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Impact of olive mill wastewaters used as fertilizer on soil quality and physiological behavior of coriander

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ABSTRACT

The impact of four amounts of olive mill wastewaters (OMW) ranged from 50 to 150 m^3/ha used as fertilizer on an alkaline soil quality was compared to water treatment based on measurement of soil pH, electrical conductivity and polyphenol content, using coriander as an indicator plant. The results revealed that soil pH and electrical conductivity changed slightly under all treatments with a maximal values under 150 m^3/ha of OMW which caused a decrease of soil pH by 0.3 points and increased soil electrical conductivity by 50 µS/cm during the first week of its application. However, soil polyphenols content increased widely under different treatments. Its initial value of 0.175 mg/g doubled under the treatment 100 m^3/ha to reach three fold value under 150 m^3/ha. The physiological parameters of the coriander improved under the treatments 50, 75 and 100 m^3/ha and showed a certain stress under 150 m^3/ha. Up to these results, OMW may be used as fertilizer up to 100m^3/ha without adversely affecting the alkaline soil quality in the arable layer. Beyond this amount, a particular attention should be paid, to soil polyphenols as far as their phytotoxicity is concerned, since a high concentration of polyphenols may exert an allelechemical effect.
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KEYWORDS

Olive mill wastewaters;
Soil acidity;
Soil salinity;
Soil polyphenol content;
Coriandrum sativum.

INTRODUCTION

The development of olive oil industry imposed environmental challenges residing mainly in pollution caused by olive mill wastewaters (OMW) that are liquid residues formed by 40 to 50% of vegetable water naturally contained in olives and those added for extracting oil[1]. It is generally estimated that trituration of one kg of olives generates 1 to 1.5 liters of OMW[2], depending on the extraction system used. The annual production of OMW is steadily increasing because of olive extension. In Morocco, for an annual olive production of 700 000 tons on an area of 1 million ha[3], olive oil industry produces more than 400.000 m^3 of OMW[4].

Purification of OMW is an expensive operation and difficult to undertake because of their high richness in organic matter and minerals[5,6]. In Morocco, because of absence of effective purification systems, OMW are dumped in nature without any treatment prior, either directly or across the public sewerage system[7]. This practice poses serious pollution problems, especially on surface water and ground water, and adverse effects on soils and crops[8]. Pollutant power of OMW is limited to three main factors that are acidity, salinity[9-11] and phenolic compounds which are phytotoxic by allelochemical effect[12].

In parallel with attempts to reduce the pollution load of OMW in several countries, particularly Mediterranean including Morocco, by natural evaporation in the storage basins, several trials are engaged to identify the economically feasible solutions for their valorization in agriculture and industry. In agriculture, these trials consist essentially to use OMW as an additive in animal feed[13] to extract phenolic and aromatic products[14], natural antioxidants and their use as herbicidal product[15].

The trials regarding use OMW as organic fertilizer, gross or composted, carried out since 1970 in Spain, Italy and Greece, have shown encouraging results especially for olive, vine, maize and rice productions without significant negative effects on soil fertility. The retained amounts vary between 50 and 150 m^3/ha depending on crops and soil types[16,17]. In Morocco, Algeria and Tunisia, transfer of this technology has been started recently, especially on olive, vine, tomato and date palm. Results of these trials were similar to those found in the northern countries of the Mediterranean and portend the possibility of using OMW as fertilizer with condition to not exceed a certain amount. However, the decision-making of this technique still confronted to some adverse effects reported by other authors, especially related to the acidity, salinity and polyphenols content[18,19]. It is within this mind that the present experiment has been carried to identify the temporal evolution of the main factors that could adversely affect soil quality and fertility due to OMW, that are salinity, acidity and polyphenol content by taking coriander as an indicator plant.

MATERIALS AND METHODS

Olive mill wastewaters used

OMW used were taken approximately after one month of their production (end of January) from an accumulation basin of a modern oil mill in Meknes region, in the North of Morocco. The chemical characteristics of OMW are presented in TABLE 1, showing that the used OMW are characterized by an acid pH, a high electrical conductivity (EC) and a high organic matter content, expressed by values of biological and chemical oxygen demand. Furthermore, it is noted that the used OMW far exceed specific limits established by Moroccan Secretariat of the Environment regarding pH, electrical conductivity, biological oxygen demand (BOD) and polyphenol content.

TABLE 1: Chemical characteristics of olive mill wastewaters used

Parameters	Values
pH	4.56
EC (mS cm^{-1} at 20°C)	6.8
Total phenolic compounds (g l^{-1})	3.6
Chemical oxygen demand COD (g l^{-1})	78
Biological oxygen demand at 5 days BOD_5 (g l^{-1})	49.1
Solid matter in suspension (mg l^{-1})	710

Soil type and indicator plant

The soil used is silty clay, basic (pH 7.98), moderately rich in organic matter (1.40%) and moderately saline with an average of electrical conductivity around 1.04mS/cm. The indicator plant used was coriander (Coriandrum sativum) cultivated largely in association with olive trees in all olive-growing regions of Morocco[21]. Its fertilizer requirements are 50 to 100 kg/ha of nitrogen, 30 to 60 kg/ha of phosphorus and 60 kg/ha of potassium[22]. Under hydroponic conditions, it may tolerate up to 25 mS/cm of salinity[23].

Treatments, experimental design and measurements

The trial was carried between February and March in 10 liters pots (30 cm height and 21 cm diameter) placed into an open glass greenhouse in the regional agricultural research center of Meknes located in North center of Morocco (33° 56' E, 5° 13' N; 500 m). The pots were filled with the same amount of soil, homogenized prior, on which coriander seeds were sown at the rate of five per pot. After sowing, different amounts of OMW were applied on pots uniformly. However, in order to apply the same irrigation, amounts of water were added to OMW (TABLE 2). During the two

TABLE 2 : Amounts of olive mill wastewaters tested as a fertilizer of coriander

Treatments	OMW (ml pot^{-1})	Water added (ml pot^{-1})	Equivalent of OMW per hectare (m^3 ha^{-1})
T0	0	675	0
T1	225	450	50
T2	340	335	75
T3	450	225	100
T4	675	0	150

months of the experiment, the pots were weekly irrigated at maximal evapotranspiration, with an average of 7 mm/week.

The experimental design was a randomized complete block, with three replications. Each of the three block consisted of five pots, each of which corresponds to an OMW treatment. Measurements consisted at weekly follow of pH, electrical conductivity and polyphenol content on soil and of physiological indicators of stress on coriander crop that are chlorophyll content, stomatal conductance and leaf temperature.

RESULTS AND DISCUSSION

Effect of OMW on soil pH, salinity and polyphenols content

A high linear correlation was found between values of soil pH and amount of OMW applied (Figure 1). This result was also found by other authors but with different significance level depending on soil type[24]. The linear relationship remained significant even after one month of OMW application, maintaining the same determination coefficient. However, the decrease of soil pH, influenced by OMW, was attenuated after this period because fort probably of soil elasticity effect. This is related to presence of calcium bicarbonate in alkaline soils, which reacts with carbon dioxide and water in the soil to produce bicarbonate (HCO^{3-}), which is able to take the ions $H3O^+$ and Al^{3+}, thereby raising the soil pH[25,26].

Practically, decrease of soil pH, observed under all treatments, is not able to adversely affect plants growth, especially in alkaline soils as the case of the tested soil type. Indeed, the higher dose of OMW (150 m^3/ha) decreased soil pH just by 0.3 points which has reduced to 0.17 points (TABLE 3) after one month because of

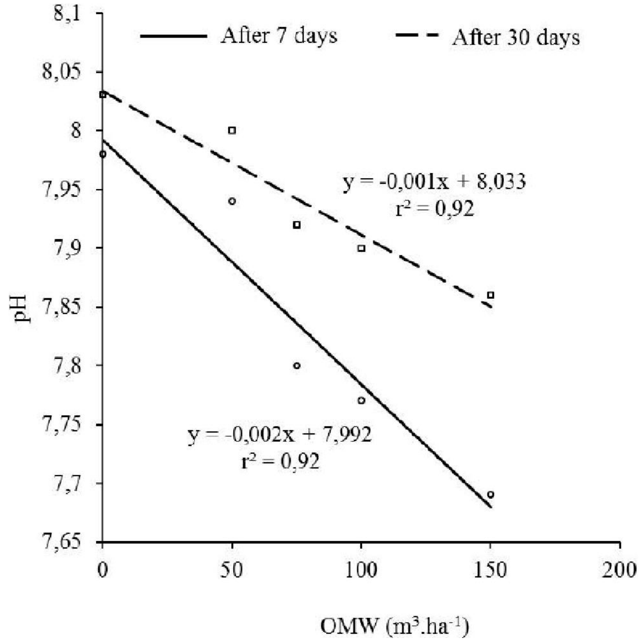

Figure 1: Relationship between soil pH and amount of OMW applied

soil elasticity and drainage of ions $H3O^+$ to deeper layers. The extrapolations of this result on neutral soils (pH 7) that are prevalent in Morocco suggests the possibility of application of OMW on this soil type until an amount of 150 m^3/ha without make it acid. The slight acidification of this soil type may greatly favors plant nutrients availability. In fact, the majority of macronutrients and micronutrients (N, P, K, Ca, Mg, S, B, Cu, Fe, Mn, Ni, and Zn) are most available within a pH range of 6 to 7. Outside of these optimal ranges, nutrients are available to plants at lesser amounts[27].

As for soil salinity, it shown that all amounts tested of OMW induced a slight increase of soil electrical conductivity (EC), but with significant levels even after one month of their application (TABLE 3). Indeed, the amounts 50, 75 and 100 m^3/ha of OMW increased respectively soil EC by 1.5%, 2.5% and 3.2% compared to the control treatment without OMW application. Under 150 m^3/ha of OMW, soil EC was increased by 50 µS/cm which is equivalent to 5%. This last result is in disagreement with those of Levi-Minzi *et al.*[28] who found that the increase of the soil EC does not exceed 3.5% even with application of high amounts of OMW up to 300 m^3/ha. By against, Hanifi and El Hadrami [29] found that soil EC did not change after application of 150 m^3/ha of OMW over three consecutive years. The contrary results may be related to drain-

TABLE 3 : Weekly evolution of soil pH, electrical conductivity and polyphenols content under different OMW treatments

Week		Control	50 m^3 ha^{-1}	75 m^3 ha^{-1}	100 m^3 ha^{-1}	150 m^3 ha^{-1}
Soil pH	1	7.98	7.94	7.80	7.77	7.69
	2	8.00	7.97	7.82	7.80	7.74
	3	8.02	7.98	7.86	7.84	7.79
	4	8.03	8.00	7.92	7.90	7.86
Soil EC (mS cm^{-1})	1	1.04	1.06	1.07	1.07	1.09
	2	1.04	1.05	1.06	1.07	1.09
	3	1.04	1.04	1.05	1.06	1.09
	4	1.04	1.04	1.05	1.06	1.08
Soil polyphenols content (mg g^{-1})	1	0,17	0,20	0,24	0,35	0,52
	2	0,12	0,19	0,21	0,27	0,42
	3	0,07	0,12	0,15	0,17	0,35
	4	0,02	0,05	0,08	0,10	0,17

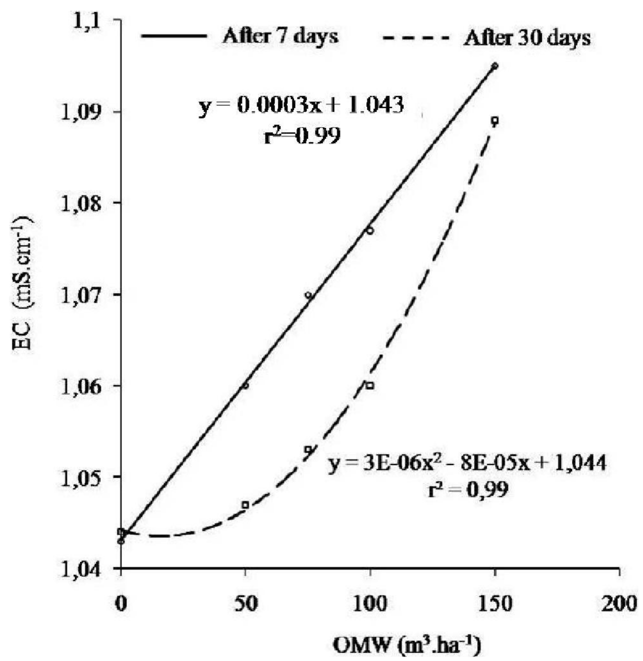

Figure 2 : Relationship between soil electrical conductivity and amount of OMW applied

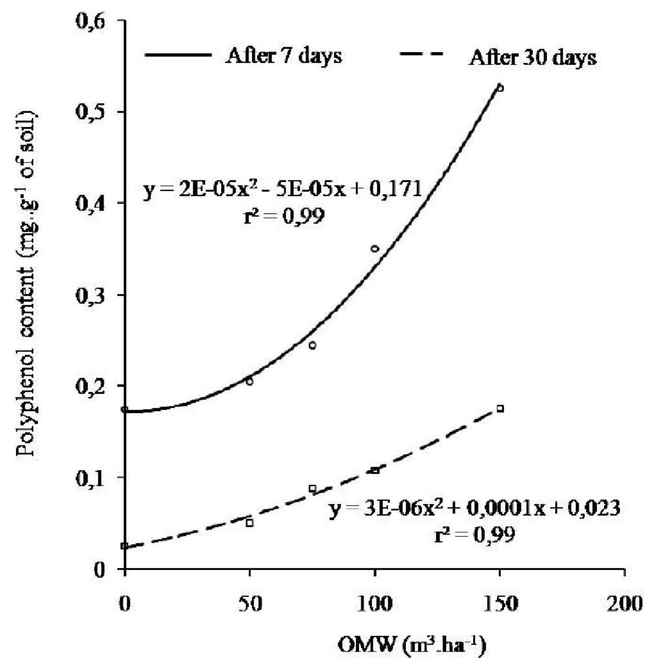

Figure 3 : Relationship between soil polyphenols content and amount of OMW applied

age capacity of the soil type used which was sandy in the last trial. In fact, more soil texture is sandy more the mineral salts are drained to the deeper layers, thereby decreasing the soil EC in the arable layer[30].

Variation of soil EC was significantly correlated in polynomial relationship with amount of OMW applied (Figure 2). The relationship indicates that amount of OMW required for increase soil EC by 0.1mS/cm is about 260 m^3/ha, which is equivalent to 10400 m^3/ha to increase it to 4 mS/cm which constitute the limit value beyond which the soil is considered saline[31,32]. However, these OMW effects concern only the soil arable layer (0-30 cm) and remain to study their impact on mineral salts accumulation in deeper layers.

Soil polyphenols content (PC) was amply increased under effect of OMW. After one week of application, the initial soil PC (0.175 mg/g) doubled under the treatment 100 m^3/ha to reach three fold value under 150 m^3/ha (TABLE 3). The moderate treatments 50 and 75 m^3/ha increased soil PC, respectively by 17 and 40%. The relationship between soil PC and amount of OMW was significant following a polynomial equation (Figure 3) which indicates that application of 1m3/ha of OMW increased soil PC by an average of 1.40 µg/g.

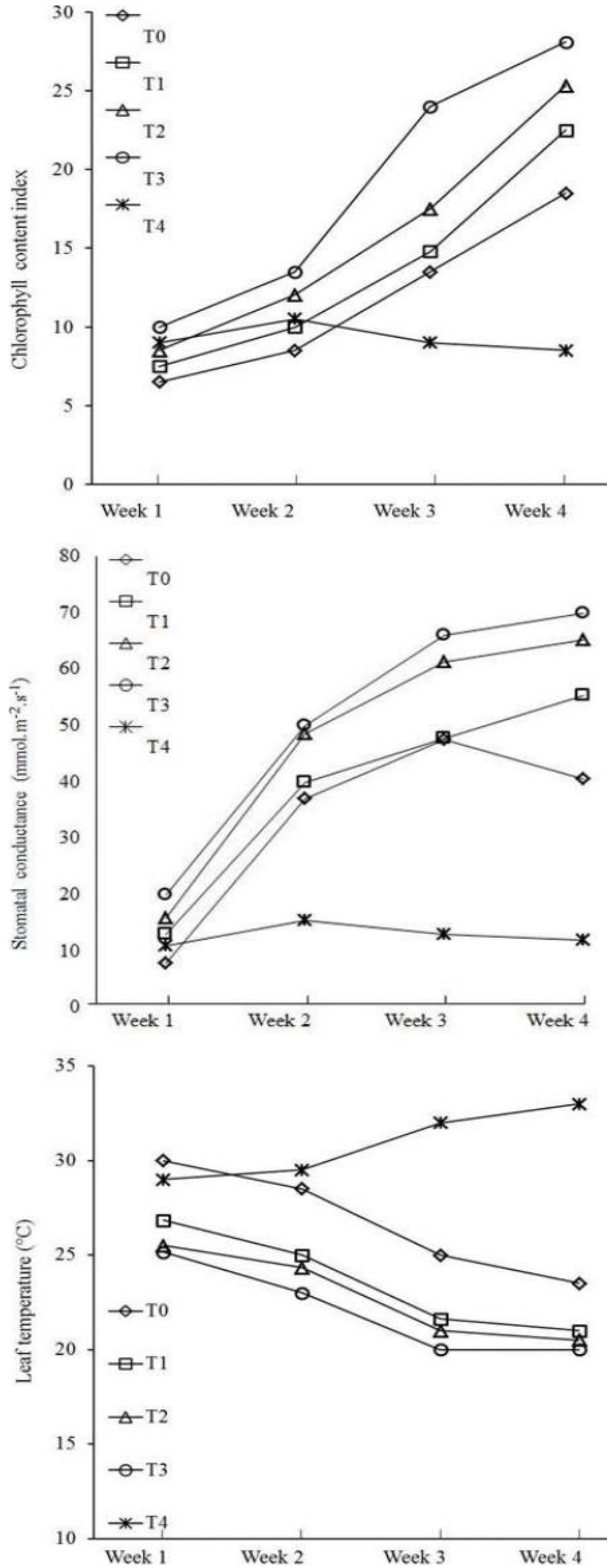

Figure 4 : Evolution of chlorophyll content, stomatal conductance and leaf temperature of coriander fertilized by different amounts of OMW

However, after one month of OMW application, soil PC decreased under all treatments by an average of 72%. This decrease was due to their deep infiltration and biodegradation in the soil. In fact, the phenolic compounds of OMW may be degraded by microorganisms[33,34] or by microbial enzymes[35,36]. However, duration necessary for their complete degradation may be considerable. Indeed, Hanifi and El Hadrami[29] found that soil PC was undetectable in soil surface layer after three years of application of 150 m^3/ha of OMW.

Effect of OMW on physiological behavior of coriander

The physiological response of coriander, taken as indicator plant, varied depending to applied OMW amounts based on weekly evolution of chlorophyll content index, stomatal conductance and leaf temperature values (Figure 4).

As for chlorophyll, an improvement of its concentration was observed under the treatments 50 and 75 m^3/ha especially from the third week of crop emergence and from the fourth week under the treatment 100 m^3/ha. This positive effect was more related to nitrogen and organic acids content of OMW. However, the treatment 150 m^3/ha induced a spectacular decrease of chlorophyll content more pronounced from the second week of its application. This depressive effect was more related to the allelechemical effect of polyphenols whose concentration in soil tripled under treatment 150 m^3/ha to reach 0.52 mg/g. Secondary, this effect may be also due to the soil salinity which was relatively elevated under this treatment compared to the control treatment. This is in agreement with the findings of Tewari and Singh[37] and Sivtsev[38] who observed that a slight increase of soil salinity induced a significant decrease of chlorophyll content in tomato and lentil.

The effect of treatment 150 m^3/ha on chlorophyll content of coriander was also explained by an induction of water stress by raising soil polyphenols content and soil salinity. Water stress may reduce chlorophyll content by decreasing assimilation and translocation of nitrogen[39]. Indeed, water deficit induced a nitrogen deficit which comes mainly from reductions in nitrogen flow at the roots, and secondarily from capacity reductions of root absorption and reduction of transport between leaves and roots due to transpiration feebleness[40]. This explanation was based on values of stomatal conductance and leaf temperature which indicate that coriander was submitted to water stress under the treatment 150 m^3/ha.

Indeed, under treatment 150 m^3/ha, transpiration flow of the coriander was reduced from the first week of its emergence, marked by a significant decrease of stomatal conductance and an increase of leaf temperature. The changes of these physiological parameters are explained by the fact that transpiration mitigation induces stomata closure and a decrease of their density, thereby decreasing stomatal conductance. Consequently, it reduces layer of steam water on leaf surface and makes accordingly leaf temperature more controlled by air temperature changes. However, coriander water status improved under the three treatments 50, 75 and 100 m^3/ha based on stomatal conductance and leaf temperature values. The positive effect of these treatments on coriander water status comes in large part from nitrogen and organic acids contained in OMW that increase rate of CO_2 assimilation, thereby improving the stomata functioning[41,42].

CONCLUSION

OMW used as an organic fertilizer on coriander has differently influences soil quality and physiological behavior of this crop depending on amounts applied. The amounts 50, 75 and 100 m^3/ha of OMW were induced slight changes of soil quality without significant effect on physiological behavior of coriander accordingly to values of chlorophyll content, stomatal conductance and leaf temperature. By against, application of 150 m^3/ha seemed detrimental to soil quality by increasing significantly soil electrical conductivity and amply soil polyphenols content that are phytotoxic by allelochemical effect. These changes in soil quality induced water stress, detected through measurement of stomatal conductance and leaf temperature on coriander, as well as nutritional stress revealed through measurement of leaf chlorophyll content.

REFERENCES

[1] G.Ranalli, G.Alfano, M.Bahammi, C.Belli, G.Lustrato; Gestion des sous-produits de la filiere oleicole au Maroc: Identification des solutions éco-compatibles et économiquement soutenables pour la valorisation des résidus de l'huile d'olive et la réduction de l'impact environnemental dans les régions de Fès, Meknès et Marrakech–, 1st Edition, United Nations organization for Industrial Development; Morocco **(2003)**.

[2] M.Achak, N.Ouazzani, L.Mandi; Revue des sciences de l'eau, **22**, 3 **(2009)**.

[3] [MAMF] Ministry of Agriculture and Marine Fisheries; Les aides financières de l'état pour l'encouragement des investissements agricoles, Rabat, Morocco **(2011)**.

[4] [SSEM] State Secretariat for Environment of Morocco; L'Industrie Oléicole au Maroc et son impact sur l'Environnement, propositions d'actions de lutte contre la pollution générée par les Huileries d'Olives: cas de la Province de Taounate, Rabat, Morocco **(2004)**.

[5] J.A.Fiestas, R.Borja; Grasas.y.Acietes, **43 (1992)**.

[6] L.Rosario, R.Ana, M.Bernardo, A.CGerardo, G.Antonio; Toxicology and Environmental Chemistry, 72 **(1999)**.

[7] Gartet, M.El Fengour, J.Gartet; Papeles de Geografía, **49**, 50 **(2009)**.

[8] N.Benyahia, K.Zein; 'Analyse des problèmes de l'industrie de l'huile d'olive et solutions récemment développées', Swiss Environmental Solutions for Emerging Countries, Lausanne, Switzerland **(2003)**.

[9] S.Khoufi, F.Alaoui, S.Sayadi; Anaerobic digestion of olive mill wastewater after Ca(OH)2 pretreatment and reuse adapted, paper presented at the international conference on wastewater treatment and reuse adapted to Mediterranean area, Tunisia, 25-28 Oct. **(2000)**.

[10] N.Fakharedine, H.El Hajjouji, G.Ait Baddi, J.C.Revel, M.Hafidi; Process Biochemistry, **41 (2006)**.

[11] R.A.Vazequez, D.R.Maestro, C.E.Graciani; Grasas y Aceites, **25 (1974)**.

[12] Q.Wang, Z.H.Li, X.Ruan, C.D.Pan, D.A.Jiang; Molecules,***15*** **(2010)**.

[13] Nefzaoui; Options Méditerranéennes: Série séminaires, 16 **(1991)**.

[14] F.Camurati, A.Rizzolo, E.Fedeli; Rivista Italiana Delle Sostanze Grasse, **58**, 11 **(1981)**.

[15] S.Kaddour, M.Kharrat, T.Souissi, D.Bouya, M.Bouhache; Chemical control of orobanchespp In Faba Bean (ViciaFaba) In the Maghreb, paper presented at the Eighth Arab Congress of Plant Protection, El-Beida, Libya, 12-16 Oct. **(2003)**.

[16] G.Alfano; Valorisation des sous-produits de l'olivier issus de système de trituration 2 et 3 phases: Expérience Italienne, paper presented at the fourth edition mediterranean days for olive tree, Meknes, Morocco, 19-21 Oct. **(2009)**.

[17] L.M.Nieto; Valorisation des sous-produits de l'olivier et des effluents liquides de l'industrie d'huile d'olive: biomasse et production d'énergie, paper presented at the fourth edition mediterranean days for olive tree, Meknes, Morocco, 19-21 Oct. **(2009)**.

[18] E.Moreno, J.Perez, A.Ramos-Cormenzana, J.Martinez; Microbios, **51 (1987)**.

[19] O.Yesilada, S.Sik, M.Sam; World Journal of Microbiology and Biotechnology, **14 (1998)**.

[20] R.M.El Idrissi; Différentiation des sols du plateau de Meknès, Master's Thesis, Université de Paris VI **(1992)**.

[21] R.Razouk, K.Daoui; Revue annuelle du projet PAF – MCA, **1 (2012)**.

[22] Skiredj, H.Elattir; Bulletin Mensuel d'Information du Programme National de Transfert de Technologie en Agriculture, **96 (2002)**.

[23] M.Neffati, B.Marzouk; The Journal of Essential Oil Research, 22 **(2010)**.

[24] E.Bonari, M.Macchia, L.G.Angelini, L.Ceccarini; Agricoltura Mediterranea, 123 **(1993)**.

[25] [IPNI] International Plant Nutrition Institute, Georgia, Report no.2 **(2010)**.

[26] N.C.Brady, R.R.Weil; The nature and properties of soils, 12th Edition, Upper Saddle River; New Jersey **(1999)**.

[27] McCauley, C.Jones, J.Jacobsen; Nutrient Management module, 8 **(2009)**.

[28] R.Levi-Menzi, A.Saviozzi, R.Riffaldi, L.Falzo; Olivae, 40 **(1992)**.

[29] S.Hanifi, I.El Hadrami; Journal of Agronomy, 7 **(2008)**.

[30] C.Bouarfa, F.Slama, A.Bahri, S.Chaumont, R.Bouhlila; Pratiques d'irrigation et rôle du drainage pour le contrôle de la salinité: Cas du périmètre irrigué de Kalaat Landelous en Tunisie, paper presented at the 1st seminar of Irrigated Agriculture Modernization, Rabat, Morocco, Avril, 19-23 **(2004)**.

[31] D.A.Horneck, J.W.Ellsworth, B.G.Hopkins, D.M.Sullivan, R.G.Stevens; Managing salt - affected soil for crop production –, A Pacific Northwest Extension publication; Washington State University **(2007)**.

[32] J.D.Rhoades, F.Chanduvi, S.Lesch; FAO irrigation and drainage paper, 57 **(1999)**.

[33] Tsioulpas, D.Dimou, D.Iconomou, G.Aggelis; Bioresource Technology, 84 **(2002)**.

[34] M.S.Fountoulakis, S.N.Dokianakis, M.E.Kornaros, G.Aggelis, G.Lyberatos; Water Research, **36**, 19 **(2002)**.

[35] A.Robles, R.Lucas, G.A.De Cienfuegos, A.Galvez; Enzyme and Microbial Technology, 26 **(2000)**.

[36] R.Casa, A.D'Annibale, F.Pieruccetti, S.R.Stazi, G.Sermanni, B.Lo Cascio; Chemosphere, **50**, 8 **(2003)**.

[37] T.N.Tewari, B.B.Singh; Plant Soil, 135 **(1991)**.

[38] M.V.Sivtsev, S.A.Ponomareva, E.A.Kuznetsova; Russ.Fiziol.Rast, 20 **(1973)**.

[39] B.Bojovié, A.Markovié; Kragujevac Journal of Science, 31 **(2009)**.

[40] F.Tardieu, P.Cruiziat, J.L.Durand, E.Triboi, M.Zivy; Perception de la sécheresse par la plante, conséquences sur la productivité et sur la qualité des produitsrécoltés : sécheresse et agriculture , 1st Edition Unité ESCo. INRA, Paris **(2006)**.

[41] J.H.Weng, F.H.Hsu; Photosynthetica, 39 **(2001)**.

[42] Y.Tazoe, K.Noguchi, I.Terashima; Plant Cell Environment, 29 **(2006)**.