THE USE OF BRASSICA GREEN MANURE CROPS FOR SOIL IMPROVEMENT AND SOILBORNE DISEASE MANAGEMENT

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INTRODUCTION

Sclerotinia spp. are among the most difficult soilborne pathogens to control. Chemical control methods for these pathogens usually offer only temporary crop protection against infection, and have little or no effect on the sclerotia. Biological control by antagonistic and parasitic microbes to plant pathogens has been associated with *Sclerotinia* control in some soils (1). Increase in beneficial microbial activity is often related to increase in organic matter (2). Organic matter is vital as a food source and haven to beneficial microorganisms that are related to disease suppression, soil structure, improvement in soil properties and crop health. The use of green manures in between successive crops helps maintain or increase organic matter in soils. However, little is known of the effects of different types of green manures on *Sclerotinia* wilt on lettuces.

Brassica plants are known to produce different types and levels of biofumigant chemicals, collectively known as isothiocyanates (ITCs) (3). ITCs are biocidal compounds, similar to metham sodium, and are produced when glucosinolades produced in the plant tissues are hydrolysed. Biofumigation by ITCs has been shown to have the potential to control many root fungal pathogens (4). There are several varieties of brassica green manures that have been selected for their ability to produce high ITCs levels as well as high plant biomass. These varieties may provide potential for direct and indirect disease control through biofumigation activity and modification of soil environment with increased organic matter. This paper presents our study on the potential of green manures crops, with and without biofumigation activity, for *Sclerotinia* disease management in lettuce.

MATERIALS AND METHODS

Three trials were conducted in Tasmania; one trial at Forth in Red Ferrosol, and two trials at Cambridge in Brown Dermosol. Trials 1 and 2 were conducted in 2001/02 (Tables 1 and 2), while Trial 3 was conducted in 2002/03 (Table 3). The trials were complete randomised block designs, with four replicates. Plot size was 1.2 m x 15 m in Trials 1 and 2, and 1.2 m x 20 m in Trial 3. The green manure crops were sown in July 2001 for Trials 1 and 2, and August 2002 for Trial 3. Control treatment consisted of replicate plots of fallow ground. BQ-Mulch, BQ-Graze, Fumus and Nemfix were the brassica green manure varieties examined. These varieties were selected in plant breeding programs for high ITCs production. The first two are fodder rapes and the latter two are mustards. Broccoli, oats and broad beans were also examined.

When the mustard and rape crops reached full flowering stage in October and November, the green manure crops were chopped up and incorporated into soil with a rotary hoe to a depth of 25 cm. Following green manure crops, and ground preparation, iceberg lettuce was planted in December 2001 in Trial 1, and Red Oak lettuce was planted in January 2002 in Trial 2, and in February 2003 in Trial 3. Procymidone fungicide (1 L active ingredient/ha) was applied onto the whole trial area in Trials 1 and 2. Although only one fungicide spray was planned in Trial 1 at the beginning of the crop, the grower applied three sprays at two weeks after planting and at two-week intervals, which was his regular practice. In Trial 2, the fungicide was applied only once after lettuce planting. No fungicide was applied in Trial 3.

At one week before incorporation, shoot and root samples of BQ-Mulch and Fumus were collected to analyse for the type and levels of ITCs. In Trial 3, plant biomass was also measured on plant materials taken from two half-metre quadrants in each plot, and after drying in an oven. Soil compaction was also assessed in Trial 3, by measuring soil penetration resistance with a mechanical cone soil penetrometer (3 readings from each plot), on soil at field capacity. In Trials 1 and 2, *S. minor* sclerotia levels in 200 g of soil from each treatment plot were determined by a wet sieving method. Plants were assessed for *Sclerotinia* wilts and other disorders that affect marketability of the lettuce. The percentages of plants with disease, disorders, and marketability were then tabulated.

RESULTS

In Trial 1, tipburn and bacterial soft rot were the main cause of unmarketable lettuces (Table 1). Only Fumus planted prior to the lettuce increased the percentage of marketable lettuces. BQ-Mulch, broccoli and broad beans had little or no effect on tipburn and bacterial rot or marketable yield compared to the control fallow treatment. Bacterial rot often occurred on the inner leaves of plants that also showed tipburn symptoms. Both symptoms have been associated with plant tissue breakdown as a result of calcium deficiency. In Red Ferrosol in Trial 1, Fumus produced the highest level of plant biomass compared to other green manures. Therefore, the high plant biomass by Fumus may be associated with increased organic matter in soil and improved calcium uptake, hence resulting in reduced tipburn and bacterial rot.

Table 1. The effects of green manure crops on marketability of a subsequent lettuce crop in Trial 1.

Pre-plant treatment	% Marketable lettuce*	% Tipburn + soft rot
Control - Fallow	71.9 a	24.1
8 plants/m^2 Broccoli	78.2 a	18.8
240 kg/ha Broad bean	78.5 a	19.2
16 kg/ha Fumus	87.8 b	8.7
16 kg/ha BQ-Mulch	73.5 a	22.3

*Within each column, means followed by the same letters are not significantly different according to least significance difference test (P = 0.05).

Soils from the trial plots in Trial 1 had negligible levels of sclerotia (ranging from 0 to 1 sclerotia in 200g soil). This finding was consistent with the negligible levels of *Sclerotinia* wilt on lettuces in the trial.

Trials 2 and 3 were conducted on the same farm, and *Sclerotinia* wilt caused by *S. minor* was the only major disease. In Trial 2, the biofumigant crops, BQ-Mulch and Fumus, reduced the percentage of plants with *Sclerotinia* wilt (Table 2). BQ-Mulch appeared to be more effective in reducing the percentage of wilted plants compared to Fumus. The non-brassica green manures, oat and broad bean crops, had little or no effect on the disease. There was little difference between the levels of sclerotia in soils from the different treatments at the end of Trial 2. This indicates that the wilt disease control in the trial with the brassica green manure may not be unrelated to reduction in sclerotia levels.

Table 2. The effects of green manure crops on *Sclerotinia* disease incidence on a subsequent lettuce crop in Trial 2.

Pre-plant treatment	No. sclerotes /200g soil* Initial (5/07/01)	Final (1/03/02)	% *Sclerotinia* wilted plants**
Control - Fallow	26 ± 6	10 ± 4	30.8 c
20 kg/ha Oats	16 ± 9	-	23.2 bc
240 kg/ha Broad bean	15 ± 3	11 ± 4	24.2 bc
16 kg/ha Fumus	16 ± 6	9 ± 4	16.5 ab
16 kg/ha BQ-Mulch	25 ± 12	7 ± 2	3.1 a

*Initial: soil sampled prior to green manure crops; Final: in soil sampled at the end of lettuce crop.
*Within each column, means followed by the same letters are not significantly different according to least significance difference test (P = 0.05).

In Trial 3, *Sclerotinia* disease appeared late in the lettuce crop at close to harvest. Frequent rainfall, and high humidity at about two weeks prior to harvest created ideal field conditions for the rapid spread of *S. minor* disease. High incidence of *Sclerotinia* wilt, ranging from 24% to 31% was recorded. There was no significant difference in the disease incidence between the different brassicas BQ-Graze, BQ-Mulch, Fumus and Nemfix (P = 0.917). The high disease incidence in this trial may have been compounded by the absence of any fungicide application.

Table 3. Brassica green manure plant densities, plant biomass and total ITCs concentration in Trial 3.

Pre-plant treatment	No. plants (/m^2)	Plant biomass (kg/m^2)	Total ITCs (µmole/g) root	shoot
10 kg/ha BQ-Mulch	186	1.28	15.76	5.51
10 kg/ha BQ-Graze	238	1.50	21.40	10.88
10 kg/ha Fumus	75	0.94	3.41	7.71
10 kg/ha Nemfix	186	1.10	4.25	14.27

With Trials 2 and 3, linear regression analysis showed that the ITCs levels in the green manure roots were negatively correlated to disease incidence (P = 0.010, r = -0.959 in Trial 2, and P = 0.050, r = -0.950 in Trial 3). In contrast, there was no relationship between the ITCs levels in the shoots and the disease incidence (P = 0.333 in Trial 2, and P = 0.539 in Trial 3). This indicates that high levels of ITCs levels in the roots could be the main cause of disease reduction with the brassica green manure treatments. In both trials, the fodder rape such as BQ-Graze and BQ-Mulch produced much higher levels of ITCs in the roots compared to the mustard, such as Fumus and Nemfix (Table 3). It is interesting that the highest plant biomasses recorded in Trial 2 were with the two fodder rapes BQ-Graze and BQ-Mulch. However, this relationship could be coincidental with the suitability of fodder rapes in Brown Dermosol at this farm.

Soil improvement was noted following BQ-Mulch in Trial 2, with reduced surface crusting and improved infiltration. In Trial 3, further evidence of soil structural improvement after brassica green manures was noted with reduced soil compaction. A linear regression analysis showed a positive correlation between the average penetration resistance of subsoil of 225 to 420 mm depth at the 90% confidence level (P = 0.081, r = 0.758), where increased soil compaction increased *Sclerotinia* wilt disease. This indicates that subsoil compaction may influence plant disease, possibly through poor infiltration and impeded root growth. However, there was no correlation between the two in the topsoil of 0 to 210 mm depth (P = 0.859). The lack of relationship in the topsoil is not surprising as soil was cultivated with a rotary hoe to a depth of 25 cm in soil preparations.

DISCUSSION

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, which produce high levels of ITCs in their roots are more effective for *Sclerotinia* control than mustards, which produce high levels of ITCs in their foliage. Brassica green manures did not eliminate *S. minor* inoculum in soil, and short-term disease suppression is believed to be the mode of action against *Sclerotinia*. As ITCs levels will diminish rapidly after incorporation into soil, their effects for disease suppression are expected to be relatively short term. As a result, brassica green manures did not control *Sclerotinia* infection at later crop stages. 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.

Other benefits from green manures that can produce longer lasting effects are often overlooked. This study shows that high plant biomass and deep tap root system, which reduced soil crusting, improved infiltration, increased organic matter and reduced subsoil compaction. These soil improvements may contribute to disease management and crop health.

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