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## VINASSE (Alcohol Industry Waste) RECYCLING IN AGRICULTURE.

T.A. Gemtos, N. Chouliaras, St. Marakis\*

### ABSTRACT

Vinasse application in agriculture as a substitute for chemical fertiliser and soil amendment was studied in field and in laboratory experiments in Greece. Different application rates, times of application, the effect of soil compaction induced by the spreading tank and the effect on chemical properties of the soil were studied in a Wheat Durum crop. Vinasse did cause a delay in plant emergence, but the plants recovered later showing no significant differences in the growth rates and characteristics. Compaction caused an increase in penetration resistance and the shear strength of the soil, but the effect on yields was not always significant. Plots with vinasse gave similar or better yields than conventional fertilisation. Vinasse caused an increase in pH and Na content at a dangerous level in the incubation experiments but in the field this increase was small and not at hazardous level for the soil.

Keywords: Vinasse, Waste, Recycling, Soil properties

### INTRODUCTION

Vinasse is a waste produced by the alcohol industry which, in Greece, uses as raw material molasses from the sugar beet industry. The waste is condensed to a dry matter content of 60% which contains 3.5% N, 0.5% P, 6.5% K and 2.5% Na. The material has a very high BOD<sub>5</sub> and it is very difficult to be cleaned economically. A possible solution is to be used in Agriculture as a substitute for chemical fertilisers and as an organic fertiliser (soil amendment) reducing the problem of the very low organic matter content of Greek soils.

The aim of the work presented here was to investigate the feasibility of vinasse recycling in agriculture and the possible problems arising from that application.

### LITERATURE REVIEW

Vinasse is produced in many countries but as the raw material it is different (sugar cane etc.), vinasse also has different properties. From the literature review it is shown that sugar cane vinasse has low concentration in Na but the later is high in sugar beet vinasse (see in literature cited). N and K concentration are relatively high while P is low. Mattiazo and de Glorie (1987) found that the application of vinasse caused an initial reduction of the soil pH which increased with time due to the microbial activity causing oxidisation of organic matter. Casarini et al. (1987) studied the effect of vinasse application on micro-organisms development in a sugar cane plantation. They observed a reduction of pH after the application of vinasse but an increase later. They observed also an increase in micro flora 60 days after the application. Ribeiro and Seizik (1983) in experiments in the laboratory

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\*T.A.Gemtos, Assistant Professor, Laboratory of Farm Mechanization, University of Thessaly, Pedio Areos, 38334 Volos, Greece and Technological Education Institution (T.E.I.) of Larissa; N. Chouliaras, Professor, T.E.I. of Larissa; St. Marakis, Assistant Professor, University of Athens.

observed that vinasse increased the saturation of the soil with bases which caused a reduction of exchangeable Al and an increase of pH.

Debruck and Lewiski (1985) studied in Germany the effects of vinasse application in agriculture. They stated that application of more than 5 ton/ha affected inversely the crops due to the salt content. They found that organic N of vinasse cannot be leached to the deeper layers of the soil and that it is delivered when the temperature rises in Spring, the time needed by the plants. They presented results showing a beneficial effect on the straw decay when the straw was incorporated in the soil and on crops, especially sugar beet and onions.

Morisot (1978) studied the effect of vinasse application in pots at rates 1% and 10% of the soil, with and without addition of chemical N. He studied the evolution of the mineral N in the soil and concluded that vinasse causes an increase of micro-organisms activity which reduces the available N in the soil the first week after the application but later on organic N is mineralised, providing sufficient N for the plants. He commented that under field conditions, vinasse should be applied a month before drilling the crop.

Dutil and Muller (1979) have studied the effect of the application of the waste from different agro-industries (including distilleries and sugar factories) in agriculture. They found that initially the available N was reduced but later the mineralization provided sufficient amounts. They observed that after 48 weeks only 40% of the organic N was mineralised. They found also that when the application rates were in excess of the needs of the plants, N leaching was greater than the control plots with chemical fertiliser. They concluded that the application rate should cover the needs of the plant. Due to the content in Na, Cl and S they suggested application every four years.

Patil et al. (1982,1984) compared the decomposition rates of farm yard manure and "spent wash" from distilleries in an incubation experiment in the laboratory. They found that spent wash decomposition was four times faster than manure. They observed a decrease in pH for the first month of the incubation experiment and an increase later in both materials. An investigation on the effect of vinasse application at rates from 5 to 100 ton/ha in glasshouse pots in Greece (Bovis and Asimacopoulos 1988) showed that soluble K and Na increased proportionally to the applied quantities. They concluded that attention should be paid to the Na content which can, in higher rates, cause alkalisation of the soil. They suggested application rates under 10 ton/ha once every four years for safety.

#### MATERIALS AND METHODS

Three years of field experiments of vinasse application in wheat durum under continuous rotation (which is the usual rotation in the non irrigated fields of Theesaly, Greece) were carried out in two soils in order to investigate:

- a) The feasibility to substitute chemical fertiliser by vinasse partly or entirely.
- b) The effect of different dates of the waste application.
- c) The effect of soil compaction caused by the distribution equipment.
- d) The effect of vinasse on the soil physical properties.
- e) The effect of the waste and especially Na (sodium) on the soil properties.

The experiments were carried out in completely randomised blocks with control treatment the conventional fertilisation at 220 Kg/ha nitrogen (100 Kg in Autumn and the rest in Spring) and 80-100 Kg/ha  $P_2O_5$ . Two soils were used one light (clay 28%, silt 25% and sand 47 % o.m. 1.6% at a river side, C1) and one heavy (clay 44%, silt 27% sand 29%, o.m. 1.2%, C2). Conventional cultivation was

applied (ploughing in Autumn without straw burning, disking for seedbed preparation and drilling in rows 17 cm apart). In the high vinasse rate (7 ton/ha) plots, only P fertiliser was added. In the low vinasse rate (3.5 ton/ha) plots, besides P, half the N needs were covered by chemical fertiliser in the Spring, the same time as the control plots.

Each plot had a width of 9 m (three passes of a drilling machine of 3 m width) and 10 m in length. 10 m corridors were left between the plots, lengthwise, to allow for the machinery turning and 2 m to the other side. Vinasse was distributed in the field by a two wheel trailer tank. The tractor and the tank compacted about 1m of soil in each pass. In order to investigate the effect of soil compaction induced by the machinery movement two additional passes of the tractor-tank system without spreading were used. The result was compaction of the central strip of the plot. Finally, each plot had two subplots uncompacted and one compacted. During the experiment the following parameters were measured:

1. Seed emergence.
2. Plant growth during the season (number of plants per unit of area, height, number of brothers, internode length, head length).
3. Physical and dynamic properties of the soil as specific gravity, resistance to penetration, shearing strength by vane and box.
4. Final yield

In order to investigate the effect of vinasse application on the chemical properties of the soils an incubation experiment was carried out. Two superficial soil samples (the properties of the soils are shown in Table 2) taken from the control plots were studied. Vinasse was added at 1.7241 g /50 g of soil in sample C1 and at 2.2414 g/50 g of soil in sample C2, so that soil organic matter increased up to 2.5%. Soil moisture was held at 2/3 of the field capacity during incubation which lasted for 9 weeks. During incubation period, soil samples were taken and estimation of the nitrogen evolution was carried out. At the end of the incubation period, all samples were analysed for total nitrogen, nitrate and ammonium forms, exchangeable-Na, exchangeable-K, electrical conductivity of 1:5 extract and pH (1:5). During the field experiments of vinasse application, soil samples were taken and the same parameters as in the laboratory experiment were studied.

## RESULTS AND DISCUSSION

Due to the available space only part of the second year results will be presented. The results are similar for the first and the third year. The differences presented in the tables are estimated through a LSD test for  $p=0.05$  level.

### 1. Plant parameters

Table 1 shows the results for the plant number measured the 25/1/93, about a month after drilling and a second measurement in March for the heavy soil. Control plots present a better emergence while in the second measurement the difference is not significant. Vinasse appears to delay emergence and probably causes some damage to the seedlings due to the initial pH reduction and the soil salinity. The same effect was also found with other crops in glasshouse experiments (Gemtos and Lellis 1994). Comparison of the two measurements shows the loss of plants which occurred during winter. Time of application effect was not significant while compaction caused worse emergence in some cases. This should be attributed to the bad covering of the seeds in compacted plots due to difficulty of penetration of the furrow openers. In the light soil the differences are not significant. Only in compacted soil there is an increased number of plants in spring. All growth

parameters of the plants taken during the growing show no significant difference in general.

Table 1: Wheat plant parameters. Plant number for control plots and after vinasse application at different times of the year, in compacted and uncompacted plots, 1992-93

Treatment	mean plant number in 100000/ha for heavy soil 1st					
	Time of Application			Compaction		
	summer	before plough	after plough	no	yes	
Control	9.25a					
Vinasse at 3.5 ton/ha	7.7b	7.6a	6.8a	8.6a	8.4a	6.9b
Vinasse at 7 ton/ha	7.1b	6.8a	7.5a	7.2a	7.5a	6.8a
Total effect		7.2a	7.1a	8.0a	8a	6.9b
	mean plant number in 100000/ha for heavy soil 2nd					
Control	6.9a					
Vinasse at 3.5 ton/ha	6.6a	7a	6.3a	6.5a	7.2a	6b
Vinasse at 7 ton/ha	6.8a	6.5a	6.8a	6.9a	6.3a	7.2a
Total effect		6.8a	6.5a	6.7a	6.7a	6.6a

Note: Same letters within the boxes show no significant difference

## II. Effect on soil physical parameters.

The measurements presented were taken in March 1993. Plots with vinasse had a higher m.c. due to the increased organic matter. The other treatments did not significantly affect m.c. The surface specific weight was not affected by treatments, even by compaction in the heavy soil. This is most likely the effect of soil swelling during winter which in the heavy soil removed the compaction effect. Deeper measurements were not taken due to the wet conditions. The effect of compaction on specific weight is significant in the light soil. Tables 3 and 4 show the effect on the penetration and the shearing resistance of the soil. The results of measurements

Table 2: General characteristics of soils used in the experiments

	cm	C1	C1	C2	C2
		0 - 25	25-50	0-25	25-50
texture		SiCL	L	C	CL
M.O.	%	1.6	1.2	1.2	0.6
CaCO <sub>3</sub>	%	2.2	4.9	6.6	12.7
pH(1:5) susp*		8.3	8.1	8.2	8.1
CEC=T	me/100g	24	25	30	26
S/T.100		sat	sat	sat	sat
E.C.(1:5) extr*	mS/cm	0.15	0.18	0.23	0.22
Na/T.100	%	0.70	0.24	0.60	1.82
P-Olsen	mg/1000g	29.1		16.8	
Ex*-K	me/100g	1.010		0.810	
Ex*-Mg	me/100g	5.60		8.80	

C1, C2: Soil Samples

(\*)Ex: Exchangeable forms, susp suspension, extr: extract



at different depths are also presented. The results for surface measurements are not presented because values, especially in the heavy soil are very small. The effect of compaction by the spreading equipment is significant in all cases. Compacted plots and plots with late Autumn applications present higher strength. This effect persists till 20 cm depth in heavy soil and 30 cm in light soil.

### III Effect on chemical properties of soil

In the incubation experiment the following results were obtained:

N: In spite of the increase of total-N in both soils after the addition of vinasse (Table 5), the nitrate forms in the vinasse treatments are at lower levels in comparison to the controls, at the end of the incubation period. In the contrary, the ammonium forms in the vinasse trials show higher values at the same time (Table 5).

Table 5. Results of the incubation experiment in laboratory: Effect of Vinasse application on soil properties

	C1	C1+V	C2	C2+V
pH(1:5) susp*	8.12b(#)	9.23a	8.06b	9.06a
E.C (1:5) extr*	0.150d	1.41b	0.23c	1.70a
ex*-Na me/100g	0.030d	4.510b	0.400c	5.980a
NH <sub>4</sub> <sup>+</sup> -N mg/1000g	38.0d	131.0b	51.0c	210.0a
NO <sub>3</sub> <sup>-</sup> -N mg/1000g	732.0b	648.0d	813.0a	675.0c
ex*-K me/100g	0.973c	4.830b	0.775d	4.940a

C1: light soil, C2: heavy soil V: Vinasse treatments

(\*): susp: suspension, extr: extract, ex: exchangeable forms

(#): Means followed by different letters in the rows are significantly different at p=0.05 (conf. int.).

**Na and K:** The results reported in Table 5 show an increase of exchangeable forms of Na and K; in the case of Na, these values give rise of exchangeable sodium percentage (ESP) to the levels of 19% and 20% for samples C1 and C2 respectively.

**pH and E.C :** Vinasse treatments also, give rise to the values of pH and salinity (Table 5); the rise of pH value is attributed to the soil sodicity that vinasse produced.

Table 6. Total-N \* of soil treatments in field experiment

	control	Summer	before plough	after plough
C1	966ab#			
Vinasse at 3.5 tn/ha		1001a	952ab	994ab
Vinasse at 7.0 tn/ha		994ab	924ab	861b
C2	959d			
Vinasse at 3.5 tn/ha		1001c	1008c	1169a
Vinasse at 7.0 tn/ha		1085b	924d	1113b

C1: light soil, C2: heavy soil \* in mg N/Kg

(#): Means followed by different letters are significantly different at p=0.05 (conf. int.) for each soil.

In the field experiment, it seems that vinasse application does not cause a significant difference in the total-N content, in comparison to control plots (Table

6). The same conclusions are given after the study of  $\text{NH}_4^+\text{-N}$  and  $\text{NO}_3^-\text{-N}$  contents and the measurement of the EC and pH values of soil samples (Tables 7 and 8). It should be noted that a high variability of the results was observed which is attributed the low homogeneity of the experimental plots. On the other hand, the increase of exchangeable Na and K in the Vinasse treatments is, in general, estimated significant in comparison to the inorganic fertiliser treatments.

Table 7. pH of soil treatments in field experiment

	control	Summer	before plough	after plough
C1	8.51a#			
Vinasse at 3.5 tn/ha		8.42b	8.55a	8.35c
Vinasse at 7.0 tn/ha		8.56a	8.12d	8.44b
C2	8.38c			
Vinasse at 3.5 tn/ha		8.11d	8.48b	
Vinasse at 7.0 tn/ha		8.14d	8.61a	8.37c

C1: light soil, C2: heavy soil

(#): Means followed by different letters are significantly different at  $p=0.05$  (conf. Int.) for each soil.

Table 8. Salinity\* of soil treatments in field experiment

	control	Summer	before plough	after plough
C1	.120ab			
Vinasse at 3.5 tn/ha		.130ab	.140a	.130b
Vinasse at 7.0 tn/ha		.150a	.110b	.120ab
C2	.210a			
Vinasse at 3.5 tn/ha		.170b	.180ab	.130c
Vinasse at 7.0 tn/ha		.160b	.160ab	.170b

C1: light soil, C2: heavy soil

(#): Means followed by different letters are significantly different at  $p=0.05$  (conf. int.) for each soil.

(\*): mS/cm of (1:5) extract

Table 9. Exchangeable-Na\* of soil treatments in field experiment

	control	Summer	before plough	after plough
C1	.056b			
Vinasse at 3.5 tn/ha		.095ab	.100ab	.115a
Vinasse at 7.0 tn/ha		.215a	.130ab	.100ab
C2	.170b			
Vinasse at 3.5 tn/ha		.290ab	.220ab	.330a
Vinasse at 7.0 tn/ha		.325a	.300ab	.290ab

C1: light soil, C2: heavy soil

(#): Means followed by different letters are significantly different at  $p=0.05$  (conf. int.) for each soil.

(\*): me/100g

The maximum value of Na found in the Vinasse treatment, (Table 9) rises at the level of 0.325 me Na /100g of soil, without causing hazardous conditions. In the same way the exchangeable form of K has been found (Table 10) at the level of 0.69 and 0.78 me K/100 g in the control treatments; the maximum values rise at the level of 1.438 and 1.577 me K/100g and they have been found in the vinasse treatments; of course this level of available K is desired.

Table 10. Exchangeable-K\* of soil treatments in field experiment

	control	Summer	before plough	after plough
C1	.688c #			
Vinasse at 3.5 tn/ha		1.225b	1.113b	1.138b
Vinasse at 7.0 tn/ha		1.438a	1.188b	1.125b
C2	.775c			
Vinasse at 3.5 tn/ha		1.313ab	1.263ab	1.575a
Vinasse at 7.0 tn/ha		1.175b	1.138b	1.388ab

C1: light soil, C2: heavy soil

(#): Means followed by different letters are significantly different at  $p=0.05$  (conf. int.) for each soil.

(\*): me/100g

## VI. YIELDS

Table 11 shows the wheat yields in 1991-92. Vinasse gave higher yields than control plots especially at the rate of 7 ton/ha. Time of application and compaction did not cause a significant effect in the heavy soil. Vinasse different rates and control treatments had a similar effect in the light soil but late Autumn applications and compaction appear to reduce yields significantly. Similar results are shown in table 12 for 1992-93. Again it appears that compaction had an adverse effect on yields in the light soil. The beneficial results of vinasse should be attributed to the increased organic matter content (important for the very poor in organic matter Greek soils) but also in the lower losses of N compared to chemical fertilisers. Fertiliser applications before drilling in Autumn can have high losses by leaching (high precipitation, low needs of plants) while Spring applications can have high losses in the air as they remain uncovered on the soil surface for several days till a rainfall would incorporate it into the soil. Vinasse has most of its N in organic form and nitrification by micro-organisms is taking place only when temperature, moisture content and chemical properties of the soil are at a proper level. At the time of high temperature and moisture of the soil plants, activity of microorganisms is also high and the mineral nitrogen produced is taken by the plants.

## CONCLUSIONS

The results of the three years showed that vinasse application can substitute entirely chemical fertilisers at the rates used by Greek farmers. Yields are higher in the vinasse plots compared to the control, in some cases the difference is statistically significant at  $p=0.05$  level.

Application of the waste during Summer, before ploughing in Autumn and before drilling did not cause reduction of yields which indicates a considerable stability of the product at high temperature. Summer application is followed within 24 hours by disking for incorporation of the material into the soil.

Table 11. Wheat yield for control plots and after vinasse application at different times of the year, and in compacted and uncompacted plots, 1991-92

Treatment	Mean Yield in tn/ha for Heavy Soil		Compaction	
	Time of Application summer	before pl	after plough	no yes
Control Vinasse at 3.5 tn/ha Vinasse at 7 tn/ha Total effect	1.798a			
	1.097a	0.937a	1.250a	1.123a
	1.086a	1.033a	1.135a	1.189a
	1.085b	0.983a	1.193a	1.156a
				1.024a
Mean Yield in tn/ha for Light Soil				
Control Vinasse at 3.5 tn/ha Vinasse at 7 tn/ha Total effect	2.054a			
	2.332ab	1.783bc	2.390ab	2.402a
	2.701b	2.650a	2.782a	2.843a
	2.746a	2.217b	2.586ab	2.623a
				2.410b

Table 12. Wheat yield for control plots and after vinasse application at different times of the year, and in compacted and uncompacted plots, 1992-93

Treatment	Mean Yield in tn/ha for Heavy Soil		Compaction	
	Time of Application summer	before pl	after plough	no yes
Control Vinasse at 3.5 tn/ha Vinasse at 7 tn/ha Total effect	1.028a			
	1.262b	1.324a	1.231a	1.292a
	1.351b	1.278a	1.431b	1.474a
	1.284a	1.3a	1.336a	1.283a
				1.23a
Mean Yield in tn/ha for Light Soil				
Control Vinasse at 3.5 tn/ha Vinasse at 7 tn/ha Total effect	1.56a			
	1.491a	1.391b	1.41b	1.548a
	1.566a	1.296b	1.358b	1.677a
	1.859a	1.343b	1.383b	1.61a
				1.444b

Note: Same letters show no significant difference within the boxes

Soil compaction by the spreading equipment did not affect yields significantly in the heavy soil but it was significant in the light soil although the effect on soil physical properties was considerable in both soils.

According to the obtained data at the end of the incubation period, the added vinasse, caused an increase value of total-N, E.C., exchangeable Na, ESP, pH, NH<sub>4</sub>-nitrogen and of exchangeable-K. Therefore, vinasse addition could be a potential hazard by producing soil salinity, sodicity and alkalinity. In the field experiments the results of vinasse plot show only a significant difference in the case of exchangeable Na and K; nevertheless, the increase of exchangeable Na keeps ESP at a low level which indicates less hazardous conditions for the soil. The increase of exchangeable K is beneficial.

From the results it can be concluded that vinasse can substitute chemical fertilisers entirely and can be applied at rates of 7 ton/ha every 2-3 years .

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