Impact of high soil pH on potato yields and grade losses to common scab

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Waterer, D. 2002. **Impact of high soil pH on potato yields and grade losses to common scab.** Can. J. Plant Sci. **82**: 583–586. The influence of soil pH on yields and grade-out due to tuber damage by common scab (*Streptomyces scabies*) was evaluated over multiple cropping seasons for potato (*Solanum tuberosum*) grown on land heavily infested with *S. scabies*. Soils with a native pH of 8.0 were adjusted to pH 7.0 to 9.0 using elemental sulfur as an acidulant and calcitic lime as the liming agent. There was little change in total tuber yields over this pH range, but the incidence and severity of scab lesions declined as the pH increased above 8.5. Marketable yields after grade-out to scab were highest at pH 9.0. This study demonstrates that in alkaline soils losses due to potato common scab may be managed by adjusting the soil pH to a point unfavorable to the scab organism. The economics of this type of pH change and its impact on subsequent crops need to be considered.

Key words: Common scab, *Streptomyces scabies, Solanum tuberosum,* liming

Waterer, D. 2002. **Incidence d'un pH élevé du sol sur le rendement de la pomme de terre et les pertes attribuables à la gale commune**. Can. J. Plant Sci. **82**: 583–586. L'auteur a évalué l'incidence du pH du sol sur le rendement de la pomme de terre (*Solanum tuberosum*) et le nombre de tubercules rejetés à cause de la gale commune (*Streptomyces scabies*). L'étude s'est déroulée sur plusieurs années dans un sol très infesté par le microorganisme. On a ajouté du soufre élémentaire comme acidifiant et du calcaire calcitique comme agent de chaulage au sol d'un pH naturel de 8,0 afin que le pH se situe entre 7,0 et 9,0. Le rendement total en tubercules a relativement peu changé avec la modification du pH, mais l'incidence et la gravité des lésions dues à la gale diminuent dès que le pH dépasse 8,5. Le meilleur rendement commercialisable après écart de triage a été observé à pH 9,0. L'étude révèle qu'on peut réduire les pertes de tubercules résultant de la gale commune dans les sols alcalins en corrigeant le pH jusqu'à un niveau que ne peut tolérer le microorganisme. Auparavant cependant, on devra tenir compte des paramètres économiques associés à la modification du pH et des conséquences de cette pratique sur les cultures ultérieures.

Mots clés: Gale commune, *Streptomyces scabies*, *Solanum tuberosum*, chaulage

Common scab caused by *Streptomyces scabies* (Thaxter) Lambert and Loria is a problem on potatoes (*Solanum tuberosum*) world wide, primarily due to its adverse effects on tuber appearance (Loria et al. 1997). Once established in a field, *S. scabies* can survive for extended periods on plant residues and consequently crop rotation provides only limited control of this pathogen (Rich 1983). Seed, soil or foliar-applied chemicals provide only limited control of soil-borne scab (Davis et al. 1974). Fumigation may provide short-term control of soil-borne scab (Anonymous 1984), but the economic and environmental costs of repeated fumigation are prohibitive. Varietal resistance to scab is available but many of the varieties presently of commercial importance in North America have only limited scab resistance (Powelson et al. 1993). The combination of these factors makes common scab one of the most costly diseases of potatoes in North America (Slack 1991).

The extent of infection and subsequent losses to common scab are influenced by soil moisture (Lapwood and Hering 1970), nutrient levels (Keinath and Loria 1989), environmental conditions (Hooker 1981) and crop management factors, such as planting and harvest dates (Waterer 2002). The common scab organism is capable of germinating and infecting its host over a wide range of soil pH (Martin 1920), but the incidence and severity of scab damage to the tubers varies with pH. In areas with acidic soils, numerous studies have noted that both the number of tubers infected and the area of the tuber surface damaged tend to increase as the pH increases from 4.0 through 7.0 (Terman et al. 1948; Odland and Allbritten 1950; Goto 1985). Although liming these acid soils often increases yields, growers are cautioned against this practice as it increases the risk of scab. In the potato-producing regions of western Canada and the United States, soils commonly range from pH 7.0 to 8.5. Addition of sufficient amounts of acid-forming amendments to shift the pH of these highly buffered soils significantly below neutral is not practical (Schaal 1946). An alternative approach to scab control on alkaline soils may be to lime the soil in an effort to increase the soil pH beyond the scab organism's tolerance range. Few studies have examined the impact of pH > 8.0 on the scab organism or the interactions between the pathogen and its host. Surveys of potato fields in New York showed that the incidence of scab was either unchanged or decreased as the soil pH increased above 7.0 (Blodgett and Howe 1934). In a pot study, Blodgett and Cowan (1935) demonstrated that liming a soil from its original pH of 7.0 through to 9.0 decreased the incidence of scab from 80% down to 10%. The concept of using high soil pH levels to control common scab is complicated by the impact that high soil pH levels may have on the productivity of both the potato crop and subsequent crops in the rotation.

This study evaluated the impact of altering the pH of an alkaline soil on crop yields, and the incidence and severity of common scab, with the objective of determining the soil pH level that produced maximum yields of marketable product.

MATERIALS AND METHODS

The main trials were conducted from 1995 through 1998 on the University of Saskatchewan Plant Science Department Potato Research plots located in Saskatoon, SK. The site features a Sutherland series sandy loam soil, pH 7.8–8.1, EC < 1 dS m^{-1}, with 4% organic matter. The site had been cropped to potatoes on a 3-yr rotation with dryland barley (potatoes-barley-barley) for the past 20 yr. Approximately 20 t ha^{-1} of cattle manure were applied to the plots every 3 yr following the potato crop. Common scab has been a consistent problem on the site.

The study was conducted in a strip-plot design with four replicates. A soil pH gradient was created within each plot ranging from pH 7.0 to 9.0 in 0.5-unit increments. Each individual plot was 4 m wide and 8 m long. The pH gradient range was generated 3 wk prior to planting by applying appropriate quantities of finely powdered (100 mesh) calcitic limestone or elemental S to the soil surface, then incorporating to a depth of 30 cm with a rotovator. The amounts of $CaCO_3$ or S required to generate each pH level were initially estimated from published liming curves and then fine-tuned in pot studies using soil from the test site. To achieve a pH of 7.5 required the application of 740 kg ha^{-1} of elemental S, with an additional 480 kg required to reach pH 7.0. Adding 1550 kg ha^{-1} of $CaCO_3$ shifted the pH up to 8.5, while an additional 1850 kg ha^{-1} of $CaCO_3$ was required to reach pH 9.0. No attempt was made to balance the S and Ca added in the pH treatments as the test site had abundant soil reserves of these nutrients. Soil pH levels (1:1 water to soil ratio) were tested 8 and 16 wk after treatment.

Standard practices for production of irrigated potatoes in western Canada were used in all trials. Based on soil tests, sufficient N as 46-0-0 was broadcast and incorporated prior to planting to meet local recommendations for irrigated potatoes (residual + fertilizer N = 175 kg N ha^{-1}). The crop was seeded in the second week of May using single cut or drop-type Elite 2 potatoes treated with the fungicide metiram as a seedpiece treatment. Metiram is not effective for the control of soil-borne common scab. The crop was seeded at 25-cm intervals in rows 1 m apart. Sufficient phosphorus (11-55-0) was applied in a band adjacent to the seed to raise soil P_2O_5 levels to 120 kg ha^{-1}. The cultivar used was Norland – an early maturing, red-skinned cultivar with moderate resistance to common scab (Powelson et al. 1993). Weed control was achieved through pre-plant application of Eptam (EPTC) and Sencor (metribuzin) followed by Gramoxone (paraquat) and Lorox (linuron) at ground crack. A rolling cultivator was used after ground crack and again 2 wk later for inter-row tillage and to throw hills. Soil moisture levels were monitored in the plots using tensiometers and/or electrical resistance meters. The plots were irrigated whenever soil water potentials fell below –60 kPa. No significant problems with insects or diseases were observed and the plots received no pesticides beyond those already described. The crop was desiccated using Reglone (diquat) in the first week of September and harvested 2 wk later. The crop was initially graded based on tuber size and freedom from physical defects such as cracks. One hundred tubers randomly drawn from each treatment replicate were then individually evaluated to determine the percentage of each tuber's surface covered with scab lesions. According to the Canada Food Inspection Agency grading standards (Canada Food Inspection Agency 1998), potatoes meet No. 1 Grade standards if less than 5% of the tuber surface is affected by scab lesions. Marketable yields in this study represent the tubers that met Grade No.1 standards for both size and freedom from excessive scab.

Data for the 4 test years were initially pooled, as error variances for the soil pH, yield and scab data were homogeneous across years. Analysis of variance tests were conducted using the GLM program of SAS (SAS Institute, Inc. 1989). The percentage data for the scab ratings were arcsin-square root transformed prior to analysis. Years were treated as random effects in the model (Gomez and Gomez 1984). As there were significant year pH level interactions for marketable yields and scab intensity the data for each year were then analyzed separately. When a significant pH effect occurred on yield or scab levels, a profile analysis procedure (Greenhouse and Geisser 1959) was used to determine the threshold pH level where that effect became statistically significant (P = 0.05). In this procedure, the value obtained at any pH level was contrasted with the mean values obtained from all lower pH levels.

A second site was used to confirm the pH effects on yields. This site (Outlook, SK) features a Bradwell series sandy soil, EC = 1.0 dS m^{-1}, 2% organic matter with a native pH of 8.1. In 1995–1997, test plots were established at pH levels of 7.5, 8.1, 8.5 and 9.0 using Norland potatoes. The trial was managed and data were collected as previously described. This site is free of common scab.

RESULTS AND DISCUSSION

The soil pH levels measured 8 wk after application of the amendments closely corresponded with the target levels (Table 1). Later in the season there was greater variability in the pH values and the actual values observed in the limed treatments were consistently below the target value. Using very finely ground forms of both the S and lime appeared to allow the desired pH change early enough in the growing season to benefit the crop. However, finely ground materials are costly and create problems with product drift during application. Amending the soil in the fall prior to the potato cropping season would allow more time for coarser but more affordable forms of lime and S to work.

The optimum pH range commonly reported for potatoes is 5.5 to 7.5 (Smith 1940), with higher pH levels causing significant yield reductions in some cases (Odland and Albritton 1950) and little effect in others (Blodgett and Cowan 1935). The yield decline associated with high pH levels is usually attributed to pH-related deficiencies of P

Table 1. Target and actual soil pH levels at 8 and 16 wk after soil amendment with S or lime (1995–1998)

	Target pH				
	7.0	7.5	8.0[z]	8.5	9.0
8 wk	6.8 ± 0.2[y]	7.5 ± 0.1	7.9 ± 0.2	8.6 ± 0.1	8.9 ± 0.2
16 wk	6.9 ± 0.1	7.4 ± 0.3	8.0 ± 0.2	8.4 ± 0.3	8.8 ± 0.4

[z]Initial soil pH.
[y]Mean ± SEM, n = 16

Table 2. Influence of soil pH on yields, incidence and severity of common scab and yields after grade out to scab for Norland potatoes – Saskatoon site (1995–1998)

		Soil pH					
		7.0	7.5	8.0	8.5	9.0	Threshold pH[z]
1995	Total yield (T ha^{-1})[y]	46.6	44.8	49.2	47.0	44.7	None
	Scab (%)[x]	11	12	12	11	9	9
	Marketable (%)[w]	62	64	59	64	84	9
	Marketable yield (T ha^{-1})[v]	29.1	28.7	29.1	30.8	37.6	9
1996	Total yield (T ha^{-1})	44.1	44.0	41.5	44.2	42.2	None
	Scab (%)	11	12	11	10	8	9
	Marketable (%)	65	63	67	72	79	9
	Marketable yield (T ha^{-1})	27.8	27.6	27.3	31.8	33.3	8.5
1997	Total yield (T ha^{-1})	45.8	46.2	43.8	46.8	47.2	None
	Scab (%)	8	8	7	5	5	8.5
	Marketable (%)	78	78	83	88	88	8.5
	Marketable yield (T ha^{-1})	35.7	36	36.3	41.1	41.5	8.5
1998	Total yield (T ha^{-1})	46.8	48.1	47.0	47.0	47.2	None
	Scab (%)	4	4	5	4	5	None
	Marketable (%)	90	90	87	91	87	None
	Marketable yield (T ha^{-1})	42	43.4	40.9	42.3	41.1	None
Mean	Total yield (T ha^{-1})	45.8	45.8	45.4	46.2	45.3	None
	Scab (%)	9	9	9	8	7	8.5
	Marketable (%)	74	74	74	79	85	8.5
	Marketable yield (T ha^{-1})	33.6	33.9	33.4	36.5	38.4	8.5

[z]Values at the threshold pH are significantly different (P = 0.05) from the average of the values obtained at all lower pH levels (Greenhouse and Geisser 1959).
[y]Yield of marketable sized tubers free of physical defects.
[x]Average percentage of the tuber surface covered by scab lesions.
[w]Proportion of the crop with less than 5% of the tuber surface affected by scab.
[v]Yield after removal of tubers with excessive scab.

and Fe (Marschner 1986). In this trial, over a total of 7 site years at two test locations, soil pH ranging from 7.0 to 9.0 had no impact on yields prior to grade-out to scab (Tables 2 and 3). No symptoms of P or Fe deficiency were apparent and the yields in all trials were well above regional norms. These results suggest that management practices that increase the soil pH to 9.0 pose relatively little threat to potato yields under the conditions and management practices common in western Canada and the United States. Blodgett and Cowan (1935) also noted little impact of increasing soil pH through to 9.0, but yields declined rapidly at higher pH levels.

Scab levels and the scab responses to the pH treatments were consistent from 1995 through 1997, but in the 1998 trial there was little scab, irrespective of the soil pH level (Table 2). This likely reflects rotation of the trial in 1998 to an area of the field with low indigenous inoculum levels. Using elemental S to lower the soil pH from the initial level of 8.0 to 7.0 had no impact on scab levels. By contrast, in the three seasons in which scab was a problem, increasing the soil pH to 8.5 or preferably 9.0 significantly reduced both the incidence and severity of common scab. The threshold soil pH values for scab control derived from this field study correspond with the thresholds observed in pot studies by Blodgett and Cowan (1935). As increasing the soil pH reduced grade-out to scab without detrimentally affecting yields, marketable yields increased with soil pH (Table 2). Averaged over the 3 test years in which scab was a significant problem, yields after grade-out to excessive scab at soil pH 9.0 were 22% higher than at the native pH of 8.0. Even greater benefits might be expected with more-sensitive cultivars or where growing conditions and management practices were more conducive to scab (Blodgett and Cowan 1935).

How high soil pH suppresses common scab is unknown. In pure culture, high pH levels have no impact on germination or growth of scab (Butler and Jones 1949). Conn and Lazarovits (1999) noted that the addition of poultry manure

Table 3. Potato yields as influenced by soil pH – Outlook site (1995–1997)

	Soil pH				
	7.5	8	8.5	9	*P*=
	Yield (t ha^{-1})				
1995	26.0	25.9	27.2	25.8	NS[z]
1996	22.5	19.5	20.5	19.3	NS
1997	28.4	30.5	27.8	31.1	NS

[z]No significant difference at $P = 0.05$.

just prior to planting a potato crop provided a significant degree of scab control. Application of the manure temporarily increased the soil pH to above 8.0. This pH shift was accompanied by an increase in levels of ammonia in the soil. Ammonia is known to be toxic to soil-borne pathogens such as *Fusarium oxysporum* (Zakaria et al. 1980) and *Sclerotinia sclerotiorum* (Huang and Janzen 1991) although its effects on *S. scabies* are unknown.

This study demonstrates the potential for effective control of common scab by liming already alkaline soils. The requisite pH shift had no adverse impact on productivity of the potato crop; however, it may have detrimental effects on subsequent crops in the rotation. Similar crop tolerance problems occur when acid soils are treated with sulfur to shift the pH to below the tolerance range of the *S. scabies* (Keinath and Loria 1989). The cost of the liming treatment will depend on the extent of pH change required, the buffering capacity of the soil and the cost of purchasing and applying the liming material. The benefits will depend on the extent of the scab problem, the degree of control achieved and the value of the crop. The material costs of this treatment may be reduced by limiting the lime application to the crop row. This is commonly done with phosphorus and certain pesticides. For any given field, a liming treatment may be required prior to each potato crop, as any effects of previous liming treatments may be lost in the three to four seasons between potato crops.

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