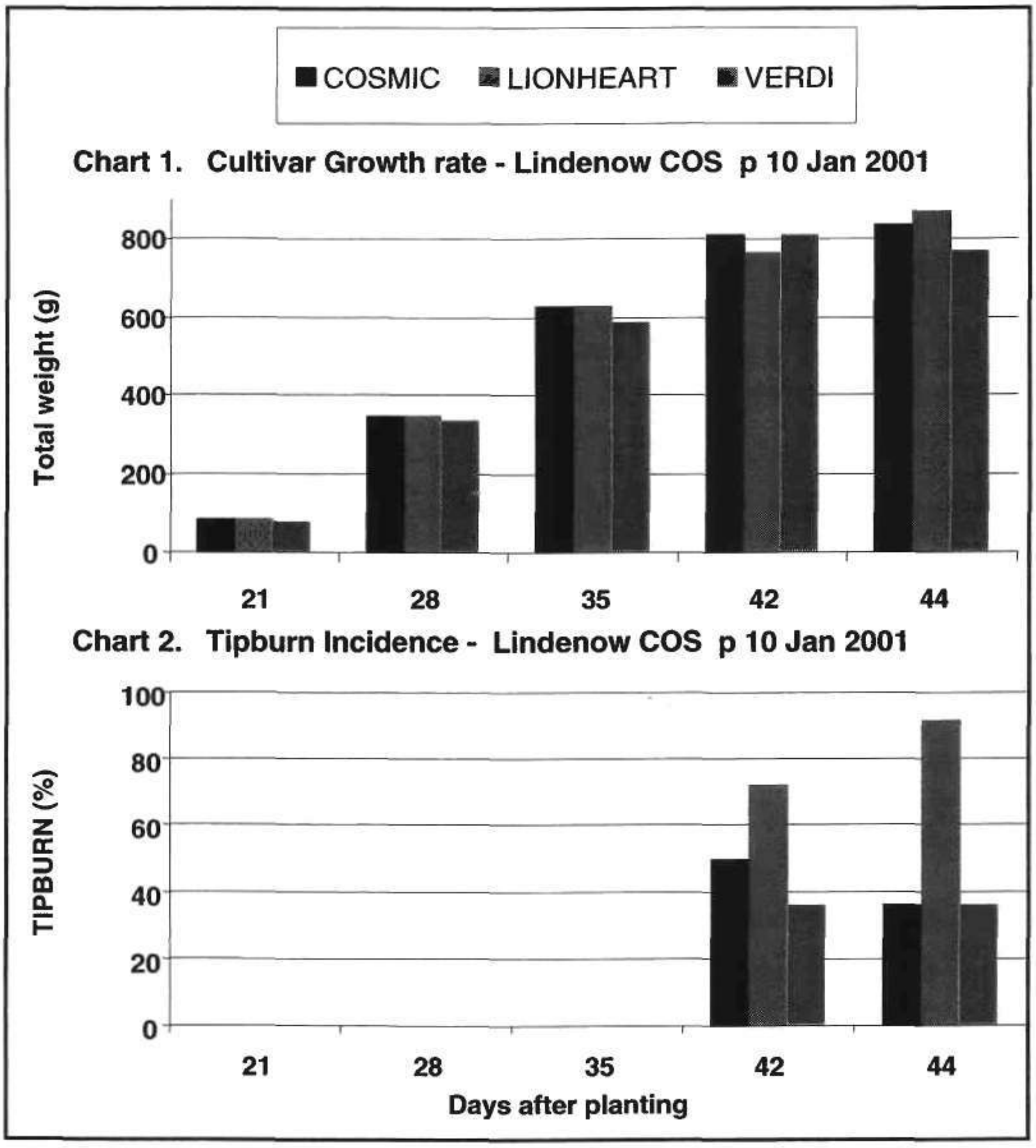
Lindenow Cos cultivar trials

The Cos cultivars Cosmic, Lionheart and Verdi are popular summer varieties in East Gippsland. Trials of these cultivars were planted at Lindenow on 10 January 2001.

Growth and Tipburn rates

The apparent differences in growth rate and average harvest weight between cultivars were not statistically significant, (figure 26, chart 1). Lionheart generally appeared to have a higher incidence of tipburn, but because the samples were bulked the statistical significance of these differences could not be established.

Figure 26. COS Cultivar Growth and Tipburn rates - Lindenow.



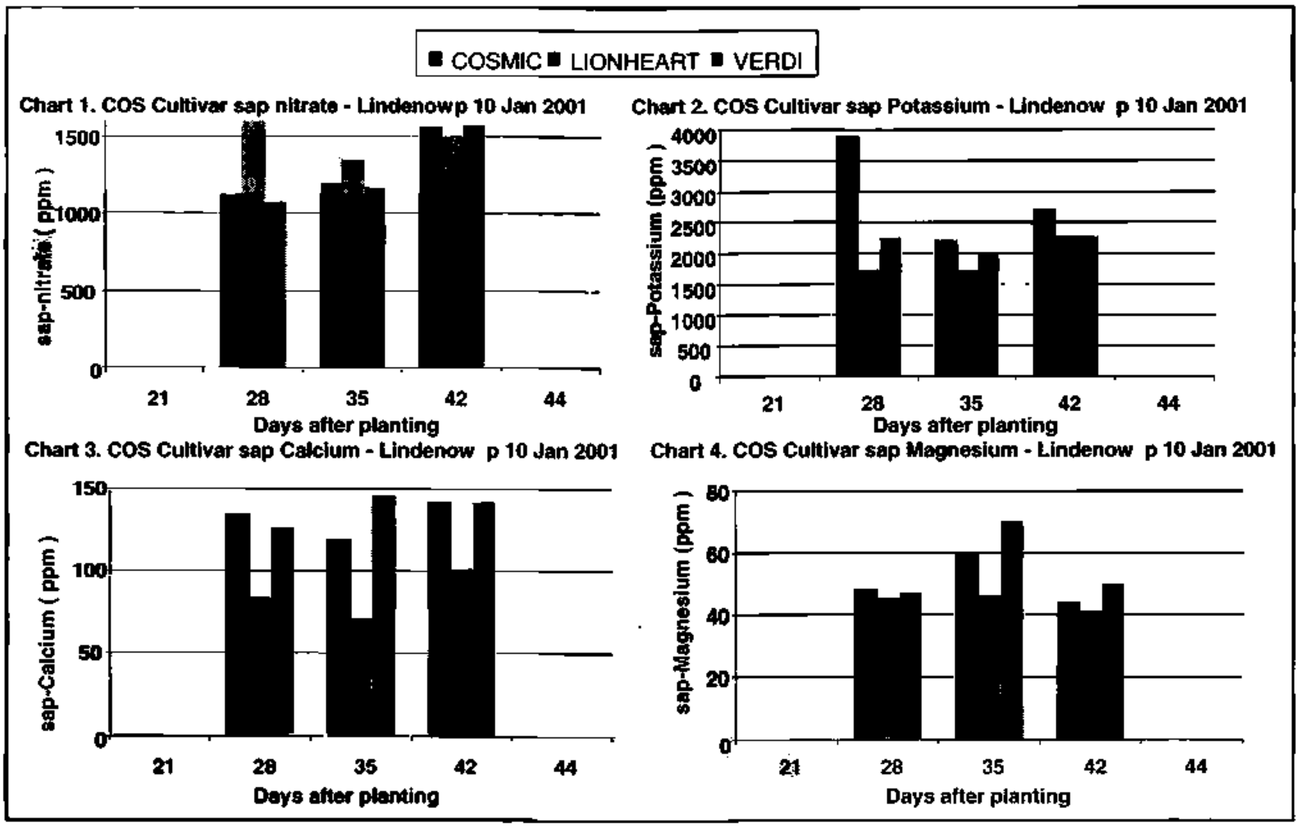
Grower comment:

The size of the three cultivars looked different in the field, Lionheart had a taller more upright habit with a tighter heart and looked bigger but all three cultivars had the same average weight. Cosmic and Verdi were cultivars with denser heads.

Leaf-sap Nutrients

The concentration of leaf-sap nitrate for all three cultivars was generally within "desirable" limits at harvest, (1500-2000 ppm). The Lionheart cultivar appeared to have a higher sap-nitrate concentration at day 28 but this difference diminished closer to harvest. (figure 27, chart 1).

Figure 27. COS Cultivar sap-nutrient concentrations - Lindenow.



In all three cultivars, leaf sap potassium was generally below the "desirable " limits, (2500 – 4000 ppm) with the exception of Cosmic at day 28, (figure 27, chart 2). In all trial plantings, the calcium concentration in the leaf-sap was well below "desirable" limits (400-600 ppm). The low tipburn cultivars Cosmic and Verdi appeared to have higher calcium concentrations than Lionheart, (figure 27, chart 3). Although we cannot generalise between cultivars, the ratio of leaf-sap nitrate to calcium at hearting was related to a higher incidence of tipburn at harvest, (table 1). This conflicts with the observations of the nutritional trials at Lindenow which suggested high sap-nitrogen to calcium ratio at hearting resulted in a lower incidence of tipburn. This important contradiction also needs further investigation before sap ratios can be used as successful predictors of tipburn.

Table 1. Nitrate to Calcium ratio - COS Cultivars - Lindenow.

	Nitrate to Calcium ratio -COS Cultivars planted Lindenow 10 Jan 2001		
% GROWTH	COSMIC	LIONHEART	VERDI
64	8.3	19.3	8.6
80	10	18.9	8.0
95	11	14.8	11.1
Harvest Tipburn (%)	36	92	36

6.4. Discussion

In year 1 cultivars grown under the same field conditions varied in their susceptibility to tipburn. The iceberg cultivar Silverado and the cos cultivar Nero, both showed a significantly greater tolerance to tipburn at all three sites compared with the other cultivars in the study.

There was variation between cultivars in susceptibility to tipburn and it should be possible to select suitable cultivars with tipburn 'resistance'. There was also variability between cultivars in resistance to downy mildew.

In year 2 the cultivar trials were more specific focussing on Desert types and Salinas types of iceberg lettuce and the slowing growing cultivars, which it appears are more likely to be resistant to tipburn.

Cultivars differed in susceptibility to tipburn throughout the season and varied in their susceptibility to tipburn as they approached maturity. The results also indicated that the iceberg cultivars Raider, Casino and Ponderosa had better keeping qualities. The cos cultivars Verdi, Donatus and Cosmic, achieved the lowest incidence of tipburn at all three locations.

Other results from the trials indicate that cos lettuce requires specific management to reduce incidence of tipburn and intercropping cos with iceberg lettuce appears to result in a higher incidence of tipburn. Variation and rapid onset of tipburn close to harvest indicates that it is important not to delay harvesting the crop as the tipburn severity continues to increase as does the risk of damage from grubs and soft rots.

In year 3 the focus was on changes to the incidence of tipburn approaching harvest for cultivars and assessing variations between cultivars approaching harvest.

At Somerville, the iceberg cultivar Sheeba developed less tipburn than the cultivar Target while at Werribee, the iceberg cultivars Silverado and Casino showed the lowest incidence of tipburn. At harvest, the iceberg cultivar Sheeba, generally showed a higher concentration of sap, nitrate, calcium and potassium than was seen in other cultivars.

The incidence of tipburn in the cultivar Casino did not change during the 4 days prior to harvest providing the Grower with a greater harvest "window" than most other cultivars.

At Lindenow, the cos cultivars Cosmic and Verdi appeared to have higher calcium concentrations and lower incidence of tipburn than Lionheart.

In well fertilised soils, harvesting 3 days earlier can reduce tipburn by as much as 30 to 50%.

Variations between cultivars provided the most dramatic changes in leaf-sap calcium in comparison with any of the other treatments applied to lettuce crops over the course of the trials. Cox etal. (1976) have suggested root development and root to shoot ratio are likely to play an important role in nutrient uptake and tipburn development in field grown lettuce. Differences in cultivar tipburn sensitivity may be related to changes in root length or vigour close to harvest.

7. Nutrition

7.1. Year 2 - 1999/00

7.1.1. Materials and Methods

In year 2 trials were set up to address the key issues identified following the monitoring for sap nutrient levels, growers fertiliser and other management practices in year1. Low calcium levels within the plant were identified and these continued to fall after hearting commenced. Hearting was a critical point and the potential for tipburn increased significantly after hearting. One approach to reducing the incidence of tipburn is to endeavour to increase the levels of calcium in leaf sap to an optimum level.

Application of Calcium Supplements

This trial evaluated the application of calcium supplements by foliar sprays. The aim was to determine if the levels of calcium in the plants can be raised and assess the impact on tipburn.

A number of foliar calcium supplements are commercially available for this purpose and used in a wide range of other horticultural applications. Foliar applied calcium can enter leaves in a variety of forms but is usually rapidly fixed and not translocated to other parts of the plant. However, the addition of certain cations or chelating agents can induce translocation of calcium, (Millikan and Hanger, 1964).

We evaluated three common, commercially available foliar supplements based on the simple inorganic forms: Calcium Chloride, Calcium Nitrate and Calcium Carbonate compared with an untreated control. Trials were conducted at the three Victorian sites in November 1999 and again in February 2000. At each trial site, a commercial planting was divided into 16 plots, each of approximately 144 plants. Each of four treatments was allocated four plots following a randomised block design. Treatments were applied by a powered knapsack unit on day 14, 21, 28 and 35 after transplant. The spray unit was calibrated and each treatment application was standardised to apply 1360g Ca/ha, the equivalent of 11mg Calcium per plant.

Plant assessment and sampling was conducted just before the spray treatments were applied.Treatments were assessed in three ways:

- Each week, all plants in all plots were assessed for tipburn incidence. After hearting it was only possible to assess external tipburn using this method.

- A further eight randomly selected plants from each plot were harvested weekly, weighed to assess crop growth rate and assessed for internal tipburn.

- At establishment, early hearting and at harvest, eight plants were collected from each plot prior to the application of treatments. Composite samples of the youngest fully expanded leaf (YFEL) were collected from each of the four replicate plots of each of the four treatment. These 16 composite samples from each site were then forwarded for leaf sap analysis for N, K, and Ca.

7.1.2. Results

Crop Growth Rates

The application of foliar Calcium supplements did not alter the growth rate of summer lettuce crops, (fig 28).

Differences in crop growth rates were evident between different locations, early / late summer plantings and between cos and iceberg crops. However, the growth rate of plants treated with different calcium supplements, were not significantly different from each other, or untreated plants. These findings show that trace amount of nutrients in calcium foliar supplements did not have a significant impact on crop growth rates.

Werribee

The grower was able to harvest a heavier crop in late December 1999. The late February 2000 crop was harvested just as the growth rate began to slow down.

Somerville

The late February 2000 cos harvest was a few days past its peak when assessed. This planting was not commercially harvested

Lindenow

Cos was accidentally harvested before final assessment but initially appeared to be growing similar to the crop at Somerville.

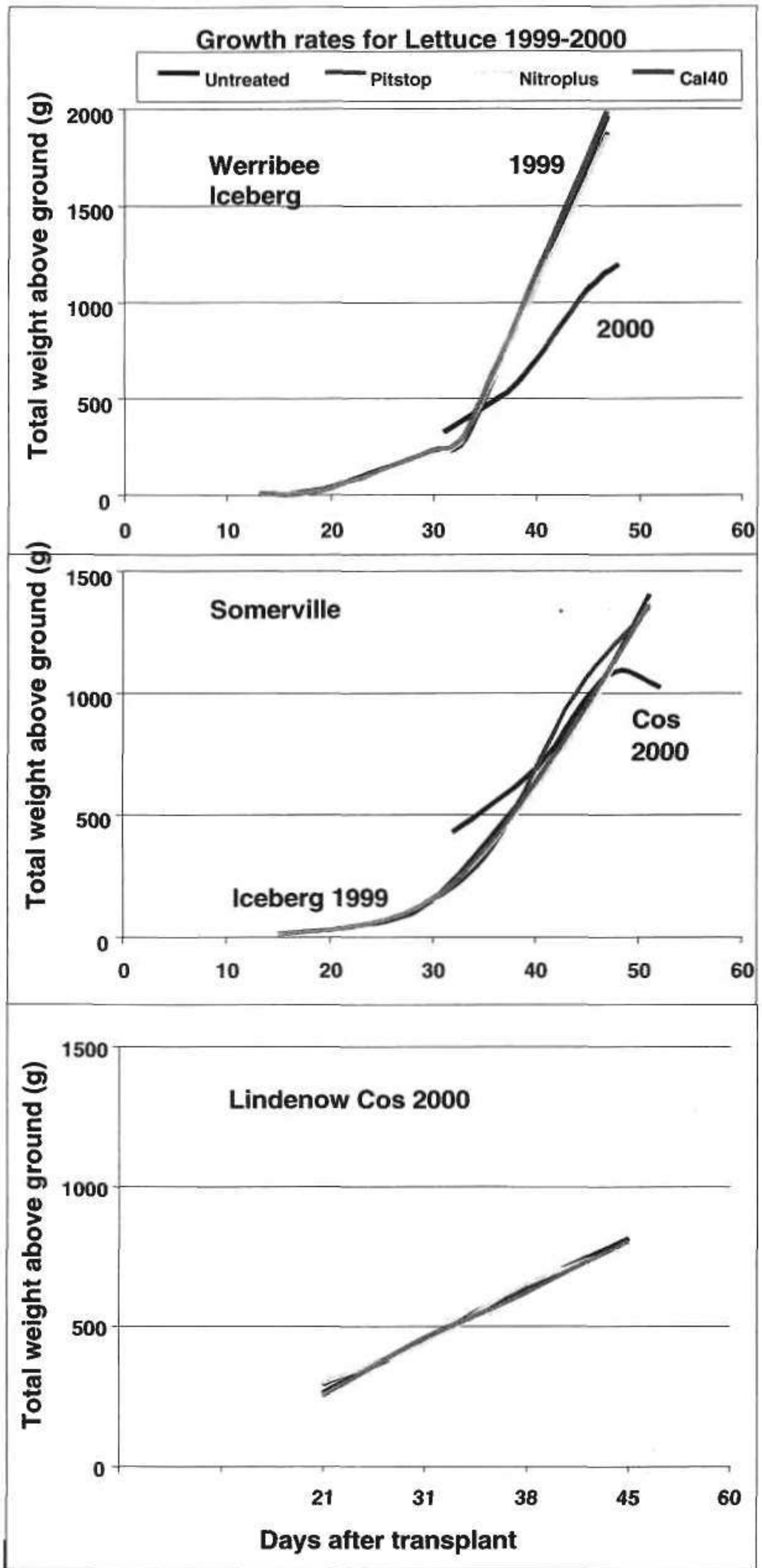


Figure 28. Crop growth rates for summer lettuce treated with Calcium supplements grown at three Victoria locations

Sap Nitrate

Satisfactory leaf-sap nitrate guidelines for lettuce are 1800-2700ppm at hearting decreasing to 1500-2000ppm at harvest, (SERVE-AG, 1999). Low values may impede growth while high values can reduce the shelf life of the harvest. Differences in leaf-sap nitrate were observed at different growth stages, location, and between cos and iceberg crops, (Figure 29). However, there were no significant differences between plants treated with different calcium supplements and untreated plants.

The observed changes in leaf-sap nitrate were consistent with the results from the 1998-1999 season.

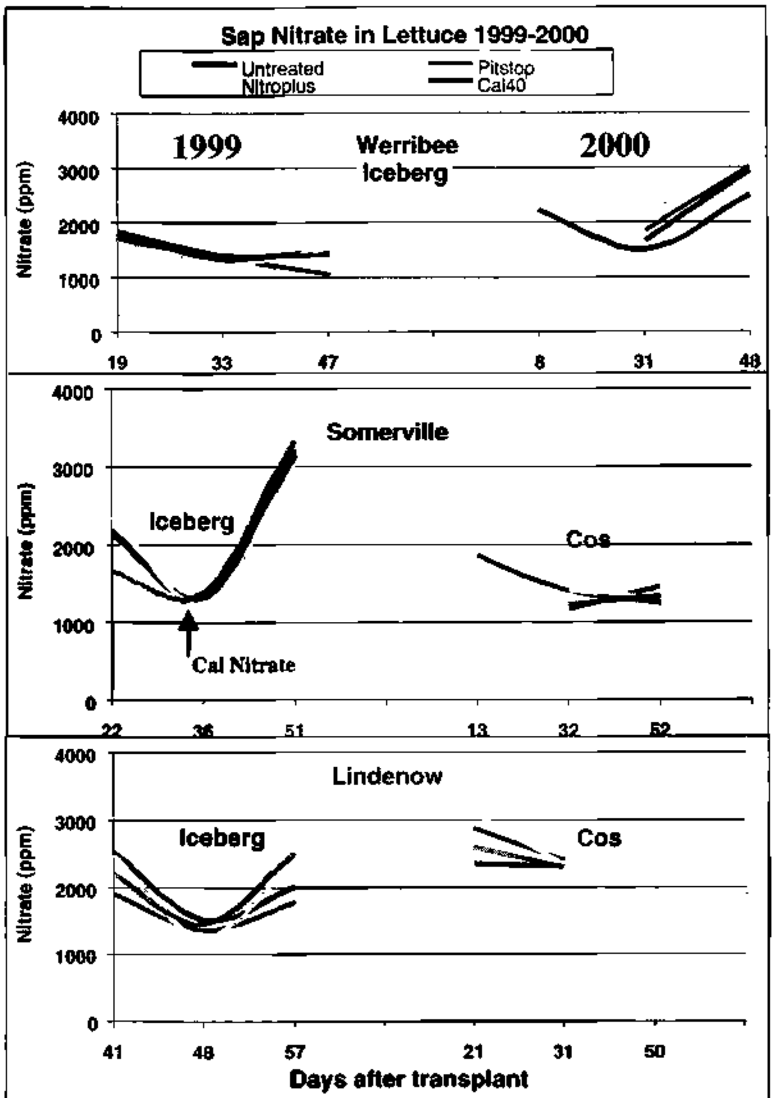


Fig 29. Concentration of leaf-sap nitrate in summer lettuce treated with different calcium supplements

Werribee

The 1999 crop performed well and leaf-sap nitrate was maintained within the optimal range. Foliar calcium nitrate was applied to the 2000 crop by the grower and may account for the high values at harvest.

Somerville

The high sap nitrate at December harvest can be attributed to nutrient uptake following application of calcium nitrate at hearting. The sap nitrate concentration of the 2000 cos crop was optimal throughout.

Lindenow

Sap nitrate concentrations in the 1999 iceberg crop increase near harvest but were not significantly above the guidelines. The 2000 Cos crop appears to be oversupplied with nitrate.

Sap Potassium

Guidelines for optimal lettuce leaf-sap potassium are 2600-4000ppm, (SERVE-AG, 1999).

There was generally a decrease in leaf-sap potassium between establishment and hearting and a recovery at harvest in some iceberg plantings but not with cos, (figure 30).

Although differences in leaf-sap potassium concentrations were observed at different stages of growth, and at different locations, there were no significant differences between plants treated with different calcium supplements and untreated plants.

Concentrations of potassium in leaf-sap did not fall below the optimal range although all plantings were initially above optimum. The soil potassium test results generally remained within the optimum range, an improvement over the previous seasons results.

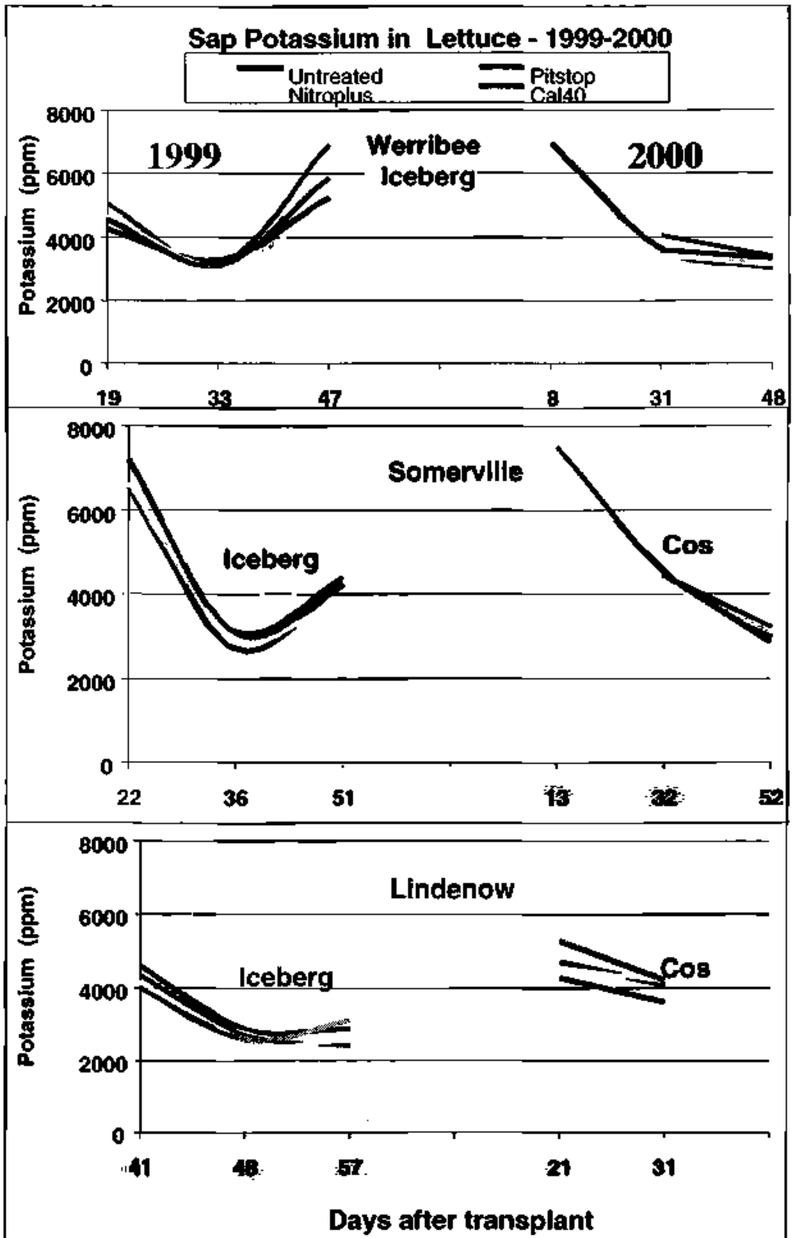


Fig 30. Concentration of leaf-sap Potassium in summer lettuce treated with different calcium supplements

Sap Calcium

Guidelines indicate that the leaf-sap calcium concentration should be maintained between 400-600 ppm throughout the life of the crop, (Serve-Ag, 1999). However for iceberg lettuce, leaf-sap calcium rapidly falls below the acceptable limit. There may be a partial recovery towards harvest possibly due to application of calcium nitrate at hearting, but leaf-sap calcium was still inadequate, (fig 31).

In cos, there was a rapid decrease below the acceptable limit and no recovery. These results are consistent with our 1998-99 season findings. The apparent differences in leaf-sap calcium concentrations between plants treated with different calcium supplements were not significantly different from untreated plants.

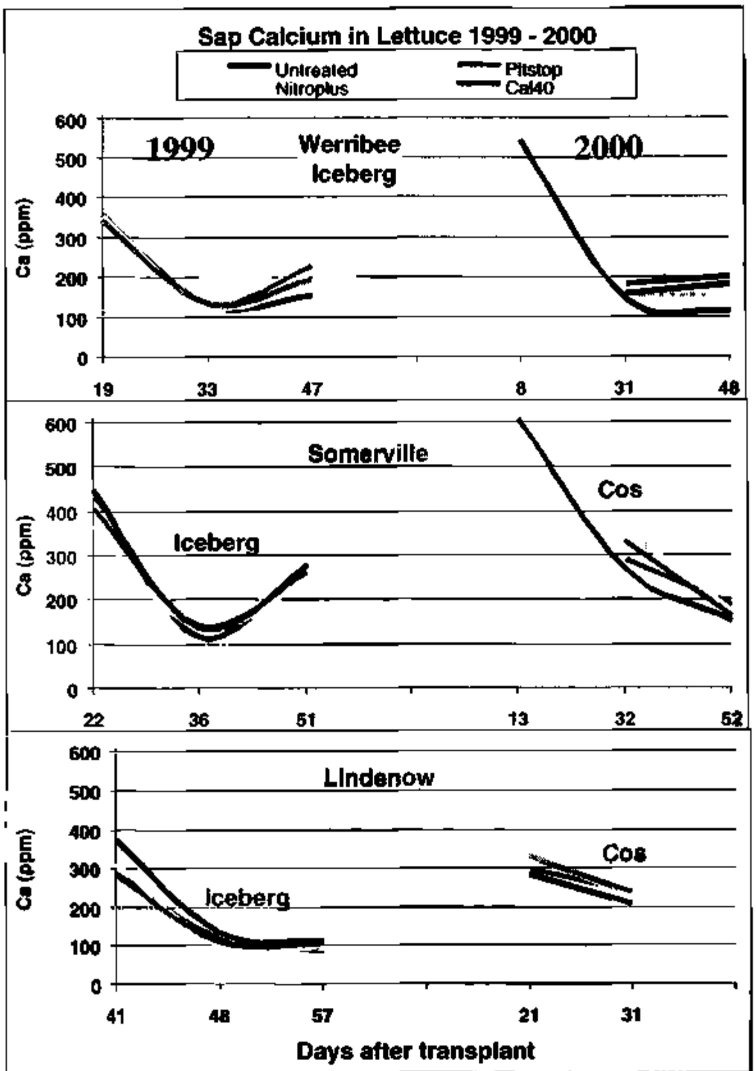


Fig 31. Concentration of leaf sap - Calcium in summer lettuce treated with different Calcium supplements.

The failure of calcium supplements to raise sap calcium concentrations may be due to:

a) Ineffective adsorption through the leaf surface, possibly by rapid drying of the spray treatment on foliage and/or removal by irrigation before absorption.

and/or

b) Immobilisation of absorbed calcium in the outer leaves which received the spray which prevented translocation of calcium to the enclosed developing heart leaves.

Tipburn

The proportion of lettuce plants with tipburn changed as the crop matured (fig 32).

The development of external tipburn was first seen in the 1999 crops as they began to heart. This early damage appeared to repair as the leaves matured.

As hearting continued to develop, the number of plants with tipburn increased. In the few days before harvest, the number of plants with tipburn increased dramatically.

Harvesting the crop early is usually not an option, especially for correct sizing of iceberg lettuce. The plant can double in weight during the week prior to harvest.

However, it is important not to delay harvesting the crop as tipburn severity continues to increase as does the risk of damage from grubs and soft rots. An example of the need for timely harvest was observed with the 2000 cos crop at Somerville. The crop was ready to harvest at day 47 and the rate and severity of tipburn increased dramatically over the following 5 days.

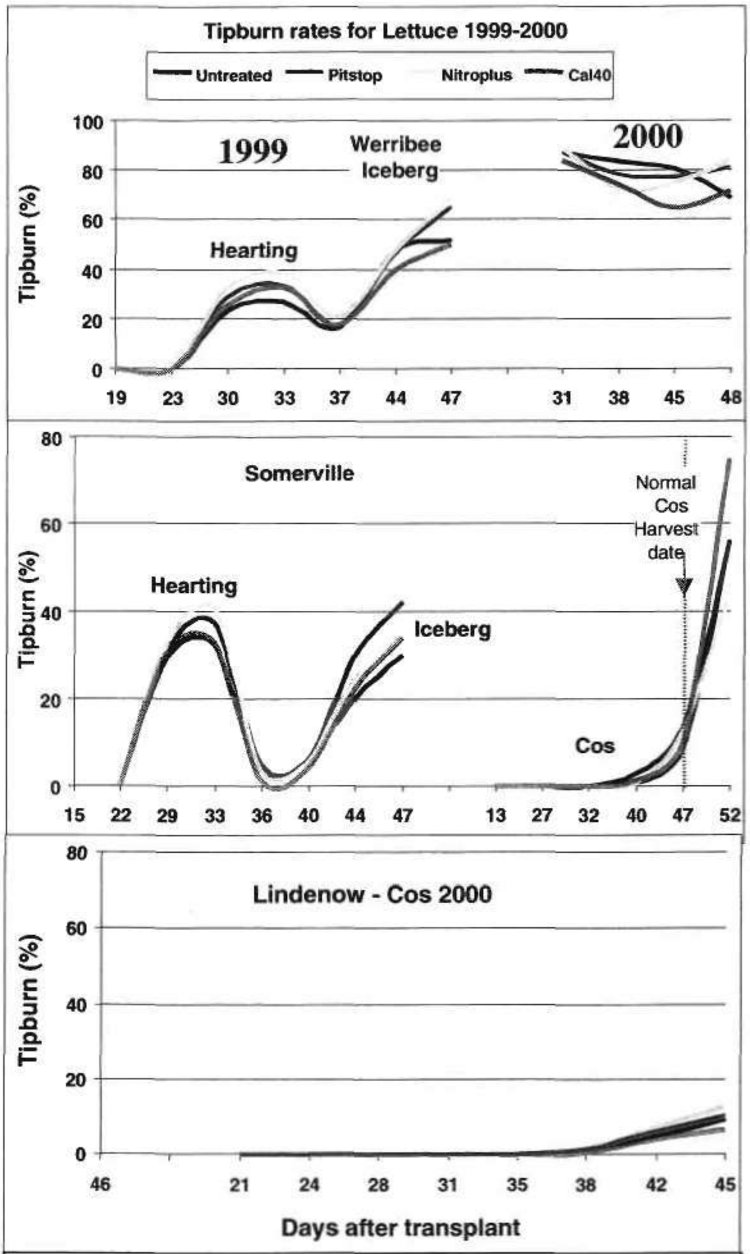


Fig 32. Incidence of Tipburn in summer lettuce treated with different Calcium supplements.

Usually, external tipburn can be excluded at harvest but any internal tipburn may not be immediately noticeable without pulling the plant apart. Internal tipburn is a real problem for summer lettuce growers because it affects some plantings more than others and it may not be visible at harvest.

7.2. Year 3 - 2000/01

7.2.1. Materials and Methods

This project has confirmed the relationship between rapid crop growth rate, falling sap-calcium concentrations and an increased incidence of tipburn. Attempts to increase calcium levels within plants by using supplementary foliar applications of calcium and the claims of effectiveness have not been substantiated by trial results. Following the previous seasons work the next step was to evaluate and modify existing nutrient inputs into crops.

Winter" Lettuce – a baseline

To establish baseline growth and sap-nutrient trends in lettuce plants grown without the climatic stresses experienced with summer lettuce production a small (unreplicated) demonstration trial was undertaken at Werribee between July and October 2000. The opportunity was also taken to study the effect of reducing potassium input compared with the Growers existing fertiliser practice. Immediately after transplant, Nitrobor® (15.5-0-0-19Ca + Boron) was applied followed by Rustica® (12-5-14) at early hearting (before row closure). For the low Potassium treatment we replaced the Rustica ® application with sufficient Nitrobor ® to provide the equivalent amount of nitrogen.

Summer Trials

Reducing nitrogen fertiliser input may be able to reduce growth rate and lower the incidence of tipburn. Similarly, potassium is a known antagonist of calcium uptake and reducing potassium fertiliser input may improve calcium uptake and reduce the incidence of tipburn. Potassium levels are generally high and there are reports that lettuce can be successfully grown using calcium nitrate alone, using residual soil potassium from previous crops. This trial also addressed the question of whether the changes in the concentration of sap-nutrients observed at all sites around day 36 are the result of the plants normal development or luxury uptake of fertilisers applied at this time.

The trial evaluated the effect of reducing normal grower potassium and nitrogen fertiliser inputs on leaf-sap calcium and the incidence of tipburn. The aim will be to determine if the levels of calcium in the plants can be raised and the effect on tipburn.The trials were conducted with Iceberg and Cos lettuce grown at three Victorian locations during the summer of 2000-2001 (table 1). The Nutrition trial treatments were variations of the Growers current fertiliser programs.All trials followed unique replicated random block designs prepared and analysed by Dr Vince Matassa (Biometrician VIDA-Horsham) using Genstat 5, to identify any significant effects of fertiliser treatments or cultivar on tipburn incidence.

Iceberg and Cos lettuce trials are discussed under separate headings to aid clarity.

Table 2. Location and timing of Nutrition and Cultivar trials.

Location	Nov-Dec 2000	Jan-Feb 2001
Lindenow	Iceberg & Cos Nutrition	COS Nutrition & Cultivars
Somerville	Iceberg Nutrition	Iceberg Nutrition & Cultivars
Werribee	COS Nutrition	Iceberg Nutrition & Cultivars

Nutrition trial treatments were based on the Grower current practice on the properties involved. Variations on the Grower treatment involved equivalent applications of nitrogen as Nitrobor® and potassium as Potash as described in table 2.

Table 3. Fertiliser treatments used in nutrition trials

Treatment	Fertiliser Application Strategy
Grower	RUSTICA® (12-5-14) at planting then NITROBOR® (15.5-0-0) + Boron, before row closure. **Current practice.**
Potash only	Potassium Sulphate (0-0-41) at planting, **No added Nitrogen**.
Cal Nitrate only	Calcium Nitrate (15.5-0.0 + Boron), **No Added Potassium.**
None added	Nutrients from previous crop, **No added Nitrogen or Potassium.**

Note: Application rates at each site are commercially sensitive and were provided "in confidence", accordingly, these details have been withheld.

Each treatment was replicated four times at each location. Each week, eight plants were collected from each plot for analysis. A composite sample was analysed for each treatment. On at least one occasion in each trial, all 16 plots were analysed separately to provide an estimate of variability between and within treatments.

Iceberg

Lindenow Iceberg Trials - The first nutrition trial with "summer" lettuce at Lindenow was conducted with the iceberg cultivar Toronto planted on the 12th of December 2000.

Sommerville Iceberg Trials - The first nutrition trial at Somerville was conducted with iceberg cultivar Target planted December 6, 2000.The second nutrition trial at Somerville with the cultivar Sheeba was planted on January 9, 2001.

Werribee Iceberg Trials - The first nutrition trial at Werribee used the summer iceberg variety Casino planted on of January 17, 2001.

Cos

Lindenow Cos Trials - The first cos nutrition trial at Lindenow was planted on December 19, 2000. The cultivar Cosmic was used and had shown good tolerance to tipburn last season. The second cos nutrition trial at Lindenow was planted on 24 January 2001. Werribee Cos Trials – The cos nutrition trial at Werribee was planted November 28, 1999 using the cultivar Nero.

7.2.2. Results Winter Lettuce

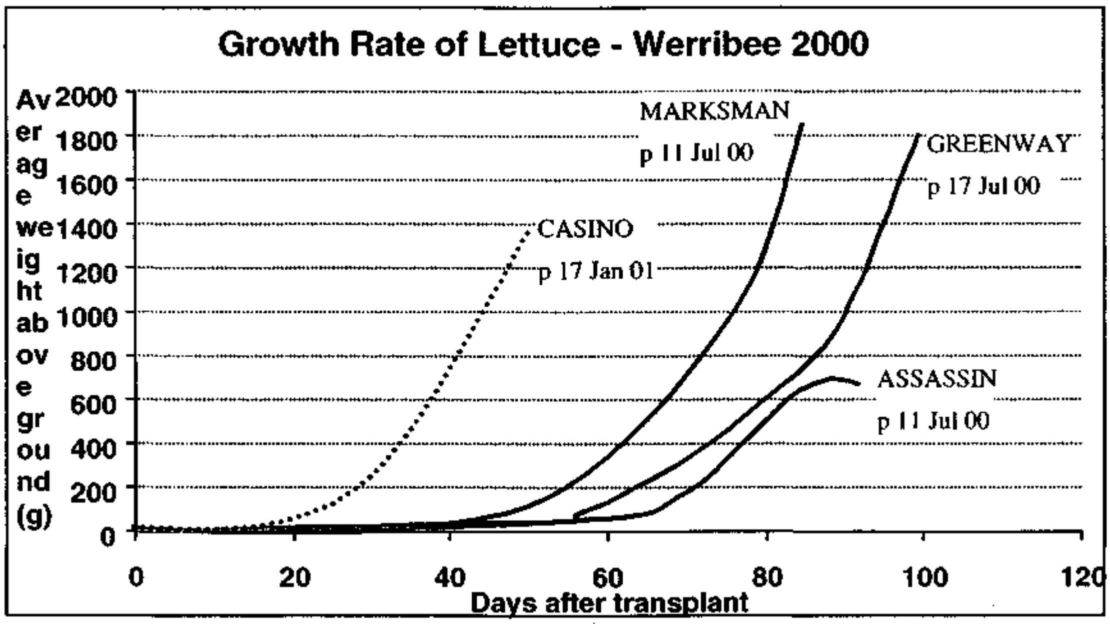
Growth rates

We did not observe any difference in growth rate or harvest size between Growers current practice and low potassium treatments in "winter lettuce" (figure 1).

Assassin planted 11 Jul 2000, had an average weight at harvest of 675g after 91 days and is a much smaller lettuce than Greenway, which was planted July 17, and had an average weight of 1869gm with Rustica® and 1811g with Nitrobor® in 99 days. Anthracnose was observed in this planting from day 91. Greenway was variable in size and many heads did not close. Lack of downy mildew resistance for Greenway limits its value to growers. Marksman, planted July 31, averaged 1850g in 85 days.

The growth rate shows a reduction in maturation time in later plantings as average temperatures increase.
The cultivar Casino planted January 17, 2001 shows that maturation time during summer can be as short as 44 days.

Figure 33. Growth rates of some winter and summer lettuce plantings

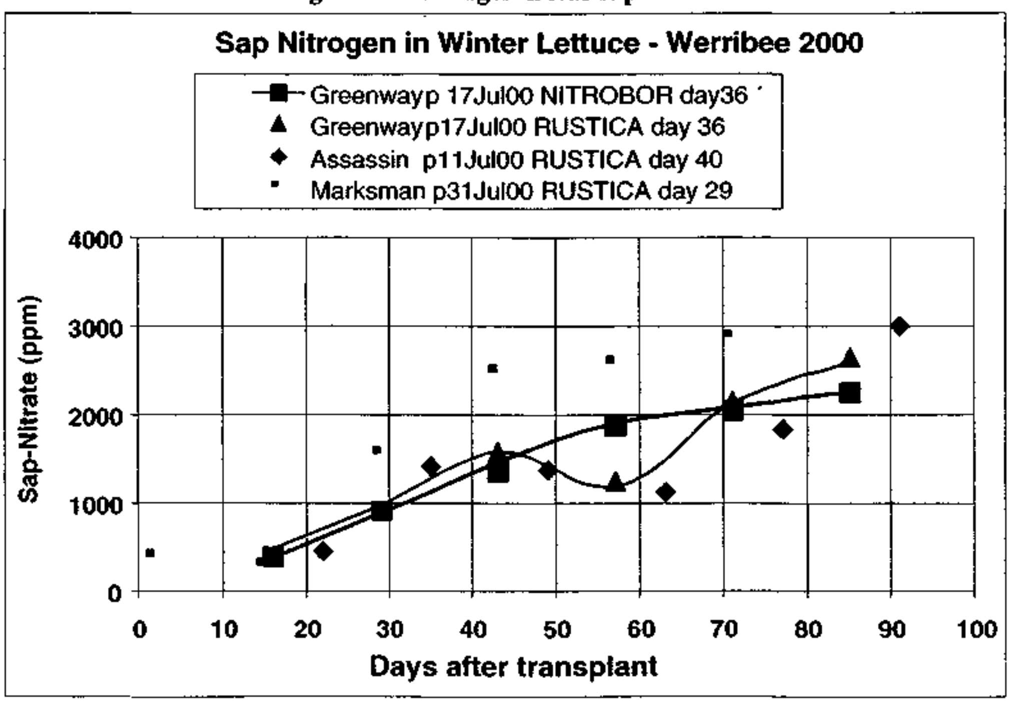


High growth rates place great demands on the plants water and nutrient uptake and distribution systems to supply the rapidly growing leaves. Transient deficiencies are sufficient to weaken plant cell walls and increase the risk of tipburn. High summer growth rates are clearly one of the major factors leading to tipburn in lettuce.

Leaf-sap Nitrate

Leaf-sap nitrate concentrations varied with the type of fertiliser used and between different planting dates, (figure 34).

Figure 34. Changes in leaf-sap nitrate concentrations.



The nitrogen in Rustica® (12-5-14) is provided as 5% nitrate and 7% ammonium. The higher sap-nitrate at day 57 with the Nitrobor® (15.5-0-0) treatment over the Rustica® treatment could be related to the reduced utilisation of ammonium nitrogen.

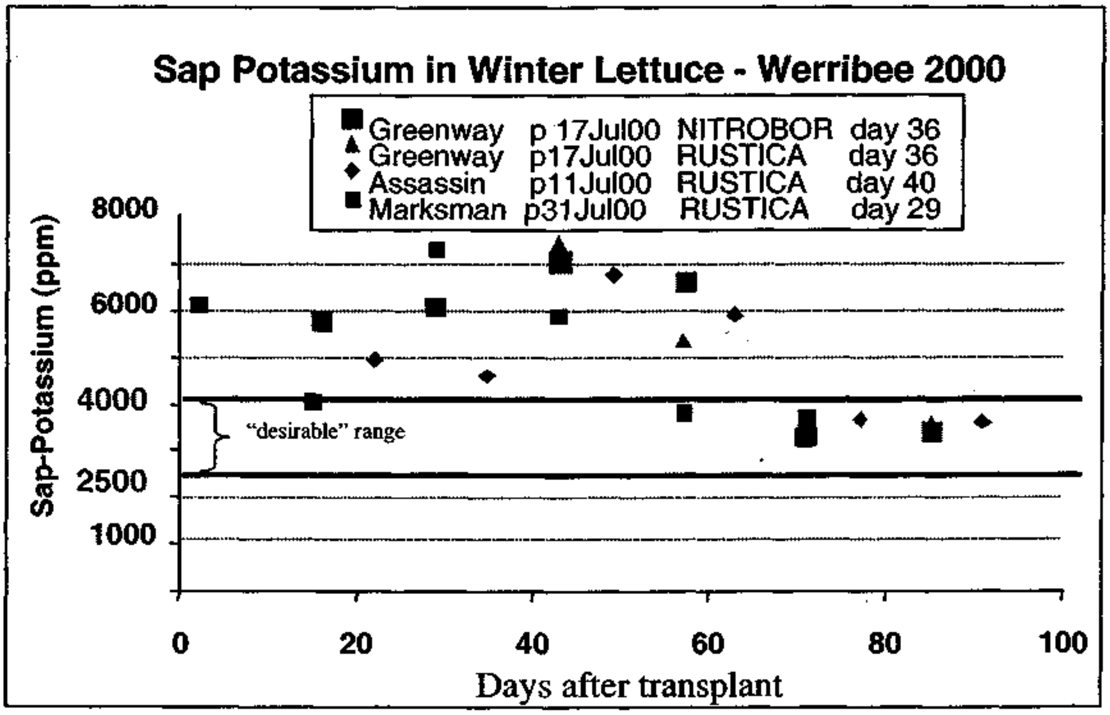
Sap nitrate continued to increase approaching harvest. It is known that plants will exploit nitrogen supplies beyond their minimal need, an attribute referred to as "Luxury uptake". In winter crops, extra nitrogen is applied to accelerate growth and finish the crop. "Luxury uptake" of nitrogen in summer crops can lead to early bolting and reduced storage-life. Growers are cautious in their use of nitrogen fertilisers in summer.

The "desirable" recommendation for sap-nitrogen at harvest is between 1500 and 2000 ppm. The observed values between 2500 and 3000 ppm suggest that too much nitrogen may have been applied to finish these winter plantings.

Leaf-sap Potassium

Changes in the concentration of leaf-sap potassium with different fertiliser treatments and planting dates are shown in figure 35. The leaf-sap potassium concentrations in all treatments and cultivars followed a similar pattern.

Figure 35. Changes in leaf-sap Potassium concentrations



Very high sap potassium were observed in all plantings at early hearting (~ day 40). The "desirable" sap-potassium range for lettuce is between 2500 and 4000 ppm throughout growth. Similar plant response patterns were observed with all cultivars and treatments.

Soil tests suggest that sufficient available potassium already existed in the soil to meet the crop needs. This supports the view that potassium fertiliser may also be oversupplied to the winter plantings. Closer to harvest, sap-potassium returns to within the "desirable" range despite high levels of potassium in the soil .

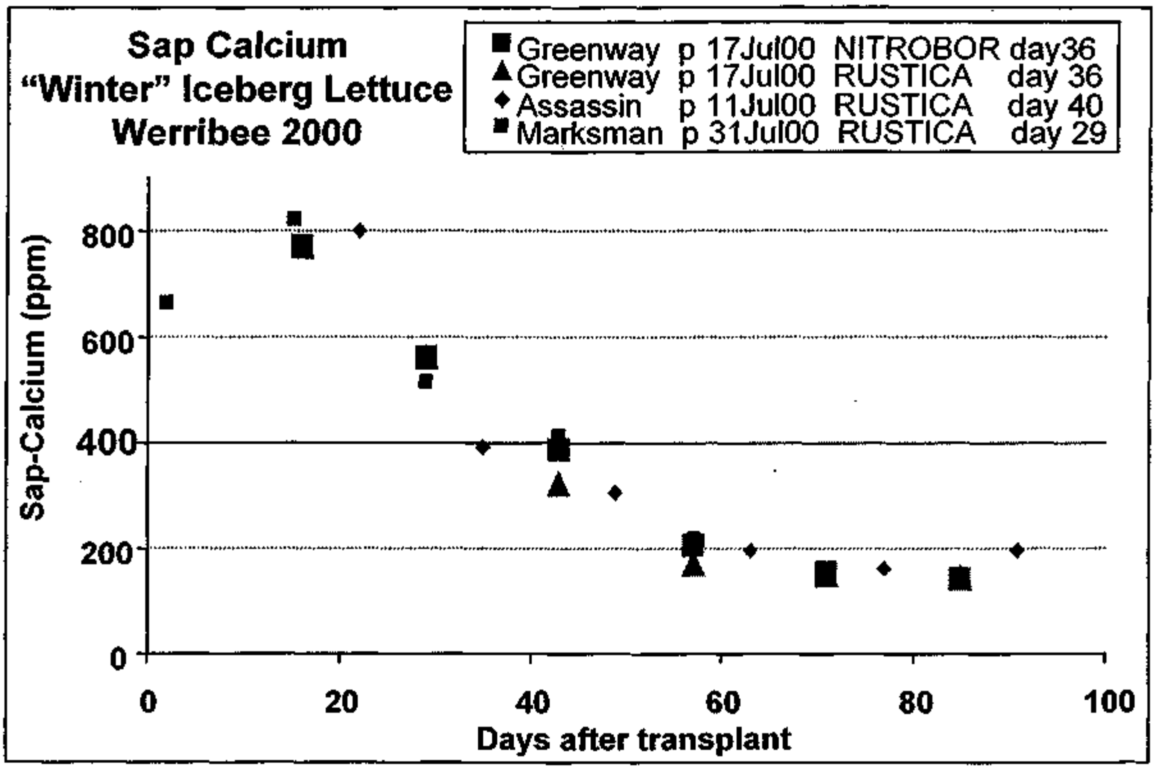
Total nutrient uptake is a function of dry-matter yield and nutrient concentration. It is a common observation that the total concentration of a nutrient within a plant increases with application of that particular nutrient in a fertiliser while the concentration of other nutrients decrease, (Bedi and Sekhon, 1977). Sap-nutrient concentrations can reflect transient changes rather than total nutrient accumulation and provide a better indication of the plants nutritional status at sampling.

While the plant can uptake excess nitrogen, it is our "belief" that the plant also has an "in-built" ability to maintain other sap-nutrient concentrations despite their oversupply in the soil.

Leaf-sap Calcium

Changes in the concentration of leaf-sap calcium between the growers current practice and low potassium treatment and between different cultivars are shown in figure 36.

Figure 36. Changes in leaf-sap Calcium concentrations



The work over the past three seasons has confirmed the relationship between low leaf-sap calcium concentrations and tipburn in lettuce and demonstrated that simple foliar calcium supplements are ineffective in raising the sap-calcium concentrations or reducing tipburn.

The changes in leaf-sap calcium in "winter" lettuce showed that all three cultivars have a very similar pattern in leaf-sap calcium concentrations over time. The "desirable" sap-calcium concentrations are between 400 and 600 ppm throughout growth. Although the concentration of sap-calcium was maintained in the "desirable" range till mid growth, it nevertheless fell to levels comparable with "summer" lettuce closer to harvest.

Despite low-concentrations of sap-calcium, no tipburn developed in any of the cultivars or plantings under the uniformly slower winter growing conditions. These observations support the view that sap-calcium is not the sole factor influencing the development of tipburn in lettuce. Tipburn is a feature of "summer" lettuce plantings and related to the plants inability to move sufficient water and nutrients to the rapidly growing leaf tissues in the enclosed heart of the lettuce plant.

The failure of any of the winter plantings of any cultivar to maintain 'desirable' levels of sap-calcium suggests that the sap-calcium concentrations recommended for lettuce may be unattainable and should be reviewed.

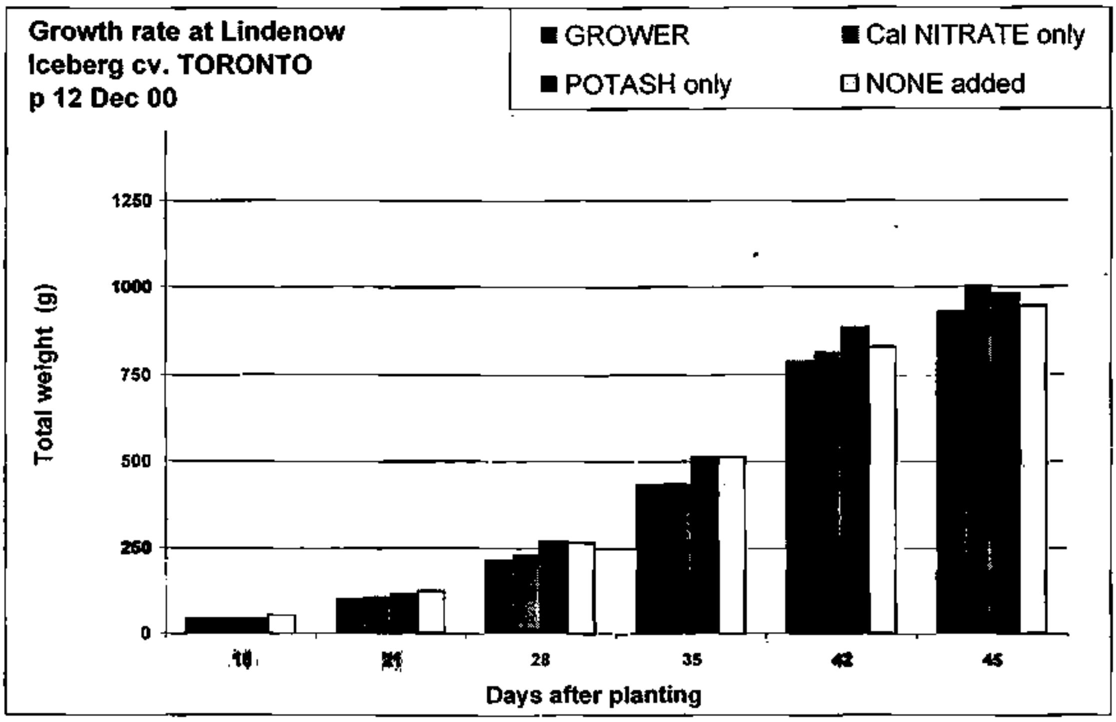
7.2.3. Results Summer Lettuce Trials

Crop Growth Rates 'Summer' Iceberg Lettuce

Lindenow nutrition trials

The first nutrition trial with "summer" lettuce at Lindenow was conducted with the iceberg cultivar Toronto planted on the 12th of December 2000. No significant differences were observed in plant weights between different treatments (figure 37).

Figure 37. Growth rate of summer lettuce nutrition trials at Lindenow

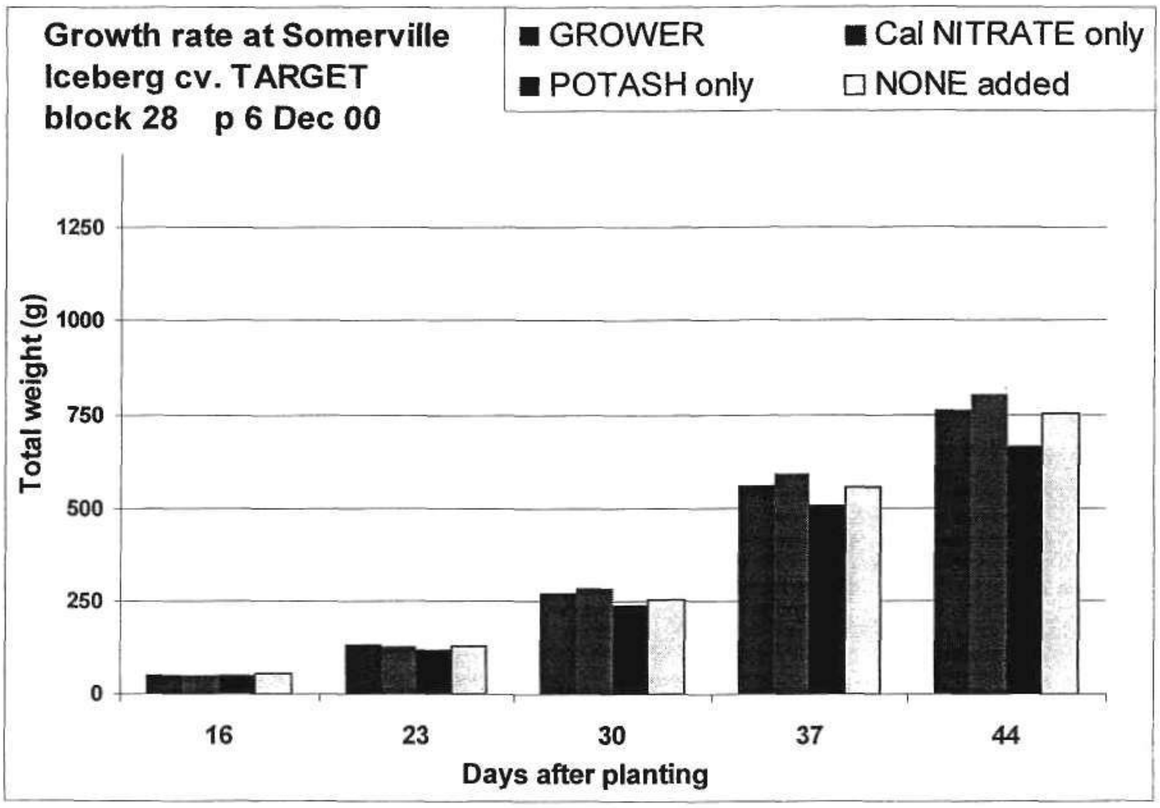


The success of the plantings without any fertiliser application reflects the amount of

sufficient residual nutrients existing in the soil from previous crops. Similar observations were made at several other trial sites, (the exception being the sandy soils at Somerville).
Growers may be able to exploit these residual nutrient reserves by reducing their fertiliser applications to the first lettuce plantings after a brassica or other crop.

Somerville nutrition trial 1
The first nutrition trial at Somerville was conducted with the iceberg cultivar Target planted 6th December 2000 (figure 38). The average plant weight at harvest for this planting was only about 60% of that observed in the 2nd nutrition trial at Somerville.

Figure 38. Growth rate of 1st lettuce nutrition trials at Somerville



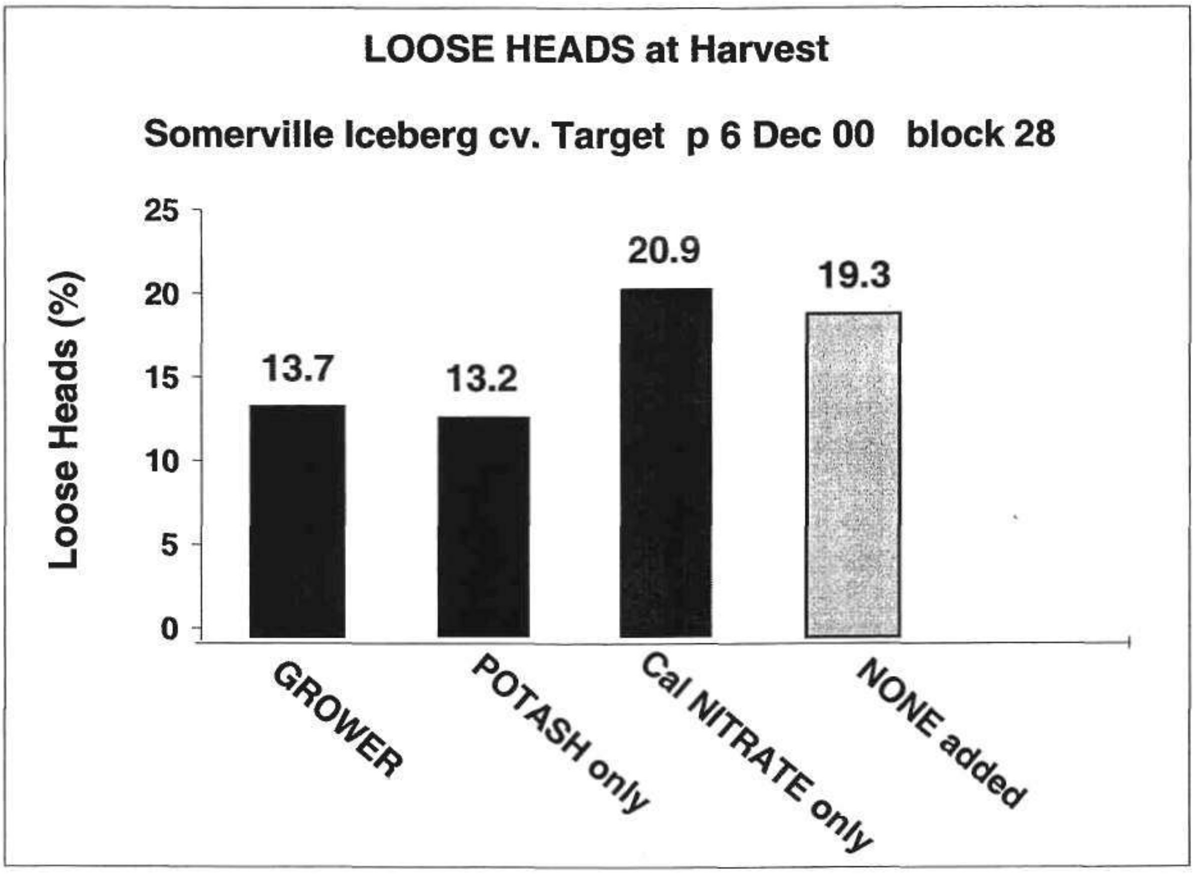
The Grower has indicated that this planting was over-watered as a result of the irrigation accidentally being left on for an extended period. As a consequence, nitrogen and potassium may have been lost through denitrification and/or leaching below the lettuce root zone.

Plants in the Potash only treatment generally appeared even smaller although statistical analysis has shown that the apparent differences are not significant given the natural variation observed within individual treatments.

The concentrations of potassium and nitrogen in the leaf sap of the December 6 trial were much lower than observed in the January 9 plantings at this site. Such low nutrient conditions are not often encountered with conventional high input vegetable production and appeared to influence the proportion of "loose heads" (figure 39).

In first trial, "loose heads" appeared to be related to lower potassium input. The absence of added potassium in the Cal Nitrate only and the None added treatments led to a 30% higher failure to form hearts. Potassium is known to be important for optimum flower set in Broccoli and these observations suggest that potassium may have a similar critical role for proper head set in lettuce.

Figure 39. Proportion of "loose heads" in the first lettuce nutrition trials at Somerville

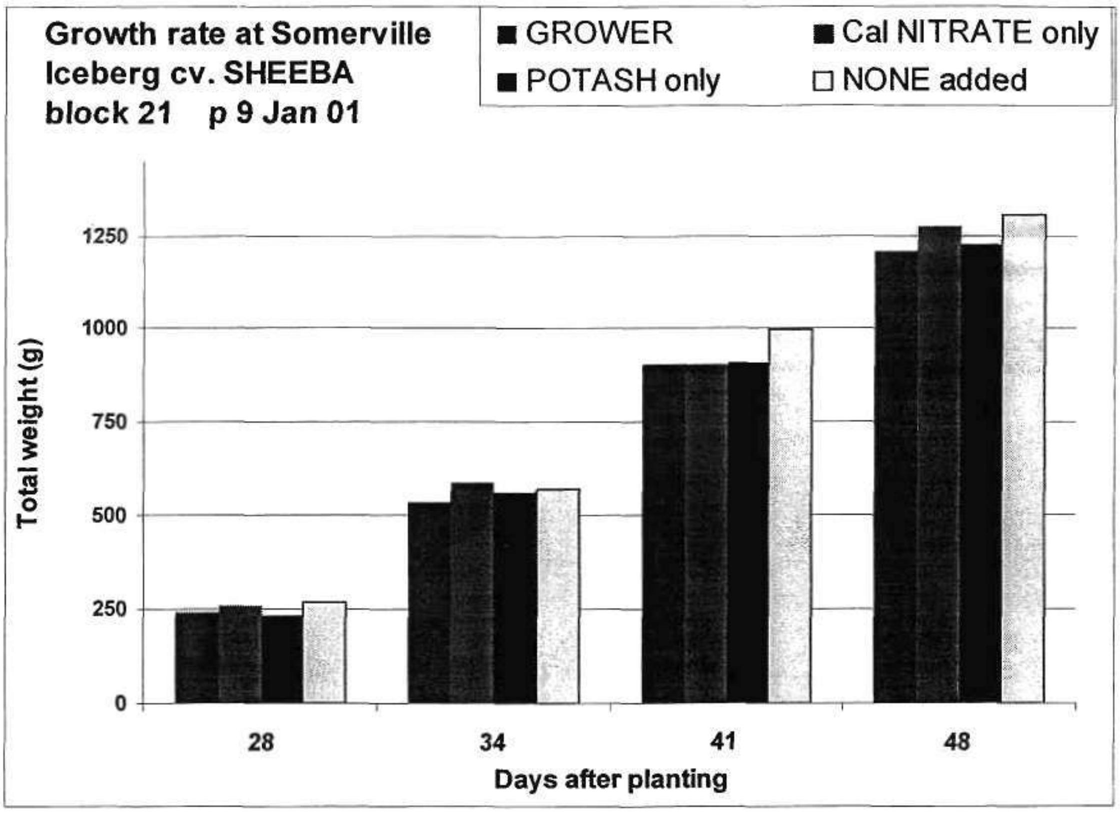


The observations of this first nutrition trial at Somerville highlight the problem of maintaining adequate nutrients in sandy soils. Unlike heavier soils, crops grown on sandy soils may not be able to exploit residual nutrients from the preceding crops before they are leached below the active root zone especially with young transplants grown on "difficult" blocks. An alternative strategy to limit leaching losses would be to apply smaller applications of nitrogen and potassium fertilisers to the crop more frequently, perhaps through fertigation.

Somerville nutrition trial 2

The second nutrition trial at Somerville with the locally popular cultivar Sheeba was planted on January 9, 2001. Average plant weight at harvest was much greater and more typical of production from this area than was the December trial (figure 40).

Figure 40. Growth rate of 2nd lettuce nutrition trials at Somerville



Again, there were no significant differences in growth rate between treatments of the same age. The loss of nutrients was not an issue as similar results were achieved with all fertiliser treatments.

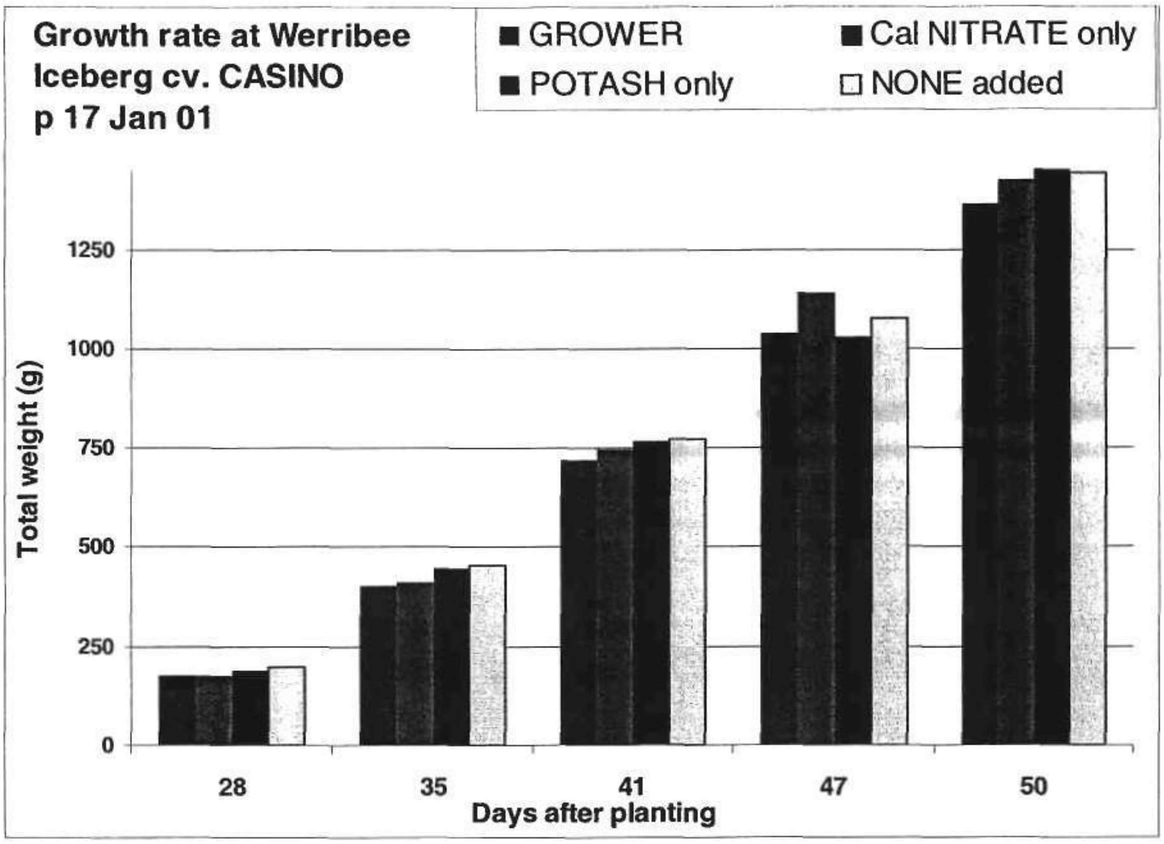
Growers have long recognised high and low performing blocks. Comparing the two Somerville plantings shows just how dramatic these differences can be. Such differences between blocks demonstrates some of the consequences of over-watering and introduces the possibility of tailoring optimum fertiliser applications to specific blocks rather than using the same application rate to all blocks in summer.

Werribee nutrition trials

The first nutrition trial at Werribee studied the locally popular summer iceberg variety Casino planted on January 17, 2001. Yet again, we observed no significant difference in growth rates between different fertiliser treatments (figure 41).

Similar growth rates were achieved without any fertiliser application although plants grown in the None Added treatment developed tipburn earlier than plants grown under the other fertiliser treatments.

Figure 41. Growth rate of lettuce nutrition trials at Werribee



Grower comment:
Werribee growers commonly maximise useable land by growing lettuce in the sprinkler lines, usually without fertiliser. These sprinkler line plantings are known to have a higher risk of failure in summer. Growers could be reluctant to reduce fertiliser inputs across their entire plantings, especially during mid summer. However these sprinkler lines would not have the residual fertiliser that would be carried over in the rest of the paddock.

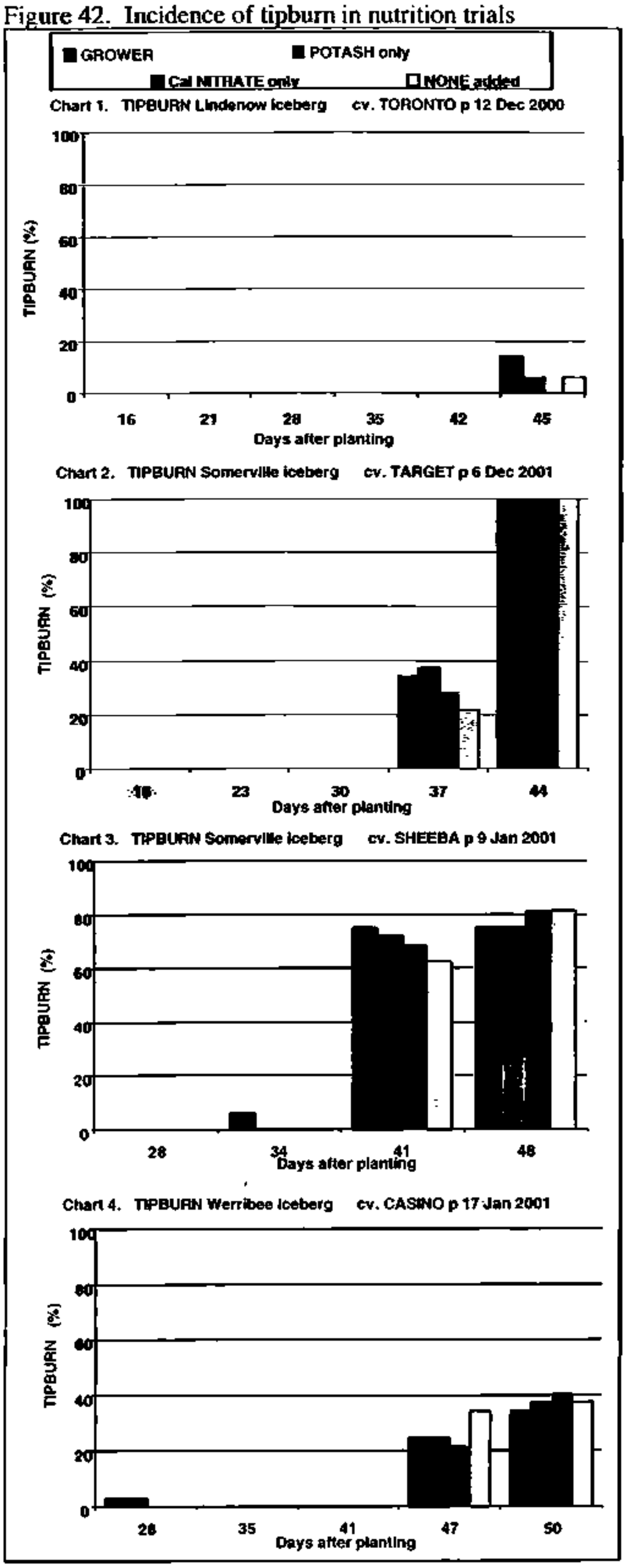
Nevertheless, the observations of this study support the view that considerable soil nutrient reserves are carried forward from previous crops. Normal growth should be possible using smaller fertiliser applications to maintain quality in mid-summer plantings.

<u>Tipburn in Iceberg trials</u>
Lindenow nutrition trials
The first nutrition trial at Lindenow was planted on the 12th December 2000. Very little tipburn was observed in the Iceberg cultivar Toronto (figure 42, chart 1). The apparent differences between treatments were not significant. The success of the plantings without any fertiliser application will encourage growers to consider the low input option for the first plantings of the season.

Somerville nutrition trial 1

The first nutrition trial at Somerville was conducted with the iceberg cultivar Target planted on 6th December 2000. Recall that the growth rate of this planting was severely restricted by nitrogen and potassium deficiencies possibly due to excessive leaching of nutrients from the sandy soil. The incidence of tipburn was also severe which further reduced the value this planting (figure 42, chart 2). The apparent differences between treatments at the early hearting stage, (day 37) were not significant. An inadequate supply of nutrients aggravated by accelerated summer growing conditions are likely to have contributed to the extensive tipburn observed in this planting at harvest.

Figure 42. Incidence of tipburn in nutrition trials



Somerville nutrition trials 2

Tipburn was still prevalent in the second nutrition trial planted at Somerville on 9 January 2001 but was much less severe and did not reduce marketability at harvest (figure 42, chart 3). Again, the apparent differences between treatments at harvest were not significant. Growers will be encouraged that all treatments produced plants of the same quality and weight.

Werribee nutrition trials

The incidence of tipburn was studied in the locally popular cultivar Casino planted at Werribee on 17th of January 2001. Casino was an excellent performer at Werribee last season as a late January planting. We did not observe any significant difference in tipburn with different fertiliser treatments at harvest (figure 42, chart 4).

Had the crop been harvested 3 days earlier, tipburn would have been reduced by as much as 1/3 to 1/2 except with the None added treatment. Although similar growth rates were achieved, tipburn developed earlier when no fertiliser was applied.

Leaf-Sap Analysis

Leaf-sap nitrate

Lindenow nutrition trials

Leaf sap-nitrate was maintained within the "desirable" range throughout the 12 December planting at Lindenow (figure 43, chart 1). This planting also achieved a good summer growth rate and showed only minor signs of tipburn. In contrast with the "winter" lettuce, we observe a typical "summer" pattern where the sap-nitrate concentration decreased close to harvest.

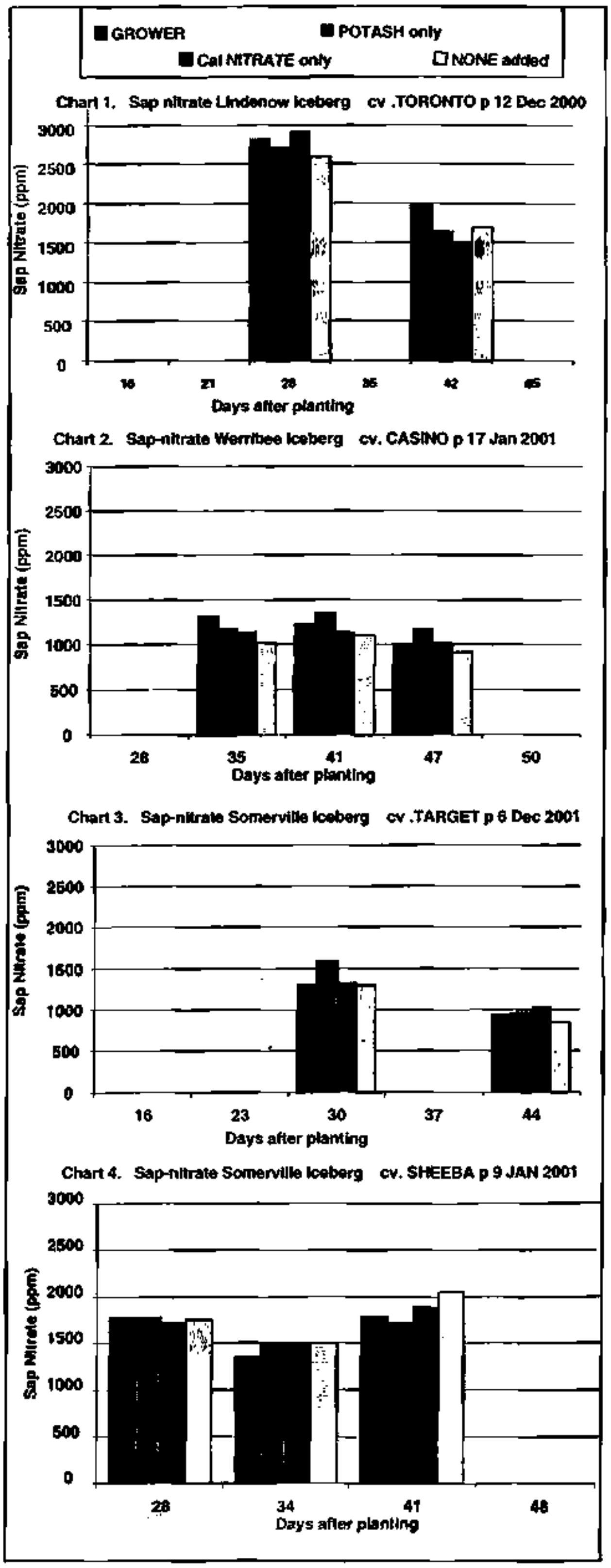
Werribee nutrition trials

Leaf-sap nitrate concentrations in the 17 January planting at Werribee again showed no significant difference between different fertiliser treatments (figure 43, chart 2). It was also noticed that neither size nor quality were affected by a lower than "desirable" sap-nitrate concentration at early hearting. This suggests that the level of sap-nitrate, (although less than "desirable"), did not limit growth or quality in this planting. Although similar growth rates were achieved without any fertiliser application, tipburn developed earlier when no fertiliser was applied.

Somerville nutrition trial 1

Leaf-sap nitrate concentrations were also marginal in the first nutrition trial at Somerville planted early in December 2000 (figure 43, chart 3). Harvest yield of this planting was severely reduced and

Figure 43. Changes in leaf sap nitrate in nutrition trials



tipburn affected all plants at harvest.

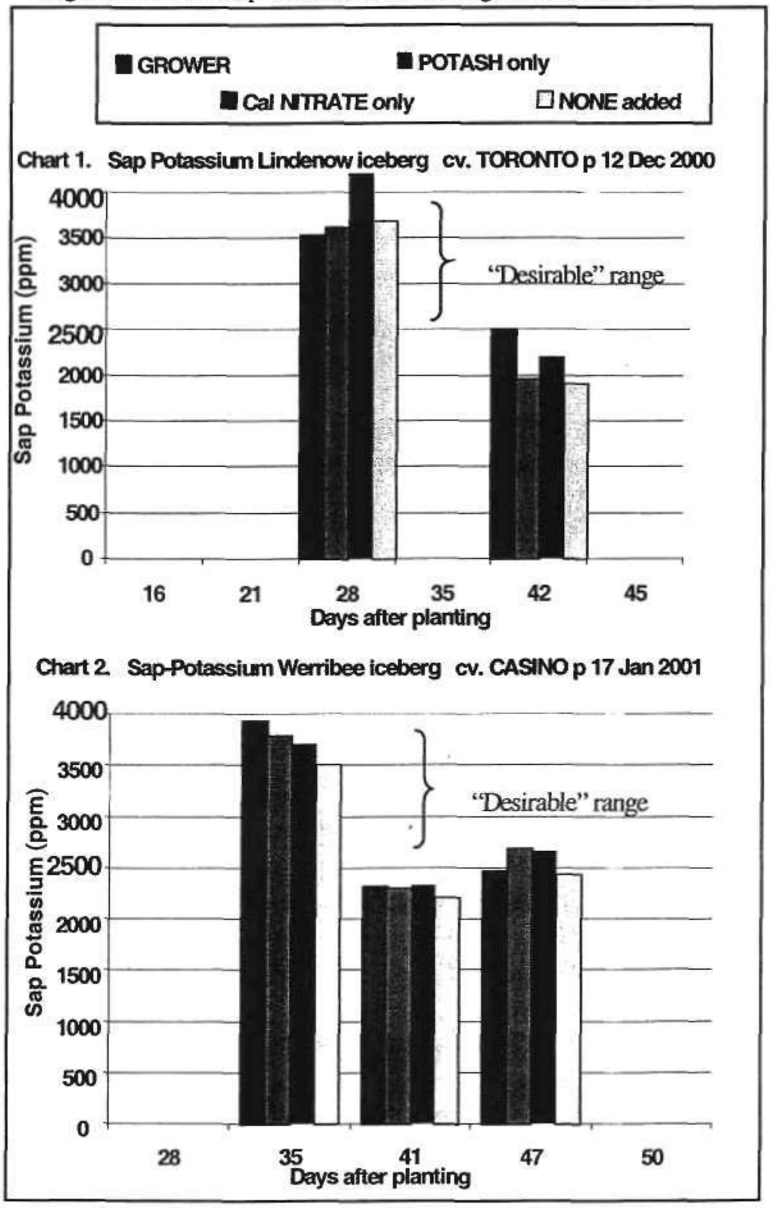
Somerville nutrition trial 2

There was generally much less variation in leaf-sap nitrate concentrations in the 2nd trial planted at Somerville on 9 January 2001 (figure 43, chart 4). Sap-nitrate was generally within the "desirable" range and differences between treatments were not significant. Nitrobor® was applied to the Grower and CalNitrate treatments on day 31, yet the concentration of leaf-sap nitrate increased in all treatments. This suggests sap-nitrate concentrations, were regulated by the plant during early hearting, independent of fertiliser application. "Luxury" uptake of nitrate by "winter" lettuce also occurred closer to maturity.

Leaf-sap Potassium

Excessive concentrations of potassium have been linked to increased tipburn in lettuce (Collier and Tibbits, 1982). Soil tests have also shown high concentrations of potassium in soils at Werribee in contrast with the often potassium deficient sandy soils at Somerville.

Figure 44. Leaf-sap Potassium in iceberg nutrition trials



Lindenow nutrition trials

The early December 2000 planting at Lindenow showed that leaf sap-potassium was maintained within "desirable" limits at early hearting, (figure 44, chart 1). This planting also maintained a normal summer growth rate and showed only minor signs of tipburn. None of the apparent differences between treatments was significant.

Werribee nutrition trials

The concentrations of leaf-sap potassium in the January Casino planting at Werribee were very similar to those observed at Somerville (figure 44, chart 2). The apparent differences in sap-potassium content at day 35 were not significant.

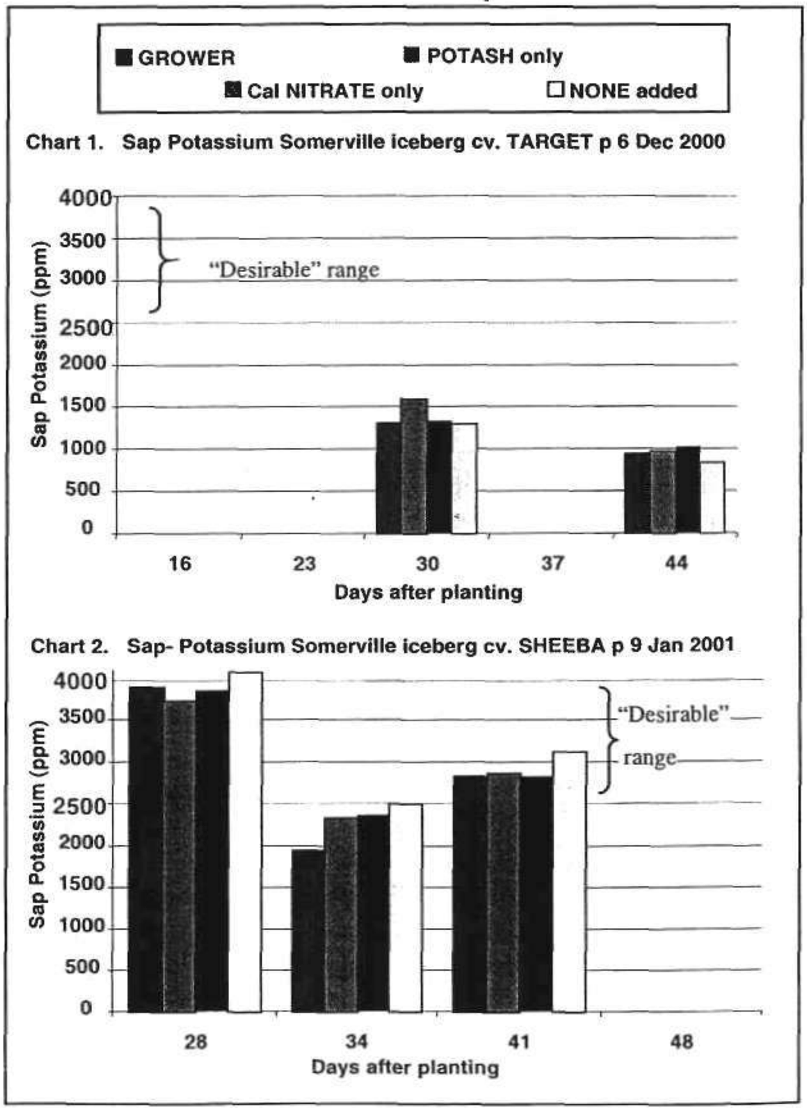
Sap potassium decreased towards the lower limit of "desirable" range at early hearting (day 41), despite high soil potassium reserves.

It is interesting to note that leaf-sap potassium at Werribee was very similar to Somerville in January despite Werribee soils containing almost 4 times the available potassium of Somerville soils. This finding has important consequences for lettuce growers on sandy soils. Even though the soil test suggests that potassium may be deficient, raising soil potassium by as much as four times may not increase the leaf-sap potassium in the plant. The plant has only utilised the amount of potassium it needs.

These results also suggest that the critical soil potassium limits for lettuce may vary with soil type and nominally "deficient" soil tests at Somerville were clearly sufficient to maintain "normal" lettuce crop growth and quality. The soil-potassium test recommendations for lettuce on sandy soils should be reviewed.

Somerville nutrition trial 1

In the early December planting at Somerville, potassium concentration in sap remained well below "desirable" limits (2500-4000 ppm) and may have contributed to the poor growth and quality of this crop (figure 45, chart 1). There were no significant differences in the concentration of potassium between different treatments at harvest. Although soil potassium was low at harvest, similar soil tests were observed in the January planting where growth was not restricted. It seems likely that nitrogen was also limiting in the December planting and may have contributed to the reduced vigour and poor uptake of potassium in this planting.



Somerville nutrition trial 2

Sap potassium concentrations in the early January planting at Somerville were generally maintained in the "desirable" range between 2500 to 4000 ppm (figure 45, chart 2).

While the apparent differences between treatments were not significant, the rapid decrease in sap-potassium in all treatments between day 28 and day 34 coincided with early hearting. On day 31, Nitrobor® was applied only to the Grower and CalNitrate treatments yet, leaf-sap potassium gradually increased in all treatments. This observation further supports the contention that the plant is able to regulate sap-nutrients during early hearting, independent of fertiliser application.

Comparing the January sap tests with the December planting at Somerville suggests the earlier planting was deficient in potassium consistent with the Growers comment of nutrient losses through overwatering.

Iceberg sap-Calcium

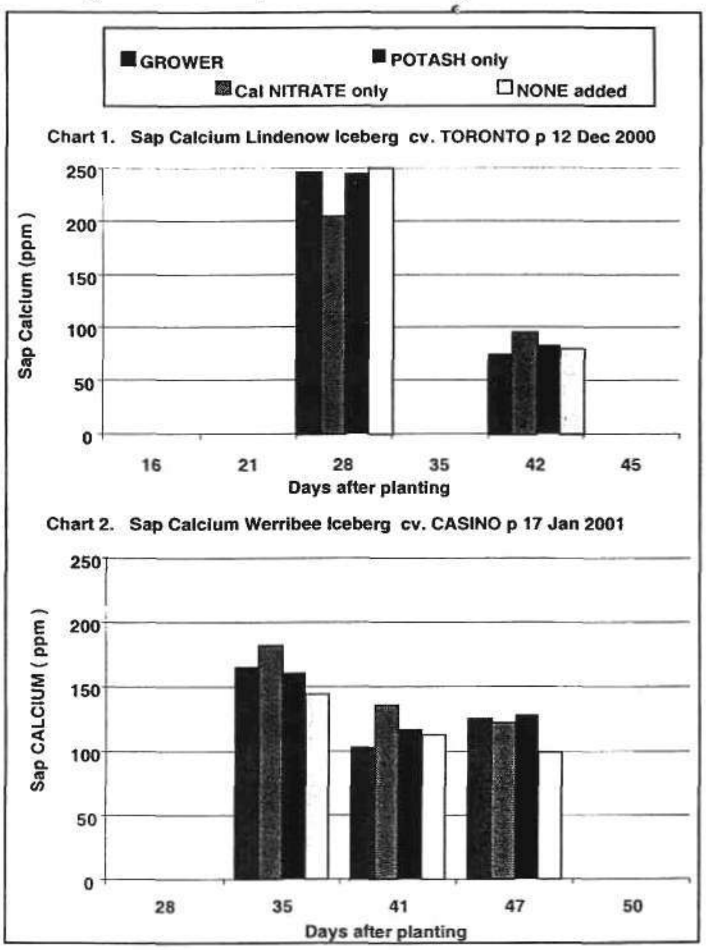
Lindenow nutrition trials
Changes in leaf-sap calcium observed in the crop planted at Lindenow on December 12 were consistent with those seen with "winter" lettuce and in previous years.

The "desirable" range for leaf-sap calcium in lettuce is between 400 and 600 ppm.

Despite nominally "undesirable" calcium concentrations at Lindenow, the success of the December 12 planting suggests these levels were adequate and the recommended levels should be reviewed, (figure 46, chart 1).

Withholding fertiliser did not significantly affect leaf-sap calcium, potassium or nitrate concentrations in this planting.

Figure 46. Leaf-sap Calcium in Iceberg nutrition trials

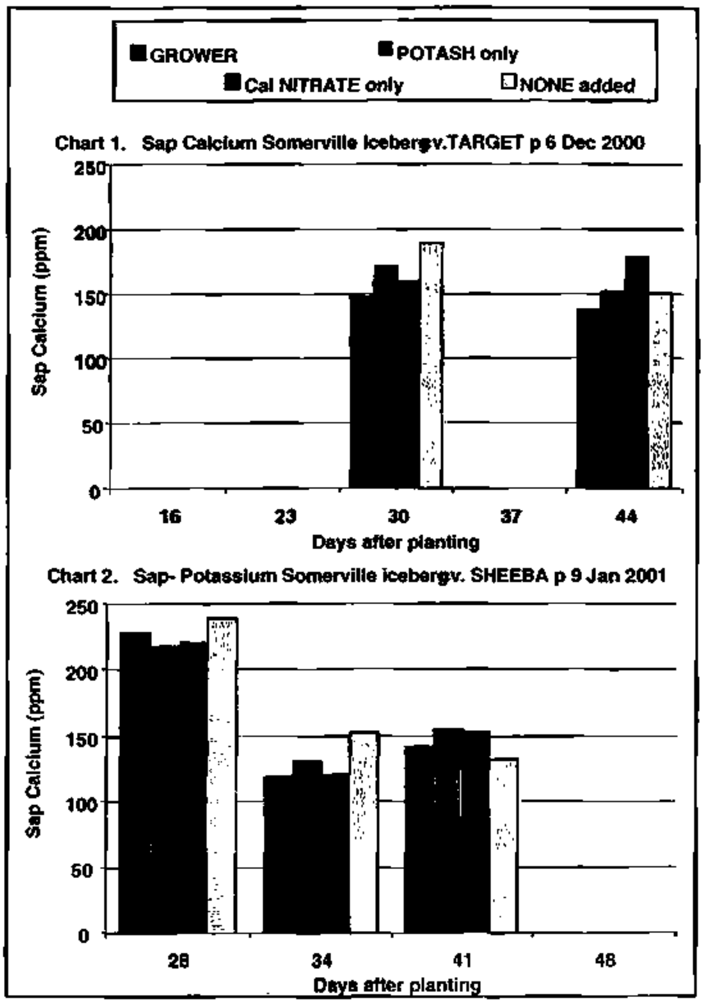


This is consistent with carryover of sufficient nutrients from previous crop to supply the first lettuce planting.

Werribee nutrition trials
Leaf-sap calcium levels in the January 17 Casino planting at Werribee were also consistent with patterns seen in other plantings (figure 46, chart 2). The apparent differences in leaf-sap calcium concentration at day 35 were not significant. Very similar values and patterns were observed in the concentration of leaf-sap calcium in all plantings and did not reflect the incidence of tipburn in the crop. The concentration of leaf-sap calcium appears to follow a predetermined pattern independent of high soil calcium or calcium supplements applied to the soil or leaves.

These results are consistent with the implication that calcium uptake by the plant is dependant on a range of factors and not necessarily the levels or availability of calcium in the soil.

Figure 47. Leaf-sap Calcium in Iceberg nutrition trials



Somerville nutrition trial 1

The growth and quality of the first trial planting at Somerville were significantly restricted by low nitrogen and potassium through over watering.

Despite the poor performance and high incidence of tipburn observed in the first trial planting, the leaf-sap calcium concentrations were very similar to those of other less affected plantings (figure 47, chart 1).

Furthermore, the apparent differences in leaf-sap calcium between treatments at harvest were not significant in either planting.

These observations further support the view that factors other than the sap-calcium concentration influence the development of tipburn in lettuce.

Sap calcium concentrations in the early January planting at Somerville were consistent with the pattern seen in "winter" lettuce and with crops studied in previous years (figure 47, chart 2).

The similar calcium levels of this crop and the less successful December planting also show that leaf-sap calcium alone is not a good indicator of tipburn risk.

Our inability to manipulate leaf-sap calcium in the field has important consequences for tipburn control. The most promising opportunities for reducing tipburn in "summer' lettuce lie with the selection of more tipburn tolerant cultivars and ensuring adequate irrigation is provided to optimise the movement of sap-nutrients to the developing leaves enclosed in the lettuce heart.

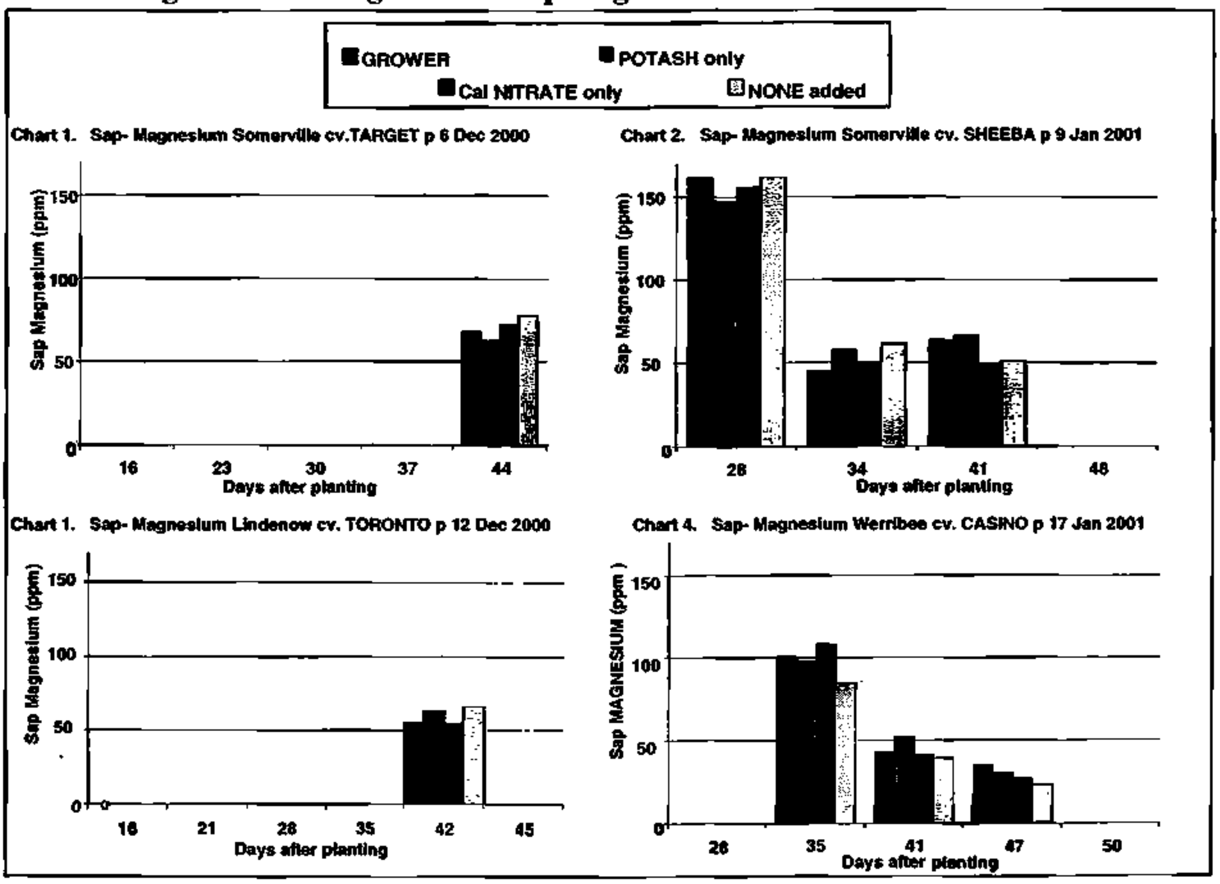
Iceberg sap-Magnesium

Magnesium accounts for a significant proportion (up to 20%) of the exchangeable cations in vegetable growing soils. Magnesium and calcium are important to the maintenance of good soil structure. Magnesium also has an important role in photosynthesis. Like potassium, excessive concentrations of magnesium may aggravate tipburn when calcium is deficient.

A preliminary monitoring study was undertaken on the advice of steering committee members considering using magnesium supplements on their summer crops. No magnesium supplements were applied to the nutrition treatments, only "natural" levels in the leaf-sap have been monitored.

The apparent differences in the leaf-sap magnesium concentration between treatments were not significant and decreased as the crop matured (figure 48)

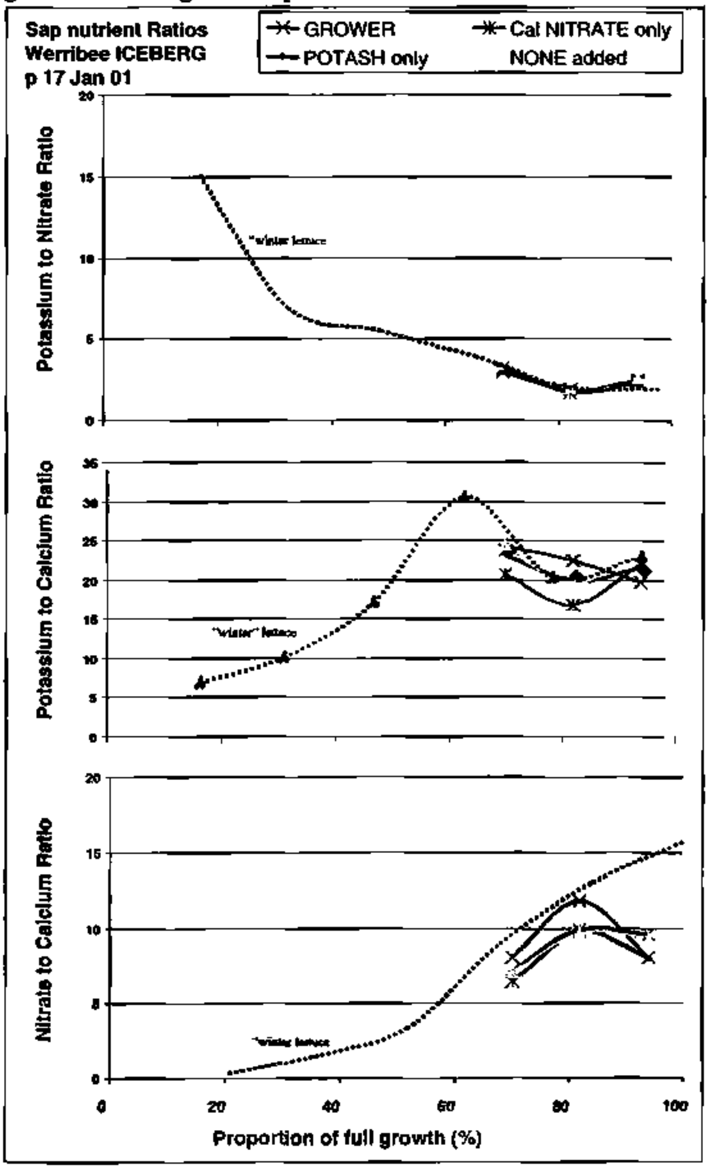
Figure 48. Changes in leaf-sap magnesium in nutrition trials.



Similar concentrations of magnesium were found in the leaf-sap of all plantings near harvest and were not proportional to the observed incidence of tipburn.
It appears that the observed concentrations leaf-sap magnesium are sufficient for normal plant growth and did not influence the incidence of tipburn.

Sap Nutrient Ratios

Figure 49. Changes in sap-nutrient ratios in lettuce - Werribee



So far we have considered changes in leaf-sap nutrient concentration separately or in relation to the growth rate or tipburn incidence in the crop. We can gain a new perspective on plant nutrition by considering changes in the ratios of sap-nutrients as the crop matures and tipburn develops. Similar nutrient ratio patterns were also observed at all three of the trial locations.

Figure 49 shows how the ratios of major nutrients change as the crop matures. The proportion of potassium to nitrate in "winter" lettuce decreased 10 fold from 15:1 at establishment to around 1.5 :1 at harvest, (figure 49).

In contrast, the ratio of potassium to calcium increased 4 fold over the same period reflecting the decrease in leaf-sap calcium as the crop matures, (figure 49, chart 2).

Finally, the proportion of Nitrogen to calcium increases nearly 30 fold from 0.5 :1 at establishment to 18:1 at harvest, (figure 49).

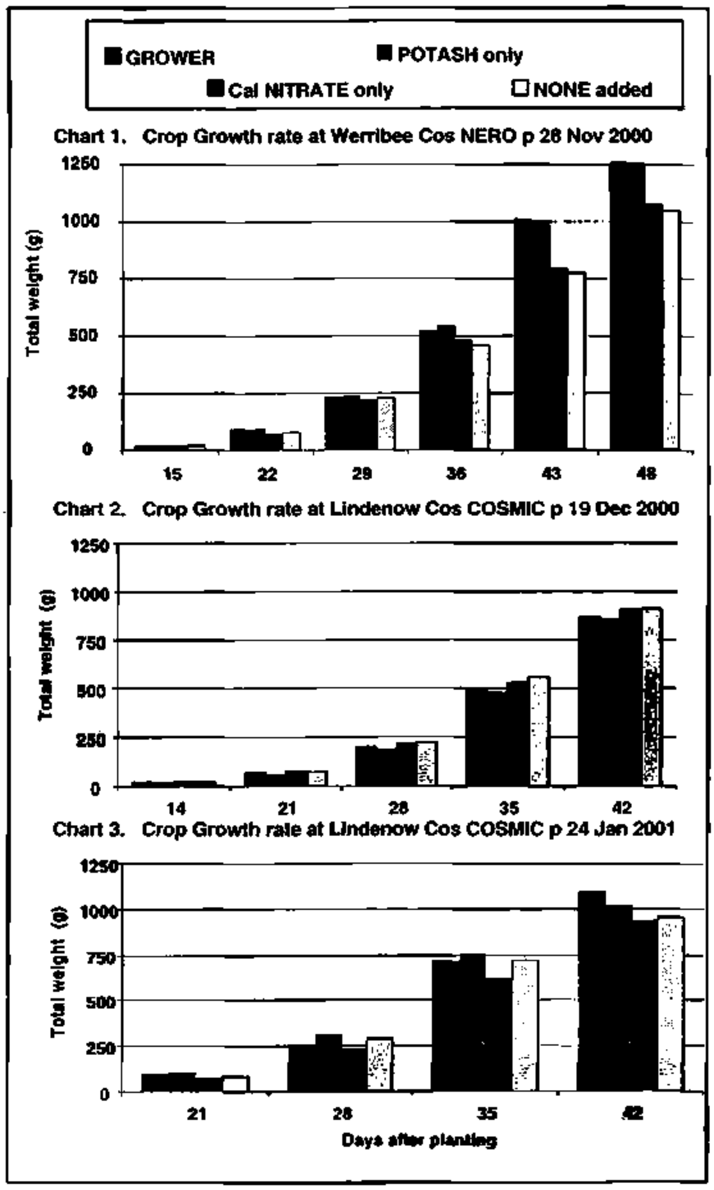
The significance of these dramatic changes is apparent when we compare ratios from "winter" with "summer" plantings. Generally, the early January Casino planting at Werribee showed very similar nutrient ratios close to harvest to the "winter" plantings. The noticeable exception was the lower nitrate to calcium ratio in the "summer" planting at harvest, (figure 49). As mentioned earlier, growers may apply extra nitrogen to winter crops to help finish the crop in cold weather but are more cautious with nitrogen in summer crops to avoid premature bolting. "Luxury" uptake of nitrogen did not occur until after the plants had reached 80% of their final size.

It is interesting to see the early January planting at Werribee showed similar nutrient ratios close to harvest despite differences in cultivar, fertiliser treatment and tipburn incidence. Plant regulation of key sap-nutrient concentrations during early hearting was independent of fertiliser application.

7.2.4 Summer Cos Lettuce

<u>Crop Growth Rates</u>

Figure 50. Growth rates of COS lettuce.



Werribee nutrient trials

The growth rates of the four nutrition treatments at each location are compared in figure 50. The cos nutrition trial at Werribee was planted on Nov 28, 2000. The cultivar Nero is a late closing variety that has been shown to have a good tolerance to tipburn. The Grower treatment was a single application of Rustica®. All treatments were applied 6 days after transplant. While the addition of potassium made little difference to the growth pattern, the nitrogen free treatments were as much as 20 % smaller at harvest.

Lindenow nutrient trial 1

The first cos nutrition trial at Lindenow was planted on the 19 December 2000. The cultivar Cosmic had shown good tolerance to tipburn last season. No significant differences were observed in plant weights between different treatments.

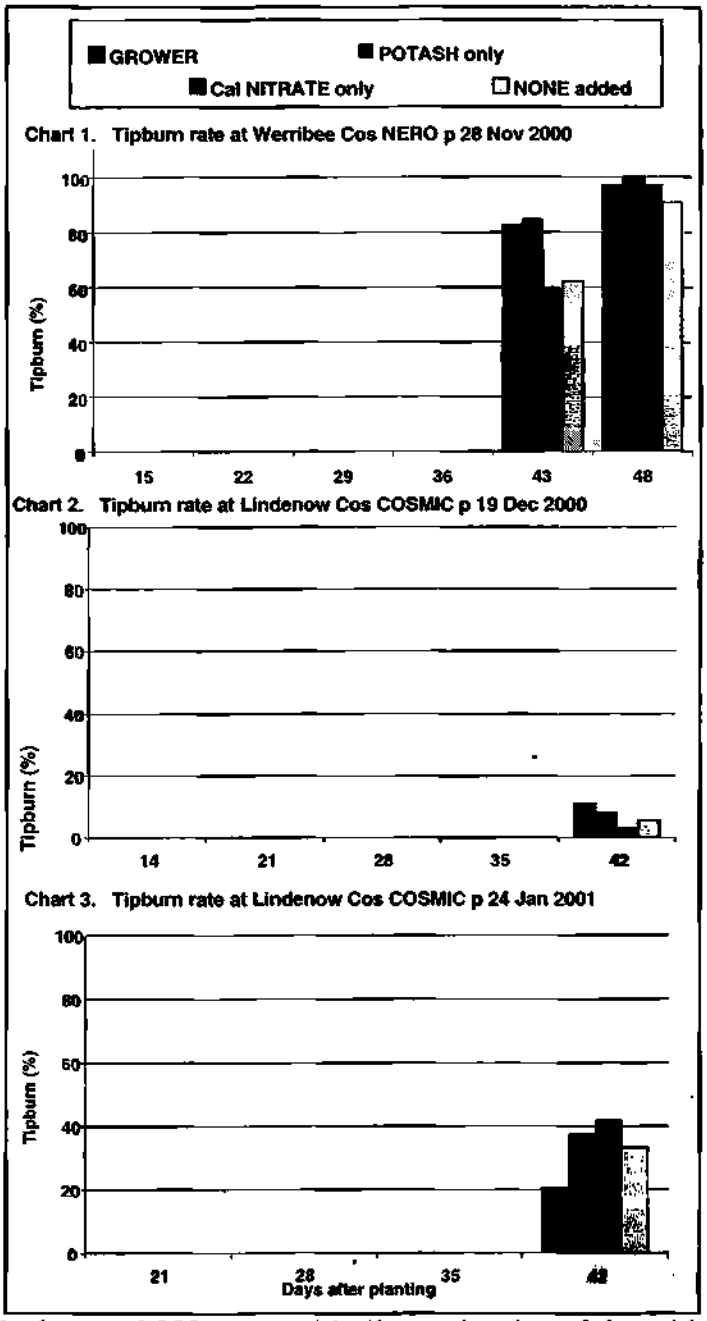
The success of the plantings without any fertiliser application can be attributed to residual nutrients from previous crops, (figure 50, chart 2). Similar observations have also been made with iceberg lettuce at other trial sites. Growers may be able to exploit these residual nutrient reserves and reduce their fertiliser applications to early cos plantings.

Lindenow nutrient trial 2

The second Cos nutrition trial at Lindenow was planted on January 24, 2001. Although the Nitrogen free treatments were generally smaller these differences were not significant, (figure 50, chart 3).

Tipburn in Cos Lettuce trials

Figure 51. Tipburn incidence in COS lettuce.



Werribee nutrition trial 1

The late November 2000 Nero planting at Werribee suffered extensive tipburn, (fig 51, chart 1). Treatments that withheld nitrogen showed fewer tipburn symptoms 5 days before harvest however there was no difference in tipburn incidence between treatments at harvest.

Our cos cultivar field trials planted at Werribee on November 26, 1998, (milestone report #3), indicated that Nero was the most tipburn tolerant variety with only 40% of plants affected. This higher tipburn tolerance was attributed to the "later closing" characteristic of Nero compared with others. However, the tipburn tolerance of Nero was not confirmed by our late January 2000 cos cultivar trial plantings, (milestone report #5).

With hindsight, a better result may have been achieved with the 28 Nov 2000 planting by harvesting the crop a week earlier when the plants had reached around 800 grams, (similar to the size of the mid-December planting at Lindenow).

Lindenow trial 1

In contrast with Werribee, the mid-December planting of cos cultivar Cosmic at Lindenow experienced very little tipburn,
(fig 51, chart 2).

Lindenow trial 2

The tipburn performance of the late-January 2001 planting of cos cultivar Cosmic at Lindenow was not as good as seen in the December trial planting, (fig 51, chart 3). At harvest, the Grower treatment showed the least tipburn.

Effects of nutritional trials on tipburn incidence in Cos

Leaf- sap nitrate

Werribee trials

Leaf-sap nitrate was generally below the "desirable" range throughout the November 28 planting. Concentrations of leaf-sap nitrate were generally higher in the Grower and CalNitrate treatments at day 36 and were reflected in the growth rate. However, this pattern did not continue through to harvest. The addition of nitrogen fertiliser increased the crop growth rate but induced premature tipburn, (figure 52, chart 1).

These observations suggest that the crop initially benefited from the addition of nitrogen and sufficient reserves were available through to harvest.

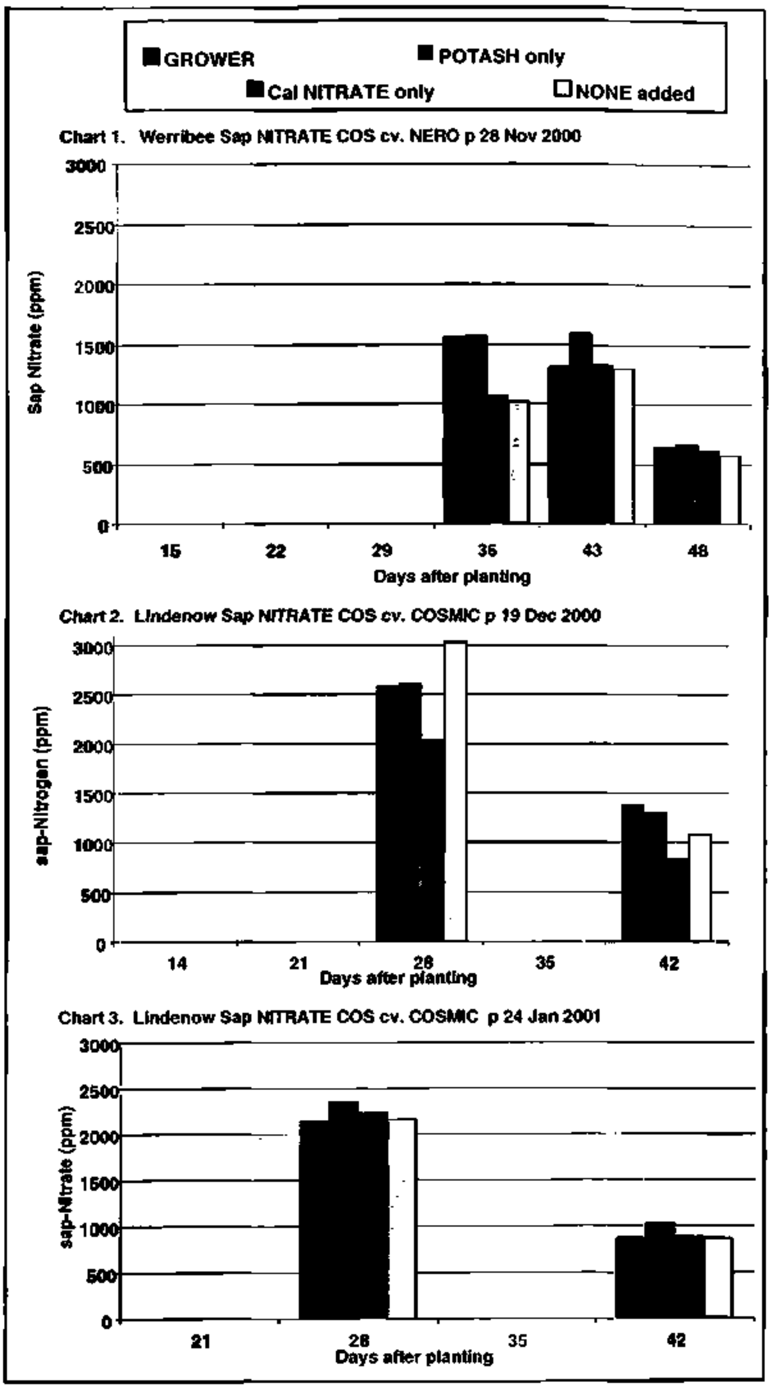
Lindenow trial 1

The concentration of leaf sap nitrate generally remained within the "desirable" range in the December 19, 2000 Cosmic planting at Lindenow, (fig 52, chart 2). This planting showed negligible tipburn when harvested at 42 days. The average plant size at 42 days was similar to the Werribee trial planting.

Lindenow trial 2

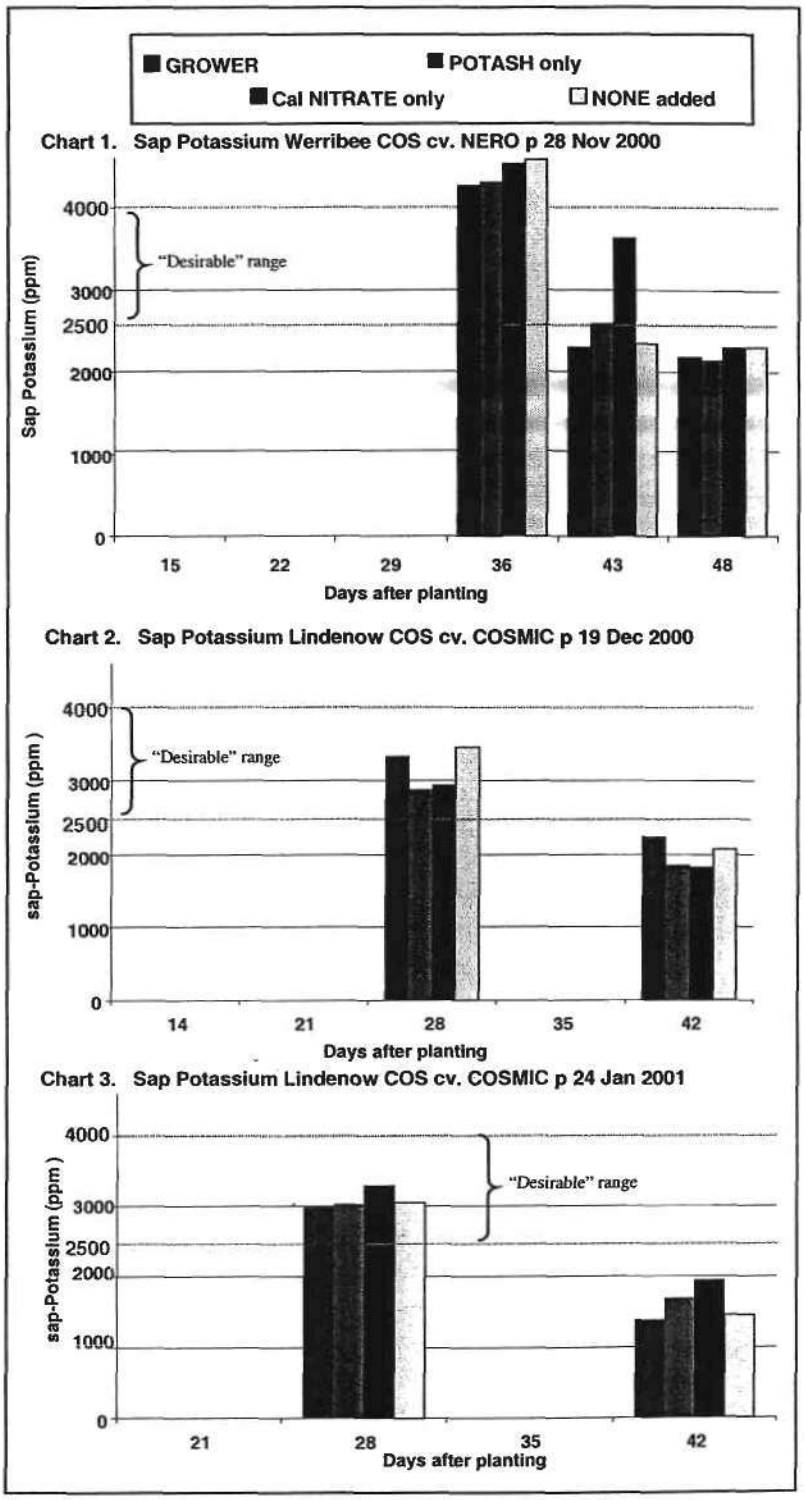
Changes in leaf-sap nitrate in the January 24, Cosmic planting at Lindenow are shown in figure 52, chart 3. Again, sap-nitrate generally remained in the "desirable" range until harvest and produced plants with similar harvest size to the December 19 trial planting at Lindenow.

Figure 52. Leaf-sap nitrate in COS lettuce.



Leaf-sap Potassium

Figure 53. Leaf-sap Potassium in COS lettuce.



Werribee trials

In the November 28 trial planting at Werribee, leaf sap potassium generally remained within "desirable" limits, (2500-4000 ppm) despite high levels of potassium in soil, (fig 53, chart1). Despite generally higher sap-potassium in the Potash treatment at day 43, none of the apparent differences between treatments at harvest were significant. We have earlier suggested that the crop may have been better harvested at day 43 and may have been over mature at harvest on day 48.

Lindenow trial 1

In the December 19 planting at Lindenow, the leaf sap potassium concentration generally decreased as the crop matured, (fig 53, chart 2), and was slightly below the "desirable" limit at harvest. The significance of the apparent differences between treatments in both the Lindenow trial plantings could not be established because replicate samples were bulked.

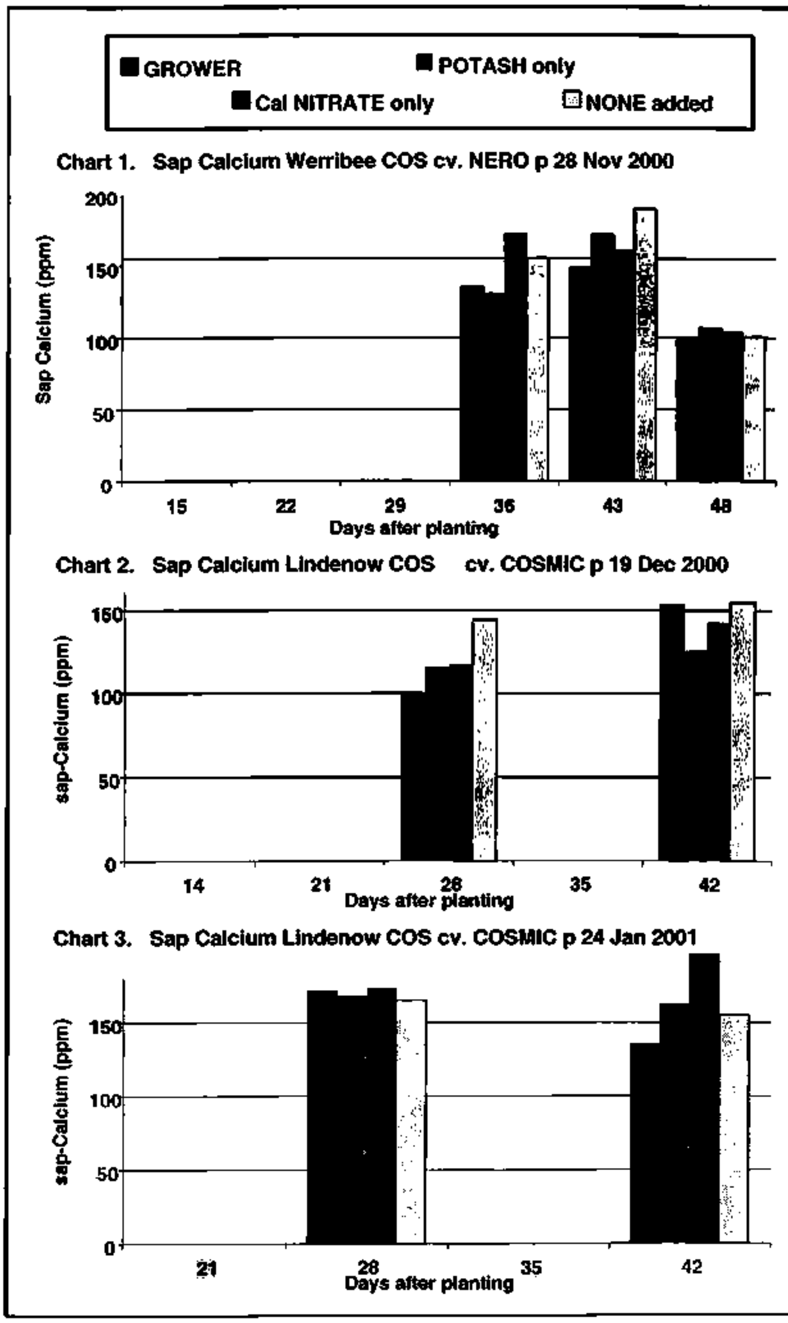
It was noted that the potassium concentration in soils at Lindenow soil, was only half that found at Werribee.

Lindenow trial 2

Sap-Potassium in the January 24 trial planting at Lindenow followed a very similar pattern to the December 19 trial planting and appears unrelated to the observed incidence of tipburn (fig 53, chart 3).

Leaf sap Calcium

Figure 54. Leaf-sap Calcium in COS lettuce.



Werribee trials.

Changes in leaf sap calcium concentrations in Nero planted Nov 28, 2000 at Werribee, (fig 54, chart 1), were very similar to patterns observed in Feb 1999 trial plantings, (milestone report #3).

Leaf sap calcium generally falls in the final week before harvest with a corresponding increase in tipburn. At harvest (day 48), none of the differences between treatments was significant. The November 28, trial planting could be considered "over mature" at day 48 and earlier harvesting would have resulted in a higher quality crop.

Lindenow trials 1

Up until harvest at day 42, the leaf sap calcium in the December 19, trial planting at Lindenow followed a similar pattern to the Werribee trial planting, (fig 54, chart 2). Concentrations of calcium in the leaf sap typically fall below the "desirable' range (400-600 ppm) within 3 weeks of transplant. Despite these low calcium levels, the 1st Lindenow trial planting developed minimal tipburn (fig 54, chart 2).

Lindenow trials 2

Sap calcium levels in the January 24 cos trial planting at Lindenow were generally less variable at hearting (day 28), than was observed in other trial plantings (fig 54, chart 3). Unfortunately, the significance of the relationship between sap calcium and tipburn incidence of the four treatments at harvest could not be statistically related to tipburn as the replicates were bulked before analysis.

Sap nutrient ratios

Changes in the relative proportions of major nutrients in cos, (tables 4,5 and 6) generally followed similar patterns to those observed with iceberg lettuce. The trial plantings at Lindenow were evaluated at the early hearting stage and again at harvest while the Werribee planting was also sampled 5 days prior to harvest. The relative proportions of the major sap nutrients did not appear to be influenced by fertiliser application being generally consistent between treatments.

The proportion of sap potassium to nitrate seen at the three trials locations did not appear to be related to the observed incidence of tipburn. Furthermore, it would be misleading to compare results gathered from different locations growing different cultivars.

The proportion of nitrate to calcium at the early hearting stage of the December 19 Lindenow trial, (table 5) was generally higher than the later Cosmic planting while tipburn was lower. This may provide an early indicator of likely incidence of tipburn. Closer to harvest the nitrate to calcium ratios were similar at all three trial locations.

The relative proportion of potassium to calcium at harvest was generally greater in the Werribee planting but this indicator was not directly related to the observed incidence of tipburn in the Lindenow trial plantings.

Table 4. Sap nutrient ratios Werribee trial COS cv. NERO

Treatment	Werribee cv. NERO planted 28 Nov 2000				
	% full growth	Tipburn (%)	Relative Proportion of Key Sap Nutrients		
			Potassium to Nitrate	Nitrate to Calcium	Potassium to Calcium
Cal NITRATE NPK 15.5-0-0 at 8% growth	75	-	2.7	12.1	33.1
	90	84	1.6	9.3	15.1
	100	100	3.3	6.2	20.2
GROWER NPK 12-5-14 at 8% growth	75	-	2.7	11.6	31.5
	90	83	1.8	8.9	15.5
	100	97	3.4	6.6	22.3
POTASH NPK 0-0-45 at 8% growth	75	-	4.2	6.2	26.3
	90	60	2.7	8.3	22.6
	100	97	3.8	5.9	22.2
NONE added NPK 0-0-0 at 8% growth	75	-	4.5	6.6	29.5
	90	62	1.8	6.9	12.4
	100	91	4.1	5.7	23.0

Table 5. Sap nutrient ratios 1st Lindenow trial COS cv. COSMIC

Treatment	Lindenow cv. COSMIC planted 19 Dec 2000				
	% full growth	Tipburn (%)	Relative Proportion of Key Sap Nutrients		
			Potassium to Nitrate	Nitrate to Calcium	Potassium to Calcium
Cal NITRATE NPK 15.5-0-0 at 8% growth	67	-	1.1	22.7	25.0
		-			
	100	8	1.4	10.5	15.0
GROWER NPK 12-5-14 at 8% growth	67	-	1.3	26.2	33.7
		-			
	100	11	1.6	9.1	14.6
POTASH NPK 0-0-45 at 8% growth	67	-	1.5	17.4	25.2
		-			
	100	3	2.2	6.0	12.9
NONE added NPK 0-0-0 at 8% growth	67	-	1.1	21.1	24.0
		-			
	100	6	1.9	7.0	13.4

Table 6. Sap nutrient ratios 2nd Lindenow trial COS cv. COSMIC

Treatment	Lindenow cv. COSMIC planted 24 Jan 2001				
	% full growth	Tipburn (%)	Relative Proportion of Key Sap Nutrients		
			Potassium to Nitrate	Nitrate to Calcium	Potassium to Calcium
Cal NITRATE NPK 15.5-0-0 at 8% growth	67	-	1.3	14.1	18.0
		-			
	100	38	1.7	6.4	10.5
GROWER NPK 12-5-14 at 8% growth	67	-	1.4	12.6	17.5
		-			
	100	21	1.6	6.5	10.2
POTASH NPK 0-0-45 at 8% growth	67	-	1.5	13.0	19.1
		-			
	100	42	2.2	4.5	10.0
NONE added NPK 0-0-0 at 8% growth	67	-	1.4	13.1	18.5
		-			
	100	33	1.7	5.6	9.3

The ratio of sap-nitrate to calcium at early hearting may help indicate plantings at risk of developing tipburn. While a physiological basis has not been established, we can speculate this ratio may reflect a balance between the growth promoting effects of nitrate and the cell strengthening role of calcium at this sensitive development stage.

7.3. Discussion

In the first season we low leaf calcium levels and concluded that application of calcium supplements prior to hearting may raise leaf-sap calcium levels and reduce the potential incidence of tipburn. Attempts to raise leaf-sap calcium in developing leaves using foliar calcium supplements were ineffective. Although differences in the concentration of leaf-sap calcium were observed in different plantings, at different growth stages and at different locations, there was no strong evidence that any of the three commercially available calcium supplements trialed raised the calcium concentration of the developing leaves or reduced the incidence of tipburn.

In addition foliar supplements containing nitrogen did not appear to increase growth rates or alter sap nitrate levels within the plants. Changes in growth rates and nutrient levels within plants were consistent with the previous seasons results. The first onset of tipburn coincided with heart formation and consequently varied with cultivar and planting date.

In iceberg lettuce sap calcium rapidly fell below the acceptable range and although it may partially recover towards harvest, remained below the acceptable range. Nitrate concentrations were within the acceptable range or slightly high while potassium generally was optimal.

The failure of calcium supplements to raise sap calcium concentrations may have been due to ineffective absorption through the leaf possibly by rapid drying of the leaf surface, removal by irrigation before absorption or by immobilisation of calcium in the outer leaves preventing movement to the heart leaves.

The previous seasons work had indicated the importance of crop growth rates, the impact of fertiliser application and lack of response to calcium supplements. Consequently in year 3 of the project the impact of varying fertiliser application on crop growth, calcium uptake and the incidence of tipburn was evaluated.

Nutrient deficiency usually restricts plant growth rate however tipburn is often found in rapidly growing plants. The trials demonstrated that reduced fertiliser input did not affect growth rates suggesting high existing soil reserves of key nutrients. Although similar growth rates were often achieved without any fertiliser application, tipburn sometimes developed earlier when no fertiliser was applied. Growers may be able to exploit residual nutrient reserves by reducing their fertiliser applications to the first lettuce plantings following a brassica or other crop.

While the total concentration of a nutrient in a plant is known to increase with dry matter yield and supply of that nutrient, the results also suggested that the lettuce plant also has an ability to control some nutrient concentrations in the sap despite their oversupply in the soil. Leaf-sap calcium concentrations of some poor performing trial plantings were very similar to those of more successful plantings and did not provide a consistent indication of tipburn risk. Evidence that the relative ratio of nitrate to calcium at hearting could provide an early indication of tipburn risk is contradictory and needs further examination. While the physiological basis for this relationship has not been examined, we can speculate the ratio of nitrate to calcium may reflect a relative imbalance between the growth promoting effects of nitrate and the cell strengthening role of calcium at this critical stage of the plants development.

Changes in growth rates and nutrient levels within plants were consistent with the findings from previous seasons and sap-nutrients concentrations do change close to harvest but these changes could not be correlated with tipburn incidence. Leaf-sap calcium concentrations of some poor performing trial plantings were very similar to those of more successful plantings. While the total concentration of a nutrient in a plant is known to increase with dry matter yield and supply of that nutrient, it is our belief that non-nitrogen sap nutrient concentrations are regulated throughout development even if they are oversupplied.

In cos lettuce, additional nitrogen fertiliser increased the crop growth rate but also induced premature tipburn.

These results have important implications for improved management and reduced input of fertilisers and indicated that reduced fertiliser input has the potential to improve tipburn without affecting growth rate and yield. There are also significant environmental implications resulting from these trials with reduced nutrient application and leaching into the environment.

8. Pest and Disease Monitoring

The aim of the first season was to document current practices and disease incidence and evaluate potential management strategies. This was to involve three main activities including the documentation of management practices: spray practices, decision criteria and cultural practices used. The second component was to monitor and evaluate disease incidence at the three trial sites and carry out a desktop audit of forecasting methods for anthracnose incidence for evaluation in subsequent seasons.

Current practices were to be evaluated by direct contact with a number of growers in each of the key regions to survey their current management practices such as frequency of application, sprays used and decision making methods.

However due improved chemical controls and the lack of incidence and consequent low impact of the disease it became of much less importance. The desk top audit was carried out and is reported in the results for season 3.

Other Monitoring Procedures.
The incidence of other diseases was also be taken into account when monitoring the trials particularly with the inclusion of new downy mildew resistant cultivars.

Also this trial included trapping to monitor the presence of native budworm or corn earworm, Helicoverpa spp. This pest caused some significant problems in lettuce crops in season 1997/98 and it is important to determine which of the two is the prime cause before an appropriate control program can be developed.

8.1. Year 1 – 1998/99

A number of the cultivars assessed were marketed as resistant to the new races of downy mildew now in Australia. The summer conditions experienced in Lindenow this year were severe with conditions suitable for the development of downy mildew, (prolonged periods of leaf wetness, high humidity and warm summer temperatures). Disease pressure was very high and provided an extreme test in both plantings

These conditions were not experienced at the other two trial sites, when downy mildew did occur it was readily controlled by the appropriate sprays.

In the first planting, the best iceberg cultivars were Iglo, Rhapsody and Silverado which showed minimal signs of downy mildew. Both Rhapsody and Silverado are claimed to be resistant to the new strain of downy mildew, (fig 24). Magnum, Charger and Buffalo were the next best.

The downy mildew results in the second planting were suspect because downy mildew was present in a number of cultivars but septoria was also present and resulted in some confusion of symptoms. The disease symptoms of mature downy mildew and septoria can be similar, and both were present on some cultivars and it is likely that it was only septoria on others, particularly those resistant to downy mildew in the first planting. Consequently, no figures for the incidence have been presented for the second planting.

8.1.1. Results

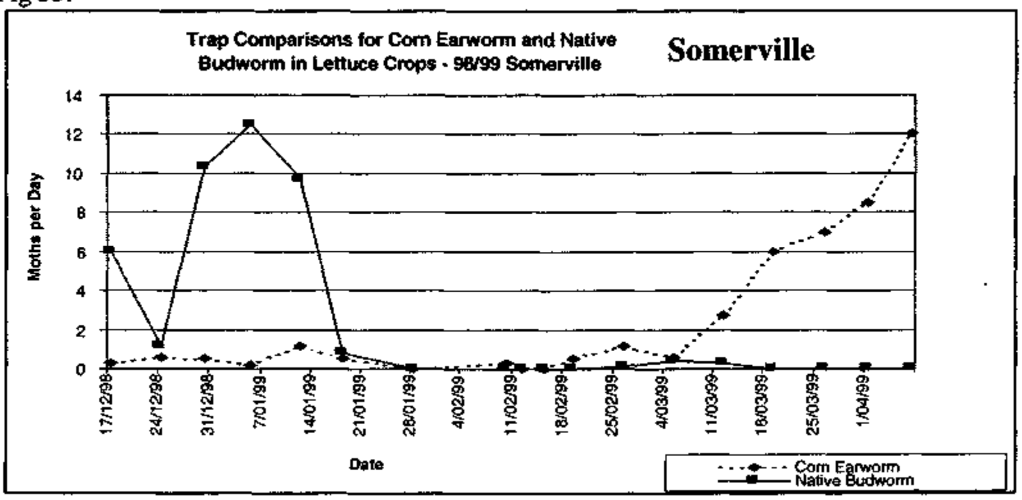
In the first planting, the best cos lettuce cultivars were Le 034 and Regal, both claimed to be downy mildew resistant, (DMR). Remus also had only minor levels of infection. However, in the second planting, Remus was not harvested due to bolting.

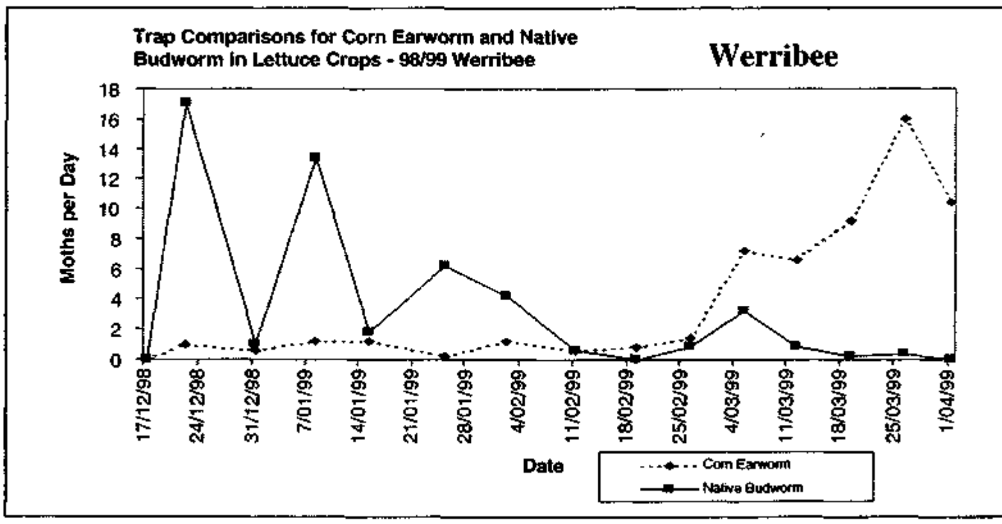
At the Somerville and Werribee sites, no downy mildew occurred at harvest for the first planting or at Werribee in the second planting. At Somerville in the second planting, eight cultivars were infected with downy mildew but infection was not severe enough to affect marketability.

Helicoverpa Grub Activity.

Traps were set up to monitor moth activity around lettuce crops. Traps at the three trial sites, Somerville, Werribee and Lindenow. In East Gippsland this monitoring has been going on for a number of years in sweet corn crops so that picture of moth activity over has been built up over the years. The trap results for each area are shown in figure 55:

Fig 55.





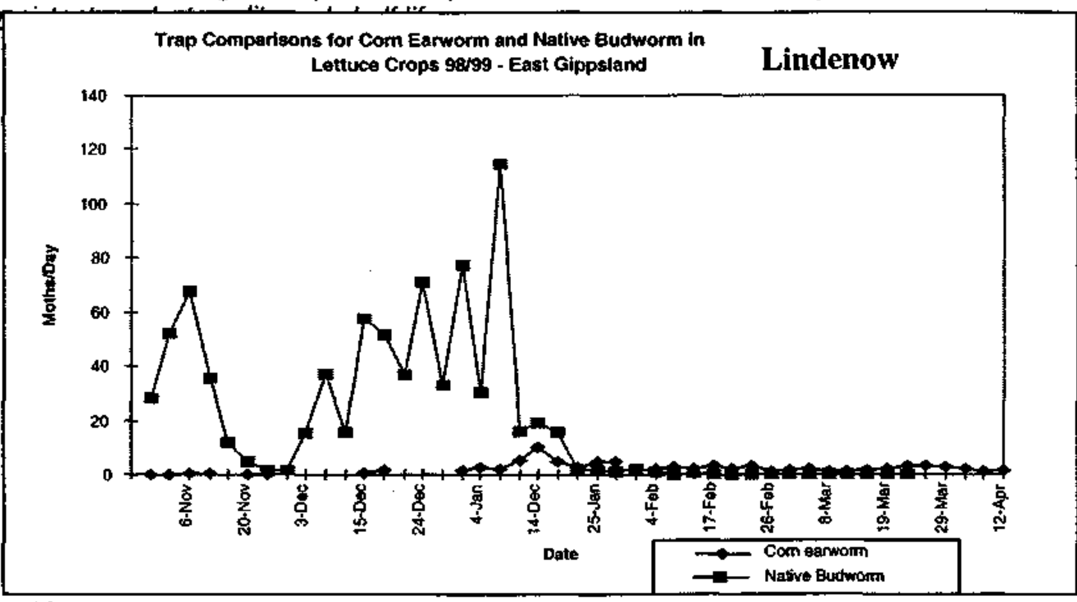


Fig 56

The patterns are very similar for the three trap sites with the exception of the latter part of the season at Lindenow (fig. 56). Early in the season, native budworm is the predominant species with corn earworm activity increasing at the end of the season. However at Lindenow, the traps associated with the lettuce crop have not provided a general indication of corn earworm activity within East Gippsland. Corn earworm activity usually increases significantly from around mid February, (fig. 56).

These results are also confirmed with independent trapping carried out by Muirs using pot traps in Cranbourne and Werribee. There was some significant grub activity in early spring but no control failures were reported. Grub damage to lettuce crops was not reported as a problem in the latter part of the season when corn earworm activity was at its peak.

Given the high native budworm moth counts early in the spring and corn earworm in late summer, the lack of grub problems in crops and no reported control failures, it would seem most likely that the species that caused the problem in the previous summer was Native Budworm.

8.2. Year 2 – 1999/00

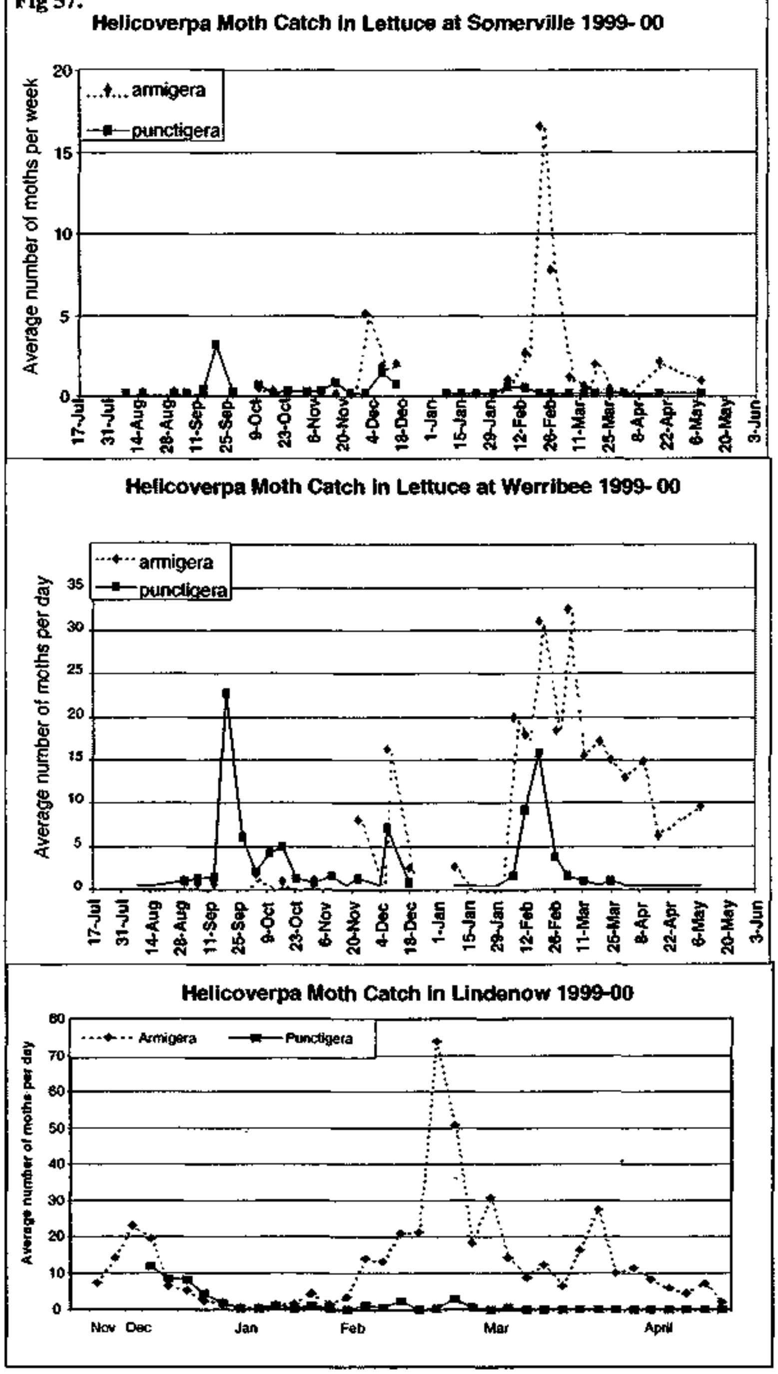
In the previous summer season (97/98), it was reported that Helicoverpa grubs (Corn Earworm or Native Budworm) had caused significant crop damage, particularly in the latter part of the season, in all lettuce growing areas. The two types are different species. Corn Earworm is of particular concern due to resistance to a wide range of chemical groups resulting in control failures in host crops. Native Budworm does not have the same resistance problems and tends to attack a much wider range of hosts.

Consequently as part of the lettuce project pheromone traps were set up to monitor moth activity around lettuce crops. The pheromones are distinctly different and will separate the species. Traps were set up at the three trial sites, Somerville, Werribee and Lindenow. In addition during periods of peak flight industry will be advised of likely increases in activity.

8.2.1. Results

Helicoverpa Grub Activity in Lettuce Crops.

Fig 57.



This summer 99/00 as in the summer of 97/98, Helicoverpa grubs (Corn Earworm and Native Budworm) caused significant damage to lettuce crops particularly in the latter part of the season, (figure 57). Some growers lost up to 3 weeks of plantings. Monitoring in season 1998/99 identified mainly native budworm however this season the problem pest was clearly Corn earworm. This is of particular concern due to its resistance to a wide range of chemical groups. The major issue this season was unprecedented pest pressure from Corn earworm in numbers not experienced previously.

Last year, the flights of *H.armigera* began late in February and gradually built up through March. In contrast, this summer, the flights came mid-February, and the trap counts for these early flights were nearly twice the numbers seen in 1999.

This year unlike last year there was no difference between traps placed near sweet corn crops and lettuce crops in the Lindenow region. The reasons for the high pest pressure this season are unknown but it now appears that this was not the case of flights being blown in from elsewhere as previously thought but that these are mainly local populations

The other issue for lettuce is the limited number of registrations for control of *Helicoverpa* spp. Success® is now registered and is effective but establishing a spray strategy for control is essential if resistance is not to develop.
Monitoring of crops and traps is vital to understand what pests are present and the numbers within a crop.

8.3. Year 3 – 2000/01

As will be discussed further under communication and technology transfer the main focus for this year was to monitor traps and advise industry via the website, faxed information and text messaging on up to date counts of moth activity during the season. Some recommendations for a suitable control strategy were made to industry.

The season generally was relatively quiet with the exception of Werribee (fig 58), which by good scouting and timely spray application was able to control the pest adequately.

In this season in Lindenow moth activity was relatively quiet with *H punctigera* active in spring as expected and *H armigera* activity climbing in early summer and reaching a peak in mid to late February, (fig 59). Activity in Somerville was even lower.

Fig. 58

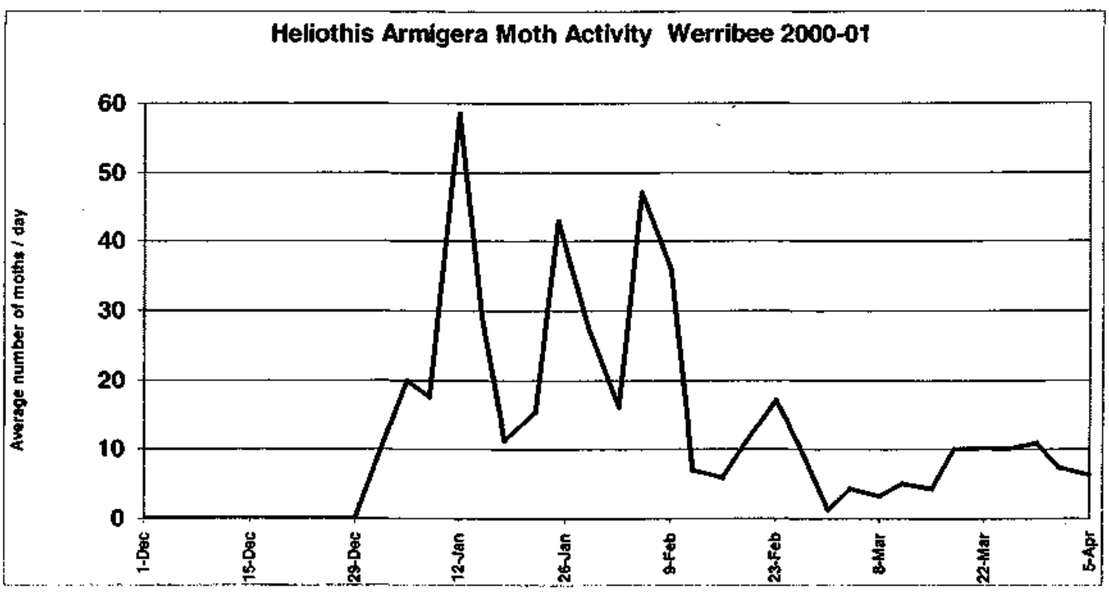
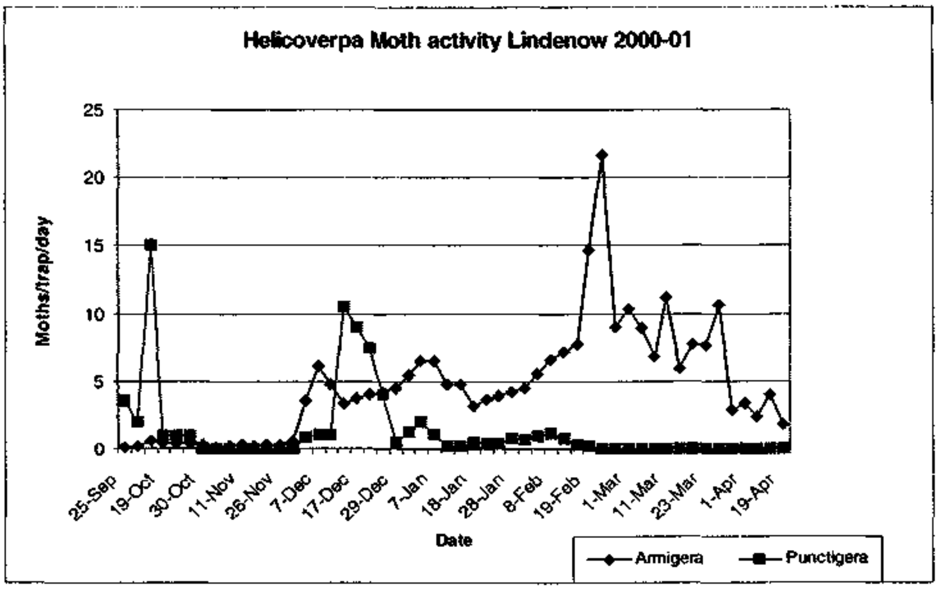


Fig. 59



8.4. Discussion

The trial results indicated significant variability between cultivars in resistance to downy mildew. Anthracnose was not of major concern and the desk top audit is attached in the appendix.
The major effort in relation to pest and disease was in monitoring for *Helicoverpa spp* with major damage occurring to crops in 1999/2000 when unprecedented pest pressure of *H armigera* (corn earworm) was experienced. Pheremone traps provided good indications or pest pressure and provided growers a basis on which to develop a control program. Scentry traps which are more effective provided a better guide as to pest pressure than the pot traps as has been previously experienced when monitoring for *H armigera* in sweet corn in East Gippsland.

For season 2000/01 a strategy was developed for the industry and pest pressure was much lower but clearly H armigera poses a significant threat to the industry due to its resistance to a wide range of chemical groups and limited options for control.

9. Shelf Life

As part of this project, an opportunity was seen to value add to the cultivar trials by carrying out storage assessments of different cultivars. A submission was made for additional funding to carry out this work. Some of the lettuce studies proposed for this season can be extended to evaluate the shelf life characteristics of both whole and minimally processed lettuce. Of particular interest are possible benefits of elevated leaf-sap Calcium and the performance of different lettuce cultivars.

Poor market quality and short shelf life of both whole and fresh-cut lettuce has been identified as an issue by industry. To investigate this trials were conducted to evaluate storage potential of both whole and fresh-cut Cos (romaine) and Iceberg type (crisphead) lettuce cultivars, grown in three different regions of Victoria.

This sub project is reported separately to this final milestone report.

10. Recommendations and Conclusions

Recommendations

Crop Nutrition

- Growers can potentially reduce their fertiliser applications to the first lettuce plantings following a Brassica or other crop.
- There is some potential to control growth rate and reduce potential tipburn by reducing excessive application of nutrients such as nitrogen and managing irrigation more effectively.
- Supplementary calcium applications using foliar sprays did not effectively increase calcium levels or reduce tipburn and are not recommended.
- Crop management is vital from heart formation which is the critical point for the first onset of tipburn.
- Tipburn develops more rapidly, extensively and earlier in January plantings than at other times.
- Better management practices are more critical with crops planted mid-summer.
- Calcium nitrate application as a side dressing was not beneficial to calcium uptake

Irrigation

- Water at night to improve the supply of calcium to developing heart-leaves and lower the incidence of tipburn.
- The impact of poor water quality will also be reduced which would be particularly beneficial for growers in the Werribee area irrigating with lower grade bore water.

Cultivars

- Cultivars had the most significant effect of any individual factor on the incidence of tipburn.
- In well fertilised soils, harvesting 3 days earlier can reduce tipburn by as much as 30 to 50%.
- Cos lettuce requires specific management to reduce incidence of tipburn.
- Cos should not be intercropped with iceberg lettuce over the critical summer period.
- It is important not to delay harvesting the crop as tipburn severity increases and crops should be harvested early.
- The incidence of tipburn in the cultivar Casino did not change during the 4 days prior to harvest providing the Grower with a greater harvest "window" than most other cultivars.
- Select suitable cultivars with tipburn 'resistance'.
- The Cos varieties Verdi, Donatus and Cosmic showed the best tolerance to tipburn.
- All Iceberg varieties showed good tolerance to tipburn with Raider, Kingsway, Toronto, Casino and Ponderosa had the least tipburn.
- The iceberg cultivar Silverado and the cos cultivar Nero, both showed a significantly greater tolerance to tipburn at all three sites compared with the other cultivars in the study.

Pest and Disease

- Scentry traps provide an effective method for monitoring pressure of *Helicoverpa spp.*
- Helicoverpa armigera caused significant damage to lettuce crops in late summer for season 1999/00.
- There is variability between cultivars in resistance to downy mildew.

Postharvest

- The Iceberg cultivars Raider, Casino and Ponderosa had better keeping qualities.
- Whole Cos cultivars Cosmic and Verdi had the longest shelf life and were the least susceptible to pink rib disorder.
- The Cos cultivars Verdi, Donatus and Cosmic, achieved the lowest incidence of tipburn in all production areas.
- When chopped, Cos cultivar Lionheart lasted the longest in shelf life trials at $0^{O}C$, Verdi and Cosmic also performed well.
- When shredded, Iceberg cultivar. Ponderosa lasted the longest in shelf life trials at $0^{O}C$, Silverdo, Raider and Kingsway also performed well.
- Genotype or cultivar had a significant effect on the storage and shelf life of both whole and fresh-cut cos and crisp head lettuce heads grown at all sites, Lindenow, Somerville and Werribee South.

Conclusions

Nutrition

- Tipburn incidence is associated with high crop growth rates.
- Failure to observe a growth restriction with reduced fertiliser input shows high soil reserves of key nutrients.
- In cos lettuce, additional nitrogen fertiliser increased the crop growth rate but also induced premature tipburn.
- In both cos and iceberg lettuce, the relative proportions of the major sap nutrients did not appear to be influenced by fertiliser application being generally consistent between treatments.
- While the total concentration of a nutrient in a plant is known to increase with dry matter yield and supply of that nutrient, it is our belief that non-nitrogen sap nutrient concentrations are regulated throughout development even if they are oversupplied.
- Foliar supplements containing nitrogen did not increase growth rates or alter sap nitrate levels within the plants.
- Concentrations of leaf-sap calcium in iceberg lettuce generally fell below the desirable range within 3 weeks of transplant.
- Nitrogen, potassium and calcium concentrations varied between crops at different sites and growth stages and have the potential to affect quality.
- Concentrations of leaf sap calcium levels started below recommended levels and continued to decrease through the life of the crop.
- When calcium was applied as a supplement, it was usually applied in conjunction with nitrogen, which also affects crop growth rates.
- Low concentrations of calcium were evident in leaf sap and dry tissue samples throughout most of the growing period.
- Nitrate levels were generally within the desired range but rose toward harvest.

- Leaf-sap calcium concentrations of some poor performing trial plantings were very similar to those of more successful plantings and did not provide a consistent indication of tipburn risk.

Irrigation

- The growers current crop irrigation practices were generally providing consistent and ideal soil moisture conditions that could be further improved by avoiding over- and under-watering.
- Soil moisture at all sites was generally maintained within a desirable range and large fluctuations in soil moisture levels were avoided.

Cultivars

- There was variation between cultivars in susceptibility to tipburn.
- At harvest, the Iceberg cultivar, Sheeba generally showed a higher concentration of sap nitrate, calcium and potassium than was seen in other cultivars.
- At Somerville, the iceberg cultivar Sheeba developed less tipburn than the cultivar Target.
- At Werribee, the iceberg cultivars Silverado and Casino showed the lowest incidence of tipburn.
- At Lindenow, the Cos cultivars Cosmic and Verdi appeared to have higher Calcium concentrations and lower incidence of tipburn than Lionheart.
- Cultivars differed in susceptibility to tipburn throughout the season.
- Cultivars varied in their susceptibility to tipburn as they approached maturity.

Plant Growth

- Changes in growth rates and nutrient levels within plants were consistent across all the three seasons.
- Tipburn was a more consistent problem in January harvests rather than April harvests at all locations.
- Monitoring sequential plantings revealed that tipburn developed earlier and was more extensive in mid summer plantings.

Pests and Diseases

- Importance of monitoring and scouting crops for pest and disease control.

Note: No issues were identified in relation to anthracnose due to low disease pressure over the monitored period.

Issues Identified

Nutrition

- Although similar growth rates were often achieved without any fertiliser application, tipburn sometimes developed earlier when no fertiliser was applied. This may be in response to shortages of nutrients other than calcium.
- Sap-nutrients concentrations do change close to harvest but these changes could not be correlated with tipburn incidence.
- Leaf-sap calcium concentrations of some poor performing trial plantings were very similar to those of more successful plantings.
- The relative ratio of leaf-sap nitrate to calcium at hearting may reflect the imbalance between the growth promoting effects of nitrate and the cell strengthening role of calcium at this sensitive stage of the plants development.

This may provide a more consistent indication of tipburn risk than the simple concentration of calcium in the leaf-sap.

- The earlier onset of tipburn in mid-summer plantings may explain growers observations that tipburn occurs simultaneously in a range of planting dates.
- Failure to observe a growth restriction with reduced fertiliser input suggests high existing soil reserves of key nutrients.
- The failure of any of the winter plantings to maintain 'desirable' levels of sap-calcium suggests that the sap-calcium concentrations recommended for lettuce may be unattainable and should be reviewed.

Irrigation

- Irrigation frequencies vary at the three Victorian sites principally due to the differing soil types and the consequent requirements for soil moisture management.

Growth Rate

- Confirmed the relationship between rapid crop growth rate, falling sap-calcium concentrations and an increased incidence of tipburn.
- High summer growth rates are clearly one of the major factors leading to tipburn in lettuce.
- Tipburn is more common in vigorously growing lettuce crops.
- Exposure to additional heat in January accelerated growth but produced smaller plants with more tipburn.
- Several factors have been implicated in the development of tipburn including soil moisture, temperature, humidity and nutrient availability.
- Nutrition and water supply are only part of the tipburn story, humidity, temperature and rainfall all play an important part in determining the crop growth rate, which impacts on the incidence of tipburn.
- January plantings were exposed to 2/3 more heat than November plantings. This additional heat imput did not reduce time to harvest but did reduced crop performance, as the plants were smaller and incidence of tipburn was higher.

11. Recommendations for future work

- The results in the final season have indicated the potential to develop improved sustainable lettuce production practices with improved nutrient application and management and maintain yield and quality and reduce tipburn. This would also evaluate the use of nitrate/calcium ratios to as an indicator of tipburn and identify which might lead to the onset of tipburn.
- *H armigera* has also been identified as a major pest and due to its resistance to a range of chemical groups requires an integrated strategy for management and new chemistry to be assessed for control.
- Establish the role of Potassium in lettuce heart formation.
- Evaluate the use of leaf-sap nitrate to calcium ratio at hearting as an early indicator of tipburn risk.
- Industry consultants consider sodium to be an important factor influencing nutrient uptake in local vegetable crops. These claims need further investigation.
- Correlation between leaf sap nitrate, calcium, growth rate and tipburn incidence.
- Extension of these research findings to benefit more growers.

12. Technology Transfer

A range of methods of technology transfer have been used including newsletters, field days, website, meetings, information sheets, Faxed information and text messaging.

Among the most effective have been specific industry presentations to grower groups particularly based around suppliers to various companies and specific growers groups. The use of newsletters and information sheets backed up with more detailed information available in annual trial reports and presented on a web site where specific details could be downloaded.

In response to industry interest and concern Faxed information was particularly used to keep industry informed of pest pressure. In Gippsland moth monitoring figures were faxed weekly to industry and in other production areas industry was kept abreast of information via the website where figures were updated weekly and phone messaging as well as information to chemical resellers and industry generally.

In addition the use of Text Messaging services were piloted as a means of getting timely information to industry particularly with respect to weekly moth counts.

Information from the project has also been extended to industry via the new NRE extension project Vegcheque to groups and in the newsletter arising from the project "Vegetable Matters".

Milestone reports have been circulated to the Steering Committee and have been available on request and specifically reports of the seasons trial results have been circulated extensively with approximately 25 additional copies of each seasons trial results sent out on request.

The effectiveness of the projects technology transfer has been assessed as part of an overall project evaluation and the impact of the project in terms of outcomes and practice change.

The Future

Information and results from the project will continue to be extended to industry via the Vegcheque project and to Vegcheque groups. A continuation of the project has been sought in part to continue the technology transfer of the project.

Extension Activities

Field Days/ Seminars

- Farm Walk – Lettuce Crop, Lindenow, January 27 1999.
- Presentation – Vegetable Field Days Werribee 6th and 7th of May 1999.

Presentations

- Werribee Vegetable Expo Seminar Series, May 4 1999.
- Glenormiston Vegetable Apprentices at IHD Knoxfield, May 19 1999.
- Steering Committee Report, May 14 1999.
- Golden State Foods Suppliers (Warragul): September 1999

- Werribee Vegetable Growers Group: August 1999, November 1999, January and February 2000
- Harvest Freshcuts Suppliers (Bairnsdale): November 1999
- Cranbourne Vegetable Growers Group: January 2000
- Hay Lettuce Industry Conference: June 2000
- Costas direct suppliers group : 21 September 2000
- Costas pack house suppliers : 22 September 2000

Website

Radio
February 1 2000 - ABC Gippsland interviewed Rob Dimsey about improving lettuce quality

Publications, newsletters and articles are listed in Appendix X.

13. Evaluation Survey - The Lettuce Best Practice Project

An evaluation was carried out on the Lettuce Best Practice project to assess whether the project was effective and whether the communication medium used could be adopted within existing and future R&D projects. Evaluation is important to look at what is being done and whether or not it is effective and relevant. Evaluation can also provide an indication of whether or not the resources are being used appropriately. Communication and extension methods could be improved or changed in accordance with the results of the evaluation.

A random telephone survey was carried out with Lettuce growers in the Werribee, Somerville and East Gippsland region. Twelve participants were surveyed from a total of 60 Victorian lettuce growers in the last two weeks of June 2001. This evaluation was to decide whether the project communication medium was an effective way of delivering information; and whether the information provide was influencing changes - farm and/or in the growers' decision-making process. The key questions the evaluation was designed to answer were:

- Are lettuce growers aware of the 'Lettuce Best Practice' project?
- What are the best types of information?
- Is the content helpful to growers?
- Are the growers using the information on farm?
- What on farm or decision making processes have changed as a result of information obtained from the project?

The feedback was collated in a Bennett's Hierarchy and shows what resources and inputs were used and what the results of these resources and inputs were. This is shown in Figure 1.

	Bennett's Hierarchy Level	*Comments*
Inputs	Inputs and Resources	Lettuce Best Practice DNRE staff for their time, fax machine, computer, industry liasing.
Inputs	Extension Activities	Lettuce Leaflet faxFacts information sheets SIM text messaging for moth counts Information sheets Web pages Field days Trial work at various locations
Inputs	People Involved	60 lettuce growers on growers database with the assortment of industry, processors and DNRE personnel 24 growers on fax list from Victoria, NSW, SA and Qld. (Only Victorian lettuces growers surveyed) 13 growers requests faxFacts
Results of Inputs	Reaction of people involved	58% were able to associate the 'Lettuce Best Practice' project by name 92% received moth count information 67% received tip-burn information 92% growers read more than one type of information supplied by the project ie lettuce leaflet and faxFacts. 75% believed information was provided frequently enough, while 25% remained neutral (ie did not agree or disagree) 92% believed information was relevant to their needs 58% stated the information was provided at the time I need it, 25 remained neutral 67% stated information provided was easy to apply to their farming system 67% stated that they had stored the information so they could refer back them, when needed.
Results of Inputs	Change in Knowledge, Attitudes, Skills, Aspirations	From the grower population that received moth counts, 91% found the information useful in terms of monitoring their own crop and making decision from the counts on their own farm From the grower population that received tip-burn counts, 63% found it useful, and 57% stated that they were able to apply the information on farm 67% sought further information on issue raised in lettuce project. More information was sought form sources such as DNRE staff, chemical and farm supplied, and buyers for aspects of fertiliser, chemical, and variety selection.
Results of Inputs	Practice Change	58% growers indicated that they had made a change on-farm and/or in their decision making process as a consequence of project (ie, closer crop monitoring, spray program alternation, planting different times

Table 7. Evaluation of Lettuce Project results according to Bennett's Hierarchy

Summary of Results:

The evaluation showed that the various types of communication medium used in the project allowed lettuce growers to select and utilised the most appropriate types for them. The growers found the information relevant, timely, applicable and able to be stored for future reference. The moth counts appeared to have the most impact with the sample population. Many stated that the bi-weekly counts made them aware of the level of moth in the region and reminded them to monitor their own crop, especially when the counts were high. There were some instance (Figure 1) where growers changed their spraying management and monitoring process as a consequence of what was read in the lettuce project and their observation in-field.

The tip-burn information provided somewhat different results. The number of people who were able to recall that they received any information relating to tip-burn was reduced. Of those that received the information, they suggested that it did not help significantly because the project was not able to arrive at any conclusive evidence to suggest what caused tip-burn and how it could be managed. Several growers did mention that the tip-burn studies allowed them to observe what was going on and identify key variables that could contribute to high incidence of tip-burn. Some examples given for identifying variables were changing from a foliage calcium spray to a fertiliser, and selecting varieties less susceptible to tip-burn. It was noted that growers who indicated the project had less influence was because these growers were not affected by moths and tip-burn. One grower replied when asked 'Is tip-burn information useful?'

> 'No [usefulness of tip-burn information] since I don't have a problem with tipburn, I skim the information in the lettuce leaflet but not necessarily use any of the information on farm. But if I have a problem with tip-burn, I would source all the information I could get to solve the problem. For growers who have a problem with tip-burn, moths and Heliothis the project has provided beneficial information' (Anonymous, 25th June 2001).

Overall, most (11 out of 12 participants) growers perceived the project as being successful. They agreed information provided was beneficial for better lettuce management.

Several growers suggested that further information and trial work needed to be carried out on variety types and corresponding applicability to specific locations; *sclerotinia* and head rot, longcore in lettuce, lettuce going to head, and moisture management.

Communication surveys

Extract from "Lettuce best practice project: Communication Strategy 1999/2000." (Rennick, 2000)

FaxFACTS EVALUATION SURVEY

A feedback sheet was faxed out to the fax recipients in the first week of May and again in the third week of May. This feedback sheet was to decide whether the information was useful and how to make the FaxFACTS better next season. The key questions the evaluation was designed to answer are:

- Has FaxFACTS raised awareness about the project?
- Is the content helpful to growers?
- Is FaxFACTS being read?

- Are growers using any of the information on farm?
- What are the best types of information or other information required?
- Is the fax an appropriate format?

The feedback was collated in Bennetts Hierarchy and shows what resources and inputs were used and what the results of these resources and inputs were. This is shown in Figure 21.

	Bennett's Hierarchy Level	*Comments*
Inputs	Inputs and Resources	Lettuce Best Practice Communication Officer 25% of their time, fax machine, computer, industry liaison.
Inputs	Extension Activities	FaxFACTS information sheet (one component of the Lettuce BP communication package)
Inputs	People Involvement	24 growers on the fax list from Victoria, NSW, SA and Qld plus distribution through Muirs (Werribee/Cranbourne) fax list and over the counter. Also mail out to 5 growers. Media releases prompted 13 people to request FaxFACTS
Results of the Inputs	Reaction of People Involved	• 50% response rate • 90% had heard about the Lettuce project before reading the fax • 89% said they would like to get the fax again next year. • 50% read all the faxes in detail • Heliothis moth counts and grub control was the most helpful information, followed by weather and then tipburn counts • Faxes followed by newsletters and then media articles were the most preferred ways to get the information • 56% liked to get the fax at the same timing • 33% would like to get the fax more often
Results of the Inputs	Change in Knowledge, Attitudes, Skills, Aspirations	• 56% sought further information on issues raised in the fax. More information was sought from sources such as DNRE staff, chemical resellers • 42% said they felt the fax helped them understand quite a bit more about the lettuce project
Results of the Inputs	Practice Change	50% of the respondents had used some of the information on their farm (eg moth counts, sap testing, spray program alteration, closer crop watching)

Table 8 : Evaluation of Lettuce FaxFACTS results according to Bennetts Hierarchy

Request for further information in FaxFACTS:

- More detailed information on the project
- Critical heliothis moth numbers at urgent times for growers
- Hydroponic lettuce information
- New lettuce varieties and performance in field
- Australia-wide information on quantity, pests, water shortage, weather problems
- Supply prediction for coming months

- Grower comments
- Quality of lettuce - results

Comments and suggestions:

- Have a group discussion on results
- Timing of the FaxFACTS is critical

GROWER COMMUNICATION SURVEY

A phone survey of growers was conducted in October/November 1999 to see where growers got their information from and whether they received and read the newsletter.

- All respondents had received the newsletter
- Many did not read the newsletter
- Pictures of disease did not illustrate the disease well
- Liked it when information is relevant, short and to the point
- Range of ways of receiving information, some liked to see (videos) others liked to read, others liked field trips
- Asked for information about lettuce mainly from chemical resellers, sales reps, family.

From the FaxFACTS evaluation . . .

It is worthwhile doing the FaxFACTS sheet again next season, as all but one of the respondents wanted to receive the FaxFACTS again. Next season some refinement and changes to the FaxFACTS and the Lettuce Communication Strategy are:

- Internet, email and the media

The FaxFACTS should be available on the web and via email .Some respondents requested that FaxFACTS be available on the email or the web. Respondents liked to get their information from newspapers and magazines. Media releases should be sent out at the start of the season giving practical tips from the last two seasons and any other time when a pest or disease problem looks likely to occur.

- Heliothis information

Heliothis information was the most useful to growers as Heliothis was a big problem in the 1999/2000 season. Heliothis moth count data needs to be published more regularly as timing is very important. We need to be able to predict the problem before it occurs and communicate this very quickly. It is very difficult to get publications out quickly on paper, so an internet site or email server with the moth counts recorded as we get them would be a better idea. The moth counts have to be in a clear and concise format with explanations on their relevance. Tips on scouting and a control program before Heliothis becomes a big problem is also necessary. A sheet of moth counts can be posted in E.E Muir and Sons window and at the Werribee South store.

- Timing

It would be good if we could follow the lettuce crop life as we record it and present any interesting or relevant findings and recommendations as we get them. This is a more logical format of presenting the information and would not be disjointed and would ensure the information was timely. It requires very quick action however to be relevant and to keep up with the crop. This could be constrained by the publication approval process. This would have to be looked at.

- More information for the farm

More information was sought (ie from chemical resellers: "relevance of mean temperature" from farm supplies: "sap testing and crop scouts") after reading the FaxFACTS. Some respondents also sought this information from DNRE. Practical tips from the last two seasons trial work need to be collated as an information sheet to send to people requesting further information as well as being available to answer questions. An information session (some respondents requested a meeting) on tips for the coming lettuce season can be held before the season commenced. A possible venue for this in Werribee South is the Werribee Shed day in September. Other venues could be found for South East Melbourne and East Gippsland areas.

- Looking outside Victoria and field lettuce

More information on new lettuce varieties and their performance in the field, pest occurrence, water shortage and weather problems along with quantities of lettuce produced was requested from other areas of Australia. According to one respondent, "This information may help to decide on whether or not to grow lettuce at times or cut or increase production and to choose the right variety for the right times". Information on hydroponic lettuce was requested but may be beyond the scope of this project as it is primarily looking at lettuce grown in the field.

- Increasing the audience

The FaxFACTS has a fairly limited audience and therefore the evaluation had a limited audience. The results of the evaluation is a representation of a section of the lettuce industry mainly in Victoria.

- Evaluate the whole Lettuce Best Practice Project

Carry out an extensive evaluation of the whole Lettuce Best Practice Project to assess the outcomes for the lettuce industry and put in place an effective, ongoing extension/communication strategy of these outcomes.

- Develop links with the Vegcheck Program

Develop links with the Vegcheck program so as the outcomes of the Lettuce Best Practice Project are extended after the project has finished.

14. Appendix 1

A range of methods of communication have been used including newsletters, field days, meetings information sheets and Faxed information.

In response to industry interest and concern Faxed information was particularly used to keep industry informed of pest pressure (see appendix Communication survey). In Gippsland moth monitoring figures were faxed weekly to industry and in other production areas industry was kept abreast of information via the website where figures were updated weekly and phone messaging as well as information to chemical resellers and industry generally.

The effectiveness has been assessed as part of the overall project evaluation.

Papers Conferences

Murdoch C, Dimsey R, Sippo J, Pierce P and Rennick T (2000). Decreasing tipburn in lettuce. Australian Lettuce Industry Conference 6-8 June, Hay, NSW.

Articles

Weekly Times – Tipburn remedy on way, May 26 1999.
Bairnsdale Advertiser – Improved lettuce quality, November 23, 1998.
Improving Lettuce Quality (14 January 2000)
Bairnsdale Advertiser 17/1/2000
Good Fruit and Vegetables March 2000
Southern Farmer February 2000
Stock and Land January 27 2000
Water Magazine (Julie Sippo)
Sent to: Cranbourne Sun, Werribee Banner and Werribee Times

***Pest a menace to lettuce crops* (27 March 2000)**
Sunday Herald Sun April 30 2000
National Marketplace News April 2000
Southern Farmer April 2000
Country News (Shepparton) April 10 2000
Weekly Times March 29 2000
Sunraysia Daily week ending 31 March 2000
Western Times, Werribee Times, Cranbourne Sun (all rang for additional info)

'Tips to prevent lettuce ailment' Weekly Times July 26 2000

Field Days/ Seminars

- Farm Walk – Lettuce Crop, Lindenow, January 27 1999.
- Presentation – Vegetable Field Days Werribee 6th and 7th of May 1999.

Presentations

- Werribee Vegetable Expo Seminar Series, May 4 1999.
- Glenormiston Vegetable Apprentices at IHD Knoxfield, May 19 1999.
- Steering Committee Report, May 14 1999.
- Golden State Foods Suppliers (Warragul): September 1999
- Werribee Vegetable Growers Group: August 1999, November 1999, January and February 2000
- Harvest Freshcuts Suppliers (Bairnsdale): November 1999

- Cranbourne Vegetable Growers Group: January 2000
- Hay Lettuce Industry Conference: June 2000
- Costas direct suppliers group : 21 September 2000
- Costas pack house suppliers : 22 September 2000

Industry Briefing notes:

"Quality Lettuce Project" a leaflet about aims of the project and findings so far. Printed 2 June 2000.

Newsletters

Issue 1 ?
Project steering committee reports.
Grower project summary sheet (circulated to all growers and stakeholders).
Issue 2: July 1999
Issue 3: October 1999
Issue 4: June 2000
Issue 5: Nov 2000
Issue 6: Sep 2001

Radio

Aired February 1 2000 - ABC Gippsland interviewed Rob Dimsey about improving lettuce quality

FaxFACTS

Werribee South and Somerville FaxFACTS:

Issue 1	Nov 30 1999
Issue 2	Dec 17 1999
Issue 3	Jan 10 2000
Issue 4	Feb 11 2000
Issue 5	Mar 22 2000
Issue 6	June 2 2000
Issue 7	Jan 25, 2001
Issue 8	Feb 16, 2001

Gippsland FaxFACTS:

Issue 1	Jan 25 2001
Issue 2	Feb 22 2001
Issue 3	Mar 19 2001

Also in seasons 99/2000. And 2000/2001 all lettuce growers in addition to corn growers in Gippsland received weekly moth counts by fax or email.

Milestone Reports

Milestone Report 2: Lettuce project trial design and protocols, October 1998.
Milestone Report 3: First season trial data and recommendations, July 1999.
Milestone Report 4: Second year trial protocols, October 1999.
Milestone Report 5: second seasons trial data documented and Best Management practices identified, July 2000.
Milestone Report 6: Third year trial protocols, September 2000.
Report 7: Third (final) seasons trials, July 2001.

15. Appendix 2

References

Reuter, D.J., and Robinson, J.B., eds. (1986), "Plant Analysis- An interpretation Manual". Inkata Press.

Krake, R. (1998), "Calibration of the AQUAFLEX Soil Moisture- Monitoring Unit" Vocational Student report for Goulburn- Murray Water Authority, Summer, 1998.

Saure, M.C. (1998), "Causes of the tipburn disorder in leaves of vegetables". Scientia Horticulturae, 76, 131-147.

Frisina, C., Hutchins J., Morris, C., Tomkins, B. and Premier R., (1997) 'The isolation of fluorescent pseudomonas and its affect on the shelf life of minimally processed lettuce' Proceedings of the: 1997 Australasian Postharvest Horticulture Conference.

Murdoch, C.C., (1999), 'Best management production practices to meet market requirements of consistent product quality and shelf life' HRDC project # VG 98082 milestone report #3.

Phillips, D., Teasdale, L., Kumar, S., Gatter, D., and Calder, T. (2000) ' Sustainable production techniques and technology transfer' Proceedings of Australian Lettuce Industry Conference, Hay 6-8 June 2000, p55-69.

Thibodeau, P.O. and Minotti, P.L.,(1969) 'The influence of calcium on the development of lettuce tipburn' J. Amer. Soc. Hort. Sci. 97: 372-376

Thompson, R.C., (1926) 'Tipburn of Lettuce' Colorado Expt. Sta. Bul. 311: 1-31.

Rennick, T., (2000) "Lettuce best practice project: Communication Strategy 1999/2000."
IHD-Knoxfield, DNRE Victoria.

BEDI, A.S. and SEKHON G.S. (1977) " Effect of Potassium and Magnesium application to soils on the dry-matter yield and cation composition of Maize" Journal of Agricultural Science (Camb.), 88: 753-758.

COLLIER, G.F. and TIBBITS, T.W., (1982) "Tipburn of Lettuce" Horticultural Review 4: 49-65.

COX, E.F., McKEE, J.M.T. and DEARMAN, A.S., (1976) "The effect of growth rate on tipburn occurrence in lettuce" Journal of Horticultural Science 51: 297-309.