Managing northern corn leaf blight in processing sweet corn

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NSW Department of Primary Industries

Project Number: VG02115

VG02115

This report is published by Horticulture Australia Ltd to pass on information concerning horticultural research and development undertaken for the vegetable industry.

The research contained in this report was funded by Horticulture Australia Ltd with the financial support of Western Rivers District Horticultural Council.

ISBN 0 7341 1361 7

Published and distributed by:
Horticultural Australia Ltd
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50 Carrington Street
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VG 02115 (May 2006)
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This report covers the activities undertaken during the period of the project from 2002 till 2006.

Date of Report-May 2006.

ISBN 0 7347 1736 9

Funding was provided by the following sources:

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Western Rivers Horticultural Council

HAL
Know-how for Horticulture™

This project was facilitated by HAL in partnership with Western Rivers Horticultural Council who provided a voluntary contribution. The Australian Government provides matched funding for all HAL's R&D activities.

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MEDIA SUMMARY

Sweet corn is a valuable commodity for Australia, grown for fresh market or processing. New South Wales is the largest sweet corn producing state, with production for processing based around the Central West of New South Wales and fresh market in the Sydney Basin.

Northern Leaf Blight (NLB) is a fungal disease that is commonly found in the majority of sweet corn growing regions in Australia. Yield loss due to the disease depends on the amount of leaf infected but in a season conducive to disease development, the whole crop may be lost.

This project examined the current management options for this disease in New South Wales through:

- A desktop study to evaluate NLB management strategies in Australia and overseas.
- Fungicide trials to test the efficacy of propiconazole, a product that was being examined for a permit for NLB control. The only fungicide registered for NLB control was a protective fungicide chlorothalonil.
- To simulate leaf disease, trials were undertaken to examine the effect of partial leaf removal on final yield of sweet corn.

The management of this disease is best achieved by using an integrated approach through the use of suitable resistant varieties, stubble management and fungicide application.

In 2005, propiconazole, a fungicide with curative and protective properties, received a permit for use on sweet corn to control NLB. In trials where there were low levels of disease, leaf lesions due to NLB were less on propiconazole treated sweet corn than on untreated plots. Access to propiconazole will provide some flexibility in the management of this disease.

When 30% and 40% of sweet corn leaves above the silks were removed (each leaf cut in half) at silking, yield loss was minimal indicating that some leaf disease especially after silking will not have serious yield consequences.

Key points to be considered in the future management of this disease include:

- Continued availability of suitable resistant varieties for the end use required.
- Further assessment of alternative fungicides as there are risks involved with the development of resistant races with only two currently available. This should also include applications of alternatives to fungicides such as potassium or phosphate sprays.
- An examination of what races of *Exserohilum turcicum* occur on corn in Australia.

TECHNICAL SUMMARY

Northern Leaf Blight (NLB) of corn is caused by a fungus, *Exserohilum turcicum*. NLB usually infects the lower leaves of sweet corn and then progresses to the middle and upper leaves. The fungus, once it infects, causes elongated necrotic lesions on the leaves. If allowed to progress the lesions can cover all the leaf and subsequently reduce yields. The symptoms become worse when rain or dew occur regularly as the fungus prefers temperatures around 20-24°C and high moisture. These conditions are often met in south eastern Australia in the autumn months.

The fungus is spread by spores from nearby crop residue and if infection occurs early enough then cob fill is reduced. Yield loss due to the disease is difficult to predict, however in a season that is conducive to disease the whole crop may be lost.

Management of NLB when conditions are conducive to rapid disease development is difficult, however the use of an integrated approach covering awareness of conditions needed for disease development, early detection of the disease, resistant varieties, plant residue management and fungicide application will assist in controlling the disease.

Fungicide options are available but the range has been limited to one fungicide until recently. The only registered fungicide (chlorothalonil) provides leaves with protection against NLB but needs to be applied regularly to cover any newly emerged leaves from infection. In 2005 propiconazole, a fungicide with curative and protective activity, received a permit for use on sweet corn to control NLB. During trials in this project, control was significantly improved at low disease levels on partially resistant varieties, with one application of propiconazole. Access to propiconazole will provide some flexibility in the management of this disease; however a provision is that its use has been limited to two applications in a season. It should be applied as protective rather than curative so that chances of resistance developing are reduced.

As a guide to the extent of yield loss that can be caused by leaf diseases such as NLB, leaf destruction trials overseas suggest that yield loss is highest when leaves from the upper third of the plants are removed (at mid-silking) compared to those in the middle and lower thirds. In the Murrumbidgee Irrigation Area of New South Wales leaf removal trials were carried out. Leaves above the silks were cut in half at weekly intervals after silking so that there was 30% (Trial 1) and 40% (Trial 2) less leaf in cut plots compared to uncut. There was a trend to a higher yield on uncut plots but this was not significant. An earlier trial had shown that when 50% of leaves above the silk were removed it resulted in a significant 11% yield loss.

Varieties of sweet corn grown currently have varying susceptibilities to NLB. Many partially resistant varieties still express symptoms of disease but development is restricted. It is possible in the future that new races of the fungus could develop that affect resistant/susceptible varieties. Also partially resistant varieties carry inoculum over from one season to the next season and therefore a new race or a more aggressive race may develop.

Populations of the *E. turcicum* fungus can vary in their aggressiveness, new races may also develop so varieties may become infected that had previously shown some tolerance. There are possibly two races of *E. turcicum* in Australia, race 1 and race 0, but this has never been studied.

Future work on this disease should cover fungicide management under higher disease levels and manipulating the timing and number of fungicide applications. A restriction on the permit limits propiconazole use to two applications; therefore further investigations could consider the optimum time of its application related to yield benefit.

An evaluation of the interaction or combination of chlorothalonil and propiconazole should be undertaken.

Other fungicides should be evaluated as resistance may develop to the limited number of fungicides currently available.

Alternatives to fungicides such as foliar fertiliser treatments have been reported to control NLB. These should be tested under Australian conditions.

The availability of resistant varieties is needed and further development should be ongoing as this is the best method of managing this disease. The number and availability of partially resistant varieties in use has been increasing.

The races of *Exserohilum turcicum* on maize and sweet corn in Australia are not known and therefore should be investigated.

INTRODUCTION

This project was initiated by Western Rivers Horticultural Council, a grower group based in the Central West of New South Wales. This group showed concerns that varieties they were growing were susceptible to the disease Northern Leaf Blight (NLB). This disease thrives in the cooler moist conditions that are often experienced in the autumn months in this region. The group supply corn for processing by Simplot Australia in Bathurst. Crops were being sown during a period of the year that resulted in harvests around April/May. In the 1999/2000 season a total crop loss of 280 hectares was recorded in the Central West of New South Wales.

The group provided a voluntary contribution for the project. Their aim for the project was a desk top study to develop management techniques for controlling NLB. At the same time a fungicide permit for propiconazole had been applied for as a control option. The efficacy of this fungicide was also to be investigated. It was to be two year project.

There were delays in project approval. The project was actually approved and signed off in March 2002, however it was back dated till July 2001 when the project was supposed to have been approved (original project number VG 01074). It was approved too late to undertake any field trials as autumn is the most vulnerable period for NLB in the Bathurst area. Therefore by March it was too late for the 2002 season. The project was given a new number VG 02115 and was to run till June 2003.

Extensions were further requested until 2006. The extensions were requested due to lack of disease especially in the Bathurst region where the majority of trial work was to be conducted. Weather conditions during the period of the project were not favourable for disease expression. Field trials at Bathurst in 2004 and 2005 were established on a grower's property however in both years there was nil or low disease. It was therefore decided to undertake some trials in 2006 in the Sydney Basin.

In addition to fungicide trials, leaf destruction or removal trials were conducted to establish a relationship between leaf loss (photosynthetic area loss) and final yield, simulating leaf disease.
An outline of activities in the autumn of each of the years (except the desktop study) is listed below.

- 2002 Desktop study.
- 2003 Field trial to examine the disease at Yanco Agricultural Institute.
- 2004 Fungicide trial Bathurst.
- 2005 Fungicide trial Bathurst, de-leafing trial Yanco.
- 2006 Fungicide trials Sydney Basin, de-leafing trial grower's property Whitton.

SWEET CORN AND NORTHERN LEAF BLIGHT

SWEET CORN AGRONOMY

The climate preferred by sweet corn is a growing season of 15-32°C. Extremes of temperatures above 35°C can cause problems such as reduced pollination and endfill (cobs may not be filled to the end with kernels). The crop takes 75-105 days from planting to harvest. Sweet corn for processing and for the fresh market is sown from October to February in different regions with soil temperature the governing factor. Harvesting therefore takes place from early January to May.

Irrigation is by furrow in the Murrumbidgee Irrigation Area (MIA), centre pivot in Dubbo (some in the MIA) and Cowra, with high pressure travelling gun irrigators in Bathurst. Processing sweet corn is grown by the farmer for Simplot Australia who harvests and transports the crop to the factory in Bathurst.

Sweet corn varieties grown are either those described as standard sweet corn such as Jubilee or Punch, or super sweet varieties such as Krispy King and Sovereign.

CORN DISEASES RECORDED IN AUSTRALIA

Diseases of sweet corn and maize in Australia include, Turcicum leaf blight (*Exserohilum turcicum*), Maydis leaf blight (*Bipolaris maydis*), Common rust (*Puccinia sorghi*), Polysora rust, (*Puccinia polysora*), *Physoderma* brown spot (*Physoderma maydis*), Maize dwarf mosaic (virus), Maize stripe (virus), Java downy mildew (*Peronosclerospora maydis*), Crazy top (*Sclerophthora macrospora*), Bacterial stalk rot (*Erwinia* bacteria), Boil smut (*Ustilago maydis*), Head smut *(Sporisorium reliana*), Charcoal rot (*Macrophomina phaseolina*), *Stenocarpella* (*Diplodia*) stalk rot (*Stenocarpella macrospora, S. frumenti, S. maydis*), *Fusarium* stalk rot (*Fusarium verticillioides*) *Gibberella* stalk rot (*Gibberella zeae*), *Fusarium* ear rot (*Fusarium verticillioides*), *Gibberella* ear rot (*Gibberella zeae*), *Stenocarpella* (*Diplodia*) ear rot (*Stenocarpella macrospora and S. maydis*), *Nigrospora* ear rot (*Nigrospora sphaerica*), *Rhizoctonia* ear rot (*Rhizoctonia* sp.) (Kaiser 1997) (Stovold 1984).

SWEET CORN PRODUCTION

Sweet corn is grown in the Central West and Riverina regions of NSW and in the Sydney Basin (Fig. 1). The Sydney Basin sweet corn is grown for the fresh market while in the other areas the crop is grown for the processing industry.

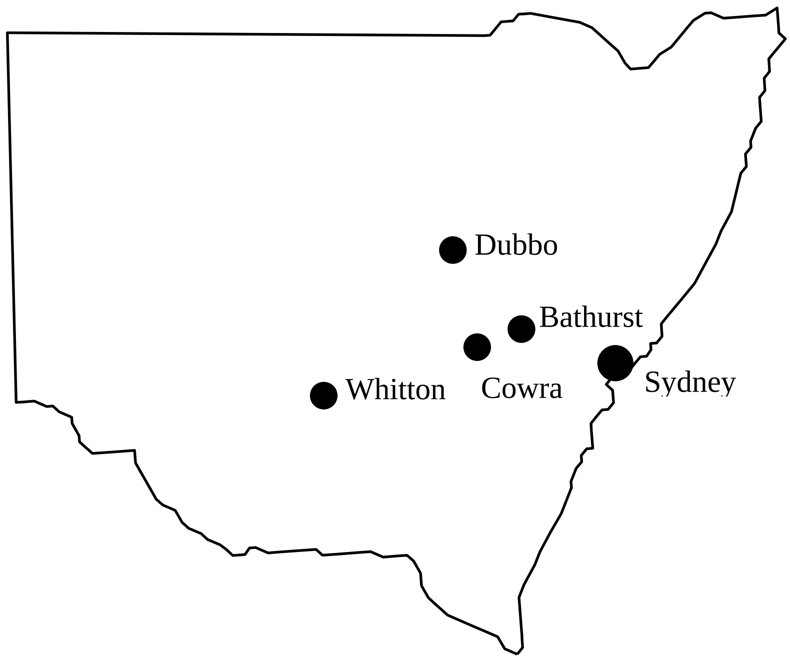

Figure 1. Map of NSW showing sweet corn growing regions.

Sweet corn is an important industry for Australia with New South Wales being the biggest producing state of sweet corn. Eighty percent of the sweet corn is for processing, either as frozen packs or for canning. Sweet corn is not affected by as many diseases in Australia as overseas, but those that can be more serious include rust, boil smut and northern leaf blight.

THE CAUSE OF NORTHERN LEAF BLIGHT

Northern leaf blight, sometimes referred to as turcica leaf blight, is caused by a fungus, *Exserohilum turcicum* (Pass) Leonard and Suggs. The fungus has been recognised under different names such as *Helminthosporium turcicum*. There are a number of races i.e. different types of the fungus, seven races have been described. In the United States there are four that affect corn, these are described as race 0, race 1, race 23 and race 23N. Which races occur in Australia is not known. Resistances have been bred into corn that may be specific to some races and if a new race develops then that resistance may break down.

Northern leaf blight is a disease that affects sweet corn only in some years. The problem is worse in varieties that are more susceptible especially when these are sown late for a late harvest and this coincides with rainfall and dews. NLB is a disease affecting sweet corn in many parts of Australia including Burdekin and late season crops in Bowen, Bundaberg and the Lockyer Valley (Qld), late season crops in Cowra, Bathurst and the Northern Rivers (NSW), Bairnsdale (Vic), and Kununurra, Carnarvon and Manjimup areas (WA).

SYMPTOMS

NLB usually infects the lower leaves of sweet corn and then progresses to the middle and upper leaves. The fungus, once it infects, causes elongated necrotic (dead) lesions on the leaves. If allowed to progress the lesions can cover all the leaf and subsequently reduce photosynthetic area and thus reducing yields.

The symptoms become worse when rain, dew or fog occur regularly. The fungus is spread by spores from nearby crop residue and if infection occurs early enough then cob fill is reduced.

DISEASE CYCLE

Exserohilum turcicum overwinters (carries over from one season to the next) as mycelia (fungal strands) and conidia (small spores or fruiting structures) on leaves from the previous season. The conidia can be carried from an old block to a recently planted one by wind and then from infected leaves to uninfected leaves within the new block.

Infection occurs when conditions are moist because of rain and especially dew. Dew periods are enough to spread the disease and allow infection. For the production of spores the fungus needs a minimum dew period of 14 hours at 20-25°C; however this does not need to occur in one stretch. There may a break in the middle of this period i.e. it may start one night then stop, then finish the next night. Long periods of high humidity may also allow conidia to be produced.

After the formation of conidia, 1hr of leaf wetness is necessary for the fungus to infect the leaf. In Australia wet summers can promote this disease and dry summers will reduce the disease levels as seen in the drought year of 2002/03. Overhead irrigation will increase the chance of the disease, however even in 2002/03 this wasn’t enough for disease development.

NLB is a sporadically occurring disease relying on a susceptible variety of corn, the availability of the fungus and suitable weather conditions. Only if all these conditions are met then disease development will take place.

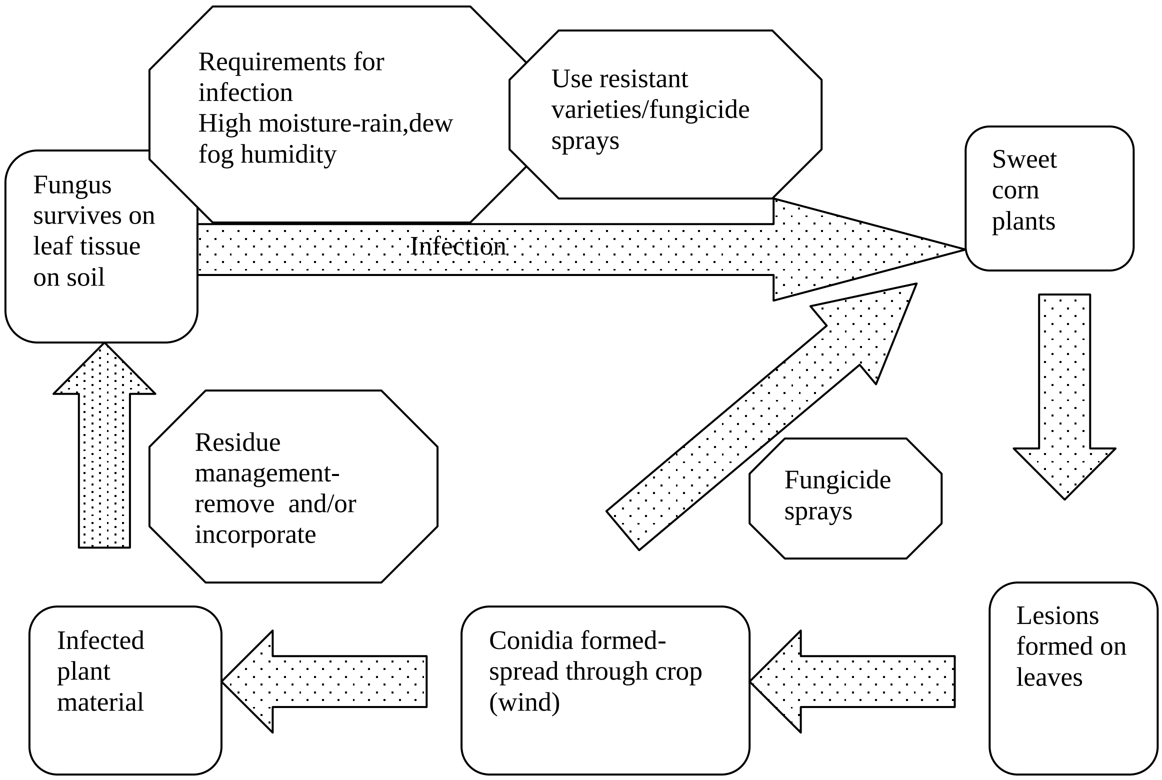

Figure 2. Diagrammatic representation of the infection process of northern leaf blight.

YIELD REDUCTIONS DUE TO NLB

Most yield loss information caused by NLB relates to maize. In overseas studies on yield reductions in maize, severe blight 2-3 weeks after pollination reduced yield by 40-70% but if the disease did not become severe until 6-8 weeks after pollination, yield was not affected. Another study found that yield was reduced about 0.2% for each 1% increment in severity of NLB at 3-4 weeks after mid silking (Pataky 1992).

In sweet corn, yield loss due to NLB in susceptible varieties was reduced 12—20% by levels of disease at 15-55% was recorded at harvest. If leaves from the lower third of the sweet corn plant are removed (at silking) it has little effect on yield. Yield reductions are highest only when the leaves above the ear are removed (Pataky 1992). Therefore chemical control must aim at keeping upper leaves free from disease.

Even though symptoms may develop on some partially resistant varieties, the yield was not severely affected when NLB severity a week before harvest was less than 8% in the upper 75% of the leaf canopy, or less than 20% for the entire leaf area (Pataky *et. al*. 1998).

DISEASE MANAGEMENT

Management of NLB when conditions are conducive to rapid disease development is difficult, however using a wide range of options as discussed below will help manage this disease better. This integrated approach should cover awareness of conditions conducive for disease development, early detection of the disease, resistant varieties, stubble management and chemical control.

CONDITIONS THAT FAVOUR DISEASE

An understanding of the conditions needed for disease is important in any management plan. As previously discussed, wet conditions and whether the disease was present last year (either near the current planting or in the area) are two important considerations as to whether the disease is going to be a problem. Crops planted late are more likely to become infected especially in cooler areas where dews may become more common when the crop is maturing. If the disease establishes early, dews will increase disease levels.

EARLY DETECTION OF THE DISEASE

Early detection is an important step in controlling diseases in many crops. Crop monitoring is important; having a crop scout look through the crop will aid in early disease or pest detection. If suspicious leaf spots are detected, forwarding them to a plant pathology diagnostic laboratory can confirm the causal agent of the disease. A number of leaf spots were found in a crop survey undertaken in 2003 but none were NLB, so not every leaf spot is NLB.

RESISTANT VARIETIES.

The availability of resistant varieties is the main and most successful method of controlling this disease. There are two types of resistance, partial (polygenic) resistance which is not race specific, where the reaction to disease is displayed as reduced lesion numbers, lesion size and sporulation. The latent period is also lengthened (the period between when spores infect a leaf and the development of lesions new spores on the leaf).

Another resistance type is called monogenic resistance which is more of a total resistance to a particular race. The disease on these plants is expressed as chlorotic (yellow coloured) lesions and the numbers of spores produced by these lesions are reduced. There is the likelihood that resistance may be broken down by new races of northern leaf blight. Races are named in relation to the *Ht* genes that they are virulent to. The races mentioned above, race 0, race 1, race 23 and race 23N are known in the United States. Race 0 is avirulent on all *Ht* genotypes ie *Ht1*, *Ht2*, *Ht3*, *HtN/0*, race 1 is avirulent on *Ht2 Ht3*, *HtN/1*, therefore it is virulent against the *Ht1* gene. Which races are in Australia has never been established however it is suspected that race 0 and race 1 are present (J.Pataky personal communication). The main resistant varieties in Australia carry the *HT1* gene and some have shown necrotic and chlorotic lesions which is evidence of race 1 and race 0 respectively.

Partial resistance is the most common type of resistance on sweet corn. Partially resistant varieties of sweet corn that are currently grown develop disease in the lower leaves of plants. Part of the resistance expression reduces the movement of disease into the upper canopy. A table of some of the common current varieties and their reaction to NLB are listed in Appendix 1.

STUBBLE MANAGEMENT.

As stubble is a source of the fungus and its method of carrying the disease over from season to season, any infected crop residue should be ploughed in as soon as possible after harvest to encourage rapid breakdown. Growing a number of kilometres away the previous years infected stubble is recommended but quite often not possible.

CHEMICAL CONTROL

Chemicals available for controlling plant diseases can be divided into two groups. There are those that provide protection to leaves and need to be applied regularly to cover new leaves. These chemicals are often referred to as protective; organisms are less likely to develop resistance to them and they have a wide spectrum of the type of fungi they affect. Other types are curative (systemic) fungicides. These show some capacity to move through leaves away from the site of application and can affect some fungi specifically. Some organisms may develop resistance to these types of fungicides.

The only registered product available for chemical control of NLB is Bravo® (chlorothalonil). The recommendation for this protective chemical is to apply it when the disease is first seen and then from 7-10 day intervals. Early detection of the disease is important as is the frequency of application compared to the predicted yield benefit at the end.

Alternative fungicides are available if they could be registered for example Tilt® (propiconazole). This product is known to control NLB however it is not registered in Australia. Propiconazole is a systemic fungicide with curative activity and some protective activity with some fungi. A permit (available at www.apvma.gov.au/permits/permits.shtml) was approved for this product in 2005.

Other chemicals tested overseas have been successful at controlling NLB including, flutriafol (Jubilee® and Impact®), difenoconazole (Score®), tebuconazole (Folicur®) and captan. Members of another group of chemicals such as azoxystrobin (Amistar®) are being used in the United States and would have the potential to control this disease in Australia; the product controls many diseases on many crops. Tilt® is the best new option however there are other candidates that should be tested in Australia.

In variety trials in the United States a mixture of mancozeb (Dithane M-45® at 1.68 kg /ha) and propiconazole (Tilt® 3.6E, 0.29litres/ha) was applied up to 4 times to reduce disease levels (Pataky *et.al*. 1998). Sometimes a combination of protective and curative fungicides works better than either on their own. Tilt® has the ability to inhibit mycelial growth of *E. turcicum* but does not affect conidial germination, whereas mancozeb (Dithane®) inhibits conidial germination (Bowen and Pederson 1988).

Chlorothalonil and propiconazole also control rust of sweet corn.

FUNGICIDE APPLICATION

Correct application of the fungicide is important therefore directions on the label need to be followed. With protective chemicals good leaf coverage is essential as any leaf left uncovered will be susceptible to the disease. Protective fungicides may also be washed off the leaf by heavy rainfall.

OTHER CONTROL MEASURES

Literature has suggested that foliar fertilisers have a controlling effect on NLB. Phosphate sprays have been shown to provide a systemic resistance to NLB. This method of control could be evaluated under Australian conditions. Application of potassium has been evaluated for assisting in the reduction of disease and was found to be successful (Reuveni and Reuveni 1998) (Reuveni *et. al.* 1998).

THE ECONOMICS OF SPRAY TREATMENTS

The actual cost of applying fungicides is important to consider when diseases need to be controlled. Sweet corn gross margins available at http://www.agric.nsw.gov.au. were used to develop Table 1. The costs of fungicides were based on chlorothalonil (2litres/ha) at $44 per litre and propiconazole (0.5 litres/ha) at $88.30 per litre. Application costs were based on $40 per ha.

% Yield Loss Expected	Yield Loss T/ha	Nil Sprays $/Ha	One Chlorothalonil $/Ha		One Propiconazole $/Ha		Chlorothalonil and Propiconazole $/Ha	
		Nil	**One**	**Two**	**One**	**Two**	**One**	**Two**
0	**0**	1425	1341	1257	1297	1169	1253	1081
10	**1.7**	1169	1086	1002	1042	913	998	825
20	**3.4**	914	831	747	786	659	742	570
30	**5.1**	659	575	491	531	403	487	315
40	**6.8**	404	320	236	276	148	232	60
50	**8.5**	148	65	-19	21	-108	-23	-196
60	**10.2**	-106	-190	-274	-235	-362	-279	-451

Table 1. Expected gross margins related to yield loss and the number of fungicidal sprays. This is based on a 17 tonne crop as per the gross margin and sprays applied separately.

TRIALS

FIELD TRIAL AT YANCO AGRICULTURAL INSTITUTE

A crop of Jubilee was sown at Yanco Agricultural Institute in January 2003. This crop was monitored until harvest for the presence of NLB and was to be used as a fungicide test block. The crop was watered with overhead sprinklers to induce the correct conditions for disease development. No disease was apparent at harvest. The possibility of inoculating the crop with the fungus was rejected because the crop was close to corn and therefore a risk for disease spread. Field trials were therefore planned for the Bathurst area the following season.

FUNGICIDE TRIALS

Aim

The fungicide efficacy trials were conducted as preliminary trials to coincide with a permit for propiconazole (Tilt®) that was due to be released. There is only one fungicide registered for NLB control and that is chlorothalonil e.g. Bravo®. Bravo® is an important fungicide for many crops acting as a protective fungicide; therefore it needs to be applied before the disease becomes established.

Many currently grown varieties have partial resistance to NLB so they may develop some disease symptoms. If conditions occur that are highly conducive to disease development, then fungicide application will become necessary. Where chlorothalonil is a protective fungicide, propiconazole offers some curative, protective and systemic activity. The product is registered in the United States for use on corn. It is a more expensive chemical than chlorothalonil but still has a role for NLB control in Australian conditions. Its role may also be in combination with chlorothalonil. Because of the cost of fungicide application the fungicide trials were only to have a maximum of two applications.

Azoxystrobin is registered in the United States for NLB control, however it is a more expensive chemical than the two mentioned previously. The chemical was tested in one of the fungicide trials. To assess the effect of fungicides it was proposed to measure the percentage of the leaf area affected.

Method

All trials included propiconazole and chlorothalonil, azoxystrobin was included in one trial in Bathurst. All trials were monitored until silking when spraying started using a back pack sprayer. Information in the desktop study suggested that keeping the top leaves free of the disease was a key in reducing the level of yield reduction due to the disease. The efficacy of the fungicides was assessed on leaf symptoms only, no yield data was collected.

Trial 1 Bathurst 2004

The trial was on a growers' property and the variety was Punch. This trial consisted of 5 replicates with 4 rows of sweet corn per plot, plots were 20 metres long. Plots were not sprayed until silking and then only sprayed once on 11 February 2004. Treatments included Cheers® (chlorothalonil 720g/l) (2 litres/ha) and Tilt® (propiconazole 250 g/l) (500ml/ha). Plots treated with propiconazole were destroyed as the permit for its use had not been approved. The site was revisited for disease assessment.

Assessment of symptoms took place on 11 March 2004. The percentage of infection was recorded on the fourth leaf from the top on each of ten random plants.

Trial 2 Bathurst 2005

This trial consisted of unsprayed plots or plots sprayed with azoxystrobin, chlorothalonil and propiconazole. The same rates as above were used for the latter two fungicides. An experimental rate was tested for azoxystrobin. Mixtures of chlorothalonil and propiconazole were also applied. Some of the fungicides were applied twice. The block was assessed before harvest but there was no disease present. The plots with fungicide treatments were not harvested. Fungicides were applied on 3 March 2005 and 22 March 2005.

Trial 3 Sydney Basin 2006
This trial was going to be based in the Bathurst area where disease development was monitored, but as no disease was found the trial was transferred to the Sydney Basin.

Two trials were conducted near Richmond on growers' properties. The varieties were Matador and Sentinel, both partially resistant but were still showing disease symptoms at the time of spray application. No other susceptible varieties could be found for this growing period. Treatments were applied on 21 March 2006. The treatments included one application of propiconazole or chlorothalonil and other plots were left unsprayed.

Assessment was by visually rating the percentage necrotic area on the leaf attached to the cob which was usually the fourth leaf from the top. This assessment took place on 7 April 2006, 17 days after the fungicide application.

Results
Trial 1 Bathurst
Low levels of disease were recorded with unsprayed, chlorothalonil and propiconazole recording 0.4, 0.04 and 0.06 percentage infection respectively.

Trial 2 Bathurst
No disease was recorded in this season.

Trial 3 Sydney Basin
Levels of disease were low at both sites. The percentage leaf area affected is recorded in Table 2. Leaf symptoms on plots treated with propiconazole was significantly less in both trials whereas chlorothalonil was significantly less in one compared to untreated controls.

Treatment	Farm 1	Farm 2
Nil	5.9 b	2.5 b
Propiconazole	1.0 a	0.6 a
Chlorothalonil	2.06 a	2.6 b

Table 2. The percentage of leaf damaged by infection of NLB on the cob leaf. Numbers with the same letter are not significant (5%).

Discussion
Reduced disease levels were fortunate (from a grower perspective) however it did create problems with testing the efficacy of fungicides. Towards the end of this project (2005) the propiconazole permit was released. The fungicide showed disease control in the Sydney Basin trials at low disease levels. The leaf assessed in these trials was not the most seriously affected leaf on the plants with the leaves below this one having slightly higher levels of infection. Infection was consistent at similar leaf position throughout the crops.

Chlorothalonil showed some disease control but as it was 17 days from fungicide application until disease assessment it was beyond the 7-10 day recommended treatment interval. Both crops were irrigated by overhead irrigation so some wash off of the fungicide was expected. A stickier chlorothalonil product is now available and would be the recommended formulation to apply.

DE-LEAFING TRIALS

Aim

These trials were established to examine the effect of leaf removal on yield. Overseas data had suggested that lower leaves if removed or damaged by disease at around silking, had no effect on final sweet corn yield, however when upper leaves were removed then yield was affected. A trial conducted in 2001 (Napier *et al* 2001) showed that when leaves on sweet corn plants (variety Dominion) were removed at 10% silking (from the silks up) the result was a yield loss of 11%. This relates to approximately 1.7 t/ha on the 17t/ha crop. Leaves were cut so that when measuring dry leaf weight at harvest there was 50% less total leaf on the cut plots than the uncut plots. Silking is a critical stage in corn development and is significant in that after silking no new leaves emerge. A diagram of corn growth stages is in Appendix 3.

Method

Trial 1-2005

The variety Golden Sweet was sown at Yanco Agricultural Institute in January 2005 and irrigated with overhead irrigation. In this trial each of the 4 treatments was replicated 6 times in a randomised block. Fifty percent of leaves were removed i.e. half of each leaf above the silk was cut off. The leaf cutting was carried out at silking (80%); silking plus one week, silking plus two weeks and other plots were left uncut.

The plots were 5 metres long and at maturity 10 plants were cut and measured for fresh weight and cob weight. The last cut in this trial was two weeks before harvest (28 April 2005). Leaf area was measured on the 10 plants from a cut treatment and the control uncut treatment and the number of leaves was counted.

Trial 2-2006

This trial was carried out on a grower's property. It was harvested on 20 February 2006, earlier than Trial 1. The variety was Jubilee and it was furrow irrigated. All the leaves were cut by approximately 50 %. The cutting times were early tasselling, 100% silking, and silking plus 1 week, with a control again left without leaf removal. Plots were 15 metres in length. Leaf weight was recorded by removing leaves in 3 places in a cut and uncut plot and removing 1 metre of plants (6 plants each time). The leaves were cut from above the cob and below the cob and kept separate, dried in a dehydrator and weighed.

At harvest 10 metres of each plot was harvested. Where two cobs were present on a plant, each was bagged separately and weighed. Cobs were assessed for quality and those judged to be suitable for market were weighed.

Results.

Trial 1

The fresh weight (of whole plant) and the weight of cobs have been tabulated in Table 3. There was no significant difference (5%) between the cut and uncut plots in either fresh weight or cob weight. Leaf area was 30% less in the cut plots than the uncut plots.

Treatment	**Fresh weight (kgs)**	**Cob weight (kgs)**
No leaf Removal	5.62 a	2.60 a
Silking	5.42 a	2.52 a
Silking + 1 week	5.62 a	2.51 a
Silking + 2 weeks	5.79 a	2.65 a

Table 3. Comparison of the mean of fresh weight (i.e. total plant weight) and cob weight (husk removed) of 10 plants at harvest. Those with the same letter are not significant (5%).

Trial 2
Although there was a trend towards increasing marketable cob weight it was not significantly different (Table 4). As cobs were split into top cobs and second cobs, the mean cob weight of marketable first cobs i.e. the cobs higher on the plant was not significant across treatments. However the mean cob weight of marketable second cobs i.e. the cobs lower on the plant was significant. The plots with leaves removed had on average 40 % less leaves than the uncut plots.

Harvest 20th February 06	Marketable cob wt (kg) per 10 metre of row,		
	First cob	**Second cob**	**Total**
Early Tasselling (22 Jan 06)	9.5a	0.01a	9.51a
100% Silking (1 Feb 06)	10.5a	0.25a	10.75a
1 week after silking (9 Feb 06)	10.19a	0.29a	10.48a
Control (No leaf removal)	10.65a	0.83b	11.48a

Table 4. Results of the de-leafing trial 2006, cob weight of the marketable second cobs was the only significant value at 5% (LSD 0.514).

Discussion
In the preliminary trial in 2001, the loss of 50% of the leaves above the silking point reduced yield by 11 %. However, the 2005 trial showed there was no significant yield loss when 30% of leaves were removed.

The trial in 2006 (40% leaf removed) showed a trend to decreasing total marketable cob weight with each cutting time but it was not significantly different. The weight of the marketable primary cobs was not significantly different however the weight of the marketable second cob was significantly higher in the uncut plots. The trial in 2006 was undertaken at a very hot time of the year and stress on plants would have been expected more on these than the trial in 2005 that was sown in January and harvested in April, a period of lower stress on the plant.

Sweet corn has shown its ability to yield well even though 50% of leaves were removed at silking. If this information is applied to sweet corn plants whose leaves are affected by plant disease, then some decision can be made regarding the potential yield loss due to the development of the disease especially post silking.

It appears from these results that if at least 70% of leaf area above the silk are maintained until harvest yield losses of less than 11 % would be expected.

WEATHER CONDITIONS OVER THE PERIOD OF THE PROJECT

The project's target region was the Bathurst area of NSW. During the period of the project, weather conditions were ideal for reduced frequency of NLB in the Central West of New South Wales. The level of rainfall over the period January to April in Bathurst (central west NSW) has been represented in Fig. 3 and Fig. 4. The total rainfall for the period is in Fig. 3. 2003 and 2004 are quite lower than others in the 10 year period. For NLB to develop, rainfall during the growing season is critical.

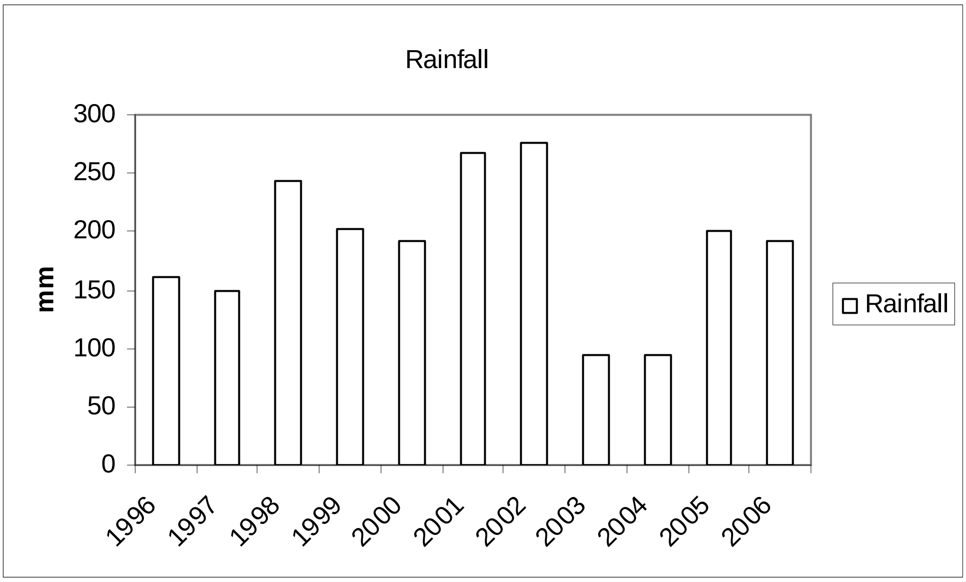

Figure 3. Graph of total rainfall for years 1996-2006, for Bathurst, NSW.

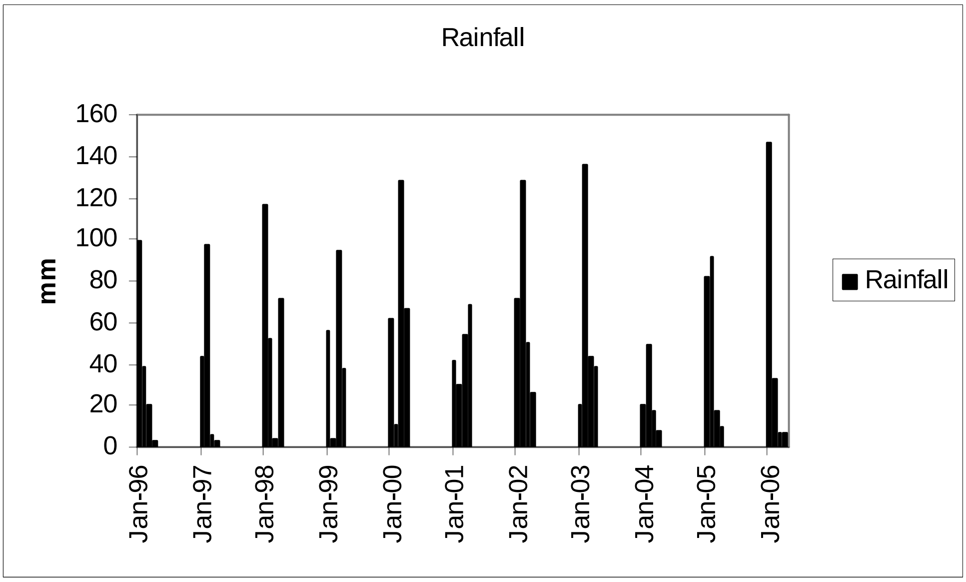

Figure 4. Graph of monthly rainfall data 1996-2006 covering the months of January to April for each year, for Bathurst, NSW.

The harvest season of 2000 was severe for NLB, but the total rainfall was not extremely high. However, rainfall in the critical months of March and April was high. This would have provided ideal NLB infection conditions. In 2005 and 2006 rainfall for the period was high but the rainfall for the March/April period was quite low, subsequently the disease did not develop.

DISCUSSION

This project developed after some serious losses were attributed to Northern Leaf Blight on sweet corn in the Central West of New South Wales in the 1999/2000 season or in other words the harvest season of 2000. Conditions were ideal for disease to develop that season with a wet March and April and the likelihood of high disease levels due to ideal disease conditions the previous year. Since that year the south eastern parts of NSW have been in a period of low rainfall and subsequently reduced NLB levels. Whether this continues is beyond the scope of this report but long term predictions by others suggest that this may be more common (periods of lower than average rainfall) in the future. Conversely other parts of Australia may be wetter than average which may increase NLB in those areas.

Management of this disease consists of using resistant varieties, improved stubble management, improved awareness of the disease, improved monitoring for early disease onset and the use of fungicides where needed.

The availability of varieties with some resistance to the disease is important and an ongoing issue that needs to be addressed. In the last five years more varieties have become available with some partial resistance to NLB, these have become readily adopted by industry. Many of these varieties develop some symptoms of NLB especially on the lower leaves, however the disease progresses slowly and the upper leaves remain relatively disease free. The fungus may vary in its ability to infect. Research has shown that various isolates of the fungus have different aggressiveness levels (Robert 1960). This may be a concern in the future if this occurs in Australian growing regions.

In fresh market sweet corn grown in the Sydney Basin a highly susceptible variety Golden Sweet is now not grown in the late autumn. Other varieties with partial resistance have been adopted such as Matador and Sentinel. The planting period and therefore the maturation period for sweet corn can be adjusted so that susceptible varieties are not planted to mature in a time conducive to the disease. For processing varieties the same can be applied. Jubilee is susceptible and therefore should not be planted to mature in that April period. Alternatives for this variety could be Punch or super sweet varieties with better tolerance such as Sovereign.

Many processing sweet corn growers grow on the same or adjacent to ground that they have had sweet corn previously. With availability of land this practice is difficult to avoid but contributes largely to the carry over of NLB from season to season.

The leaf removal simulates leaf disease through removal of photosynthetic area. Researchers have looked at this effect on sweet corn especially in the United States. It is essential that the top leaves of sweet corn remain free of disease to reduce yield loss. At around silking, removal of leaves from the bottom third of the plant has less affect on yield than the removal of leaves above the ear when significant yield loss can occur. Therefore partially resistant varieties do not suffer high yield loss when the lower leaves become infected. Researchers have identified that these varieties may suffer negligible yield loss when the severity of NLB was less than 8% in the upper 75% of the plant canopy (Pataky 1992).

Some indication of yield loss due to leaf loss was measured during this project. In earlier work (Napier *et.al.* 2001), 11% yield loss occurred when 50% of the leaves were removed above the silk at silking, this is a significant loss of close to 2 tonnes per hectare but not a huge loss. Two trials within this project where 30% and 40% of leaves above the silk were removed, showed no significant loss of marketable cobs overall. However where cobs were separated in the latter trial, the second cobs showed a significant difference between the uncut plots and each of the three cutting times.

The information gives some interpretation of the interaction of leaf removal and yield loss; however it can only be used as a guide. Levy and Leonard (1992) showed that infection by *E. turcicum* produces a greater effect on reducing yield compared to just the removal of photosynthetic area by removing leaves. Yield loss is always going to be related to when the epidemic begins and its continuation. Early epidemics on susceptible varieties will cause severe yield loss if no fungicides are used. Crops need to be monitored and where possible applications of fungicide need to coincide with keeping the upper leaves free of disease.

With the availability of propiconazole there will be improved fungicide control options for this disease for sweet corn growers. The permit for Tilt® is available at the Australian Pesticides and Veterinary Medicines Authority (APVMA) website www.apvma.gov.au/permits/permits.shtml. The permit allows only two applications of propiconazole in a season. Therefore both chlorothalonil (protective) and propiconazole (protective and curative) are currently available for NLB control in sweet corn. How many sprays need to be applied is related to disease levels, the economics of fungicide application and the projected yield loss. Therefore careful consideration should be given to the timing of these sprays. For later infection, upper leaf protection is a priority, lower leaves may be infected but do not cause high yield loss.

Protective fungicides are limited in that they need to be on leaves before infection takes place. Unprotected leaf tissue regularly emerges from the leaf whorl during the rapid growth period of sweet corn up to silking. Using a combination of propiconazole and chlorothalonil may be the best option to keep the leaves above the silk free of disease especially as propiconazole is limited to two applications in a season. Having two fungicides gives some assistance at reducing the possibility of resistance occurring. Using propiconazole before the disease gets too severe will also reduce the chance of fungicide resistance developing. These fungicides will also control rust.

The range of fungicides available for use in Australia is limited and alternatives should be examined. These could include flutriafol (Jubilee® and Impact®), difenoconazole (Score®), captan, tebuconazole (Folicur®) and azoxystrobin (Amistar®). Having the option of a variety of fungicides gives a reduced chance of fungicide resistance developing.

Trials could have been inoculated with the fungus causing NLB but this was not considered because they were situated on growers' properties in sweet corn growing regions.

TECHNOLOGY TRANSFER

An extension note was prepared on NLB.

RECOMMENDATIONS.

Further work on this disease should include:

- The management of currently available fungicides under heavy disease pressure.
- Assessment of alternative fungicides that are currently available and used on other crops in Australia.
- Using foliar fertilisers instead of fungicides for controlling NLB.
- Continual development of resistant varieties for Australian conditions.
- Examine races of *E.turcicum* in Australia.

ACKNOWLEDGEMENTS

Thanks for assistance with this project go to the Vegetable team at Yanco Agricultural Institute including Meryl Snudden, Alan Boulton and Scott Munro. Liz Mudford (Biometrician Yanco Agricultural Institute). Also to Damien Courtier (Snowy River Seeds), George Smith (Grower-Bathurst), Nicholas Gray (Elders), Paul Newell (Pacific Seeds), Steve Muldoon, Barry Hunt and Scott Stevenson (Simplot Australia).

APPENDICES

APPENDIX 1 CURRENT SWEET CORN VARIETIES AND THEIR REACTION TO NLB.

Variety	NLB resistance rating	Company	End Use
Goldensweet	susceptible	Snowy River, Lefroy Valley	Fresh Market
Gladiator	tolerant	Snowy River, Lefroy Valley	Fresh Market
Matador	tolerant	Snowy River, Lefroy Valley	Fresh Market
Columbus	tolerant	Snowy River	Fresh Market
Lancaster	tolerant	Snowy River, Lefroy Valley	Fresh Market
Rising Sun	moderately susceptible	Snowy River, Lefroy Valley	Fresh Market
Goldensweet Improved	moderately susceptible	Snowy River, Lefroy Valley	Fresh Market
Goldenpearl	moderately susceptible	Snowy River, Lefroy Valley	Fresh Market
Samurai	moderately susceptible	Snowy River, Lefroy Valley	Fresh Market
Entrée	moderate tolerance	Snowy River	Fresh Market
Crunch	tolerant	Snowy River, Lefroy Valley	Fresh Market
Everest	moderately susceptible	Snowy River, Lefroy Valley	Fresh Market
Empire	moderately susceptible	Snowy River	Fresh Market
Punch	moderately susceptible	Snowy River	Fresh Market/Processing
Prelude	moderately susceptible	Snowy River	Fresh Market
Enterprise	moderate tolerance	Snowy River	Fresh Market
Bliss	moderately susceptible	Snowy River,	Fresh Market
Catcher	moderate tolerance	Lefroy Valley	Fresh Market
Kahuna	tolerant	Lefroy Valley	Fresh Market
Basin	susceptible	Seminis	Fresh Market
Sheba	susceptible	Seminis	Fresh Market
Passion	intermediate resistant	Seminis	Fresh Market
Cabaret	intermediate resistant	Seminis	Fresh Market
Madonna	susceptible	Seminis	Fresh Market
Obsession	intermediate resistant	Seminis	Fresh Market
5770	susceptible	Seminis	Fresh Market
Sentinel	highly resistant	Sunland seeds	Fresh Market
Max	moderately resistant	Sunland seeds	Fresh Market
Hybrix 5	susceptible	Pacific seeds	Fresh Market
Jubilee	susceptible	Syngenta	Processing
Magnum	susceptible	Syngenta	Fresh Market
Krispy King	tolerant	Syngenta	Fresh Market/Processing
Sovereign	tolerant	Syngenta	Fresh Market

The information in Appendix 1 was collected from the companies listed either through literature provided or by personal communication.

Some definitions applicable to the above table.

Resistance.

The ability of a plant variety to highly restrict the growth and development of a specified pest or pathogen and/or the damage they cause when compared to susceptible plant varieties under similar environmental conditions and pest or pathogen pressure. Resistant varieties may exhibit some disease symptoms or damage under heavy pest or pathogen pressure.

Intermediate resistance.

The ability of the plant variety to restrict the growth and development of the specified pest or pathogen, but may exhibit a greater range of symptoms compared to resistant varieties. Intermediate resistance plant varieties will still show less severe symptoms or damage than susceptible plant varieties when similar environmental conditions and/or pest or pathogen pressure.

Susceptibility

The inability of the plant variety to restrict the growth and development of a specified pest or pathogen.

Tolerance

The ability of a plant variety to endure abiotic stress without serious consequences for growth, appearance and yield.

Seed companies are reducing the usage of the word tolerance.

APPENDIX 2 PROPOSED PRIME FACT-NORTHERN LEAF BLIGHT OF SWEET CORN

Northern Leaf Blight (NLB) also known as Turcica leaf blight is a disease which occurs occasionally on susceptible varieties of sweet corn. Outbreaks of NLB, otherwise known as turcica, are dependent on presence of spores in crop residue or soil, and suitable weather conditions. Only if these conditions are met will disease development take place.

Cause
The disease is caused by a fungus, *Exserohilum turcicum*.

Symptoms
This fungus causes elongated brown lesions on the leaves. If allowed to progress the lesions can cover all the leaf and subsequently reduce photosynthetic area and thus reduced yields.

Source of infection
The fungus is spread by spores from nearby crop residue and if infection occurs early enough cob fill is reduced.

Spread by
Wind can carry spores from an infected site to a non-infected site. Rain splash and wind will increase the spread of disease within infected crops by moving spores from plant to plant.

Favoured by
Infection occurs when conditions are moist because of rain and especially dew. Dew periods are enough to spread the disease and allow infection. For the production of spores (conidia), the fungus needs a minimum dew period of 14 hours at 20-25°C; however this does not need to occur in one stretch. There may a break in the middle of this period for example it may start one night then break, then finish the next night. After the formation of conidia one hour of leaf wetness is necessary for the fungus to infect the leaf. In Australia wet summers can promote this disease and dry summers will reduce the disease levels. Overhead irrigation will increase the chance of the disease.

Disease Management
Management of NLB is difficult particularly when conditions are favourable for the disease. However, a wide range of control options are available to help control this disease. An integrated approach to disease management including awareness of conditions conducive for disease development, early detection of the disease, use of resistant varieties, good stubble management and chemical control is required for successful NLB control.

Early detection of the disease
If NLB develops before silking yield loss can be high. Yields losses are significantly lower if it develops after silking.

Early detection of the disease is therefore an important step in controlling this disease. Having someone independent look through your crop is a good idea especially if that person has a good background in pest monitoring. If suspicious leaf spots are detected, samples should be sent to a suitable plant pathology diagnostic laboratory for correct identification.

Resistant varieties
Where available, using suitable resistant varieties is the most successful method of controlling this disease. However there is the chance that the resistance can be broken down by new races of NLB. Many new varieties have partial resistance that may still express some symptoms of the disease especially on the lower leaves. Matching resistant varieties to regions that best suit the correct maturity group or sweetness needs to be carefully planned.

Stubble management
Corn stubble is a source of the fungus and the most common source of disease from season to season. Any infected crop residue should be ploughed in as soon as possible after harvest to encourage breakdown. If possible, plant new crops several kilometres from previously infected sites.

Chemical control
Chemicals are available for control of NLB in sweet corn. Method of chemical application is important, and label directions should be strictly followed. When using protectant fungicides, good leaf coverage is essential, as any untreated leaf will be susceptible to disease. A number of sprays will be necessary to control NLB so the economics of the number of sprays should be considered. Early detection of the disease and monitoring its spread is important when undertaking a chemical control programme. Currently chlorothalonil is registered for NLB control and in 2005 a permit was approved for propiconazole. The latter fungicide has more curative and systemic activity than chlorothalonil.

APPENDIX 3 CORN GROWTH STAGES

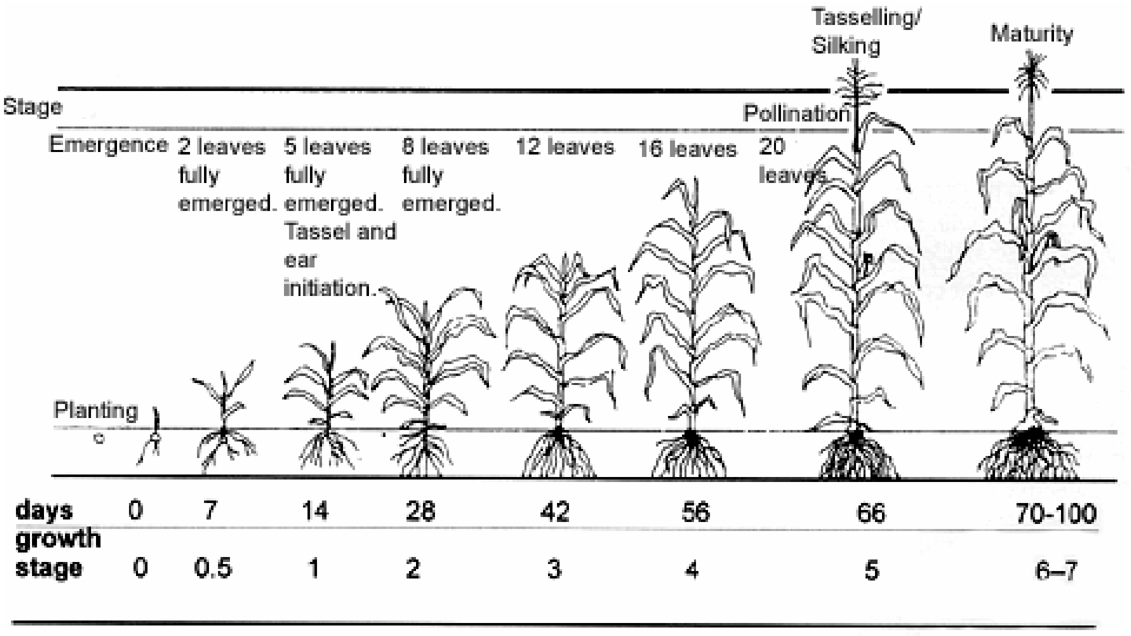

Diagram courtesy of NSW DPI and the Department of Natural Resources and Energy, Victoria, 'Maize Check' 1998.

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