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POTENTIAL OF WASTEWATER FOR COMMERCIAL BARLEY PRODUCTION[1]

A. D. Day, J. A. McFadyen, T. C. Tucker, and C. B. Cluff[2]

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[2]Agronomist and Graduate Assistant, Department of Plant Sciences; Soil Scientist, Department of Soils, Water, and Engineering; and Hydrologist, Water Resources Research Center; University of Arizona, Tucson, Arizona 85721; respectively.

ABSTRACT

Experiments were conducted in southern Arizona to investigate the effects of irrigation with pump water and a pump water-wastewater mixture on barley (Hordium vulgare L.) growth, grain yield, and grain quality; soil properties; and irrigation water quality.

In 1974 and 1975, on small plot research, barley irrigated with a 50:50 mixture of pump water and wastewater significantly exceeded barley irrigated with pump water alone in plant height, number of heads per unit area, number of seeds per head, seed weight, grain yield, and straw yield. In large field studies conducted from 1970 through 1977, barley irrigated with the mixture had taller plants, more lodging, lower grain volume-weights and higher grain yields than barley irrigated with pump water alone.

Soils irrigated with both types of irrigation water had similar pH. Soluble salts ($ECx10^3$), exchangeable sodium percentage, nitrate-nitrogen, and extractable phosphorus were significantly higher in soils irrigated with the pump water-wastewater mixture than in soils irrigated with pump water. Water quality analyses showed that the pump water-wastewater mixture had lower total soluble salts, lower nitrate-nitrogen, and higher phosphorus levels than pump water alone.

Additional Index Words: Cereal grains, irrigation water, soil, sewage, waste, pollution.

INTRODUCTION

An adequate supply of water has always been a problem for inhabitants in the semi-arid southwestern United States. Since surface water is limited, ground water reserves have been pumped to supply the agricultural, municipal, and industrial needs. Agricultural use of water combined with large increases in population have greatly increased the demand for ground water and have resulted in a lowering of the water table. Alternative sources of irrigation water must be used whenever possible by commercial agriculture to reduce the gap between the rates of pumping and recharge of ground water supply in the Southwest. One alternative is the use of treated municipal wastewater for crop irrigation. This would provide low-cost irrigation water that contains large quantities of plant nutrients. The utilization of municipal wastewater as a source of irrigation water and fertilizer for crop production can also greatly reduce environmental pollution around metropolitan areas throughout the United States.

LITERATURE REVIEW

A number of farming areas have effectively utilized treated municipal wastewater for irrigation. At Seabrook Farms in New Jersey, spray irrigation of sewage sludge and wastewater combinations was used on 1,418 hectares of crop land (Skulte, 1956). Chaiken et al. (1973) noted that in Muskegon County, Michigan 4,050 ha of land were used to grow corn (*Zea mays* L.), beans (*Phaseolus vulgaris* L.), wheat (*Triticum aestivum* L.), and sudangrass (*Sorghum sudanense* (Piper) Stapf) with wastewater irrigation. Dugan et al. (1975) reported that wastewater was used in the irrigation of sugar cane (*Saccharum officinarum* L.) and grassland in Hawaii.

In addition to providing irrigation water, treated municipal wastewater may be a potential source of plant nutrients for field crops (Bole and Bell, 1978). Chapman (1962) found that the amount of nitrogen, phosphorus, and potassium obtained from 10.28 ha-cm of Madison, Wisconsin wastewater were equivalent to that of 125 kg of a 20-20-10 inorganic fertilizer. Day et al. (1962) reported that cereal grains irrigated with wastewater produced higher grain yields than cereal grains irrigated with pump water with no additional fertilizer. Day et al. (1975) found that wheat grain grown with wastewater contained more total protein than grain raised with well water plus suggested amounts of N, P, and K.

Investigations have been conducted concerning the possible hazards of ground water, crop, and soil contamination by municipal wastewater. According to Pound and Crites (1973) soil filtration of wastewater alleviated the chemical contamination of groundwater. Sorber et al. (1972) suggested that percolation of wastewater through 1.5 to

3m of continuous fine soil will significantly reduce biological contamination of ground water. Young et al. (1972) reported that shallow soil depths of 5 to 15 cm were sufficient to remove viruses from wastewater.

Concerning biological contamination of crops, Rudolf et al. (1951) found that pollutional bacteria from untreated wastewater adhered firmly to the outer surface of tomatoes (Lycopersicum esculantum Mill); however, there was no evidence that bacteria, amoeba, or helmenth eggs penetrated healthy, unbroken surfaces of vegetables or caused internal contamination. Babov (1962) noted that the level of bacterial contamination of vegetables irrigated with wastewater did not differ from the bacterial level of vegetables irrigated with fresh water if wastewater irrigation was terminated shortly before harvest.

The effects of continuous irrigation with wastewater on soil accumulation of heavy metals have been investigated, Michel et al. (1974) recommended the need for continuous research to determine the long term effect of heavy metals present in wastewater upon soil properties; however, Day et al. (1972) found that wastewater irrigation for 14 years in southern Arizona did not result in any detrimental effects on Grabe silt loam soil that could not be corrected by minor changes in field crop culture.

Additional research is needed to study the effects of municipal wastewater on growth, yield, and quality of field crops and soil properties when it is utilized for commercial agriculture by an entire irrigation district. Therefore; the objectives of this research were: (a) to compare the response of barley (Hordeum vulgare L.) irrigated with a mixture of pump water and wastewater with the response of barley irrigated with pump water alone, (b) to compare the effects of pump water and pump water-wastewater irrigation on soil properties, and (c) to compare the quality of a pump water-wastewater mixture with the quality of pump water alone as a source of irrigation water for barley production.

MATERIALS AND METHODS

Buckeye, Arizona is an agricultural community located about 48 km (30 mi) west of Phoenix in central Arizona. The Buckeye Irrigation Company is located there and provides irrigation water to about 7,290 ha (18,000 acres) of farmland, which is known as the Buckeye Irrigation District. Beginning in 1962, the Buckeye Irrigation Company began using treated municipal wastewater from the city of Phoenix for irrigation water. From the initial use of 98.6 ha-m (800 acre-feet), the amount of wastewater used by the Buckeye Irrigation Company increased to 4,932 ha-m (40,000 acre-feet) by 1968. In 1971, a long-term contract with the city of Phoenix was signed to provide the Buckeye Irrigation Company with 3,700 ha-m (30,000 acre-feet) of treated municipal wastewater annually for 40 years. The need to investigate the effect of treated municipal wastewater upon the crops, soils, and irrigation water was recognized and wastewater research studies were conducted in the Buckeye area from 1970 through 1977.

Crop Response

Representative barley fields were selected on similar soil types and under similar management practices for investigation in 1974 and 1975. The dominant soil type in the fields studied was a Gilman loam. The Gilman soil series belongs to the family of the coarse-loamy, mixed (calcareous), Hyperthermic, Typic Torrifluvents. The effects of two irrigation treatments: (a) pump water and (b) a 50:50 mixture of pump water and wastewater (pump water-wastewater) on barley growth were compared by sampling the selected barley fields each year. The experimental design was a modified Randomized Complete Block with four replications. 'Arivat' barley was the cultivar evaluated each year.

Barley irrigated with pump water alone was fertilized with 112 kg/ha of N prior to planting; whereas barley irrigated with the pump water-wastewater mixture was not supplemented with commercial fertilizer. All other cultural practices in the two irrigation treatments were similar. The barley crop was harvested by hand sickle, each year at maturity from four 0.405 m^2 plots in each selected field. Data collected for comparison of the irrigation treatments from each plot were: (a) plant height, (b) heads per unit area,(c) seeds per head, (d) seed weight, (e) grain yield, and (f) straw yield.

From 1970 to 1977, representative fields of barley in the Buckeye Irrigation District ranging from 16 to 65 ha (40 to 160 acres) were selected for irrigation study. Twenty-five barley fields were irrigated with pump water alone. Another 25 barley fields were irrigated with the pump water-wastewater mixture. At maturity, the following data from each field were obtained: (a) plant height, (b) loding, (c) grain volume-weight, and (d) grain yield. The barley was combine-harvested in May each year.

Standard analysis of variance was followed for all data analysis and Student-Newman-Kuel's Test was used to compare treatment means as outlined by Little and Hills (1972).

Effects on Soil Properties

At each harvest in 1974 and 1975, soil samples from the 0-30 cm depths were collected from each plot within each selected field. The soil samples were analyzed for paste pH, electrical conductivity ($ECx10^3$), exchangeable sodium percentage (ESP), nitrate-nitrogen (NO_3-N), and extractable phosphorus according to methods described by Black et al. (1965).

Water Quality

Techniques described by Taras (1971) were used to monitor the water quality of the pump water and wastewater used for irrigation of barley fields in 1974 and 1975. Additional data from annual water quality reports of the Buckeye Irrigation Company and the Roosevelt Irrigation Company were studied. Based on the accumulated data, a composite result of water quality analysis was formulated for the irrigation water used on each selected field.

The amounts of total solubles salts, NO_3-N, and total P accumulated on each selected field from the pump water or pump water-wastewater irrigations were determined from the composite water quality data in conjunction with the amount of water applied. Barley consumptive water use data compiled by Erie et al. (1965) was used to estimate the amount of water applied.

RESULTS AND DISCUSSION

Crop Response

In 1974 and 1975, in small plot research, barley irrigated with a 50:50 mixture of pump water and wastewater produced taller plants more heads per unit area, heavier seeds, higher grain yields, and higher straw yields than barley irrigated with pump water alone (Table 1). Number of seeds per head were not significantly affected by the irrigation treatments.

Comparison of large barley fields from 1970 through 1977 showed that barley irrigated with the pump water-wastewater mixture had taller plants, more lodging, lower grain volume-weights and higher grain yields than barley irrigated with pump water alone (Table 2).

The vegetative growth of barley, as indicated by the plant height and straw yield data, was higher when it was irrigated with the pump water-wastewater mixture than the vegetative growth produced with pump water irrigation. Increased vegetative growth derived from the pump water-wastewater irrigation may be a partial explanation for the increased lodging. Although barley irrigated with the pump water-wastewater mixture out-yielded barley irrigated with pump water alone, its lower grain volume-weight (seed weight and/or size) may be indicative of lower grain quality and marketability (Table 2). If a grower's objective is to produce barley for pasture forage, he may obtain higher vegetative yield by using wastewater as a partial source of irrigation water than by using pump water alone.

Effects on Soil Properties

Results of soil analyses are shown in Table 3. In the 0-30 cm depth, all soil samples tested were slightly alkaline with a pH of about

8. Irrigation treatments did not result in a significant pH change. Electrical conductivity, exchangeable sodium percentage, NO_3-N, and extractable P were significantly higher in soils irrigated with the pump water-wastewater mixture than in soils irrigated with wastewater alone.

Water Quality

Average depths of water penetration were similar for the two irrigation treatments (Table 4). Pump water contained more total soluble salts and NO_3-N than did the pump water-wastewater mixture. The pump water-wastewater mixture had a higher P content than pump water alone (Table 4).

Water quality for irrigation is influenced by soluble salt concentrations. Excessive levels of soluble salts in irrigation water may be detrimental to plant growth by inhibiting germination, limiting water uptake due to osmotic effects, and by specific toxic effects on plants by ions present in the irrigation water. Because it had a lower concentration of total soluble salts (Table 4), the pump water-wastewater mixture was superior to pump water alone for irrigation purposes in the Buckeye area.

The NO_3-N content in the pump water-wastewater mixture was lower than the NO_3-N content in the pump water alone (Table 4). This, however, does not account for the organic and ammonium forms of nitrogen that may be present in wastewater and may be transformed into NO_3-N over a period of time. The higher nitrate content of soils irrigated with the pump water-wastewater mixture (Table 3) may have resulted from the forgoing condition present in municipal wastewater.

From the experience in the Buckeye Irrigation District, it is believed that treated municipal wastewater can be used as a partial source of irrigation water and plant nutrients in the commercial production of barley in the irrigated areas of the Southwest and also in similar regions throughout the world.

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LIST OF TABLE HEADINGS

TABLE 1

Average plant height, heads per unit area, seeds per head, seed weight, grain yield, and straw yield from barley grown with pump water and pump water plus wastewater near Buckeye, Arizona in 1974 and 1975.

Irrigation treatment	Year	Plant height	Heads per m^2	Seeds per head	Seed weight	Grain yield	Straw yield (12% moisture)
		(cm)	(no.)	(no.)	(mg/seed)	(kg/ha)	(kg/ha)
Pump water	1974	86 b+	509 b	25 a	43 b	5,526 b	5,835 b
	1975	84 b	533 b	27 a	41 b	5,846 b	6,094 b
	1974-75 average	85 b	521 b	26 a	42 b	5,686 b	5,965 b
Pump water plus wastewater	1974	96 a	562 a	28 a	46 a	6,732 a	7,702 a
	1975	92 a	581 a	26 a	48 a	7,327 a	7,893 a
	1974-75 average	94 a	572 a	27 a	47 a	7,030 a	7,798 a

\+ Means in the same column for the same year or years followed by the same letter are not different at the 5% level of significance using the Student-Newman-Keuls' Test.

TABLE 2

Average plant height, lodging, grain volume-weight, and grain yield from 25 fields of barley grown with pump water and 25 fields of barley grown with pump water plus wastewater near Buckeye, Arizona from 1970 through 1977.

Irrigation treatment	Plant height	Lodging	Grain volume-weight	Grain yield
	(cm)	(%)	(kg/hl)	(kg/ha)
Pump water	86 b+	60 b	62 a	4,102 b
Pump water plus wastewater	96 a	75 a	60 b	5,248 a

+ Means in the same column followed by the same letter are not different at the 5% level of significance using the Student-Newman-Keuls' Test.

TABLE 3

Average pH, electrical conductivity, exchangeable sodium, nitrate-nitrogen, and extractable phosphorus in the 0 to 30-cm depth of soils from fields irrigation with two irrigation treatments for the production of barley near Buckeye, Arizona in 1974 and 1975 (2-year average).

Irrigation treatment	Paste pH	Electrical conductivity	Exchangeable sodium percentage	Nitrate nitrogen	Extractable phosphorus (CO_2 extraction)
	(pH)	(EC x 10^3)	(ESP)	(ppm)	(ppm)
Pump water	8.0 a+	1.8 b	5.7 b	4.8 b	2.5 b
Pump water plus wastewater	7.9 a	2.3 a	10.7 a	7.4 a	6.2 a

+ Means in the same column followed by the same letter are not different at the 5% level of significance using the Student-Newman-Keuls' Test.

TABLE 4

Average depth of penetration, total soluble salts, nitrate-nitrogen, and phosphorus for pump water and pump water plus wastewater used to irrigate barley near Buckeye, Arizona in 1974 and 1975 (2-year average).

Irrigation treatment	Penetration of irrigation water	Total soluble salts	Nitrate nitrogen	Phosphorus
	(cm)	(ppm)	(ppm)	(ppm)
Pump water	64 a+	3,655 a	16.0 a	0.0 b
Pump water plus wastewater	64 a	1,910 b	8.1 b	3.6 a

+ Means in the same column followed by the same letter are not different at the 5% level of significance using the Student-Newman-Keuls' Test.