SULFUR REQUIREMENTS OF RUSSET BURBANK POTATOES IN WASHINGTON'S COLUMBIA BASIN

by
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Introduction

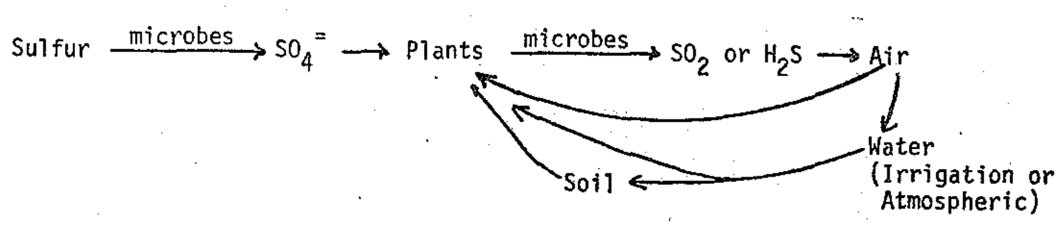
There is no question about sulfur being necessary for plant life. Sulfur is a constituent of three amino acids and is therefore essential for protein synthesis. The actual amount of sulfur needed by potatoes is relatively small, and no surfur deficiencies in potatoes, under field conditions, have been reported. When a sulfur deficiency does occur in other plants, it results in a slow loss of green color starting in terminal leaves and in small, weak plants.

Some believe that the amount of sulfur obtained from the air exceeds the potato requirement. Sulfur dioxide (SO_2) and hydrogen sulfide (H_2S) are constantly being released into the atmosphere from many sources, and then being brought back to earth by precipitation. Sulfur containing gases can also be absorbed directly through the leaves. Some studies indicate that increasing rates of sulfur decrease the uptake of nitrogen, chloride, and potassium by plants.

It has been estimated that the amount of sulfur removed from the soil by a potato crop amounts to about 11 to 12 Kg per hectare (9-10 lb/acre). Studies in Washington have shown that the amount of sulfur removed from the soil depends upon the size of the yield. About 2.4 lb of sulfur are contained in 100 cwt of potatoes. Thus, 400 cwt would remove 9.6 lb of S from the land, whereas 800 cwt would remove 19.2 lb of S.

Sulfur forms sulfuric acid when oxidized. The oxidation in nature is a microbial process. One pound of sulfur will produce enough acid to dissolve about 3.1 lb of limestone, and it participates in the pathways shown in the diagram. At near optimum moisture and temperature levels, most of the conversion of solid, unusable sulfur forms to soluble, plant usable forms takes place over a few weeks or months, Figure 1.

Figure 1.



When some potato growers wanted to lower the pH of their calcareous Columbia Basin soils to about pH 5 to control potato scab, we became alarmed. Large quantities of sulfur would be required, and calcium would be lost from the soil in the process.

Some questions concerning sulfur that appeared to need answers were:

1. How much sulfur is needed under various growing conditions?
2. How much is presently being applied to Columbia Basin soils?
3. Is there evidence for a sulfur response on potatoes in our area?

Procedure

In 1975-76, Chevron sampled irrigation water from the Columbia River in the Umatilla-Patterson-Boardman area. Averaged data from three locations are presented in Table 1.

Table 1. Average pounds sulfur/acre inch of Columbia River water (1976).

Month	lb S/ acre inch
April	1.67
May	1.23
June	.82
July	.73
August	.82
September	.97
October	1.23
November	1.31
Mean	1.10

The amount of sulfur in Columbia River water is highest in the spring and fall, and lowest in the summer months. It averages out to roughly a pound of sulfur per acre inch of applied water.

Water is applied, both to grow crops and to stop soil erosion by wind, throughout an eight month period or longer in the Columbia Basin area. Typical amounts of water required to grow a potato crop, and corresponding amounts of sulfur contained in that water are listed in Table 2.

Table 2. Amounts of Water Required to Grow a Potato Crop. *

Days to Grow Crop	Acre in. Water Applied	lb S/ Acre Applied	Typical Cwt. Produced	lb S in Tubers
90	27	27	400	9.6
100	30	30	420	10.1
120	36	36	520	12.5
140	42	42	605	14.5
160	48	48	700	16.8
180	54	54	775	18.6

*Based on an average evapotranspiration rate of .30 acre inch of water per day.

It is obvious that the amount of sulfur applied depends upon the number of days the crop is to be grown. The calculations are based on an evapotranspiration rate of .30 acre inches per day, and an irrigation water sulfur content of one pound per acre inch of water. Actual sulfur content of the water is high for the spring and fall months, but low during the hot summer months. Conversely, the rate of water application is low in the spring and fall, but high during the hot summer months. Therefore, use of the estimate of one pound of sulfur per acre inch of irrigation gives only a rough estimate of how much sulfur is being applied to the soil with the irrigation water. Though it slightly overestimates the amount of sulfur applied, it is sufficiently accurate when one realizes that three times as much sulfur is being applied than actually required by the crop.

In addition to the water, sulfur for potatoes in the Columbia Basin can be obtained through mildew control, ammonium sulfate fertilizer, and potassium sulfate fertilizer. The total amount applied could range from the estimates of Table 2 to approximately 118 or more lb of sulfur per acre (Table 3). The total amount of sulfur applied could even exceed the amounts shown in the table by using more sulfate fertilizer than shown or by applying an additional sulfur treatment for mildew control.

Table 3. Estimated Amounts of Sulfur Applied per Year per Acre When Growing Potatoes in the Columbia Basin (all sources).

Sources of Sulfur	lb/Acre
Water = 150 days x .30 acre in/day	45
Mildew Control	12
Ammonium Sulfate (100 lb/acre)	24
Potassium Sulfate (200 lb/acre)	37
Total	118

In a large number of experiments, we have established that the average amount of sulfur removed from the soil by potatoes depends on the size of the crop. It amounts to about .024 lb sulfur/cwt of potatoes. Thus, a 35 ton crop would remove about 17 lb of sulfur. Nearly 100 lb would be left in the soil, if none were leached away. Of course, leaching the soil for salinity control and because of irrigation water application inefficiencies, much of this sulfur moves beyond the plant root zone.

Linear correlation coefficients relating petiole sulfur and total yield were calculated using the results of 1600 tissue analyses. The coefficients were not large, but many were negative, suggesting a decrease in yields as plant petiole SO_4-S levels increased. Table 4 provides data from a typical study.

Table 4. 1975 K_2H Minimum Tillage Study.

Days after Planting	% Petiole SO_4-S	r Value SO_4-S vs. Yield	Significance
80	.231	-.3529	NS
95	.206	.3094	NS
107	.203	-.6078	NS
117	.189	.0514	NS
128	.174	.3516	NS
139	.157	-.3183	NS
149	.144	.0076	NS

If sulfur were causing a reduction in yield, the size of the negative coefficients would be expected to increase as the growing season progressed, because sulfur was being added continuously in the water. There is a trend in this direction in data obtained from a study on the Royal Slope (Table 5).

Table 5. 1975 Royal Slope Minimum Tillage Study.

Days after Planting	% Petiole SO_4-S	r Value SO_4-S vs. Yield	Significance
70	.221	.0493	NS
80	.192	-.1026	NS
90	.229	-.0227	NS
100	.276	-.1330	NS
111	.219	-.2082	NS
121	.195	-.2210	NS
131	.212	-.7250	NS
142	.147	-.8699	*

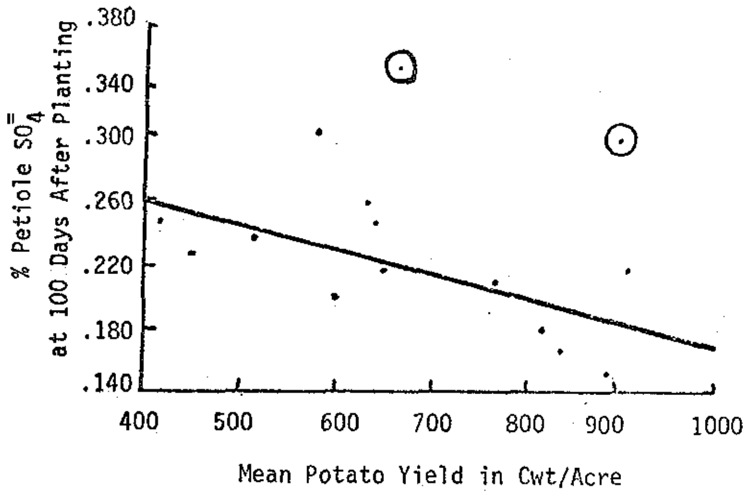
There was a similar trend for the data obtained from a similar study conducted at the Othello Research Station, with some of the negative correlation coefficients reaching the 1% level of significance (Table 6). The Othello Station had been irrigated several years longer than the Royal Slope Station and therefore more sulfur had been applied.

Table 6. 1975 Othello Minimum Tillage Study.

Days after Planting	% Petiole SO_4-S	r Value SO_4-S vs. Yield	Significance
81	.191	-.0015	NS
91	.291	-.4519	*
103	.226	-.1254	NS
113	.248	-.2714	NS
123	.218	-.2887	NS
133	.190	-.6422	**
145	.188	-.4930	*
155	.156	-.6030	**

To establish an optimum petiole sulfur level, we selected the two highest-yielding plots out of 15 experiments, regardless of treatment, and calculated a linear correlation coefficient between yield and petiole SO_4-S levels. It turned out to be a -.618, which was significant at the 5% level if the two highest points (circles) were omitted from the calculations. The slope of the regression line changed when the circled dots were included in the regression, but the conclusion was unchanged -- namely that SO_4-S levels in the plant apparently can get high enough to reduce potato yields.

Figure 2. Regression: Petiole SO_4-S vs. Total Yield (Highest yielding plots in 15 experiments)



Nevertheless, the data are difficult to evaluate because, in a series of sources of nitrogen and potassium studies in which the amount of sulfur in the fertilizer was high, there was neither an advantage nor a disadvantage from using the sulfate containing fertilizer (Table 7 & 8). If the sulfur were producing a significant growth effect, evidence of it should also have been found in these experiments.

Table 7. Source of Nitrogen Studies.

	NH_4NO_3	$(NH_4)_2SO_4$	Urea
Total yield cwt/acre	540	553	530
Percent No. 1's	67	68	68
Specific gravity	1.082	1.082	1.082
Blackspot index	67	67	68
Chip color	26	26	26
% petiole nitrates	3.28	3.53	3.47
% petiole total N	2.73	2.88	2.83
" " " P	.33	.34	.33
" " " K	7.30	7.50	7.41
" " " Ca	1.52	1.37	1.41
" " " Mg	.77	.73	.76

Table 8. Source of Potassium Studies.

	KCl	K_2SO_4	KNO_3
Total yield cwt/acre	554	550	598
Percent No. 1's	70	71	68
Specific gravity	1.084	1.084	1.088
Blackspot index	69	68	65
Chip color	26	25	24
% petiole nitrates	4.84	6.10	5.78
% petiole total N	3.15	3.03	3.07
" " " P	.33	.31	.28
" " " K	9.20	8.60	8.70
" " " Ca	2.87	2.63	2.82
" " " Mg	1.34	1.30	1.37

In addition, several studies with sulfur coated urea have shown no evidence of a sulfur effect.

Petiole nitrate levels in the potassium source studies were consistently higher where potassium sulfate was used. This suggested that sulfur enhanced the uptake of nitrogen. Since the percent total nitrogen was depressed, the higher nitrate levels may have resulted because they were not being used for growth. If nitrogen is available and growth slows down, regardless of the cause, *nitrates tend to accumulate*. This conclusion is supported by the negative correlation with yield. As the season progressed, the percentage sulfur in the petiole actually decreased, though the correlations between petiole SO_4-S and yield became more negative (Tables 5 & 6). Unfortunately, we do not have sulfur petiole data for the studies of nitrogen and potassium fertilizer sources. In some other studies, though, applying sulfate sulfur in the fertilizer markedly increased the amounts of sulfate sulfur in potato petioles.

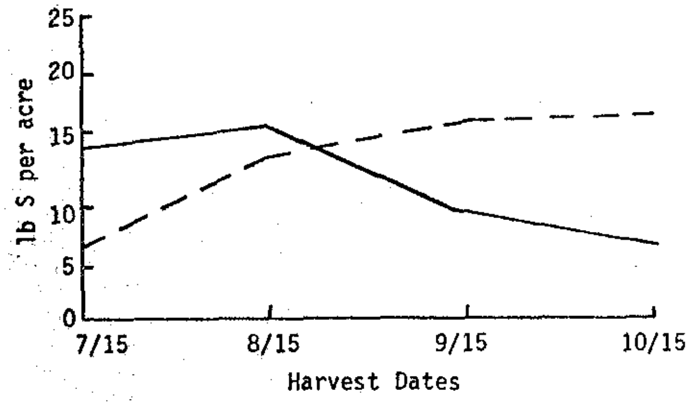
How much sulfur is needed to grow a large potato crop? In another experiments, there were 8 replications of 10 plants each. Thus, the means (Figure 3) represent the amounts of *sulfur in 80 plants exclusive of the roots*. Note the broken line, the amount of sulfur increased as the yield increased. Note also the solid line after August 15; there was a decrease in the sulfur content of the vines almost corresponding to the increasing amount of sulfur in the tubers. The agreement might have been even better had it been possible to include loose leaves that had fallen to the ground by the October 15 sampling data. Actual amounts of sulfur found in the plant and tubers in this experiment are given in Table 9.

Table 9. Pounds of Sulfur in Vines and Tubers. *

Sampled	Tubers	Vines	Total S
7/15	6.6	14.6	21.3
8/15	14.2	17.0	31.2
9/15	16.7	10.0	26.7
10/15	17.6	6.8	24.4

*1968 data. Planted April 1. Yield Oct. 15 = 732 cwt/acre.

Figure 3. Pounds of Sulfur in Vines and Tubers Exclusive of Roots, 1968 Data. (Planted April 1. Yield Oct. 15 = 732 cwt/acre.)



There was only .2% sulfur in the 16-16-16 fertilizer used for the above studies, or 6 lb/acre. The amount of sulfur in the tubers and vines totaled 31 lb/acre on August 15. There might reasonably have been an additional 9 lb in the roots (not determined), for a total of 40 lb of sulfur in the 732 cwt/acre potato crop. If a 50% efficiency factor could be assumed, the total amount of sulfur in the soil necessary to grow a 732 cwt/acre potato crop would approximate about 80 lb/acre of sulfur. Only 18 lb of this would be removed from the land, however, leaving about 100 lb of sulfur in the soil if none were leached away (e.g., Table 3). Within a few years, an excess of sulfur could accumulate in the soil if judicious irrigation were practiced.

Summary

A number of replicated block experiments using nitrogen and potassium sources were conducted in various parts of the Columbia Basin over a period of years. No advantages were obtained from using nitrogen and potassium sources containing sulfur. There is some indication that the amount of sulfur contained in Columbia River water is adequate to grow a 35 ton, or larger, potato crop; and, that additional sulfur might even tend to depress yields. The data strongly suggest that over a period of time, detrimental effects might occur from the addition of too much sulfur.

The data are only suggestive, but they should serve as a caution to alert the industry of trends that might be taking place in the Columbia Basin.