SHOULD YOU APPLY LIME FOR POTATO PRODUCTION IN CENTRAL WASHINGTON

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The downward trend of soil pH in some areas of the Columbia Basin as well as eastern Washington and northern Idaho has been reported at this conference and in the literature (10,12,14). The virgin soils of the Columbia Basin are found to be neutral to alkaline in reaction (pH 6.5 to 7.8). The soils have been only slightly weathered because of the semi-arid climate of the region. However, the initiation, approximately thirty years ago, of intensive agriculture with its application of fertilizers and irrigation water has significantly changed the environment of these soils. This has changed the soil chemistry and biology.

Acidification of Columbia Basin soils can be explained by the removal of the basic cations calcium (Ca) and magnesium (Mg) from the soil by crop removal and leaching and the acidification from added fertilizer materials. The application of ammonium based nitrogen sources (urea, $(NH_4)_2SO_4$, etc.) and reduced forms of sulfur (elemental S) to the soil system has in effect added hydrogen ions (H+) to the soils. The decreased Ca and Mg concentration and increased H ion concentration combine to increase soil acidity (lowered soil pH). The rate of soil acidification varies widely across the soils of the Columbia Basin because of differences in soil properties and management practices. The rate of acidification appears to be greatest on sandy noncalcareous, poorly buffered soils and under potato rotations. Soils that have been subjected to potato rotations have been affected by the large rates of ammonium based fertilizers applied and the heavy levels or irrigation. Acidification will also be affected by other crops in the rotations and their fertilizer and irrigation management.

In some areas of the Columbia Basin, soils that had pH values ranging from 6.6 to 7.2 as recent as ten years ago now have pH values ranging from 5.5 to 6.5. Some isolated fields have been found to have 1:1 soil:water pH values below 5.5. The concern about liming is directed to these soils with pH values at and below 5.5. For the purpose of this paper pH values will be assumed to be based on a 1:1 soil:water pH measurement.

Although the chemistry and properties of these recently acidified soils have not been extensively studied, it is important to consider how they may differ from traditional acid soils.

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More traditional acid soils, such as those in the eastern and central United States, have formed in acid parent materials or under high weathering conditions. These soils have been acid for many years and generally have acid subsoils to a depth of several feet, taking in the entire rooting zone. The acidification in the Columbia Basin is recent and limited to the plow layer, with the lowest pH generally found in the upper 6 inches of the soil profile. Under our current conditions, soils with pH values as low as 5.5 appear to have relatively high base saturation or relatively high levels of exchangeable Ca and Mg. At this time our acid soils appear to be low in free aluminum (Al) and Manganese (Mn). In older acid soils high levels of free and exchangeable aluminum are generally considered to be major causes of reduced crop production.

Possible Effects of Acid Soils on Potato Production

Before liming a soil to improve potato production, consider the effects of acid soils on production. The possible effects of acid soils on potato production might include: (1) changes in nutrient availability, (2) changes in soil and plant nitrogen relationships, (3) changes in levels of potentially harmful aluminum and manganese, and (4) changes in plant disease complexes and the occurrence of physiological disorders.

Nutrient Availability

The effect of increased soil acidity on nutrient availability in older acid soils has been reported in many basic soils textbooks. As pH drops below 6.0 the levels of plant available Ca, Mg, K, and Na generally decline as exchange sites become more occupied by H and Al. This lowering of the base saturation level in very acid (pH < 5.0) soils or in soils with very low cation exchange capacity, may cause these cations to beome limiting to crop growth. Under our soil conditions where the base saturation appears to be remaining high even at pH values around 5.5, Ca and Mg would not be expected to be limiting under most conditions. In soils that had previously been low in Mg or K, the lowering of soil pH might further decrease the availability of Mg and K.

Under older acid soil conditions plant available phosphorus has been shown to decrease rapidly below pH 6.0. This decrease in plant availability is due to the formation of relatively insoluble iron and aluminum phosphate compounds as the levels of iron and aluminum increases in solutation as pH drops. However, under our conditions this effect on plant available P may be more gradual below pH 6.0 because lower levels of solution iron and aluminum do not cause unavailable iron and aluminum P compounds to form. In only slightly acid conditions more plant available calcium phosphates may dominate phosphate solubility. Under our current fertilization programs P fertilizer needs will probably not change drastically with moderate shifts in soil pH.

The volume of the rooting zone that has actually been acidified determines the effect of lowered soil pH on nutrient availability in recently acidified soils.

Because only the upper portion of our Columbia Basin soils have been acidified, most crops have roots growing into soil with a pH value well above 6.5. Therefore, except for shallow rooted crops, the acidification effect is lessened as the roots contact higher pH subsoils.

Nitrogen Relationships

At soil pH levels below 5.5 the rate of microbial release or mineralization of nitrogen and sulfur from soil organic matter may decrease. The rate of conversion of ammonium to nitrate (nitrification) also decreases. Under our conditions reduced mineralizations will probably not affect nutrient supply because of low organic matter levels in our soils. However, upon liming, a flush of plant available nitrogen may be observed as easily mineralizable organic compounds are broken down as microbial populations increase. This nitrogen flush has been observed for wheat in the Pendleton area (personal communications with Paul Rasmussen). The effect generally occurs only in the first year following liming.

As the rate of conversion of NH_4 to NO_3 (nitrification) is decreased at lower pH values, more NH_4 is taken up by the plant. This could then have an effect on the level of nitrate nitrogen found in potato petioles. Johnson and Jackson (7) found as they limed a Central Oregon potato soil to raise the pH from 5.4 to 6.3 they increased the percent nitrate nitrogen in the petioles (Table 1). Although petiole nitrate nitrogen was lower with the more acid soil the potatoes were not nitrogen deficient and yielded more at the lower pH. As our soils become more acid we may need to re-evaluate our interpretation of petiole nitrate levels and their relationship to yield.

Table 1. The effect of K, Lime, and S on Nitrate-N concentration of petioles on 8-5-80 Johnson, 1981(7).

Lime or S	pH	K treatment lb K/a[1]		
		0	200	800
		% NO_3-N		
Elemental S	4.5	2.02	1.68	1.43
0	5.3	2.29	1.80	1.63
2 T/a lime	5.9	2.43	2.07	1.75
4 T/a lime	6.4	2.44	2.15	1.84

[1] K applied as KCl

Aluminum and Manganese Toxicity

At pH values below 5.0 in older acid soils, the level of solution Al and Mn often increases to a level that interferes with plant growth. To date there has been no indication of Al toxicities with crop growth on our recently acidified soils. Manganese toxicities and elevated levels of Mn in leaves have been noted in some orchards where soil pH values have dropped below 5.0 in localized zones near the trees. No Mn toxicity in Columbia Basin row crops has been reported.

Plant Diseases and Physiological Disorders

The interactions between soil pH and various plant diseases and physiological disorders has been studied for many years. One of the most studied interactions has been the effect of pH and calcium on the occurrence and severity of potato scab. On highly buffered calcareous soils of southern Idaho, both gypsum and sulfur reduced common scab of potato (1). However, because the $CaCO_3$ present in the soil buffers or resists change in pH, the change in soil pH was only 0.1-0.4 pH units. Tissue analyses of tuber peelings showed a significant reduction in Ca from treatments involving sulfur and gypsum, indicating that higher Ca levels in tuber peelings were associated with higher scab susceptibility. Goto (4) in Japan found that the amount of exchangeable calcium in very acid soils was positively correlated with scab index of potato tubers, when the content of exchangeable Ca in soil exceeded 7.5 meq/100 g soil. In Queensland, liming of pH 5.1 soil was found to increase the incidence and disease index of powdery scab on potatoes (6). Acidifying this soil with sulfur to a pH level below 5.1 decreased powdery scab. In northern Ireland, sulfur treatments slowed down the development of foliage blight while the incidences of tuber blight, common scab, and black scurf in the cultivar King Edwards were reduced by the sulfur treatments and increased by lime (3). However, Easton and Nagle (2) found that sulfur either gave no control or inadequate control of shallow and deep-pitted scab near Eureka, Wa. It appears that under those conditions where the scab organisms are present in the soil, liming may tend to increase the incidence and intensity of scab.

The physiological disorder of potato tubers known as internal brownspot (IBS) has been reported to be influenced by stress factors such as high temperature and fluctuation in water supply. However, nutrient imbalance, such as inadequate Ca supply to affected tissue or a localized deficiency within the plant has been suggested as a primary cause (5). Hiller et al. (5) report that to date, little success has been reported in controlling IBS when Ca treatments are applied to field soil. However, Tzeng et al. (15) working with a Wisconsin soil with a cation exchange capacity of 4 meq/100 g soil, pH 5.9, and soil extractable Ca of 1.7 meq/100 g (340 mg/kg) (very low) found that Ca additions the soil significantly increased Ca levels in the peel. They found that the occurrence of IBS was significantly decreased as the Ca level in the peel increased. These results may indicate that at extremely low levels of plant available Ca the addition of Ca as gypsum or lime may have a positive effect on tuber quality.

Results of Liming Trials for Potato Production

The effect on yield, grade, or quality of potatoes of liming naturally acidic soils has been reported by many researchers from throughout the United States and the world and these effects have not been consistent. Lee and MacDonald (9) working with very strongly acid soils in New Brunswick, Canada, found that raising soil pH from 4.6 to either 4.9 or 5.2 with dolomitic limestone increased tuber yield and improved tuber quality. Greenhouse work indicated that potato production on these very strongly acid soils could be improved either by raising soil pH to 4.9 or by the application of Ca phosphate and Mg fertilizers without raising soil pH. Lime application to a pH 4.8 Alaskan soil increased yield, plant vigor, practically eliminated physiological leaf necrosis, and increased Ca and depressed Mn and Zn concentrations in both foliage and tubers (8). The production of potatoes on acid coarse-textured soils in Quebec was studied by van Lierop et al. (16). In greenhouse work they found that no yield increases were produced by liming soils which had pH values higher than 4.6 (0.01 M $CaCl_2$) or 4.9 (H_2O). Yields were generally not increased by liming when the concentration of extractable soil Al was $<$ 0.90 meq/100 g. These and other studies on naturally acid soils suggest that even under these highly acid conditions soil pH must be below 5.0 before a response to liming should be expected. However, closer to home, Oregon State University recommends the application of lime for western Oregon potato production where the OSU soil test for calcium is less than 4 meq/100 g soil and pH is below 5.5. These recommendations and finding would suggest that we should not be concerned about lime until soil pH goes below 5.5 and probably at or below 5.0.

Ca Response

The availability of Ca to the potato crop is also of interest under acid soil conditions. When potatoes were grown in acid coarse-textured Quebec soils no Ca deficiencies were observed: apparently this crop can absorb sufficient Ca when soils contain as little as 0.7 meq Ca/100g (140ppm) (16). In a recent series of studies Simmons et al. (13) investigated the effect of applied Ca sources on yield and quality of potatoes. Soils ranging from pH 4.7 to 5.9 were studied. These sandy soils with low exchange capacity range in soil test Ca from .6 to 1.8 meq Ca/100 g (510 to 1425 lbs Ca/a) (Table 2). In 1983 the total yield and grade were not significantly affected by the source of Ca applied (Table 3). However, the yield of 6-13 oz. tubers was greater with $CaSO_4$ sources than with lime or 0-46-0. Yield of 6-13 oz. tubers appeared to be increased by split applications of Ca as preplant $CaSO_4$ and sidedress $Ca(NO_3)_2$ (Table 4). The authors could not determine if solubility, placement, timing or some interaction was responsible for the differences found between rates of preplant and sidedress. Simmons et al. compared Ca response on four Wisconsin sites and obtained a yield response on two sites with less than 1.25 meq Ca/100 g (1000 lbs Ca/a) and no response on two sites with greater than 1.25 meq Ca/100 g (1000 lbs Ca/a) (Table 5).

They concluded that it is most likely a response will be noted where initial test levels of Ca are less than .6 meq Ca/100 g (500 lbs/a), possible when between .6-1.0 meq Ca/100 g (500-800 lbs/a) and unlikely when greater than 1.0 meq Ca/100 g (800 lbs/a). These levels of soil Ca are well below the levels that we are finding under our most acid low cation exchange capacity conditions. Therefore, we should not expect to find Ca deficiencies for a long time.

Table 2. Soil test levels at indicated locations of the calcium study. (Simmons, et al. 1985(13)).

Location	pH	P	K	Ca	Mg
		lbs/a			
1983					
Hancock	5.9	205	170	780	135
1984					
Hancock	5.9	225	170	640	155
Plover	5.0	220	270	510	140
Spooner	5.3	161	521	1250	310
Antigo	4.7	400	415	1425	280

Table 3. Effect of calcium source on tuber yield and grade (83). Hancock, Wisconsin. Simmons, et al. 1985(13).

Source	Total yield	Grade A	Grade B	Grade C	Yield US1A 6-13 oz
	cwt/a		%		cwt/a
$CaSO_4$ (A)[1.]	408	55	13	31	95
$CaSO_4$ (G)	412	60	11	29	120
$CaSO_4$ (S)	404	61	12	27	116
90-99 Lime	392	58	14	28	88
0-46-0	387	58	14	28	87
LSD (0.05)	NS	NS	NS	NS	21

1. A = Ampel $CaSO_4$, G = U.S. Gypsum Granular, S = U.S. Gypsum Sieve.

Table 4. Effect of applying preplant $CaSO_4$ in combination with sidedress $Ca(NO_3)_2$, Hancock (84). Simmons, et al. 1985(13).

Preplant Ca rate	Sidedress Ca (lbs Ca/a) 0	75	150
lbs/a	Yield (6-13 oz) cwt/a		
0	91	132	116
75	91	162	119
225	143	166	140
375	118	129	158
525	109	131	152

Significance: Pr > F	
Preplant (PP)	0.1242
Sidedress (SD)	0.0064
PP * SD	0.3804

Table 5. Effect of Ca rate on yield of tubers at four Wisconsin locations (84). Simmons et al. 85(13).

Preplant	Site	1	2	3	4
Ca[1]	Ca (lbs/a)	640	510	1250	1425
	Ca (meq/100 g)	0.8	0.6	1.6	1.8
		Yield US1A (6-13oz) cwt/a			
0		91	192	57	86
75		91	241	59	88
225		143	220	77	96
375		117	232	76	92
525		109	242	77	81
LSD (0.05)		37	34	NS	NS

[1] lbs/a of Ca applied as $CaSO_4$.

Lime Response in Central Oregon and Washington

Under the high elevation short growing season conditions of central Oregon, Johnson and Jackson (7) have studied the effect of soil pH and K levels on the yield and quality of potatoes at the Powell Butte Experiment Farm. Earlier studies had indicated that lime and/or gypsum additions could increase yields. The authors suggest that these increases have probably resulted from better soil physical conditions and better moisture penetration. A study in 1980 was designed to compare the effect of added S and lime as well as added K on soil properties and potato production. The soil studied had soil test levels of 160 ppm K, 36 ppm P, 10.1 meq Ca/100 g, and 3.9 meq Mg/100 g. Sulfur and lime were added to the soil with a pH of 5.3 to give a pH range from 4.5 to 6.4. The yield of tubers was increased by the added S and decreased by added lime (Table 6). The additions of K as KCl increased yield at all pH levels (Table 7). There was no evidence of a significant lime-K interaction. A specific reason for the decreased yields with increasing pH could not be determined. It is possible that the lime actually improved growth potential that was then limited by another growth factor. However, the author could not suggest another limiting factor. However, lime treatments increased phosphorus concentrations found in the petiole samples. This suggests that increased soil pH was not limiting P availability to the plants.

Table 6. Effects of Lime and S on pH, yield and grade of Russett potatoes. Johnson, 1981(7).

Lime or S	pH	Total yield T/a	#1 T/a
Elemental S	4.5	17.20	9.88
0	5.3	15.11	8.14
2 T/a lime	5.9	14.35	7.84
5 T/a lime	6.4	13.12	6.83

Table 7. Effect of K, Lime, and S on yield of Russett potatoes. Johnson, 1981(7).

Lime or S	K treatment, lb K/a[1.] 0	200	800
	Total yield, T/a		
Elemental S	14.5	17.60	18.75
0	11.34	14.48	18.33
2 T/a lime	9.49	14.91	17.27
4 T/a lime	10.09	13.63	15.34

1. K applied as KCl.

In 1986 Easton (personal communications from G. D. Easton) included a liming treatment in a soil additive study conducted on the Rosa Unit of the Irrigated Agriculture Research and Extension Center at Prosser. Two tons of sugarbeet lime was preplant incorporated and standard production practices were followed. The soil had a pH of 6.1-6.3, soil test levels of 40 ppm P and 304-358 ppm K. The lime application in the year of potato production reduced yield from 567 to 485 cwt/a (Table 8). The percent #1 tubers was decreased slightly by liming (not statistically significant). This soil would not have been expected to respond to liming.

Although this work is not conclusive and additional research is needed, it does point out the possible negative effects of liming only slightly acidified soils.

Table 8. Effect of liming on yield of potatoes at Prosser, (Easton, 1986).

Treatment	Total yield cwt/a	% #1
Control	567	77
2 tons sugarbeet lime	485	62

SUMMARY AND RECOMMENDATIONS

With a few of our soils acidified within the last 10-30 years with pH values near 5.5, the question of whether or not we need to lime at this time is relevant. When we consider the effect of liming on naturally acid soils and the limited information available on our recently acidified soils, we probably have not reached a point where liming is essential. The potato is one of the more acid tolerant crops even under very acid conditions. With our acid zone only in the upper portion of the soil profile and the high base saturation of even our most acid potato soils in the Columbia Basin, liming is not critical at this time. The addition of lime to raise the soil pH and possibly supply Ca on very low cation exchange capacity soils may be necessary on a few isolated soils. However, the research data and experience is currently not available to define the specific soil pH or exchangeable Ca levels necessary to obtain an economic response in tuber yield or quality. In some cases lime or gypsum, where soils are affected by high sodium, may improve soil physical properties to the point that a response might be obtained. However this is not a soil pH or nutrient availability response.

On those soils where the pH has dropped below 6.0 we should adjust our management practices to slow as much as possible the acidification process. The addition of excess N should be avoided. Excess N not only adds additional H ions to the soil system, but also encourages the loss of Ca and Mg from the system as they are leached out with the excess nitrates. The use of reduced forms of S, such as elemental S, should be limited because microbial oxidation of reduced S forms also supplies H ions to the soil solution. When possible, needed S should be applied in the sulfate form. Irrigation should be scheduled to limit leaching loss to that needed to prevent salt buildup. Excessive irrigation increases leaching loss of Ca and Mg, as they move out of the soil with nitrate.

Lime applications will be needed on less acid tolerant crops before it is needed on potatoes. Mahler and McDole (11) found peas and lentils to be much less acid tolerant than wheat grown on recently acidified soils under northern Idaho conditions. Peas and lentils had a minimum acceptable soil pH of 5.6 and 5.5 respectively required for maximum yields. Cereal minimum acceptable soil pH ranged from 5.2 to 5.4. We should expect legumes such as peas and alfalfa to be among the first crops to show yield reductions caused by soil acidification.

If your soil pH is low enough that you are concerned about the need for application of lime, field test strips will help you determine the lime response under your conditions. However, remember that the reaction of lime with your soil is a slow process and lime should be applied well in advance of the crop need (several months). Start with an application of 1 to 2 tons of lime per acre, depending on your soil texture. Heavier soils will require more lime for the same pH change. Remember do not overlime, this will cause your soil to respond as a calcareous soil.

As more research information is obtained and as dealers and growers gain more experience, our understanding of the liming situation will undoubtedly change. Therefore, all parties concerned must work together as we learn to manage the ongoing acidification of our Columbia Basin soils.

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