FINAL REPORT

Developing alternative methods for Sclerotinia disease control on vegetables in Tasmania

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Acknowledgements

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Mark Shakelton at CSIRO Entomology, Perth, conducted plant analysis for isothiocyanates in brassica green manure tissues.

Photographs

In Tasmania, white mould due to *Sclerotinia sclerotiorum* in bean crops (Photograph 1), and lettuce drop due to *S. minor* on lettuce crops (Photograph 2), are major causes of decline in crop yield.


Photograph 1


Photograph 2

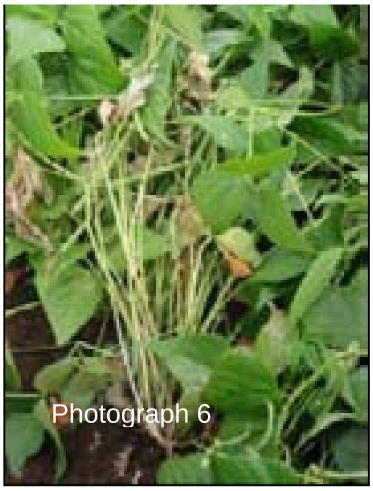
A trial was conducted on an iceberg lettuce crop at Forth to evaluate the potential of biocontrol agents and new fungicides for *Sclerotinia* control (Photograph 3). Effective *Sclerotinia* control was achieved by the fungicide Boscalid on a Red Oak cos lettuce at Cambridge (Photograph 4).


Photograph 3

Photograph 4

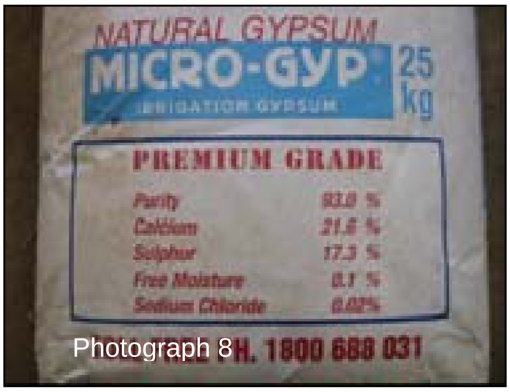
Fungicide application at early flowering stage and before canopy closure between plant rows is critical for effective *Sclerotinia* control on a bean crop (Photograph 5). Bean plants with mild (Photograph 6) and severe (Photograph 7) *Sclerotinia* disease.


Photograph 5


Photograph 6


Photograph 7

MicroGyp, based on natural gypsum (Photograph 8), is a low-cost fertilizer product that has been shown to improve *Sclerotinia* control when applied in combination with Sumisclex fungicide). Two brassica green manure crops: an early flowering mustard (Fumus), adjacent to non-flowering rape (BQ-Mulch) at Cambridge (Photograph 9).



Photograph 8


Photograph 9

BQ-Mulch, a fodder rape that produces high levels of toxic and persistent root ITCs, suppressed *Sclerotinia* disease on lettuces that were planted after green manure crops at Cambridge (Photograph 10). Higher numbers of wilted plants can be seen in the untreated plot that was previously fallow (left), compared to the mostly healthy plants in the plot previously planted with BQ-Mulch (right).


Photograph 10

The strong and deep tap root system of BQ-Mulch (Photograph 11) can help to reduce soil compaction. Soil compaction or soil penetration resistance was measured using a mechanical soil penetrometer at the end of the subsequent lettuce crop (Photograph 12).


Photograph 11


Photograph 12

Summary

Trial studies were conducted in Tasmania as part of the HAL project VG00048, "Developments of biological controls for *Sclerotinia* diseases of horticultural crops in Australia". The studies examined and identified a range of new options that could be used in an integrated *Sclerotinia* disease management strategy, incorporing biological, cultural, and chemical methods. The underlying strategies were aimed at detecting, eradicating and reducing pathogen levels in the soil, suppressing the pathogen, reducing plant susceptibility, and preventing fungal invasion. Almost all trials in Tasmania, were conducted within commercial lettuce crops, which are highly susceptible to *Sclerotinia* and have a relatively short growing period, enabling consecutive trials in the same growing season. The research conducted in Tasmania can be divided into six main topics, and the key findings are summarized below.

Fungicide control

Field trials conducted in Tasmania showed that the fungicide procymidone (sold as Sumisclex and Fortress) gave consistent and effective control of *Sclerotinia* disease caused by *S. minor* and *S. sclerotiorum,* under high disease pressure. Procymidone is usually the fungicide of choice and is frequently the only fungicide used for *Sclerotinia* disease control in many crops in Tasmania.

Boscalid (BAS510-01F), a new class of fungicide, was shown to be highly effective against *S. sclerotiorum* and *S. minor* on bean, lettuce and pyrethrum crops in Tasmania. Under conditions that are highly favourable to *Sclerotinia* disease, the consistency and efficacy of Boscalid were similar to procymidone. This makes it a suitable alternative to procymidone for *Sclerotinia* control in a range of horticultural crops. Procymidone is a dicarboximide fungicide, while Boscalid belongs to benzanilide chemical group.

Effective fungicide application methods are essential for good disease control, with appropriate spray volume and timing in different types of horticultural crops.

Reducing plant susceptibility

In trials conducted in Tasmania, two products, Agri-Fos (phosphorus acid) and MicroGyp (natural gypsum or calcium sulphate), consistently improved disease control when applied in combination with Sumisclex. Sumisclex plus Agri-Fos or MicroGyp were shown to further reduce the percentage of diseased plants by 1% to 5%, when compared to Sumisclex alone.

Unlike Sumisclex, Agri-Fos and MicroGyp have no direct activities against *Sclerotinia*, but may have reduced infection indirectly by increasing the plant's natural defence system and reducing plant susceptibility to fungal infection. These two materials were not as effective as Sumisclex when applied on their own.

Although the additional level of improvement in disease control by Sumisclex plus Agri-Fos or MicroGyp are considered to be relatively small, ranging from 1% to 5% compared to Sumisclex alone, the low cost of the latter products could still make it cost effective.

Agri-Fos and MicroGyp are fertilizers, which do not leave any chemical residues on treated plants. These findings indicate the importance of plant health in combating plant diseases. Plants have their own mechanisms for preventing fungal invasion, and an unhealthy crop with nutrient deficiencies is usually more susceptible to disease than a healthy crop.

Biocontrol agents

Contans, based on *C. minitans* biocontrol fungus, was identified as the most promising potential biocontrol agent for *S. sclerotiorum* and *S. minor* control in three initial biocontrol trials conducted in Tasmania. Under low disease pressure, Contans could provide early disease control when applied as a pre-plant soil treatment or post-plant spray applications.

With other biocontrol products that were evaluated in Tasmania, they were less effective and there were inconsistencies in their levels of disease control under different conditions, indicating that further improvements in their performance are required before commercial use can be recommended.

With many biocontrol agents, including Contans, their efficacy for prolonged *Sclerotinia* control appeared to be limited. They appeared to be less effective under high disease pressure, and against actively growing

Sclerotinia pathogens under favourable wet conditions, at the late crop stage. In commercial crops, *Sclerotinia* infection rarely occurred early in the crop stage, and prolonged disease control is vital as it spreads rapidly under ideal moist conditions in a dense crop canopy during the late crop stage. Therefore, under high disease pressure, fungicide applications following early biocontrol agent treatments are still recommended.

Brassica green manures

This study indicated that brassica green manure plants that produce high plant biomass and high concentrations of biofumigants may offer advantages over non-brassica green manure plants for *Sclerotinia* disease control. BQ-Mulch, which produces high levels of isothiocyanates (ITCs) in roots, was found to be more effective for *Sclerotinia* control than Fumus, which produces high levels of ITCs in its foliage. The effectiveness of BQ-Mulch may be related to the high level of the non-volatile, but more persistent and toxic, 2-phenylethyl-ITC produced in its root tissues.

The fumigating activities, either by ITCs or other toxic bioactive compounds produced by the green manures, are likely to diminish rapidly after their release or formation in soil, and their effects for disease suppression are expected to be relatively short term. As a result, poor control of *Sclerotinia* may occur late in the crop's development, on lettuce planted after the brassica green manure crops. Therefore, under conditions that are ideal for the *Sclerotinia* disease, fungicide control methods should also be used, in conjunction with brassica green manures, for disease management.

This study showed that the high plant biomass and deep tap root systems of brassica green manures, helped reduce soil crusting, improved infiltration, increased organic matter and reduced sub-soil compaction. These overall soil improvement effects are likely to increase soil fertility and improve soil structural properties, thereby contributing to improved crop health and disease control.

Soil amendments with mustard meal, PERLKA and urea

A preliminary laboratory test conducted in this study showed that cold pressed mustard meal, urea and PERLKA were highly effective in killing sclerotia of *S. minor* at very high rates (10 g/kg soil or equivalent to 16 tonnes/ha). These three materials contain, or can convert into, toxic compounds, which behave as soil fumigants.

However, when applied at much lower rates, i.e. 500 and 1000 kg/ha, in field studies, they did not eradicate the *S. minor* pathogen. The results indicate that unless very high rates are used, the defatted mustard meal, urea and PERLKA are unlikely to be effective for long-term management over the fallow period, but may be useful for suppressing disease in the short-term. They are unlikely to replace post-plant fungicide applications, but could be considered for use as an additional tool for an integrated disease management practice.

Detection

Sclerotinia may cause seedling damping-off, and the susceptibility of seedlings appeared to be closely associated with plant architecture. Plant architecture could therefore be a useful guide when selecting plant varieties for use in crop rotations, particularly in ground that has high *Sclerotinia* pressure.

There was a positive correlation between the sclerotia levels and disease incidences on lettuces in the field. This indicated that the wet sieving method for sclerotia population may be useful for detecting high levels of sclerotes, and hence for identifying high disease pressure sites.

In Tasmania, apart from mycelial growth from sclerotes, *S. minor* was noted to produce apothecia on sclerotes. Infection by *S. minor,* however, is still predominantly due to mycelial infection at the base of plants. In contrast, widespread *Sclerotinia* disease due to *S. sclerotiorum* in Tasmania is frequently associated with infection by ascospores of the fungus. Effective disease control methods in different crops would be determined by the species of *Sclerotinia* pathogen and its mode of infection, as well as crop growth and susceptible periods. Selection of paddocks that enable good air flow and rapid drying of crops, in order to minimize risk to *Sclerotinia* disease, are critical. Effective disease control can be difficult to achieve in the presence of field conditions that are highly conducive to the pathogen.

Introduction

In Tasmania, *Sclerotinia* diseases caused by *S. sclerotiorum* and *S. minor* have become widespread in the north-west and southern regions, where intensive horticultural cropping occurs. They affect many crops, such as beans, brassicas, carrots, lettuces, peas, potatoes and pyrethrum. *Sclerotinia* produces sclerotia that can survive in soil over a long period of time. As a result, with intensive cropping, *Sclerotinia* inoculum in the soil could increase to such a high level that fungicide spray programs alone may not give adequate control of the disease in highly susceptible horticultural crops.

Among the horticultural crops, lettuce is considered to be the most susceptible crop to *Sclerotinia* infection, which results in lettuce drop. In north-west and southern Tasmania, many lettuce crops cannot be grown without the regular use of procymidone fungicide spray program. In some areas, where lettuces are sown every year, high losses ranging from 10% to 20% can still occur despite a regular fungicide spray program. Other crops in Tasmania, such as beans and carrots, can also sustain heavy losses due to *Sclerotinia* diseases. *Sclerotinia* disease on beans is caused by *S. sclerotiorum*, primarily through infected flowers by ascospores. Carrot crops infected by *S. sclerotiorum* in the field are rejected for export to overseas markets due to increased risk of post-harvest storage rot.

The perennial crop, pyrethrum, is susceptible to both species of *Sclerotinia*, resulting in wilting of young plants as well as direct flower infection of matured plants. Increasing frequency of *S. sclerotiorum* infection on peas, potatoes, and poppies have also been observed in the field. However, the impact of the disease on crop yield is unknown in these crops. Late infections of these crops have been noted to cause dramatic increases in sclerotia populations in soil, which can then pose a threat to subsequent crops in the rotations. Apart from obvious infections on maturing and matured plants, *Sclerotinia* pathogens, particularly *S. minor* can also cause seedling damping-off of most vegetable and field crops. The seedling damping-off caused by the *Sclerotinia* pathogens resembles that caused by other common soil pathogens such as *Fusarium, Pythium*, and *Rhizoctonia*, and is therefore often mistakenly attributed to the latter.

In many vegetables and field crops, *Sclerotinia* control programs consist of a regular fungicide application at the onset of *Sclerotinia* disease in each growing season. Although *Sclerotinia* diseases on the susceptible crops can usually be controlled effectively with a regular fungicide spray program, these fungicide sprays are an additional cost to crop production. There are also occasions where frequent rainfall and dense crop canopy help create an ideal environment for the disease. Adverse weather conditions can prevent spray applications, and hence affecting the timing of fungicide sprays, and therefore reducing the effectiveness of disease control. Poor control of *Sclerotinia* diseases will lead to losses in yield and quality, as well as market share, in an industry that values consistency, quality and timely delivery of produce. The over reliance on fungicides for disease control could also result in their reduced efficacies. Fungicide resistance and enhanced degradation of benomyl, iprodione and vinclozolin have been reported following frequent use (Subbarao 1998).

Procymidone (sold as Sumisclex and Fortress) is often used for *Sclerotinia* control in Australia. Since 1990s, it is widely used for *Sclerotinia* control in Tasmania, and therefore, it is considered to be a relatively new fungicide. Although no enhanced degradation or resistance has been found in this project or other studies (Pung & O'Brien 2000), we must still be cautious and vigilant in its use to ensure its availability for long-term use. High disease pressure, poor fungicide application methods, multiple fungicide sprays, and lack of other suitable fungicides for use in alternation with procymidone, could result in a loss of efficacy.

This project takes a new approach to examining and developing a long term *Sclerotinia* disease management strategy. The aims of the studies conducted in Tasmania were to evaluate and develop both short and long-term management strategies that are suitable for *Sclerotinia* control in horticultural crops. Long-term strategies that were investigated included the evaluation of promising biological methods, such as commercial biocontrol agents, green manures and break crops. The short-term strategies examined were pre-plant and post-plant chemical control methods to determine if there are other products that could be used in combination or in alternation with the current fungicide program.

As lettuce is the most susceptible crop to *Sclerotinia* wilt, almost all trials in Tasmania were conducted with lettuce as the benchmark crop. Although *Sclerotinia sclerotiorum* can also cause *Sclerotinia* wilt, *S. minor* is the most common cause of lettuce wilt. Disease management for *S. sclerotiorum* is similar to that used for *S. minor*. Therefore, suitable disease management method identified in these studies could also be used to manage susceptible crops and sites that are known to have high levels of *S. sclerotiorum*.

The areas of study examined in the Tasmanian trials were:

- The effectiveness of bacteria and fungal biocontrol agents, used in pre- and post-plant treatments, for use in wilt disease management.
- The effectiveness of alternative chemical soil treatments, used in pre-plant treatments, for use in wilt disease management.
- Methods for improving *Sclerotinia* control on crops in the field after planting, with the use of new fungicides and fungicide mixtures containing materials that enhance plant defence systems.
- The effectiveness of a range of green manure crops, including brassica green manures, for use in high *Sclerotinia* pressure areas, for long-term disease management.

General Discussion

Fungicide control

Since the mid 1990s, procymidone (Sumisclex) has set a new benchmark for *Sclerotinia* control in Australia. Field trials conducted in Tasmania in this project, showed that the fungicide, procymidone (sold as Sumisclex and Fortress) gave very consistent and effective control of *Sclerotinia* disease caused by *S. minor* and *S. sclerotiorum,* under high disease pressure. Most other registered fungicides, such as benomyl and iprodione, as well as many relatively new fungicides such as azoxystrobin, fluazinam, fludioxinol and tebuconozole, were found to be less effective than procymidone in the presence of high disease pressure, or conditions conducive to *Sclerotinia* pathogens in this study, as well as in a previous project (Pung & O'Brien 2000). As a result, procymidone is usually the fungicide of choice and is frequently the only fungicide used for *Sclerotinia* disease control in many crops. The sole reliance on procymidone for *Sclerotinia* control poses a risk of losing the fungicide through overuse. Although there is still no evidence of fungal resistance or enhanced degradation of procymidone, it is still good practice to use no more than two applications in a crop or to alternate its use with a fungicide from a different chemical group. Sumisclex is a dicarboximide fungicide, while BAS510-01F is a benzanilide, a new fungicide chemical group.

In Tasmania, Boscalid (BAS510-01F), a new class of fungicide, was shown to be highly effective against *S. sclerotiorum* and *S. minor* on bean, lettuce and pyrethrum crops. Different rates of the product evaluated indicated that 800 g/ha of Boscalid was adequate for *Sclerotinia* control. Under conditions that are highly favourable to *Sclerotinia* disease, the consistency and efficacy of Boscalid were similar to procymidone. Therefore, Boscalid is a suitable alternative to procymidone-based fungicides like Sumisclex and Fortress, for *Sclerotinia* control over a range of horticultural crops. Boscalid is currently being registered for use on grapes in Australia, and therefore, there is potential for extending its use for *Sclerotinia* control in horticultural crops.

Residual fungicidal effects by procymidone, when applied at the early crop stage before canopy closure, approximately 2 and 4 weeks after lettuce planting, appeared to be effective in controlling late infection. Fungicide residues in soil appeared to be critical in controlling the mycelial growth of *Sclerotinia* and in preventing lower leaf infections. Therefore, an effective fungicide application method is essential for good disease control. In Tasmania, procymidone spray application is often followed by irrigation in order to drench the fungicide into the plant base and top-soil. This method of drench application helps optimise disease control on lettuce crops. In other crops such as beans, spray timing was shown to be critical for effective control (Pung & O'Brien 2000).

Reducing plant susceptibility

Three preliminary trials conducted in Tasmania indicated that two sprays of Bion applied at 14 day intervals following procymidone at planting, gave as good *Sclerotinia* disease control as three sprays of procymidone (Sumisclex). Bion belongs to a new category of plant protection products called plant activators, which work by stimulating or inducing the development of systemic acquired resistance in plants. On its own, Bion has no direct effect on the *Sclerotinia* pathogens, and gave poor disease control. Unfortunately, the availability of Bion is uncertain and it is also expected to be a relatively expensive. However, these initial trial findings highlight the potential of harnessing and enhancing plants' own natural defense mechanisms to improve *Sclerotinia* disease control.

Further trials conducted in Tasmania revealed that two other products, Agri-Fos (phosphorus acid) and MicroGyp (natural gypsum or calcium sulphate), also showed similar improvement in disease control when applied in combination with Sumisclex. Sumisclex plus Agri-Fos or MicroGyp were shown to further reduce the percentage of diseased lettuce and bean plants by 1% to 5%, when compared to Sumisclex alone. The improvement in *Sclerotinia* disease control by these products was also repeated in field trials conducted for *S. minor* control in pyrethrum crops (Pung & Cross 2003). The use of Sumisclex mixtures with Agri-Fos or MicroGyp, provided two different modes of activity for *Sclerotinia* control. Sumisclex is highly effective in directly inhibiting the fungal pathogen. Agri-Fos and MicroGyp have no direct activities against *Sclerotinia*, but may reduced infection indirectly by increasing the plant's natural defence system and reducing plant susceptibility to fungal infection. Therefore, these two materials were not as effective as Sumisclex if it is applied on their own.

Although the level of improvement in disease control by Sumisclex plus Agri-Fos or MicroGyp are considered to be relatively small, ranging from 1% to 5% of further reduction in disease plants compared to Sumisclex alone, the low cost of the latter products could still make it cost effective. Assuming that there are an estimated 16 plants/m2 or 160,000 plants/ha, a 1% improvement in disease control will result in an additional 1,600 plants/ha for sale with a total value of $800, based on a wholesale price of $0.50 per plant. The current cost of 2 L/ha Sumisclex application is $130 per hectare, 3 L/ha Agri-Fos 600 is $17.60, and 2.5 kg/ha MicroGyp is $1.50.

Biocontrol agents

Contans, based on *C. minitans* biocontrol fungus, was identified as the most promising potential biocontrol agent for *S. sclerotiorum* and *S. minor* control in three initial biocontrol trials conducted in Tasmania. It is a well formulated product that is easy to use and has a relatively good shelf-life. Under low disease pressure, Contans could provide early disease control when applied as a pre-plant soil treatment, drench application onto seedlings plugs prior to planting or post-plant spray applications. Its efficacy for prolonged *Sclerotinia* control however, appeared to be limited. It was less effective against actively growing *Sclerotinia* pathogens under favourable wet top-soil conditions, at the late crop stage. This might be related to the relatively slow growing *C. minitans* compared to the *Sclerotinia* pathogens. Contans had been registered for use to control *Sclerotinia* in Europe and United States of America. In Australia, unless there is severe restriction in the use of fungicides as in Europe and USA, its availability is uncertain due to competition with effective fungicides, its relatively high registration cost, and the small market size in Australia.

With other biocontrol products that are available in Australia (but not registered for disease control) and that were evaluated in this study, there were inconsistencies in the levels of disease control in different trials, indicating that further improvements in their performance are required before commercial use can be recommended.

Some of the biocontrol agents, including Contans, when applied at planting or after planting, have been noted to reduce *Sclerotinia* disease on lettuces at the early crop stage. Unfortunately, they were found to be less effective in late disease control. With commercial crops, early *Sclerotinia* infection rarely occurred early in the crop stage due to the upright seedling growth, and rapid drying of exposed top-soil by wind and sunlight. The delay in infection may also be associated with a lag period before the pathogen become active in soil and the onset of favourable conditions. Our pot trial study indicates that sclerotes in soil have a lag period of about 29 days before plants were infected. This lag period may be associated to stimuli required for eruptive germination of the sclerotes and mycelial growth. Moreover, as plants mature, their lower leaves spread out and come in contact with soil surface, covering the gaps between plants. This helps create ideal moist conditions beneath the plants for *Sclerotinia* infection as well as its rapid spread to adjacent plants.

Brassica green manures

This study indicates that brassica green manure plants that produce high concentrations of biofumigants offer advantages over non-brassica green manure plants for disease control. Fodder rapes such as BQ-Mulch, which produce high levels of ITCs in their roots, are more effective for *Sclerotinia* control than mustards such as Fumus, which produce high levels of ITCs in their foliage. These differences may be related to the different types of ITCs with different properties (Stirling & Potter 1998). Leaf glucosinolates generally produce volatile ITCs that are lost rapidly, whereas root glucosinolates often produce non-volatile but more toxic ITCs that can also persist over a longer period in soil (Sarwar et al 1998).

Apart from ITCs released by the brassica green manure, other modes of activity may also be involved. These activities could include other toxic bioactive compounds that are released or produced in soil. The fumigating activities, either by ITCs or other toxic bioactive compounds are likely to diminish rapidly after their release or formation in soil, and therefore their effects for disease suppression are expected to be relatively short term. As a result, at close to harvest, poor control of *Sclerotinia* may occur on lettuces planted after the brassica green manures. Therefore, under conditions that are ideal for the *Sclerotinia* disease, fungicide control methods should also be used in conjunction with brassica green manures for disease management.

While the concept of biofumigation with ITCs produced by brassica green manures for *Sclerotinia* control may be an attractive natural process, we must also be realistic in our expectations. As with any biological systems, the success of the biofumigation process will be subject to variability in response to plant varieties, soil types, locations, environment, and crop management practices. Under conditions that are ideal for the *Sclerotinia* disease, fungicide control methods should also be used in conjunction with brassica green manures to ensure effective disease control. Ideally, early disease suppression resulting from the brassica green manure may help reduce one or two early fungicide applications in the subsequent crop.

Other benefits from green manures that can produce longer lasting effects are often overlooked. In this study, their high plant biomass and deep tap root systems helped reduce soil crusting, improved infiltration, increased organic matter and reduced sub-soil compaction. These overall soil improvement effects are likely to increase soil fertility and improve soil structural properties, thereby also contributing to crop health and disease management.

Soil amendments with mustard meal, PERLKA and urea

A preliminary laboratory test showed that cold pressed mustard meal, urea and PERLKA were highly effective in killing sclerotia of *S. minor* at very high rates (10 g/kg soil or equivalent to 16 tonnes/ha). The common theme among these three materials is that they contain, or can convert into, toxic compounds, which behave as soil fumigants. However, when applied at much lower rates (500 and 1000 kg/ha) in field studies, they did not eradicate the *S. minor* pathogen.

The mustard meal and PERLKA appeared to suppress disease at the early crop stage, when applied one day before planting. Urea applied as soil treatment at 500 kg/ha, six weeks before planting, did reduce *Sclerotinia* infection of the subsequent lettuce crop at the early crop stage. Like the brassica green manure, BQ-Mulch, the disease suppressive activities of these materials appear to be temporary, and higher disease incidence similar to the untreated control were recorded on lettuce plants, at close to harvest. Therefore, unless very high rates are used, the cold pressed mustard meal, urea and PERLKA are unlikely to be effective for use in long-term management over the fallow period, but may be useful for suppressing disease in the short-term. They are unlikely to replace post-plant fungicide applications, but could be considered for use as an additional tool for an integrated disease management practice. These materials must also be used with great caution as very high levels of these materials might also be toxic or adverse to crop health and beneficial soil microbes.

Detection

Sclerotinia may cause seedling damping-off, and the susceptibility of seedlings appeared to be closely associated with plant architecture. Seedlings of Rocket, BQ-Mulch and Fumus, which have lower leaves in contact with soil over a long period, were susceptible to infection. As these seedlings matured and became taller, they were no longer susceptible to *S. minor* infection.

In contrast, young seedlings of onions, beets, and spinach, which have upright foliage, were less susceptible to damping-off. Plant architecture could, therefore, be a useful guide when selecting plant varieties for use in crop rotations, particularly in ground that has high *Sclerotinia* pressure. There was a positive correlation between the sclerotia levels and disease incidences on lettuces in the field. This indicated that the wet sieving method for sclerotia population may be useful for detecting high levels of sclerotes, and hence for identifying high disease pressure sites. However, in determining the threshold levels for sclerotia populations, local environments must also be taken into account, as a rapid increase in disease incidence could occur with relatively low sclerotia populations in a poorly drained soil and under prolonged wet conditions.