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Olive pomace compost use for fenugreek germination

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Abstract. Morocco is among the major olive-growing countries around the Mediterranean, its productivity increases from one year to the next, especially after the introduction of the Green Morocco plan, which aims for an increase in the olive-growing area by the year 2020. The increase in productivity especially in olive oil is strictly accompanied by an increase in waste generated after crushing. The objective of this study is to value the olive pomace compost from traditional system as a soil amendment, and study its effect on the cultivation of herbaceous plants. The germination test is carried out in small pots, placed in a sunny place in a laboratory. 25 Fenugreek seeds were germinated in each pot which contains soil and a well-defined percentage of compost (5%, 10%, 15%, 20% and 25%). The seeds were irrigated regularly twice a week. All the tested seeds in different percentages of compost germinated at a rate of more than 90%. The final germination rate for the different concentrations was significantly important from the control (the pot that contains only soil). However, the 5% compost concentration allows an optimal germination rate. As well as the vigour of the seedlings that approves the positive effect of using olive pomace compost with a significantly high vigour index for all compost percentages (5%, 10%, 15%, 20% and 25%). The olive pomace compost use also improved the dry matter weight of the fenugreek seedlings for all percentages.

Key words: fenugreek germination, fertilizing power, olive pomace compost.

INTRODUCTION

In the Mediterranean countries, the environmental impact of olive oil production is significant. Indeed, the extraction of olive oil requires a large amount of water and generates huge amounts of waste during a limited period of 3 to 4 months per year (Ouzounidou et al., 2010; Mechri et al., 2011; Ntougias et al., 2013). According to the Food and Agriculture Organisation of the United Nations, 2.7 million tons of olive oil are annually produced worldwide, 76% of which are produced in Europe. Other olive oil producers are Africa (12.5%), Asia (10.5%) and America (0.9%) (Morillo et al., 2009).

In Morocco, the olive tree is the main planted fruit species. It is present throughout the national territory because of its capacity to adapt to all bioclimatic levels (El Mouhtadi et al., 2014). Indeed, the olive tree constitutes more than half of the arboricultural species, with more than 60 million trees on an area exceeding 560,000 ha (El Mouhtadi et al., 2014). In terms of production, the 2018–2019 campaign was marked by a new production record of about 2 million tons of olives, an increase of 42% compared to the average olive production of the last five years (Harbouze, 2019).

The waste generated following olive crushing, used to be discharged directly into the surrounding environment, which causes strong phytotoxic and antimicrobial effects. In fact, olive waste increases soil hydrophobicity, decreases water retention and infiltration rate, and affects acidity, salinity, nitrogen immobilization, microbial activity, nutrient leaching, lipid concentration, organic acids and naturally occurring phenols (Sierra et al., 2007; Regni et al., 2016). However nowadays and with the emergence of the principle of sustainable development, which insists on the harmonious balance between the protection of the environment, including water resources, which are particularly fragile in Morocco (World bank group, 2017) on one hand, and industrial production on the other hand, force us to think differently.

The valuation of olive pomace constitutes a potential source of additional income that can contribute to improving the profitability of olive-growing farms. The olive pomace can be used as fuel, livestock feed, fertilizers and as thermal insulation in some construction materials (Ajmia Chouchene, 2010).

The pomace use as an organic amendment has been a widespread practice in olive groves for a long time. Indeed, in addition to being economical and easily achievable, it has positive effects on soil characteristics and crops (Amirante, 2003; Niaounakis & Halvadakis, 2006 and Lozano-Garcia et al., 2011). Similarly, the olive pomace use has improved the soil biological activity (Innangi et al., 2017). The amendment by olive pomace has gone beyond olive groves to be used in herbaceous crops. In fact Brunetti et al. (2005) found an increase in the production of Triticum turgidum L. related to grain weight, number of grains per square meter, and soil organic matter content after amendment by olive pomace. Another study carried out in central Italy by Regni et al., 2017, showed that the application of olive pomace and its compost for 8 consecutive years on the soil of olive groves, significantly increased olive trees vegetative activity and fruit yield, as well as the oil phenols concentration.

However the abusive use of raw pomace as an amendment has shown some problems related to the needed time for germination and root development due to their high organic load, the mineral salts it contains, its low pH and the presence of phytotoxic compounds (Del Buono et al., 2011; Gigliotti et al., 2012; Proietti et al., 2015). Therefore, composting is necessary to stabilize the high organic content and benefit from a soil amendment rich in humic compounds, cation exchange capacity and water retention capacity (Malik et al., 2009).

The objective of this work is to study the effectiveness of a compost composed of olive pomace and cattle manure, used as a soil amendment, when germinating fenugreek seeds. Different concentrations of compost (5%, 10%, 15%, 20% and 25%) are tested during the germination trial in order to determine the optimal dose. A set of parameters were determined during and at the end of the vegetative period, namely seedling vigour, germination rate, dry matter weight and root development.

MATERIALS AND METHODS

Experimental design

The experiment consists of germinating 25 fenugreek seeds in moderate percentages of olive pomace compost (Table 1) and soil, in order to identify the fertilizing power of this compost and to determine the optimal useful dose for plants.

Table 1. Percentages of compost and soil used in the experiment

Compost percentage	0%	5%	10%	15%	20%	25%
Soil percentage	100%	95%	90%	85%	80%	75%

The percentages are on weight.

The table below illustrates the percentages in used compost and soil:

The soil used in this study comes from 'Salé' city (Salé, Morocco, latitude 34°03'11" North, longitude 6°47'54" West, altitude above sea level: 34 m). It was sampled from the topsoil (0–20 cm deep) of a callistemon. It is a sandy type of soil with the following main properties (Table 2):

Table 2. Soil physico-chemical parameters (Ameziane et al., 2020a)

Physico-chemical parameters	Soil characteristics
Clay in %	9 ± 0.044
Sand in %	68 ± 0.088
Silt in %	23 ± 0.044
pH	7.61 ± 0.044
Electrical conductivity in µS cm^{-1}	85.5 ± 0.149
Moisture in %	4.51 ± 0.044
Organic matter in %	6.88 ± 0.125
Total organic carbon %	4.88 ± 0.333
Total nitrogen in %	0.134 ± 0.02
Total Phosphorus %	0.0103 ± 0.003
Calcium %	0.48
Potassium %	0.0445
Magnesium %	0.0243
Sodium %	0.0092

The obtained values represent the average of three repetitions.

The compost used in this work is already prepared in a previous study (Ameziane et al., 2020b). It consists of 43% olive pomace and 57% cattle manure, which is mixed in a 30-litre barrel. The barrel is perforated to provide an aerated environment and placed in a sunny location. The composting process took 130 days to obtain mature compost, of which physico-chemical characteristics are presented in Table 3:

Table 3. Physico-chemical properties and germination index of mature compost (Aameziane et al., 2020b)

Measured parameters	Mature compost
pH	8.61 ± 0.03
Humidity in %	30.4 ± 0.14
EC in mS cm^{-1}	2.06 ± 0.22
OM %	38.4 ± 0.76
K_2O %	2.8 ± 0.36
NTK %	1.3 ± 1.89
P_2O_5 %	0.42 ± 0.86
COT %	22.32 ± 0.89
C/N %	17.16
The germination index in %	73 ± 0.65

The obtained values represent the average of three repetitions.

Before starting the germination test, the fenugreek seeds are disinfected with bleach, washed thoroughly with water and then rinsed with distilled water. Next, these seeds are put to germinate in small pots (φ (Top): 15 cm, Height: 14 cm, φ (Base): 10 cm). For each percentage of compost corresponds three pots, in each one of them 25

Fenugreek seeds have been sown at a depth of approximately 0.5 cm with a space of 1.5 to 2 cm between seeds. The pots are then placed in a laboratory.

Each pot has been regularly irrigated twice a week with Salé High School of Technology well water, and of which physico-chemical characteristics are in accordance with the Moroccan standard for irrigation water (Ministry of Energy, Mines, Water and Environment, 2007) (Table 4). The germination test lasted for 12 days.

Table 4. Irrigation water physico-chemical parameters (Ameziane et al., 2020a)

Physico-chemical parameters	Irrigation water characteristics
pH	7.49 ± 0.047
Electrical conductivity in mS cm^{-1}	1.024 ± 0.016
Temperature in °C	18.13 ± 0.058
Suspended matter e mg L^{-1}	0.232 ± 0.033
Salinity in ppb	0.3 ± 0.1
Nitrates in mg L^{-1}	7.04 ± 0.007
Chlorides in mg L^{-1}	192.5 ± 0.044
Boron in mg L^{-1}	0
Sulphates in mg L^{-1}	21.33 ± 0.005
Ortophosphates in mg L^{-1}	0.0134 ± 0.0001
The SAR	0.53 ± 0.5

The obtained values represent the average of three repetitions.

Plant material

Fenugreek is a Fabaceae family member. This specie has several varieties. It adapts to various types of soils. The best soils are between permeable clay and sandy. It is generally cultivated in bour without additional irrigation in areas with rainfall between 300 and 450 mm (Bernard, 1999).

Measured parameters

Several parameters were regularly monitored during this germination test:

The germination rate is calculated by the formula of Belcher & Miller (1974):

$$\mathrm{G}\,\% = 100 \times \frac{\sum n}{N} \quad (1)$$

where n is the number of sprouted seeds and N is the number of tested seeds.

The vigour is determined by the formula of Abdul-Baki & Anderson (1973):

$$VI = \%\, G \times SL \quad (2)$$

where SL is the length of the seedling in cm and % G is the germination rate.

Germination kinetics: this involves daily calculation of the germination rate under the different compost concentrations (Hajlaoui et al., 2007). It is expressed by the number of seeds germinated each day after the beginning of the experiment. This parameter allows a better understanding of the ecological significance of the germination behaviour of the studied seeds as well as the set of events that begin with the water absorption stage by the seed and end with the elongation of the embryonic axis and the emergence of the radicle.

Dry matter: Just after harvest, the seedlings dry matter weight of each pot, (stems + leaves + roots) was measured after drying in an oven at 105 °C to constant weight (Jacquemin, 2012).

Statistical analysis

The obtained results correspond to the average of 3 repetitions (three pots for each treatment). The experimental data were subjected to unidirectional variance analysis (ANOVA) and the average separations were made by the smallest difference (LSD) at the significance level of $P < 0.05$, using the Statgraphics centurion XVI program for Windows.

RESULTS AND DISCUSSION

Olive pomace compost addition effect on germination kinetics and final germination rate

At the first observation of Fig. 1 it can be seen that seeds germination rate is important for all compost concentrations compared to the control. (Fig. 1). We note a slow-down in the germination process as the compost dose increases. But despite this decrease, the germination rate of the different percentages (5%, 10%, 15%, 20% and 25%) remains high compared to the control.

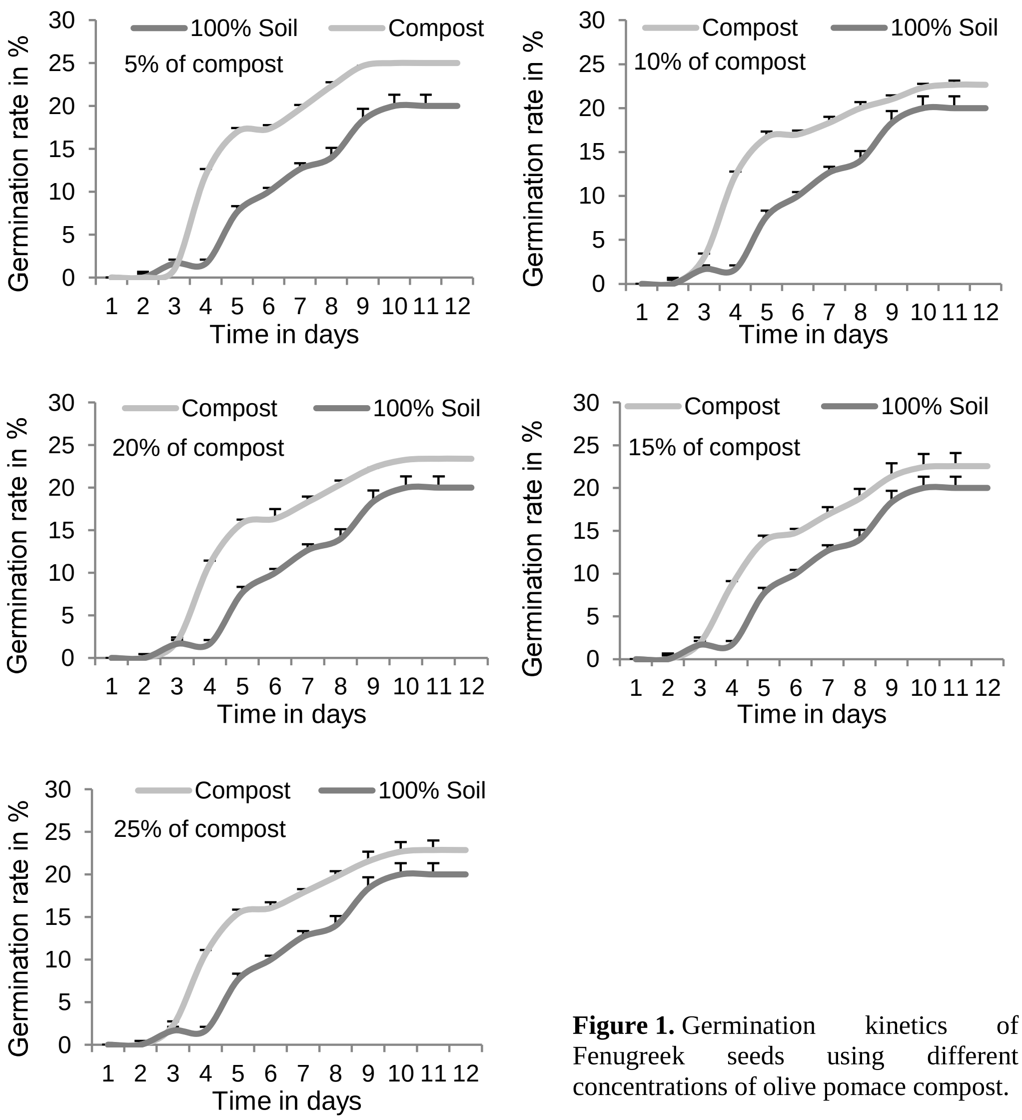

Figure 1. Germination kinetics of Fenugreek seeds using different concentrations of olive pomace compost.

The germination kinetics allows us to distinguish three important phases (Fig. 1):

– A latency phase, essential for the appearance of the first germs, and during which the germination rate remains low. The duration of this phase is short for the different concentrations (2 days), while it is longer for the control (4 days).

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– A more or less linear phase, corresponds to a rapid increase in the germination

– rate, which evolves proportionally to time (from the 2nd to the 10th day), during this phase an accelerated germination of the seedlings is noticeable for all compost concentrations compared to the control.

– A phase that corresponds to the final germination percentage, which is a stage that reflects the germination capacity of the fenugreek seeds for each concentration. This capacity seems important for all compost percentages compared to the control.

In general, all tested seeds germinated at a rate of more than 90% for all compost doses. Indeed, the final germination rate for the different concentrations is significantly different from the control. However, the 5% compost concentration allows an optimal germination rate (100%) (Fig. 2).

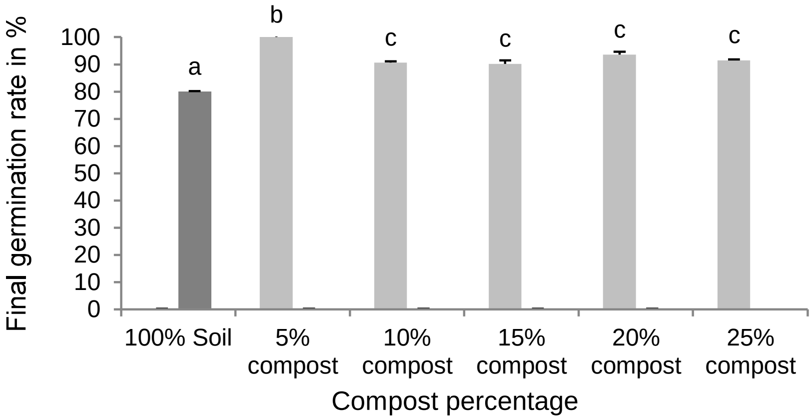

Figure 2. Final Fenugreek seedlings germination rate using different concentrations of olive pomace compost. (Values with different letters are significantly different: $p < 0.05$).

Plant germination is strongly linked to the availability of the nutrients elements, mainly nitrogen, which is responsible for the development of foliage and the plants aerial parts (Jean-François Morot-Gaudry, 1997). This explains the precocious germination of plants fertilized by the compost compared to control plants. In fact, the studied compost has a high nitrogen concentration (1.3%) (Table 3) compared to the control (0.134%) (Table 2).

Olive pomace compost addition effect on dry matter weight

The compost addition at different percentages improves the fenugreek seedlings dry matter weight (stems, leaves and roots), compared to the control (Fig. 3). The improvement is notable ($p < 0.05$) for 5%, 10% and 15% compost concentrations, while it is not significantly different from the control ($p > 0.05$) for 20% compost concentration. The increase in the seedlings dry matter weight can be explained by the richness of the compost in nitrogen and macro-elements, namely sodium, calcium, magnesium and potassium, which participate in the formation of plant tissues and represent 99% of their mass (Union of Fertilizer Industries, 1998). It is noticeable that the added compost concentration is inversely proportional to the weight in dry matter, which could be attributed according to Del Buono et al. (2011) to a high phenols concentration contained in the compost. A similar result was observed when using olive pomace compost for germinating Festuca and Italian ryegrass (Del Buono et al., 2011).

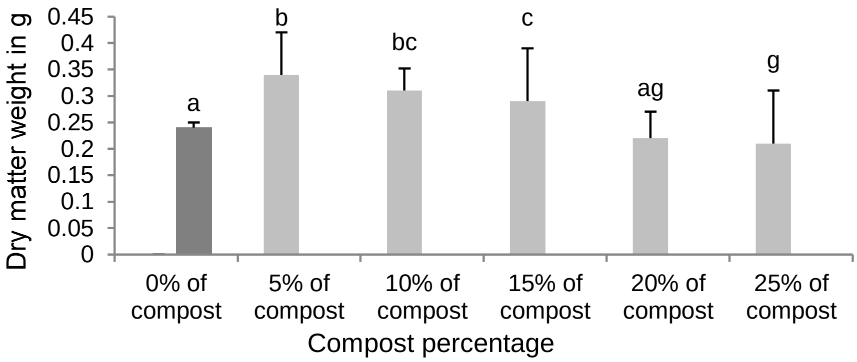

Figure 3. Effects of different percentages of compost on the weight of residual dry matter (Values with different letters are significantly different: $p < 0.05$).

Pomace compost addition effect on seedling vigour

The seedling vigour results (Fig. 4) show a positive effect of the use of olive pomace compost, which is reflected in a high vigour index compared to the control for the different percentages. In fact, the seedlings sown in the 5% compost percentage show an optimal vigour index (214.83) that is significantly different from the other percentages and from the control. Like the 10%, 15%, 20% and 25% percentages, the vigour index is high and significantly different from the control.

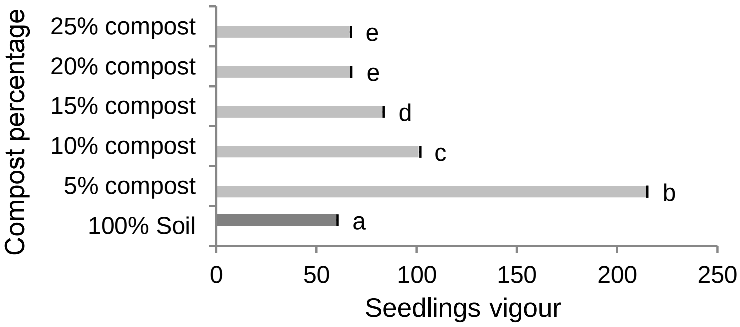

Figure 4. Fenugreek seedlings vigour using different olive-pomace compost concentrations. (Values with different letters are significantly different: $p < 0.05$).

In general, the fenugreek seedlings vigour index is significantly improved with the compost addition for all the used percentages compared to the control. Seedling vigour is linked to the presence of many nutrients, most important are nitrogen, which promotes growth, phosphorus, which stimulates root development, and potassium, necessary for plant nutrients assimilation (Mickaël Delaire, 2005). All these elements are abundant in the compost (NKT: 1.3%; P_2O_5: 0.42%; K_2O: 2.8%) (Table 3) compared to the control soil (NKT: 0.13%; Total phosphorus: 0.01%; Total potassium: 0.04%) (Table 2). This explains the important vigour of plants fertilized by different compost doses compared to control plants. But as for the weight in dry matter, this vigour decreases when the concentration of compost increases, which approves the existence of a phytotoxic compound that affects the seedlings vigour.

Pomace compost addition effect on root development of seedlings

Concerning the pomace effect on fenugreek seedlings root structure; we note a positive effect on root formation (Fig. 5). This effect is apparent for all compost concentrations. Root length was significantly different from the control for 5%, 10%, 15% and 20% concentrations. Similarly, root thickness is important for all concentrations, except for 25% compost concentration which is similar to the control (Fig. 6). Root development and vigour are strictly related to the phosphorus abundance in the soil (Plassard et al., 2015). Therefore, the important phosphorus concentration in the compost (0.42%) (Table 3) compared to that of the control (0.01%) (Table 2) can explain the significant roots development of plants fertilized by the compost. Same results have been also observed during germination of Festuca and Italian ryegrass (Del Buono et al., 2011).

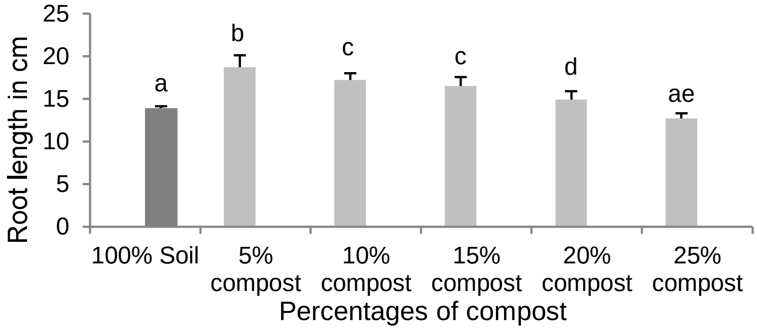

Figure 5. Root length for different concentrations of olive pomace compost. (Values with different letters are significantly different: $p < 0.05$).

Summarizing the obtained results we can say that the olive pomace compost presents an important nutritive contribution to the Fenugreek germination. Indeed, the pomace addition at different doses (5%, 10%, 15%, 20% and 25%) allowed an optimal germination compared to the control. The compost addition also increased the Fenugreek plants dry matter weight compared to the control for 5%, 10% and 15% compost concentrations. Similar results were observed by Del Buono et al. (2011) during the germination of Festuca and Italian ryegrass, as by Alburquerque et al. (2007), who reported a significant increase in Ryegrass plants dry matter weight, after been amended with olive pomace compost for 87 days. The present study also showed that the olive pomace compost addition allowed a significant improvement in the seedlings vigour and the root development of the plants, especially for 5%, 10%, 15% and 20% doses. This improvement could be attributed to the pomace compost richness in fertilizer elements (NTK, P_2O_5 and K_2O) required for the growth and development of most plants (Table 3)

(Regni et al., 2016). Likewise, Del Buono et al. (2011) found significant root development of Festuca and ryegrass following their amendment with olives pomace compost.

Figure 6. Fenugreek seedlings root development for different compost percentages.

Our results are consistent with studies carried out in other countries and on other plants. Indeed in Italy, the olive pomace compost amendment of olive trees for 8 years significantly increased the vegetative activity and fruit yield of olive trees (Regni et al., 2017). In an Italian study conducted by Proietti et al. (2015), an increase in vegetative activity and productivity of olive trees was observed after being amended with olive pomace compost for three consecutive years (Proietti et al., 2015). This increase in yield is due to the increase in organic matter, total nitrogen, assimilable phosphorus and exchangeable potassium content (Lopez-Pineiro et al., 2008). In fact, several studies show that soil amendment with pomace compost over time allowed an increase in soil organic matter and nutrient content (total nitrogen, phosphorus and exchangeable potassium) without modifying the soil pH and salinity (Ferarra et al., 2012; Chartzoulakis et al., 2010; Uygur & Karabatak, 2009; Montemurro et al., 2004). No negative effects on the quality of olive oil were observed in the studies mentioned above. This supports the view that pomace compost does not affect fruit quality.

CONCLUSIONS

In conclusion, in the present experiment, the used soil low fertility, and the olive-pomace compost important content in fertilizing elements, necessary for plant development (NTK, P_2O_5, K_2O), has allowed a significant Fenugreeks plants growth. The olive-pomace compost addition in different percentages (5%, 10%, 15%, 20% and 25%) to the Fenugreeks plants has improved their growth parameters (germination rate, seedling vigour and root development). Indeed the plants germination rate was important compared to the control for all compost percentages, the plant dry matter weight, the plants vigour and root development were significantly important compared to the control especially for 5%, 10% and 15% compost doses. Our study agrees with the results obtained by other authors and confirms that soil amendment with olive pomace compost can be a sustainable alternative to expensive and polluting chemical fertilizers. In perspective, further field trials on other crops are planned to confirm the obtained results.

REFERENCES

Abdul-Baki, A.A. & Anderson J.D. 1973. Vigor determination in soybean seed by multiple criteria. *Crop Science*, n° **13**, pp. 630–633.

Ajmia chouchene. 2010. *Experimental and theoretical study of processes for the valorisation of olive oil by-products by thermal and physicochemical means.* Doctoral thesis in Energy Engineering-Process Engineering, under the supervision of F. Zagrouba, Monastir, National Engineering School of Monastir, and G. Trouve, University of Haute-Alsace, Mulhouse, 220 pp. (in French).

Alburquerque, J.A., Gonzalvez, J., Garcia, D. & Cegarra, J. 2007. Effects of a compost made from the solid byproduct (alperujo) of the two-phase centrifugation system for olive oil L.). *Bioresour. Technol*. **98**(4), 940–945.

Ameziane, H., Nounah, A., Kabbour, M.R. & Khamar, M. 2020a. Agronomic valuation of olive pomace obtained by different extraction systems. *Eco. Env. & Cons*. **26**(1), 414–422.

Ameziane, H., Nounah, A., Khamar, M. & Zouahri, A. 2020b. Composting olive pomace: evolution of organic matter and compost quality. *Agronomy Research* **18**(1), 5–17.

Amirante, P. 2003. I sottoprodotti della filiera olivicola-olearia. In: Fiorino, P. (Ed.), Olea, Trattato di Olivicoltura. Edagricole, Bologna, pp. 291–303 (in Italian).

Belcher, E.W. & Miller, L. 1974. Influence of substrate moisture level on the germination of sweetgun and pine seed. *Proceeding of the Association of Official Seed Analysis* **65**, pp. 88–89.

Bernard, Le Clech. 1999. *Field crop production*. References 2nd edition. 412 pp. (in French).

Brunetti, G., Plaza, C. & Senesi, N. 2005. Olive pomace amendment in Mediterranean conditions: effect on soil and humic acid properties and wheat (*Triticum turgidum* L.). J. *Agric. Food Chem*. **53**, 6730–6737.

Chartzoulakis, K., Psarras, G., Moutsopoulou, M. & Stefanoudaki, E. 2010. Application of olive mill wastewaterto a Cretan olive orchard: effects on soil properties, plant performance and the environment. *Agric. Ecosyst. Environ*. **138**(3–4), 293–298.

Del Buono, D., Said-Pullicino, D., Proietti, P., Nasini, L. & Gigliotti, G. 2011. Utilization of olive husks as plant growing substrates: phytotoxicity and plant biochemical responses. *Compost Sci. Util*. **19**, 52–60.

El Mouhtadi, I., Agouzzal, M. & Guy, F.2014. The olive tree in Morocco. *OCL*, **21**(2) D203. (in French).

Ferarra, G., Fracchiolla, M., Al Chami, Z., Camposeo, S., Lasorella, C., Pacifico, A., Aly, A. & Montemurro, P. 2012. Effects of mulching materials on soil performance of cv. nero di troia grapevines in the Puglia region, southeastern Italy. *Am. J. Enol. Vitic*. **63**(2), 269–276.

Gigliotti, G., Proietti, P., Said-Pullicino, D., Nasini, L., Pezzolla, D., Rosati, L. & Porceddu, P.R. 2012. Co-composting of olive husks with high moisture contents: organic matter dynamics and compost quality. *Int.Biodeterior. Biodegradation* **67**, 8–14.

Hajlaoui, H., Denden, M. & Bouslama, M. 2007. Study of the intraspecies variability of saline stress tolerance of chickpeas (Cicer arietinum L.) at the germination stage. *Tropicultura*, **25**, 168–173 (in French).

Harbouze, R., Pellissier, J.-P., Rolland, J.-P. & Khechimi, W. 2019. *Synthesis report on agriculture in Morocco*. CIHEAM-IAMM, pp.104 (in French).

Innangi, M., Niro, E., D'Ascoli, R., Danise, T., Proietti, P., Nasini, L., Regni, L., Castaldi, S. & Fioretto, A. 2017. Effects of olive pomace amendment on soil enzyme activities. *Applied Soil Ecology* **119**, 242–249.

Jacquemin, L. 2012. *Production of hemicelluloses from straw and wheat bran on a pilot scale. Study of the technical performance and environmental assessment of an agro-process*. Doctoral thesis. National Polytechnic Institute of Toulouse, 345 pp. (in French).

Jean-François Morot-Gaudry. 1997. *Nitrogen assimilation in plants biochemical and molecular physiological aspects*, Paris, INRA-Quae, Mieux comprendre, 422 pp. (in French).

Lozano-Garcia, B., Parras-Alcantara, L. & del Toro Carrillo de Albornoz, M. 2011. Effects of oil mill wastes on surface soil properties, runoff and soil losses in traditional olive groves in southern Spain. *CATENA* **85**(3), 187–193.

Lopez-Pineiro, A., Albarran, A., Rato Nunes, J.M. & Barreto, C. 2008. Short and medium term effects of twophase olive mill waste application on olive grove production and soil properties under semiarid Mediterranean conditions. *Bioresour. Technol*. **99**, 7982–7987.

Malik, S.Y. Haddadin, Jamal Haddadin, & Omar, I. 2009. Arabiyat, Butros Hattar, Biological conversion of olive pomace into compost by using Trichoderma harzianum and Phanerochaete chrysosporium. *Bioresource Technology* **100**(20), 4773–4782.

Mechri, B., Cheheb, H., Boussadia, O., Attia, F., Ben Mariem, F., Braham, M. & Hammami, M. 2011. Effects of agronomic application of olive mill wastewater in a field of olive trees on carbohydrate profiles, chlorophyll a fluorescence and mineral nutrient content. *Environ. Exp. Bot.* **71**(2), 184–191.

Mickaël Delaire. 2005. *Variations in the mineral absorption capacity of the roots of young Acer pseu-doplatanus, L. (Aceraceae) as a result of the recent and ancient nutritional history of the plant. Application to off-ground cultivation of woody plants.* Plant biology. University of Angers, 180 pp. (in French).

Ministry of Energy, Mines, Water and Environment, in charge of Water and Environment. 2007. Quality Standards: Water intended for irrigation. (in French).

Montemurro, F., Convertini, G. & Ferri, D. 2004. Mill wastewater and olive pomace compost as amendments for rye-grass. *Agronomie* **24**, 481–486.

Morillo, J.A., Antizar-Ladislao, B., Monteoliva-Sánchez, M., Ramos-Cormenzana, A. & Russell, N.J. 2009. Bioremediation and biovalorisation of olive-mill wastes. *Applied Microbiology and Biotechnology* **82**, 25–39.

Niaounakis, M. & Halvadakis, C.P. 2006. *Olive Processing Waste: Management Literature Review and Patent Survey*, second ed. Elsevier Ltd., Kidlington, Oxford, UK. 514 pp.

Ntougias, S., Gaitis, F., Katsaris, P., Skoulika, S., Iliopoulos, N. & Zervakis, G.I. 2013. The effects of olives harvest period and production year on olive mill wastewater properties–evaluation of Pleurotus strains as bioindicators of the effluent's toxicity. *Chemosphere* **92**(4), 399–405.

Ouzounidou, G., Zervakis, G.I. & Gaitis, F. 2010. Raw and microbiologically detoxified olive mill waste and theirimpact on plant growth. *Terr. Aquat. Environ. Toxicol*. **4**, 21–38.

Plassard, C., Robin, A., Le Cadre, E., Marsden, C., Trap, J., Herrmann, L.,Waithaisong, K., Lesueur, D., Blanchard, E. & Chapuis-Lardy, L. 2015. Improving the bioavailability of phosphorus: how to make the most of plant skills and soil biological mechanisms?. *Innov. Agron*. **43**, 115–138 (in French).

Proietti, P., Federici, E., Fidati, L., Scargetta, S., Massaccesi, L., Nasini, L., Regni, L., Ricci, A., Cenci, G. & Gigliotti, G. 2015. Effects of amendment with oil mill waste and its derived-compost on soil chemical and microbiological characteristics and olive (Olea europaea L.) productivity. *Agric. Ecosyst. Environ*. **207**, 51–60.

Regni, L., Gigliotti, G., Nasini, L. & Proietti, P. 2016. Reuse of olive mill waste as soil amendment. In: Olive Mill Waste: Recent Advances for Sustainable Management, C.M. Galanakis Ed.; Elsevier-Academic Press: Oxford, UK, pp. 97–117.

Regni, L., Nasini, L., Ilarioni, L., Brunori, A., Massaccesi, L., Agnelli, A. & Proietti, P. 2017. Long term amendment with fresh and composted solid olive mill waste on olive groveaffects carbon sequestration by prunings, fruits and soil. *Front. Plant Sci*. **7**, 20–42.

Sierra, J., Marti, E., Garau, M.A. & Cruanas, R., 2007. Effects of the agronomic use of olive oil mill wastewater field experiment. *Sci. Total Environ* **378**, 90–94.

Union of Fertilizer Industries. *Fertilization*. 7th edition. 1998. 78 pp. (in French).

Uygur, V. & Karabatak, I. 2009. The effect of organic amendments on mineral phosphate fractions in calcareous soils. *J. Plant Nutr. Soil Sci*. **172**, 336–345.

World bank group. 2017. *Management of Urban Water Scarcity in Morocco*, 38 pp. (in French).