High Rates of Sewage Sludge in Barley Production

A. D. Day, M. A. Solomon, M. J. Ottman, and B. B. Taylor

ABSTRACT

A greenhouse experiment was conducted at the University of Arizona, Tucson, Arizona, to study the effects of liquid sewage sludge loading rates on the vegetative growth, yield, and quality of barley grain and straw. Vegetative growth, grain yields, and straw yields were similar whether barley was grown with inorganic N or equivalent amounts of plant-available N from sewage sludge. Sewage sludge loading rates higher than three times the recommended plant-available N rate decreased barley stands in the seedling stage. The loss of stand was compensated for by higher tillering later in the season. High sludge loading rates tended to delay maturity, increase tillering, and increase straw yield; however, they did not affect grain yield. Concentrations of cadmium (Cd), copper, (Cu), lead (Pb), nickel (Ni), and zinc (Zn) in barley grain and straw and the amounts of heavy metals recovered in the soil following each harvest were similar to the control for all sewage sludge treatments.

INTRODUCTION

Land application of sewage sludge as a disposal method is widely practiced in many metropolitan areas. Since 1984, sewage sludge from Tucson, Arizona, has been applied on farmlands as an alternative to disposal in landfills. Present guidelines by the Arizona Department of Health Services (ADHS) for land application of sewage sludge dictate that application rates be limited to the nitrogen requirement of the crop. However, projected increases in municipal sludge and limitations in land areas for disposal may require higher application rates than those presently recommended. The objective of this research was to study the effects of different sewage sludge loading rates on the vegetative growth, yield, and quality of barley grain and straw.

MATERIALS AND METHODS

In 1987 and 1988, a greenhouse experiment was conducted at the University of Arizona, Tucson, Arizona to study the effects of liquid sewage sludge loading rates on the vegetative growth, yield, and quality of barley grain and straw. The plants were grown in pots filled with Brazito sandy loam soil, which is a member of the coarse-loamy, mixed Typic Torrifluvents. Anaerobically digested liquid sewage sludge was obtained from the Ina Road Sewage Treatment Plant, near Tucson, Arizona. The sewage sludge had a pH of 7.6, 1.5% total solids, 9% total N, 5.4% phosphoric acid, and 0.4% potash, on a dry weight basis. The average heavy metal contents, on a dry weight basis were: 10 mg/kg cadmium (Cd), 886 mg/kg copper (Cu), 218 mg/kg lead (Pb), 53 mg/kg nickel (Ni), and 118 mg/kg zinc (Zn).

The sludge loading rates consisted of seven treatments, each replicated four times as follows:

1. Check (a soil with no fertilizer applied).
2. Recommended amount of N for barley (112 kg N/ha from ammonium nitrate).
3. Liquid sewage sludge in amounts to provide the recommended plant-available N (112 kg N/ha).

4 -7. Liquid sewage sludge rates to provide plant-available N in amounts equal to 2, 3, 4, and 5 times the recommended plant-available N, respectively.

The plant-available N in the sewage sludge was estimated at 6.8%, determined by adding the NO_3-N, NH_4-N and the rapid and slow fractions of organic-N. Each sludge treatment was mixed with 20 kg of soil, using a cement mixer, and placed in plastic pots 25 cm in diameter and 40 cm deep. The mixing was accomplished, one rate at a time, starting with the highest rate and progressing to the lowest rate. To minimize puddling, sufficient drying periods were allowed between sludge applications. Once the soils treated with sewage sludge were sufficiently dry, the clods were crushed to make a smooth planting surface. For the inorganic-N treatment, ammonium nitrate was applied 3cm below the soil surface at planting. Gustoe barley was planted the last part of December each year and thinned to nine plants/pot 1 week after seedling emergence. Shallow and frequent hand watering was continued throughout the growing season, to prevent moisture stress and to minimize leaching. The grain and straw were harvested by hand at maturity.

RESULTS AND DISCUSSION

Barley responded more in vegetative growth than in grain yield to increases in sewage sludge loading rates (Table 1). Vegetative growth and grain yields were similar whether barley was fertilized with inorganic N or the equivalent amounts of plant-available N from sewage sludge. Sewage sludge loading rates more than three times the recommended plant-available N rate decreased barley stands in the seedling stage. Dying seedlings exhibited chlorosis and tip-burn, similar to symptoms of salt toxicity. Surviving plants regained vigorous growth later in the season. It is suggested that high concentrations of soluble salts in the high sludge loading rates caused initial seedling death; however, the excess salts were leached-out of the soil during subsequent watering.

Sludge loading rates higher than the recommended plant-available N level tended to delay maturity, increase tillering, and increase straw yield. Grain yield was not increased by higher sludge application rates because some tillers did not produce heads and others produced small heads.

Heavy metal concentrations in barley grain and straw and the amounts of metals recovered in the soil following each harvest were similar for all fertilizer treatments (Table 2).

Previous analyses indicated that the heavy metal content of Tucson sludge is very low and most of the metals are not readily available for plant-uptake or contamination of ground water because they usually interact with the soil to form insoluble compounds and complexes. Studies have shown that over 90% of sludge-born heavy metals were retained in the top 0 - 15cm depth of the soil horizon and less than 10% of those metals were recovered by plants.

The foregoing observations, in conjunction with Pima County's industrial sludge pre-treatment requirements, indicate that, on the basis of heavy metals, sewage sludge from Tucson, Arizona is safe for disposal on crop lands at rates higher than those presently recommended.

REFERENCE

Artiola, J. F. 1988. Manual of operating procedures for the analysis of selected soil, water, plant tissue, and wastes chemical and physical parameters. Operation No. 7. Department of Soil and Water Science, University of Arizona, Tucson, Arizona. 167 p.

Table 1

Average plant survival, planting to heading, plant height, tillers, heads, seed weight, grain yield, and straw yield from barley grown with various sewage sludge loading rates in the greenhouse at Tucson, Arizona in 1987 and 1988.

Treatment[+]	Plant Survival (no/pot)	Planting to heading (day)	Plant height (cm)	Tillers (no./pot)	Heads (no./pot)	Seed weight (g/1000)	Yield Grain (g/pot)	Yield Straw (g/pot)
1	9 b[‡]	90 a	58 a	28 a	27 a	47 a	28 a	54 a
2	9 b	92 a	62 a	31 a	29 a	46 a	35 b	61 a
3	9 b	94 a	61 a	40 ab	35 ab	47 a	40 b	71 b
4	9 b	96 a	58 a	43 ab	36 ab	46 a	46 b	82 b
5	8 b	96 a	60 a	42 ab	38 ab	46 a	46 b	79 b
6	6 a	97 a	59 a	51 b	41 b	47 a	41 b	90 c
7	5 a	97 a	61 a	52 b	45 b	46 a	43 b	92 c

[+]Treatments:

1. Check (a soil with no fertilizer applied).
2. Recommended amount of N for barley (112 kg N/ha).
3. Liquid sewage sludge to provide the recommended rate of plant-available N.

4 - 7. Sewage sludge rates to provide plant-available N in the amounts equal to 2, 3, 4, and 5 times the recommended N rate.

[‡]Means between treatments, within columns, followed by the same letter are not different at the 5% level of significance using SNK.

Table 2

Average heavy metal concentrations in barley grain and straw and amounts recovered from the soil, in the greenhouse, using various sewage sludge loading rates at Tucson, Arizona in 1987 and 1988.

Material sampled	Treatment +	Heavy metal content (μg/g)				
		Cadmium	Copper	Lead	Nickel	Zinc
Grain	1	0.3 a ‡	10 a	5 a	32 a	22 a
	2	0.4 a	9 a	1 a	33 a	22 a
	3	0.3 a	12 a	2 a	38 a	30 a
	4	0.4 a	12 a	3 a	36 a	32 a
	5	0.4 a	13 a	4 a	35 a	35 a
	6	0.4 a	12 a	1 a	35 a	40 a
	7	0.4 a	16 a	6 a	40 a	40 a
Straw	1	0.5 a	7 a	9 a	54 a	30 a
	2	0.4 a	7 a	9 a	38 a	37 a
	3	0.5 a	8 a	10 a	47 a	48 a
	4	0.6 a	7 a	12 a	44 a	52 a
	5	0.7 a	7 a	17 a	50 a	46 a
	6	0.5 a	10 a	10 a	51 a	36 a
	7	0.4 a	10 a	4 a	47 a	45 a
Soil	1	1.3 a	13 a	20 a	58 a	79 a
	2	1.6 a	15 a	22 a	64 a	78 a
	3	1.4 a	15 a	20 a	65 a	87 a
	4	1.5 a	15 a	16 a	57 a	78 a
	5	1.6 a	17 a	29 a	67 a	82 a
	6	1.2 a	20 a	19 a	70 a	96 a
	7	1.4 a	27 a	16 a	62 a	86 a

+ Treatments:

1. Check (a soil with no fertilizer).
2. Recommended amount of N for barley (112 kg N/ha).
3. Liquid sewage sludge to provide the recommended rate of plant-available N.

4 - 7. Sewage sludge rates to provide plant-available N in amounts equal to 2, 3, 4, and 5 times the recommended N rate.

‡ Means between treatments, within columns, followed by the same letter are not different at the 5% level of significance using SNK.