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Effect of three types of composts of olive oil by-products on growth and yield of hard wheat "*Triticum durum* Desf."

MEDJAHDI Nadjet*, DJABEUR Abderezzak and KAID-HARCHE Meriem

Laboratory Productions, Plant and Microbial Valuations (LP2VM), Department of Biotechnology, Faculty of Natural Sciences and Life, University of Science and Technology of Oran Mohamed Boudiaf USTO -MB, BP. 1505 El M'Naouer 31000 Oran, Algeria.

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The extraction of olive oil generates colossal by-products quantities; generally unexploited and causes serious environmental problems in Algeria. In tackling this problem, we performed three types of composts (C_1: 50% cows manure, 50% olive husks and olive mill wastewaters; C_2: 50% olive husks treated by the lime, 50% cows manure with fresh urea and olive mill wastewaters; C_3: 50% olive husks, 50% cows manure and water) for five months to use them as biofertilizers for hard wheat "*Triticum durum* Desf." 'Waha' cultivar. Results obtained showed that at the end of composting, the pH stabilized at 7.29 to 7.45; however saltiness was variable. For the three composts, the organic matter was degraded and the polyphenols content decreased significantly; C_2 was the compost that contains more mineral elements (N, P, K, Ca and Na). Indeed, the use of this compost as biofertilizer allowed an increase of the yield to 30.61% and an improvement of wheat growth, spikes' number (5.25±0.3 per plant in comparison with 1±0.09 for control) and seeds (57.12±0.99 per plant in comparison with 14.87±1.88 for control).

Key words: Compost, Olive husks, olive mill wastewaters, *Triticum durum* Desf., Algeria.

INTRODUCTION

Algerian olive cultures take the first place in fruit agriculture. In 2013, the olive production reached 5, 787, 400 qx, a part of this is intended for olive conserve (1, 749, 345 qx per year) and the rest for olive oil (4,038,055 qx per year) (Directorate of Agricultural Statistics (DSA), 2013); in fact, the production of olive oil had been 715, 970 hl.

The Technical Institute of Fruit Tree and Vine of Algeria (ITAF) recorded in 2013 an annual production of 497, 199 tons of olive oil by-products; 198, 880 tons of them are solid waste (olive husks) and 298, 319 tons liquid by-products called olive mill wastewaters. The production of olive oil is in increase in Algeria which lead to the rise of the by-products. The negligence of these later causes a great pollution.

The olive husks are rich in carbon and organic matter easily degradable, but because of their high content on

*Corresponding author. E-mail: biotech-med@hotmail.fr. Tel: +213771 55 54 99.

Table 1. Composition of the three composts (C_1: compost 1; C_2: compost 2; C_3: compost 3).

Composts	Composition
C_1*	50% olive husks + 50% dry cows manure
C_2*	50% olive husks treated by the lime 0.5% + 50% cows manure with fresh urines
C_3	50% of olive husks + 50% of cows manure

*The final product was humidified by olive mill wastewaters diluted to 1/3 during the first month of composting and with plain water for the last 5 months.

polyphenols, they cause serious environmental problems (Alburquerque et al., 2004). Several researches were performed to exploit this waste in order to minimize pollution. The olive husks were treated and transformed into activated charcoal (Hemsas, 2008) or exploited for bio-combustion in order to produce electrical energy (Jaako et al., 2004). Also, they were used as cattle food, thanks to their nutritive values (Mennane et al., 2010).

Farmers historically have applied animal manure and human wastes to the land to increase their productivity (Nikus et al., 2004; Abebe et al., 2005). It was established that the organic matter portion of the soil is very important to maintain soil's physical and chemical properties optimum for crop production. Recently, extensive application of chemical fertilizers is becoming of increasing concern to the environment and human health (Fojlaley et al., 2014).

Therefore, using organic wastes like olive husks as fertilizers may reduce the amount of chemical applied to the soil; alternatively this can be achieved through other methods such as composting (Al-Widyan et al., 2005; Hachicha et al., 2006; Toscano et al., 2013; Gómez-Muñoz et al., 2013; Fernández-Hernández_et al., 2014), which is considered as an appropriate low-cost technology for organic waste recycling and organic fertilizer production (Antizar-Ladislao et al., 2006; Arvanitoyannis and Varzakas, 2008) and may well represent an acceptable solution for by-products disposal, adding value to this waste and enhancing the sustainability of the olive oil production system (Salomone and Ioppolo, 2011).

Because of the compact physical properties of olive husks due to their high content in lignin and fatty matter, saltiness, acidity and weak content of nitrogen (Alburquerque et al., 2004), it would be better to mix them with bulking agents in order to accelerate organic matter degradation; these substances can be manure, dead leaves and cereals straws (Garcia-Gomez et al., 2003; Alfano et al., 2008; Jenana et al., 2009).

Wheat is considered as one of the most important and strategic crops in the world. Algeria is the eight world's importer of these cereals; Technical Institute of Crop (ITC) imported 1.08 million tons of wheat in 2013 at 439 million dollars. Wheat culture have an agricultural importance in Algeria, which was cultivated at 1, 447, 902 ha in 2013 (ITC, 2013), but the production quality decreases and remains insufficient to reach local needs. There are several ways for increasing wheat production of which one of them is the appropriate application of organic residues (Yassen et al., 2010; Iqbal et al., 2014).

For this reason, it seems ingenious to use these huge amounts of by-products as organic fertilizer after composting. This study has an environmental interest, by the recuperation of waste for useful purposes, and an economical one by increasing yield and production of wheat and other species.

MATERIALS AND METHODS

Compost material

The olive husks and olive mill wastewaters were provided in November 2010 by a traditional olive oil extraction unit situated in the city of Sig (50 m altitude some 43 km, West North out of Mascara (West of Algeria) (35° 25′ 0″ N longitude; 0° 10′ 0″ E latitude). This region has Mediterranean climate. The cows manure was provided in November 2010 by a farm located in the suburbs of Mascara city.

Vegetal materials

We used hard wheat (*Triticum durum* Desf.) 'Waha' variety (Algerian) as test plant of the fertilizer value of composts. Wheat seeds were provided in October 2011 by the Technical crops Institute of the city of Saida (West of Algeria).

Composting

Composts were prepared in heap of 1 m high and 0.5 m width. Three types of composts were performed during five months; their composition is demonstrated in Table 1. An amount of 80 kg of composts (C_1; C_2; C_3) was each one mixed in tanks, and later placed on the soil; outdoors in nature. All composts were humidified with plain water during the process and covered with plastic film to preserve humidity. The humidification and ventilation were weekly.

During composting, the follow-up of temperature and pH was carried out every week.

Physicochemical analysis of olive husks and composts

Two hundred grams of olive husks (before composting) and the three composts were dried at 105°C and crushed to undergo the following physicochemical analyses:

pH and saltiness (electrical conductivity "EC")

pH and saltiness (electrical conductivity "EC") were measured according to the international method of 1/5 (Mathieu and Pieltain, 2003).

Dry material (DM)

DM was measured according to classical method by drying substrates at 105°C and calculated as seen in the following formulae (Mathieu and Pieltain, 2003):

Organic matter (OM)

OM was measured by substrates calcination in a muffle furnace at 850°C during one hour then calculated by classical method (Aubert, 1978).

Assimilable phosphorus

Assimilable phosphorus was calculated by Olsen method using blue molybdenum reactive and optic densities was read on the spectrophotometer at 860 nm (Olsen et al., 1954).

Total nitrogen

Total nitrogen was quantified according to Kjeldahl method by measuring the ammonia excess after organic matter mineralization (Van Reeuwijk, 1995).

Secondary elements (minerals)

Na, Ca and K were analyzed by a flame spectrophotometer (Pansu and Gautheyrou, 2003).

Organic carbon

Organic carbon was analyzed with Ann method by titration according to the diphenylamine principle (Dabin, 1967).

Total polyphenols

Total polyphenols were analyzed by Singleton and Rossi method (1965) according to the principle of Folin-Ciocalteu reactive and reading optic density on the spectrophotometer at 460 nm.

Use of composts

Five hundred seeds were chosen according to their size and quality and placed to germinate at 20°C in the dark. Ten days after, 100 seedlings were transplanted into 4 m^2 plots area containing soil of argilo slimy texture (Abad, 2009) and 3 kg composts (substrate 1 "S_1" = soil + C_1 ; substrate 2 "S_2" = soil + C_2 ; substrate 3 "S_3" = soil + C_3 and C "control" = soil). Seedlings were watered and the growth of stems length was followed up every week during six months. At the end of plants growth, we recorded the number of spikes and seeds and then calculated their weights per plant and for each substrate.

Statistical analysis

For physicochemical parameters, all data were analyzed in three replications. The experimental data were subjected to tests of variance analysis (ANOVA) at the risk of 5% and the obtained data were evaluated statistically using Student's t-test; least significant difference was calculated at P<0.05 and signaled faces by letters (a, b and c) knowing that; P<0.05 significant difference "a", P<0.01 very significant difference "ab" and P<0.001 highly significant "abc".

RESULTS

Evolution of pH and temperature during composting

During composting, three phases of temperature and pH were distinguished. In the first phase, temperature and pH increased; however in the second one they decreased. During the last one, temperature was around 18-20°C and pH stabilized around 7.29-7.45 (Figure 1).

Physicochemical parameters

The physicochemical analyses results were shown in Tables 2 and 3. Physicochemical analyses were made at 5 and 6 months, but because of the slight difference between them, only those of 5 months are represented. In comparison to natural olive husks, the composted products have neutral to alkaline pH; an increase in saltiness of composts C_2 and C_3 and it decreases for C_1. The organic matter and polyphenols were more degraded in C_3 than C_1 and C_2 which was the richest in mineral elements (Na, Ca, K and N) and the most saline one.

Effect of composts on wheat plants growth

The statistical tests revealed that the growth of plants was significantly better in the substrates containing composts than the soil; S_1, S_2 and S_3 favored wheat plants to reach maximal length of stems (85.93 cm ± 1.75; 86.48 cm ± 1.68; 88.9 cm ± 1.23, respectively) compared to 71.8 cm ± 2.75 for the soil (Figure 2). Moreover, leaves had a bright green color and roots' ramification was dense.

The yield in number of spikes, seeds and weight was more important in the three substrates than the soil; we noted 36 ± 1.31; 57.12 ± 0.99 and 37.75 ± 1.03 seeds per plant for S_1, S_2 and S_3, respectively in comparison with 14.87 ± 1.88 seeds for control (Figures 3 and 4).

We noted an increase of the yield in weight of 1000 seeds of 16.32, 30.61 and 26.53% to S_1; S_2 and S_3 respectively in comparison with control. The yield in number of spikes of plants grown in S_1 was less than S_2 and S_3; but in seeds number, it was almost the same as S_3 (36 ± 1.31; 37.75 ± 1.03 seeds per plant for S_1; S_3, respectively) (Figure 3).

The yield in number of spikes was significantly better for plants grown in S_2 than those of S_3 (5.25±0.3 and 4.37±0.7 spikes per plant for S_2; S_3, respectively), and the number of seeds (57.12 ± 0.99 and 37.75 ± 1.03 seeds for S_2 and S_3, respectively) (Figure 3).

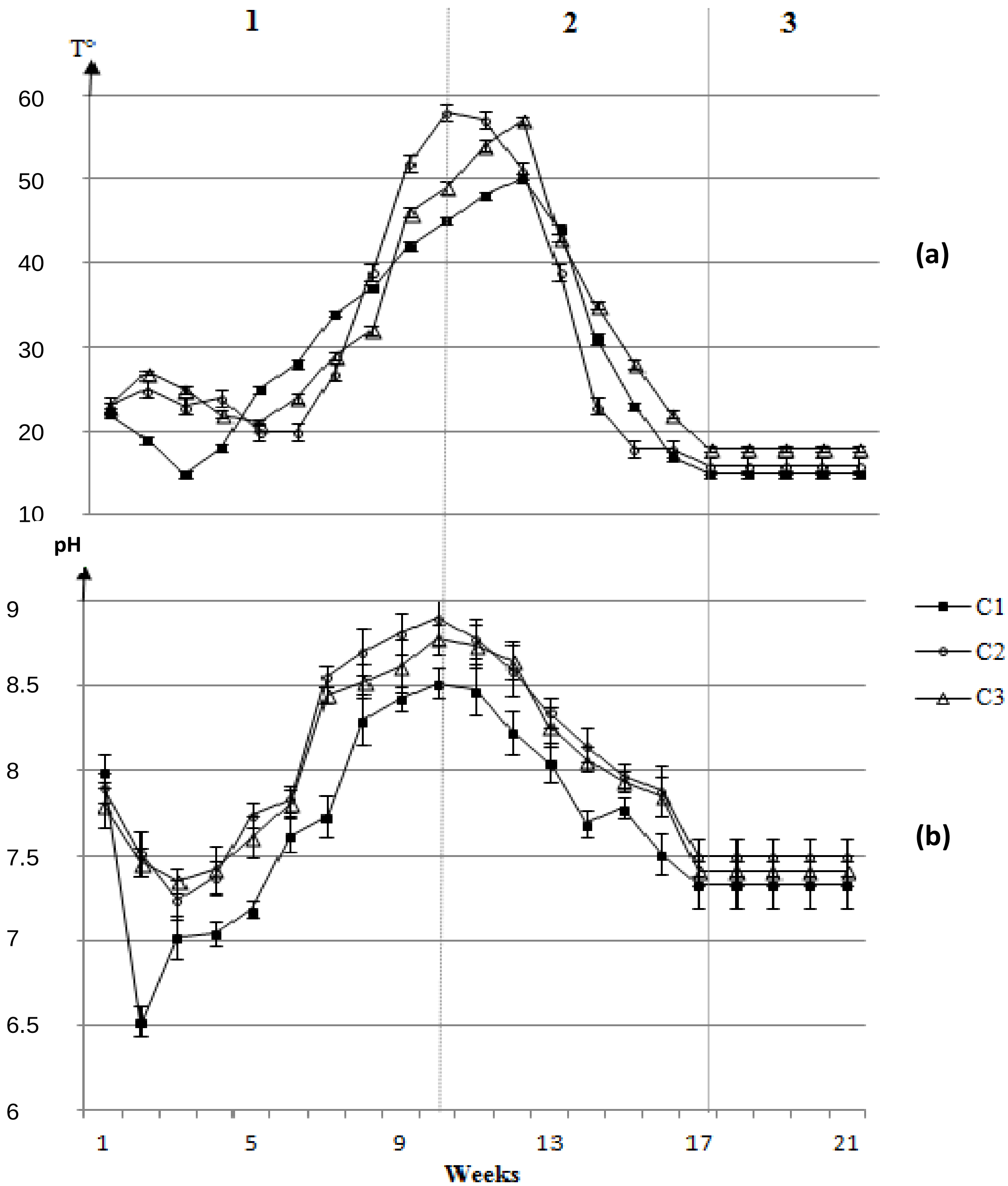

Figure 1. Evolution of temperature (a) and pH (b) of the three composts during the process (C_1: 50% cows manure + olive husks 50% + olive oil wastewaters ; C_2: 50% Olive husks treated by the lime + 50% cows manure (with fresh urea) + olive oil wastewaters; C_3: 50% Olive husks + 50% cows manure + water; "1": phase 1; "2": phase 2; "3": phase 3)

Table 2. Results of physicochemical analyzes (EC, Electrical conductivity; DM, Dry matter; OM, Organic matter) of the olive husks (oh), the three composts (C_1; C_2; C_3) and the soil (C).

Samples	pH	EC (µs/cm)	DM (%)	OM (%)	Polyhenols (mg/g)
Oh	6.17±0.04	1492.66±1.52	44.66±2.08	93.30±0.55	4.28±0.06
C_1	7.30±0.04	151.33±1.52	17.68±1.49	26.49±0.62	1.19±0.04
C_2	7.29±0.06	2580±2.08	16.12±1.23	21.20±0.38	1.07±0.05
C_3	7.45±0.08	3850±1	9.48±0.61	20.14±0.69	0.95±0.07
C	7.16±0.05	165±3.51	5.65±1.10	2.63±2.40	0.01±0.003

Table 3. Results of carbon (C) and minerals (Na, Sodium; K, Potassium; P, Phosphorus; N, Nitrogen) analysis of the olive husks (oh), the three composts (C_1; C_2; C_3) and the soil (C).

Samples	C (%)	Na (mg/g)	Ca (mg/g)	K (mg/g)	P (µg/g)	N (mg/g)
Oh	54.12±0.20	52±0.83	2.4±0.53	140±0.45	66.4±0.48	0.4±0.06
C_1	15.37±0.25	14±0.77	3.2±0.23	10±0.69	51.2±0.36	0.6±0.08
C_2	12.3±0.36	54±0.55	4±0.22	160±0.15	251.2±0.66	0.88±0.04
C_3	11.68±0.10	120±0.25	6.2±0.32	260±0.93	237.6±0.53	1.22±0.07
C	1.53±0.06	4±0.30	2.6±0.45	2±0.25	16±0.37	0.2±0.03

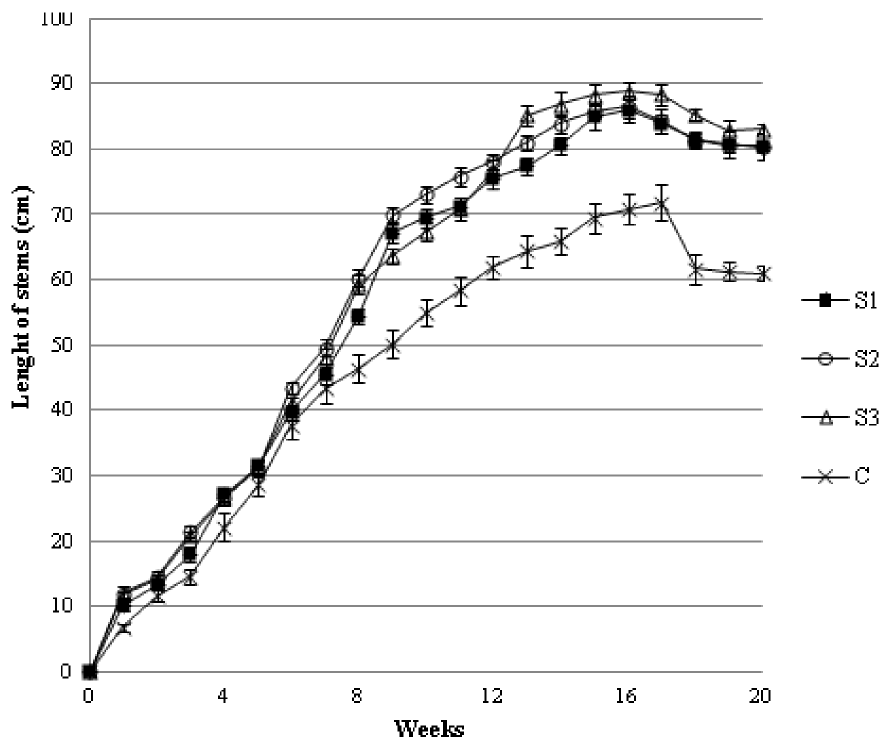

Figure 2. Evolution of wheat plants (S_1: Substrate containing soil + 3kg C_1; S_2: Substrate containing soil + 3kg C_2; S_3: Substrate containing soil + 3kg C_3; C: Control "soil": the vertical bar indicates the standard deviation of the mean of 100 plants per substrate.

DISCUSSION

Three pH and temperature changs have happened during composting. This agrees with many authors results (Vlyssides et al., 1996; Hachicha et al., 2008). The first is a mesophilic phase that corresponds to the high microbial activity ensuring an important production of heat (De-Viron, 2000).

The second is a thermophilic phase where only heat-resistant bacteria are present to degrade the organic matter transformed into CO_2 (Mustin, 1987). At the processing end, the temperature of composts decreased and the total polyphenols become stable which indicates the end of composts degradation and maturation (Kapetanios et al., 1993). At this stage, the humification predominates giving a stable product, mature and rich in humus (Mondini et al., 2004). At the end of composting, pH decreased to stabilize at 7.29 to 7.45.

We found a high salinity of compost humidified by olive mill wastewaters during the mesophilic phase. This is due to the degradation of organic components and liberation of olive mill wastewaters soluble salts (Paredes et al. 2001); though mineralization of organic matters during composting also participates in salinity increase. Our results are close to those obtained by Vakili et al. (2012).

We had noted a significant difference of the electrical conductivity between composts. Even if C_1 had been humified with olive mill wastewaters, an EC lower than C_3

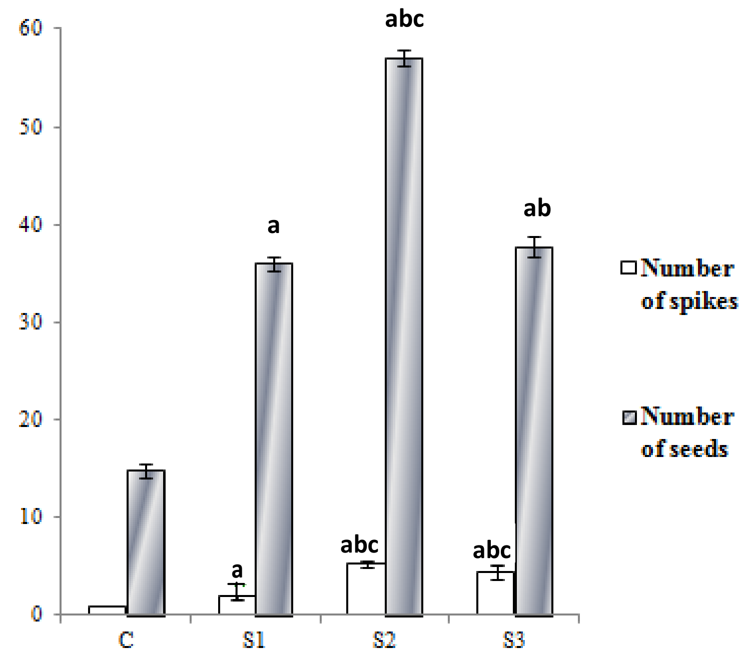

Figure 3. Number of spikes and seeds per plant of wheat (P< 0.05 significant difference "a", P <0.01 very significant difference "ab" and P < 0.001 highly significant "abc").

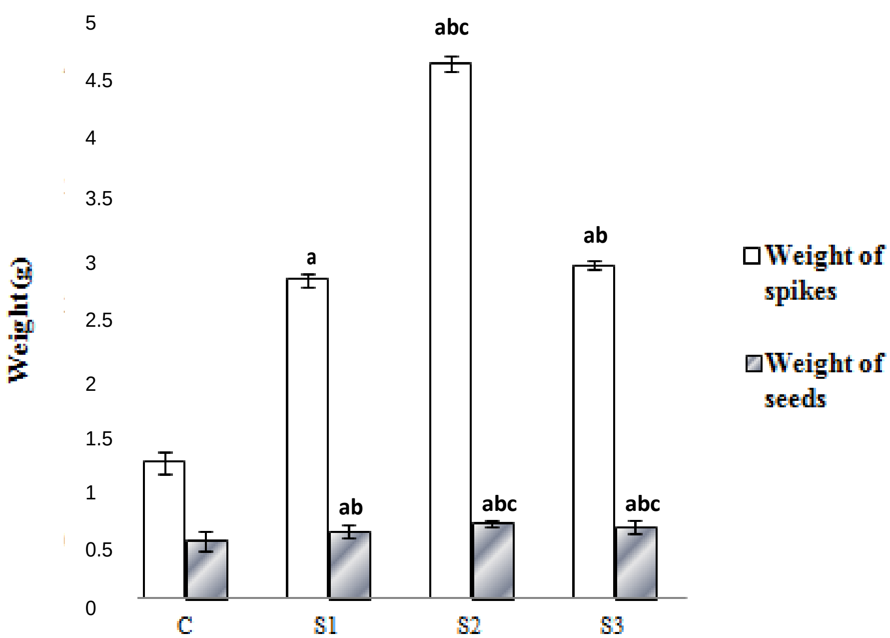

Figure 4. Weight of spikes and seeds per plant of wheat (P< 0.05 significant difference "a", P<0.01 very significant difference "ab" and P < 0.001 highly significant "abc")

was produced (151.33±1.52; 3850±1 µs/cm,respectively); this can be explained by a low organic matter degradation of C_1 which led to a lower release of salts compared to C_3.

At the end of the process, organic matters decreased. This can be explained by the mineralization phenomena. Our results are similar to those obtained by Sangaré et al. (2002) concerning compost of faeces, leftovers and urine from sheep and results of Hachicha et al. (2009) studies of olive mill wastewater compost sludge and poultry manure and Michailides et al. (2011) about compost of olive husks and olive leaves. The organic matter was significantly more degraded in C_2 and C_3 (21.20%±0.38; 20.14%±0.69, respectively) than C_1 (26.49%±0.62); this is due to the composition of these milieus (C_2 and C_3) which favored an adequate microbial activity.

On the other hand, for the C_2 the addition of the lime in this compost had accelerated the degradation of the lignified texture of olive husks. This has been shown by Garcia-Gomez et al. (2003) about olive husks and cotton waste compost; Sellami et al. (2008) about compost of olive husks, poultry manure and sesame shells.

In comparison with natural olive husks, carbon content in composts was low and the nitrogen was increased; because during composting, microorganisms use the carbon to degrade the organic substance and release nitrogen.

Our results reveal that there are significant differences in the content of carbon and nitrogen between composts; notably, more important values in nitrogen and maximum reduction in carbon that is, C_2 and C_3. These were in correlation with the results obtained by Bernal et al. (1998) about compost of olive mill wastewater and many solid wastes; Hachicha et al. (2006); Hachicha et al. (2009) and Tortosa et al. (2012) about compost of olive mill waste and poultry sheep manure. For C_2, the increase of nitrogen is due to the addition of the urea in the milieu (Sangaré et al. 2002).

The C_3 have more content in nitrogen than C_2 (1.22 mg/g±0.07; 0.88 mg/g±0.04 for C_3 and C_2, respectively), this can be explained by the presence of urea in this later (C_2), this substance is acidifying and when mixed with plant wastes (manure and residue), it stimulated bacterial activity, resulting in a significant loss of nitrogen as ammonia.

During composting, the C/N had decreased and this indicate the maturity of compost (Abdelhamid et al., 2004) This is in correlation with the results of Vlyssides et al. (1996) about solid residue and wastewaters and Vakili et al. (2012) about compost of palm oil bio-wastes and poultry litter.

About the phosphorus, the result showed an increase in C_2 and C_3 (251.2 µg/g±0.66;237.6 µg/g±0.53, respect-tively) in comparison with olive husks in its natural state (66.4 µg/g±0.48).

The final composts contain higher concentration of secondary mineral elements (Ca, K, Na); a significant increase was noted in C_2 and C_3 minerals in comparison with the olive husks before composting and C_1. Ben Jenana et al. (2009) also noted an increase in these elements in a compost of posidonia, chicken manure and solid fraction of olive mill residues.

The final composts content in polyphenols decreased significantly in comparison with olive husks before composting (4.28 mg/g ± 0.06 to 0.95 at 1.19 mg/g) and ccording to Echeverria et al. (2011), it occurs due to the degradation of phenolic compounds during process in humic acid-forming.

Results reveal that S_2 marked the best developments of wheat plants and better yield in number of seeds (57.12±0.99) than the control (14.87±1.88) and in weight of seeds (0.644 g±0.035; 0.496 g±00.8 for S_2 and soil, respectively), also in number of spikes (5.25±0.3; 1±0.09 for S_2 and soil, respectively) and in their weights (4.54 g±0.07; 1.16 g±0.09 for S_2 and soil, respectively). Thanks to their high contents of mineral elements; the manure and olive mill wastewaters improved the nutritious quality of olive husks and increased their fertilizing ability. Indeed, Sellami et al. (2007) and Hachicha et al. (2008) reported that the compost of olive husks and manure, irrigated by olive mill wastewaters favours a better growth and yield of potato, as well as Jenana et al. (2009) results, on the compost of olive husks with the Posidonia and chicken manure on the tomato.

We noted that the development of wheat plants Waha cultivar was distinctly better in substrates containing composts than the soil (control), due to the presence of humic substance in composts which improve the plants growth and the mineral elements concentration.

Few studies have been published about wheat growth on olive husks compost, however we noted the effect of other types of composts on wheat growth such as Eusuf Zai et al. (2008) who tested compost with pea residue and chicken manure on a wheat cultivar: “Norin 61” and noted an improvement of growth and yield; same results were obtained by Ahmed et al. (2008) about “Inqlab 91” cultivar with a compost of fruit and vegetables waste.

Other data revealed that the yield in number of spikes, seeds and their weights was also better in substrates containing the compost than the control. This can be due to a good mineral nutrition. Notably, for S_2 a significant increase of the yield at 30.61% in weight of 1000 seeds in comparison with the control, these results are better than those found by Sefidkoohi et al. (2012) who reported an increase of 26.4% in weight of 1000 seeds of wheat cultivar ‘N-81-19’ using 40 t/ha of solid wastes compost + 1/2 NPK in comparison with the control. It has even been recommended that Hafidi et al. (2012) have shown an increase in the seeds yield of wheat cultivar ‘Marchouch’ of 111% in comparison with the control, using 12.8 kg of compost (based on sludge + green waste) in $4m^2$ area. It can be more interesting to increase the amount of compost that we produced for better increase of wheat yield.

Conclusion

Results obtained show that the composting of by-products improves nutritive quality. Final products had neutral pH and high saltiness. Organic matters were degraded and mineral elements content (N, P, K, Ca) increased but polyphenols decreased. Substrate containing soil and compost made of olive husks treated by the lime, cows manure with fresh urines and olive mill wastewaters ensured best development of wheat plants and improve the yield.

The compostage of these wastes and their transformation in organic fertilizers is an interesting alternative for improvement of wheat production, minimization of importation of this one and valorization of olive oil by-products ensuring sustainable development irrespective of the environment.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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