Olive Wastes Spreading in Southern Italy: Effects on Crops and Soil

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Abstract: In the area where olive trees are largely cropped, olive oil wastes recycling could determine environmental risks, but if its use is sistematically checked, agricultural crops obtain benefits and soil fertility improves.

The results of research on crop responses and some characteristics of Apulian soils ("terra rossa", clay and loamy soil) as affected by olive mill wastes (OWW) application are reported. The olive transformations systems are: i) traditional method of pressure; ii) "decanter" to three phases.

In the two field experiments OWW was spread on durum wheat crop (at tillering stage) and on a young olive three orchard. To the beginning of trial the physical and chemical characteristics of soil and oil residues composition were determined. Moreover, influence of OWW on lysimeter perennial ryegrass was also studied.

The main results obtained show that during the crop cycle of olive no significant variations in the soil organic C content as effect of OWW spreading were observed. In the no treated plots, sampled after the treatments, a great stability of soil organic C was found while the treated plots showed wide fluctuations. On the other hand, spreading 50 m^3 ha^{-1} of traditional olive waste an increase of organic C and exchangeable K on loamy-clay soil was observed. On "terra rossa" the effects on organic C and available P were more evident just when applied large quantities of liquid olive traditional wastes.

Crop responses of durum wheat show that about yield no significant difference was observed between the treatments. On olive tree the soil management with OWW influences slowly the orchard growth and yield and more evident effects could be observed in the future with further OWW application.

Keywords: olive waste water, soil fertility, durum wheat, olive, ryegrass

1 Introduction

The oil extraction process from olive (*Olea europea* L.) fruits produces a big quantity of liquid waste, so called Olive Waste Water (OWW), either using the centrifuge method (about 100 l of OWW per 100 kg of milled olives) or the traditional or pressure one (about 40 l per 100 kg of milled olives). Their removal is a problem greatly felt by the producers and millers, for the pollution risk (especially for the poliphenolic substances). The italian law permits the OWW spreading on capable soils from agronomical use. The maximum OWW amount usable in the fields is of 80 m^3 ha^{-1} for the centrifuge method and 50 m^3 ha^{-1} for pressure method. Similar situations with analogous problems, can be found in the other olive oil production countries of the Mediterranean area (Northern Africa, Spain, Greece).

The OWW directly produced by the olive oil process (i. e. without preliminary treatments) has chemical properties (organic carbon, potassium and phosphorus content) that can increase the soil fertility (Tomati and Galli, 1992). The bibliography reports positive results with the not-treated OWW application confirming the fertilisation value (Vitagliano *et al*., 1975; Fiestas Ros de Ursinos, 1977; Morisot, 1979; Janer del Valle, 1980; Potenz *et al*., 1985; Briccoli Bati and Lombardo, 1990; Di Giovacchino and Seghetti, 1990; Bonari and Ceccarini, 1991; Saviozzi *et al*., 1991; Ben Rouina *et al*., 1999). Soil experimental results show that some soil physical properties improved after the application of OWW (Pagliai, 1996) and that soil organic matter, available P and exchangeable K contents increase (Brunetti *et al*., 1995; Ferri *et al*., 2001).

In this paper the main results of a 3year research period about the effect of OWW disposal in a semi-arid environment and ryegrass lysimeter responses are reported, focusing the attention on crop productivity and soil fertility, in order to evaluate the possibility to remove OWW without pre-treatment.

2 Material and method

Apulia region is a very important agricultural district for the Italy because 53% is plain and 45% is hilly. This situation and peculiar pedological and climatic conditions are able to promote agricultural practices and arable cropping. Among agricultural products to promote in Apulia Region are included wine, table grape and olive oil.

The main characteristic of Apulian district are the total absence of rivers and torrents. The waters coming from the rains are absorbed from the calcareous layers or flow directly in subsoil through sinkhole, swamp, dolina constituting an underground network at the sea level .

Typical soils of the Region are: red mediterranean soils on limestone of Cretaceous (Rhodoxeralfs). These soils, uncommon in the world, are very frequent in southern Italy. Only in Apulia Region represent 50% of surface. In some cases there are typical Litosols directly layed on calcareous rocks with soil fertility very poor.

The brown soils or calcareous-brown are another typical class of “Apulian” soils and finally also Vertisols are diffused (Xerochrept and Chromoxererts).

The experimental site was located in Monopoli, for the durum wheat and olive experiments.

A more detailed experiment description is reported in Williams (2000a), Rinaldi *et al*. (2001 and 2002), Ferri *et al*. (2001). The main characteristics of the OWW are the following: (1) pH=5.2; (2) Nitrogen=1.6 g· l^{-1}; (3) P_2O_5= 829 mg· l^{-1}; (4) K_2O = 1,044 mg· l^{-1}; (5) Carbon = 43.3 mg· l^{-1}.

Soil samples were collected before and after the treatments (0 cm-40 cm depth) from all elementary plots. Determinations of soil N-NO_3, exchangeable N-NH_4, $NaHCO_3$-extracted P, NH_4Ac extracted K, total organic carbon (Ministry of Agricultural Resources, 1992) were carried out.

2.1 Durum wheat

The crop management of durum wheat (*Triticum durum* Desf.) was carried out following the common practices used in the area, with soil tillage with disk plough, pre-sowing phosphate fertilisation (about 80 kg· ha^{-1} of P_2O_5) and a nitrogen fertilisation (75 kg of N· ha^{-1}) with ammonium nitrate at 6-8 leaves stage. OWW was spread at the amount of 50 tons per hectare when the crop was at a development stage of tillers formed and with 4—6 leaves. A randomised block design with three replications was arranged with the treatments “Treated” and “Not-Treated” applied to elementary plots of 1,000 m^2 each layed on two separate areas (upper and lower). Stem number, leaf area and dry matter weight were recorded every 14 days in order to study crop growth dynamic. At harvest, main biometric measurements, yield components and grain quality were recorded and then statistically analysed either for each year or globally for the 3-year period.

2.2 Olive trees

In an old olive orchard, in 1997 young olive plants were transplanted to increase the number of plant per hectare. In November 1998, we individuated twenty young olive plants for each treatment: for each plant the main biometric parameters (main branch height, plant height, branch length and branch and bole diameter) were recorded to evaluate the crop growth of the olive trees. The same measurements were repeated every 6 months.

In January 1999, 2000 and 2001, OWW was spread at 50 t· ha^{-1} amount. The olive fruits were harvested in October, measuring, for each plant, yield, yield components and olives morphological characteristics. The soil fertility of this cropped field was also analysed during the experimental period, through very frequent soil sampling.

2.3 Perennial ryegrass

Another esperimental trial was carried out on red mediterranean soil in lysimeters and the following treatments were compared: T1) Olive mill wastes obtained by the traditional press system as 50 $m^3 \cdot ha^{-1}$ (OWW –50); T2) The same OWW as 200 $m^3 \cdot ha^{-1}$ (OWW – 200); T3) The same OWW treated with MnO_2 catalyzer in a specific reactor of 2,000 m^3 in aerobic conditions (OWWC – 200); T4) Compost obtained by the mixing of solid olive waste, olive leaves, straw, sawdust, chicken-manure (COMPOST); T5) Untreated control (CONTROL), applied on Perennial ryegrass (*Lolium perenne* L. cv "Barvestra").

The Perennial ryegrass was sown on 19 September 2000 with 30 $kg \cdot ha^{-1}$ of seeds. Shoots were harvested 0.5 cm from the soil level to minimize soil contamination. The sample were weighted (fresh weight) and the dry weight was determined. Moreover, Leaf Area Index and SPAD measurements (a rapid a non destructive estimate of leaf greenness determined by portable chlorophyll-meter) were recorded.

3 Results

3.1 Durum wheat

The variability of grain yield was mainly due to climatic behaviour: in fact, the rainfall distribution was more regular in the first than the others years (data not reported), influencing the plant growth and final yield. In the third year low temperatures during flowering caused spikelets infertility and the lowest yield.

The plant number decreased in the 40—50 days period after the spreading, especially when at spreading time, the plants were more developed and the leaves formation finished. The effect of OWW on the plants was of a moderate phytotoxicity, with some necrosis in the younger leaves and the plant response was the formation of a greater number of secondary shoots. As a consequence, also leaf area index (LAI) and total dry matter resulted lower in the "T" than in the "NT" crop, in particular 2—4 weeks after spreading. The OWW spreading caused a number of necrotic spots (about 20 %—30 % of leaf surface) and this phenomena reduced the LAI and carbon assimilation, especially if high temperature and rainfed conditions followed the spreading.

Globally, the yields were comparable with local average and resulted statistically equal in the two treatments, both in the yearly and 3-year period analysis (Table 1). This result can be considered a good response of durum wheat to OWW application.

Table 1 Main durum wheat characteristics. For each year different letters indicate a significant difference among the means at LSD test (*P* > 0.001)

	Grain yield ($t \cdot ha^{-1}$)	Avg plant population ($n \cdot m^{-2}$)	Avg LAI ($m^2 \cdot m^{-2}$)	Total dry matter at harvest ($t \cdot ha^{-1}$)	1,000 seeds weight (g)	White seeds (%)
1999						
Treated	2.54	132	0.72	7.99	46.89	7.75 b
Not Treated	2.61	158	0.97	7.78	46.91	16.00 a
2000						
Treated	1.71	351	1.34	10.45	46.23	6.00
Not Treated	1.79	303	1.59	10.60	46.69	6.00
2001						
Treated	1.19	238 b	0.86	7.52 b	42.40 b	4.54
Not Treated	1.22	299 a	0.93	9.26 a	46.63 a	4.58

3-year period						
Treated	1.81	240	0.97	8.65	45.17	6.10
Not Treated	1.87	253	1.16	9.21	46.74	8.86

By numerous soil sampling observations on experimental data recorded during the cropping cycles, some considerations can be made:

- Very interesting trends were observed on soil mineral NNO_3 concentrations recorded in october '00: increase in lower and upper areas of the field, in comparison to values recorded in November '98 (t0), but the treatments effect is not evident. (Figure 1).
- A general increase on soil organic C was recorded as in lower field than in upper one, mainly in the shallow soil horyzon (Figure 1) in OWW-treated plots.

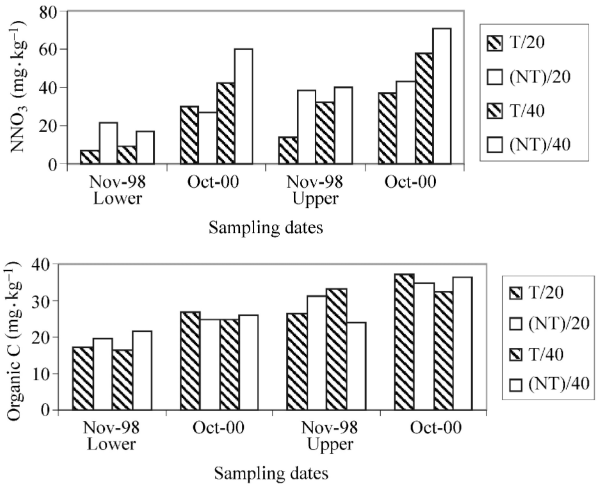


Fig.1 NNO_3 and total organic C (TOC) variations recorded in two soil layers (0 cm — 20cm; 21 cm — 40 cm) in treated (T) and untreated (NT) plots in the durum wheat field divided in "upper" and "lower" areas

Soil $NaHCO_3$ — P as affected by OW treatment does not change, even if significant differences between upper and lower fields were recorded only at the beginning of the trial (Figure 2).

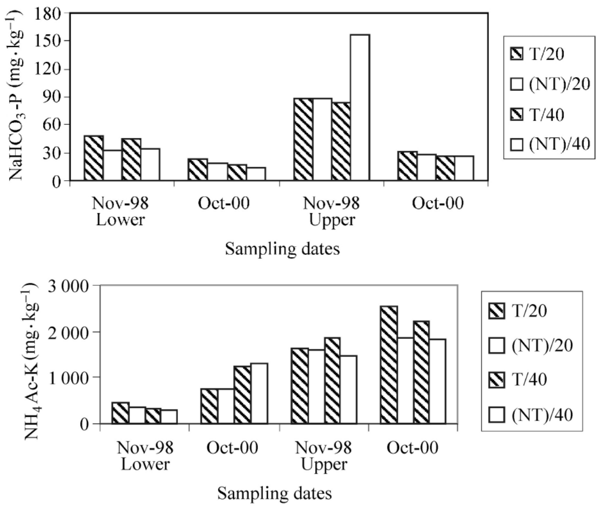


Fig.2 Available P and exchangeable K variations observed in two soil layers (0 cm — 20 cm, 21 cm — 40 cm) in treated (T) and untreated (NT) plots in the durum wheat field divided in "upper" and "lower" areas

The effects of the treatments with OWW on soil NH_4Ac-K (Figure 2) appear more evident in the last sampling date (October 2000), mainly in upper field.

3.2 Olive trees

Some results are summarised in the Table 2. The olive tree growth is generally fast in the first year, but few differences between treatments have been observed. We can note only a light increase of branch diameter in the "Not Treated" thesis.

Table 2 Main olive fruit and plant characteristics. Different letters indicate a significant difference among the means at LSD test (*P* > 0.001)

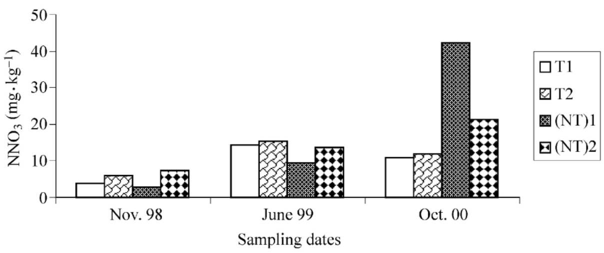
	Olive yield (g plant^{-1})	Olive weight (g olive^{-1})	Kernel percentage (%)	Olive length (cm)	Olive width (cm)
3-year period					
Treated	1,717	3,62	36,7	2,20	1,65
Not treated	1,718	3,42	36,5	2,19	1,61
	Main branch height (%)*	Plant height (%)*	Bole diameter (%)*	Branch lenght (%)*	Branch diameter (%)*
3-year period					
Treated	13.25	37.37	101.0	74.56	74.66 b
Not treated	13.66	34.29	102.6	77.68	87.49 a

* as percentage respect to the initial value.

The yield showed a globally not significant difference between the treatments. It is important to underline that the soil management effects influence slowly the orchard growth and yield, whereas more evident effects could be observed in the future with further waste applications.

Before and after treatments with OWW the following variations concerning the main chemical parameters were observed:

NNO_3 contents of soil do not change during trial period (Figure 3).Organic C content increases in treated and untreated plots. For consequence is very hard to individuate for this parameter an influence of OWW spreading (Figure 3).Soil Phosphorus extracted with $NaHCO_3$ solution shows a significant increase after OWW spreading only in one treated plot (Figure 4). Exchangeable Potassium variations of the soil show an increase also in untreated plots, but after OWW spreading appears more evident (Figure 4).



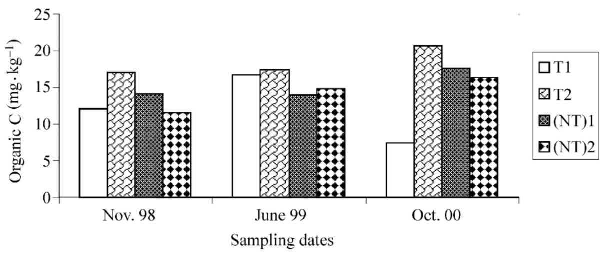


Fig.3 NNO_3 and total organic C (TOC) variations recorded in the shallow horyzon (0 cm — 20 cm) in treated (T1, T2) and untreated (NT1, NT2) plots cropped with olive orchards during trial period

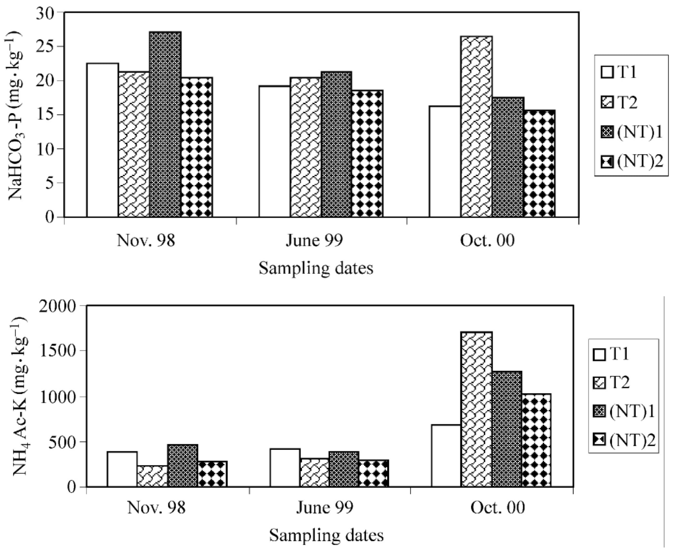


Fig.4 $NaHCO_3$-P, NH_4Ac-K variations recorded in the shallow soil horyzon (0 cm — 20 cm) in treated (T1, T2) and untreated (NT1, NT2) plots cropped with olive orchards during trial period

3.3 Perennial ryegrass

The Table 3 presents the mean values of first shoots harvesting of the parameter measured (fresh and dry weight, SPAD and LAI). Although, only one harvest for Perennial ryegrass was not enough to draw general conclusion, it could be noted that no differences between T1 (treatment with lowest amount of OWW, such as 50 $m^3 \cdot ha^{-1}$) and control was found for fresh weight, dry weight and LAI (425.6 and 446.13 g $lysimeter^{-1}$ for fresh weight respectively; 61.28 and 60.76 g $lysimeter^{-1}$ for dry weight; 1.22 and 1.23 for LAI). On the contrary when OWW was applied in large amount (200 $m^3 \cdot ha^{-1}$ for T2 and 200 $m^3 \cdot ha^{-1}$ of OWW catalyzed for T3) significant reduction of measured parameters were observed.

Moreover, the application of compost (T4) in the lysimeter showed intermediate results. Finally, no difference between the treatment was found for SPAD reading, indicating that the leaf greenness was not influenced by OWW and compost application in this early growing stage.

Table 3 Mean value of the fresh and dry weight, SPAD and LAI of first Perennial ryegrass harvest

Treatments	Fresh weight (g)	Dry weight (g)	SPAD	LAI
Control	446.13	60.76	38.46	1.23
OWW-50	425.60	61.28	37.64	1.22
OWW-200	223.43	31.93	38.13	0.63
OWC-200	97.93	14.23	38.44	0.28
Compost	332.87	47.48	37.57	0.92

Before and after the spreading of OWW, lysimeters soil was sampled at the depth of 50 cm. The variations of main soil chemical constituents were reported in Table 4.

In Table n. 4, soil nitrates show different trends: i) NNO_3 seems higher after the OWW spreading in "control", "OWW–50" and "compost" treatments; ii) on the contrary the highest doses of OWW supplied (OWW-200 and OWWC–200) determine a decrease of soil NNO_3.

Organic C (Table 4) shows an interesting trend. In the soils (lysimeters) treated with OWW-200, OWWC–200 and compost a light increase of organic C contents was observed , clearly dependent from olive mill wastes applications. Soil available P (as extracted in $NaHCO_3$) variations (Table 4) show a large increase only in OWWC200-treated lysimeters, in comparison to "control". Very poor variations were observed in other cases.

Table 4 Soil characteristics of samples collected in lysimeters before and after OWW spreading (depth of sampling: 50 cm)

Treatment	NNO_3 mg/kg		Organic C g/kg		$NaHCO_3$-P mg/kg		NH_4Ac-K mg/kg	
Sampling date	3.04	15.09	3.04	15.09	3.04	15.09	3.04	15.09
Control	8.65	30.7	12.15	11.85	19.59	14.17	2,292	968
OWW-50	8.99	19.48	12.66	12.42	18.96	19.49	1,780	1,240
OWW-200	9.53	2.71	14.00	14.80	25.26	37.04	2,216	2,608
OWWC-200	20.44	1.27	14.08	14.78	25.98	22.79	1,554	1,582
Compost	9.26	25.57	11.97	12.34	17.89	17.79	2,168	1,578

Very large variations on K content recorded in "control" (–8%) are largely attenuated when OWW (OWW–0, –00) and compost were spreaded (Table 4).

4 Conclusions

This first results are very interesting because offers to the farmers other possibilities to spread OWW during the winter months, especially in semi-arid environments.

We suggest, however, also in consideration of other results obtained in this research (Williams, 2000a and 2000b; Rana *et al*., 2002), to follow these guidelines during OWW application: to spread OWW uniformly at the amount allowed by the law; to avoid soil wet conditions; to spread OWW on durum wheat when the crop is at 3—5 leaves stage; to do not use OWW excessively concentrated; to spread OWW in cloudy days or in the afternoon to reduce gas emissions.

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