



Know-how for Horticulture

**Control of downy
mildew on nursery
seedlings**

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VIC Department of
Primary Industries

Project Number: NY 406

CONFIDENTIAL*

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Final report for the Horticultural Research and Development Corporation Project NY406

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ISBN 0 7306 6784 7

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Submitted December 1997

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INDUSTRY SUMMARY

Downy mildews on seedlings (pansies, stocks and brassicas) are the major disease problem for the nursery industry with economic losses estimated at \$4 million annually in Australia. This project evaluated fungicides, tested seed for contamination, monitored spore release, recorded weather data, examined the effect of light on disease development and reviewed the literature on downy mildews in nurseries, to develop integrated control strategies. These strategies, which consist of both management practices and fungicide spray programs, have been adopted by commercial nurseries in Victoria and the incidence of downy mildew has dropped by 80-100% on Brassica seedlings and by 100% on stock seedlings. Sales of stock seedlings have risen by 30%.

Management Practices to reduce the disease are:-

(1) **Controlled watering.** Where possible avoid watering plants in the morning because this is the time when spores are released and need water for infection. One heavy watering is preferable to a long light watering. (2) **Ventilation.** Maintain a well ventilated environment to lower humidity and to reduce spore production and infection. This may mean fewer plants and trays per square meter. (3) **Nutrition.** Maintain a balanced program of nutrition because a potash deficiency will increase the susceptibility of seedlings to downy mildew. (4) **Hygiene.** Remove sources of spores in the nursery, such as heavily infected seedlings, old infected seedlings and weeds.

Fungicide protocols to reduce the disease are:-

On removal of seedlings from germination chambers, apply a drench of a systemic fungicide (Agrichem product, pending registration), once a fortnight and spray with a registered contact fungicide, such as Mancozeb®, once a week. If no disease is present in the nursery during summer then commence a preventative spray program in late March or April when the temperature falls to about 15°C and rain is prevalent (Melbourne).

Downy mildews form masses of "downy", usually white spores (mauve on pansies), on the undersurfaces of leaves. This is followed by black speckling on the upper surface, yellowing and premature leaf fall in brassicas and stocks. On pansies it causes a light green discoloration of the upper leaf surface. Spores (asexual, i.e. vegetative) are produced overnight on the undersurface of leaves and released in the morning as the air dries out. Spores need wet leaf surfaces to germinate and infection takes up to 3 hours. The fungus then grows within the leaf for 5-7 days (brassicas) before spores appear again. Downy mildews prefer cool temperatures, e.g. on brassicas the optimum temperature range for disease development is 8 °C -16°C, with a range of 4 °C -26°C.

Spread of the disease in Australia is not associated with contaminated seed but, with airborne spores dispersed by wind from older infected seedlings to young healthy seedlings; or in the case of the brassica downy mildew from alternative hosts, e.g. the cruciferous weed, shepherd's purse. Fungi causing downy mildew diseases are specific to particular genera of plants e.g. brassica downy mildew infects crucifers (e.g. broccoli, Brussels sprouts, cabbage, cauliflower and Chinese cabbage), whilst pansy downy mildew only infects pansies.

TECHNICAL SUMMARY

Downy mildews on seedlings (pansies, stocks and brassicas) are the major disease problem for the nursery industry in Australia, with economic losses estimated at 10-12% or \$4 million annually. This project tested seed for contamination, evaluated fungicides, monitored spore release, recorded weather data, examined the effects of light on disease development and reviewed the literature on downy mildews in nurseries, to develop integrated control strategies.

A survey of *Brasstea* seed grown commercially at nurseries around Melbourne showed that contaminated seed does not appear to be responsible for the epidemics of downy mildew on *Brassica* seedlings in nurseries. A total of three grow-on trials were conducted with 23 cultivars of *Brassica* seeds, obtained from six commercial seed companies, in the glasshouses at IHD. None of these trials detected downy mildew contamination of seeds.

Fungicide efficacy trials were initially conducted in the glasshouses at IHD, then later at two commercial nurseries on the cauliflower cultivar 'Paleface'. In these trials, 18 fungicides, both contact and systemics, were screened. By a process of elimination two contact and two systemic fungicides were selected for evaluation alone and in combination under two environmental conditions at a commercial nursery. Systemic fungicides were applied as a drench once a fortnight and contact fungicides were applied as a spray weekly. Weekly assessments for disease incidence indicated that the best performing fungicides under the 'dry' treatment (seedlings grown for two weeks under glass, two weeks under cloth and four weeks outside) were Euparen® or Euparen® plus Foli-R-Fos®; and under the 'wet*' treatment (seedlings grown for two weeks under glass then for six weeks outside) either Euparen® plus Foli-R-Fos® or Mancozeb® plus Foli-R-Fos®. The disease was initially slower to develop on the 'dry*' treatment than on the "wet*" treatment.

Trapping of the brassica and pansy downy mildew spores with a Burchard spore trap, indicated that spore release started from about 8.00 am onwards, peaked at 10.00 am to 12.00 noon and petered out in the early afternoon. No spore release occurred on days with continuous rain, but release was prolific afterwards. Very few spores were trapped during the night.

Growers were recommended to adopt the following strategies: (1) avoid watering seedlings in the mornings, (2) space trays of seedlings to improve ventilation, and (3) adopt fungicide protocols (when phosphonic acid is registered). These strategies have been adopted by 2 large commercial nurseries in Victoria, and the incidence of downy mildew has dropped by 80-100% on brassicas and by 100% on stocks. In addition sales of stock seedlings have risen by 30%.

The epidemiological studies (spore trapping, disease survey and weather monitoring), indicated that there is scope to develop a predictive model for downy mildew on nursery seedlings. The success of the phosphonic acid fungicide, to control downy mildew on nursery seedlings, suggests that registration should be sought for the product. Preliminary evaluation of light on downy mildew suggest further work is needed in this area.

EXTENSION

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ACKNOWLEDGMENTS

Financial support for project NY406 was provided by the Horticultural Research and Development Corporation. The Nursery Industry Association of Australia and Agriculture Victoria.

The authors thank Mr Richard Wall, the management and staff at Floriana Nursery, Cnr Greens and Perry Roads, Keysborough, Vic. 3173 and Mr Peter Wood, the management and staff at Woodlyn Nurseries Pty. Ltd., 2320 South Gippsland Highway, Five Ways. Vic. 3977 for use of their nurseries as field sites and for their tremendous in-kind support for the project. The achievements of this project would not have been possible without the enthusiastic cooperation and assistance of these nurseries.

The authors thank Ian Pascoe and Martin Mebalds for their contributions and planning at the commencement of the project. Dr. Bob Taylor (Consultant) 12 Corsewall Close, Hawthorn Vic. 3122 and Ian Atkinson (NIDO), P. O. Box 55 Lyons, ACT 2606 are thanked for advice on the project.

The authors acknowledge South Pacific Seeds, 18 Marron St. Ashwood. Vic. 3147 for donations of cauliflower seeds: Bayer Australia Ltd. 633-647 Springvale Road, Mulgrave North, Vic. 3170; BASF Australia, 500 Princes Highway, Noble Park, Vic. 3174; Schering Pty. Ltd.. 141 Burnley St Richmond, Vic. 3121; and Sandoz Australia Pty. Ltd. 68 Falcon St. North Fitzroy. Vic. 3068; for donations of fungicides.

ADOPTION BY INDUSTRY

The nursery industry needs to adopt the integration of the following practices to control downy mildew on nursery seedlings. Fungicides alone will not control downy mildew if disease pressure is high.

- **Irrigation:** Avoid watering seedlings in the mornings when spores are released and available for infection.
- **Ventilation:** Improve ventilation by spacing trays of seedlings and by growing fewer seedlings per punnet so leaf surfaces will dry off quickly, reducing leaf wetness and conditions which are suitable for infection.
- **Hygiene:** Remove sources of spores, by roguing heavily infected trays of seedlings, control weeds which may act as an alternative host for the *Brassica* downy mildew and avoid placing healthy seedlings near diseased seedlings.
- **Nutrition:** Maintain a balanced program of nutrition as a deficiency of potassium (K) will make seedlings (cauliflowers) more susceptible to the disease.
- **Fungicides:** If seedlings are free of the disease during summer, commence a preventative spray program in late March or early April (Melbourne) when temperatures are falling to 15°C and rainfall is on the increase. Apply a combination of a registered systemic fungicide (Agrechem product pending registration) as a drench once a fortnight and a weekly spray of a registered contact fungicide e.g. Mancozeb®, till about October when temperatures are consistently above 15°C and rainfall is declining.
- **Monitor:** Check seedlings at least once a week to detect early signs of the disease.

FINANCIAL BENEFITS

Nursery A adopted the integrated management strategies and fungicide protocols developed by the project at the commencement of 1996 and applied it to their *Brassica* and stock seedlings very successfully. They reported less disease in the nursery and attributed increased tray sales of Brussel sprouts (36%), cabbage (24%), cauliflower (14%), austral stocks (16%) and dwarf stocks (30%) to control of the disease. At one stage their healthy stocks were in such demand that they could not meet their orders. When healthy seedlings are produced, there is less labour involved in beautifying the product for sale. As the nursery management pointed out, if healthy stock seedlings are produced, then customers are more likely to purchase other seedlings.

DIRECTIONS FOR FUTURE RESEARCH

There are several directions for future research on integrated disease control of downy mildews on nursery seedlings.

- Registration of the systemic fungicide, phosphonic acid, is required for the industry nationally. This is being addressed by HRDC Project NY97011 and Agrechem Manufacturing Industries, Pty. Ltd.
- National extension of the projects findings are being addressed by HRDC project NY97011.
- There is scope to investigate the application of light and blue igloo film covers to control diseases in the nursery industry.
- There is scope to develop a predictive model for downy mildew on nursery seedlings which would avoid calendar sprays and enable a spray as required approach to fungicide applications.
- There is potential to breed resistance (i.e. tolerance) to downy mildew into popular nursery seedling lines such as white pansies.

TECHNICAL REPORT

Introduction

Downy mildew diseases cause enormous problems in Australian nurseries, where economic losses are estimated at 10% to 12% in production of ornamental and vegetable seedlings. Crop loss estimates, made by growers, suggest that losses due to downy mildews account for about \$4 million in retail sales nationally (Minchinton *et al* 1995). Of particular concern is the presence of the disease on *Brassica* seedlings (*Brassica oleracea* L.) pansy seedlings (*Viola tricolor* L.) and stock seedlings (*Matthiola incarta* R. Br.). These seedlings are major nursery lines with the former two being grown throughout the year.

1 Symptoms

The disease occurs on cotyledons, true leaves, hypocotyls and stems. The symptoms of downy mildews is the production of a 'downy' mass of spores (sporangiospores and sporophores), generally on the lower leaf surface. Spores are usually white, e.g. on brassicas, but are mauve on pansies and grey on poppies. Symptoms of flecking, speckling and blotching appear on the upper leaf surfaces and heavily infected leaves may yellow, prematurely wither and die. On pansies the disease causes a light green discoloration of the upper leaf surface. On alyssum, galls are formed in the leaf tissue. In contrast, powdery mildews produce a "powdery" mass of white spores on the upper leaf surface. Leaves may eventually yellow but they tend to persist on the plant.

2 Life Cycle

Spores of the fungus germinate on wet leaf surfaces to produce a germ tube which forms an appressorium at its tip. A penetration peg emerges from beneath the appressorium and directly penetrates the cuticle, with the coenocytic hyphae passing between the epidermal cells and ramifies in the intercellular spaces (Channon, 1981). Hyphae penetrate cell walls, but not the cell membrane, to form haustoria (Chou, 1970). In this way the fungus obtains its nutrition from the host. It grows unseen within the host tissue for 5-7 days and then sporangiophores with sporangiospores (asexual) emerge through stomata on the undersurface of the leaf during the night (Davison, 1968; Chou, 1970). As the host tissue prematurely senesces, the fungus produces oospores. It is an obligate parasite and can survive the death of host tissue by going systemic within the plant prior to leaf abscission or by surviving as oospores in leaf debris (Channon, 1981). Oospores are not considered a problem for the nursery industry as seedlings are grown in a sterilized non soil mix.

3 Biology

As downy mildews are obligate parasites they only grow in living plant tissues. They cannot be grown on agar culture plates. The *Brassica* downy mildew was grown sparsely on tissue cultured callus by Ingram (1969b) and Achar (1995). Downy mildew diseases are prevalent in cool wet months, but can occur all year around. The diseases are generally debilitating rather than fatal and therefore make seedlings unsaleable. The optimum temperature for infection from sporangiospores was 8°C to 16°C (Felton and Walker, 1946). The time for infection to take place, morphologically, varies with temperature. At 15°C infection was reported to take 18 hrs to 24 hrs (Chu, 1935) whilst at 20°C to 25°C it only took 6 hrs (Chou, 1970). The biochemical processes for infection to take place, however, are set up within 3 hrs

of spores landing on leaves (Channon and Hampson, 1968). Only a deficiency of potash has been shown to make cauliflowers more susceptible to downy mildew (Quanjer, 1928), whilst excess or deficiencies of nitrogen, phosphorus or potash or deficiencies of sulphur had no effect on susceptibility of plants to the disease (Felton and Walker, 1946).

4 The Fungus

The fungus *Peronospora parasitica* (Pers. ex Fr.) Fr. is the cause of downy mildew on cruciferous plants (Appendix 2), whilst *P. violae* de Bary ex Schroter causes downy mildew on pansy. Seedlings of alyssum or Sweet Alice (*Lobularia maritima* (L.) Desu. and Poppy (*Papaver* L.) are infected with *P. galligena* and *P. arborescens* (Beck.) Casp. Ber. Beckamen. respectively. On *Hebe* Comm. ex Juss. the disease is caused by *P. grisea* (Ung.) Ung. See Appendix 3 for a list of downy mildews on nursery plants.

Downy mildews are classified in the Order Phycomycetes and Class Oomycetes and are distantly related to the phytophthoras and pythiums (Spencer, 1981). Species concepts, which are very confusing in the downy mildews were recently reviewed by Hall (1996). There are about 5 formae speciales of *P. parasitica* (Channon, 1981) and 3 races of the fungus within the variety *B. oleracea* var. *botrytis* (Thomas and Jorudain, 1990). Downy mildews are host specific, so will not transfer from one host genera to another. Although the downy mildew on stocks and brassicas is caused by *P. parasitica*, it is a different race on each host genera and will not cross infect the other genera (Jafar, 1963). Downy mildew on weeds such as wild radish (*Raphanus* sp.) and *Capsella bursa-pastoris* (L.) Medic (Shepherds purse) can act as reservoirs for the carry over of spores from one season to the next to infect cultivated brassicas (McMeekin, 1969; Sherriff and Lucas, 1990).

5 Seed

The seedborne nature of the disease is well documented; it has been found on radish seed in India (Jang and Safaeulla, 1990), on cabbage seed in South Africa (Achar, 1995) and Russia (Polyakov and Vladimrskaya, 1964) and on Chinese cabbage seed in China (Chang *et al.* 1963). Experiments were designed to determine whether the symptoms of downy mildew on young *Brassica* vegetable seedlings were associated with *P. parasitica* contaminated seed.

6 Fungicides

Nurserymen in Victoria and New South Wales have experienced difficulties in controlling downy mildew on *Brassica*, stock and pansy seedlings. White pansy cultivars, followed by clear yellow and clear blue cultivars are the most susceptible (Boudier, 1987). In one nursery 100% of *Brassica* and stock seedlings were infected whilst another nursery ceased growing stocks due to the disease. A survey of Victorian vegetable and seedling growers by Smith and Price (1996) in 1992, revealed that the incidence of downy mildew on *Brassica* seedlings in shadehouses ranged from 1%-100%. Seedlings of alyssum are infected every few years with *P. galligena* and poppy seedlings are infected most winters with *P. arborescens*.

Fungicides currently sprayed by nurserymen for control of downy mildew in seedlings are metalaxyl, furalaxyl, chlorothalonil, copper hydroxide, copper oxychloride, mancozeb, zineb, phosphonic acid, propineb, propamocarb, oxyadixyl, rovril and triadimenol (Smith and Price, 1996). Only the coppers and the dithiocarbamates are registered for the *Brassica* downy mildew and these plus furalaxyl are registered for downy mildew control on ornamentals.

on *P. tabacina* on tobacco in the field indicated that prolonged rainy weather and leaf wetness, although conducive to spore production, inhibited dissemination (Dixon *et al*, 1936). Hartmann *et al* (1983) described the effects of atmospheric water potential, free water and temperature on germination of *P. parasitica* sporangia.

Time for spore release varies amongst the downy mildews. For *P. tabacina* and *P. cubensis* spore release was shortly after sunrise, whilst, for *P. sorghi* it was from midnight to 500 hrs (Kenneth, 1970), for *S. maydis* between 200hrs-700 hrs (Semangoen, 1970) and for *P. viticols* it was recorded from 1800 hrs-2000 hrs. (Corbaz, in Populer 1981). Shao *et al* (1990) reported 8 times as many sporangia being released in the morning (100 hrs to 1300 hrs) compared with the afternoon for Chinese cabbages in China. Lin (1981), reported that the frequency of release of sporangiophores from Chinese cabbage increased after 200 hrs and peaked at 600 hrs to 800 hrs with few or none detected from 800 hrs to 2000 hrs.

Spores of *P. parasitica* stored in dry soil or in dust in an open shed were infective after several weeks in summer and after several months in winter. However, in moist soil, survival was shorter, a few days in summer and a few weeks in winter (Krober, 1970). Long distance dispersal of *P. parasitica* has not been investigated, though, *P. tabacina* reportedly moved 400 km/month in Europe (Populer, 1964).

Survey

There is little information available on the incidences of downy mildew diseases in nurseries or on the range of host plants attacked. The downy mildew on brassicas, *P. parasitica* is considered to be distributed world wide (Channon, 1981). In Victoria, Australia, the disease incidence of *P. parasitica* on cabbage seedlings was reported at 76% to 100% during 1992 (Smith and Price, 1996). It is a major problem on summer cauliflower seedlings in the United Kingdom (Whitwell and Griffin, 1967; Davie and Wafford, 1987), on cabbage seedlings in South Africa (Brophy and Laing, 1992), on cabbage and broccoli seedlings in the USA (McMeekin, 1969) and on Chinese cabbage in China (Lin, 1981). Downy mildew on stocks (*P. parasitica*) is a problem in Australia (Trimboli and Hampshire, 1978) and in New Zealand (Jafar, 1963), and *P. violae* is a serious problem on pansies in France (Boudier, 1987) and in Victoria, Australia.

Surveys of the disease on brassicas were carried out in two nurseries in metropolitan Melbourne to determine the initial incidence of the disease, to establish whether our protocols were being adopted and were effective. A list of downy mildew diseases on ornamentals (constructed from herbarium data, overseas reports and from local nursery visits) was constructed to provide an indication of potential hosts of downy mildews in Australian nurseries (Appendix 1).