Fertilizer Effects on Common Scab of Potato and the Relation of Calcium and Phosphate-Phosphorus

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ABSTRACT

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Results showed significant linear correlations between common scab (caused by *Streptomyces scabies*) of potato and the Ca, PO_4, Mn, and Fe content of tuber peelings. Treatments with nitrate and ammonium fertilizers and the nitrogen stabilizer, N-Serve [2-chloro-6-(trichloromethyl)-pyridine] at 0.6, 1.1, and 1.7 kg/ha with ammonium sulfate (200 kg N/ha) did not significantly affect scab severity. Treatment with N-Serve, however, reduced Mn, Mg, Cu, Zn, and K in potato tissue; and B was increased. Treatments with triple-superphosphate (84 to 336 kg P_2O_5/ha) significantly reduced the extent of scab and significantly changed scab lesion morphology by reducing lesion height and depth. The effect of triple-superphosphate on potato scab appeared to be indirect, since the pathogen *(S. scabies)* was not inhibited by triple-superphosphate. Levels of P in potato petioles and peelings were linearly correlated with common scab. The effect of phosphate-P was related to calcium levels and results with phosphate-P suggest a phosphate-calcium interaction. Foliar sprays with manganese (0.2 kg/ha) also were shown to produce a slight, but significant scab reduction.

Additional key words: Russet Burbank, calcium, phosphate, manganese, N-Serve, N-form.

This report describes field studies that were designed to determine whether plant nutrient levels correlate with the severity of common scab [*Streptomyces scabies* (Thaxt.) Waksman and Henrici]. An abstract (3) has been published describing a portion of this work.

Most of the literature dealing with nutritional relations to common scab involves effects of manganese, nitrogen-form, and calcium. Wenzl (21) reviewed the literature involving effects of micronutrients on common scab and found the effects to be generally erratic. Several workers reported scab to be reduced by applications of manganese sulfate to soil (11, 12, 15, 16).

Forms of nitrogen have been reported to influence scab (10), and several workers reported (8, 9, 19) scab reduction when the ammonium form of nitrogen was stabilized with N-Serve [2-chloro-6-(trichloromethyl)-pyridine]. N-Serve is specifically active against *Nitrosomonas* spp., the soil bacterium responsible for rapid conversion of ammonium to nitrite (6).

High ammonium and low nitrate levels in the soil (9, 19) have been reported to be important for disease reduction, but the low nitrate requirement was not defined. McIntosh (13) reported some control in the field with N-Serve application at 0.5 μg/g, but in the greenhouse, N-Serve showed no effect with soil treatments involving either 5.0 or 13.0 μg/g.

Our preliminary field studies with N-Serve at 0.6 kg/ha showed no effect on common scab. With irrigation treatments involving 6 and 9 weeks of high moisture (moisture depletion to −0.46 bars), N-Serve at 1.7 kg/ha showed no effect on common scab, but scab was increased when N-Serve was applied to plots irrigated at lower moisture (moisture depletion to −1.80 bars) levels (4). Because this study provided no evidence for phytotoxicity with N-Serve and the residual nitrate level in the field was low (56 kg/ha in the upper 61-cm of the soil profile), the lack of disease control was attributed to reasons other than form-of-nitrogen. N-Serve reduction of manganese concentration in potato tissue may explain increased scab severity (4).

Calcium also may influence common scab severity. Horsfall et al. (7) reported increased calcium levels in tubers with increased calcium in soil and observed calcium in tuber peelings to be positively correlated with scab severity. Eichinger (5) further indicated that calcium ion deposits could drastically alter periderm cells of the peel, making the areas with high calcium deposits highly susceptible to *Streptomyces* spp. and hypothesized that anions neutralizing calcium ions (e.g., oxalate, phosphate) may reduce disease severity.

Many of the reports involving nutritional effects on common scab fail to relate results to nutrient changes in the potato, and because of this, there may exist a certain amount of confusion. The objective of this investigation was to clarify nutritional relationships. Several nutritional variables (nitrogen-form, sulfur, manganese, and phosphorus) were related to common scab, nutritional changes within plant tissue were observed, and correlations were made between nutritional relationships within the potato and disease severity to determine if there is a nutritional basis for scab susceptibility.

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MATERIALS AND METHODS

The site selected for field investigations was located on a Pancheri silt loam (20) near Blackfoot, Idaho, with a pH from 7.5 to 8.0. The noncalcareous surface has a high percentage of exchangeable calcium and overlies a highly calcareous (20-30% calcium carbonate equivalent) subsoil at a depth of about 30 cm. The field was unsuited for commercial potato production because of common scab in previous crops.

Cultural practices.—Basic cultural practices were similar each year. Uncut certified 'Russet Burbank' seed was planted at 26 cm spacing in rows 92 cm apart. Disulfoton (3.4 kg/ha) was applied for insect control at time of planting. For weed control, Eptam (EPTC at 0.56 kg/ha) was applied each year and trifluralin (0.56 kg/ha) was additionally applied in 1971. Incorporation of herbicides was to a depth of 13 cm by a tractor-powered rototiller. Irrigation was with solid-set sprinkler systems with sprinkler heads arranged on 12.2 m centers, and irrigation scheduling was carried out by the grower cooperator. Individual plots were four rows wide (3.8 m) and 7.6 m long. Potatoes were harvested in October each year.

Plot treatments in 1971.—The 1971 experiment was designed as a randomized block with six replications and 12 treatments to compare effects of nitrogen source, sulfur, N-Serve, and pentachloronitrobenzene (PCNB) on common scab control. Table 1 shows the treatments that were applied and rates of application. Previous work with PCNB and sulfur has shown effective control of common scab (4); therefore, treatments of PCNB and sulfur were included as standards.

Pentachloronitrobenzene treatments were applied broadcast on 4 May within 4.0% of the desired concentration and were incorporated to a depth of 13 cm by a tractor-powered rototiller. Immediately prior to planting, preweighed amounts of sulfur for each plot row were applied by hand to the center of precut furrows (15 cm deep and 19 cm wide), and uncut seed were planted in furrows with a potato planter.

Ammonium sulfate or calcium nitrate treatments were applied at 200 kg/hectare (ha) N, and all plots received 168 kg/ha P_2O_5 as triple-superphosphate. N-Serve was thoroughly mixed with the nitrogen fertilizer treatments immediately prior to application. All fertilizers were applied at time of planting (12 May) with an endless belt applicator attached to the planter.

Plot treatments in 1973.—The 1973 experiment was designed as a randomized block factorial with five replications and 16 treatments to compare effects of nitrogen sources, triple-superphosphate, manganese, and potassium on common scab. The treatments included two rates of manganese (0 and 0.27 kg/ha) in combination with eight fertilizer treatments shown in Table 3.

Potatoes were planted on 15 May and eight fertilizer treatments were sidedressed on 1 June. Manganese was applied as foliar sprays using manganese chelate (disodium manganous ethylenediamine tetraacetate dihydrate) at the rate of 0.13-0.14 kg Mn/ha with each application. Tuber initiation was negligible at the time of the first application (25 June) and at the time of the second application (13 July), tubers were several millimeters in diameter.

Two sources of triple-superphosphate were compared (sulfur-coated triple-superphosphate and triple-superphosphate without sulfur coating). Application of 168 kg/ha P_2O_5 with the sulfur-coated P_2O_5 source provided 67 kg S/ha. As a check on possible effects of sulfur in the coating, plots receiving no P_2O_5 were also treated with elemental sulfur (flowers of sulfur) at 67 kg S/ha.

Plot treatments in 1974.—The 1974 experiment was designed as a randomized block factorial with six replications and 10 treatments. This factorial combination involved elemental flake sulfur (0 and 673 kg/ha) with five rates of triple-superphosphate (0, 84, 168, 252, and 336 kg P_2O_5/ha).

Potatoes were planted on 16 May. Plot rows were sidedressed with fertilizers, including $(NH_4)_2SO_4$ at 200 kg N/ha, on 29 May.

Scab evaluation.—Potatoes were graded and tubers weighing 113 g and over were evaluated for scab. Tubers were washed and grouped into four classes of relative scab coverage. In 1971, class groupings were as follows: 1 = 0-trace (trace = 1-2 lesions totaling less than 1 cm^2); 2 => trace-3%; 3 => 3-5%; 4 => 5% scab coverage. In 1973 and 1974, scab was markedly more severe and class groupings were changed to account for the more severe scab. These classes were as follows: 1 = 0-trace; 2 => trace-5%; 3 => 5-10%; 4 => 10% scab coverage. Since tubers with scab coverage greater than 5.0% are not acceptable for the U. S. No. 1 grade (1), the tubers with 5.0% or less provided a criterion of economic significance. Scab may also be evaluated on the basis of appearance and in certain instances, tubers with scab coverage greater than 3.0% also may be unacceptable for the U. S. No. 1 grade (when high contrast occurs between lesions and tuber periderm). Percentage values were transformed to arcsin percentages prior to statistical analyses. Indices of relative scab severity were calculated as previously described (2).

Plant tissue and soil analyses.—Petioles were collected from plots each year in mid-July. The petiole from the last fully matured leaf was selected from forty or more plants per plot. For peel samples, twelve tubers were randomly collected from each plot sample after grading and scab evaluation. Tubers were washed thoroughly and rinsed in 50 μM HCl with a final rinsing in distilled water. Periderm samples were collected by shallow peeling for chemical analyses. Samples were oven-dried and ground through a 250-μm (60-mesh) screen in a Wiley mill. Soil samples were collected by taking a minimum of eight subsamples per replicate, and prior to analysis, samples were appropriately oven-dried and ground. Nutrient evaluations were made by Analytical Services, Department of Plant and Soil Sciences, University of Idaho, Moscow, using standard colorimetric, atomic absorption, and flame photometry procedures.

Histology.—For histological evaluation of scab lesions, tubers were randomly collected from harvested samples after grading. From tubers in each plot, 15 scab lesions were randomly selected within 2.5 cm from the tuber stem-ends. A slice about 1.0 mm wide and 5.0 mm deep was removed from the center of each scab lesion and placed in formalin-acetic-acid until it was stained at a later time. Scab lesions were stained and examined using the method of Nielsen (17).

Bioassay.—Bioassay evaluations were made to determine if triple-superphosphate fertilizer inhibited *S. scabies*. Assay disks were dipped into a saturated solution of triple-superphosphate (same source as used in field studies), and placed upon soil-extract-agar plates seeded with *S. scabies*. Triple-superphosphate solution was prepared by autoclaving an excess of triple-superhosphate for 20 minutes at 1 atmosphere pressure (15 psi) and cooling to room temperature.

RESULTS

Effect of N-Serve and nitrogen-form.—Ammonium sulfate with N-Serve at either of several rates (0.6, 1.1, 1.7 kg/ha) showed no scab control (Table 1) and despite low residual nitrate (6.5 μg N/g of soil in upper 30 cm of soil profile and 3.3 μg N/g from 30-60 cm) differences between ammonium sulfate and calcium nitrate treatments were not significant. In contrast, sulfur and PCNB treatments both reduced scab.

Treatment with N-Serve (1.7 kg/ha) showed multiple effects on plant nutrient levels (Table 2). Since some of these effects were reversed with the addition of sulfur, results suggested a pH relationship. N-Serve reduced manganese, copper, magnesium, zinc, and potassium in tuber peelings and increased the boron level. With the

TABLE 1. Effect of 1971 fertilizer and chemical treatments on common scab severity of potato and Ca/PO_4-P ratios in tuber peelings

Treatment	Scab incidence[r]				Ca/PO_4-P[r] ratios
	Scab[q] index	% of tubers with scab coverage of:[s]			
		Scab-free	With > 3% scab coverage	With > 5% scab coverage	
$Ca(NO_3)_2$[t]	4.6 a	23 ab	16 a	7.5 a	0.65 a
$(NH_4)_2SO_4$	3.9 ab	31 ab	11 abc	4.3 abc	0.39 b
$Ca(NO_3)_2$ + S[u]	3.4 bc	38 bc	7 abcd	2.9 abcd	0.58 a
$(NH_4)_2SO_4$ + S[v]	2.5 cd	53 cde	2 de	0.4 d	0.33 b
$(NH_4)_2SO_4$ + N-Serve[w]	4.7 a	18 a	16 a	6.9 a	0.37 b
$Ca(NO_3)_2$ + N-Serve[w]	3.8 ab	28 ab	9 abcd	2.9 abcd	0.59 a
$(NH_4)_2SO_4$ + S[v] + N-Serve[w]	3.1 bcd	42 bcd	5 bcde	1.1 bcd	0.28 b
$Ca(NO_3)_2$ + S[u] + N-Serve[w]	2.5 cd	55 cde	3 cde	0.6 cd	0.34 b
$(NH_4)_2SO_4$ + N-Serve[x]	4.7 a	16 a	13 ab	7.0 a	
$(NH_4)_2SO_4$ + N-Serve[y]	3.7 ab	26 ab	7 abcd	1.0 bcd	
$(NH_4)_2SO_4$ + PCNB[z]	2.0 d	70 e	1 e	0.6 cd	
$(NH_4)_2SO_4$ + PCNB + N-Serve[w]	2.4 cd	60 de	3 de	0.5 cd	

[q]Higher values denote higher scab.
[r]Level of significance for Duncan's multiple range test. Treatment means not followed by the same letters are significantly different, P = 0.05.
[s]Determined as percentage by weight.
[t]All nitrogen treatments applied at 200 kg N/ha with triple-superphosphate at 168 kg P_2O_5/ha.
[u]Sulfur applied at 897 kg/ha with $Ca(NO_3)_2$.
[v]Sulfur applied at 673 kg/ha with $(NH_4)_2SO_4$.
[w]N-Serve [2-chloro-6-(trichloromethyl)-pyridine] applied at 1.7 kg/ha.
[x]N-Serve applied at 0.6 kg/ha.
[y]N-Serve applied at 1.1 kg/ha.
[z]Broadcast application of PCNB (pentachloronitrobenzene) at 28 kg/ha.

TABLE 2. Effect of 1971 fertilizer and N-Serve treatments on nutrient levels in tuber peelings

Treatment	Nutrient levels in tuber peelings[v]								
	$\mu g/g$ dry weight								
	Ca	PO_4-P	Mn	Fe	Cu	Mg	Zn	B	% K
$Ca(NO_3)_2$[w]	327 ab	521 a	36 ab	912 a	16 a	2,752 abc	28 a	8 bc	3.90 ab
$(NH_4)_2SO_4$	278 bc	760 cd	67 c	952 a	22 b	2,793 bc	36 b	5 ab	4.14 bcd
$Ca(NO_3)_2$ + S[x]	345 a	604 abc	70 c	831 a	25 b	2,665 abc	31 ab	7 abc	4.06 abc
$(NH_4)_2SO_4$ + S[y]	233 c	760 cd	70 c	937 a	15 a	2,643 abc	27 a	10 c	4.32 d
$(NH_4)_2SO_4$ + N-Serve[z]	272 bc	760 cd	30 a	792 a	15 a	2,582 a	24 a	15 d	3.85 a
$Ca(NO_3)_2$ + N-Serve[z]	317 ab	542 ab	32 a	860 a	15 a	2,810 c	26 a	7 abc	4.26 cd
$(NH_4)_2SO_4$ + S[y] + N-Serve[z]	232 c	896 d	58 bc	1,004 a	15 a	2,603 ab	25 a	5 ab	4.01 ab
$Ca(NO_3)_2$ + S[x] + N-Serve[z]	227 c	688 bc	67 c	023 a	15 a	2,788 bc	25 a	4 a	4.08 abc

[v]Level of significance for Duncan's multiple range test. Treatment means not followed by the same letters are significantly different, $P = 0.05$.
[w]All nitrogen treatments applied at 200 kg N/ha with triple-superphosphate at 168 kg P_2O_5/ha.
[x]Sulfur applied at 897 kg/ha with $Ca(NO_3)_2$.
[y]Sulfur applied at 673 kg/ha with $(NH_4)_2SO_4$.
[z]N-Serve [2-chloro-6-(trichloromethyl)-pyridine] applied at 1.7 kg/ha.

addition of sulfur (673 kg/ha) however, the manganese, magnesium, and potassium were not significantly different from ammonium sulfate plots receiving no added sulfur.

A significant positive linear correlation ($r = +0.56$) was observed between calcium levels in tuber peelings and indices of scab severity. An increase of scab was related to an increase of calcium. Negative correlations were observed with manganese ($r = -0.40$), phosphate-P ($r = -0.35$), and iron ($r = -0.29$), and several nutrients showed no correlation with common scab (boron, potassium, magnesium, zinc, copper, and nitrate).

Calcium and phosphate-P relationships.—Variables of nitrogen-form and N-Serve from the 1971 trials suggested a close relationship between calcium and phosphate-P with common scab (Table 2).

In the 1973 trials, triple-superphosphate reduced the severity of common scab (Table 3), and sources of nitrogen and phosphate that were compared showed no differential effect on scab severity.

Results from 1973 supported 1971 results by showing that tissue levels of phosphate-P and calcium are closely correlated with scab severity. Treatment with triple-superphosphate at 168 kg/ha P_2O_5 significantly increased phosphorus levels in potato peelings and reduced levels of calcium and zinc. In contrast, no effect was observed on levels of manganese, iron, magnesium, sodium, or potassium. When calcium and phosphate-P were expressed as calcium:phosphate-P ratios, values were highly correlated with scab severity, and the calcium: phosphate-P ratios were significantly reduced with the addition of triple-superphosphate fertilizers.

As calcium is increased in tuber peelings, results suggested that scab suppression by triple-superphosphate may be reduced. When potassium chloride was added with triple-superphosphate, the calcium level in tuber peelings and scab severity were significantly higher than the same phosphate treatment without potassium chloride, but potassium, total phosphorus or phosphate-P levels remained unchanged.

Results of the phosphate-rate study in 1974 (Table 4) further corroborate the relationship of phosphorus and calcium to common scab. Scab was significantly reduced with added triple-superphosphate. The calcium: phosphate-P ratios were highly correlated with common scab severity. When scab data from all three years were correlated with calcium:phosphate-P ratios, a near-

TABLE 4. Effect of 1974 phosphate rates on severity of common scab of potato and Ca/PO_4-P ratios in tuber peelings

Kg/ha P_2O_5	Scab incidence (% of tubers with scab coverage of:)[x,y] With > 5% scab coverage	With > 10% scab coverage	Ca/PO_4-P ratios[z]
0	68 a	26 a	3.7 a
84	50 b	13 b	3.0 b
168	43 b	11 b	2.3 c
252	34 b	6 b	2.0 c
336	42 b	10 b	2.1 c

[x]Determined as percentage by weight.

[y]Level of significance for Duncan's multiple range test. Treatment means not followed by the same letters are significantly different, $P = 0.01$.

[z]Level of significance for Duncan's multiple range test. Treatment means with uncommon letters are significantly different, $P = 0.05$.

TABLE 5. Effect of phosphate on scab lesion morphology on potato

Kg/ha P_2O_5	Mean values in μm[x] Lesion height[y]	Lesion depth[z]
0	286	414
252	245	369
LSD ($P = 0.05$)	32	LSD ($P = 0.10$) 39

[x]Values represent means of 90 scab lesions (15 lesions per replicate with six replicates) randomly selected from area within 2.5 cm of tuber stem-ends.

[y]Lesion height (raised area) above normal tuber surface.

[z]Penetration of lesion below normal surface.

TABLE 3. Effect of 1973 phosphate fertilizer treatments on common scab severity of potato and Ca/PO_4-P ratios in tuber peelings

Treatment	Scab incidence (% of tubers with scab coverage of:)[s,t] With > 5% scab coverage	With > 10% scab coverage	Ca/PO_4-P ratios[s]
NH_4NO_3[u] + S[v]	74 c	49 c	4.0 c
NH_4NO_3 + S[w] + P_2O_5[x]	52 ab	26 ab	3.2 ab
NH_4NO_3 + S[y] + P_2O_5[x]	47 a	21 a	2.6 a
NH_4NO_3 + S[y] + P_2O_5[x] + KCl[z]	62 bc	38 bc	3.4 bc
NH_4NO_3 + P_2O_5[x]	45 a	23 a	3.2 ab
$(NH_4)_2SO_4$ + S[v]	69 c	45 c	
$(NH_4)_2SO_4$ + S[w] + P_2O_5[x]	46 a	26 a	
$(NH_4)_2SO_4$ + P_2O_5[x]	46 a	23 a	

[s]Level of significance for Duncan's multiple range test. Treatment means not followed by the same letters are significantly different, $P = 0.05$.

[t]Determined as percentage by weight.

[u]All nitrogen treatments applied at 200 kg N/ha.

[v]Flowers of sulfur applied at 67 kg/ha.

[w]Sulfur coating on triple-superphosphate equivalent to 67 kg/ha.

[x]Triple-superphosphate applied at 168 kg/ha P_2O_5.

[y]Sulfur applied at 291 kg/ha - 67 kg/ha with sulfur coating on triple-superphosphate + 224 kg S/ha as flowers of sulfur.

[z]168 kg/ha K_2O.

perfect correlation was observed (r = +0.99).

Histological evaluation of scab-lesion morphology further substantiated the scab-reducing effect of triple-superphosphate (Table 5). With treatment, lesion height was decreased and there was a trend ($P = 0.10$) for decreased lesion depth.

Since triple-superphosphate showed no inhibition of *S. scabies* in petri-plate culture, the effect of triple-superphosphate on scab severity appears to be indirect.

Although residual phosphorus levels in soil were high (> 20 μg P/g of soil in the upper 23 cm of soil profile), phosphate treatments showed striking effects. Triple-superphosphate treatments reduced scab severity and significantly increased total yield (9-17%) and yield of U. S. No. 1 potatoes (83-104%).

The banded flake-sulfur used in this study had no effect on calcium or phosphate-P levels in petioles or tuber peelings and no effect on scab severity or tuber yield.

Phosphorus and phosphate-P levels were increased in petioles and tuber peelings as application rates increased to 252 kg/ha. In tuber peelings, with P_2O_5 applied at 168 kg P_2O_5/ha, calcium and manganese were significantly reduced, but higher and lower rates did not show this effect. Petioles, however, showed no reduction of either calcium or manganese with P_2O_5 treatment.

Manganese relationship.—Manganese chelate showed a slight but significant reduction of scab index from 9.4 to 8.3 when ammonium nitrate was used, but not when ammonium sulfate was used. No significant effect was observed on percentage of U. S. No. 1 tubers. Manganese levels in petioles from untreated plants and from plants treated with manganese were respectively 54 and 72 μg/g of dry tissue.

DISCUSSION

Results suggest a relationship between calcium and phosphate with common scab severity. This relationship is indicated by several lines of evidence:the positive correlation between scab and calcium in tuber peelings, the positive correlation between scab and calcium:phosphate-P ratios, and the consistent suppression of common scab following phosphate treatments.

Eichinger (5) indicated that calcium ion deposits could alter periderm cells of the peel, making them more susceptible to infection by *S. scabies*. Eichinger reasoned that anions neutralizing calcium ions (e.g., oxalate, phosphate) may reduce disease severity. Our observations support this concept. If the effect of phosphate is based upon a calcium interaction, it would follow that two factors should be present to produce this effect: (i) calcium levels should be sufficiently high for predisposition to *S. scabies* infection and (ii) phosphate levels should be sufficiently high to compensate for the calcium.

Light scab infection and low tissue calcium may have contributed to the inability to detect differences in infection between calcium nitrate and ammonium sulfate treatments or with treatments involving N-Serve. There was, however, a significant positive linear correlation between scab and calcium, whereas a negative correlation existed between scab and phosphate-P. Fertilization with ammonium sulfate resulted in a significantly lower calcium:phosphate-P ratio than fertilization with calcium nitrate. Similarly, treatment with N-Serve in the presence of calcium nitrate and sulfur reduced calcium and calcium:phosphate-P ratios in tuber peelings. This relationship with N-Serve was not apparent with ammonium sulfate, ammonium sulfate, and sulfur, or when applied with calcium nitrate without sulfur. Results indicate that the effects of N-Serve are not limited to the ammonium form-of-nitrogen and suggest a relationship between calcium level and sulfur. Since the presence of sulfur apparently was required for reduction of calcium and calcium:phosphate-P ratios, results also may suggest effects by soil pH.

Recently Polizotto et al. (18) demonstrated a relationship between form-of-nitrogen, calcium, and phosphorus in potato tissue. Using solution culture techniques with adequate corrections for calcium and sulfate variables, they observed a suppression of calcium and magnesium and an increase of phosphorus in potato tissue with the ammonium nitrogen-form compared with the nitrate nitrogen form. These observations suggest the possibility that the ammonium-nitrogen form may influence common scab by an effect on calcium and on phosphate.

Huber and Watson (8) found scab to be more severe after fertilization with calcium nitrate than with ammonium sulfate. They inferred that the effect was not due to sulfate or calcium since calcium or potassium sulfates (at 56 to 900 kg/ha) showed no effect on scab. However, they did not demonstrate the effect of calcium and potassium sulfates on calcium levels in tuber tissue. Therefore, the possible effects of calcium were not eliminated.

It need not follow that calcium in plant tissue is increased with calcium sulfate treatment. On a calcareous soil having a pH of 7.7, Davis et al. (2) observed a significant reduction of calcium in tuber peelings following treatment with gypsum at a high rate (4,100 kg/ha). With this reduction of calcium in tuber tissue, there was a significant reduction of common scab. Similarly, Menzies (14) reported scab reduction with calcium sulfate.

The possibility exists that the effect observed by Potter et al. (19) and Huber and Watson (9) may be explained on the basis of calcium:phosphate-P ratios, and it is suggested that future work involving effects of nitrogen-form and N-Serve on common scab take this into consideration.

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