BORON AND SULFUR NUTRITION OF POTATOES

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Two of the essential plant nutrients, boron (B) and sulfur (S), have not been studied at greatlengths in terms of their requirements for potato production. The physiological roles of the essential plant nutrients in potato production were reviewed recently by Kunkel and Thornton (1986). It was of interest to consider B and S in our N utilization studies because these nutrients are present in soluble forms and follow the pattern of NO_3-N in regard to mobility and the way they move with soil water. A supply of S is needed along with N as a constituent of protein. The role of B in plant nutrition is not well defined. Excess B is detrimental and limits plant growth. Toxicity symptoms of B appear as severe necrosis at leaf tips and margins resulting in upward cupping of leaves (James and Weaver, 1964).

It was of interest to determine if luxury consumption of S along with subtoxic levels of B might prove beneficial in ameliorating N use for sustaining uniform growth of tubers. Typical deficiency symptoms for N, S and B are indicated in Table 1 along with the anticipated removal of these nutrients by the harvested potato crop. Table 2 shows the relative B requirements of selected crops. It has often been stated that the level of B needed for growth of crops with high B requirements approaches the toxicity level of crops with low requirements.

In the case of both B and S, irrigation water may be an important source of supply. In our area, the S content of irrigation water has probably been examined more closely than the B content. With the exception of some portions of the Yakima River, the S distributed in irrigation from other Washington rivers is nearly adequate for many crops (Table 3). Fortunately, there is little or no problem from sources of water which contain high B (Table 3). The B and S content or irrigation water from wells may differ from one well to the next and needs to be determined for each well.

The calibrations of B and S soil tests are lacking in precision and responses of potatoes to these nutrients are not well documented. Generally B fertilization in this area has been restricted to B responsive crops like alfalfa with a recommendation to apply 1 to 2 lb B/a (3 lb/a maximum) when the soil test falls below 0.5 ppm B (James and Weaver, 1964). There are usually no recommendations for B on potatoes. When S is needed typical rates for potatoes range from 20 to 40 lb S/a.

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Procedures

An experiment was conducted with Russet Burbank on sprinkler irrigated Warden silt loam at Prosser, Wa. The primary purpose was to evaluate the response of potatoes to S and B treatments. The replicated treatments involved 300 and 500 lb N/a, 0, 20 and 40 lb S/a and 0, 2 and 4 lb B/a. Related aspects of the study were not reported here, but involved the effect of B fertilization on the uptake of ^{15}N-tagged fertilizer, treatments with 0, 20 and 40 lb P/a and 40, 75 and 150 lb K/a.

The pre-treatment soil tests are in Table 4. Potatoes were planted April 25 and harvested September 20. Tissue samples consisting of petioles and whole plants were collected during the season. Tuber yield was recorded at harvest time with a determination of grade out and internal characteristics of tubers.

Results

Total yield of tubers in Table 5 showed no response to B, but there was a trend toward higher yield with 40 lb S/a. The N rate was constant at 300 lb N/a. The internal defects involving hollow heart (HH), brown center (BC) and internal brown spot (IBS) were low without many noticeable differences among B and S treatments (Table 6). The treatment with 20 lb S/a, 2 lb B and 500 lb N/a footnoted in Table 6 seemed to involve unusually high incidence of BC at 28%. One explanation is that BC may result from interrupted growth brought on by greater susceptibility to stress of the larger high N vines. There is some speculation a limited Ca supply in the plant tops resulting in a lower Ca/K ratio of nutrients going into the tubers favors internal disorders. This situation needs further study.

The grade out, size and specific gravity of tubers obtained with all treatments were acceptable. The U.S. No. 1 grade amounted to about 80% with over 40% of total tubers in > 8 oz category. The specific gravity covered a narrow range of 1.083 to 1.087 for the various treatments.

There is considerably more work left to do on chemical analysis of plant samples for N and S in this study. The B concentration and total uptake in plant tops and tubers are in Table 7. The B concentration in plant tops was more than five times as high as the B concentration in tubers; this resulted in nearly twice as much total B uptake in the tops as in tubers based on measurements late in August (Table 8). The total B uptake in tubers changed very little between samplings in August and September. These results show about one-fourth of a pound of B per acre taken up by whole plants with removal of less than one-tenth of a pound per acre in the harvested tubers.

Table 9 shows on the average a trend for the highest percent U.S. No. 1 tubers for the treatment with 2 lb B/a. The trend in Table 9 may relate to the trend in Table 10 where the percentages of > 8 oz tubers were numerically higher where 40 lb S/a was combined with either 2 or 4 lb B/a. These treatment effects were not statistically significant under the conditions of this experiment.

There was no evidence of B toxicity with fertilization at rate of 4 lb B/a. A report from Maine indicated plants were stunted with reduced yield from B at 4 lb/a or more (Porter et al., 1986). Yield reduction resulted from fewer tubers per hill rather than reduced tuber size. Increasing rates of B fertilizer increased petiole B levels from 14 to 54 ppm in mid-July. It was concluded there was no advantage in increasing tissue B levels above the control values. In our study, one point of interest was to determine the possibility for increasing tuber size in conjunction with B treatments which reduced tuber numbers as reported in the study from Maine. In Maine, the acidic soil at pH 5.5 probably maintained greater solubility of B than did our soil at pH 6.8, which may explain why they observed toxicity with 4 lb B/a and we did not.

Summary

It is too early to conclude that wide-scale B and S fertilization is needed to maintain potato yields. More testing is needed to determine if B and S interacting with other nutrients benefits potato quality factors. Although soil tests for B and S are not well calibrated, they may show trends in fertility and prompt changes for improved fertility management. Water analysis including B and S content may be helpful in determining nutrient requirements or irrigated crops.

REFERENCES

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Table 1. Symptoms of Nitrogen, sulfur and boron deficiency in potato plants and nutrient removal in 30-ton potato crop.

Element	Deficiency symptoms	Nutrient removal in 30-ton
Nitrogen (N)	Plants are light green with slow growth showing chlorosis first on older leaves.	180
Sulfur (S)	Plants may show general chlorosis and usually have symptoms first on young leaves.	14†
Boron (B)	Acute deficiency may cause death of growing tips; lateral shoots are produced with dying tips to give shortened internodes and a bushy appearance.	0.04†

† For comparison, phosphorus removal at 42 lb is about three times S removal and zinc removal at 0.12 lb is three time B removal.

Table 2. Relative boron requirement for various crops.

Low	Medium	High
Potatoes	Carrot	Alfalfa
Corn	Onion	Asparagus
Wheat		Sugarbeet

From James and Weaver, 1964.

Table 3. SO_4-S content of irrigation water from rivers in Washington.

Source	Location	S† lb/acre ft	B‡ range, ppm
Columbia R	Main Canal	10.2	0.00-0.09
Columbia R	Head, Potholes Canal	47	0.00-0.09
Snake R	Pasco	25.3	-
Yakima R	Roza Canal	2.0	0.00
Yakima R	Head, Sunnyside Canal	3.8	0.00-0.01

† Reported by Dow and Cline, 1975; ‡ Reported by James and Weaver, 1964.

Table 4. Soil test results for Russet Burbank potato fertility experiment at Roza field E-40, 1986.

Soil test	Result
pH	6.8
$NO_3 + NH_4$-N†	1.4 ppm
P	14 ppm
K	141 ppm
S	4.7 ppm
B	0.31 ppm
OM	0.7%
Soluble salts	0.49

† Sum of ppm in 0-3 ft soil profile.

Table 5. Potato yields (t/a) with treatments including boron and sulfur fertilizers, 1986.†

S applied	B applied, lb/a		
lb/a	0	2	4
0	27.9	27.9	-
20	28.0	27.9	27.9
40	-	28.9	32.7

† Includes 300 lb N/a as NH_4NO_3 with S as K_2SO_4 and B as Solubor.

Table 6. Russet Burbank potatoes showing internal defects designated hollow heart (HH), brown center (BC) and internal brown spot (IBS) with sulfur and boron treatments, 1986.

Sulfur lb/a		B lb/a 0	2	4
		% defective tubers		
0	HH	1.6	2.4	-
	BC	3.1	5.5	-
	IBS	3.1	3.2	-
20	HH	0.8	0.8 (7.8)†	3.1
	BC	4.7	9.4 (28.1)†	7.8
	IBS	3.2	2.4 (1.6)†	3.1
40	HH	-	1.6	0
	BC	-	3.1	4.7
	IBS	-	1.6	3.1

† Rate was 500 lb N/a with all other treatments at 300 N/a.

Table 7. Total boron concentration in plant tops and tubers of Russet Burbank potatoes sampled 8/26/86.

	B applied, lb/a		
Sample	0	2	4
	B concentration in tissue (ppm)		
Tops	36	53	57
Tubers	5.5	7.7	7.9

Table 8. Total boron uptake in plant tops and tubers of Russet Burbank potatoes sampled 8/26/86 and in final harvest, 9/20/86.

	B applied, lb/a		
Sample	0	2	4
	Total B uptake (lb/a)		
Tops	0.13	0.14	0.15
Tubers	0.06	0.09	0.09
Total	0.20	0.23	0.24
Final harvest			
tubers	0.07	0.08	0.08

Table 9. Potato grade-out and size following treatments with boron and sulfur, 1986.

S applied lb/a	B applied, lb/a 0	2	4
	U.S. No. 1 tubers, %		
0	73	83	0
20	81	82	75
40	-	83	77

Table 10. Potato grade-out and size following treatments with boron and sulfur, 1986.

S applied lb/a	B applied, lb/a 0	2	4
	U.S. No. 1 tubers > 8 oz, %		
0	45.9	45.1	-
20	42.9	42.7	39.4
40	-	48.5	47.7