UTILIZATION OF WASTES FROM OLIVE AND SUGAR BEET PROCESSING INDUSTRIES IN FERTIRRIGATION

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ABSTRACT

"Alpechin" and "vinaza", by-products from the olive and sugar beet processing industries, respectively, were used for irrigating and fertilizing annual crops. The influence of the addition of these two products on the chemical and physical properties of a vertic xerofluent soil, and on crop development and production was studied. A rotation of maize (spring-summer) and lettuce (winter) was estalished on eight plots of 25 m². Three different treatments with "alpechin" and "vinaza" were applied to six of the plots. The other two plots were fertilized and irrigated conventionally. Electrical conductivity of soil solution, bulk density, infiltration rate and water profile of the soil were affected by the treatments. The first maize crop showed no clear differences in development and production between the various plots, but in the second maize crop remarkable influences of the treatments were found. The lettuce production decreased as the doses of "alpechin" and "vinaza" increased.

INTRODUCTION

Utilization of wastewaters on agricultural land is a well-established practice, recognized as a desirable means, both environmentally and economically, of disposal. Land application results in recycling of nutrients essential for plant growth and supplies organic matter to the soils. However, wastewater effects on soils, crops, underground waters, etc., should be evaluated prior to its application (DINGES, 1982).

Beneficial effects of wastewater on soils and crops have been reported on many occasions (BOUWER AND CHANNEY, 1974; JACOBS, 1977; SAAVEDRA et al., 1984). However, some soil properties can be negatively affected by a continuous use of wastewater as fertilizer. RICHARDS et al. (1966) and ROWSEL et al. (1983) reported decreases in the water infiltration rate of soil treated with wastewater, while TRAVIS et al. (1971) found that the infiltration rate decreased only in fine-textured soil when treated with effluents of very low organic matter contents. Other negative effects can be produced on physical, chemical and biological soil properties and crops because of a unappropriate management of wastewater application (DINGES, 1982; JACOB, 1977). The disposal of the liquid by-products from olive and sugar beet processing industries, "alpechin" and "vinaza", is a problem in southern Spain because of their high organic matter and soluble salt contents (CABRERA et al., 1984). For years both effluents were discharged directly into water courses without any treatment leading to a negative impact on water quality. Nowadays, "vinaza" and "alpechin" are

kept in ponds where evaporation during the summer, producing consequent stink and other nuisances, or are treated in anaerobic digestors to produce effluents still rich in organic matter and salts.
Some aspects of the physical and chemical properties of soil irrigated with digested "vinaza" of "alpechin" are studied in this paper.

MATERIALS AND METHODS

Experimental work was carried out in a field situated at the Aljarafe Experimental Farm C.S.I.C. (SW Sevilla). Eight plots of 25 m^2 each were used for crop rotation (maize-lettuce). Two plots (test plots) were treated with commercial fertilizer (Table 1). The other six plots received digested "vinaza" and "alpechin" in three different doses (37.5, 25.0 and 12.5 l of "vinaza" or "alpechin" per plot, mixed homogeneously with irrigation water in each application). Some data on the composition of the digested "vinaza" and "alpechin" and irrigation water are shown in Tables 2 and 3, respectively. Amounts of N, P and K supplied with maximum waste doses are given in Table 1.
Plots were irrigated in furrows. Table 4 shows the number and amount of applications and the rainfall during the experimental period.
The soil of the plots is classified as vertic xerofluvent. Its average particle size distribution is 43.8% for the fraction >200 µm, 23.9% for 200-20 µm, 7.5% for 20-2 µm and 24.8% for <2 µm. These average values were calculated from a total of 16 profiles (2 profiles per plots).
Systematic sampling of soil and soil solution was carried out at different dates during the experimental period. Soil samples for physical analysis were taken in stainless steel cylinders (8 cm diameter x 4 cm high and 8 cm diameter x 2 cm high) at different depths. Soil samples for chemical analysis were taken at two depths (0-25, 35-45 cm), air dried, ground and sieved to 2 mm.
Soil solutions were extracted at 60 cm depth with a pressure-vacuum, soil-water sampler.
Soil-water content up to 3 kPa was determined by suction in porous plate funnels by a technique similar to that described by VOMOCIL (1985) and from -10 kPa to -1.5 MPa by pressure in ceramic plate chambers (RICHARDS, 1948). Bulk density (D_b) was calculated from the mass/volume ratio of soil samples in cylinders 8 cm in diameter x 4 cm high.
Saturated hydraulic conductivity (Ks) was determined in a constant-head permeameter according to FLANNERY and KIRKHAM (1964) in an apparatus designed by MARTIN-ARANDA (1973).
Water infiltration was measured in situ by the double-ring infiltrometer. Water content in the field was determined using the neutron probe Troxler 3333. Electrical conductivity (E.C.) of the soil-water system was measured in situ with a soil-salinity sensor 5100-A and a salinity bridge 5500 Soil Moisture Equipment Co.
Total N and available P (OLSEN et al., 1954) were determined in the soil. Saturated soil pastes were prepared as described by the U.S. Salinity Laboratory staff (1954). Electrical conductivity (E.C.) and major anion ($CO_3^=$, HCO_3^-, Cl^-, $SO_4^=$ and

TABLE 1: Fertilizing of test plots and of those treated with maximum doses of "vinaza" and "alpechin"

Crop	Test			"vinaza" Max. dose			"alpechin" Max. dose		
	N	P kg ha^{-1}	K	N	P kg ha^{-1}	K	N	P kg ha^{-1}	K
Maize	80*	66	125	167	2.6	1768	36	2.8	405
Lettuce	32	26	50	22	0.4	236	5	0.4	54

*plus two doses of 300 kg ha^{-1} urea

TABLE 2: Some data on the composition of the "vinaza" and "alpechin".

	"Vinaza"	"Alpechin"
pH	9.40	9.21
E.C. (mS cm^{-1})	21.9	7.1
Total non-volatil solids (mg l^{-1})	16114.0	4230.0
Total volatil solids (mg l^{-1})	4900.0	3120.0
Kjeldahl-N, NH_4-N (mg l^{-1})	742.0	157.0
Total P, PO_4-P (mg l^{-1})	11.3	12.7
Total Cl (mg l^{-1})	3351.0	582.0
Total S, SO_4-S	131.0	36.0
Total Na (mg l^{-1})	3163.0	815.0
Total K (mg l^{-1})	7850.0	1800.0

TABLE 3: Composition of the irrigation water

pH	E.C. mS cm^{-1}	SAR	$CO_3^{=}$	HCO_3^-	Cl^-	$SO_4^{=}$	NO_3^- meq/l	Na^+	K^+	Ca^{++}	Mg^{++}
8.24	1.81	2.64	1.16	6.65	7.41	3.18	0.77	6.77	0.067	5.45	7.74

TABLE 4. Number and amount of water application during experimental period in the eight plots

Crop	Year	Period	Water application (times in the period)	Amount of water applied each time (mm)	Rainfall (mm)
Maize	1985	April-August	15	45	148.6
Lettuce	1985-1986	December-March	2	80	275.1
Maize	1986	April-August	15	44	65.8

NO_3^-) and cation (Ca^{++},, Mg^{++}, Na^+ and K^+) contents were determined in both soil solution and extracts from saturated soil pastes.

RESULTS AND DISCUSSION

Physical properties of the soil

In order to characterize the soil-water relationships, the soil-water content at different matrix potentials were determined (Fig. 1). These results show that the experimental plot soil has a relatively high available water capacity. Bulk density (D_b) and saturated hydraulic conductivity (Ks) values at different times during the experimental period are shown in Table 5. Prior to the application of "vinaza" and "alpechin" (April 1985, at maize planting), Db and Ks at 0-20 and 20-40 cm had similar values in all the plots. Only after the first maize crop, D_b for the plot treated with maximum "alpechin" doses increased slightly at 0-20 cm depth. This increase was more noticeable after the second maize crop cycle (September 1986) where a considerable decrease in Ks was also observed.
Water infiltration experiments carried out after the second maize crop (September 1986) showed an important decrease in the infiltration rates during the first 15 min in all the plots.

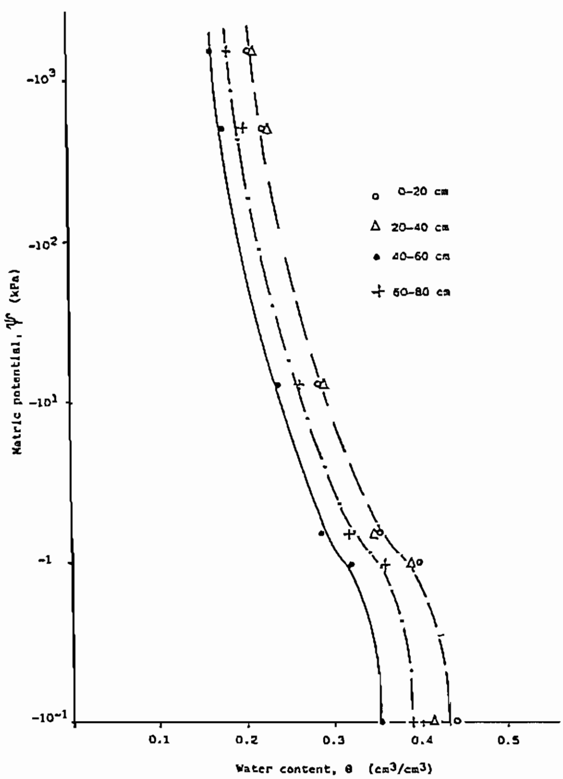

Fig. 1: Soil-moisture characteristic curves of soil prior to applications of "vinaza" and "alpechin"

TABLE 5: Values of bulk density (D_b) and saturated hydraulic conductivity (Ks) at different dates during the experimental period

Year	Sampling date	Depth (cm)	Test $D_b(g/cm^3)$	Test Ks(mm/h)	"Vinaza" max. $D_b(g/cm^3)$	"Vinaza" max. Ks(mm/h)	"Alpechin" max. $D_b(g/cm^3)$	"Alpechin" max. Ks(mm/h)
1985	April	0-20	1.43 ± 0.03	45.9 ±3.9	1.47 ±0.03	52.1 ±6.1	1.46 ±0.03	51.5±5.5
		20-40	1.51 ± 0.02	23.0 ±5.1	1.54 ±0.03	30.1 ±5.3	1.53 ±0.04	28.4±5.4
	September	0-20	1.50 ± 0.02	42.0 ±3.1	1.53 ±0.06	43.2 ±5.2	1.60 ±0.02	35.3±6.1
		20-40	1.54 ± 0.03	22.5 ±5.0	1.56 ±0.04	30.6 ±3.4	1.62 ±0.04	22.8±4.7
1986	April	0-20	1.48 ± 0.04	35.9 ±4.2	1.51 ±0.02	35.2 ±4.5	1.50 ±0.02	35.5±4.5
		20-40	1.54 ± 0.02	23.8 ±3.9	1.56 ±0.04	22.6 ±3.0	1.54 ±0.03	21.2±4.0
	September	0-20	1.58 ± 0.02	25.7 ±7.3	1.61 ±0.03	21.3 ±5.4	1.70 ±0.02	6.3±2.9
		20-40	1.58 ± 0.04	21.2 ±6.1	1.64 ±0.04	18.9 ±5.0	1.65 ±0.01	14.0±5.2

After 90 min infiltration rates remained practically constant at 25, 20 and 9 mm/h for the test max. vinaza and max. alpechin plots, respectively. The very low value of the max. alpechin-teated plot agrees with the corresponding value of Ks (Table 5) and can be attributed to the "alpechin" applications. These results are similar to those reported by TRAVIS et al. (1971) and ROWSELL et al. (1983).

Water profiles of the same three plots considered above at three dates during the second maize crop are shown in Fig. 2. The three water profiles are similar at the first developmental stage of plant emergence (7 May). Afterwards water profiles of the test plot show water contents which are much lower than the other plots. These differences could be attributed to the different water-extraction rates of the plants in each plot because of their differing development (Fig. 3).

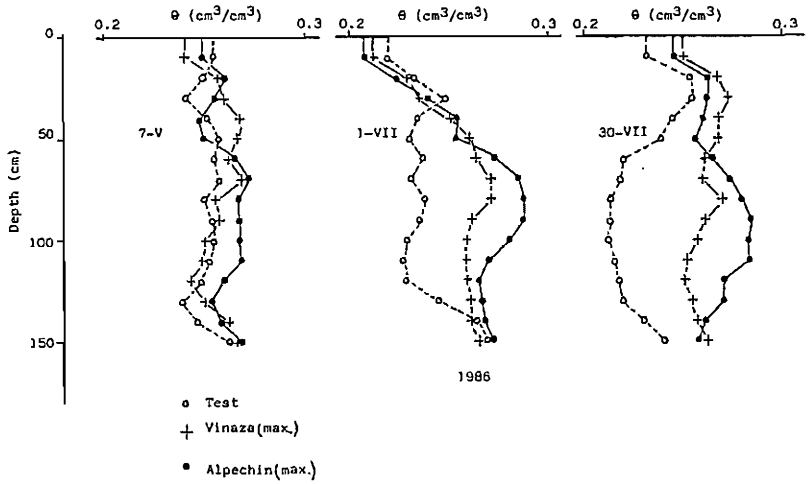

Fig. 2: Evolution of water profiles at different dates in 1986

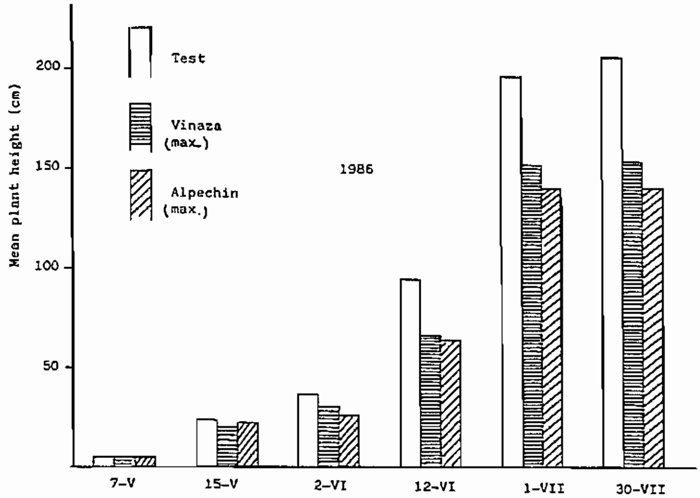

Fig. 3: Plant height of maize crop at different dates during 1986

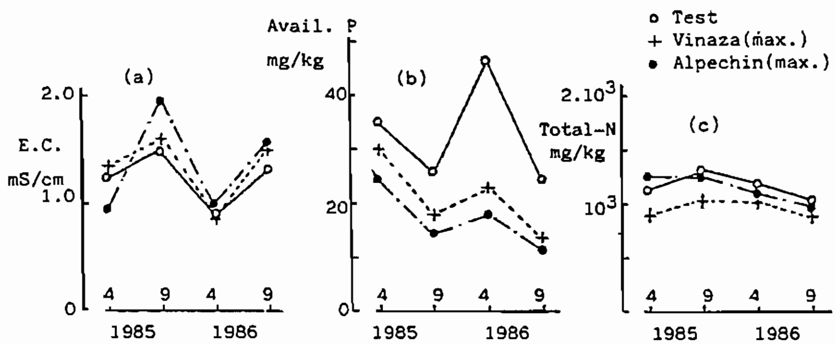

Fig. 4: Variation of some soil properties during the experimental period: (a) Electrical conductivity; (b) Available phosphorus; (c) Total nitrogen

Chemical properties of the soil

E.C. values of the saturation extracts are lower at the end of winter than at the end of summer, coinciding with the end of the lettuce and maize crops, respectively (Fig. 4). This seasonal variation corresponds to a similar behaviour of the major anion and cation contents of the soil extracts. However, no significant differences were found between plots.
Available P of superficial soil (0-25 cm) shows also a seasonal variation: values at the end of winter are greater than at the end of summer (Fig. 5). Throughout the experimental period available-P values of the test plots were higher than those of the treated plots. A decreasing trend in the available P values can also be observed in the vinaza- and alpechin-treated plots. Low values and a decreasing trend of available P of treated plots could be due to the low P supply in "vinaza" and "alpechin".

Total nitrogen values of the soils of the eight plots trend to decrease throughout the experimental period, but no significant differences were observed between plots (Fig. 5).
During the first lettuce crop (January-April 1986) and the second maize crop (May-July 1986) the E.C. of the soils at 30 and 60 cm depth and the composition of the soil solution at these depths were monitored in the test plot and in those treated with the highest doses of "alpechin" and "vinaza". Figure 5 shows the variation of three of these parameters from January to July. Through this period the values of E.C., alkalinity, chloride, sulfate, sodium, potassium, calcium and magnesium of the treated plots were higher than those of the test plots, indicating salt accumulation in the former due to the "vinaza" and "alpechin" treatments.

From January to April it was found that E.C. and soils and concentration of sulfate, nitrate, sodium, potassium and

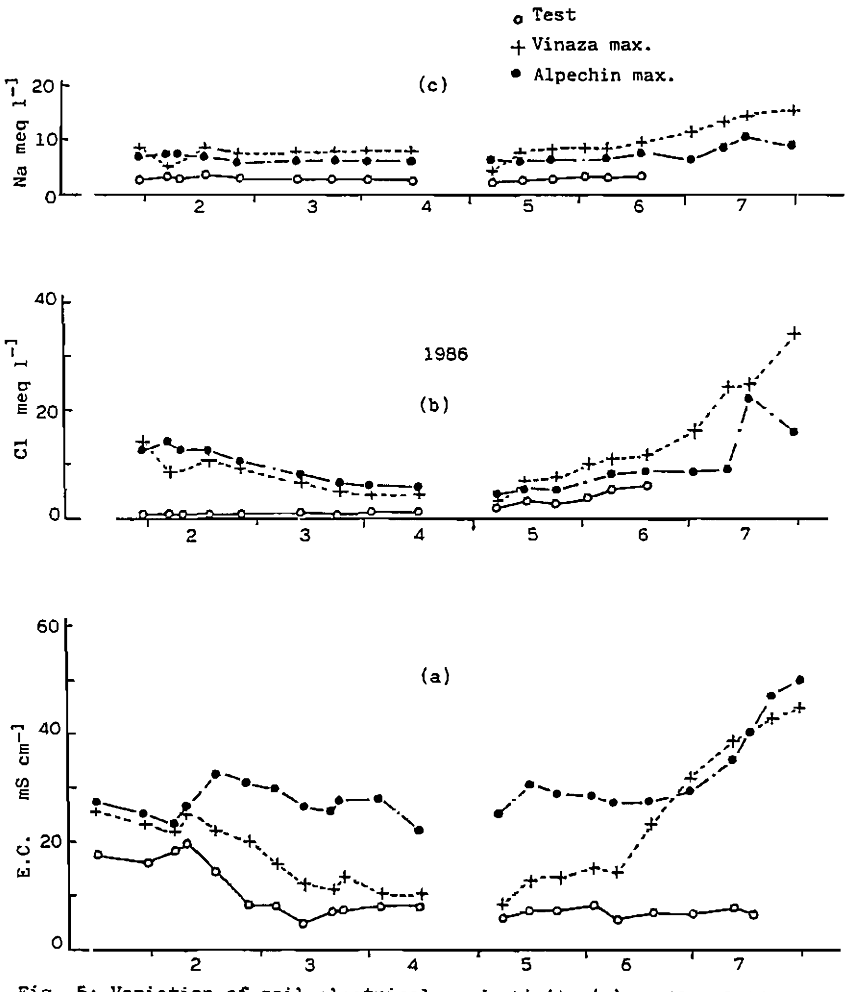

Fig. 5: Variation of soil electrical conductivity (a), soil solution chloride and sodium concetrations (b, c) during the first lettuce crop (Jaн-Ap 1986) and the second maize crop (May-Aug 1986)

calcium decreased while alkalinity increased in the soils solutions of the three plots. However, chloride and magnesium concentrations decreased sharply in the two treated plots, but remained almost constant in the test plot. The decrease in some of the soil solution components points out the leaching during the rainy season of the accumulated salts.
From May to July E.C. of the soils and soil solution concentrations of chloride, sulfate, sodium, potassium, calcium and magnesium increased in the three plots, although less in the test plot. In the same period alkalinity remains constant and nitrate pass through a maximum in the three plots. The increase of some of the soil solution components indicates the accumulation of soluble salts from the irrigation water, "vinaza" and "alpechin" in the soils.

Crop yields

Maize and lettuce yields are shown in Table 6. The first crop of maize was heavily affected by a fungi pest (Ustilago maydis) which produced a decrease in the number of normal cobs, especially in the test plot. The weight of maize grain yielded in this crop reflects clearly the influence of the pest. Therefore, no differences can be attributed to treatments.

Yields of the lettuce and second maize crop were higher in the test plot than in the treated plots. Decreases in both crop yields are observed as the rate of "vinaza" and "alpechin" applied increases. In lettuce crop higher yields were found in vinaza-treated plots than in those where "alpechin" was applied. In maize crop differences were found between the development of plants in test, maximum "vinaza" and maximum "alpechin" (Fig. 3).

Both maize and lettuce yields from treated plots seem to reflect the high values of salinity of the soil solution observed during the crop cycles (Fig. 5). However, differences between yields in treated and untreated plots can also arise from the different amounts of nutrients applied (Table 1).

TABLE 6: Crop yields

Plot		Maize				Lettuce	
		1st crop		2nd crop		No. plants	Total weight Ig/plot
		normal cobs %	grain Ig/plot	normal cobs %	grain Ig/plot		
Test		57	26.6	94	27.5	93	68.6
"vinaza"	Min.	76	32.7	68	16.1	94	57.7
	Med.	84	37.2	63	12.6	93	52.9
	Max.	76	36.9	68	11.2	98	50.8
"alpechin"	Min.	81	31.2	83	17.3	95	46.1
	Med.	83	31.2	61	11.2	93	46.6
	Max.	72	28.8	69	12.3	94	45.2

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REFERENCES

BOUWER, H. and CHANNEY, R.L. (1974): Land treatment of wastewater. Advances in Agronomy 26: 133-169.

CABRERA, F., TOCA, C.G., DIAZ, E. and ARABARRI, P. (1984): Acid mine-water and agricultural pollution in a river skirting the Doñana Natural Park (Guadiamar river, South West Spain) . Water Research 18: 1469-1482.

DINGES, R. (1982): Natural systems for water pollution control. Van Nostrand Reinhold Company, New York.

FLANNERY, R.D. and KIRKHAM, D. (1964): A soil core water permeameter for field use. Soil Sci. 97: 233-241.

JACOBS, L.N. (1977): Utilizing municipal sewage wastewater and sludge on land for agricultural production. North Central Regional Extension, publication No. 52. Michigan State University.

MARTIN-ARANDA, J. (1973): Factores fisicos fundamentales en la economia de agua de los suelos de Andalucia Occidental. Alcance agronomico en cultivos de regadio. Ph.D. Thesis, University of Granada, Spain 291 pp.

OLSEN, S.R., COLE, C.V., WATANABE, F.S. and DEAN, L.A. (1954): Estimation of available phosphorus in soils by extraction with sodium bicarbonate U.S. Department of Agriculture, Circular 939.

RICHARDS, L.A. (1948): Porous plate apparatus for measuring moisture retention and transmission by soil. Soil Sci. 66: 105-110.

RICHARDS, T. and SCHWARTZ, S. (1966): Soil chemical changes and infiltration rate reduction under sewage spreading. Soil Sci. Soc. Am. Proc. 30: 641-646.

ROWSELL, J., MILLER, M. and GROENEVELT, P. (1985): Self-sealing of earthen liquid manure storage ponds: II. Rate and mechanism of sealing. J. Environmental Quality 14(4): 539-543.

SAAVEDRA, M., TRONCOSO, A and ARAMBARRI, P. (1984): Utilizacion de aguas fuertemente contaminadas en el riego del olivo. Anales de Edafologia y Agrobiologia 43: 1449-1466.

TRAVIS, D., POWERS, W., MURPHY, L. and LIPPER, R. (1971): Effect of feed lot lagoon water on some physical and chemical properties of soils. Soil Sci. Soc. Am. Proc. 35: 122-126.

VOMOCIL, J.A. (1965): Porosity. In: C.A. Black (Ed.), Methods of soil analysis. Part I. Agronomy. American Society of Agronomy, Madison, WI, Chapter 9, pp. 299-314.

U.S. Salinity Laboratory Staff (1954): Diagnosis and improvement of saline and alkali soils (Ed. L.A. Richards).