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USE OF NH_4HCO_3-DTPA SOIL TEST TO ASSESS AVAILABILITY AND TOXICITY OF SELENIUM TO ALFALFA PLANTS[1/]

KEY WORDS: Selenium Soil Test, Selenium Toxicity

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ABSTRACT

This study was carried out to determine if ammonium bicarbonate-DTPA soil test (AB-DTPA) of Soltanpour and Schwab for simultaneous extraction of P, K, Zn, Fe, Cu and Mn can be used to determine the availability index for Se. Five Mollisols from North Dakota were treated with sodium selenate and were subjected to several wetting and drying cycles. These soils were extracted with hot water and with ammonium bicarbonate-DTPA (AB-DTPA) solution for Se analysis. Alfalfa plants were grown in these soils in a growth chamber to determine plant uptake of Se. In addition to the above experiment, coal mine soil and overburden materials from Western Colorado were extracted and analyzed as mentioned above.

It was found that hot water and AB-DTPA extracted approximately equal amounts of Se from Mollisols. A high degree of correlation (r^2=0.96) was found between Se uptake by plants and AB-DTPA extract-

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able Se. Extractable level of Se in treated soils was decreased with time due to change of selenate to less soluble Se forms and plant uptake of Se. An AB-DTPA extractable Se level of over 100 ppb produced alfalfa plants containing 5 ppm or higher levels of Se that can be considered toxic to animals. Soils with about 2000 ppb of extractable Se were highly toxic to alfalfa plants and resulted in plant concentrations of over 1000 ppm of Se. The high rate of selenate (4ppm Se) was less toxic to alfalfa plants in soils of high organic matter content. This lower toxicity was accompanied with lower extractable levels of Se.

The AB-DTPA solution extracted on the average about 31% more Se than hot water from the mine and overburden samples and was highly correlated with the latter (r^2=0.92). The results indicated the presence of bicarbonate-exchangeable Se in these materials.

INTRODUCTION

The ammonium bicarbonate-DTPA soil test of Soltanpour and Schwab,[3] as modified by Soltanpour and Workman[4], extracts P, K, Zn, Fe, Cu, and Mn simultaneously from soils. It is obvious that monitoring the plant availability of additional elements with the above soil test will make soil testing more efficient. This is especially true for laboratories, such as that of the authors, that are equipped with plasma spectrometers that are capable of simultaneour determination of many elements[5].

The purpose of the study reported here was to determine if the ammonium-bicarbonate-DTPA (AB-DTPA) soil test can be used to assess selenium availability to plants.

MATERIALS AND METHODS

Five Mollisols from North Dakota (table 1) were treated with sodium selenate at 0, 0.5, 1, 2, and 4 ppm rates of Se using four replications. Eight hundred grams of each soil were potted and placed in a growth chamber. Seeds of alfalfa plants (*Medicago sativa*, Ladack variety) were planted in the pots. Three replications were used for planting and one replication was kept in the growth chamber for soil analysis. The soil moisture in each pot was brought to the field capacity with distilled water. Moisture losses were determined daily by weighing and were replenished.

Two cuttings of alfalfa (cut about 2 cms above the soil level) were obtained at the bloom stage for yield and Se uptake measurements. Soils from the pots with no plants were air dried after being subjected to wetting and drying cycles for 4 weeks. Soils from pots with plants were air dried after the second harvest. The air dry soil samples were extracted with hot water[6] and AB-DTPA solution[4]. The soil samples from the pots with no plants were digested with perchloric acid for total Se determination.

Table 1. Some properties of the soils used in the greenhouse study.

ID	pH	%O.M.	Texture	Acid Effervescene (lime)
A	6.9	6.5	silty clay loam	No
B	7.0	6.3	"	No
C	7.6	5.0	"	Yes
D	7.7	3.7	"	Yes
E	7.8	3.1	"	Yes

The plant samples were dried at 40°C and digested with nitric-perchloric acids. Selenium in plant and soil digests and soil extracts were analyzed by using a hydride generator attached to an inductively-coupled plasma spectrometer[7].

In addition to the above experiment, coal mine soil and overburden samples were analyzed for hot water and AB-DTPA extractable Se. These samples were from two different coal mines, one in Northwest and the other in the West Central part of Colorado.

RESULTS

The results indicated that hot water and AB-DTPA extracted approximately equal amounts of Se from Mollisols (Figure 1). The

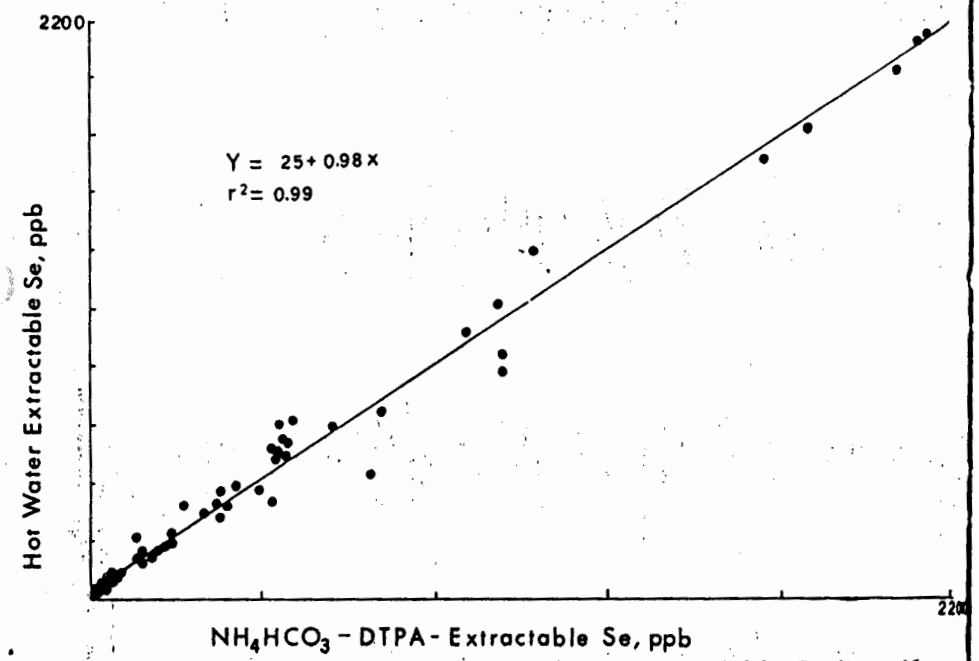

Figure 1. Hot water soluble versus NH_4HCO_3-DTPA soluble Se in soils before planting and after harvest.

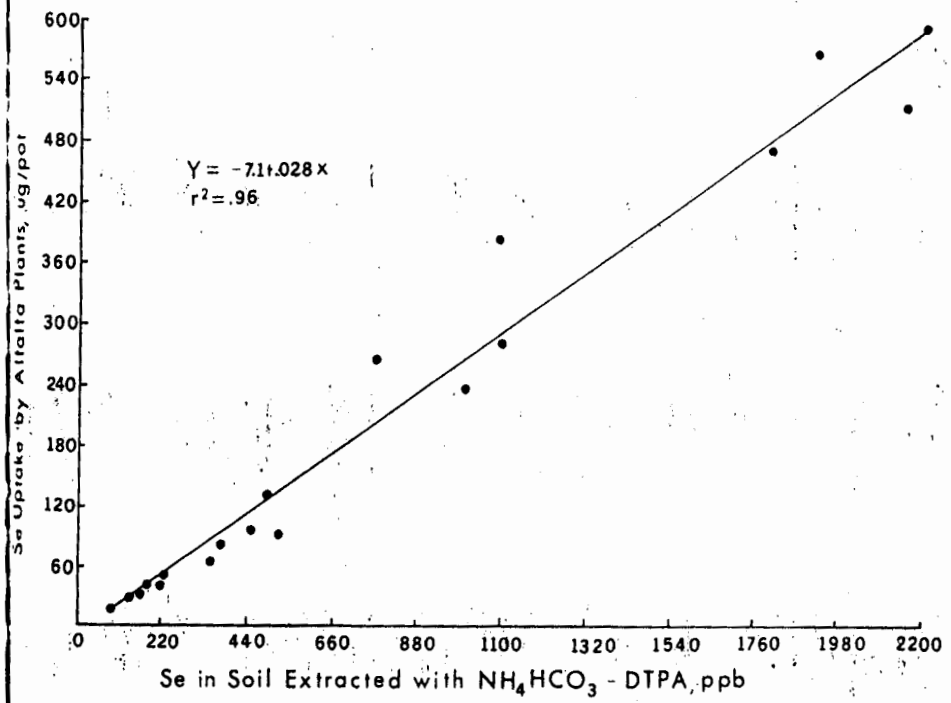

Figure 2. Selenium uptake by two cuttings of alfalfa as a function of NH_4HCO_3-DTPA extractable Se in soils.

relationship between Se uptake and Se extracted with AB-DTPA is shown in Figure 2. It seems that AB-DTPA can be used to assess Se availability as well as hot water. Extractable levels of Se in treated soils decreased with time (table 2) due to change of selenate to less soluble forms and plant uptake.

The selenate was toxic to alfalfa plants especially at higher rates and in soils with lower organic matter contents (Table 2). Plants with a Se concentration of 360 ppm or higher produced very low yields. At a Se concentration of about 1000 ppm yield was negligible. Plants growing in soils with about 2000 ppb of

Table 2. Yield and composition of alfalfa plants and soil levels of selenium.

Soil	Se Added	Total Soil Se*	AB-DTPA Se *	AB-DTPA Se **	Yield 1st cut	Yield 2nd cut	Composition 1st cut	Composition 2nd cut	Total Se Uptake
	ppm	ppm	----ppb------		------g------		-----ppm-------		µg
A	0	0.69	31	15	2.45	2.71	0.24	0.25	1.3
B	0	0.66	19	14	2.01	2.68	0.42	0.31	1.7
C	0	0.47	14	16	2.28	3.30	0.43	0.20	1.6
D	0	0.43	15	16	1.89	2.41	0.34	0.32	1.4
E	0	0.40	12	12	2.11	2.79	0.25	0.22	1.1
A	0.5	1.08	137	39	2.32	2.56	11.2	2.20	31.6
B	0.5	1.06	160	43	1.99	2.81	12.6	2.53	32.2
C	0.5	0.87	179	43	2.31	1.99	11.3	5.55	37.2
D	0.5	0.99	208	42	2.01	2.36	14.6	5.21	41.6
E	0.5	0.76	217	33	1.92	2.08	15.4	5.40	40.8
A	1.0	1.50	329	67	2.06	1.89	26.2	6.07	65.4
B	1.0	1.58	353	58	2.27	2.04	29.5	7.20	81.6
C	1.0	1.33	431	61	2.10	3.21	31.8	4.78	82.1
D	1.0	1.42	500	67	1.90	2.68	38.3	6.94	91.4
E	1.0	1.31	475	66	1.91	2.26	49.6	8.00	112.8
A	2.0	2.25	lost	155	1.78	2.19	88.1	11.1	181.1
B	2.0	2.17	737	142	1.85	2.93	127	10.5	265.7
C	2.0	2.21	1050	146	1.76	2.69	133	18.0	282.5
D	2.0	2.08	1040	248	0.49	2.28	625	34.2	384.2
E	2.0	2.04	959	207	0.18	1.50	867	54.4	237.7
A	4.0	4.17	1720	344	0.17	2.98	1143	92.8	470.8
B	4.0	3.64	1830	431	0.12	1.97	1248	212	567.4
C	4.0	3.23	2060	446	0.06	1.86	1068	241	512.3
D	4.0	3.33	2140	726	0	1.40	--	222	310.8
E	4.0	3.54	2110	774	0	0.56	--	360	201.6

* refers to soil samples going through 4 weeks of wetting and drying with no plants grown in them.

**refers to soil samples obtained after the second cutting of alfalfa plants.

Table 3. Hot-water soluble v.s. AB-DTPA extractable Se in coal mine soil and overburden materials from a coal mine in West-Central Colorado.

I.D. #	Hot-water Se (ppm)	AB-DTPA Se (ppm)	pH
2099*	0.27	0.26	7.7
2100*	0.24	0.25	7.7
2101*	0.20	0.14	7.9
2102	0.01	0.02	7.5
2103	0.01	0.01	7.4
2104	0.10	0.33	7.6
2105	0.10	0.36	7.6
2106	0.03	0.06	7.8
2107	0.01	0.03	7.5
2108	0.01	0.03	7.6
2109	0.01	0.04	7.6
2110	0.02	0.06	7.1
2111	0.05	0.11	6.3
2112	0.01	0.04	7.8
2113	0.02	0.04	7.2
2114	0.02	0.04	7.5
2115	0.01	0.02	7.7
2116*	0.01	0.03	4.3
2117*	0.01	0.03	3.5

* Mine waste material

extractable Se contained over 1000 ppm of Se in the first cutting. This observation indicates that alfalfa, while not considered as a Se accumulator, can accumulate Se to a dangerously high concentration.

Moxon as quoted by the National Academy of Science[8/] stated that, in general, animals consuming feeds containing 5 to 40 ppm of Se over a period of time show symptoms of Se poisoning

Table 4. Hot-water soluble v.s. AB-DTPA extractable Se in coal mine soil and overburden materials from a coal mine in North-West Colorado.

I.D. #	Hot-water Se (ppm)	AB-DTPA Se (ppm)	pH
2059	0.12	0.16	7.2
2060	0.21	0.29	7.2
2061	0.18	0.19	7.2
2062	0.03	0.03	7.4
2063	0.02	0.02	7.3
2064	0.02	0.02	7.4
2065	0.02	0.02	7.2
2066	0.01	0.01	6.2
2067	0.05	0.08	5.1
2068	0.31	0.53	7.7
2069	0.31	0.46	7.7
2070	0.10	0.14	7.6
2071	0.05	0.08	7.5
2072	0.08	0.12	7.6
2073	0.55	0.66	8.0
2074	0.79	1.04	7.9
2075	0.26	0.40	7.7
2076	0.28	0.43	7.0
2077	0.11	0.15	6.9
2078	0.02	0.02	5.3
2079	0.03	0.08	5.9
2080	0.40	0.67	7.6
2081	0.36	0.46	7.2
2082	0.22	0.35	7.6
2083	0.06	0.15	7.9
2084	0.17	0.31	7.7
2085	0.14	0.29	7.7
2086	0.12	0.21	7.7
2087	0.09	0.16	7.7
2088	0.11	0.22	8.1
2089	0.08	0.16	7.7
2090	0.06	0.09	7.6
2091	0.08	0.13	7.3
2092	0.07	0.09	7.0
2093	0.12	0.19	7.1
2094	0.10	0.18	7.0
2095	0.03	0.03	7.2
2096	0.06	0.06	7.2

(alkali disease). Alfalfa plants growing in soils containing over 100 ppb of AB-DTPA extractable Se showed Se contents of 5 ppm or more. Therefore, tentatively, an AB-DTPA extractable Se level of 100 ppb in soil is suggested as a critical level for feed toxicity. Soils containing about 2000 ppb of AB-DTPA extractable Se were extremely toxic to alfalfa plants and produced extremely toxic feed.

The analysis of coal mine soil and overburden samples (table 3) showed that AB-DTPA and hot water extractable Se values were highly correlated (r^2=0.92). These results yielded the following regression:

$$Y = 0.0258 + 1.3084x$$

where Y is AB-DTPA and x hot water extractable Se. The results indicated that in case of these samples AB-DTPA extracted on the average about 31% more Se than hot water, probably due to the presence of bicarbonate-exchangeable Se in these samples.

CONCLUSION

It is concluded that AB-DTPA soil test can be used to obtain an index of the selenium availability and toxicity. It is tentatively suggested that an AB-DTPA extractable Se level of 100 ppb in soil be considered as suspect in producing toxic feed.

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SPECIFIC SORPTION OF TRACE AMOUNTS OF CADMIUM BY SOILS

KEY WORDS: Trace metals, heavy metals, cadmium, specific sorption

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ABSTRACT

Sorption of trace quantities of Cd in four soils of different chemical and mineralogical properties, was studied. Initial Cd concentrations were between 15 to 150 µg. l^{-1}. The sorption isotherms were linear and had a positive intercept in three of the soils, indicating a constant partition-high affinity sorption isotherm (Giles et. al[6]). The data also followed the Freundlich sorption isotherm, and the Freundlich K parameter was taken as a measure of the relative affinity of the different soils for the Cd metal sorbed. Cadmium sorbed was extracted by 1N-NH_4Cl followed by 0.1N HCl, and the fraction remaining in the soils was considered specifically sorbed Cd. This fraction also followed a linear sorption isotherm, and was around 30% for the four soils studied. The sorption order for the amount of specifically sorbed Cd showed that the Boomer soil (kaolinite-iron oxides) had the lowest affinity for specific sorption of this metal. This was taken as evidence that kaolinite and iron oxides have a lower capacity for retaining cadmium through specific sorption mechanism(s) than the materials present on the other soils (2:1 layer silicates and humic substances). The existence of specific mechanism(s) responsible by the sorption of trace quantities of Cd in soil solutions has important implications on soil-plant relationships, Cd mobility in soil profiles and control of Cd activity in soil solutions.

INTRODUCTION

Interest in the chemistry of Cd in soil has come about as a consequence of recent findings, which demonstrate that contamination of soils by this metal, may result in acute toxicities to and excessive accumulation by economic crops.[16,17]

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