Effects of industrial orange wastes on soil characteristics and on growth and production of durum wheat

Adalgisa Belligno, Marzia G. Di Leo, Mario Marchese, Rosalena Tuttobene

Agron. Sustain. Dev. 25 (2005) 129–135
© INRA, EDP Sciences, 2005
DOI: 10.1051/agro:2004063

Research article

Effects of industrial orange wastes on soil characteristics and on growth and production of durum wheat

Adalgisa BELLIGNO, Marzia G. DI LEO, Mario MARCHESE, Rosalena TUTTOBENE*

Dipartimento di Scienze Agronomiche, Agrochimiche e delle Produzioni Animali, Via Valdisavoia 5, 95123 Catania, Italy

(Received 16 July 2003; accepted 21 October 2004)

Abstract – With the aim of evaluating the possibility of recycling industrial orange wastes as soil conditioners, a research was carried out to study the effects of different doses of this orange wastes on soil parameters, some growth parameters and production of durum wheat in a Mediterranean environment where the soils are generally poor in organic matter. Three doses were used in the first year; in the second year the same doses and the residual effects of the previous treatments were studied. Soil characteristics, crop growth and yield were determined. Conditioning positively influenced some parameters of the soil. The organic matter had only partly modified its own structure due to the decomposition process during the year after the conditioning. The processes of degradation of the organic matter were predominant as compared with the humification ones under the pedologic and climatic conditions of the trials (sandy soil and dry hot climate). Conditioning carried out with doses higher than the minimum had a depressive effect on the crop productivity due to the excessive vegetation vigour.

industrial orange wastes / soil parameters / durum wheat / growth / yield

1. INTRODUCTION

Disposal of waste from processing, besides affecting production costs and reducing competitiveness, has a highly negative environmental impact due to the polluting effect of these materials. The use of by-products from the agricultural and food industry as soil conditioners in agriculture, apart from representing one of the possible ways of resolving the problem of their disposal, can contribute to a re-equilibration in the humic balance of agricultural soils that are becoming ever poorer in organic matter (o.m.). This is particularly true in the Mediterranean area, where organic matter degradation is predominant in comparison with humification since the high temperature and high oxygen content of the soils lead to an intense mineralization rate. Moreover, organic matter supplies are lacking.

In recent years, the solution to these problems has provided an incentive for research aimed at evaluating the possibility of recycling by-products of the citrus fruit-processing industry. Indeed, the use of this organic matrix, with its negligible heavy metal content, to reintegrate o.m., could be an answer to the problems of soil fertility maintenance and, above all, helps to preserve the environment in agricultural areas of the Mediterranean. Citrus (orange, lemon and mandarin) waste is mainly converted into compost [3, 6, 12]. The recycling of citrus waste is mainly limited by its high water content (about 85%) which in turn affects transport cost. Correia Guerrero et al. [1] increased the production of fresh and dry matter of lettuce grown in pots in a greenhouse, enriching the soil with dried orange (pulp and peel) waste, applied according to an increasing amount of nitrogen. Tamburino et al. [10], studying the processes controlling the natural drying of orange pulp, demonstrated that it is possible to exploit solar energy to dry citrus pulp in some agricultural areas of the Mediterranean, thus facilitating the recycling of waste as organic fertilizer and fodder.

The re-use of dried citrus wastes as organic fertilizer could be justified by the low cost technology for the recycling of nutrients contained in these wastes and by the reintegration of organic matter into the soil.

Until now no information has been available in the literature concerning the effects of dried citrus waste on the soil characteristics. The research reported here was performed to examine the short-term effects of soil conditioning with dried orange wastes, highlighting the immediate and residual effects on some chemical and physical characteristics of the soil as well as on the growth and the production of durum wheat (*Triticum durum* Desf.).

2. MATERIALS AND METHODS

The research was carried out over a two-year period (1997–1998) in 0.5-m^3 (1 × 1 × 0.50) lysimetric basins. The variety

* Corresponding author: r.tuttobene@unict.it

Table I. General soil properties.

Parameters	
Reaction (pH) 1:5 (H_2O)	7.35
Sand(%)	71
Loam (%)	17
Clay (%)	12
E.C. (Electric Conductivity saturation paste extract basis μmhos cm^{-1})	845
K^+ (meq l^{-1})	68
Ca^{++} (meq l^{-1})	133
Mg^{++} (meq l^{-1})	110
S.A.S. (Soil Aggregates Stability%)	24.30
Total $CaCO_3$ (%)	2.60
Total N (‰)	14.50
C/N	11.90
T.O.C. (Total Organic Carbon %)	1.43
T.E.C. (Total Extractable Carbon %)	0.87
HA + FA (Humic Acids +Fulvic Acids %)	0.71

of durum wheat used was “Mongibello”. The soil (Tab. I) was prevalently sandy, sub-alkaline, lacking total limestone and organic C; the C/N value demonstrated that the organic matter was well humified; the low E.C. from the saturated paste extract was due to the low content in soluble cations.

In a randomized block design with five replications, the following treatments were studied:

1st experimental year

– unconditioned soil (A);

– 3 kg m^{-2} (B) orange waste supply;

– 9 kg m^{-2} (C) orange waste supply.

2nd experimental year

– unconditioned soil (A + 0 = A_1);

– unconditioned soil where in the 1st year of experimentation 3 (B + 0 = B_1) and 9 (C + 0 = C_1) kg m^{-2} had been supplied, respectively;

– repeating the soil conditioning with 3 (B + 3 = D) and 9 (C + 9 = E) kg m^{-2}, respectively.

The orange wastes used in the two-year trial were previously air-dried for six months to obtain a 35% humidity. The characteristics of this organic matrix are shown in Table II. The orange wastes have an acid reaction and are rich in organic carbon, nitrogen and Ca^{++}, whose content is five-fold higher than the other cations. Sowing was carried out on December 4 and 10 in the two experimental years, respectively, using 400 germinating kernels per square meter. The experimental plot (0.5 m^2) constituted 4 rows 0.80 m long (0.20 m between rows).

Three samplings of the soil were carried out in the first year of the trial, before sowing (November), during the crop cycle (May) and after harvest (September) and two in the second year, before sowing (November) and after harvest (May). On these samples, the contents of soluble and exchangeable cations from the saturated paste extract, Cation Exchange Capacity (C.E.C.), Sodium Absorption Rate (S.A.R.), Nitrogen and Organic Carbon (Total T.O.C., Extractable T.E.C., Humic+Fulvic HA+FA) were determined and the humification parameters, represented by the Humification Degree (DH), Humification Rate (HR) and Humification Index (HI), were calculated, according to the official methods for chemical analysis of the soil [5]. In addition, pH, Electric Conductivity (E.C.) and Soil Aggregate Stability (S.A.S.) according to the Robinson and Page method [7] were determined.

Table II. Orange waste characteristics in the two years.

Characteristics	1st year	2nd year
Humidity on use (%)	38.30	10.00
pH	5.95	5.85
Total N (‰)	27.90	21.30
C/N	14.50	18.80
Total P (‰)	3.80	3.60
Ash (%)	14.90	10.10
T.O.C. (%)	40.60	40.00
T.E.C. (%)	24.60	24.50
HA + FA (%)	15.00	15.20
DH (Humification Degree %)	67.50	62.20
HR (Humification Rate %)	39.70	38.10
HI (Humification Index)	0.48	0.61
Ca^{++} (meq 100 g^{-1})	275	221
Mg^{++} (meq 100 g^{-1})	41	27
K^+ (meq 100 g^{-1})	53	62
Na^+ (meq 100 g^{-1})	31	31
Protein (mg g^{-1} s.s.)	30.30	24.60
Total carbohydrate (mg g^{-1} s.s.)	36.30	34.60

All the plants in 0.15 m of one row (about 12 plants or 18 culms) for each lysimetric basin in 5 replicates were taken in 3 successive phenological phases (tillering, heading and early milk ripening), cutting them at ground level. Leaf area (Area measurement system Delta–T Devices Ltd., Burwell Cambridge, England) and dry weight (by drying in forced-air oven at 105 °C) were determined. These parameters were used to calculate LAI (Leaf Area Index) and CGR (Crop Growth Rate in g m^{-2} d^{-2}) according to Hunt [2].

In the first year, undisturbed soil cores were taken at a depth of 0–20 cm in the same sample area used for the epigeal part of the crop and then dried at 60 °C. Each sample was subdivided into three sub-samples of 50 g, on which, after treatment with sodium metaphosphoric acid (in 10% solution), washing and filtering on a 0.150-mm square mesh sieve, the root length (cm) was determined [4, 11]. The root length data were converted into Root Length Density (RLD) which relates the root length to the soil volume (cm cm^{-3}), using the value of the soil bulk density.

Percentage data (TOC, TEC, etc.) were arcsin $\sqrt{\%}$ transformed before statistical analysis; actual percentages are shown. Data of soil and crop parameters were subjected to analysis of variance (ANOVA), and means were separated by Least Significant Difference (LSD) if the F-test was significant at $P \leq 0.05$ (different letters indicate significant differences at $P \leq 0.05$). The analysis

Table III. Chemical parameters of the soil in relation to the treatments.

1st year

Treatments / Soil parameters	November	May			September		
		A	B	C	A	B	C
C.E.C. (Cations Exchange Capacity meq 100 g^{-1})	19.80 a	18.70 a	22.10 a	18.20 a	18.10 a	19.00 a	19.70 a
Na^+ solub. (μeq 100 g^{-1})	68 c	60 c	120 b	210 a	70 c	110 b	210 a
Na^+ exch. (meq 100 g^{-1})	1.17 a	1.14 a	1.10 a	1.27 a	1.13 a	1.25 a	1.38 a
K^+ solub. (μeq 100 g^{-1})	47 e	40 e	100 c	230 a	30 f	60 d	130 b
K^+ exch. (meq 100 g^{-1})	0.83 b	0.65 c	0.95 b	1.75 a	0.58 d	0.83 b	1.75 a
Ca^{++} solub. (μeq 100 g^{-1})	133 d	120 d	230 c	890 a	110 d	260 c	570 b
Ca^{++} exch. (meq 100 g^{-1})	10.0 a	10.4 a	9.40 a	11.10 a	8.60 a	9.10 a	10.80 a
Mg^{++} solub. (μeq 100 g^{-1})	110 e	100 e	240 d	760 a	100 e	290 c	550 b
Mg^{++} exch. (meq 100 g^{-1})	0.42 a	0.41 a	0.42 a	0.43 a	0.42 a	0.42 a	0.43 a
S.A.R. (Sodium Absorption Rate)	0.51	0.49	0.49	0.53	0.53	0.57	0.58
Total N (‰)	1.18 c	1.11 c	1.30 b	1.68 a	1.05 c	1.32 b	1.74 a
T.O.C. (%)	1.43 c	1.48 c	1.69 b	2.05 a	1.52 c	1.74 b	1.95 a
C/N	12.60	15.10	14.20	13.60	13.00	12.10	10.20

2nd year

Treatments / Soil parameters	November	May				
		A_1	B_1	C_1	D	E
C.E.C. (Cations Exchange Capacity meq 100 g^{-1})	19.70 b	20.50 ab	24.00 a	19.80 b	19.50 b	23.0 a
Na^+ solub. (μeq 100 g^{-1})	32 a	24 c	27 b	29 ab	26 bc	23 c
Na^+ exch. (meq 100 g^{-1})	2.80 a	2.74 a	2.37 a	2.23 a	2.47 a	1.78 a
K^+ solub. (μeq 100 g^{-1})	11 e	9 f	37 d	48 c	84 b	296 a
K^+ exch. (meq 100 g^{-1})	0.8 d	0.96 c	1.03 c	1.5 b	1.6 b	3.8 a
Ca^{++} solub. (μeq 100 g^{-1})	79 e	68 f	102 d	196 c	258 b	423 a
Ca^{++} exch. (meq 100 g^{-1})	11.30 b	13.40 a	13.60 a	14.00 a	13.60 a	14.60 a
Mg^{++} solub. (μeq 100 g^{-1})	74 e	65 f	88 d	98 c	191 b	270 a
Mg^{++} exch. (meq 100 g^{-1})	0.64 a	0.68 a	0.71 a	0.64 a	0.67 a	0.81 a
S.A.R. (Sodium Absorption Rate)	1.15	1.03	0.89	0.82	0.92	0.64
Total N (‰)	1.05 c	1.00 c	1.38 b	1.61 b	1.70 b	3.06 a
T.O.C. (%)	1.24 e	1.48 d	1.71 c	1.92 b	1.94 b	3.21 a
C/N	11.80	14.80	12.40	11.90	11.40	10.50

A: unconditioned soil; B: 3 kg m^{-2} orange waste supply; C: 9 kg m^{-2} orange waste supply.
A_1: unconditioned soil (A+0); B_1: B+0 kg m^{-2}; C_1: C+0 kg m^{-2}; D: B+3 kg m^{-2}; E: C+9 kg m^{-2}.
In each row values followed by different lowercase letters are significantly different at $P \leq 0.05$ using the LSD test.

was performed for all samples, as regards soil parameters, separately for each sampling, as regards LAI, CGR and RLD (sampling was not an experimental factor).

3. RESULTS AND DISCUSSION

3.1. Chemical characteristics of the soil

We studied the effects of the organic matter on soluble and exchangeable cation contents, Cation Exchange Capacity, Sodium Absorption Rate, and on Total Organic Carbon and Nitrogen levels as well as on their ratio (Tab. III). In the first year we did not observe significant variations in unconditioned treatments from November to September in soluble and exchangeable cations, Total Organic Carbon and total N, except in K^+ which showed a decrease. The contents of the soluble cations were affected by conditioning and showed significant increases in May and September according to the doses of conditioner. The exchangeable Na^+, Ca^{++} and Mg^{++} were not affected by conditioner supply, whereas K^+ showed an

Table IV. Extractable (T.E.C.), humic and fulvic organic carbon (HA+FA) and humification parameters (DH, HR, HI) in relation to the treatments.

1st year				
Treatments Soil parameters	November	May		
		A	B	C
T.E.C. (%)	0.87 a	0.84 a	0.96 a	1.08 a
HA + FA (%)	0.71 a	0.69 a	0.76 a	0.87 a
DH (%)	81.60	82.20	79.20	80.50
HR (%)	49.50	48.90	45.00	42.40
HI	0.224	0.217	0.263	0.241

2nd year						
Treatments	November	May				
Soil parameters		A_1	B_1	C_1	D	E
T.E.C. (%)	0.71 d	0.87 c	0.93 c	1.09 bc	0.99 bc	1.76 a
HA + FA (%)	0.65 d	0.76 c	0.82 bc	0.89 b	0.84 bc	1.33 a
DH (%)	97.50	88.10	88.90	81.70	85.40	75.50
HR (%)	63.70	51.60	48.20	46.50	43.50	41.40
HI	0.025	0.136	0.134	0.226	0.176	0.325

A: unconditioned soil; B: 3 kg m^{-2} orange waste supply; C: 9 kg m^{-2} orange waste supply.
A_1: unconditioned soil (A+0); B_1: B+0 kg m^{-2}; C_1: C+0 kg m^{-2}; D: B+3 kg m^{-2}; E: C+9 kg m^{-2}.
In each row values followed by different lowercase letters are significantly different at $P \leq 0.05$ using the LSD test.

increase proportional to the dose used in both samplings. These data are confirmed by the values of Cation Exchange Capacity which was not affected by soil conditioning. The conditioning also determined significant increases in both samplings of the oxidable organic carbon (Total Organic Carbon) and of Nitrogen in proportion to the amount added.

The increase in the soluble cations and exchangeable K^+ in the conditioned treatments highlights a greater mobilization of the elements in comparison with the unconditioned treatment, determined by the acidification due to the functional acid groups present in the added biomass. Furthermore, the Sodium Absorption Rate continuously showed an equilibrated quantity of ions and therefore a favorable habitat for the plants. The greatest solubility of the bivalent cations, in B and C treatments in response to the increased organic supply, may be attributed to the accelerated mineralization process, which determined a greater presence of CO_2 in the system. The Total Organic Carbon and N values, which were constant for the same dose from May to September, demonstrated that the organic matrix was a source of easily degradable carbon, as confirmed by the C/N values.

In the second year, we observed significant decreases in the unconditioned treatments from November to May in all soluble cations and increases in exchangeable K^+ and Ca^{++}. Total Organic Carbon and C/N also increased, presumably because the crop presence enriched the soil with root exudates, whereas N was constant. In the treatments without (B1 and C1) and in those with more conditioner (D and E), significant increases in the soluble Ca^{++}, Mg^{++} and K^+ and in exchangeable K^+ were observed. Owing to conditioning, an increase in N and Total Organic Carbon and a reduction in C/N were confirmed. The degradation of the conditioner macro-molecules, in particular the pectin, likely contributed to an increase in the soluble cations in the medium, without, however, contributing to an improvement in the Cation Exchange Capacity

3.1.1. Extractable humic and fulvic organic carbon and humification parameters

Values of the organic carbon, as well as the humification parameters, are reported in Table IV with the aim of evaluating if and how the wastes added to the soil influenced the state of the organic matter. In the first year we did not observe significant variations in the values of Total Extractable Carbon and Humic Acids +Fulvic Acids following the conditioning. On the contrary, a year after the conditioning a dose-dependent increase in Total Extractable Carbon and Humic Acids +Fulvic Acids was observed. The Humification Degree and Humification Rate did not show increases in the conditioned treatments.

A year after conditioning, the organic matrix supplied had already in part modified its own original structure, mostly due to the decomposition process. The increase in Humic Acids +Fulvic Acids in the conditioned treatments and the parallel decrease in the Humification Degree and Humification Rate demonstrate that the physiological state of the soil had not been improved yet by the organic supply. The greater Humic Acids +Fulvic Acids values indicated the presence of humic-like substances that had not degraded yet. The processes of demolition of the organic matter were predominant as compared with the synthesis ones since the high temperatures and the high oxygen content of the sandy soil determined an intense mineralization rate.

Table V. Physical parameters of the soil in relation to the treatments.

1st year							
Treatments Soil parameters	November	May			September		
		A	B	C	A	B	C
pH	7.35 d	7.38 d	7.33 d	7.24 e	8.40 a	8.32 b	8.01 c
E.C. (µmhos cm $^{-1}$)	1380 d	1260 de	2100 c	5210 a	1090 e	2020 c	3410 b
S.A.S. (Soil Aggregates Stability %)	24.30 c	25.50 c	25.00 c	42.00 a	28.50 bc	31.20 b	43.60 a

2nd year						
Treatments Soil parameters	November	May				
		A_1	B_1	C_1	D	E
pH	8.04 ab	8.13 a	8.00 b	7.92 c	7.75 d	7.62 e
E.C. (µmhos cm $^{-1}$)	1283 c	1040 d	1187 c	1890 b	1840 b	3590 a
S.A.S. (Soil Aggregates Stability %)	26.20 c	26.80 c	28.00 c	32.20 b	37.70 b	66.40 a

A: unconditioned soil; B: 3 kg m^{-2} orange waste supply; C: 9 kg m^{-2} orange waste supply.
A_1: unconditioned soil (A+0); B_1: B+0 kg m^{-2}; C_1: C+0 kg m^{-2}; D: B+3 kg m^{-2}; E: C+9 kg m^{-2}.
In each row values followed by different lowercase letters are significantly different at $P \leq 0.05$ using the LSD test.

3.2. Physical characteristics of the soil

The effects of the conditioning on the reaction of the soil, the Electric Conductivity of the extract of saturated paste and on Soil Aggregate Stability, are reported in Table V. The soil reaction showed a significant rise from May to September (pH from 7.38 to 8.40) in the unconditioned treatment in the first year. This increase was attributable to the increased concentration in salts, determined by the reduction in soil water content. The supply of the organic substance, such as orange wastes with an acid reaction, determined a significant decrease in pH in the C treatment in comparison with the control in May, and in all the treatments, in September. In the period May-September, the sugar-rich organic matrix is easily attacked by micro-organisms according to the studies of Schnurer et al. [8] and Sparling et al. [9], and undergoes a marked oxidation and mineralization process, which justifies the lower pH (7.24) level of the C treatment in the early stages of drought (May), and of all the treatments in September. From May to September the soil reaction tended to rise, including the conditioned treatments, showing significant increases in B and C (from 7.33 to 8.32 and from 7.24 to 8.01, respectively). These increases in pH were related to the rise in cations linked to the evapotranspiration recorded during the summer period. The increase in pH was lower in the C treatment, where a greater production of CO_2 was found (data not reported), as a consequence of mineralization of the organic substance observed in the same period which blocked the alkalizing effect of the cations.

In the second year, notwithstanding the massive release of soluble cations in the medium, a significant dose-dependent decrease in pH was found in all the treatments in comparison with the control, mainly depending on the demolition process of the organic matter and on the sandy texture of the soil. The decomposition of the organic matrix balanced the excess of hydroxyls acidifying the system. In addition, the organic matter played a tampon effect thanks to its functional acid groups. Increases in the Electric Conductivity proportional to the conditioner dose were observed in both years in relation to the rising levels of the soluble cations. The rising values of Soil Aggregates Stability in both years testify that the organic matter contributed to improving the aggregation of the soil particles, especially in May of the second year with the highest dose of conditioning where Soil Aggregates Stability was more than double that in the control.

3.3. Growing season and crop growth

The two years were characterized by fairly different weather conditions that influenced the growth course. In the first year, from December to June, 223 mm of rain were recorded with a regular distribution during the growing season (52% in the winter period, 48% from March to June); in the second year, rainfall did not exceed 140 mm during the growing season. In the first year, in both treatments with soil conditioner, there was an increase in the length of the shooting phase compared with the control (25 more days), mainly due to an early beginning; the differences between the conditioned treatments and the control were reduced to a few days (maximum 5) in the booting, flowering and ripening phases; the period between milk and full ripening lasted on average 52 days and the total cycle ended at 188 days after sowing for all the treatments.

In this year the conditioner determined a significant increase in leaf area development (Leaf Area Index) and crop growth capacity (Crop Growth Rate), irrespective of the doses in all the samplings (Fig. 1). Leaf Area Index showed, on average of two doses applied, increases of 104 (tillering), 98 (heading) and 87% (milk ripening), when compared with the control (2.5, 2.8 and 3.0 at the three samplings). On average of the two conditioning treatments, Crop Growth Rate values were significantly higher than in the control, reaching 3.1 (tillering-heading) and 20.9 g m^{-2} d^{-1} (heading-milk ripening), respectively. Root Length Density was positively affected by the soil conditioner with an increase compared with the control (about 5 cm cm^{-3})

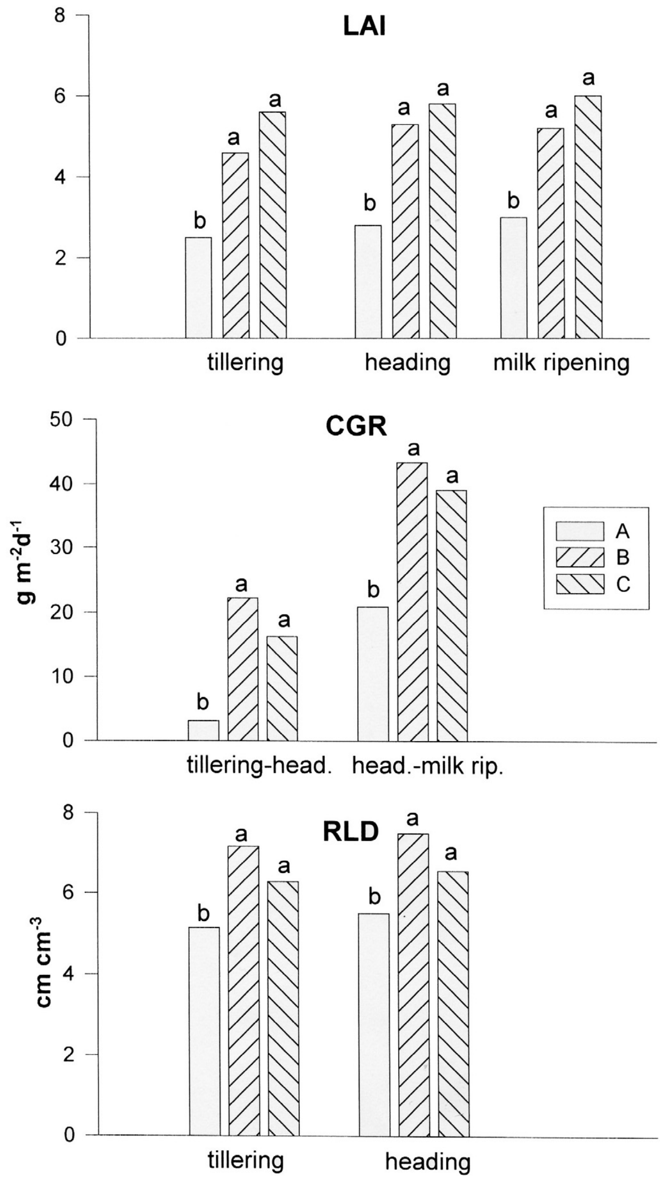

Figure 1. Leaf Area Index (LAI), Crop Growth Rate (CGR) and Root Length Density (RLD) of crop in the 1st year. A: unconditioned soil; B: 3 kg m^{-2} orange waste supply; C: 9 kg m^{-2} orange waste supply. For each sampling different lowercase letters indicate significant differences at $P \leq 0.05$ using the LSD Test.

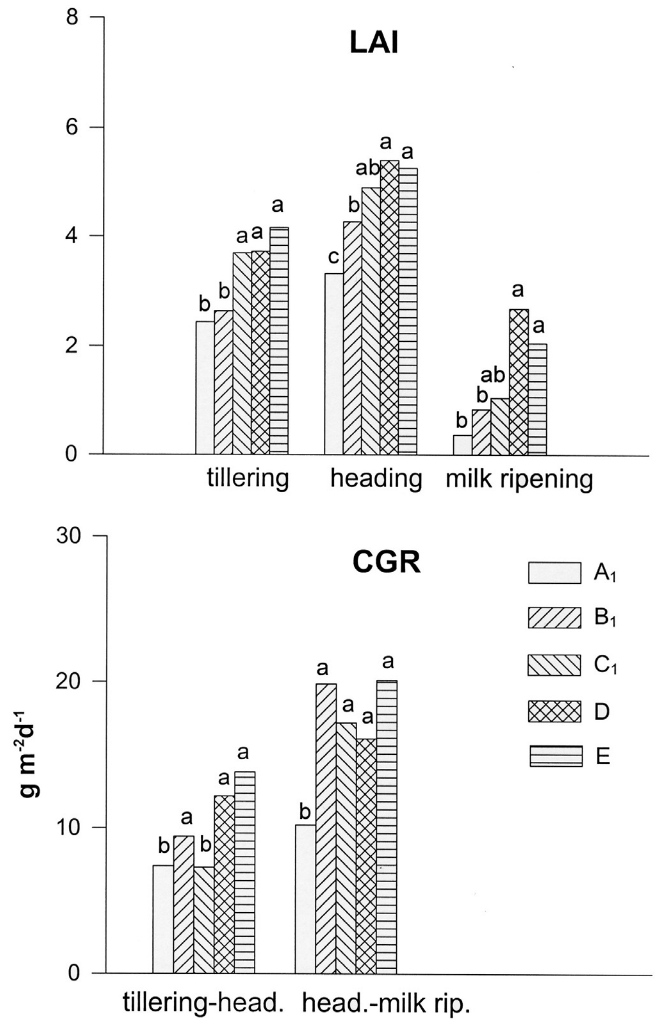

Figure 2. Leaf Area Index (LAI) and Crop Growth Rate (CGR) of crop in the 2nd year. A_1: unconditioned soil (A+0); B_1: B+0 kg m^{-2}; C1: C+0 kg m^{-2}; D: B+3 kg m^{-2}; E: C+9 kg m^{-2}; A, B and C correspond to the orange waste supplies of the 1st year: unconditioned soil, 3 kg m^{-2} and 9 kg m^{-2}, respectively. For each sampling different lowercase letters indicate significant differences at $P \leq 0.05$ using the LSD Test.

equal to 31% at tillering and 28% at heading, on the average of the two doses.

In the second year, the lack of rain influenced the length of the biological cycle which amounted to 151 days, with a difference of more than one month compared with the first year; no differences were recorded among the treatments as regards the length of the phenological phases: shooting lasted only 15 days, the interval between milk ripening and full ripening 20 days. At the milk ripening stage, Leaf Area Index (Fig. 2) showed very low values for all the treatments due to the arid conditions of the season that caused an early senescence of the leaves; there was also a rust attack that damaged the plants in the B_1, C_1, D and E treatments; the percentages of plants damaged were equal to 15 and 35% in the B_1 and C_1 treatments and to 60% on the average of the D and E treatments. Also in this year, the conditioning, especially when realized with the highest doses, determined significant increases in Leaf Area Index; at tillering, when the crop leaf area still had not reached the maximal expansion, a higher value was recorded on the average of B_1, C_1, D and E treatments (3.9) compared with the control and A1 treatment (2.5); at heading, when the crop leaf area reached the maximal expansion, progressively higher values were recorded as the amount of the conditioning increased. In the period between heading and milk ripening, the Crop Growth

Table VI. Yield (t ha^{-1}) in relation to the treatments.

	1st year				
Treatments	A	B	C		
	3.00 a	2.20 b	2.00 b		
	2nd year				
Treatments	A_1	B_1	C_1	D	E
	1.68 a	1.32 a	0.53 b	0.34 b	0.50 b

A: unconditioned soil; B: 3 kg m^{-2} orange waste supply; C: 9 kg m^{-2} orange waste supply.
A_1: unconditioned soil (A+0); B_1: B+0 kg m^{-2}; C_1: C+0 kg m^{-2}; D: B+3 kg m^{-2}; E: C+9 kg m^{-2}.
In each row values followed by different lowercase letters are significantly different at $P \leq 0.05$ using the LSD test.

Rate showed significantly higher values (+79%) in the treatments compared with the control, without statistical differences between the different doses (18.3 g m^{-2} d^{-1} on average).

3.4. Production

The grain yield of the first year was significantly and negatively influenced by the excessive vegetative growth induced by soil conditioning (Tab. VI). In fact, the thesis treated with wastes produced only 2.1 t ha^{-1}, with a decrease of 30% when compared with the control. The grain yield obtained in the second year, in general very low due to the very low supply of water during the ripening phase, was negatively influenced by the conditioning when carried out with doses higher than the minimum; in fact, the most productive treatments were the control and B_1 (1.5 t ha^{-1} on average against the 0.45 t ha^{-1} on the average of the other treatments).

4. CONCLUSIONS

Conditioning with "dried industrial orange wastes", carried out with different doses on wheat-cultivated soil, had both direct and residual effects on soil parameters.

In conclusion, the present research indicates that the re-use of dried orange waste as a soil conditioner in areas with a Mediterranean climate where normally organic matter supplies are lacking, could be a feasible technique for the reintegration of organic matter supply, provided that the amount of wastes is defined according to the requirements of the crop and the soil conditions.

REFERENCES

[1] Correia Guerrero C., Carrasco De Brito J., Nuno Lapa, Santos Oliveira J.F., Reuse of industrial orange wastes as organic fertilizers, Bioresource Technol. 53 (1995) 43–51.

[2] Hunt R., Plant growth analysis, Edward Arnold (Ed.), London, 1978.

[3] Intrigliolo F., Calabretta M.L., Giuffrida A., Torrisi B., Rapisarda P., Tittarelli F., Anselmi M., Roccuzzo G., Trinchera A., Benedetti A., Compost degli scarti dell'industria agrumaria, L'Inf. Agr. 4 (2001) 35–39.

[4] Newman E.I., A method of estimating the total length of root in a sample, J. Appl. Ecol. 3 (1996) 139–145.

[5] Osservatorio Nazionale Pedologico e per la qualità del suolo del suolo, Metodi ufficiali di analisi chimiche del suolo, Ministero delle Risorse Agricole Alimentari e Forestali (Mi RAAF), Roma, 1994.

[6] Rapisarda P., Intelisano S., Fanella S., Intrigliolo F., Tittarelli F., Canali S., Benedetti A., Sequi P., Utilizzo degli scarti di lavorazione dell'industria agrumaria, L'Inf. Agr. 11 (1998) 95–96.

[7] Robinson D.O., Page J.B., Soil aggregate stability, Soil Sci. Soc. Am. Proc. 15 (1950) 25–29.

[8] Schnurer J., Clarholm M., Rosswall T., Microbial biomass and activity in an agricultural soil with different organic matter contents, Soil Biol. Biochem. 17 (1985) 611–618.

[9] Sparling G.P., West A.W., Modification of fumigation-extraction technique to permit simultaneous extraction and estimation of microbial C and N, Commun. Soil Sci. Plant 19 (1988) 77–87.

[10] Tamburino V., Zimbone S.M., Indagine sperimentale sull'essiccazione naturale del pastazzo di agrumi. VI Convegno Nazionale di Ingegneria Agraria, Ancona 11–12 settembre, 4, 1997, pp. 377–388.

[11] Tennant D., A test of modified intersect method of estimating root length, J. Ecol. 63 (1975) 995–1001.

[12] Van Heerden I., Cronjé C., Swart S.H., Kotzé J.M., Microbial, chemical and physical aspects of citrus waste composting, Bioresource Technol. 81 (2002) 71–76.