**VG222**
**Integrated management of onions**

**Andrew Watson**
**NSW Agriculture Yanco**

*Know-how for Horticulture™*

VG222

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# Project Title Integrated management of onions (Onion 75 tonne club)

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## Objectives

Improve onion yields, quality and production efficiency by integrated management of weeds, pests and diseases and the use of a comparative analysis of grower practices.

## Acknowledgments

The authors wish to thank the Onion 75 Tonne Club growers for the voluntary contributions to this project and the HRDC for providing matching funds. Technical assistance is acknowledged from Mr Andrew Watson, particularly for crop monitoring and data collection.

# Industry Summary

This project had a primary aim of reducing production costs by identifying management strategies that could be made more efficient. A group of growers (75 tonne club) contributed funds to this project and their practices were compared with one another as well as other producers in the area. Particular emphasis was given to disease management although a number of broader aspects of integrated crop management were studied.

Onion crops were monitored and growers' records were used to compare management practices and production outputs. Regular monitoring enabled the early detection of production problems. Benefits were immediately realised through the timely application of chemicals (herbicides, insecticides and fungicides). Pesticide usage was greatly reduced where growers adhered to recommendations from monitoring. For example, several growers in the 75 tonne club grew crops in the 1994 season without the use of systemic fungicides and only minimal use of protectants compared with control growers in the district.

Accurate identification of pests and diseases was a critical component to underpin crop monitoring. There were several instances where growers had mistaken the cause of crop health problems. Several workshops were held to encourage accurate identification of diseases by careful microscopic examination of samples. A dissecting microscope was purchased from project funds and is located at the Horticultural Research and Advisory Station at Griffith to assist growers and crop scouts to identify diseases in the future. Monitoring methodology was developed through this project and a number of strategies (short-cuts) were devised to improve its efficiency and effectiveness. These techniques have already proved useful to growers and crop scouts.

A weather-based computer model to forecast conditions favourable to the development of downy mildew was evaluated over three seasons with very encouraging results. The unit will continue to function in the district with the assistance of NSW Agriculture who will provide a warning service when major disease episodes are predicted. A spray trial was conducted to compare the effectiveness of several registered and developmental fungicides for downy mildew. A metalaxyl plus mancozeb spray program was the more effective than any other chemical treatment. Collaboration

with Mr Rob O' Brien of the Queensland DPI has shown that phenylamide resistance is present in the downy mildew population from the Riverina. Together these results suggest that fungicide resistance is at an intermediate stage and that the judicious use of these chemicals is required to preserve their effectiveness.

There are a few areas where further research would be of benefit. Developing better weed management strategies is a priority due to the withdrawal of certain products and the lack of registration of certain other potentially useful chemicals. Research is also required to establish a spray threshold for thrips. This project chose an arbitrary spray threshold of 20-50 thrips per plant, but there is some evidence that a higher threshold may be possible without any significant loss in yields.

# Technical Summary

A number of key aspects to onion production in the Riverina were studied over a three year period. Many of the horticultural factors were identified from a comparative analysis of grower practices and a database of set physical parameters (soil type etc.) on individual enterprises. This project had a strong emphasis on the development and adoption of integrated disease management systems. In particular, downy mildew was a target for improved management techniques.

Onion crops in the Riverina were monitored over a three year period and growers' records were used to compare management practices. Regular monitoring enabled the early detection of production problems, especially for timely application of chemicals. A weather-based computer model to forecast conditions favourable to the development of downy mildew was evaluated with very encouraging results. A spray trial was conducted to compare the effectiveness of several registered and developmental fungicides for downy mildew. Despite the detection of a fungal isolate that was resistant to phenylamide fungicides, a metalaxyl plus mancozeb spray program was the more effective than any other chemical treatment. This suggests that fungicide resistance is at an intermediate stage and that careful use of these chemicals is required to preserve their effectiveness.

Information collected from this study has been used to develop a best management guide for onions grown in the Riverina. There is not room in this summary to discuss each of the key factors and recommendations derived from this study to maximise yields. Following is a list of key factors and discussion points that will appear in the final report:

(i) Site selection & planning rotations - soil type; irrigation method, bed width, laser grading, run lengths, salinity and water table depth, soil chemical tests, soil physical tests, gypsum application, need for late summer irrigations, planning for winter irrigation to establish crops.

(ii) Crop establishment to bulb initiation - seed age and quality assurance; fungicide seed dressings; optimum sowing dates and spreading risks; cultivar specific interactions with sowing dates and weather; sowing density for bulb market size requirements; irrigation schedules and effectiveness; fertiliser requirements and timing; sap

analysis for nutrients; weed management - pre and post emergent herbicides; hand chipping; monitoring crops for pests and diseases; correct identification of causes for poor crop health; chemical control strategies.

(iii) Bulb initiation to harvest - rapid vegetative growth and increased emphasis on monitoring for pests and diseases; using weather model (EnviroCaster) to predict downy mildew; timing for final irrigation and harvest; strategy for harvesting in heat-wave conditions; correct topping techniques.

(iv) Post harvest management - requirements for curing onions and storage; minimising bruising during grading; bagging and storage; requirements for export; developing a quality management system; ISO certification.

# Introduction

Australia produces in excess of 225,000 tonnes of onions annually, and all but about 60,000 tonnes are consumed domestically. Our export onions are regarded for their high quality, but our production efficiency must be internationally competitive for the industry's continuing development.

New South Wales produces about 40,000 tonnes annually (21% of national production). Almost the entire crop is grown in close proximity to the Murrumbidgee Irrigation Area (MIA), located in the Riverina region of south western NSW. This region grows intermediate day type onions that are predominantly selections of the variety, *Pukekohe* (or *Creamgold*).

Between the 1950's and 70's, the Riverina was one of the nations major production areas, but was known for it's lower yields, questionable quality and non-sustainable grower practices. Yields averaged only 27 tonnes/ha (Pravero and Salvestrin, *pers. comm.*) compared to a national average of 50 tonnes/ha. Access to better production technology and marketing intelligence in the 1980's saw changes in the Riverina's onion industry. Onion quality was improved by changing to new varieties, and optimising row spacings, plant densities, nutrition and irrigation practices. In addition, the industry responded to marketing information regarding customer preferences for size, shape and colour.

Towards the end of the 1980s average yields for onions in the Riverina were close to 38 tonnes/ha (Salvestrin, *pers. comm.*). Production had shifted away from cultivars of *Silverskin Whites*, to early *Gladalan* types and selections of *Creamgold* and *Early Creamgold*. However, impediments to high yields and quality still existed despite these improvements.

To build on this progress, a project, funded by local industry and HRDC, commenced in 1992 aiming to integrate management practices and increase profitability of Riverina onion growers. A group of 12 growers became part of what was known as the 75 Tonne Club. Members were interested in lifting yields, quality and sustainability by using on-farm research and up to date technology. Use of Australian and current *best practices* were adopted where appropriate.

# Materials & methods

## Crop Monitoring & Disease Management

Growers kept records of all cultural practices and made observations of their crop's progress. Local scouts and researchers monitored crops every 7-10 days. Monitoring practices were established to determine general crop performance, to map the progress of diseases, and to advise growers on appropriate spray strategies. Written reports for growers included chemical spray recommendations. Grower records were later checked for compliance with these recommendations. A comparative assessment of grower practices was modelled on the successful *RiceCheck* program (J. Lacy, NSW Agriculture, Finley) used in the NSW Rice Industry.

Downy Mildew was considered the most important disease for which IPM technology could minimise losses and reduce reliance on phenylamide fungicides. A review of relevant literature on downy mildew is included in the appendix. A weather-based model was used to forecast downy mildew infections in crops. An *EnviorCaster* unit (Neogen Corp., USA), fitted with a version of the *DownCast* model (Jesperson & Sutton, 1987) was evaluated over three seasons. Spraying recommendations were made from both crop monitoring and the disease prediction model.

Chemical efficacy trials were established at the Horticultural Research & Advisory Station of NSW Agriculture at Griffith in 1992 and 1993. A range of registered and experimental fungicides were evaluated for downy mildew control in replicated plots of onions (cv. *Early Creamgold*).

Onions infected with downy mildew were sent to Rob O'Brien at the Queensland DPI at Indooroopilli where they were screened for phenylamide resistance in greenhouse bioassays. Onion isolates of the fungus, *Botrytis*, were analysed using molecular techniques to distinguish different species. This work was done in collaboration with Dr Michael Gillings, Molecular Biologist, BCRI and Joanne Luck, Technical Officer. Genetic fingerprints were obtained by amplifying ribosomal RNA gene internal transcribe spacer regions using the polymerase chain reaction and from randomly amplified polymorphic DNA (RAPD) patterns on agarose gels.

## Technology Transfer

Adoption of improved practices by growers was facilitated by use of participative group methods for information sharing. These included: farm walks; meetings; workshops on disease recognition and control; regular crop reports and publications.

# Results

## Key Findings on Disease Management 1992/3

* Downy mildew was first detected in commercial crops of four growers on 26th October 1992. Fungicide sprays of registered products containing a phenylamide plus a dithiocarbamate controlled the disease on three properties especially where the initial infected area was only small (as it was on one property). The fourth grower had initially used inappropriate chemicals (copper and benomyl) and failed to achieve significant control until changing to products containing phenylamides.

* The *EnviroCaster* model detected several periods that were favourable for downy mildew including the period when field symptoms were first noticed. A total of 37 days were favourable for downy mildew of which there were 4 groups of days which could be described as *high risk* periods. Infections in crops were first detected following the longest *high risk* period in October.

* There was a distinct relationship between when disease symptoms were detected and the growth stage of the crop. Crops were never infected before bulb initiation. Downy mildew first appeared in crops with dense sowing rates and cultivars with thick succulent leaves. White and red skin cultivars were generally more susceptible to downy mildew.

* Downy mildew failed to become established in the fungicide efficacy field experiment.

* Careful diagnostic skills were required to confirm the cause of disease problems. There were three examples where growers had mistaken other problems with downy mildew. Firstly, yellowing and death of older leaves of young plants (2-3 leaf stage) was not attributed to any pathogens. These symptoms was possibly due to herbicide injury. Secondly, a patch of wilting plants was shown to be affected by the disease, pink root, caused by the fungus *Pyrenochaeta terrestris.* Thirdly, a similar patch of wilting plants were affected by a bacterial rot.

## Key Findings 1993/4

### Weed management

Different properties had specific weeds to manage and therefore prescriptions for herbicide programs were made on an individual basis. Sound crop rotations on permanent beds helped lessen weed pressure and hence reliance on post-emergent herbicides. Following are the major outputs from small herbicide evaluation trials conducted on several properties to establish efficacy at different rates of application and observations from crop management:

* Herbicides such as *Roundup* (R) and *Spray Seed* (R) caused phytotoxicity when applied too late and thereby made contact with emerging plants. Best results were obtained when *Roundup* was applied no later than 4 days before crop emergence on heavy clay soils, and no less than 7 days before emergence on lighter soils.

* Weed control using post-emergent herbicides was most effective when completed before the 3 leaf stage, as onions were affected by phytotoxic burns when sprayed after this stage. *Totril* (R) and *Tribunil* (R), used singly or together, controlled most broadleaf weeds. *Probe* (R) was the most effective chemical for controlling larger wireweed plants. (Both *Probe* and *Tribunil* are being withdrawn from sale, which is likely to result in fewer options for chemical control in future). Hand chipping of weeds was virtually the only option for broadleaf weeds after the 3 leaf-stage.

* Grass herbicides, such as *Fusilade* (R) and *Sertin* (R) were applied at later growth stages without harming crops.

### Disease Management

Cool and wet weather conditions prevailed early in the season. Poorly established crops were found to have either problems with sowing depth (too deep) or rots caused by the fungus, *Rhizoctonia.* Some growers had thought that this problem was due to insect damage and had used insecticides to no avail. The following points summarise disease management findings:

* The *EnviroCaster* (Downy Mildew forecaster) unit detected a *high risk* infection period from September 13-18 with only sporadic and isolated dates through October and early November. Downy mildew was detected two weeks after the *high risk* period on several properties generally as very low level infections. Growers were advised to change from a nil or protectant fungicide spray program to products that contained phenylamides when mildew was found on their properties. All properties successfully contained the disease except one block of early onions that were not made known to the crop monitors. The disease was allowed to spread undetected through a secondary infection period in early October and would have been exacerbated by an irrigation event. Losses were estimated to be about 30%, affecting both size and quality.

* Growers responded differently to fungicide application recommendations. There were equal numbers of growers in these two classes. Those growers that followed recommendations used 0-3 phenylamide sprays, 1-4 dithiocarbamate sprays, and 2-3 copper sprays. This contrasts with those growers who followed their own programs using up to 5 phenylamides, 6 dithiocarbamates and coppers, 1 benomyl and 3 phosphonic acid sprays.
* Monitoring confirmed that certain cultivars were more susceptible to mildew infections, particularly white skin varieties.

* A field experiment to assess the relative efficacy of fungicides for the control of onion downy mildew demonstrated that only *Ridomil MZ* (R) significantly reduced mildew infections over the unsprayed control treatment. Results are summarised in the Table 1.

**TABLE 1.** ***Fungicide efficacy to onion downy mildew, Griffith HRAS 1993***

| Treatment number | Fungicide | Rate of product/ha | Mean Disease Rating (1-5) |
|---|---|---|---|
| 1 | *Acrobat* | 2.0 kg | 2.2 ab |
| 2 | *Acrobat* | 3.0 kg | 2.3 ab |
| 3 | *Bravo 500* | 3.3 L | 2.3 ab |
| 4 | AGF/7-15 | 5.5 kg | 2.3 ab |
| 5 | AGF/6-162 | 3.3 kg | 2.3 ab |
| 6 | *Dithane* | 2.0 kg | 2.0 ab |
| 7 | *Ridomil MZ* | 2.5 kg | 1.7 b |
| 8 | RPA 403397 | 1.2 kg | 2.0 ab |
| 9 | RPA 403397 | 2.4 kg | 2.3 ab |
| 10 | Unsprayed | - | 2.8 a |

* Testing for the sensitivity of Griffith isolates of *Peronospora destructor* to metalaxyl was done in collaboration with Rob O'Brien from the Queensland DPI. Some difficulties were experienced with isolates surviving until the tests were carried out. One surviving isolate was found to be resistant to the downy mildew fungus.

* There is no evidence that the leaf blight fungus, *Botrytis squamosa*, occurs in Australia. A single record from Victoria some years ago was not confirmed since no material had been preserved. Genetic fingerprints derived from amplification of ribosomal RNA transcribe spacer regions failed to separate *Botrytis* species. However, good separation was obtained with the randomly amplified polymorphic DNA (RAPD) technique. Onion isolates from Riverina crops conformed to either *B. cinerea* or *B. allii*. We found that while analyses performed at the same time could be compared with some confidence, reactions performed on different days were not always identical. The apparent problems with the reproducibility and portability of RAPD analysis make its routine and widespread use for strain differentiation problematical.

## Key Findings 1994/5

* The 1994-5 season was characterised by exceptionally dry conditions. Salinity was the most significant problem this season. One grower lost 85 acres due to saline irrigation water. This affected block had very poor emergence (<5% plant establishment). Several other crops suffered from reduced foliage growth and bulb sizes attributed to the low rainfall and increased salinity.

* No Downy Mildew was detected throughout the season in any onion crops. The dry conditions are likely to be responsible. The *EnviroCaster* only detected one day (27th September) conducive for downy mildew infection between early September to late October. Of the eleven growers whose crops were monitored, five did not apply any fungicide sprays. The remaining growers applied 1-4 sprays of dithiocarbamate +/- copper. This is a significant reduction from previous years in the number and variety of fungicides used. Control growers from outside the 75 tonne club used 1-2 phenylamides, 5-6 dithiocarbamate +/- copper and 1 benomyl. This result vindicates the effectiveness of the monitoring program.

# Discussion

There are many factors identified in this study that are important to achieving higher yields. The key factors are:

* Paddock selection (soil type, low salinity and no herbicide residues)
* Appropriate crop rotations
* Optimum seedbed preparation (or renovation of permanent beds)
* Sowing varieties at appropriate time and rate
* Optimum weed control at early crop stage
* Optimum irrigation scheduling to maintain soil moisture
* Optimum timing and application rates for fertilisers
* Crop health management using integrated management strategies
* Harvest onions at optimum maturity - *90% tops down*
* Cure stored onions in open sheds or use of forced air
* Eliminate bruising of onions across the grader
* Establishment of Quality Assurance programs

At the conclusion of the 3 year project, it was possible to make key recommendations for Riverina onion growers that were based on the best management practices of the 75 Tonne Club members. They are as follows:

## 1. Site Selection

* <u>Long term planning</u> is a requirement for successful long-term outcomes. A four year plan should include crop rotations that suit onion production. For instance, avoid a pasture phase just prior onions to minimise problems with wireworms.

* Consider the <u>soil type, irrigation type, bed width and production methods</u>. Sandy loam soils with furrow irrigation can yield 33% lower than a self-mulching clay under furrow. Avoid growing white varieties on heavy clay soils to minimise discolouration. Choose Self-mulching *Wunnamurra* or *Yooroobla* clay soil in preference to the *Cobram* or *Willbriggie* clay loam soils. Sandy soils are only suitable with overhead spray irrigation.

* Check for salinity and waterlogging problems. Ensure the water table is more than one metre from the surface. If less than one metre, water should be tested for salt levels. Also consider installation of observation wells to monitor water table.

* Land preparation should commence 9 months prior to sowing. Beds should be formed up prior to the onset of autumn rains.

* At least one or two pre-irrigations should be used at the end of summer to activate any pre-emergent herbicides in the soil if a broadleaf crop was the previous crop.

* Establishment or renovation of permanent beds should commence 18 months, and as close to 2 months prior to sowing. Beds should be kept in a weed free state, and worked to create a fine tilth.

* Conduct chemical soil tests every year, and physical tests every 3 years. Tests should be performed 6 months prior to sowing.

* On sodic soils, apply gypsum at 5 tonnes/ha initially, and top-up as required. Gypsum will reduce problems with plant emergence on crusting soils and reduce clods at harvest.

* Access to water from on-farm storage or water courses provides more options for winter irrigations. Establishing a crop on rainfall is preferred but unpredictable.

* Paddocks should be laser-graded at 1 in 800 for loamy soils and up to 1 in 150 for heavier self-mulching clay soils. The optimum is to minimise irrigation runs to 400 metres on a 1 in 800 slope, but runs can often extend to 600 metres.

## 2. Crop Establishment - Bulb initiation

* Only use new seed. Germination of 2-year-old seed could be less than 50%. Conduct seed germination and vigour tests on any old seed intended for use. Seed should not be stored near chemicals or fuel, and are best kept in a cool, dark place.

* Optimum sowing dates for:(i) *Gladalan* Types - irrigated up s-15th May, and (ii) *Creamgold* Types - irrigated up after 15th May.
Risk Management - Sowing prior to these dates could result in bolting. If *Gladalans* are sown after the 15th of May, the bulbs will be smaller and mature later. On poorer soils (ie *Cobram* loam) earlier sowings can be used to advance the crop, but no pre-plant fertiliser should be used to avoid bolting. On the more fertile self mulching soils early sowing should not commence until the beginning of May.

  If early sowings experience rain followed by warm temperatures, quick germination and growth of onions occurs. Herbicide application at this time could also be used to retard crop growth along with weeds. Early sowings usually results in enhanced plant populations that are critical to good yields. If late plating cannot be avoided, plant establishment should be encouraged with pre-plant fertiliser and careful use of herbicides.

* *Early Creamgold* is the best onion cultivar for storage, and more likely to tolerate heatwave conditions at harvest. Growers should continually evaluate new early varieties under local conditions.

  Ensure good establishment of *Early Creamgold* and *Creamgold* with adequate soil moisture after sowing. About 25-30 mms of rain or irrigation is required to establish a good root system.

* Use *Apron* (R) seed dressing where *Pythium* fungus is a problem (when planting into cold and wet soils).

* Aim for plant densities of 50-60 plants/m with 6-10 plant rows on 1.5 to 1.8 meter beds. Supermarkets now demand onions of *60 mms* or greater diameter and North Asian markets prefer onions of *80 mm* or greater diameter. Therefore plant densities closer to 50 plants/m

square are preferred.

* Water stress should be avoided in late winter-early spring, just prior to the rapid vegetative growth phase from early September to mid-November. Use irrigation scheduling aids such as tensiometers or soil probes to assess water available to plants. Ensure good subbing of water to the centre of the bed for even germination and watering.

* Fertilisers: apply between 180 and 200 units of Nitrogen (about 7-8 bags of Urea equivalent). In several side dressings prior to bulb initiation. (Bulb initiation occurs when the bulb is twice the diameter of the stem). Soil and Leaf analysis should be used as a decision making tool for other elements such as potassium.

  On high pH soils (above pH 8.0) apply up to 3 sprays of foliar zinc in late winter and early spring.

* Herbicides such as *Roundup* (R) or *Spray Seed* (R) should be used with caution. *Roundup* should be applied no later than 4 days before crop emergence on heavy clay soils, and no less than 7 days before emergence on lighter soils. Don't use *Roundup* on sandy soils, particularly if the soil is wet.

  Weed control using post emergent herbicides should be completed before the 3 leaf stage, as onions are susceptible to burn after then. *Totril* (R) and *Tribunil* (R) can be used singly or together to control most broadleaf weeds. *Probe* (R) should be retained for specific problems with wireweed. (Both *Probe* and *Tribunil* are being withdrawn from sale, which is likely to result in fewer options for chemical control in future). Trials in Tasmania has shown pre and post emergent applications of *Goal* (R) and *Stomp* (R) to be highly effective for the control of problem weeds fat hen and wireweed. However, there is no current registration for the use of either of these herbicides in NSW.

  Hand chipping of weeds is virtually the only option for broadleaf weeds after the 3 leaf-stage. Sound crop rotations on permanent beds can help lessen the weed pressure and hence reliance on post emergent herbicides.

Grass herbicides, such as *Fusilade* (R) and *Sertin* (R) can be applied at later growth stages without harming the crop. Observe for resistance in ryegrasses to the *Fops* and *Dims* groups of grass herbicides (see *Onions Australia*, 1992). *Select* (R) can be more effective where resistant ryegrasses exists.

* Correct identification of Pests and Diseases is critical for effective control. Ensure diagnosis is correct by consulting with appropriate experts for identification of diseases. Consider employing scouts to check the crop twice weekly. Management strategies for major diseases are given in Table 2.

**Table 2.** ***Management strategies for major onion diseases in the Riverina***

| Disease | Symptoms | When to monitor | Comments |
|---|---|---|---|
| Downy Mildew *Peronospora destructor* | lesions and wilting of leaves; grey mildew | bulb initiation to maturity - check most mature crops in the district; also look for self-sown plants | * white cultivars appear to be more susceptible<br>* disease develops more in high density plantings with lush canopies<br>* phenylamide/dithiocarbamate sprays controlled disease in commercial plantings and an experimental trial - this is despite the discovery of resistance in an isolate collected from a seed crop grown in the district and stresses the need for the judicious use of these chemicals to preserve their usefulness |

| Disease | Symptoms | When to monitor | Comments |
|---|---|---|---|
| Purple blotch *Alternaria porri* | small lesions develop with white centres; these elongate as they expand forming rings of brown spores; surrounding tissue turns yellow and purple | early bulbing to maturity | * occurs in crops more where there is damage caused by other agents such as thrips feeding or chemical burns or hail<br>* older leaves are more susceptible<br>* lesions are often colonised by *Stemphylium* |
| Stemphylium Leaf Blight *Stemphylium* spp. | olive to black fungal growth on leaves | all growth stages | * common on dead leaf tissue such as leaf tips and often associated with injury caused by chemicals, diseases, insects and hail |
| Pink Root *Pyrenochaeta terrestris* | plants wilt and roots have pink roots | bulb initiation to maturity - requires warm conditions (24-28°C) | * occurs in ground with poor rotations<br>* some 'hotspots' in crops can be confused with downy mildew due to the wilted appearance of leaves and their subsequent colonisation by other fungi |

| Disease | Symptoms | When to monitor | Comments |
|---|---|---|---|
| Botrytis rots *Botrytis allii* & *Botrytis cinerea* | grey spore masses form under humid conditions on rotting tissue on bulbs | storage diseases | * ensure seed is free of Botrytis<br>* optimise plant density and fertiliser application<br>* avoid bruising during harvesting and grading<br>* cure and store onions correctly |
| Black mould *Aspergillus niger* and Blue mould *Penicillium* spp. | discoloured areas on bulbs with black spore masses (black mould) and blue green (blue mould) | storage diseases (no *Botrytis* leaf blight diseases were recorded in this study although they are recorded overseas) | * withdraw irrigation 21 days before harvesting<br>* avoid bruising during harvesting and grading<br>* reduce storage temperatures and humidity so that no free moisture occurs on bulbs |
| Damping off *Rhizoctonia* & *Pythium* spp. | wilting and death of seedlings | crop establishment | * monitor establishing crops & confirm causal pathogen<br>* seed can be dressed with *Apron* (R) fungicide to prevent *Pythium*<br>* *Rhizoctonia* rots may be more severe on permanent beds |

| Disease | Symptoms | When to monitor | Comments |
|---|---|---|---|
| Bacterial rots *Pseudomonas* spp. & *Erwinia* spp. | plants in the field wilt as bulbs develop rots - in storage, soft rots are often associated with a foul odour; rots may occur on the surface of bulbs or be internal and only become visible when bulbs are cut or squeezed | usually after bulb initiation in the field, and storage diseases | * rots are favoured by excess soil moisture and are usually associated with over-irrigation, particularly close to maturity<br>* avoid bruising during harvesting and grading<br>* reduce storage temperatures and humidity so that no free moisture occurs on bulbs |

**Figure 1** Monitoring onion crops enabled early detection of crop health problems

**Figure 2** Downy mildew was predicted by a weather-based model on the EnviroCaster unit that was purchased for this project

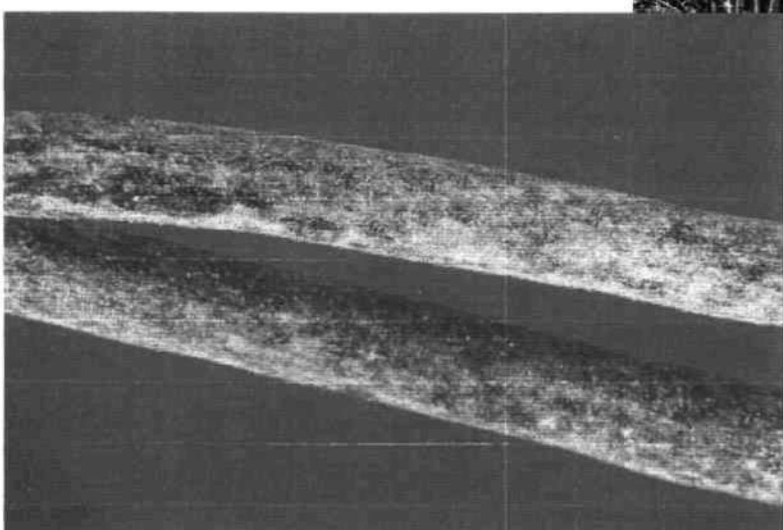


**Figure 3** Thrips injury on onion leaf

**Figure 4** Thrips feeding on onion leaf

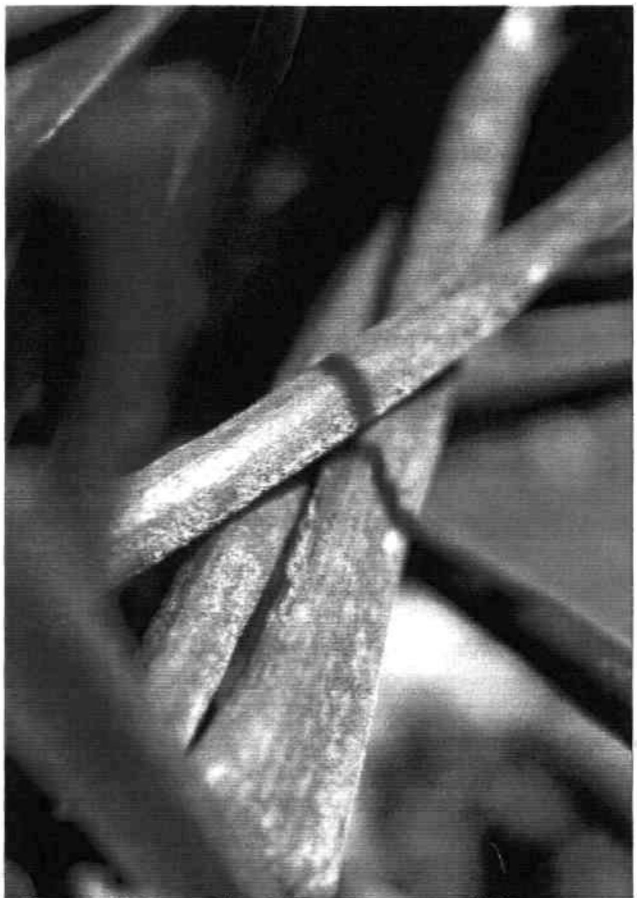


**Figure 5** Growth of the downy mildew fungus, *Peronospora destructor*, on infected leaves

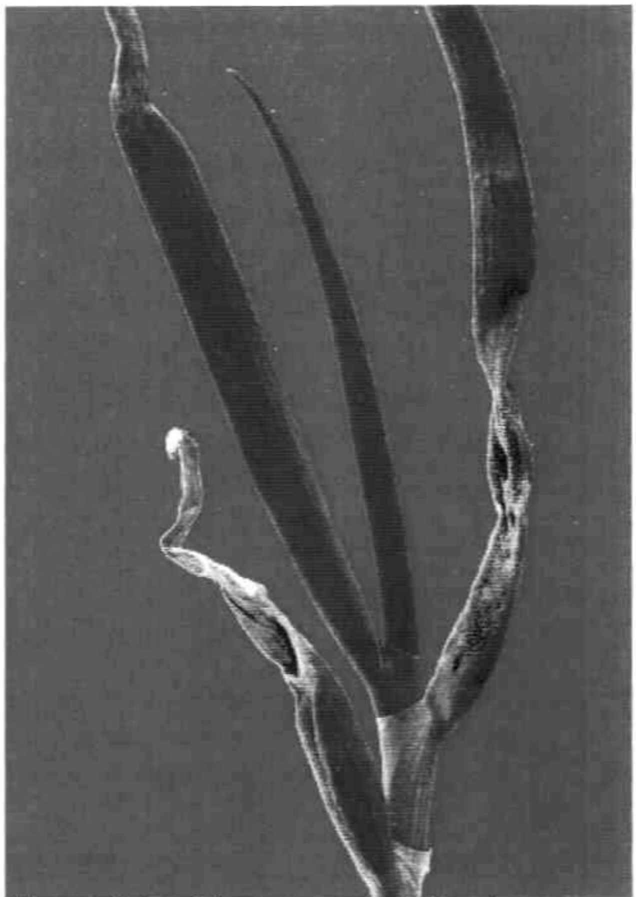


**Figure 6** Leaf lesions caused by downy mildew

**Figure 7** Purple blotch (*Alternaria porri*) and stemphylium leaf blight (*Stemphylium vesicarium*) are often associated with downy mildew infections

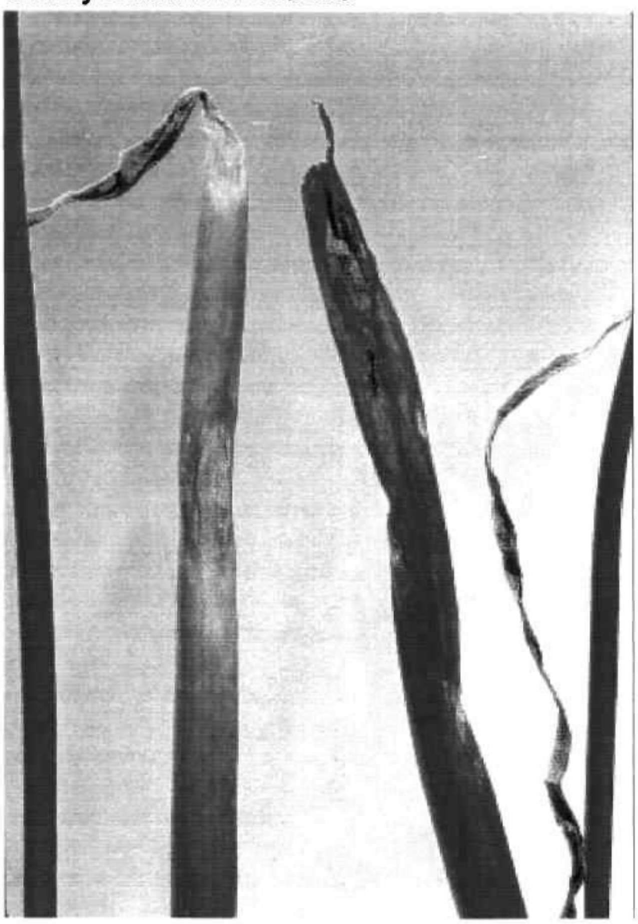


**Figure 8** Leaf tip die-back has many causes and tissue is often associated with secondary pathogens which can be mistaken for primary diseases

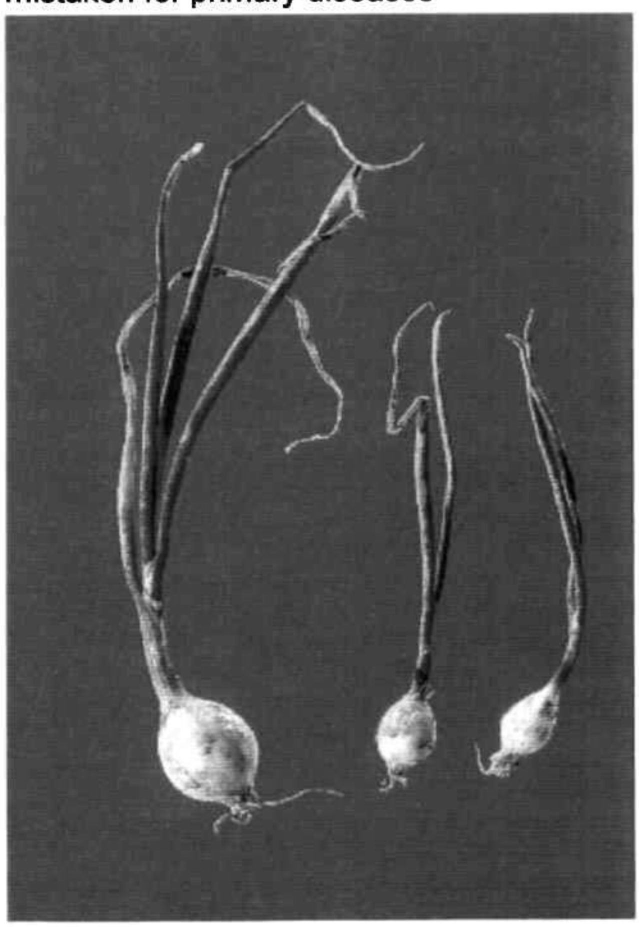


**Figure 9** Wilting caused by pink root (*Pyrenochaeta terrestris*) was encouraged by moisture stress, high temperatures and poor crop rotation

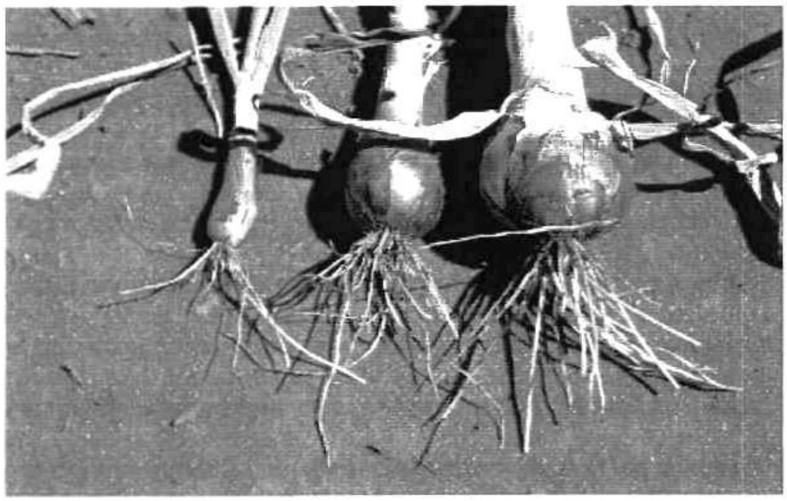


**Figure 10** Pink root symptoms developed on a sandy soil during drought conditions

**Figure 11** Internal symptoms of botrytis neck rot

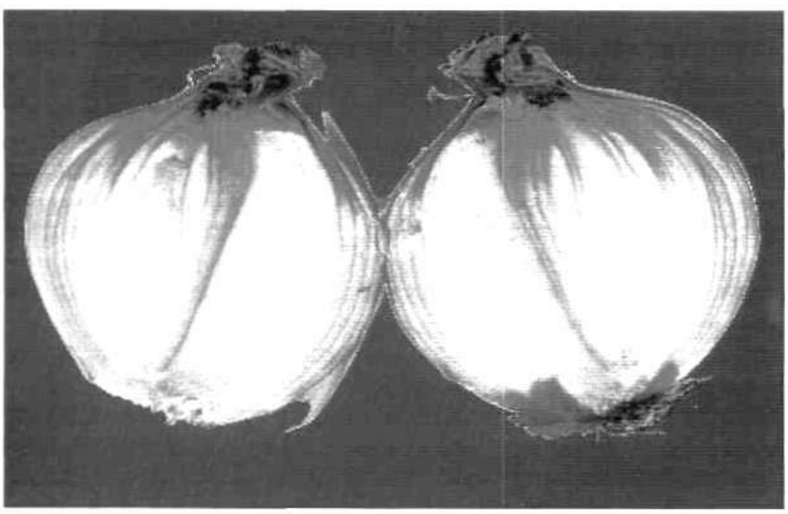
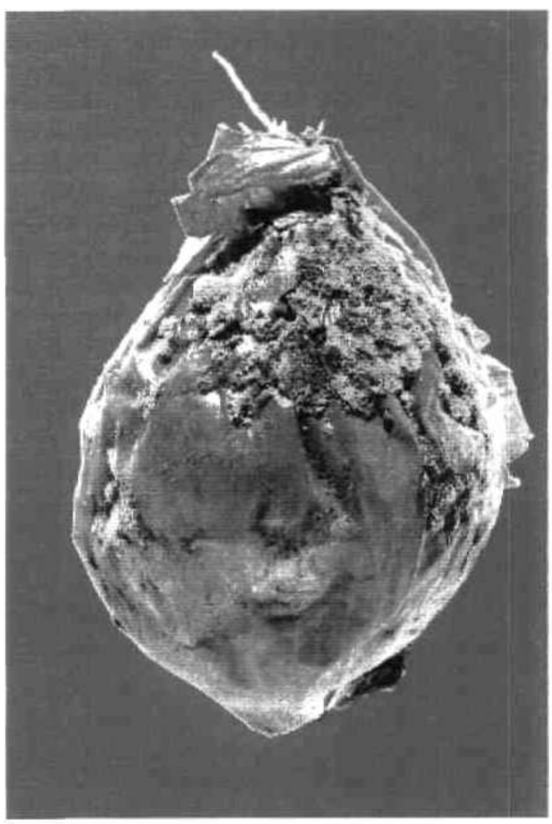


**Figure 12** Botrytis rots develop in storage under humid conditions



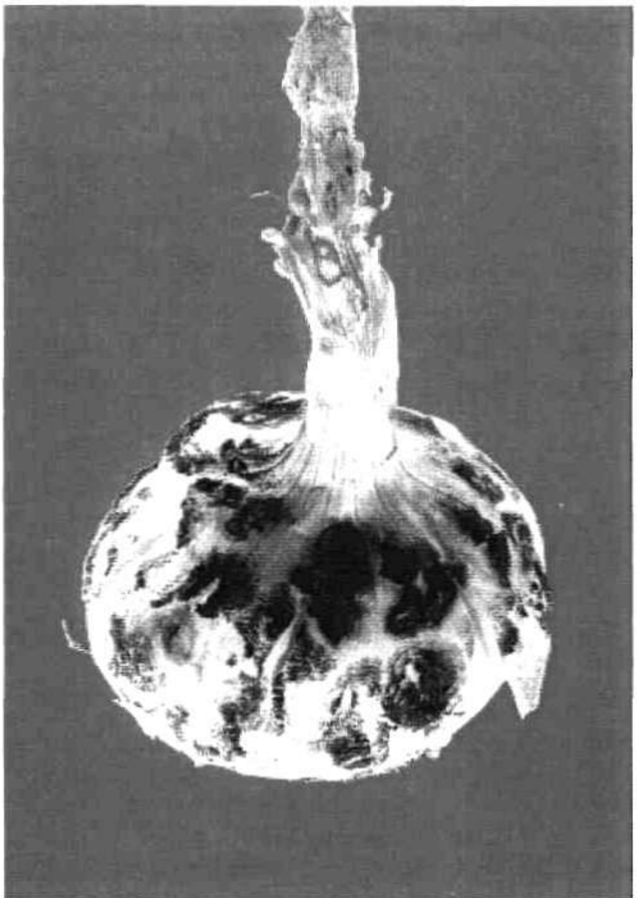


**Figure 13** Smudge (*Colletotrichum circinans*) is only a problem on white cultivars during warm and wet weather

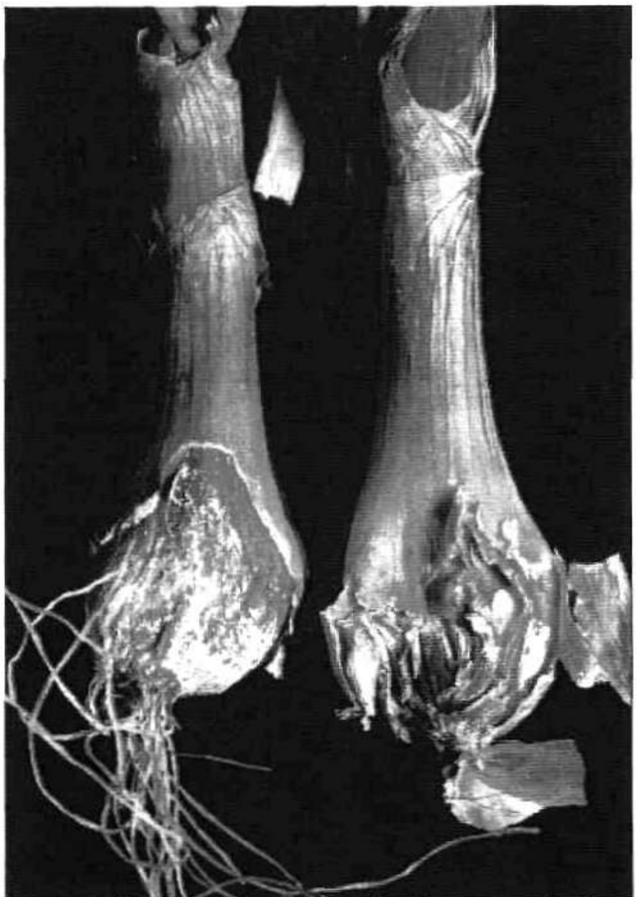


**Figure 14** Fusarium basal rot occurs during warm conditions, especially where insects have damaged developing bulbs

**Figure 15** Blue mould is a storage disease that is caused by several *Penicillium* species

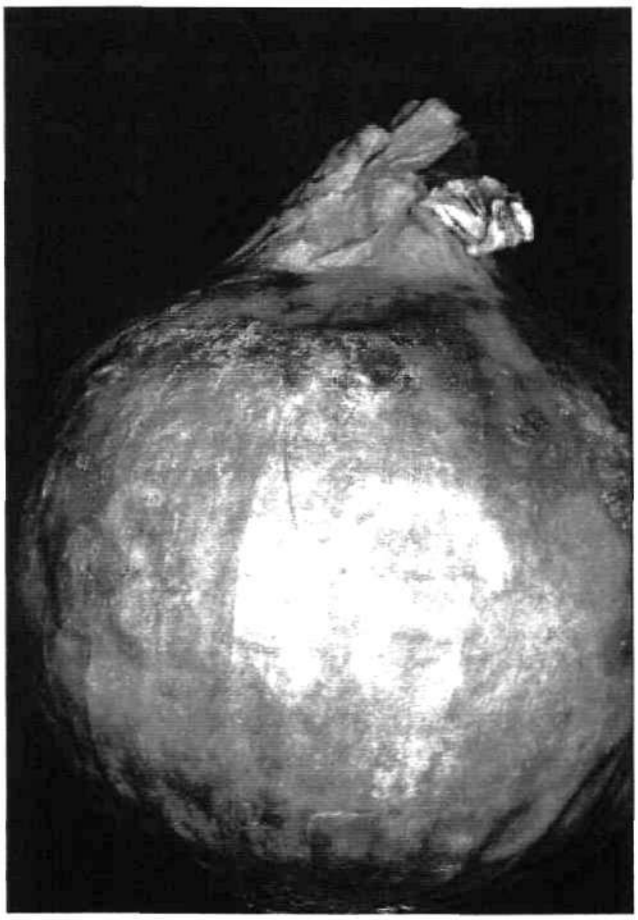


**Figure 16** Black mould (*Aspergillus niger*) is a major storage disease when temperatures are above 15 C together with very humid conditions

**Figure 17** Wilting plants with a bacterial rot caused by *Erwinia carotovora* that enters through dying or damaged leaf bases

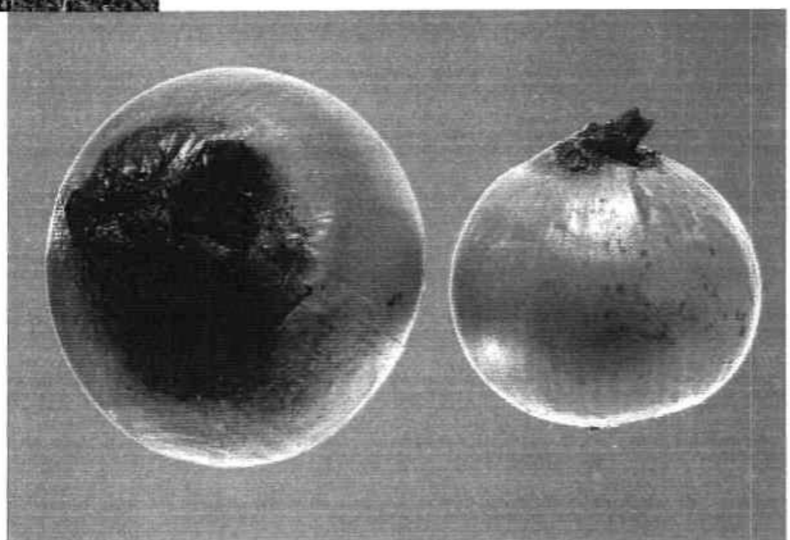


**Figure 18** Breakdown of neck tissue associated with bacterial rot in storage

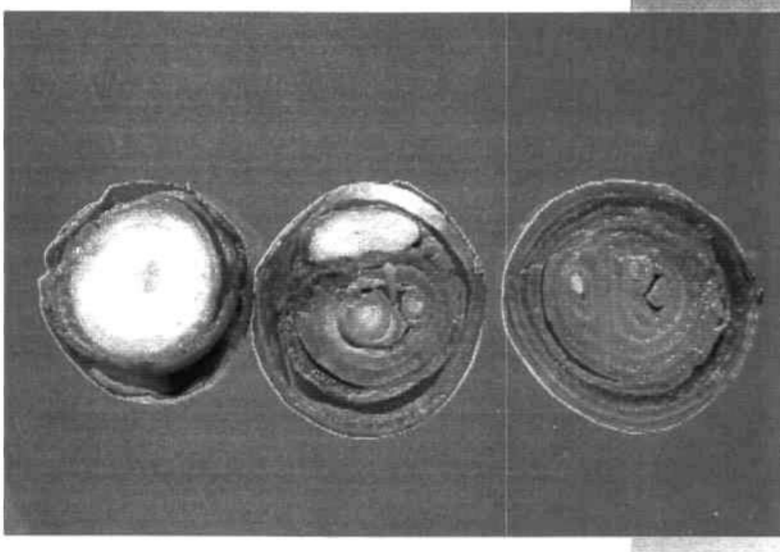


**Figure 19** Internal symptoms of bacterial rot caused by one of several *Pseudomonas* species

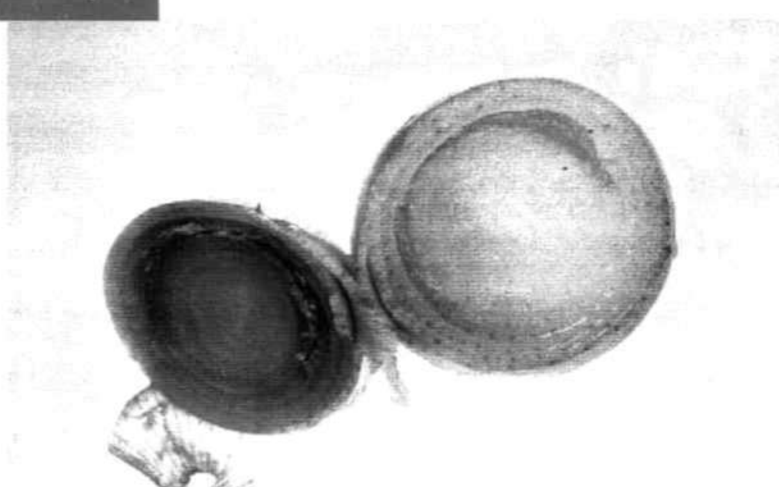


**Figure 20** Bacterial internal browning of one or two rings is caused by *Pseudomonas aeruginosa*

**Figure 21** Salinity caused production losses, particularly when onions were adjacent to rice

**Figure 22** White rot (*Sclerotium cepivorum*) symptoms on seedlings

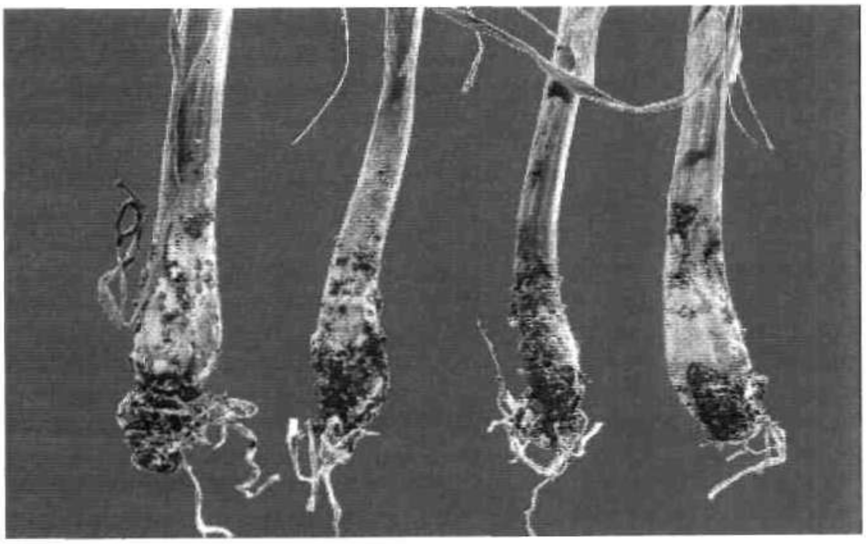
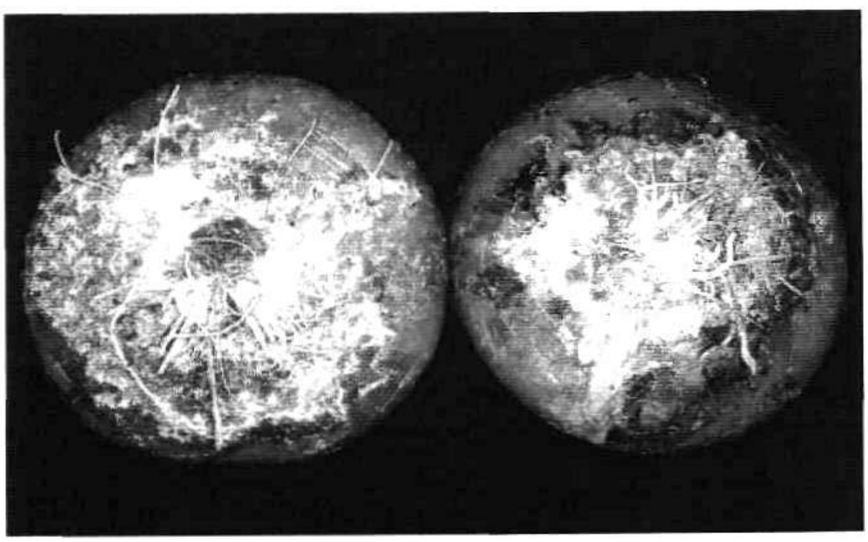


**Figure 23** White rot symptoms on maturing bulbs



* If using animal manures, check for onion maggot infestation. Avoid over-saturation of soil, as this will favour wireworm infestations.

* Thrips infestations can reach 20-50/plant before spraying is required. Apply sprays during the warmer part of the day when thrips are more active. Control of host weeds around the paddock can restrict thrips numbers in early spring.

### 3. Bulb Initiation - Harvest

* Mid-September to late October is a period of rapid vegetative growth in riverina onion crops. Check regularly for downy mildew infestations. Plant densities of 50 plants/m or less will minimise build up of humidity, and therefore reduce the risk of disease establishment.

* Cease irrigations 3 weeks prior to harvest. Fertiliser should not be applied after the bulb initiation stage.

* Harvest at optimum period. Harvest at *90% tops down* to maximise skin setting and before bulbs sunburn. If daytime temperatures exceed 38°C, stop harvesting operations. During prolonged heatwave conditions, the crop should be topped and lifted late in the evening, and transported to an open storage shed early morning before temperatures rise. No harvested bins should be left in the paddock if temperatures are high. If harvested onions get wet, use forced air drying for 48 hours. All tops on harvested onions should be no less than 1 cm.

### 4. Crop Hygiene - Post Harvest

* Cure onions in an open sided shed at least 2-3 weeks for domestic market and at least 3-4 weeks for export. Although the optimum storage for onions is 2-3°C and 70% humidity, storage at 27°C with forced air ventilation at nigh in an open, windy shed is probably the most practical solution.

* Onions for long-term storage should be size/graded with all diseased or damaged bulbs removed. Otherwise, minimise handling of the onions.

* Harvesting and grading machinery should be inspected regularly for faults causing bruising to bulbs.

* All grower-packers should market graded onions in 20 kilo bags. All bags should be clearly labelled using high quality bags and presentation.

* Consider introducing a Quality Management (QM) system to maximise quality outputs from the growing, harvesting and packing-shed operations. Aim for *ISO 9000* status with AQIS, particularly for those packing for export markets. The Australian Horticultural Corporation (AHC) has training packages on QM.

* All refuse and discarded bulbs should be removed from the farm or deep buried. Volunteer plants should be destroyed. Both machinery and packing shed should be cleaned out each season to minimise disease carry-over. High pressure water is useful to remove soil clods and organic material. Disinfectants (preferably phenolics) should be used on equipment coming into the area from other production districts. The Riverina is free of the important onion diseases, White Rot (*Sclerotium cepivorum*) and Onion Smut (*Urocystis colchici*) and due diligence by the grower community is required to maintain this area-freedom.

* Growers should consider the efficiency of the packing-shed operations, and how *ISO 9000* operations are carried out in those sheds already certified. Take opportunity to visit state-of-the-art packing sheds in other states, such as Tasmania or South Australia.

## Extension/adoption by industry

* One professional scout operates in the Riverina who is trained in crop monitoring techniques that were developed in this project.

* The *EnviroCaster* unit has been maintained in a commercial onion crop and growers are alerted to disease *high risk* periods by telephone. NSW Agriculture District Horticulturist, Mark Hickey is responsible for maintaining the unit and advising growers.

## Directions for future research

* Further research is required to determine spray thresholds for thrips which were set at an arbitrary levels of 20-50 thrips per plant in this project.

* Registration needs to be obtained for the herbicides, *Stomp* and *Goal* for control of fat hen and wireweed in NSW.

* A market-focussed project aimed at producing quality onions for export is required to help develop the onion industry in the Riverina.

* Further testing of downy mildew populations for resistance to phenylamide fungicides.

## Financial/commercial benefits

This project clearly demonstrated that IPM techniques can be adopted by Riverina growers and significantly reduce the number of chemical sprays used. Monitored crops saved 8 fungicide sprays in 1993 and 5 sprays in 1994 as well as 5 further growers who applied no fungicides.

Higher yields and quality were achieved by predicting disease occurrence with weather-based models and detecting diseases earlier by regular crop monitoring. Alternatively, losses were exacerbated where inappropriate chemicals were applied or where disease was left undetected for longer periods in crops that were not monitored.

The reduced use of phenylamide fungicides may prove to be critical in halting the spread of resistant populations of the downy mildew fungus in the Riverina.

# Appendix

## Onion Downy Mildew - Review of Literature

Downy mildew of onions is caused by *Peronospora destructor* (Berk.) Fr. and was first recorded in NSW by Cobb in 1891 (J.Walker, unpublished). It is widespread and damaging mainly during spring in cool damp seasons but is much reduced by hot dry weather. The surface of infected leaves have elongated lesions that are first noticeable as light green areas that may develop blue-grey velvety growth as the fungus produces spores (conidia). Leaf tips may dry out and are frequently colonised by the dark mould *Stemphylium botryosum*. Foliage may be almost completely destroyed during the course of four infection cycles (Hildebrand & Sutton, 1982). Bulbs from affected plants are smaller, resulting in reduced yields, a predisposition to storage rots and lower market value (Walker, 1952).

Sources of infection may include contaminated seeds, systemically infected bulbs from the previous season and older infected crops (Letham & Cother, 1982). A number of studies in the last decade have determined the exact environmental conditions required for the infection and spread of *Peronospora destructor* (Hildebrand & Sutton, 1982; 1984a; 1984b; 1984c; Sutton and Hildebrand, 1985). The infection cycle is characterised by long latent periods (9-16 days) and short periods (1-2 days) when the fungus sporulates, disperses and infects leaves (Hildebrand & Sutton, 1982). An early study by Yarwood (1937, 1943) showed that sporulation requires daily cycles of light and darkness. Spores are produced at night and are subsequently dispersed during the day.

The generation of spores is very sensitive to atmospheric humidity. High relative humidity (RH>95%) is required for sporulation. The ambient temperature during humid nights determines the time required for spores to develop and mature (Hildebrand & Sutton, 1984c). For example on cool nights (6 C) sporulation was completed only when high RH began within 4 hours after dark, but at moderate temperatures (14 C) spores matured even when high RH began as late as 7 hours after dark. Fungal structures bearing spores (conidiophores) can only develop between droplets of water on the leaf surface (Hildebrand & Sutton, 1982). Rain or heavy dew at night reduces or prevents sporulation except when these events occur early, that is before sporulation commences (Sutton & Hildebrand, 1985).

Dispersal of spores is triggered by declining RH (and to a lesser extent by increasing RH) that usually occurs at dawn Hildebrand & Sutton, 1982). Leach *et al.* (1982) also found that red-infrared radiation (IR) enhances spore release even in a saturated atmosphere. They further postulated an electrostatic mechanism by which IR and changes in RH act to release spores.

Dispersed spores survive on host leaves for 1-3 days or longer when conditions are favourable, but for shorter periods under adverse conditions (Bashi & Aylor, 1983, Hildebrand & Sutton, 1984a). These studies found that cool temperatures, moderate RH and low irradiation were the preferred conditions for survival of spores. Spores die at an exponential rate as RH is increased from around 50% to 95%. Successful progression of the disease requires spores that were dispersed after dew dries during the morning to survive until the wet period of that evening. The number of spores released and the availability of shaded leaf surfaces on which to survive will therefore influence the potential progression of the disease.

A rapid rate of deposition of dew in the evening is one critical factor required for spore germination and infection (Hildebrand & Sutton, 1984a). Low rates of dew deposition causes alternating wetness and dryness that is lethal to germinating spores. In one laboratory experiment, a single cycle of 10 min wetness and 10 min dryness reduced germination by about 70%. The pathogen enters onion leaves through stomates when there is a minimum of 3 hours of leaf wetness.

Quantitative and temporal relationships of temperature, rain, high humidity, rate of dew deposition and dew duration have been used to construct a forecaster of onion downy mildew (Jesperson & Sutton, 1987). The basis of the forecasting system was to predict sporulation and infection by the fungus. The system called 'Downcast' was evaluated under field conditions to determine its validity and effectiveness for timing fungicide sprays. It was concluded that fungicide programs should start at about the time of the first sporulation-infection period.

## References

Bashi,E. & Aylor,D. (1983).
Survival of detached sporangia of *Peronospora destructor* and *Peronospora tabacina*. Phytopathology, 73:1135-1139.

Hildebrand,P.H. & Sutton,J.C. (1980).
Maintenance of *Peronospora destructor* in onion sets. Canadian Journal of Plant Pathology, 2:239-40.

Hildebrand,P.H. & Sutton,J.C. (1982).
Weather variables in relation to an epidemic of onion downy mildew. Phytopathology, 72:219-224.

Hildebrand,P.H. & Sutton,J.C. (1984a).
Effects of weather variables on spore survival and infection of onion leaves by *Peronospora destructor*. Canadian Journal of Plant Pathology, 6:119-126.

Hildebrand,P.D. & Sutton,J.C. (1984b).
Relationships of temperature, moisture, and inoculum density to the infection cycle of *Peronospora destructor*.Canadian Journal of Plant Pathology, 6:127-134.

Hildebrand,P.H. & and Sutton, J.C. (1984c).
Interactive effects of the dark period, humid period, temperature, and light on sporulation of *Peronospora destructor*. Phytopathology, 74:1444-1449.

Jesperson,G.D. & Sutton, J.C. (1987).
Evaluation of a forecaster for downy mildew of onion (*Allium cepa* L.). Crop Protection, 6:95-103.

Leach,C.M., Hildebrand,P.D. & Sutton,J.C. (1982).
Sporangium discharge by *Peronospora destructor*. Influence of humidity, red-infrared radiation, and vibration. Phytopathology, 72:1052-1056.

O'Brien,R.G. (1992).
Control of onion downy mildew in the presence of phenylamide-resistant strains of *Peronospora destructor* (Berk.) Caspary. Australian Journal of Experimental Agriculture, 32:669-74.

Sutton,J.C. & Hildebrand,P.H.(1985).
Environmental water in relation to *Peronospora destructor* and related pathogens. Canadian Journal of Plant pathology, 7:323-330.

Walker,J.
A checklist of plant diseases occurring in NSW (unpublished).

Walker,J.C. (1952).
'Diseases of vegetable crops'. (McGraw-Hill Book Company: New York)

Yarwood,C.E. (1937).
Relation of light to the diurnal cycle of sporulation of certain downy mildews. Journal of Agricultural Research, 54:365-373.

Yarwood, C.E. (1943).
Onion downy mildew. Hilgardia, 14:595-691.

## Publications

Tesoriero, L., Salvestrin, J., O'Brien, R., Galea, V., MacManus, G Ransom, L. & Hingston, L. (1993).
Managing onion downy mildew in Australia. *Onions Australia*, 10:22-26.

Salvestrin, J. & Tesoriero, L. (1995).
Comparative analysis as a means of improving yield, quality and sustainability of Australian onions. *Proceedings of the First International Symposium of Edible Alliiaceae*, Mendoza, Argentina, 1994.

Salvestrin, J., Tesoriero, L. & Hickey, M. (1995).
Best management guide for Riverina onion growers. *Onions Australia*, 12:13-17.