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PLANT VALUE OF ZINC IN ORGANIC WASTES[1]

Ali A. Parsa and W.L. Lindsay[2]

ABSTRACT

The purpose of this study was to evaluate Denver sewage sludge and Colorado garbage compost as sources of available Zn for plant growth and to determine the residual effects of application of these solid wastes on the available Zn level of soil.

An extensive greenhouse experiment was conducted in which two successive crops of corn were used to evaluate the solid wastes as sources of Zinc. Solid wastes were used at the rate of 500, 2,000 and 8,000 ppm on a soil basis. These solid wastes were air dried or ashed before application with or without inorganic Zn. The two solid wastes studied could be used as Zn fertilizers at moderate application rates. Results of this experiment showed that Zinc in possible organic combinations in solid wastes were superior to their inorganic ash or $ZnSO_4$ for correcting Zn deficiency in plants and increasing the available Zn level of soil.

INTRODUCTION

A sharp increase in production of solid wastes is one of the problems associated with modern living. To solve this problem, man is searching for safer means of waste disposal; for the conventional means such as burning, land-fill and dumping into waterways, pollute the air, the soil and the waters to which man owes his very existance.

Agricultural utilization of solid wastes is not new. Man has used various organic wastes to enrich his soil for production of food and fiber throughout recorded history. So far, most research work on solid waste has been limited to their value as sources of major plant nutrients or their role in improving physical properties of the soil. As a result, their value as sources of available micronutrients has for the most part been overlooked.

Emphasis of the literature on the major plant nutrients of solid wastes is reflected in Krishnamoorthy's (4) "study of composting during the past sixty years," in which most of the authors discuss solid wastes either as N-P-K sources or as soil building material. Anderson (1) estimated that the United states urban population produces 10 million tons of garbage per year, which amounts to 2.5 million tons of dry matter containing 50,000 tons of N; 50,000 tons of P and 2,500 tons of K per year.

The effects of sewage and compsot on the improvement of physical properties of soil have been reported by several research workers. Ubysz and Zimniak (13) found a marked increase in moisture retention of sandy soils when treated with compost following late spring and summer rains. Lunt (6) reported that sewage sludges improved soil structure and tilth and had longer lasting effects than barnyard manure.

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1. Part of a thesis submitted by the senior author in partial fulfillment of the requirements of the Ph. D. degree received March 1970.

2. Assistant Professor, Department of Soil Science, College of Agriculture, Pahlavi University, Shiraz, Iran, and Professor of Soils Department of Agronomy, Colorado State University, Fort Collins, Colorado, U.S.A., respectively.

Solid wastes would be of particular interest to agriculture if they either contained or gave rise to natural metal chelates after application to soil. According to Wallace (14) metal chelates are important in plant nutrition. Solubilization of Fe by natural chelates in soils, is one of the important mechanisms by which plants obtain Fe from soils. Separation and identification of natural metal chelates in soils is largely an unexplored field. Stewart (12) reported that natural chelates play a role in the biochemistry of plants. Mortensen (10) supported the forementioned hypothesis by showing that soil organic matter is capable of complexing metals that are important in plant nutrition. Miller (8) reported that water soluble natural chelating materials improved the availability of trace metals. Miller and Ohlrogge (9) were able to form Zn chelates by reacting inorganic Zn with plant and manure extracts. Khanna and Stevenson (3) found that various fractions of soil organic matter, when titrated with transition metal ions, formed stable metal complexes. Chesnin (2) concluded that organic Zn carriers were more effective than inorganic carriers. In their experiment the Zn content of corn increased with increasing application of Zn in organic forms. Miller, *et al* (7) reported that poultry manure, in addition to its N-P-K value, could correct Zn and iron deficiencies on corn. They concluded that the organic fraction of manure is important in rendering Zn and Fe more available to plants.

MATERIALS AND METHODS

Solid Wastes

Two solid waste materials were used in this study. One was a garbage compost obtained from the Richland composting plant near Boulder, Colorado. The composting process involved the use of an aerobic composter capable of transforming 10C tons of inocming garbage wastes per day into an odorless product. The processing time was approximately 14 days followed by a four-week curing period in stockpile.

The other solid waste was a concentrated waste – activated sludge to which $FeCl_3$ and lime had been added to facilitate flocculation of the suspended solids prior to vacuum filtration. Chemical analyses of the two solid wastes are given in Table 1.

The Soil

The soil used in this experiment was slightly acid, Zn deficient Haxtun-Anselmo sandy clay loam. The analyses of this soil are given in Table 2.

Greenhouse Experiment

A greenhouse experiment was conducted to determine if the solid wastes could alleviate Zn-deficiency and increase dry matter yield of Corn *(Zea mays)*. Two kilograms of soil were weighed into plastic lined cartons and adequate N, P, K, and S were supplied. The differential treatments consisted of sewage sludge and garbage compost. The materials were applied at rates of 500; 2,000 and 8,000 ppm on a dry-weight basis. These solid waste products were also ashed and applied at equivalent rates based upon the air-dried materials prior to ashing. The solid waste materials were applied both with and without additional Zn fertilizer at 5 ppm Zn as $ZnSO_4 . 7H_2O$.

Table 1. Analyses of the air-dried solid wastes used in this study.

Solid Wastes	pH 1:1	Ignition Loss	Ca	Mg	N	P	Fe	Zn	Cu	Mn	H_2O Soluble B
		%	%	%	%	%	%	ppm	ppm	ppm	ppm
Denver Sewage Sludge	8.5	50	7.38	0.45	4.57	1.75	1.48	1720	324	253	2.0
Colorado Garbage Compost	7.0	22	1.03	0.31	0.51	0.01	4.75	1050	648	484	12.00

Table 2. Analyses of the Zn-deficient soil used in this study.

	pH Paste	E.C.X10^3	Lime ($CaCO_3$)	Organic Matter	$NaHCO_3$ Ext. O	Exch. K	DTPA-Extractable Fe	Zn	Cu	Mn
		mmhos/cm	%	%	ppm	ppm	ppm	ppm	ppm	ppm
Haxtun-Anselmo S.Cl.L.	6.00	0.10	0.00	0.65	14.4	200	17.4	0.39	0.54	23.0

Three weeks after harvest larger roots were removed and corn was reseeded. No further addition of Zn or solid wastes were made. Adequate levels of other nutrients were maintained as in the first crop.

The experimental design was completely randomized factorial. Corn seed was hybrid WF9 X 38-11. Four plants per pot were grown for seven weeks for each crop. Day temperatures were 24-28°C and night temperatures were 18-20°C. After harvest, the above-ground portion of the plants was removed, washed in 0.1 N HCl for approximately thirty seconds, rinsed twice in deinoized water, and dried at 70°C in a forced-draft oven. The dried plant materials were weighed and ground in a Wiley mill equipped with a 20-mesh stainless steel sieve and cutting blades. The dried plant materials were digested with a mixture of nitric-perchloric-sulfuric acids and Zn content in the digestate was determined by atomic absorption.

Greenhouse Incubations

Soil samples were removed from the greenhouse experiment following the first and second crops for DTPA extraction of available Zn, Fe, Mn and Cu. In addition, soils from the 8,000 ppm treatment were analyzed for available Zn prior to planting. The results served as an index of available Zn from the solid wastes during the 20-week period.

Analytical Methods

Soil analyses were made by the routine methods of the Colorado State University Soil Testing Laboratory. The solid wastes as well as the dried plant materials were digested by a mixture of perchloric-sulfuric-nitric acids. Zn, Fe, Cu, Mn, Ca and Mg were determined in the digestates by absorption spectrophotometry. Total N was determined by the Kjeldahl method, using standard sulfuric acid as a titer. Phosphorus in the digestates was determined by the use of molybdovanadate reagent. Color intensities were read on a Coleman model 14 spectrophotometer. Solid wastes were ashed for ten hours at 600 C in a muffle furnace. DTPA-extractable micronutrient test in soil was that devised by Lindsay and Norvell (5). Hot water-soluble Boron was determined by curcumin colour reaction.

Statistical treatments of the data consisted of one-way analysis of variance for each crop, and two-way analysis of variance for the combined results of two crops. Significant differences between the means were calculated by Tukey's Q at 0.05 level as listed by Snedecor and Cochran (11).

RESULTS AND DISCUSSION

Dry Matter Yield

The average dry matter yields of the two crops are shown in Figure 1. These are the means dry matter yields of three replications. The significant difference between the means expressed as Q.05 accompanies the figure.

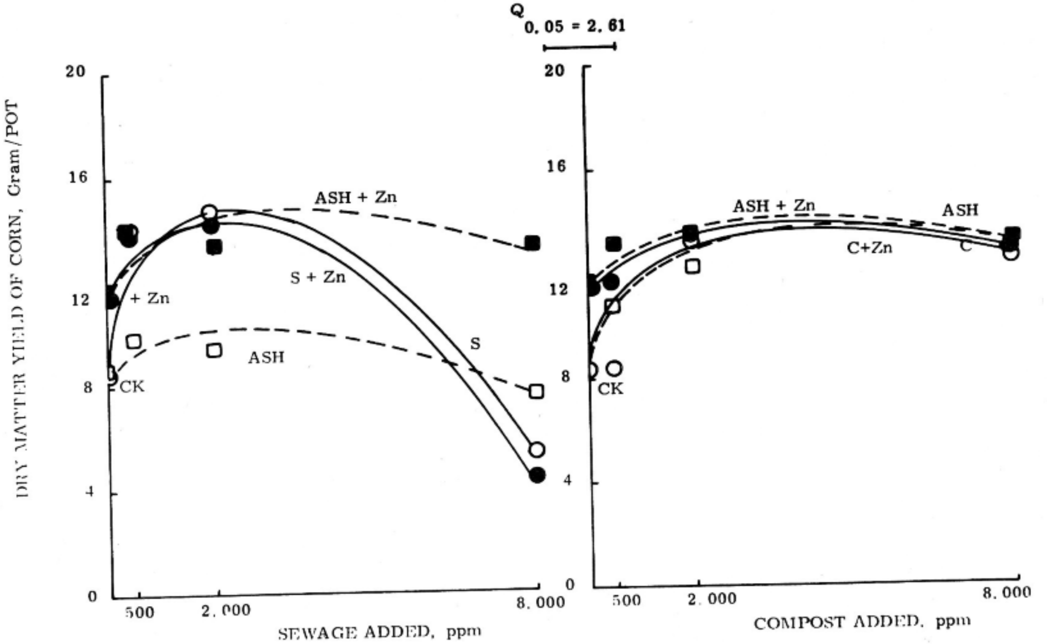

Figure 1: The effect of sewage sludge, garbage compost, their ash, and added Zn fertilizer on the average dry matter yield of two successive cropping of corn on a Zn-deficient soil in the greenhouse.

The response to the application of sewage sludge was more pronounced in the second crop when the soil was depleted of its indigenous Zn. The response to the sewage sludge applications up to 2,000 ppm was superior to that of inorganic Zn. Further addition of sewage sludge severely depressed the dry matter yield for both crops, but the depression was less in the second crop. As a side experiment, a third crop of corn was grown only in pots receiving the 8,000 ppm of sewage. The average dry matter yields of three replicates for the third crop were as follows: Check, 4.1 grams; 5ppm Zn, 8.4 grams; 8,000 ppm sewage, 20.8 grams; and 8,000 ppm sewage +5 ppm Zn, 18.3 grams per pot. These unusually high yiled in the third crop may reflect a high residual value of sewage sludge as a source of Zn. Reduction in yield with the high sewage rate for the first two crops was nearly eliminated by ashing. These observations suggest that the depressing factor or factors may be associated with organic fraction, since ashing and incubation eliminated the yield depression. Zn deficiency symptoms were not found on the sewage-treated plants. The plants receiving 8,000 ppm sewage appeared wilted and dark green. These symptoms were most pronounced on the first crop, less on the second crops, and absent on the third crop.

Addition of 5 ppm Zn to sewage failed to increase dry matter yield over that of sewage alone. In fact Zn addition to sewage caused a slight depression in dry matter yiled.

Sewage ash was far less effective in increasing the dry matter yield than was sewage. Ineffectiveness of the ash was even more noticeable for the second crop. Ash treated plants showed progressive Zn deficiency symptom as cropping continued. Apparently the inorganic Zn in ash was less available to plant than that present with the organic fraction of the sewage sludge. Inclusion of 5 ppm Zn with the ash significantly increased dry matter yield. The increase was more noticeable in the second crop than in the first. Additions of Zn eliminated Zn deficiency symptoms on the ash treated plants of both crops.

The average dry matter yield for the two crops indicated a significant yield response to all levels of compost treatment. Inclusion of 5 ppm Zn with the compost did not increase the dry matter yield of corn significantly.

Ashing did not affect the response to compost significantly in either direction. Addition of 5 ppm Zn to the ash treatments did not increase yield in the first crop. In the second crop addition of Zn significantly increased the dry matter yield at the 500 ppm and 2,000 levels of ash. The average dry matter yield, however, did not show any significant response for the ash + Zn treatments.

Zn content of Plants

The Zn content of the corn tissues of the second crop are plotted in Figure 2. The values are the means of three replications. Ashing the solid wastes reduced the Zn content of plants in all cases. Apparent exceptions were the 500 and 2,000 ppm sewage treatments. The Zn content of plants on these treatments was actually less than the Zn content of their ash-treated counterparts. The total Zn uptake (dry weight + Zn content) of these treatments, however, exceed those of the ash treatments. The increase in Zn uptake of

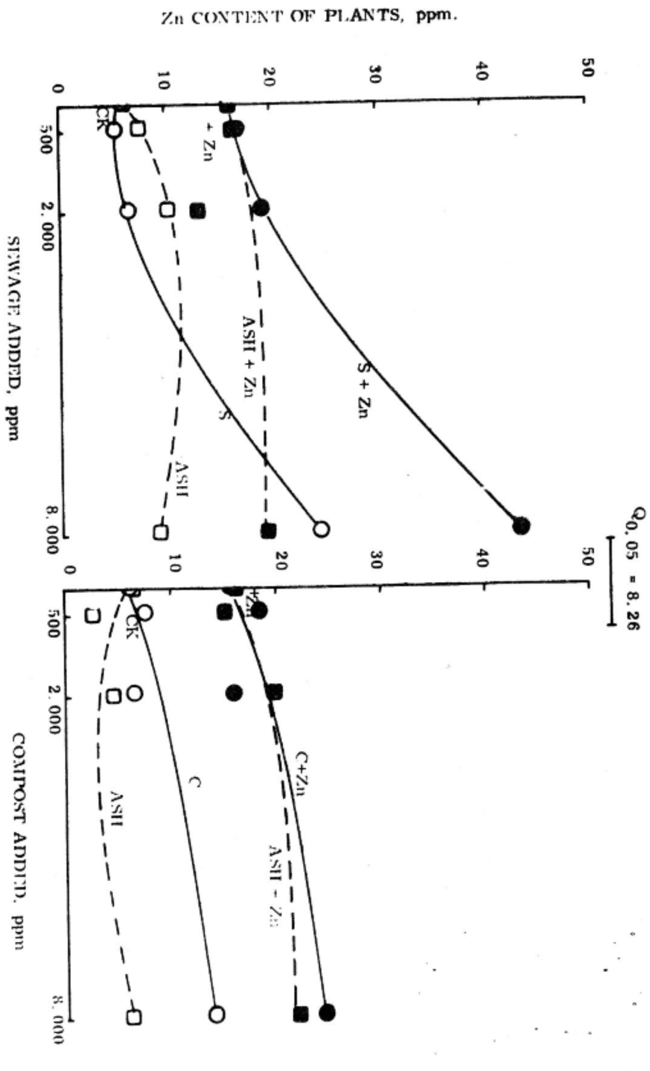

Figure 2: The effect of sewage sludge, garbage compost, their ash, and added Zn fertilizer on the Zn content of the second crop of corn grown on a Zn-deficient soil in the greenhouse.

corn plants from solid wastes (organic sources) is in agreement with work of Chesnin (2) who demonstrated that corn plants took up more Zn from synthetic Zn chelates than $ZnSO_4$.

Severe Zn deficiency symptoms on the ash-treated plants of the second crop indicated that Zn from the ash was not effective in increasing the yield or the Zn content of plants. Ashing of compost also reduced the Zn content in plants. Addition of 5 ppm Zn to sewage ash, compost and compost ash resulted in increased Zn content of the plant tissues.

Greenhouse Incubation

DTPA-Extractable Zn

Figure 3, shows the DTPA-extractable Zn for the greenhouse soil 20 weeks after the addition of various rates of solid wastes. All levels of sewage treatment contributed significantly more to the soil Zn-pool than their ash counterparts. With compost, only the higher rates had significant effect.

Figure 4, reports the DTPA-extractable Zn for the soil to which 8,000 ppm solid wastes were added and cropped in greenhouse with two successive croppings of corn. DTPA-extractable Zn was determined before each cropping and after harvest representing a total contact period of 20 weeks. A critical examination of Figure 4, reveals some interesting facts whcih are also reflected in Table 3. These results indicate that more Zn remained in soil when treated with sewage and compost than their ashes, and that sewage was a more effective source of Zn than compost. The percentage of Zn remaining available from the Zn SO_4 treatment was nearly the same as from the ash treatment.

Table 3:

Initial and final levels of DTPA-extractable Zn in a greenhouse soil treated with 8,000 ppm solid wastes, their ashes, and inorganic Zn.

Solid waste	Total Zn Added	DTPA-Ext. Zn Initially	DTPA-Ext.Zn After 20 weeks		
	ppm	ppm	% total Added	ppm	% initial Ext.
Sewage	13.7	7.4	54.0	5.3	71.6
Sewage ashed	13.7	1.2	8.8	0.4	33.3
Compsot	8.4	3.0	35.7	1.6	53.3
Compost ashed	8.4	2.0	23.8	0.7	35.0
5 ppm Zn as $ZnSO_4$	5.0	5.2	104.0	1.8	34.6

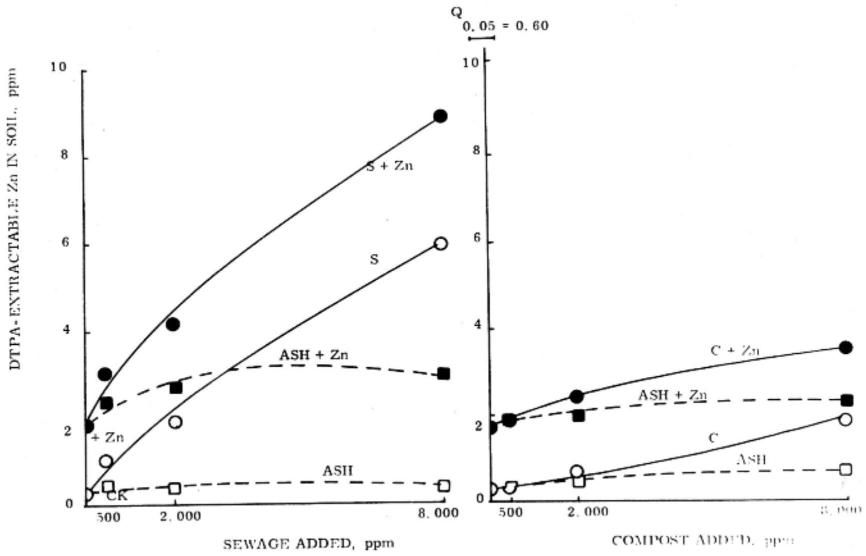

Figure 3: The effect of sewage sludge, garbage compost, their ash, and added Zn fertilizer on the average DTPA-extractable Zn in soil after two successive croppings of corn in the greenhouse.

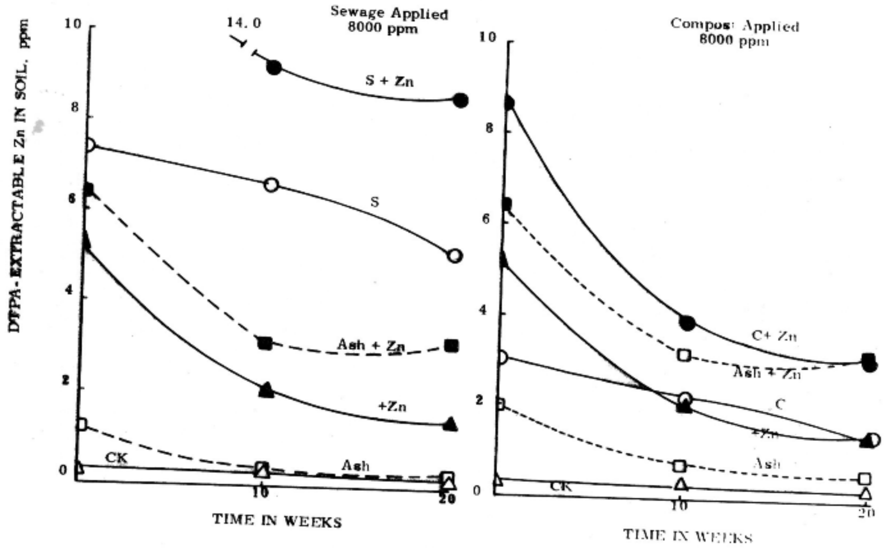

Figure 4: The DTPA-extractable Zn from the Zn-deficient soil to which various combinations of sewage, compost, their ashes, and Zn fertilizer were added and cropped over a 20-week period.

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