Soil nutrition and common scab disease of potato in Australia

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Abstract
This research was conducted over 3 years in fields heavily infested with common scab (*Streptomyces scabies*) in Victoria, Australia. It is widely thought that high soil pH is the main driver of increased common scab expression. The four soil pH modifiers, hot lime, magnesium oxide, dolomite and gypsum, significantly increased soil pH, but the effect on common scab development appeared to be seasonal i.e. in some seasons, these amendments increased common scab, but in others they did not. Sulfur, which lowered soil pH, did not consistently reduce common scab. Our results suggest that pH alone may not be a driver for the development of common scab symptoms.

Key Words
Streptomyces scabies, soilborne diseases, *Solanum tuberosum*, plant disease suppression

Introduction
Common scab causes significant loss in yield and quality of potatoes worldwide. The disease symptoms are lesions on the surface of the mature tuber and these can vary widely, being raised, netted, shallow or deep-pitted. It is not clear what factors directly determine the nature of the scab symptoms, and different symptoms can be caused by strains of the same species (Loria *et al.* 1997). Infection of potato tubers is primarily through immature lenticels; therefore tubers are most susceptible to infection during the six week period of rapid tuber growth that commences when the tuber diameter reaches twice that of the stolon.

There are significant gaps in the knowledge of how soil factors such as nutrients influence disease. Understanding these relationships may help identify new disease reduction strategies. A number of soil macro- and micronutrients have been implicated in modifying disease severity (Lambert *et al.* 2005, Huber 1991). However, the specific impact of each factor on disease has not been clearly resolved. The availability of many soil nutrients is pH-dependent, and the most consistent factor associated with increased common scab incidence worldwide is increased soil pH.

In Australia, Lacey and Wilson (2001) found that common scab severity was related to soil pH combined with the concentration of exchangeable calcium (Ca), magnesium (Mg) and potassium (K) cations in Tasmanian ferrosol soils. The role of calcium in enhancing common scab disease has been extensively studied but the specific role of calcium is confounded by its effects on pH (Horsfall *et al.* 1954, Doyle and MacLean 1960; Lambert and Manzer 1991; Keinath and Loria 1989). Further, the concentration of soil calcium does not necessarily reflect the concentration in the tuber. Calcium plays many important roles in tuber physiology, including the regulation of stress-related factors caused by the environment and disease. Increased availability of manganese has been shown to reduce common scab in some trials but not in others (McGregor and Wilson 1964; 1966). Low pH soils tend to have higher levels of manganese. *Streptomyces* species are strong manganese oxidizers and all cultural conditions which lead to increased manganese availability lead to reduced common scab. However, manganese is quickly immobilised.

Soil characteristics greatly affect the severity of potato scab which is most severe in soils with pH 5.2-7.0. In some cases, scab control can be achieved by lowering the soil pH through the use of acidifying fertilizers or applications of sulfur, but generally pH values inhibitory to *S. scabies* are also unfavourable for potato root growth, thereby reducing yields. It has been demonstrated that calcium-based fertilizers such as agricultural lime and hot lime increase the incidence and severity of common scab, but whether this is a direct effect of pH on the pathogen or an indirect effect due to the influence of pH on other aspects of soil chemistry is unknown. High calcium levels in the absence of changes in pH may induce scab, and exchangeable calcium is reportedly a more reliable parameter than the soil pH (Davis *et al.* 1976; Goto 1985). Sulfur was the first nutrient to be used to control common scab and its suppressive effect was thought to be due to a reduction in soil pH. However, Davis *et al.* (1974) demonstrated reductions in common scab severity by the application of sulfur and gypsum even though the treatments did not significantly reduce soil pH due to the highly buffered soil.

The research undertaken in this study aimed to identify nutrient-based fertilizers that reduce common scab in the field, and determine whether their activity is a direct effect on the pathogen, or an indirect effect that enhances the resistance of the potato plant.

Materials and methods

Replicated field trials were established at Cora Lynn, Victoria, Australia over 3 seasons with potato varieties (Simcoe in 2005/06, Denali in 2007/08, and Trent in 2008/09) which are susceptible to common scab. The natural pH of the soil was 5.2 in water. There were five soil treatments in 2005/2006 and eight in 2007/08 and 2008/09)

Table 12. Effects of soil treatments on incidence of common scab disease symptoms and total yield of tubers.

Treatment	Application time	Incidence of common scab (%)	Total tuber yield (t/ha)
2005/2006 Simcoe			
Untreated	Nil	20^{b}	26^{b}
Dolomite 5 t/ha	2 weeks prior to planting	22^{b}	27^{b}
Elemental S 1.5 t/ha	2 weeks prior to planting	15^{ab}	20^{a}
Hot lime 5 t/ha	2 weeks prior to planting	59^{c}	27^{b}
pH plus 125 L/ha	Tuber set	8.8^{a}	27^{b}
LSD P=0.05		9.5	3.5
2007/2008 Denali			
Untreated	Nil	37^{ab}	38
Dolomite 5 t/ha	2 weeks prior to planting	42^{b}	38
Hot lime 5 t/ha	2 weeks prior to planting	37^{ab}	38
pH plus 125 L/ha	Tuber set	23^{ab}	39
Magnesium oxide 5 t/ha	2 weeks prior to planting	35^{b}	36
Potash 100 kg/ha	2 weeks prior to planting	37^{ab}	40
Epsom salts 40 kg/ha	2 weeks prior to planting	30^{ab}	40
Gypsum 5 t/ha	2 weeks prior to planting	28^{a}	39
LSD P=0.05		14.5	ns
2008/2009 Trent			
Untreated	Nil	86	19
Elemental S 1.5 t/ha	2 weeks prior to planting	73	19
Hot lime 1 t/ha	2 weeks prior to planting	88	18
pH plus 125 L/ha	Tuber set	90	18
Magnesium oxide 5 t/ha	2 weeks prior to planting	89	17
Epsom salts 168 kg/ha	2 weeks prior to planting	83	19
MnSO4 168 kg/ha	2 weeks prior to planting	89	19
Hot lime 1 t/ha & Epsom 168 kg/ha	2 weeks prior to planting	88	20
LSD P=0.05		ns	ns

The following measurements were made during the season: 8 weeks after planting plots were assessed for plant emergence and height; at harvest tubers were assessed for disease incidence and severity, total and marketable yield. In 2007/2008 and 2008/2009 soil was collected at tuber set and plant petioles prior to senescence for determination of nutrient status.

Results

Season 2005/2006 Simcoe

At 8 weeks after planting there was no significant difference between treatments for plant emergence and height. At harvest, common scab severity was significantly reduced by pH plus, but significantly increased by the application of hot lime (Table 12). Total yield was significantly reduced by elemental sulfur.

Season 2007/2008Denali

Some of the treatments significantly altered the nutrient status of the soil at tuberset and affected nutrient uptake into the potato plant (Table 13). None of the treatments reduced soil pH. Dolomite increased symptoms compared to the untreated control (Table 12). Both hot lime and gypsum significantly increased soil pH but this did not lead to elevated levels of common scab. Gypsum and Epsom salts significantly increased (P<0.04) marketable yield.

Table 13 Summary of treatment effects on soil nutrient status and of plant parts 2007/2008 (Denali) and 2008/2009 (Trent).

	2007/2008 Denali			2008/2009	Trent
Treatment	Soil nutrient status	Petiole nutrient status	Peel nutrient status	Petiole nutrient status	Peel nutrient status
Dolomite	↑Cu		↑Cu		
Epsom		↓Cu			↑Co P
Gypsum	↑pH Ca Cu Mn S	↑S Co	↑S Cu ↓Na		
Hot lime	↓%H Al K:Mg ↑ Ca Mg	↓Mn	↑S Cu	↓Mn	↑Ca Mg P
MgO	↓%H K:Mg ↑Mg pH	↓Mn Cu Co		↓ Mn	↑ Mg P ↓ Ca
Potash		↓ Cu			
Hot lime & Epsom				↑Na ↓ Mn	↑ Ca Mg P
MnSO4				↑ Mn	↑Mn ↓ Ca Mg
Sulfur					↑S Co ↓Ca

Season 2008/2009Trent

Several treatments significantly altered the nutrient status of the soil and uptake into the plant (Table 12,Table 13). Although several treatments modified the concentrations of calcium, manganese and sulphur in plant tissues, this did not alter disease levels on tubers at harvest. None of the treatments had an effect on common scab, total or marketable yield and specific gravity (Table 12). The overall level of common scab disease was very high on this susceptible variety.

Discussion

It is widely thought that soil pH is the main driver of common scab expression, with high pH increasing the incidence of common scab. The soil pH modifiers hot lime, magnesium oxide, dolomite and gypsum significantly increased soil pH, but the effect on common scab development appeared to be seasonal i.e. in some seasons, these amendments increased common scab, but in others they did not. Sulfur, which lowered soil pH, did not consistently reduce common scab. Our results suggest that pH alone may not be a driver for common scab symptom development.

In some seasons, gypsum and hot lime increased soil calcium but did not increase disease incidence on tubers. Different forms of calcium affected common scab disease expression differently, impacting on disease severity rather than incidence. In glasshouse studies, addition of 1 t/ha of hot lime increased soil calcium without increasing the severity of common scab on tubers (Wiechel *et al.* 2007). This would allow growers the option to apply small amounts of lime to increase soil pH without fear of exacerbating common scab symptoms.

Manganese has been linked to a reduction in common scab in some trials but not in others (McGregor and Wilson 1966). In our trials, however, elevated soil and plant manganese levels were not associated with a reduction in common scab. Low pH soils tend to have higher levels of manganese. The soils in this trial were pH 5.2, so the amount of manganese available may have already been high and any additions leached out. Lack of control of common scab in some seasons may have been due to the timing of application resulting in less optimal rates and possible leaching of nutrients during the interval between application and tuberset, the time when tubers are the most susceptible to infection. The research showed that nutrient amendments were taken up by the plant into the petiole and peel, but this did not translate into reduced disease symptoms.

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