# Research Review

## Supplement to the literature review on

# Non-water control measures for potato common scab

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# Preface

In 2004, the British Potato Council commissioned a review of research on non water-based approaches to potato common scab control. The work identified several measures that can influence the development of common scab symptoms but which have not been extensively evaluated in GB. This supplement to the original report provides more detail on the measures. It summarises the available literature on:

1. The use of manganese as a potential control for common scab of potato
2. Potential biological control agents for the control of common scab on potatoes
3. The effect of bulky organic amendments on common scab of potato.

*British Potato Council*

# MANGANESE AS A POTENTIAL CONTROL FOR COMMON SCAB OF POTATO

## *Background*

Practical recommendations for control of common scab (causal organism *Streptomyces scabiei*) on potato crops invariably include avoiding alkaline soils and irrigation at critical stages of crop growth. There is also a long history of experimentation demonstrating that green manuring can reduce common scab on potato. The idea of a single underlying mechanism to all these control strategies is attractive.

Availability of manganese in soil is greater under acid and moist conditions and following incorporation of readily decomposable organic matter. Mortvedt *et al.,* (1963) claim common scab has never been found on field crops showing manganese toxicity symptoms. These observations have logically led to investigations on the role of manganese in development of common scab symptoms on potato.

## *Laboratory and Glasshouse Studies*

The direct effect of manganese on *S. scabiei* was investigated by Mortvedt *et al.,* (1963). A pathogenic isolate of *S. scabiei* was serially transferred between agar media containing different amounts of manganese. Added manganese started to inhibit growth of *S. scabiei* in the second transfer. Addition of 250ppm manganese to the media greatly reduced vegetative growth, but not sporulation of *S. scabiei (Table 1).*

TABLE 1. GROWTH OF *STREPTOMYCES SCABIEI* ON SYNTHETIC AGAR CONTAINING DIFFERENT AMOUNTS OF MANGANESE (AFTER MORTVEDT *ET AL.,* 1963)

| **Generation** | **Oven dry weight of S. *scabiei* (mg)**<br>**ppm Mn in media**<br>**0** | **10** | **100** | **250** |
|---|---|---|---|---|
| 1 | 34.3 | 32.0 | 36.3 | 22.5 |
| 3 | 28.6 | 31.3 | 28.8 | 6.8 |
| 5 | 32.9 | 31.5 | 28.5 | 7.9 |
| 7 | 26.1 | 29.3 | 12.6 | 4.3 |

After transfer from a medium containing large amounts of manganese to one containing little manganese *S. scabiei* grew normally. Concentrations of manganese necessary to inhibit vegetative growth of *S. scabiei* on agar were greater than found in soils. However, on agar divalent manganese oxidised to unavailable forms: this is unlikely to occur in acidic soils because of their buffering capacity. In earlier work Mortvedt *et al.,* (1961) achieved suppression of common scab when much smaller concentrations of manganese were present in sand surrounding tubers.

Mortvedt *et al.,* (1963) grew potato plants in nutrient solutions containing different amounts of manganese but keeping the developing tubers in separate boxes over the nutrient solution.

 

The tubers were inoculated with *S. scabiei*. Increasing the concentration of manganese in the nutrient solution increased the concentration of manganese in the tuber periderm but the scab index decreased only marginally (*Tables 2 and 3*).

TABLE 2. COMMON SCAB INDEX AND PERIDERM MANGANESE CONTENT OF POTATO TUBERS VARIETY CHIPPEWA FROM PLANTS GROWN IN SEPARATE SOLUTIONS OF DIFFERENT MANGANESE CONCENTRATION (AFTER MORTVEDT *ET AL.*, 1963)

| **Solution Manganese Content (ppm)** | **Scab Index<br>0 = Scab Free<br>100 = Completely Scabbed** | **Periderm Manganese Content (ppm)** |
|---|---|---|
| 0.1 | 21.2 | 27 |
| 1.0 | 18.8 | 34 |
| 4.0 | 19.8 | 49 |
| LSD 5% | NS | 4 |

TABLE 3. COMMON SCAB INDEX AND PERIDERM MANGANESE CONTENT OF POTATO TUBERS VARIETY RED PONTIAC FROM PLANTS GROWN IN SEPARATE SOLUTIONS OF DIFFERENT MANGANESE CONCENTRATION (AFTER MORTVEDT *ET AL.*, 1963)

| **Solution Manganese Content (ppm)** | **Scab Index<br>0 = Scab Free<br>100 = Completely Scabbed** | **Periderm Manganese Content (ppm)** |
|---|---|---|
| 0.5 | 51.0 | 26 |
| 2.0 | 49.6 | 46 |
| 8.0 | 42.8 | 54 |
| 16.0 | 52.6 | 86 |
| 32.0 | 46.0 | 120 |
| LSD 5% | NS | 33 |

This indicates scab index was not related to manganese content of the periderm.
Mortvedt *et al.,* (1961) filled the boxes in which the potatoes were growing with sand containing different amounts of manganese. When added in this way manganese reduced scab on the tubers *(Tables 4 and 5).*

 

TABLE 4. COMMON SCAB INFECTION OF CHIPPEWA POTATOES AS INFLUENCED BY CONCENTRATIONS OF MANGANESE IN THE TUBER ZONE, GREENHOUSE EXPERIMENT (AFTER MORTVEDT *ET AL.*, 1961)

| **Manganese Added to Sand (ppm)** | **Scab Index 0 = Scab Free 100 = Completely Scabbed** | **Tubers Free Of Scab (%)** |
|---|---|---|
| 0.0 | 26.0 | 50 |
| 0.5 | 19.7 | 50 |
| 2.0 | 16.0 | 60 |
| 5.0 | 14.0 | 72 |
| 10.0 | 7.5 | 85 |
| LSD 5% | 9.6 | - |

TABLE 5. COMMON SCAB INFECTION OF CHIPPEWA POTATOES AS INFLUENCED BY CONCENTRATIONS OF MANGANESE IN THE TUBER ZONE, GROWING ROOM EXPERIMENT (AFTER MORTVEDT *ET AL.*, 1961)

| **Manganese Added to Sand (ppm)** | **Scab Index 0 = Scab Free 100 = Completely Scabbed** | **Tubers Free of Scab (%)** |
|---|---|---|
| 0.0 | 11.6 | 64 |
| 2.0 | 6.3 | 80 |
| 5.0 | 4.5 | 86 |
| 10.0 | 1.8 | 93 |
| 20.0 | 0.0 | 100 |
| LSD 5% | 2.9 | - |

The authors concluded that in a field situation any control of common scab by manganese will be by direct action of water soluble manganese on *S. scabiei* itself. They supported this conclusion with the observation that tubers in treatments with high manganese content were scabbed on their upper surfaces where the manganese had been leached away during watering.

## *Relationships Between Common Scab and Plant and Soil Manganese Content*

Comparing manganese content of plants and soil from crops with different losses to common scab may help establish a relationship between manganese and common scab. The situation is more complex than it first appears since Lambert and Manzer (1991) showed most elements, including manganese, but excluding potassium, were present at higher concentrations in scabby periderm tissues than healthy tissues. In an investigation in 1989, manganese content was 48 ppm in scabby periderm and 39 ppm in healthy periderm. In 1990, corresponding values were 194 and 82 ppm. Size of tuber scab lesions was negatively correlated with tuber manganese (r = -0.63) and tuber periderm manganese (r = -0.58). Davies *et al.*, (1976a) showed a significant negative linear correlation between common scab and manganese content of potato tuber peelings (r = -0.40) and Davies *et al.,* (1976b) showed a significant negative correlation between common scab and manganese levels in petioles (r = -0.471). In all these cases variation in manganese resulted from manipulation of liming, irrigation or fertiliser application which were the principal trial treatments.

Lacey and Wilson (2001) showed little relationship between soil manganese content and common scab levels in 35 soils ($R^2 = 0.01$).

## *Field Trials Showing Beneficial Effects of Manganese on Scab*

The initial field trial of Mortvedt *et al.,* (1961) gave ambiguous results. Manganese sulphate at rates of 56 and 168 kg/ha (50 and 150 lbs/acre) was mixed with the fertiliser and applied in bands beside the seed at planting. Manganese sulphate had no statistically significant effect on yield or development of scab on the potatoes; however, there was a trend towards lower levels of common scab with increased manganese application *(Table 6).*

TABLE 6. YIELD AND SCAB INDEX OF RED WARBA POTATOES AS INFLUENCED BY VARYING AMOUNTS OF MANGANESE SULPHATE APPLIED IN THE FERTILISER BAND (AFTER MORTVEDT *ET AL.*, 1961)

| Manganese Sulphate Applied Kg/Ha | Scab Index 0 = Scab Free 100 = Completely Scabbed | Tubers Free of Scab (%) |
|---|---|---|
| 0 | 8.2 | 21 |
| 56 | 7.6 | 24 |
| 168 | 7.2 | 30 |

**Notes :-** Soil pH not stated.
Scab index possibly reduced by wet growing season.

Further work by Mortvedt and colleagues (Mortvedt *et al.,* 1963) gave more definitive results. In two trials manganese sulphate was applied at rates of 56, 168 and 504 kg/ha (50, 150 and 450 lbs/acre). Manganese sulphate was mixed with the fertiliser and applied in side bands 50mm lower than the seed pieces at planting. Manganese sulphate was also broadcast at a rate of 168 kg/ha in a 30cm band in the tuber zone. Potato yield was not affected by manganese application but scab index was significantly reduced in both trials by application of 504 kg/ha manganese sulphate in the row or 168 kg/ha broadcast in the tuber zone *(Table 7).*

TABLE 7. EFFECT OF MANGANESE SULPHATE APPLICATION ON THE COMMON SCAB INDEX OF POTATO (AFTER MORTVEDT *ET AL.*, 1963)

| **Manganese Sulphate (Kg/Ha)** | **Scab Index 0 = Scab Free 100 = Completely Scabbed** | |
|---|---|---|
| *Applied Below Seed* | **Trial 1** | **Trial 2** |
| 0 | 43.2 | 14.1 |
| 56 | 26.7 | 10.6 |
| 168 | 31.1 | 7.9 |
| 504 | 13.4 | 5.8 |
| *Broadcast In Tuber Zone* | | |
| 168 | 14.4 | 3.3 |
| LSD 5% | 18.3 | 7.8 |
| Initial Soil pH | 5.5 | 4.9 |

Mortvedt *et al.*, (1963) noted that broadcast application of manganese sulphate in the tuber zone appeared more effective than band application beneath the seed and interpreted this by suggesting that manganese may have a direct effect on *S. scabiei*.

The other commonly cited evidence for reduction of potato common scab by manganese application is work of McGregor and Wilson (1964 and 1966). In an initial experiment application of manganese sulphate at 63 kg/ha (0.5 cwt/acre) and no manganese application were compared. Manganese sulphate was mixed with the compound fertiliser and spread along the drills, the potatoes were planted and covered by splitting the drills. The manganese was, therefore, placed around the seed tuber. Manganese treatment reduced the number of tubers per plant but mean tuber weight was increased so overall yield was unaffected. The percentage of tubers with common scab was markedly reduced by manganese treatment *(Table 8).*

TABLE 8. EFFECT OF APPLICATION OF MANGANESE SULPHATE (63 KG/HA) IN THE PLANTING DRILL ON THE PERCENTAGE OF POTATO TUBERS WITH SCAB (AFTER MCGREGOR AND WILSON 1964)

| **Treatment** | **Tubers with scab (%)** |
|---|---|
| Manganese Sulphate 63 kg/ha | 19.1 |
| Nil Manganese Sulphate | 46.5 |
| | P< 0.1% |

**Note :-** Soil pH 7.0, site prone to Mn deficiency.

In follow-up work, McGregor and Wilson (1966) used four sites to study the effect of manganese sulphate on common scab on potato. Manganese sulphate was applied at rates of 0, 31 and 63 kg/ha (0, 28 and 56 lbs/acre) in the same way as described above. Common scab on the harvested crop was measured as a scab index (Mortvedt *et al.*, 1961 & 1963). Manganese sulphate at 31 kg/ha markedly reduced common scab index at all sites, 63 kg/ha also markedly reduced common scab index at all sites but there was little additional effect to the 31 kg/ha application *(Table 9).*

 

TABLE 9. EFFECT OF DIFFERENT APPLICATION RATES OF MANGANESE SULPHATE IN THE PLANTING DRILL ON COMMON SCAB OF POTATO (AFTER MCGREGOR AND WILSON 1966)

| | Manganese Application Kg/Ha | | | |
|---|---|---|---|---|
| | **0** | **31** | **63** | **LSD 5%** |
| **SITE 1 (pH 6.2)** | | | | |
| Scab Index | 19.9 | 11.8 | 10.0 | 2.50 |
| Scab Free Tubers % | 31.9 | 55.8 | 62.7 | 7.84 |
| **SITE 2 (pH 6.2)** | | | | |
| Scab Index | 43.9 | 21.7 | 18.3 | 6.14 |
| Scab Free Tubers % | 3.4 | 22.2 | 32.0 | 12.95 |
| **SITE 3 (pH 6.9)** | | | | |
| Scab Index | 49.9 | 18.4 | 16.4 | 12.76 |
| Scat Free Tubers % | 3.5 | 31.6 | 40.6 | 15.56 |
| **SITE 4 (pH 6.2)** | | | | |
| Scab Index | 21.8 | 7.6 | 6.1 | 3.28 |
| Scab Free Tubers % | 42.5 | 73.5 | 77.3 | 7.50 |

Manganese treatment significantly increased potato yield at site 4. At other sites manganese treatment increased yield but not significantly. As in earlier investigations by McGregor and Wilson (1964) tuber number tended to decline and mean tuber weight tended to increase with manganese treatment.

Further reports of beneficial effects of manganese application on common scab of potato are cited by Keinath and Loria (1989) and Rogers (1971). In 1955 Spatz found 6 kg/ha manganese sulphate reduced the proportion of badly scabbed tubers from 70% to 20%, Guntz and Coppenet (1957) also showed that manganese can potentially control common scab on potato. Davies *et al.,* (1976b) demonstrated a slight, but significant, scab reduction (from index 9.4 to 8.3) following two foliar sprays of manganese chelate at 0.135 kg/ha. Grzeskiewicz *et al.,* (1990), working in Poland, reported that ammonium sulphate (an acidifying fertiliser) reduced common scab infection in potato and that infection was further reduced by application of manganese sulphate or manganese chelate, the chelate being most effective. In Bangladesh, Saha *et al.,* (1997) showed that manganese sulphate increased potato yield and reduced common scab development. The effect was correlated to the application rate up to a maximum application of around 10 kg/ha.

Trials by ADAS, Cambridge, cited by Lang (1981) suggested use of manganese sulphate to suppress common scab of potato was sometimes effective, but not always. Effectiveness was apparently unrelated to any other easily identified factor.

 

## *Field Trials Showing No Beneficial Effects of Manganese on Scab*

The work of McGregor and Wilson (1964 and 1966) is often compared with similar Scottish work conducted by Rodger *et al.*, (1967) and Gilmour *et al.*, (1968).

In 1966 a trial near Perth (Rodger *et al.*, 1967) studied the effects of manganese sulphate foliar spray together with manganese sulphate (163 kg/ha, 56 lb/acre) and flowers of sulphur (440 kg/ha, 3.5 cwt/acre) spread singly and in combination in the ridge. No significant effects on common scab score index *(Table 10)* or tuber yield were found.

TABLE 10. EFFECT OF FOLIAR MANGANESE SPRAYS AND SOIL APPLIED MANGANESE AND SULPHUR ON POTATO SCAB (AFTER RODGER *ET AL.*, 1967)

| Treatment | Scab score index |
|---|---|
| Untreated Control | 0.91 |
| Manganese Sulphate Spray (22 kg/ha) | 1.02 |
| Manganese Sulphate In Ridge (63 kg/ha) | 0.94 |
| Sulphur In Ridge (440 kg/ha) | 1.02 |
| Manganese Sulphate (63 kg/ha) + Sulphur (440 kg/ha) In Ridge | 0.96 |
| SE | +/- 0.09 |

The trials were continued in 1967 at 2 sites in Fife and 2 in Perthshire (Gilmour *et al.*, 1968). Manganese sulphate was applied at 0, 15 kg/ha (13 lb/acre) or 57 kg/ha (51 lb/acre) in mixture with a granular or powdered fertiliser. The fertiliser was applied over open ridges, except at site 2 where it was applied on the flat and rotavated in. There were no significant treatment effects on incidence of common scab *(Table 11)*.

TABLE 11. EFFECT OF ADDITION OF MANGANESE SULPHATE TO GRANULAR AND POWDERED FERTILISER ON POTATO COMMON SCAB (AFTER GILMOUR *ET AL.*, 1968)

| | **% tubers with more than ⅛ surface scabbed rate of manganese sulphate** | | |
|---|---|---|---|
| | **0 kg/ha** | **15 kg/ha** | **57 kg/ha** |
| **GRANULAR FERTILISER** | | | |
| Site 1 | 8.6 | 7.9 | 9.4 |
| Site 2 | 69.4 | 65.3 | 60.9 |
| Site 3 | 42.8 | 38.2 | 31.7 |
| Site 4 | 18.0 | 2.4 | 4.3 |
| **POWDERED FERTILISER** | | | |
| Site 1 | 6.3 | 2.8 | 3.7 |
| Site 2 | 61.7 | 56.5 | 59.1 |
| Site 3 | 25.1 | 30.2 | 26.9 |
| Site 4 | 9.8 | 7.9 | 5.0 |

**Notes:-** Standard errors: Site 1 +/- 4.2, Site 2 +/- 5.9, Site 3 +/- 7.2, Site 4 +/- 5.7
Initial/Final pH Site 1 7.0/6.2 Site 2 6.7/6.2
Site 3 6.8/6.5 Site 4 6.6/5.9

Rogers (1971) reported that manganese chelate, $Na_2$ Mn EDTA, applied at 163 kg/ha had no effect on potato scab or yield.

In eight unpublished trials carried out by the North of Scotland College of Agriculture from 1965 to 1967 where appreciable amounts of common scab occurred there were no significant effects of manganese application on disease expression.

Rogers (1969) demonstrated a decrease in scab after incorporation of 5 t/ha dried grass meal but not when only 2.5 t/ha was incorporated. Incorporation of dried grass meal increased soil exchangeable manganese level only slightly (by 6-9 ppm) and by less following incorporation of 5 t/ha dried grass meal than 2.5 t/ha. Therefore, he concluded that effects of incorporation of dried grass on soil manganese levels were not responsible for suppressing common scab.

## *Summary and Conclusions*

In their review of effects of plant nutrients on common scab, Keinath and Loria (1989) concluded in relation to manganese "The results of field trials have apparently not been favourable enough to warrant the use of manganese sulphate for scab control". This succinctly summarises the current situation, particularly as unsuccessful trials are less likely to be reported than successful.

Manganese is a common trace element deficiency in UK field crops. Soils usually contain far more manganese than required by crops but most is unavailable. Manganese moves between the unavailable tetravalent form and the available divalent form depending on soil acidity and reduction-oxidation potential. The chemistry of manganese in soil is, therefore, complex and soil analysis is generally regarded as a poorly reliable indication of potential deficiency problems in the UK.

Attempted use of manganese to suppress common scab in potato crops has usually involved soil, rather than foliar, application. This follows work of Mortvedt *et al.*, (1961 & 1963) suggesting that manganese may be harmful to common scab through toxicity in the soil.

However, for correction of trace element manganese deficiencies soil application is not recommended because manganese applied in this way is normally rapidly rendered unavailable (SAC, 1992). McGregor and Wilson (1966) comment that soil application of 31 or 62 kg/ha manganese sulphate can only increase water soluble manganese for a limited period and it therefore seems unlikely that soluble manganese concentration in the soil during tuber formation would be sufficiently high to control *S. scabiei*.

Therefore, there is an inconsistency between the accepted short term activity of manganese sulphate in soil and the longer period after application before it could be expected to affect infection of potato tubers by *S. scabiei*. Rogers (1971) attempted to overcome this by using manganese frit and chelate. However, manganese frit appeared ineffective against *S. scabiei in vitro* and manganese chelate was ineffective in a field trial.

The contradictory results obtained from field investigations into the efficacy of manganese against common scab have not been satisfactorily explained. Keinath and Loria (1989) refer to "… unexplained inconsistencies". The efficacy of manganese application does not appear related to soil pH or manganese content. The greatest control achieved by Mortvedt *et al* (1963) followed application of the very large amount of 504 kg/ha manganese sulphate but there was also significant control after application of 168 kg/ha. However, McGregor and Wilson (1964 and 1966) achieved suppression of common scab using only 31 or 63 kg/ha manganese sulphate. One variable which is difficult to assess from the published records is the precise application technique employed: typically the manganese sulphate is described as "spread along the bottom of the drill" (McGregor and Wilson, 1964) or "spread over the opened drills" (McGregor and Wilson, 1966). Without detail of the width of the band over which the manganese sulphate was spread it is difficult to envisage the concentration of manganese different parts of the potato plant will experience during their development and growth. If manganese is harmful to common scab through toxicity in the soil then accurate placement will be imperative, and further studies in this area may be worthwhile.

Potato crop morphology makes it a difficult model for studying effects of manganese on common scab. Studies of other root crops susceptible to common scab such as swede or red beet might help elucidate the mechanisms involved. These crops have a much simpler growth pattern and the site of infection is more accessible to treatment.

# POTENTIAL BIOLOGICAL CONTROL AGENTS FOR THE CONTROL OF COMMON SCAB ON POTATOES

Encouragement of organisms antagonistic to *Streptomyces scabiei,* the causal agent of common scab, has been suggested as a mechanism explaining observations such as the effects of bulky organic manures, green manures and the suppressive effects of some soils. This led to laboratory investigations of relationships between antagonistic and pathogenic strains of *Streptomyces spp*. Little of this work has been extended into field trials and those trials which have been conducted have been relatively simple. The best indication of the possible value of biological control agents probably arises from work at University of Minnesota using pot grown trials.

## *Attempted Control of Common Scab using Antagonistic* Streptomyces *Strains*

Liu *et al.,* (1995) identified two suppressive *Streptomyces* strains, grew them on a vermiculite-oatmeal broth base and mixed the resulting inoculum into a scab-conducive soil at 1, 5 and 10% v/v. Single potato tubers were grown in 16 litre pots of treated and untreated soil for four years. In the first year both *Streptomyces* strains tested (*S. diastatochromogenes* strain Pon SSII and *S. scabiei* strain Pon R) significantly reduced the number of scab lesions per tuber compared to treatments without the suppressive strains *(Table 12).*

TABLE 12. BIOCONTROL OF POTATO COMMON SCAB BY SUPPRESSIVE STRAINS OF *STREPTOMYCES* IN FIELD-POT TESTS, YEAR 1 (AFTER LIU *ET AL.*, 1995)

| Treatment | Lesions Per Tuber | Significance* |
|---|---|---|
| Unamended conducive soil | 7.83 | a |
| 1% broth base added to soil | 8.14 | a |
| 1% broth base plus strain Pon R | 4.75 | b |
| 1% broth base plus strain Pon SSII | 4.80 | b |
| 5% broth base added to soil | 6.41 | ab |
| 5% broth base plus strain Pon R | 1.81 | de |
| 5% broth base plus strain Pon SSII | 2.79 | cd |
| 10% broth base added to soil | 4.45 | bc |
| 10% broth base plus strain Pon R | 1.32 | de |
| 10% broth base plus strain Pon SSII | 1.39 | de |
| Non conducive soil | 0.03 | e |

*Treatments with the same letters are not significantly different (P=0.05) – Duncan's multiple range test.

All treatments with suppressive strains significantly reduced scab lesion number per tuber, compared with treatments without the suppressive strains. Incorporating broth medium containing suppressive bacteria at 5% v/v or 10% v/v gave greater reduction in scab lesion number than using 1% v/v during the first year potatoes were grown in the soil. In the second and subsequent years there were no significant differences between the rates at which the media used to produce the suppressive strains were incorporated. There were no significant differences in the level of disease control provided by the two strains but for strain Pon SSII, disease control increased every year following inoculation at the 1% level but was constant following inoculation at the 10% level *(Table 13)*.

TABLE 13. BIOCONTROL OF POTATO COMMON SCAB USING *STREPTOMYCES* STRAIN PON SSII FOR FOUR YEARS AFTER INOCULATION (AFTER LIU *ET AL.*, 1995)

| **Treatment** | **Lesions per Tuber** | | | |
|---|---|---|---|---|
| | **1989** | **1990** | **1991** | **1992** |
| 1% broth base added to soil | 8.14 | 24.94 | 8.74 | 8.30 |
| 1% broth base plus strain Pon SSII | 4.80 | 11.04 | 2.81 | 1.71 |
| 5% broth base added to soil | 6.41 | 19.81 | 10.77 | 7.99 |
| 5% broth base plus strain Pon SSII | 2.79 | 7.60 | 2.98 | 1.26 |
| 10% broth base added to soil | 4.45 | 13.84 | 9.92 | 8.12 |
| 10% broth base plus strain Pon SSII | 1.39 | 4.22 | 2.46 | 1.16 |

In the work of Liu *et al.,* (1995) the average disease reduction over all inoculum doses for the four years of cropping was 73% for strain Pon SSII and 64% for strain Pon R. This demonstrates potentially worthwhile disease control if the practical problems of field scale application can be solved.

A later paper from the University of Minnesota (Ryan *et al.,* 2004) suggested practical application of Liu *et al.* (1995)'s work had proven difficult. Ryan *et al.* (2004) attempted to elucidate some of the reasons for inconsistent control by studying a range of pathogenic and antagonistic isolates on different potato cultivars. They found different pathogenic isolates of *Streptomyces scabiei* were affected differently by antagonistic *Streptomyces* strains when trialled in a greenhouse pot experiment level *(Table 14)*.

TABLE 14. BIOCONTROL OF POTATO COMMON SCAB, CAUSED BY DIFFERENT PATHOGENIC ISOLATES OF *STREPTOMYCES SCABIEI*, BY ANTAGONISTIC *STREPTOMYCES* (AFTER RYAN *ET AL.*, 2004)

| **Pathogen Isolate** | **Common scab lesions per tuber** | |
|---|---|---|
| | **Antagonist added** | **No Antagonist** |
| 82 | 5 | 18 |
| 89 | 28 | 25 |
| RB2 | 22 | 21 |
| RB4 | 18 | 18 |

Only isolate 82 was effectively controlled by inoculation of soil with antagonists. Three out of five antagonistic isolates gave significant reductions ($P = 0.05$) in lesion numbers after inoculation with isolate 82. In contrast, in *in-vitro* assays, isolate 82 had the smallest zone of inhibition and was inhibited by the least number of antagonists.

Averaged over all four pathogen isolates only one antagonist isolate (antagonist 63 – out of five antagonists tested) reduced common scab significantly compared with an untreated control. *(Table 15)*.

 

TABLE 15. THE EFFECTIVENESS OF DIFFERENT ANTAGONISTIC *STREPTOMYCES* ISOLATES AS A BIOCONTROL FOR POTATO COMMON SCAB (AFTER RYAN *ET AL.*, 2004)

| **Antagonist Isolate** | **Common scab lesions per tuber** |
|---|---|
| None | 20 |
| 15 | 21 |
| 161 | 21 |
| GS 41-6 | 21 |
| GS 12-11 | 17 |
| 63 | 7 |

Only antagonist 63 reduced disease significantly compared with untreated control.

Different cultivars differed significantly in their susceptibility to common scab. The amount of disease varied between two years of trialling. Effectiveness of different antagonistic isolates in reducing scab varied but there was no significant cultivar-antagonist interaction in either year of the study.

Stevenson and James (1995) included a non pathogenic strain of *Steptomyces scabiei*, obtained from University of Minnesota, in a field trial of potential chemical controls for common scab. 35ml of vermiculite carrying the trial strain was placed on each seed piece after planting and before covering with soil. Four potato varieties were trialled and the non-pathogenic *Streptomyces* strain had no significant effect on scab lesion area index of any variety (*Table 16*).

TABLE 16. EFFECT OF A NON-PATHOGENIC ISOLATE OF *STREPTOMYCES* ON COMMON SCAB LESION AREA INDEX OF FOUR POTATO VARIETIES (AFTER STEVENSON AND JONES, 1995)

| **Variety** | **Lesion Area Index** | | |
|---|---|---|---|
| | **Untreated** | **Non Pathogenic Streptomyces Isolate applied at Planting** | **LSD 5%** |
| LA chipper | 40.1 | 33.7 | 8.2 |
| Snowden | 13.7 | 9.3 | 5.3 |
| FL 1533 | 6.9 | 7.8 | 4.4 |
| FL 1625 | 7.0 | 6.1 | NS |

Beausejour *et al.* (2001) compared the effectiveness of two geldanamycin (antibiotic) producing strains of *Streptomyces hygroscopicus ssp. geldanus* and one strain which does not produce geldanamycin. The two geldanamycin producing strains significantly reduced common scab symptoms but the strain which does not produce geldanamycin gave no protection against common scab.

Beausejour *et al.* (2003) conducted field trials to evaluate efficacy of the geldanamycin producer *Streptomyces melanosporofaciens* strain EF-76 as a biocontrol for potato common scab in the presence or absence of chitosan. Chitosan has been shown effective against several fungal diseases, probably by eliciting plant defence mechanisms. In two years of experiments *S. melanosporofaciens* strain EF-76 always gave a significant reduction in the severity of potato common scab, and sometimes, but not always, the incidence of common scab (*Table 17*).

TABLE 17. EFFECT OF CHITOSAN AND OF *STREPTOMYCES* MELANOSPOROFACIENS EF-76 ON COMMON SCAB OF POTATO UNDER FIELD CONDITIONS (AFTER BEAUSEJOUR *ET AL* , 2003)

| **Treatment** | **2000 Disease Severity Index *** | **2000 Disease Incidence %** | **2001 Disease Severity Index *** | **2001 Disease Incidence %** |
|---|---|---|---|---|
| Talc (control) | 2.83 a | 91 a | 1.61 a | 47 a |
| Chitosan | 2.36 b | 83 b | 1.53 a | 46 a |
| Strain EF-76 in talc | 2.49 b | 91 a | 1.26 b | 26 b |
| Strain EF-76 in chitosan | 2.05 c | 56 c | 1.31 b | 24 b |

**1 = Healthy 10 = 90% + surface area scabbed.*
*Numbers in a column followed by the same letter did not significantly differ (p = 0.05)*

Treatments were applied as 0.5g of formulation powder on top of each tuber at planting.

Doumbou *et al.* (1998) studied potential biocontrol by bacteria and fungal strains which degrade thaxtomin A, the main phytotoxin produced by *S. scabiei*. Potato tubers were soaked in cultures of thaxtomin A utilising bacteria or fungi before planting into pots of sterile sand inoculated with pathogenic *S. scabiei.*

At harvest the bacterial thaxtomin degrading strains were found to have reduced the incidence and severity of common scab but the fungal strains had no effect (*Table 18*).

TABLE 18. EFFECT OF THAXTOMIN A – UTILISING BACTERIA AND FUNGI ON COMMON SCAB OF POTATO (AFTER DOUMBOU *ET AL.*, 1998)

| **Thaxtomin utilising strain** | **% Tubers infected** | **% surface scabbed** |
|---|---|---|
| None (control) | 73 a | 27 a |
| Streptomyces EF-50[+] | 35 b | 1 c |
| Streptomyces EF-73[+] | 20 c | 1 c |
| Ralstonia Pickettii S-2016[+] | 30 b | 5 b |
| Penicillium CL-8* | 75 a | 24 a |
| Trichoderma CL-22* | 73 a | 24 a |

*Values in a column followed by the same letter are not significantly different P = 0.05*

[+] *Bacterial strains able to degrade thaxtomin A*
** Fungal strains able to degrade thaxtomin A*

## *Other Potential Bio-control Agents for Potato Common Scab*

Several phages active against *Streptomyces* have been identified. McKenna *et al.* 2001, studied the efficacy of a selected *Streptomyces* phage as a potential biocontrol. Tubers infected with common scab were treated in a circulating bath of phage suspension for 24 hours or treated in the same way in an autoclaved phage suspension. Treated tubers were planted into boxes of sterilised soil. Common scab was assessed on daughter tubers at harvest (*Table 19).*

TABLE 19. EFFECT OF STREPTOMYCES PHAGE (∅ASI) APPLICATION ON COMMON SCAB OF POTATO (AFTER MCKENNA *ET AL.*, 2001)

| **Treatment** | **Number Lesions per Tuber** | **Lesion surface area %** |
|---|---|---|
| Non phage treated | 44.23 a | 23.00 a |
| Phage treated | 3.82 b | 1.20 b |
| Numbers in a column followed by different letters are significantly different P = 0.05 | | |

The efficacy of *Bacillus subtilis*, which is thought to suppress many plant diseases, against common scab was investigated by Schmiedeknecht *et al.* 1998. Field plot trials were carried out from 1994-1997 and commercial plot trials (3ha) from 1993-1996. A water-dispersible granule formulation of *Bacillus subtilis* was applied to the seed tubers before planting and compared with untreated, pencycuron and tolclofos-methyl treated seed. Schmiedeknecht *et al.* 1998, only present pooled results as a percentage of untreated control (see *Table 20*) but found reduction in common scab index of up to 65% in plot trials and 64% in commercial plots.

TABLE 20. INFLUENCE OF DIFFERENT BACTERIAL AND CHEMICAL TREATMENTS ON THE REDUCTION OF COMMON SCAB ON POTATOES IN FIELD TRIALS (AFTER SCHMIEDEKNECHT *ET AL.*, 1998)

| **Treatment** | **Relative Disease Severity %** |
|---|---|
| Untreated | 100 a |
| Pencycuron | 87 ac |
| Tolclofos-methyl | 81 c |
| *B subtilis* FZB24 | 66 bc |
| *B subtilis* FZB27 | 43 b |
| *B subtilis* FZB42 | 76 ac |
| *B subtilis* + pencycuron | 66 bc |

Numbers with the same letter are not significantly different, P = 0.05

 

## *Summary and Conclusions*

Possible mechanisms of biological control have been studied by Neeno-Eckwall *et al.* (2001). Resource competition and antibiotic production are two potential mechanisms. Studies of the disease-causing potential of antibiotic resistant mutants suggested both resource competition and the production of inhibitory compounds by suppressive isolates were important. The situation is obviously complex and this leads to a number of obstacles to successful biological control of common scab:

- Common scab is caused by a wide range of *Streptomyces* species and strains which may be differently inhibited by bio-control agents.
- The balance of pathogen and bio-control will be affected by soil type and other environmental variables.
- The effect of bio-control agents may vary with potato variety.
- These obstacles may be overcome in different ways.
- Use of antagonistic isolates capable of providing broad-based control.
- Development of rapid screening techniques of pathogen populations in fields to allow the effectiveness of a bio-control agent to be assessed in an individual situation.

However, biological control may only form one component of an effective integrated control programme for common scab. In particular, manipulation of the soil environment to favour antagonistic and inhibit pathogenic organisms may be an effective alternative, or complement to, inundative introduction of bio-control organisms. Use of green manuring or incorporation of bulky organic manures has sometimes given worthwhile control of common scab. These techniques may work by encouraging antagonistic organisms, and where no control is obtained this may result from the absence of a natural population of antagonists: in these circumstances artificial introduction of antagonists may reduce the variability in response to these techniques.

# EFFECT OF BULKY ORGANIC AMENDMENTS ON COMMON SCAB OF POTATO

## *Background*

Disease control has rarely been the primary justification for use of bulky organic amendments on potato crops. When manures were applied for their nutrient content, before the widespread availability of chemical fertilisers, growers found their effects on disease inconsistent and variable from site to site and year to year (Lazarovits, 2001). Organic manures have other potential benefits for potato crops, such as reducing soil compaction and increasing water holding capacity, which might be expected to reduce development of common scab. Nevertheless many authors, and contemporary internet based material, do not recommend application of animal manures to land intended for potato production (e.g. Hooker, 1981 and Powelson *et al.,* 1983) because of an increased risk of common scab.

The most extensive, recent programme of work investigating effects of bulky organic amendments on common scab of potato is that of the group of G. Lazarovits at Agriculture and Agri-Food, Ontario, Canada. Their investigations of different organic amendments over a number of years cropping give the best indication of the possible value of bulky organic amendments for control of common scab in UK potato crops. It should, however, be noted that no equivalent work in UK conditions has been identified.

## *Experimental Results*

### Manures

Conn and Lazarovits (1999) investigated effects of organic manures applied four weeks before planting potatoes and incorporated to a depth of 15cm. A single application was made and the effect on the scab index of three succeeding potato crops assessed (*Table 21*).

 

TABLE 21. EFFECTS OF MANURES ON POTATO SCAB IN TWO COMMERCIAL POTATO FIELDS IN ONTARIO (AFTER CONN AND LAZAROVITS 1999)

| Manure | Rate | Scab Index Year 1 | Scab Index Year 2 | Scab Index Year 3 |
|---|---|---|---|---|
| **Site B** | | | | |
| Untreated | | 1.3 (+/- 0.90) | 2.4 (+/- 1.7) | 2.0 (+/- 0.80) |
| Solid cattle | 100 t/ha | 1.2 (+/- 0.72) | 1.7 (+/- 0.62) | 1.5 (+/- 0.61) |
| Liquid swine | 55 hl/ha* | 0.25 (+/- 0.09) | 0.60 (+/- 0.12) | 0.9 (+/- 0.12) |
| Wood based chicken | 66 t/ha | 0.23 (+/- 0.16) | 2.2 (+/- 0.09) | 2.1 (+/- 0.28) |
| **Site M** | | | | |
| Untreated | | 3.4 (+/- 0.40) | 1.0 (+/- 0.30) | 1.2 (+/- 0.30) |
| Solid cattle | 100 t/ha | 2.9 (+/- 0.59) | 1.0 (+/- 0.25) | 1.5 (+/- 0.26) |
| Liquid swine | 55 hl/ha* | 1.8 (+/- 0.03) | 1.1 (+/- 0.72) | 1.4 (+/- 0.26) |
| Wood based chicken | 66 t/ha | 1.1 (+/- 0.23) | 1.2 (+/- 0.18) | 2.4 (+/- 0.22) |

Scab Index 0 = 0%   1 = 5%   2 = 6-15%   3 = 16-25%
4 = 26-35%   5 = 36-60%   6 = 61-100%
(+/- SE of mean, three replicate pots)

* A rate of 55 hl/ha is given in results tables, but materials and methods suggests a rate of 550 hl/ha

There was no effect of manure treatment on total tuber yield. Solid cattle manure had little effect on the scab index of potato. Liquid swine manure and wood based chicken manure both markedly reduced the scab index of potatoes planted in the year of application. At site B application of liquid swine manure continued to suppress common scab for a further two years but at site M there was no effect in year 2 and in year 3 the scab index was highest on plots receiving chicken manure in the first year.

## Other Organic Amendments

Lazarovits *et al.* (1999) investigated effects of soymeal and meat and bone meal applied four weeks before planting potatoes and incorporated to a depth of 15cm. A single application was made and the effect on scab index and yield of three succeeding potato crops assessed *(Tables 22 and 23*).

TABLE 22. EFFECT OF SOYMEAL AND MEAT AND BONE MEAL SOIL AMENDMENTS ON POTATO SCAB IN TWO COMMERCIAL FIELDS IN ONTARIO (AFTER LAZAROVITS *ET AL.*, 1999)

| Amendment | Rate | Scab Index Year 1 | Scab Index Year 2 | Scab Index Year 3 |
|---|---|---|---|---|
| **Site B** | | | | |
| Untreated | | 1.3 (+/- 0.9) a | 2.4 (+/- 1.7) a | 2.0 (+/- 0.8) b |
| Soymeal | 37 t/ha | 0.3 (+/- 0.1) a | 1.1 (+/- 0.7) c | 1.5 (+/- 0.6) c |
| Meat bone meal | 37 t/ha | 0.3 (+/- 0.1) b | 1.8 (+/- 0.3) b | 3.0 (+/- 0.1) a |
| **Site M** | | | | |
| Untreated | | 3.4 (+/- 0.4) a | 1.0 (+/- 0.3) b | 1.2 (+/- 0.3) c |
| Soymeal | 37 t/ha | 0.7 (+/- 0.1) b | 0.6 (+/- 0.2) c | 2.3 (+/- 0.3) b |
| Meat bone meal | 37 t/ha | 0.7 (+/- 0.1) c | 1.3 (+/- 0.2) a | 2.4 (+/- 0.6) a |
| Means (+/- SE) followed by the same letter within each site and year are not significantly different. | | | | |

TABLE 23. EFFECT OF SOYMEAL AND MEAT AND BONE MEAL SOIL AMENDMENTS ON TOTAL AND MARKETABLE POTATO YIELDS IN TWO COMMERCIAL FIELDS IN ONTARIO (AFTER LAZAROVITS *ET AL.*, 1999)

| Amendment | Total yield (marketable yield) kg/plot | | |
|---|---|---|---|
| | Year 1 | Year 2 | Year 3 |
| **Site B** | | | |
| Untreated | 30 (22) | 32 (20) | 22 (10) |
| Soymeal | 14* (13) | 46 (33) | 25 (18) |
| Meat bone meal | 18* (17) | 51* (30) | 27 (3) |
| **Site M** | | | |
| Untreated | 43 (11) | 33 (26) | 29 (22) |
| Soymeal | 21* (19) | 44 (40) | 43 (16) |
| Meat bone meal | 23* (21) | 31 (21) | 38 (11) |
| Marketable yield = less than 5% surface area scabbed<br>• Significantly different from control at P = 0.05 | | | |

Soy meal and meat and bone meal were both phytotoxic. The potato plants were stunted and this was reflected in much reduced total yield in the first year. Phytotoxicity was so severe that weed growth was absent.

 

Incorporation of soymeal and meat and bone meal both greatly reduced common scab on harvested tubers. At site M the reduced proportion of potatoes unmarketable because of scab more than compensated for the reduction in total yield and soymeal and meat and bonemeal both increased marketable yield.

In the second cropping year soymeal continued to suppress common scab at both sites and this was reflected in increased marketable yield. In the third cropping year soymeal reduced scab index at site B, but increased it at site M; meat and bone meal increased scab index in the third year at both sites.

Use of ‘Nature Safe’ an organic fertiliser made primarily of poultry feathers at 10t/ha has also been investigated in Canada. In trials at two sites in 1999 use of ‘Nature Safe’ reduced scab by 60-80% and in 2000 scab was still 50% less on ’Nature Safe’ treated plots. In 2001 scab was present at the same severity in treated and untreated plots. Total tuber yield was unaffected but ‘Nature Safe’ increased marketable yields by reducing scab (Conn *et al.*, 2002).

## Ammonium lignosulfonate

Ammonium lignosulfonate is a by-product of the pulp and paper industries. Large amounts are produced annually and much is incinerated. It is known to improve physical, chemical and biological properties of saline and eroded soils and as a carrier of micro and macro nutrients. Soltani *et al.*, (2002) have reported investigations of its effects on common scab of potatoes.

TABLE 24. EFFECT OF AMMONIUM LIGNOSULFONATE (ALS) SOIL AMENDMENT ON POTATO SCAB AND YIELD IN FOUR COMMERCIAL POTATO FIELDS IN ONTARIO (AFTER SOLTANI *ET AL.*, 2002)

| **Treatment** | **Potato Scab Index Year 1** | **Potato Scab Index Year 2** | **Yield t/ha**<br>**Year 1 Total (Marketable)** | <br>**Year 2 Total (Marketable)** |
|---|---|---|---|---|
| **Site K** | | | | |
| Untreated | 3.7 (+/- 0.5) a | 2.3 (+/- 0.6) a | 16 (1) | 9 (3) |
| ALS | 0.7 (+/- 0.4) b | 0.1 (+/- 0.1) b | 13 (12) | 7 (7) |
| **Site V** | | | | |
| Untreated | 2.3 (+/- 0.5) a | 0.4 (+/- 0.2) a | 21 (7) | 14 (14) |
| ALS | 1.2 (+/- 0.4) b | 0.2 (+/- 0.1) a | 26 (18) | 17 (17) |
| **Site G** | | | | |
| Untreated | 3.0 (+/- 0.9) a | 3.8 (+/- 0.6) a | 8 (3) | 14 (1) |
| ALS | 1.0 (+/- 0.3) b | 1.1 (+/- 0.3) b | 21 (18) | 11 (8) |
| **Site W** | | | | |
| Untreated | 2.0 (+/- 0.2) a | Not applicable | 14 (5) | |
| ALS | 0.6 (+/- 0.1) b | Not applicable | 14 (12) | |

Means (+/- SE) followed by the same letter within each site and year are not significantly different.

ALS applied at about 6,000kg solids/ha.

Incorporation of ammonium lignosulfonate greatly reduced scab index of potato crops for two years after incorporation (*Table 24*). Ammonium lignosulfonate can be phytotoxic but even when total yield was reduced, marketable yield was greatly increased because of the reduced amount of scab.

## *Problems and Obstacles to the Use of Bulky Organic Amendments for Scab Control*

- The response may be inconsistent: the effect of manures on specific pathogens may be soil specific (see Conn and Lazarovits, 1999 – data on Verticillium wilt).

- The effective application rates may be at or above the maximum growers would wish to use.

- The application rates of nitrogen containing manures described in the trials above are grossly in excess of the maximum allowed under the Nitrate Vulnerable Zone Regulations.

- The use of animal manures may have consequences for the microbiological safety of following crops, particularly category 1 crops under the Assured Produce Guidelines.

- Use of some of the materials of animal origin (such as meat and bone meal) may conflict with regulations to control the spread of BSE (Bovine Spongiform Encephalopathy Order 1991).

- The Waste Management Licensing Regulations and similar legislation may apply to some of the materials described.

- Many materials were phytotoxic at the rates used including chicken manure (Conn and Lazarovits, 1999) – which caused some stunting and ammonium lignosulfonate – in 1999 some plots failed to emerge and had to be replanted .

- The more valuable materials tested (such as soymeal and meat and bone meal) have to be used at rates which may not be economic (although competitive in price with methyl bromide), Tenuta and Lazarovits, 1998.

- Even the less valuable materials may be prohibitively expensive when delivery and other costs are considered. Soltani *et al.*, 2002 estimated a delivery cost of $2,000/ha alone for ammonium lignosulfonate. With potential improvements in gross income of $1,150 to $2,470/ha in year 1 and $490 to $1,150/ha in year 2 they thought treatment was probably uneconomic.

## *Possible Reasons for the Effect of Bulky Organic Amendments on Scab Control*

- Alteration in pH. Ammonium lignosulfonate reduced pH by 0.4 to 0.6 units. Swine and cattle manure decreased pH but chicken manure temporarily increased pH to pH 8 - at the upper limit for development of *Streptomyces scabiei* (the causal agent of common scab). Soy meal and meat and bone meal also temporarily increased pH up to between 8 and 9.

- Ammonia production. Ammonia produced by the breakdown of organic manures after application may be toxic to *S. scabiei*.

 

- Presence of volatile fatty acids (including acetic, proprionic, butyric, isobutyric and valeric). When these are present in sufficient quantity in organic amendments to soil with low pH there can be anti-microbial activity.

- Stimulation of biocontrol – organic amendments increase the microbial population (ALS increased bacterial and fungal numbers two to eight times). This may increase competition for existing nutrients, at the expense of *S. scabiei* or it may increase the proportion of antagonistic organisms.

## *Possible Future Strategies*

- Localised application (banded). This appears the most promising immediate development.

- Apply manure for several years in a row prior to the year of potato cropping.

- Within a growing season, apply manures further in advance of planting to reduce phytotoxic effects.

- Develop an integrated approach using organic manures to control, or partially control weeds, nematodes and diseases other than common scab.

- If the mechanisms of control can be identified it may be possible to measure appropriate soil characters and predict the effect on *S scabiei* in a field by carrying out simple laboratory analyses. Elucidating the mode of action may suggest ways in which rates of application of organic amendments can be reduced and techniques modified to allow disease reduction over several years.

## Present Situation

- Growers in the Alliston area of Ontario are applying poultry manures as a means of managing scab and other pathogens. Increases in marketable yields offset the costs of carriage, handling and application and a limited supply of manure is now becoming a problem. However, care is needed as manures are variable and not all are effective. Composting manures for only a few days can destroy the disease suppression effect (Lazarovits 2001).

- Conn and Lazarovits (1999) summarised the current situation thus: “The impact of manures on disease incidence cannot be easily predicted and factors such as manure composition, soil characters, season of application and probably numerous others influence the ultimate effect on the resident pathogen populations and their activities”.

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