Project Title	A desk-study to determine the possible causes of tip burn in conifers
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Project leader:	Dr Olga M Grant, EMR
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Key staff:	Dr Olga M Grant
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The results and conclusions in this report are based on a series of experiments conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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Grower Summary

Headline

- Tip burn in *Chamaecyparis lawsoniana* is likely to be caused by an interaction of fertiliser use and growing conditions; suitable further experimental work has been identified.

Background and expected deliverables

British Conifer Growers have faced tip burn for at least ten and in some cases up to twenty years. Tip burn refers to the problem whereby the tips of plants become scorched or discoloured. Conifer growers in Britain have found that tip burn is particularly prevalent in certain varieties of *Chamaecyparis lawsoniana* (Lawson cypress) especially cultivars ‘Ellwoodii’, ‘Ellwood’s Pillar’, ‘Ellwood’s Gold’ and ‘Ellwood’s Golden Pillar’. It also occurs in ‘Snow White’, ‘Silver Threads’, ‘Fleckellwood’ and ‘Springtime’. It occurs in many other varieties of *C. lawsoniana* to a lesser degree. Symptoms develop either at the liner stage or later when the plants are in 2 or 3 L pots. Tip burn is less problematic later when the conifers mature and are planted directly in the soil. Even where conifers recover from tip burn, the problem can delay sales by a year or more, increasing production costs.

The cause and incidence of tip burn has long been debated. Growers and consultants have cited controlled release fertilisers (with added trace elements), excessive feeding, hot weather in July and August, container size, poor drainage, conifer ‘softness’ and growing environment as potential causes of the problem, but the exact cause or the reason why some crops are unaffected is not clear.

Given current uncertainty regarding the cause of tip burn in *C. lawsoniana*, in this project both a literature review and survey of conifer growing nurseries were conducted to identify the most possible causes. If appropriate, this information might be used to develop a further experimental project to deliver guidelines for minimising the risk of tip burn.

This project aimed to:

- Assess the incidence of tip burn in conifers on nurseries in the UK.

- Collate information regarding varieties, growing environments, compost types, fertilisers used, container types and irrigation where conifers are grown on nurseries.

- Collate information from the literature regarding tip burn and related conditions.

- Decide whether future experimental work is required.

Summary of the project and main conclusions

Grower survey

A questionnaire was sent to all members of the Association of British Conifer Growers and to all HNS levy payers who had registered as having an interest in conifers. The aim of the questionnaire was to assess the extent of tip burn on conifer nurseries in the UK and to determine what factors might be associated with its appearance. Growers were asked to provide information regarding varieties grown, years in which tip burn occurred, the time of year of its occurrence, type of growing media and fertiliser used, irrigation practice and time of trimming plants.

Highlights of grower survey:

- Of those growers who responded to the questionnaire, 76% of those growing *C. lawsoniana* are either currently experiencing problems with tip burn, or have done so in the past.

- Half of the growers who have found tip burn on *C. lawsoniana* on their nurseries said it occurred either in 2006 or 2007, though two intimated that tip burn was not severe in these years.

- Two of the nurseries where tip burn occurred in 2006/2007 had not suffered from the problem previously.

- Several nurseries indicated that the varieties 'Ellwood's Gold', 'Ellwoodii', and 'Ellwood's Golden Pillar' were affected by tip burn. A few nurseries also mentioned problems with 'Snow White', 'Silver Threads' and 'Treasure'. 'Pygmaea Argentea' was mentioned as problematic by two respondents.

- In general, there appears to be a tendency for more severe tip burn during the summer months, but the problem does occur at other times too.

- Ten out of the sixteen growers who suffer from tip burn on *C. lawsoniana* say it is possible that the affected plants were sometimes overwatered.

- Conversely, eleven growers said that the growing media in the pots of the affected plants was sometimes dry.

- All the growers who responded to the relevant question, use controlled release fertilisers (CRFs).

- Clipping of plants apparently has limited, if any, effect on tip burn.

Tip burn has apparently been less prevalent in recent years. In some cases this has occurred without any change in nursery practice. For those who consider that a change in practice has removed the problem, the changes included one or more of the following:

- Stopped using Osmocote Plus; changed from Osmocote with Trace Elements to straight Osomocote with no trace elements and added trace elements in a supplement (Micromax or FTE 255); one grower now uses Planacote rather than Osmocote Plus

- Changed from Fritted Trace Elements FTE 253a to FTE 255

- Potted plants into smaller containers

- Slightly reduced the amount of lime in the growing medium

- Stopped trimming plants

Literature review

The literature review was undertaken to collate all existing information on tip burn and related issues. A search was carried out using Web of Science to find relevant 'peer-reviewed' scientific publications. Relevant HDC articles were also obtained.

The Dutch Product Board for Horticulture (Productschap Tuinbouw) was contacted to find out if any relevant work had been undertaken in the Netherlands. The web sites of government-funded agricultural organisations in several countries were searched to obtain any relevant information from elsewhere. Information regarding personal observations and experience of the problem of tip burn was sought from contacts both inside and outside the United Kingdom.

Highlights of literature review:

Previous HDC funded work has noted the development of tip burn on *C. lawsoniana* grown with a wide range of controlled release fertiliser products, but that incidence did not vary between application rates. Conflicting information was gathered on the effect of media pH and the occurrence of tip burn.

Tip burn has also been associated with calcium deficiency, boron deficiency, boron toxicity, phosphorus toxicity and a lack of water availability.

Results

The literature review, in conjunction with the questionnaire, has allowed us to rule out some of the previously mooted possible causes of tip burn in conifers. We can now focus on the remaining possible causes:

- Certain CRFs, including Osmocote Plus, which have added trace elements
- Excessive fertilisation
- Too much of a trace element
    - Boron
    - Manganese
    - Phosphorus
- Hot weather
- Container size
- Poor drainage
- Conifer 'softness'
- Growing environment

Conclusions

Following analysis of all the available information, it was considered that tip burn most probably relates to an interaction between nutrient application and growing conditions.

Growing conditions such as container size, irrigation / drainage and the temperature and radiation in the growing environment influence the availability of nutrients, transport rate of those nutrients, or susceptibility to nutrient deficiency or toxicity. Regarding several of the aspects associated with tip burn however, there are a number of inconsistencies in the literature, grower's observations and general sources of information.

Some significant information gaps exist:

- Toxicity concentrations for various trace elements are unknown for *C. lawsoniana.*

- The actual availability of nutrients to plants from CRF in growing media is unclear and varies according to type of CRF, rate of application, type of growing media, temperature and water availability.

- Why certain varieties are more susceptible to tip burn is unclear.

Future work

Further experimental work would help to provide some of this missing information:

- Nutrient analysis of affected plants to improve understanding of the influence of nutrition on tip burn.
- Assessment of the effect of growth rates on tip burn.
- Examination of the effect of different controlled release fertilizers (CRFs), growing media, temperatures and water availability, on incidence of tip burn.

Financial benefits

For all commercial growers, tip burn results in a delay in sales and most commonly loss of sales and revenue. This desk-study has identified further areas of work that could lead to a better understanding of the problem and solutions which would eradicate the problem.

Action points for growers

- As a result of this initial desk study, we cannot yet recommend any radical changes to existing nursery practice to eradicate tip burn

Science Section

Introduction

The false cypresses (Genus *Chamaecyparis*, Family *Cupressaceae*) consist of six wild species and innumerable cultivars. They originate on both coasts of North America, and in Japan and Taiwan. The most popular garden species is the Lawson cypress, *Chamaecyparis lawsoniana*, which has given rise to over 200 cultivars (Bird 1997).

British Conifer Growers have observed tip burn for at least ten and in some cases up to twenty years. Tip burn refers to the problem whereby the tips of plants become scorched or discoloured. Conifer growers in Britain have found that tip burn is particularly prevalent in certain varieties of *C. lawsoniana* especially cultivars 'Ellwoodii', 'Ellwood's Pillar', 'Ellwood's Gold' and 'Ellwood's Golden Pillar'. It also occurs in 'Snow White', 'Silver Threads', 'Fleckellwood' and 'Springtime'. It appears in many other *C. lawsoniana* to a lesser degree. Symptoms develop either at the liner stage or later when the plants are in 2 or 3 L pots. Tip burn is less problematic later when the conifers mature and are planted directly in the soil. Even where conifers recover from tip burn, the problem can delay sales by a year or more, increasing production costs.

During initial questioning, growers and other commentators suggested that tip burn may relate to those controlled release fertilisers which have added trace elements, or to excessive fertilisation. An alternative suggestion was that the problem is associated with hot weather in July and August. Other factors were considered to also play a role, including container size, poor drainage, conifer 'softness', and growing environment. Even at nurseries where the problem of tip burn has been overcome, there is much uncertainty regarding how it was solved.

Given current uncertainty regarding the cause of tip burn in *C. lawsoniana*, a literature review and survey of conifer growing nurseries were undertaken, with a view to narrowing down possible causes. If appropriate, this information could be used to develop a further experimental project to determine the specific cause(s) and practical solutions. Such a project would deliver guidelines for minimising the risk of tip burn.

Methods

There were two main components to this project – a survey of nurseries where conifers are produced, and a review of the existing literature and other sources of information.

1. Survey of the incidence of tip burn on nurseries

A questionnaire was sent to all members of the Association of British Conifer Growers (ABCG) and all HDC HNS levy payers registered with an interest in conifers. There were two main aims to conducting this survey. The first was to assess the incidence and severity of tip burn on nurseries producing conifers in Britain. The second was to obtain information on a variety of factors, in order to relate the incidence of tip burn to the conditions in which the plants are grown, and thus to try to elucidate the possible causes of tip burn. This second aim required considerable discussion with conifer growers and other parties, and analysis of the available literature (see part 2) in order to determine the optimum questions to ask. To address the second aim, conifer growers were questioned as to the main conifer species and varieties grown on their nurseries, occurrence of tip burn in different years, varieties and production stages affected, time of year when tip burn was most severe, growing media, irrigation, nutrition, clipping, the extent of damage, etc. (Appendix 1). Growers were also asked to provide photos of tip burn on their nurseries, if possible, and provide copies of any foliar or irrigation water analysis that had already been undertaken. The questionnaire was approved by the ABCG and HDC prior to being sent to approximately 100 growers.

2. Literature review

To obtain as much information as possible on tip burn in *C. lawsoniana*, firstly peer-reviewed scientific publications on tip burn and related conditions in any plant species, and secondly on conifers in general, were consulted. Web of Science was used to search for such articles. This led to some related literature searches, such as on nutrient deficiencies in crop plants. Next, HDC reports on topics of potential relevance, such as nutrition of HNS, were consulted. We attempted to contact government-funded horticultural organisations in other countries to find out if the problem had been studied elsewhere. Productschap Tuinbouw (Product Board for Horticulture) was contacted to find relevant work undertaken in The Netherlands. Internet sources were also consulted. The web sites of government-funded agricultural organisations in several countries were searched to obtain any relevant information. Finally, we followed several leads, talking to and contacting growers, consultants, researchers, and technical representatives in the UK and abroad.

Results

1. Survey of the incidence of tip burn on nurseries

Occurrence of tip burn

Twelve respondents to the questionnaire either no longer grow conifers or only trade in conifers rather than grow them themselves. Three more do not grow *Chamaecyparis*, though one of these has experienced tip burn type problems in *Juniperus* and *Thuja plicata*. For one respondent who has not seen tip burn problems at any point in the last 20 years, conifer production accounts for less than 1% of production. Five other growers who do grow *Chamaecyparis* have never had tip burn problems on conifers on their nurseries. This leaves 16 growers who have found, or are finding, tip burn on *C. lawsoniana* on their nursery. One of these growers has also found similar problems with *Leylandii*. This, however, has been considered by most growers we spoke to as a separate issue, possibly relating to aphid damage, and is the subject of another HDC project (HNS 151).

Eight out of the 16 growers who have found tip burn on *C. lawsoniana* on their nurseries said the problem occurred either in 2006 or 2007, though two of these said the problem was not severe in these years. Two of the nurseries where tip burn occurred in 2006-2007 had not suffered from the problem previously. Overall fewer nurseries experienced the problem in 2006-2007 than in the previous two years (11 nurseries). Nine nurseries responded that they had tip burn problems in the years 1990-1999, but some nurseries could only provide more recent data (only 3 of the nurseries that responded that they have had problems with tip burn on *C. lawsoniana* actually said they did not have the problem in the years 1990-1999). No nursery responded that they had the problem before 1990, begging the question, what has changed since then, although in discussions with growers prior to the start of this project, some said the problem has been occurring intermittently for 20 years.

For all the nurseries that have not found tip burn on *C. lawsoniana*, conifer production accounts for less than 25% of production. In contrast, 6 of the nurseries which have experienced the problem said that conifer production accounts for >75% of production.

Varieties affected

Several nurseries indicated that the varieties ‘Ellwood’s Gold’, ‘Ellwoodii’, and ‘Ellwood’s Golden Pillar’ were affected by tip burn. A few nurseries also mentioned problems with ‘Snow White’, ‘Silver Threads’ and ‘Treasure’. ‘Pygmaea Argentea’ was mentioned as problematic by two respondents. Eight other varieties were mentioned by different nurseries. One grower felt that particularly yellow varieties such as ‘Lemon Queen’, ‘Royal Gold’, and ‘Chantry Gold’ tend to be especially affected, and also drew attention to a new variety, ‘Sulphur Spire’, which is severely affected in pots, but not affected when planted out in soil.

Only one respondent considered that tip burn was associated with a particular source of liners.

Thirteen out of the 16 growers who have had tip burn on their nurseries said that the problem resulted in plants that could not be sold. Crop losses on different nurseries include: 100% of ‘Treasure’, 95% of ‘Pygmaea Argentea’, up to 90% of ‘Ellwood’s Golden Pillar’ and up to 80% of ‘Ellwood’, ‘Ellwood’s Pillar’, ‘Ellwood’s Gold’, ‘Snow White’, and ‘Silver Threads’. For another two growers for whom tip burn did not prevent sale, sale was delayed. The economic impact of tip burn is clearly great for several conifer growers.

<u>Time of year</u>

One respondent felt that the problem was most severe between January and March, one between January and June, two between April and June, one June-July and another April-September. Six growers identified the problem as being most severe July-September and one September-October. Only one grower thought the problem was equally severe all year round. In general, therefore, there appears to be a tendency for more severe tip burn during the summer months, but the problem does occur at other times too. Correspondingly, eight growers felt that tip burn was accentuated during hot weather.

<u>Growing conditions</u>

Tip burn occurred on plants grown on gravel, Mypex, or sand beds. All of the nurseries use overhead sprinkler irrigation. On one nursery where plants suffered from tip burn grown using overhead irrigation, plants receiving trickle irrigation were not affected. Ten out of the 16 growers who have, or have had, tip burn on *C. lawsoniana* on their nursery say it is possible that the affected plants were sometimes overwatered; conversely the same growers plus one other say that the compost in the pots of the affected plants sometimes appeared dry. Seven of the nurseries where tip burn occurs/occurred use mains water only for irrigation, a further three use a combination of mains and reservoir water, and one uses a combination of mains and river water. One of the nurseries uses groundwater, and two use reservoir water only. Only three of the growers treat the irrigation water (one with nitric acid, one with chlorine, and one with both). Where analysis of irrigation water was provided, the concentration of the boron in the water was from <0.01 ppm to 0.04 ppm. pH of the irrigation water, where provided, was higher than 6.5.

Of the growers who have/ had tip burn on *C. lawsoniana* and answered the question regarding compost specification (13 in total), four use 100% peat, two use 80% peat, 20% bark, and the rest use varying proportions of peat (always 75% or over), and bark (≤ 25%), grit, sand, or sterilized soil. All used controlled release fertiliser (CRF). Six used Osmocote Plus, 5 used other Osmocote formulations, one used Sincrocell, and one said a Hortifeed formulation was used. Rates of CRF application were 2.5 – 4 kg m^{-3}. One grower stated that tip burn occurred on plants grown with Osmocote Plus, but not on plants grown with Osmocote 12-14 months i.e. without trace elements. Unfortunately only one of the growers who has not had tip burn on the nursery responded to the question on type of CRF – this grower used Osmocote Exact with a peat/bark mix, similarly to several of the growers who did experience tip burn on the nursery.

Five of the growers who found tip burn on their nursery clipped the affected plants, but only two of these felt tip burn worsened after clipping. No grower indicated that tip burn only appeared after clipping plants.

<u>Changes in practice</u>

One grower stopped growing varieties affected by tip burn in order to avoid the problem. Six other growers for whom tip burn was, but is no longer, a problem say they have changed some aspect of their practice. This leaves nine growers for whom tip burn was not a problem in 2006-2007 but for whom it was before, who have not changed any aspect of the way they grow conifers. For those that consider that a change in practice has removed the problem, the changes were one or more of the following:

- Stopped using Osmocote Plus; changed from Osmocote with trace elements to straight Osomocote with no trace elements and added trace elements in a supplement (Micromax or FTE 255); one grower now uses Planacote rather than Osmocote Plus
- Changed from fritted trace element formulation FTE 253a to FTE 255
- Potted plants into smaller containers
- Slightly reduced the amount of lime in the growing medium
- Stopped trimming plants

Another grower said that on his nursery they started hosing pots rather than using overhead irrigation to minimise the incidence of wet leaves, also reduced exposure of the plants to splash from sandbeds, and now use collected reservoir water instead of hard mains water, and reduced the use of dolodust (lime). This grower however primarily had problems with Leylandii rather than *C. lawsoniana*.

Changes in fertiliser use are a recurring theme. One grower who stopped using Osmocote Plus around 1994 and now uses Planacote and adds trace elements (in the form of Micromax), says that since this change there has been a dramatic reduction in tip burn from 80% unsaleable plants to <1%. This grower now only sees low frequency tip burn on 'Ellwood's Golden Pillar' and 'Ellwood's Pillar'. Another said changing from Osmocote with trace elements added to CRF that does not contain trace elements, and adding trace elements separately, removed the problem completely. Another who changed from Osmocote with trace elements to straight Osomocote with no trace elements and adds trace elements in a supplement says the problem is almost solved. One grower suggests that around 1991/1992 the formulation of Osmocote was changed and at this point tip burn became a problem. However one grower says that while stopping use of Osmocote Plus greatly reduced the severity of tip burn, tip burn still persists. Additionally, several of the growers on whose nurseries there are problems have never used Osmocote Plus. In one case, 10 L 'Pygmaea Argentea' pruned hard late summer 2006 and top dressed with Osmocote (no trace elements) showed tip burn on old foliage March/April 2007. On the same nursery, younger 'Pygmaea Argentea' that were potted into 5 L pots are showing tip burn, whereas older plants potted into the same size plants are not. Another grower thought that potting into too large a pot exacerbated the problem (and the problem is almost gone now that smaller pot sizes are used).

One respondent kindly supplied foliar analysis from both affected and unaffected plants, sampled in 2006. Higher concentrations of potassium, sodium, calcium, magnesium, nitrogen, sulphur, phosphorus, iron (Fe), manganese (Mn), boron, copper (Cu), and molybdenum were found in the affected than in the unaffected plant tissue. It is unlikely that necrotic tissue would be associated with high concentrations of nitrogen, so differences probably do not relate to the tip burn. Mn concentration in tip burn plants was 492 ppm, compared to 428 ppm in non-tip burn plants.

<u>Pests and disease</u>

One grower suggested that there may be an association between tip burn on *C. lawsoniana* and a *Keithia* infection on a *Thuja plicata* windbreak.

2. Literature review

<u>Tip burn in *C. lawsoniana*</u>

C. lawsoniana does not feature in the peer-reviewed scientific literature; indeed scientific publications on conifers in general are very few and their scope is limited. The problem of tip-burn does feature in the peer-reviewed scientific literature but never in relation to conifers.

C. lawsoniana 'Ellwoodii' was, however, included in a Horticultural Development Council (HDC) project comparing a range of 12-14 month CRFs (Monaghan 1999; HNS 43d). 'Ellwoodii' plants at Efford grew most with Polyon and Multicote 12, and least with Ficote 180 TE. Marked tip burn was observed July-August onwards where Osmocote Exact Standard, Ficote 180 TE, and Sincrocell 12 were used as the CRFs. Some scorching also occurred with Osmocote Exact Hi-Start. Plants grown with Multicote 12 appeared to be the least affected. At Johnson's of Whixley nursery, foliage scorch occurred in autumn 1998 and spring 1999. Symptoms were marked in plants grown with Osmocote Exact Lo-Start, Ficote 180 TE, Sincrocell 12 and Sincrostart and Plantacote pluss. Tip burn appeared least severe in plants grown with Polyon. In HNS 43d, the CRFs were all used at the manufacturer's recommended rates. This project was later followed by another HDC project (Monaghan 2004; HNS 43f), which aimed at establishing optimal rates of controlled release fertiliser (CRF) nutrition. Container liners were spring-potted and raised outside on sand beds with overhead irrigation for spring marketing in the following calendar year. CRF (Osmocote 12-14 Exact Standard 15N, 9P, 9K, traces) was incorporated at potting into the peat-based compost at 0, 2, 4 or 6 kg m^{-3}. The manufacturer's recommended rate is 5 kg m^{-3}. Retail quality was obtained at 4 kg m^{-3} but some further growth or quality enhancement was found at 6 kg m^{-3}. The same results were found over 2 years at HRI Efford and one year at Johnson's of Whixley nursery. The compost used was 100% premium peat with 1.5 kg m^{-3} Mg lime (adjusted) and 750 g m^{-3} suSCon green for vine weevil control. Tip scorch did not significantly differ between different CRF concentrations.

Some work on tip burn in *C. lawsoniana* 'Ellwoodii' was carried out by Aendekerk (1999), for the Product Board of Horticulture (Productschap Tuinbouw) in the Netherlands. In a study on "Prevention of brown tips in *C. lawsoniana* 'Ellwoodii'", the author states that brown tips can be prevented by maintaining the substrate pH at less than 6 and ensuring the correct potassium concentration is maintained. Rooted cuttings were grown outdoors for 8 months in 1998 and 1999 in a standard nutrient solution and in 8 solutions with increased pH (pH = 6.7) and various potassium:magnesium ratios. The report concluded that tip burn was due to a lack of magnesium and manganese in leaves, but reasons for reaching this conclusion are unclear.

In the 1990s tip burn symptoms in *C. lawsoniana* 'Ellwoodii' and other varieties were studied in experiments on commercial nurseries in the UK (information provided by Bill Riley). Tip burn occurred in a patchy manner some years and at some localities. Onset was usually in late June or early July. Symptoms varied from slight with tip necrosis followed by regrowth to the whole plant dying back from the scorched tips and becoming deformed. Tip burn could affect upper and lower growth alike. Varietal susceptibility was not consistent between years. Foliar analysis for nutrient deficiency was inconclusive. Treatments with water-soluble fertiliser containing trace elements (Peters Professional 20+10+20) increased the tip burn, as did CRFs containing trace elements (Osmocote Plus, Ficote TE), or base fertilisers (PG mix 14+16+18) with trace elements. Soft plants grown in tunnels and transferred outside were also prone to tip burn. Where irrigation was uneven, plants under drought stress were more prone to tip burn. According to this source, CRF without trace elements (Osmocote, Ficote) and with no traces from other sources eliminated tip burn but gave soft, feathery growth. As a compromise one third rate (150 g m^{-3}) of Micromax (Scotts) trace element was added, with the effect that tip burn was minimised and growth was normal. Supplementary feeding was given without trace elements. Unfortunately, it has not been possible to acquire any original data or figures to ascertain the actual differences between treatments, or the consistency of results over time.

A horticultural consultant has provided information that tip burn has been observed on *C. lawsoniana* on several nurseries (over time) and that it is worse on certain subjects such as 'Ellwood's Gold'. This consultant associates the problem with manganese toxicity occurring at low pH, and therefore recommends using fritted trace elements, rather than water soluble trace elements, because trace elements in fritted form become available extremely slowly, reducing the potential for the plants to accumulate elements too quickly. In addition, he recommends using calcium nitrate rather than an ammonium-based fertiliser, because ammonium-based fertilisers are acidifying, and hence accentuate the problem. He suggests that pH should be maintained (using limestone) in the range 5.5 to 6.5. This consultant's analysis of the situation is the opposite of that of Aendekerk (1999, above), and the hypothesis of manganese toxicity has not been scientifically investigated.

<u>Tip burn in ornamental plants</u>

Only one peer-reviewed scientific article concerns tip-burn in ornamental plants, but in that case tip-burn features as one of several symptoms of boron toxicity. In that as in several other articles that feature tip-burn, the problem is described in relation to a single particular factor, already known to cause the condition in a given species. The factors in different experiments vary, and no publication deals with ascertaining the cause of tip burn for a particular crop. Bunt (1988) mentions that certain hardy nursery stock species are susceptible to high levels of soluble phosphate fertiliser application, especially when grown in loam-less media that do not fix phosphorus (P) (about 60% of the superphosphate added to these media remains in water-soluble form). Pale leaves, leading to chlorosis and iron deficiency symptoms, chlorosis and tip die-back in *Cytisus*, and bronzing and leaf drop in *Elaeagnus pungens* 'Maculata' have been reported in association with high concentration of soluble P. *Chamaecyparis lawsoniana* 'Ellwood's Gold' is included in a list of species found to be sensitive to high concentrations of P, though Bunt (1988) does not state what the symptoms are in 'Ellwood's Gold'. The occurrence of P toxicity is dependent upon the balance between levels of available P and other elements, as well as on the media.

<u>Tip burn in conifers</u>

Some information on tip-burn can be gleaned from the United States Department of Agriculture Forest Service, in an article on boron (United States Department of Agriculture, Forest Service 2001), although the information relates to trees grown for commercial forestry as opposed to ornamental nursery production. Boron occurs in very low concentrations in most soil parent material but it is the micronutrient that most commonly limits yield of agricultural crops (United States Department of Agriculture, Forest Service 2001). Deficiencies have occurred in over 132 crops around the world, including forest trees grown in plantations. However, boron first received attention due to its toxic effects. The USDA states that an adequate concentration of boron in bare-root seedling tissue is 10 to 100 ppm, and in container seedling tissue is 20 to 100 ppm. The range between deficient and toxic concentrations of boron is very narrow.

Tip burn in other crops

Tip burn is associated in the scientific literature with a very wide range of situations. It cannot be assumed that the cause of tip burn symptoms in another species will also cause tip burn in *C. lawsoniana.* Tip burn has been noted to occur in lettuce under excessive light in a greenhouse in summer (Seigner *et al.* 2006) and although Frantz *et al.* (2003) describe tip burn in lettuce as a calcium deficiency disorder, they point to the benefit of gradually increasing light and temperature, instead of imposing sharp light/dark transitions in high light, high temperature, and high CO_2 controlled environment production, in order to reduce tip burn. Tip burn has been noted in relation to sulphur nutrition in spring onion (Abbey *et al.* 2002) and is sometimes associated with fluoride injury (Spierings 1967, Fornasiero 2001, Tomar & Aery 2002). Tip burn in lime seedlings has been associated with salinity stress (ElHag & Sidahmed 1997). Lieten (2002a) noted tip burn in emerging leaves of strawberry plants under high humidity. In soybeans (*Glycine max* (L.) Merr.), Krogmeier *et al.* (1991) showed that leaf-tip necrosis occurs after foliar-fertilisation with urea, and that this is associated with accumulation of toxic concentrations of urea in the leaves. They also found that leaf-tip necrosis after fertilisation increased as the nickel content of the nutrient solution the plants were grown in decreased. They suggested that nickel-deficient soybean plants may have lowered urease activity which might make them more susceptible to leaf burn when foliar-fertilised with urea. Tip burn in sugar beet was described in detail by Fife & Carsner (1945), who suggested that it develops when beets that have been grown in fertile soils with an abundance of nitrogen for a relatively long time are then grown under a low light intensity – complete recovery occurs if the beets are grown under high light intensity.

An internet search on tip-burn leads to photos and descriptions of tip burn on a very wide range of species, caused by a very wide range of factors. These include calcium deficiency, excess chlorine and frost damage. Fluoride is suggested as a cause of tip burn in Easter lilies, dracaenas, spider plants (*Chiorophytum comosum*) and marantas, but fluoride damage can be prevented by liming the soil to raise the pH (http://www.schundler.com/tipburn.htm).

Excessive fertiliser or addition of fertiliser to dry soil is also blamed. Low humidity or cold conditions are suggested as causes, but only for tropical plants moved into houses.

Discussion

It is clear from the above that tip burn does not refer to the same condition or cause in all species, and that although there is speculation as to the cause of tip burn in *C. lawsoniana*, little evidence exists. Nine growers for whom tip burn was not a problem in 2006-2007 but for whom it was before, have not changed any aspect of the way they grow conifers. This suggests it is possible that the problem is merely not demonstrating itself recently for environmental or other reasons, and that the changes in practice which some growers think have solved the problem may not be relevant. While *C. lawsoniana* can act as a host for *Keithia*, only one grower suggested this as a possible cause, and based on the survey and literature review there is little indication that the problem with *C. lawsoniana* is either pathological or entomological. Investigation of the impact of different CRFs and the rate of application of CRF on tip burn in *C. lawsoniana* in HDC projects is an indication that tip burn had already been associated with some aspect of nutrition. The Dutch study on tip burn of *C. lawsoniana* also focused on nutrition.

<u>Application of controlled release fertilisers</u>

Rates of CRF application used on the nurseries surveyed were 2.5-4 kg m^{-3} – not excessive according to Monaghan (2004). It is of interest to note that, despite several growers citing Osmocote Plus as being associated with tip burn, in autumn 1998 and spring 1999 at Efford in a trial of 12 CRFs, plants grown with Osmocote Plus were amongst those showing the least severe tip burn (Monaghan 1999). This was also the case in a trial of the same 12 CRFs at Johnson's of Whixley. The Efford data show that tip burn in plants grown with Osmocote Plus was less severe than in plants grown with Osmocote Exact Standard 12-14, Ficote 180 TE, and Sincrocell 12, while at Johsons's of Whixley, tip burn in plants grown with Osmocote Plus was less severe than in plants grown with Osmocote Exact Lo-Start 12-14, Fitocote 180 TE, or Sincrocell 12.

Osmocote and Multicote granules are coated with a layer of resin, whereas Polyon, Plantacote pluss, and Sincrocell granules are coated in polyurethane polymer, and Ficote 180 TE granules are coated in polyolefin polymer (Rainbow A, 1999, Speciality mineral and organo-mineral fertilisers – products and markets. *Proceedings of the International Fertiliser Society*. No. 432, York, UK, cited in Monaghan 1999). Water penetrates CRF granules and the nutrients dissolve, setting up a strong diffusion gradient over the resin layer. These nutrients then diffuse into the surrounding medium. The rate at which nutrients diffuse from the granule is limited by a combination of the thickness of the coating and the temperature.

Manufacturers can modify release rates through the thickness of the coating or the number of micropores in the membrane. At a higher temperature, nutrients diffuse faster from the granule, resulting in a shorter life. Consequently, nutrient availability to the plant is mediated by the interaction of temperature and moisture (Monaghan 1999). This interaction could explain the associations (in the grower survey) with summer months/hot weather and with large containers. Nutrient release in summer is greater, irrigation may in some cases be excessive, and in large pots in particular if drainage is poor, roots could become exposed to a high concentration of nutrients in the growing medium.

Nutrient deficiency?

In the available literature, tip burn in a range of species is often associated with deficiencies or toxicities of one of a range of elements.

Calcium deficiency

Mostafa & Ulrich (1976) associated tip burn in sugar beet with calcium deficiency: in nutrient solution tip burn was associated with a failure to translocate sufficient calcium to the top of the plant to support rapid young leaf growth. Tip burn in cut flowers has been associated with calcium deficiency and is seen to occur where the substrate in which they are grown is inadequately watered (Suarez 2006). Tip burn has also been seen as an early response to calcium deficiency in strawberry ('Nyoho'), before yellowing and eventually senescence of the entire leaves (Jeong *et al.* 2001). Calcium deficiency causes several disorders in a wide range of crops, e.g. blossom-end-rot in tomatoes, peppers and melons, bitter pit in apples, internal browning in pineapples, internal brown fleck in potatoes and also tip burn in lettuce (Joubert 2005). Calcium is necessary to strengthen cell walls and to maintain membrane integrity, so a deficiency can lead to leaky membranes which in turn can lead to loss of chlorophyll. Factors that enhance the development of calcium-related disorders include insufficient calcium uptake by the plant due to insufficient moisture in the rootzone, low available soil calcium and cation imbalances in the soil or fertigation solution, poor root growth and saline root zones; inadequate calcium distribution to low transpiring, rapidly developing plant organs due to poor xylem development, high transpiration rates in leaf canopies, strong carbohydrate sinks in the plants, high growth rates and auxin and enzyme activities, and cultivar susceptibility (Joubert 2005). Calcium deficiency could occur in pots of *C. lawsoniana* if any of these conditions are met e.g. in rapidly growing plants in media with insufficient calcium.

Boron deficiency

Tip burn, amongst other symptoms, has been seen in rice (*Oryza sativa* L.) as a result of boron (B) deficiency (Yu & Bell 1998). Tip burn of strawberry ('Elsanta') has also been associated with B deficiency (Lieten 2002b): in an experiment in which plants were grown in peat and rockwool and nutrient solution was applied with drip irrigation, without B application the B leaf tissue concentration dropped below 25 ppm and 36% of the leaves showed tip burn symptoms. At an application rate of 7.5 μmol L^{-1} B in the nutrient solution, boron leaf tissue concentration was 40 – 55 ppm and no tip burn symptoms were seen. Leaf tip chlorosis has also been found in aubergines suffering from boron deficiency (Kreij and Basar 1997).

One of boron's most critical functions involves the development and growth of new cells and therefore one of the first visual symptoms of boron deficiency is cessation of meristem activity, followed by death of new leaves. Boron deficiency also reduces the stability of membranes, causing them to leak amino acids and sugars. This means that boron deficiencies weaken the plant's physical and chemical defences. Passive flow of soil boron relies on mass flow of soil solution to newly formed root tips, which have the greatest absorptive capacity. After uptake, xylem water flow delivers boron throughout the plant. The ability of a tissue to obtain boron is mainly a function of its transpiration demand (United States Department of Agriculture, Forest Service 2001). Drought causes nutrient disturbance to plants, since the rate of diffusion of nutrients in the soil is reduced, and transpiration is also reduced (Hu *et al.* 2006). Minimising plant moisture stress is therefore important to prevent boron deficiency. Visible boron deficiency symptoms manifest themselves at the growing point. Root elongation is reduced, and terminal buds and young leaves become distorted and/or discoloured and may die. At low foliar concentrations of boron, conifer seedlings appear stunted with terminal buds small or absent. Species with the greatest lignification tend to have the highest requirement for boron, so boron deficiency can be particularly severe in woody plants. Sensitivity to low boron concentrations is increased under high solar radiation (United States Department of Agriculture, Forest Service 2001). Low soil water can depress boron uptake and mobility in the plant. High ammonium concentrations in the growing media result in a rise in pH of the media, which can result in the induction of boron deficiency (Figure 2); high ammonium levels also reduce calcium uptake (Bunt 1988). As with calcium deficiency, boron deficiency could possibly occur in rapidly growing *C. lawsoniana*.

Toxicity?

Varietal differences clearly occur within *C. lawsoniana* in susceptibility to tip burn. Varietal differences in susceptibility are consistent with toxicity symptoms in a variety of other species, in relation to either boron or manganese toxicity (Dučić and Polle 2007, Nable *et al.* 1997b, Yau *et al.* 1997).

Boron toxicity

Francois & Clark (1979) investigated boron tolerance in 25 ornamental shrub species, by applying boron (B) in the irrigation water. Several species were little affected by 7.5 ppm B, but others were severely damaged or killed by the same concentration, and moderately damaged by only 2.5 ppm B in the irrigation water. The sensitive species were yellow sage (*Lantana camara*), juniper (*Juniperus chinensis*), Chinese holly (*Ilex cornuta*), wax-leaf privet (*Ligustrum japonicum*), laurustinus (*Viburnum tinus*), thorny elaeagnus (*Elaegnus pungens*), xylosma (*Xylosma congestum*), photinia (*Photinia* x *Fraseri*), and Oregan grape (*Mahonia aquifolium*). Many of these showed tip burn in addition to symptoms such as premature leaf drop or interveinal chlorosis. Tip burn also occurred on several 'tolerant' species including blue dracaena (*Cordyline indivisa*), southern yew (*Podocarpus macrophyllus*), and glossy abelia (*Abelia* x *grandiflora*). Tip-burn is a typical visible symptom of B toxicity across a range of species – chlorotic and/or necrotic patches, often at the margins and tips of older leaves (Nable et al. 1997a). These symptoms reflect the distribution of B in most species, with B accumulating at the end of the transpiration stream. The chlorotic/necrotic patches have greatly elevated B concentrations compared with the surrounding leaf tissues.

Boron is commonly carried in water and toxicity can occur when using irrigation water with concentrations as low as 0.5 to 1.0 ppm. The boron status of nursery soils or growing media can be monitored with seedling nutrient analysis and tests of irrigation water (United States Department of Agriculture, Forest Service 2001). In this survey, where analysis of irrigation water was provided by one grower, the concentration of the boron in the water was from <0.01 ppm to 0.04 ppm (depending on whether the irrigation water was chemically treated). Such values are 'excellent' according to Bunt (1988). However, the considerable variation between individual samples makes diagnosis of boron deficiency or toxicity difficult (United States Department of Agriculture, Forest Service 2001). The plant available fraction is the best indicator for evaluating a soil's potential for inducing B toxicity in plant species (Nable *et al*. 1997a). The form of B in soils greatly affects its availability to plants. Boron retention is greatest in soils high in organic matter. Soils high in calcium restrict boron availability, so high concentrations of calcium can protect crops from boron toxicity.

Whilst critical foliar concentrations for B toxicity have been established in many crop and tree species, there are serious problems with the use of foliar analysis for diagnosing B toxicity (Nable *et al.* 1997a). In species that accumulate B in their leaves, these tissues normally contain 40 – 100 ppm B. However, the leaves can contain 240 ppm when B in the soil approaches toxic concentrations, 700 to 1000 ppm in extreme conditions of B toxicity. There is a very wide range of critical values for B toxicity, sometimes even for the same species. This is due to the steep gradient of B within leaf blades, with B accumulating in tips and margins, and how this gradient is affected by environmental conditions. Under different transpiration conditions, the overall leaf B concentrations can vary substantially, though the effect on growth can be the same. Accordingly, experimental conditions lead to different critical concentrations for B toxicity being established. Furthermore, B is readily leached from leaves by rain, providing another reason why foliar analysis of field grown plants should be interpreted with caution. As a result of these problems, it has been suggested that B concentrations in healthy regions of leaves should be compared with B concentrations in necrotic/chlorotic regions. If there is a large gradient between these regions then it is very likely that B toxicity is the causal agent, according to Nable *et al.* (1997a). In tip-burned plants on one of the nurseries, foliar B concentration was 34 ppm, whereas that in the foliar analysis of plants not showing tip burn was 28 ppm. This difference in B concentration between affected and unaffected plants is not very large, and the value in tip-burned plants is not high, being within the 'normal' range (30 – 40 ppm) according to Bunt (1988).

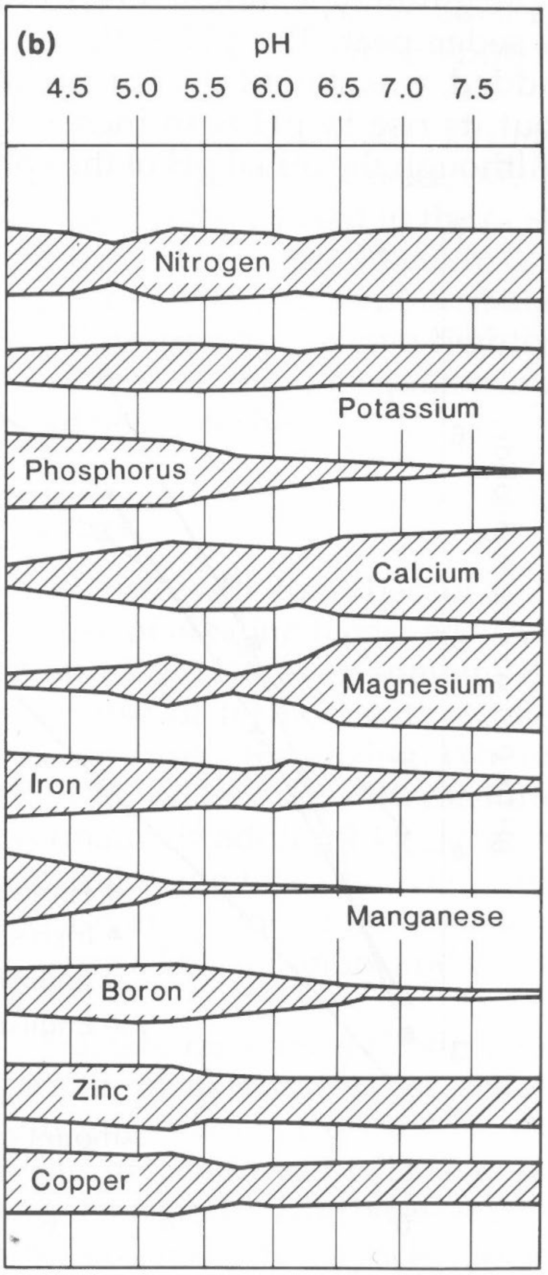

Figure 2. Effects of pH on nutrient availabilities in a typical lightweight potting mix. From Bunt (1988), after Peterson J.C. (1981, Modify your pH Perspective, Florists' Review 169: 92-94). The figure shows that boron is more available at lower pH, and that manganese availability is greatly increased at pH < 5. The availability of phosphorus is also greater in more acid media.

Manganese toxicity

For a wide range of plant species, formation of brown spots is a characteristic development of manganese (Mn) toxicity symptoms in older leaves. This is followed by chlorosis and necrosis and leaf shedding, and then a reduction in vegetative growth of the whole plant (El-Jaoul and Cox 1998). At relatively low pH values, acidification converts 'oxide' forms of Mn into readily soluble forms, so allowing increased uptake by plant roots (Handreck 1999). The author describes the two main pre-requisites for Mn toxicity as pH < 5.0 (see Figure 2) and an inadequate supply of iron. Supplementation of potting mixes with Mn-containing materials can allow Mn toxicity to occur at a higher pH. Some barks are naturally high in Mn. Mn toxicity can also occur under anaerobic conditions in the medium caused by poor drainage (Bunt 1988). Several of the growers surveyed who have, or have had, tip burn on *C. lawsoniana* on their nursery say it is possible that the affected plants were sometimes overwatered. Overwatering and poor drainage therefore may be a factor leading to Mn toxicity. Mn toxicity could be occurring on several nurseries but for different reasons, and probably due to a combination of some of the following: use of high-Mn containing bark, excessive use of trace elements, low pH of the growing media, high light intensity, overwatering/poor drainage.

It has been suggested that the problem of tip burn as seen in *C. lawsoniana* is similar to that seen in several other ornamental plants such as geranium and begonia, and that chemical analysis has consistently revealed high concentrations of Mn accumulation in the affected tissue. However, the concentrations are not always higher than those indicated as 'adequate' in texts such as van den Burg (1985). Dučić and Polle (2007) pointed out that conifers are generally relatively tolerant to Mn – aboveground biomass formation of Douglas fir in their experiment was only inhibited at foliar Mn concentrations of about 3600 ppm. Timmer (1991) indicated values of 100-5000 ppm as the critical Mn range for conifer seedlings. St. Clair & Lynch (2005) sampled foliage from various forest tree species at sites throughout central Pennsylvania, and found that the average Mn concentrations per species, for evergreen species ranged from 748 to 2124 ppm, but also found large variation (± 200 ppm on average) within species. Reichman *et al.* (2004) found that amongst five Australian species, the foliar Mn concentration causing toxicity ranged from under 300 ppm to over

7000 ppm; with huge variation even between species of the same genus. It is very difficult to determine whether a foliar concentration is 'toxic', without critical concentrations having been experimentally determined for the species (and this has never been done for *C. lawsoniana*). Le Bot *et al.* (1990) suggested that the ratio of magnesium to Mn in shoot tissues is a good indicator for predicting the presence or absence of toxicity symptoms, but, Maher and Thomson (1991) found that the critical ratio of magnesium: Mn depended on the experimental conditions. One grower provided the results of foliar analyses on *C. lawsoniana* plants that showed tip burn and those that did not (see survey results). The difference (64 ppm) between samples from plants with and without tip burn is well within the range of natural variation indicated in St. Clair and Lynch's (2005) study. The values are higher than Bunt (1988) describes as normal for ornamentals (30 – 200 ppm), but far lower than what he describes as excessive (> 800 ppm). They are well within the range indicated by van den Burg (1985) as 'adequate' for young *C. lawsoniana* in pots (171-795 ppm).

On one nursery Mn concentration in the water was 3 ppm. This is far lower than the 'high' concentration (55 ppm) used in the nutrient solution which resulted in loss of chlorophyll in leaves in St. Clair & Lynch's (2005) experimental study. The irrigation water on nurseries is unlikely to be a source of Mn toxicity. Handreck (1995) suggests that up to 36 ppm extractable Mn would not be toxic to most plants growing in media of pH 6.0, but 60 ppm extractable Mn may be if the medium pH were to fall below 5.5. Analysis of growing media on nurseries during the season would be necessary to see whether excessive Mn is available to *C. lawsoniana* on some of the nurseries where tip burn occurs.

The association in the grower survey between tip burn and summer/hot weather may relate to greater release of nutrients from CRFs when the temperature of the growing medium is high, but if Mn toxicity is partly responsible for the condition, higher light intensity during summer could be intensifying the toxicity (this has been found particularly where shade adapted leaves are exposed to high light intensity (González *et al.* 1998). One grower found the problem did not occur in plants that were shaded.

Phosphorus toxicity

Bunt's (1988) comments on susceptibility of *C. lawsoniana* to phosphorus (P) toxicity, along with the association of P toxicity with chlorosis and tip die-back in some susceptible species, might indicate that this could be occurring on some conifer nurseries. Not all conifer growers use base fertiliser, and not all base fertilisers contain superphosphates, so it is unlikely to be the cause in all cases, but could account for some. Bunt (1988) pointed out the risk of P toxicity in loam-free media, for sensitive species, which includes *C. lawsoniana*, and one grower felt that use of loam reduces the incidence/severity of tip burn.

Van den Burg (1985) indicates that adequate concentrations of P in the foliar tissues of *C. lawsoniana* are 2200 – 4300 ppm. Foliar analysis provided by one grower showed 6820 ppm in tip-burned plants. Van den Burg, however, does not provide information regarding toxic levels. For some ornamentals P concentrations of up to 7,000 ppm are normal (Bunt 1988).

Other microelements

The copper concentration in the tip-burned analysed nursery *C. lawsoniana* sample (16 ppm) was within the range described as normal (10 – 25 ppm) by Bunt (1988). The molybdenum concentration was fractionally higher than Bunt's 'normal' category, but far lower than would be described as excessive. Zinc concentrations (57 ppm in unaffected tissue, 73 ppm in tissue from a tree with tip burn) were higher than Bunt's 'normal' range (30 – 50 ppm), but far lower than he describes as excessive (> 200 ppm). Overall, the analysis does not provide any striking indications of toxicity or deficiency, but this information is only available for one nursery.

It has been suggested that the use of fritted trace elements (FTE) provides more control over trace element availability than the use of CRF with added trace elements, and therefore the use of fritted trace elements could remove the incidence of toxicity. Bunt (1988) considers that for microelements such as boron for which a narrow range exists between deficiency and toxicity application in fritted form is the safest option.

Conclusions

Information obtained regarding tip burn in *C. lawsoniana* is conflicting, not least in that several growers associate tip burn with a CRF with trace elements, the use of which in a previous HDC study (Monaghan 1999) resulted in a lower incidence/severity of tip burn than several other CRFs. There is a lot of discrepancy between different growers' observations. There is a considerable quantity of speculation, but very little real scientifically-based evidence. Overall, it is considered that some serious information gaps exist:

- Toxicity concentrations in foliar tissue for various trace elements are unknown for *C. lawsoniana*
- Actual availability of nutrients to plants from CRF in growing media is limited (although some is included in Monaghan 1999)
- The reasons for greater susceptibility to tip burn of certain varieties are very unclear
- There is considerable inconsistency in the literature and in general sources of information, regarding several of the aspects associated with tip burn

One of the aims of this project was to use the desk-study to plan experimental work to further elucidate the causes of tip burn, if appropriate. An appropriate course of action would be:

1. Foliar nutrient analysis should be performed on leaf samples from affected and unaffected regions of the same plants as soon as tip burn is sighted on a nursery. Samples from both affected plants and unaffected plants should be analysed. It is quite possible, however, that the 'unaffected' plants will have been exposed to very similar conditions, but that the symptoms may as yet not have manifested themselves in those plants not showing signs of tip burn. For this reason, foliar analysis should also be performed on tissues of plants of the same variety from nurseries where there has been no incidence of tip burn at that time. Foliar analysis only provides an indication of what is happening – nutrient concentrations may have been altered by necrosis, rather than causing it. In addition, therefore, nutrient analysis should be performed on samples of growing media taken at the time that the tip burn is manifested. This will provide information about the availability of nutrients in the growing media at the time the tip burn is occurring.
2. Growth rates and chlorophyll contents of susceptible and non-susceptible varieties should be compared, to assist in determining why some varieties are more susceptible. This in turn should narrow down the range of possible causes of the condition in the susceptible varieties.
3. Laboratory work should investigate nutrient availability for different CRFs, at different rates of application, in different peat/bark/lime mixes, at different temperatures and with adequate, limited, and excessive water availability. Such work would determine the CRFs, rates of application, and irrigation regimes to be applied in the following experiment
4. The response should be determined for a selection of susceptible cultivars to the interaction of the following factors:
    a. CRF type
    b. Growing media (peat *vs*. peat/bark)
    c. Water availability (adequate *vs.* excessive irrigation)
    d. Radiation and humidity (influencing growth rate)
5. Results from (4) should be validated on nurseries.

Technology transfer

- Presentation to members of the Horticultural Trade Association on HNS work at EMR, including this project, 14th February 2007.

- Results of the grower survey and main points from the literature review will be summarised in a presentation to the ABCG October 18th, at the HTA headquarters in Theale.
- This project will also be discussed in an article for the ABCG newsletter.
- The project will be summarised in an article in HDC News October 2007.

Glossary

ABCG: Association of British Conifer Growers
B: Boron
CRF: Controlled release fertiliser
FTE: Fritted trace elements
Mn: Manganese
P: Phosphorus
SRF: Slow release fertiliser
Tip burn: the problem whereby the foliar tips of plants become scorched or discoloured

<u>Fertilisers referred to in text/survey</u>

Product	Analysis
Ficote 180 TE	14-8-8+traces
Multicote 12	15-7-15+traces
Osmocote 16-18 months Exact	16-8-9
Osmocote Plus 12-14 Spring	15-9-11+2+traces
Osmocote 12-14 months	17-10-10
Osmocote Standard 12-14 months	17-10-10
Osmocote Exact Standard 12-14 months	15-9-9+traces
Osmocote Exact Hi-Start 12-14 months	15-10-10+traces
Osmocote Exact Lo-Start 12-14 months	15-8-10+traces
Peters Professional	20-10-20
PG mix base fertiliser	14-16-18
Plantacote pluss 12 months	14-8-14+traces
Polyon	17-5.5-11+traces
Sincrocell 12	14-18-13+traces

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Appendices

Appendix 1.
The following questionnaire was sent to conifer growers in March 2007.

Conifer tip burn survey

Section A

1 **Contact details**

Your name/ nursery					
Address					
Post code					
Telephone		Mobile		Fax	
E-mail					

Section B

2 **What percentage of production do conifers account for on your nursery?** (Please tick appropriate box)

Less than 25%	25 – 49%	50 – 75%	More than 75%

3 **Which are the three main species of conifers produced on your nursery?**

1.

2.

3.

4 **At what stages of production do you grow conifers?** (Please tick appropriate box)

From liner to 7.5 L pot	From 7.5 L pot to 15 L pot	Larger than 15 L pot

5 **Do you grow any of the following varieties of *Chamaecyparis lawsoniana?*** (Please tick appropriate box)

Percentage of total conifer production

	0	1-10	11-25	26-50	51-75	>75
Ellwoodii						
Ellwood's Pillar						
Ellwood's Gold						
Ellwood's Golden Pillar						
Snow white						
Silver threads						
Fleckellwood						
Springtime						

6 **Do you grow any other variety of *Chamaecyparis lawsoniana?*** (Please state which)

…………………………………………………………………………………………..

7 **Has tip burn been a problem on your nursery in 2006-2007?**

Yes	No

8 **Was tip burn a problem on your nursery in the years 2000-2005?**

Yes	No

9 **Was tip burn a problem on your nursery in the years 1990-1999?**

Yes	No

10 **Was tip burn a problem on your nursery before 1990?**

Yes	No

If yes, when? ……………………………………………………………

11 **If you answered yes to any of Questions 11-14, please number the varieties below in the order that they are/were most severely affected by tip burn**
(1 = most affected)

	’06- ‘07	’00- ‘05	’90- ‘99	before ‘90
Ellwoodii				
Ellwood’s Pillar				
Ellwood’s Gold				
Ellwood’s Golden Pillar				
Snow white				
Silver threads				
Fleckellwood				
Springtime				
Other (please name below)				

12 **Did tip burn occur on plants at the**

	Yes	No
Liner stage?		
2 L or 3 L pot stage?		
Larger than 3 L pot stage?		

13 **Did the problem continue when plants were potted up to a larger pot?**

Yes	No

14 **Do you buy in liners?**

Yes	No

If yes, from where?……………………………………..……………………..

15 **Has tip burn on your nursery been associated in particular with any one source of liners?**

Yes	No

16 **At what time of year do you think that the incidence of tip burn was most severe?** (Please tick appropriate box)

Jan – Mar?	Apr - Jun?	Jul - Sep?	Oct – Dec?

17 **Was tip burn apparently accentuated during hot weather?**

Yes	No

18 **On what kind of beds (gravel, Mypex etc.) were the affected plants sited?**

……………………………………………………………………………………

Were the same variety of plants on a different kind of bed unaffected?

Yes	No

If yes, what kind of bed? ……………………………………………………

19 **Were the affected plants receiving overhead irrigation?**

Yes	No

If so, what nozzles do you use? ……………………………..……………

What was the rate of water application? ……………………..……………

Were plants of the same variety receiving a different method of irrigation unaffected?

Yes	No

If yes, what method of irrigation? ………………………….…..……………

20 **Was it possible that the affected plants were occasionally over-watered?**

Yes	No

21 **Was the compost in pots of the affected plants occasionally dry?**

Yes	No

22 **What is your source of irrigation water?** (Please tick appropriate box)

Mains	Groundwater	River	Reservoir	Recycled

23 **Is the irrigation water chemically treated?**

Yes	No

How? ……………………………..………………………………………………….

24 **Have you had the irrigation water chemically analysed?**

Yes	No

What was the concentration of Boron (B)? …………………….……………

What was the pH? ………………….……………………………...…………

Could you supply the analysis?

Yes	No

25 **Please provide the specification of compost that was used for the affected plants**

…………………………………………………………………………………………

26 **Were plants of same variety potted in a different kind of compost unaffected?**

Yes	No

If so, please supply the specification of that compost.

…………………………………………………………………………………………

27 **Was controlled release fertiliser used on the affected plants?**

Yes	No

If so, what type of CRF was used? ……………………………………..……

At what rate was CRF applied? …………………………………………..……….

Do you mix it into the compost on-site, or buy in ready-mixed media with CRF already incorporated?

………………………………………………………………………………………

28 Was controlled release fertiliser used on the affected plants of the same variety?

Yes	No

Was CRF of the same type used and at the same rate?

Yes	No

If not, please specify the type/rate ……………………………………..…….

29 If you answered no to Question 27 or Question 28, what method of fertilising was used?

………………………………………………………………………………………

………………………………………………………………………………………

30 Was Osmocote Plus used anywhere on your nursery at the time tip burn was occurring on any of the varieties below? (please tick appropriate box on the next page and state rate)

Osmocote Plus specifications:

Formula	**15-8-11**	**15-9-12**	**15-9-11**
Total Nitrogen (N)	15%	15%	15%
Ammoniacal nitrogen	7.4%	7%	7%
Nitrate nitrogen	7.6%	8%	8%
Available phosphate (P_2O_5)	8%	9%	9%
Soluble potash (K_2O)	11%	12%	11%
Magnesium (Mg)	1.45%	1%	1%
Sulfur (S)	2.4%	2.3%	2.3%
Boron (B)	0.02%	0.02%	0.02%
Copper (Cu)		0.05%	0.05%
Iron (Fe)	0.35%	0.45%	0.45%
Chelated iron	0.175%	0.23%	0.23%
Manganese (Mn)	0.05%	0.06%	0.06%
Molybdenum (Mo)	0.014%	0.02%	0.02%
Zinc (Zn)		0.05%	0.05%

Variety	Use?	Rate of application
Ellwoodii		
Ellwood's Pillar		
Ellwood's Gold		
Ellwood's Golden Pillar		
Snow white		
Silver threads		
Fleckellwood		
Springtime		
Other (please name below)		

31 Did you clip the affected plants?

Yes	No

If so, at what time of year? ....

Did the appearance of tip burn increase after clipping?

Yes	No

Did tip burn only appear after clipping?

Yes	No

Were other plants of the same variety clipped at the same time but not manifest the symptoms?

Yes	No

32 Did tip burn on your nursery result in plants that could not be sold?

Yes	No

If so, what varieties could not be sold and what percentage of plants of those varieties could not be sold?

....

33 Did tip burn on your nursery delay sale of plants?

Yes	No

34 If tip burn used to occur on your nursery, but now no longer occurs, did you change any aspect of your production?

Yes	No

If yes, did this change relate to (please tick appropriate boxes)

	Yes	No
Drainage?		
Irrigation?		
Fertiliser application?		
Growing environment?		
Other? (please state below)		

If you ticked "Yes" for any of the above, please state what change was made

……………………………………………………………………………………

35 If tip burn is currently occurring on your nursery, would you agree to a site visit by a member of EMR?

Yes	No

36 Can you provide any digital photographs of tip burn on your nursery? (Please e-mail to olga.grant@emr.ac.uk)

37 Have you had any foliar analysis of affected and unaffected plants undertaken?

Yes	No

If so, can you provide the results? (Please enclose or e-mail olga.grant@emr.ac.uk)

Completion and return of this form

Please add any other comments or information which you consider important

....

....

....

....

Please check that you've completed all sections and return in the pre-paid envelope provided to the HDC by Friday 18 May 2007

Thank you for your co-operation.