Effect of Selenium on the Nitrogenous Constituents of the Potato

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The effect of soil applications of selenium on Katahdin potatoes was investigated in each of 2 years. Sodium selenite was banded to the soil at rates of 0.0, 5.6 (2.5), 11.2 (5.0), and 18.0 (7.5) kg/ha (ppm) 1 day prior to planting of potatoes. In both years the protein content was significantly higher in tubers from plants given selenium than in the controls. However, selenium fertilization greater than 11.2 kg/ha did not result in further increases in the protein content. Nonprotein nitrogen was significantly reduced by selenium treatment. The essential amino acids threonine, valine, isoleucine, leucine, and phenylalanine of the protein fraction increased significantly. An overall increase in the total and protein amino acids as well as a decrease in the free amino acid pool occurred with selenium fertilization. These trends were consistent in each of the 2 years of the study.

INTRODUCTION

Selenium deficiency in humans and livestock is prevalent worldwide, especially in Finland, New Zealand, and parts of China. The selenium content of soils of the northeastern and northwestern United States is also low (less than 0.10 ppm), and selenium supplementation might be useful. Selenium in the form of selenite has been added to soils and observed to increase the amount of selenium (Girling, 1984) available to plants. It is an accepted practice in New Zealand and Finland now to add selenium to fertilizers that are used for forage and crop production. According to Korkman (1987), granulated selenium (1% Se^{6+}) can be added to granule fertilizers. In Finland, solutions containing Se^{6+} are sprayed onto fertilizer granules at a concentration of 6 g of Se/kg in fertilizers used for silage and 16 g of Se/kg for fertilizer used in cereal production (Korkman, 1987). It is also important that the effect of selenium supplementation on the nutritive value of the crops be studied. Selenium is now considered an essential mineral for adult humans and intakes of 50–70 μg/day are suggested (Committee on Dietary Allowances, 1989).

Uptake of selenate and selenite has been considered to be analogous to that of sulfate and sulfite, respectively (Girling, 1984). Since selenium and sulfur share several common properties, selenium tends to replace sulfur in molecules like cysteine and methionine. Gissel-Nielsen (1971) found that the selenite selenium was metabolized into selenomethionine and translocated to the arial parts of the plant. Peterson and Butler (1962) and Shrift and Ulrich (1969) showed that the uptake of selenium in both Se accumulator and nonaccumulator plants proceeded at the same rate. Butler and Peterson (1967) found that nonaccumulator plants contained protein-bound selenium as the insoluble selenomethionine and inorganic selenium, while in Se accumulator plants the selenium was converted into the soluble (and presumably less phytotoxic) selenoamino acids methylselenocysteine and selenocystathionine.

Potatoes are excellent sources of nutritionally important compounds such as protein and several essential amino acids. According to Kaldy and Markakis (1972), raw potatoes can provide higher quality protein than soybeans. The high lysine content of potato protein also makes it an ideal supplement to cereal protein. Thorn et al. (1978) reported potatoes to contain less than 0.01 ppm of selenium. Selenium supplementation of the potato, a crop consumed most widely by humans, could also help increase selenium intake by humans especially in areas of selenium-deficient diets.

The protein content of potato tubers can be influenced by several factors such as fertilizer and mineral nutrition. Tjornhom and Bychkov (1975) found that the protein content of tubers was increased by nitrogen fertilization. Tuber protein has been shown to be increased by soil supplementation of minerals such as magnesium (Klein et al., 1982) and molybdenum (Mondy and Munshi, 1988). No studies have addressed the effects of selenium fertilization on the protein and amino acid content of the potato tuber. The objective of this study was to investigate the effect of supplementing sodium selenite (Na_2SeO_3) on the nitrogenous constituents of the potato.

MATERIALS AND METHODS

Katahdin potatoes (*Solanum tuberosum*) grown at the Cornell Vegetable Research Farm in Freeville, NY, were used in this study. The selenium concentration of the soil was found to be 0.11 ppm. Selenium, in the form of sodium selenite (Na_2SeO_3, 99% obtained from Aldrich Chemical Co. Inc.) was banded onto the soil at rates of 0.0, 5.6 (2.5), 11.2 (5.0), and 18.0 (7.5) kg ha^{-1} (ppm). Since selenite (SeO_3^{2-}, i.e., Se^{4+}) is the predominant selenium form at the soil pH of 6.8, sodium selenite was preferred to sodium selenate. Also, the selenate form (SeO_4^{2-}, i.e., Se^{6+}) is more easily leached and more expensive than the selenite selenium form. The investigation was carried out in each of 2 years. There was no industrial selenium contamination at the site of study. The tubers were mechanically harvested 18 weeks after planting. They were washed and stored in mesh bags at 5 °C and 95% relative humidity until analyzed.

Tubers were cut longitudinally from bud- to stem-end and the slices separated into cortex and pith sections, frozen, and lyophilized in a Stokes freeze drier. The lyophilized tissue was ground in a Wiley mill and passed through a 40-mesh screen. Lyophilized powder was used to determine total nitrogen, nonprotein nitrogen, protein nitrogen, protein amino acid, and selenium contents.

Determination of Protein. The AOAC (1975) method was used to determine total nitrogen. A modified version of the method by Desborough and Weiser (1974) was used to deter-

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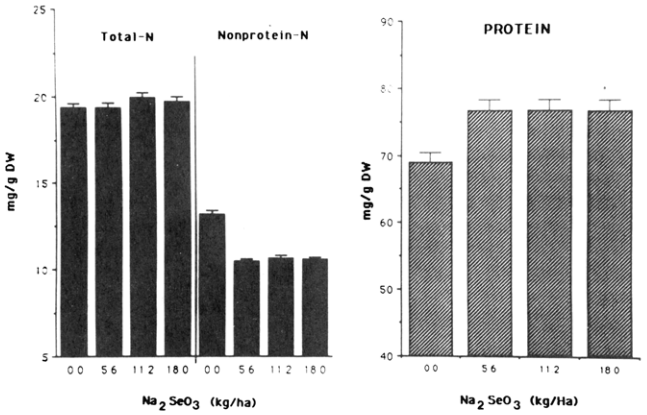

Figure 1. Effect of soil applications of sodium selenite (Na_2SeO_3) on the total nitrogen, nonprotein nitrogen, and protein content of the cortex section of Katahdin potato tubers.

mine the nonprotein nitrogen. Lyophilized tissue was mixed with TCA to precipitate the proteins; the mixture was centrifuged at 20000*g* and filtered, and nonprotein nitrogen was determined on the filtrate.

Protein nitrogen was determined by subtracting nonprotein nitrogen from total nitrogen and multiplying the result with the 7.5 Kjeldahl conversion factor as described by Desborough and Weiser (1974).

Amino Acid Analysis. The precolumn derivatization method of amino acid analysis using high-performance liquid chromatography (HPLC) was used (Biddlingmeyer et al., 1984). The derivatization reagent consisted of ethanol–triethylamine (TEA)–water–phenyl isothiocyanate (PITC) in the ratio of 7:1:1:1. The free amino acid pool was extracted with 2 mL of distilled water, and 20 μL of the supernatant was derivatized. The derivatized volume was reconstituted to 200 μL, and 20 μL of this volume was injected into the HPLC. The total amino acid content was assayed by hydrolyzing the aqueous extract. Hydrolysis was carried out by adding 0.1 M HCl to the extract and heating the mixture to 150 °C for 95 min. The hydrolyzed sample was derivatized, reconstituted, and injected into the chromatograph. Selenocysteine and selenomethionine were used as standards in addition to the standard amino acids.

Selenium Analysis. Selenium content of lyophilized potato tissue was determined by using the diaminonaphthalene fluorometric method of Olson et al. (1975).

Statistical Analysis. Complete random design was employed, and statistical significance of the data was determined by analysis of variance (ANOVA) with protected LSD test (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

During both years of the study both the protein nitrogen and protein content of tubers from plants given selenium were significantly ($p < 0.05$) higher (Figure 1) than the control values. At selenium supplementation of 5.6 kg/ha the increase in the protein content was 6.7%. Higher levels of selenium supplementation did not result in further increases in the protein content of the tubers. Since potato protein is considered to be of higher nutritional quality than soybean protein, this increase in protein is significant.

In both years of the study the total nitrogen of tubers from plants supplemented with selenium was not significantly different from that of the controls. Nonprotein nitrogen of tubers from plants given selenium was significantly ($p < 0.05$) lower than the control values. The nonprotein fraction consists largely of free amino acids and amides, and decreases in the free amino acid fraction (Table II) may have accounted for the decrease in the nonprotein fraction.

The effect of selenium fertilization on total amino acid fraction is shown in Table I. The essential amino acids, threonine, valine, isoleucine, leucine, and phenylalanine,

Table I. Effect of Selenium on Total Amino Acid Content of the Cortex Region of Katahdin Potato Tubers

amino acid	amino acid content, mg/g DW, with Na_2SeO_3 applied at			
	0.0 kg/ha	5.6 kg/ha	11.2 kg/ha	18.0 kg/ha
Asx	30.70	35.95	33.13	35.76
Glx	16.83	26.79	21.83	20.61
Ser	3.54	3.67	4.99	5.13
Gly	2.49	2.57	3.50	4.13
His	1.86	2.13	2.49	2.85
Arg	9.74	11.22	11.98	5.78
Thr[a]	2.61	2.72	3.55	3.84
Ala	2.33	2.54	3.82	5.49
Pro	2.25	2.23	3.61	7.16
Tyr	3.35	4.17	3.84	1.19
Val[a]	4.84	5.79	7.16	7.54
Met[a]	1.41	2.18	1.68	2.15
Cys	0.87	1.03	1.04	0.44
Ile[a]	3.26	3.82	3.73	4.94
Leu[a]	4.26	4.40	4.95	7.23
Phe[a]	3.47	4.18	4.07	5.31
Lys	4.02	4.55	5.37	6.69
total	97.83	119.94	120.74	126.24

[a] Essential amino acids.

Table II. Effect of Selenium on the Free Amino Acid Content of the Cortex Region of Katahdin Potato Tubers

amino acid	amino acid content, mg/g DW, with Na_2SeO_3 applied at			
	0.0 kg/ha	5.6 kg/ha	11.2 kg/ha	18.0 kg/ha
Asx	33.65	25.98	29.32	28.60
Glx	17.13	11.39	9.92	11.18
Ser	1.66	1.33	1.45	1.44
Gly	0.37	0.50	0.29	0.32
His	0.98	0.47	0.98	0.95
Arg	3.95	3.57	3.14	3.75
Thr[a]	0.77	0.62	0.54	0.62
Ala	0.86	0.67	0.56	0.67
Pro	2.73	2.49	2.72	2.95
Tyr	1.56	0.79	0.88	0.99
Val[a]	3.39	2.54	2.60	2.99
Met[a]	0.79	0.64	0.74	0.83
Cys	0.03	<0.02	0.02	<0.02
Ile[a]	1.65	0.98	1.09	1.26
Leu[a]	0.67	0.42	0.47	0.57
Phe[a]	1.68	0.97	1.01	1.22
Lys	1.43	0.76	1.10	1.09
Trp[a]	0.69	0.49	0.58	1.64
total	73.99	54.66	56.32	61.09

[a] Essential amino acids.

increased 47%, 56%, 53%, 52%, 70%, and 53%, respectively, due to the high application rate of selenium compared to the control. The free amino acid content of potatoes receiving selenium fertilization is given in Table II. The essential amino acids of this fraction, threonine, valine, isoleucine, leucine, and phenylalanine, decreased 23%, 20%, 35%, 27%, and 36.5%, respectively. Tryptophan and methionine followed a similar trend at the lower levels of selenium application but increased significantly at the highest level of selenium application (18 kg/ha).

All essential amino acids of the protein fraction increased significantly (Figure 2) with the highest level of selenium, resulting in the greatest increases. The cysteine content of the tubers was decreased significantly by selenium fertilization. No significant amounts of selenocystine or selenomethionine were detected. Similar trends were observed for both the cortex and pith regions.

Selenium supplementation did not affect the yield and dry matter content of the tubers. Plant growth and maturity were normal, and no visible symptoms of selen-

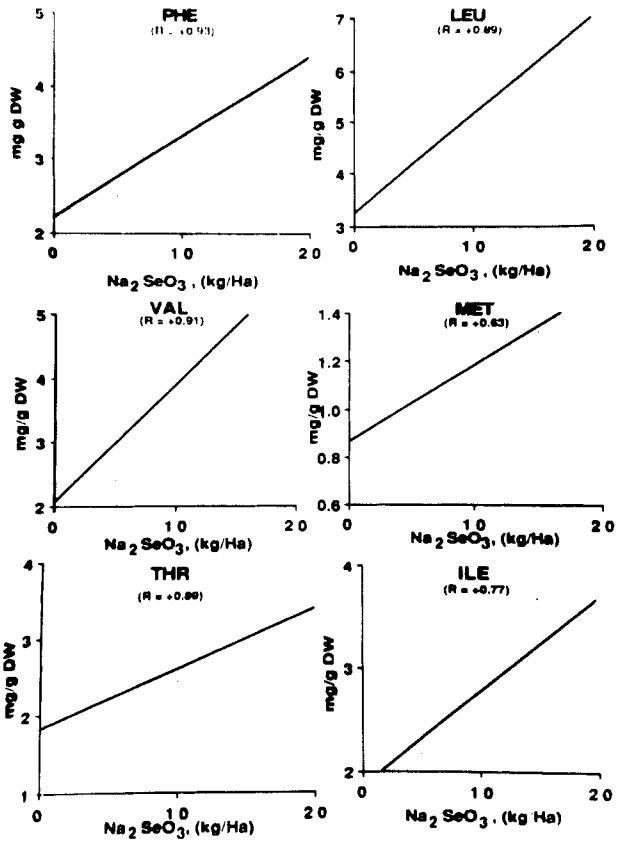

Figure 2. Effect of sodium selenite (Na_2SeO_3) on the essential amino acid content of the protein fraction of Katahdin potato tubers.

osis were observed. The selenium content of tubers supplied with the highest level of Na_2SeO_3 was 0.93 ppm FW. A 100-g serving of potato would provide 93.0 mg of selenium, which is well below the toxic level (775 mg) as recommended by Combs and Combs (1986). Therefore, selenium fertilization can not only improve the protein and amino acid content of potatoes but also increase the selenium content of tubers without reaching toxic levels.

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Registry No. Ser, 56-45-1; Gly, 56-40-6; His, 71-00-1; Arg, 74-79-3; Thr, 72-19-5; Ala, 56-41-7; Pro, 147-85-3; Tyr, 60-18-4; Val, 72-18-4; Met, 63-68-3; Cys, 52-90-4; Ile, 73-32-5; Leu, 61-90-5; Phe, 63-91-2; Lys, 56-87-1; Trp, 73-22-3; asparagine, 70-47-3; aspartic acid, 56-84-8; glutamic acid, 56-86-0; glutamine, 56-85-9; Se, 7782-49-2; N_2, 7727-37-9; sodium selenite, 10102-18-8.