Moroccan Journal of Chemistry
ISSN: 2351-812X
http://revues.imist.ma/?journal=morjchem&page=login
Mehdaoui & al. / Mor. J. Chem. 9 N°4 (2021) 776-790
DOI: https://doi.org/10.48317/IMIST.PRSM/morjchem-v9i3.25595

What effects does an organic amendment to olive waste have on the soil and crop yield

I. Mehdaoui [a*], ***Z. Majbar*** [a], ***I. Atemni*** [a], ***S. Jennan*** [a], ***T. Ainane*** [b], ***Y. Gaga*** [c], ***M. Taleb*** [a], ***Z. Rais*** [a], ***A. Chetouani*** [d]

[(a)] *Engineering Laboratory of Organometallic, Molecular, and Environmental Materials. Faculty of Sciences Dhar Mahraz, Sidi Mohamed Ben Abdellah University, Fez, Morocco*
[(b)] *Higher School of Technology - Sultan Moulay Slimane-Khenifra University*
[(c)] *Laboratory of Biotechnology, Conservation, and Valorization of Natural Resources -LBCVRN. Faculty of Sciences Dhar Mahraz, Sidi Mohamed Ben Abdellah University, Fez, Morocco*
[(d)] *LCAEE faculty of sciences Oujda University Moh 1 Morocco*

** Corresponding author:*
mehdaouiimane2@gmail.com

Received 12 April 2021,
Revised 01 Nov 2021,
Accepted 06 Dec 2021.

Abstract

Intensive agriculture or phenomena such as pollution, compaction, and/or erosion lead to a decrease in the amounts of organic matter of soils; thus, causing a decrease in their fertility. The use of an organic amendment in agriculture could combat soil degradation. In this sense, two organic amendments with olives waste (OW) and olive mill wastewater (OMW) have been manufactured. The objective of this work is to examine the capacity of these amendments to improve soil quality in comparison with manure (M). Three types of soil were tested: the first has been amended for two years with a compost of similar composition (S_1), the second not amended (S_2), and the third corresponds to an agricultural soil that is amended with chemical fertilizer (S_3). All the trials were carried out on two vegetable gardens: potato and radish. The ANOVA shows that the amendment effect was highly significant on all the physicochemical parameters studied except humidity. In conclusion, this product could be an alternative to chemical fertilizers and considered as a perennial solution adapted to the context of sustainable development to the recovery of olive waste.

Keywords: *Soil. organic amendment. olive waste. physicochemical characterization. fertility. Statistical analysis.*

1. Introduction

Soil is considered an essential resource for the production of food on the planet. Hence, it is a limited resource that requires special attention and management to ensure the viability of agriculture [1,2]. Accordingly, the Moroccan government has set up a Green Morocco Plan program (GMP) aimed at increasing the cultivated areas, improving the quality of products, and obtaining gains in export market share [3]. However, a large area of agricultural soils experiences a reduction in organic matter content of 6 to 10% per year [4,5]. Most farmers are moving towards the use of chemical fertilizers and pesticides to protect plants from phytotoxic diseases. This use has a long-term impact on the soil condition [6]. Recently, the composting of organic waste has led to a stable and nutrient-rich amendment [7-12], based on co-products: vegetable water and olive waste [13], wineries [14], wastewater treatment plant sludge [15], ... The literature review shows that the addition of compost to the soil helps to preserve their nutrients for a long time and ensures more penetration of air and water which is essential for microorganisms promoting growth cultures [16,17]. The objective of this work is to examine the effect of compost, previously prepared by co-composting household organic waste and olive-growing waste, on the soil and the yield of the cultivation of radishes and potatoes.

2. Materials and methods

2.1. Materials

- ***Plant material:***

Radish variety *Raphanus Sativus National and Koruda variety* potato.

- ***Organic amendements :*** three types of organic amendments were tested; two composts are previously prepared at the LIMOME laboratory (**OMW** and **OW**) and **Cattle manure.** The **OMW compost** is composed of green waste (GW), poultry droppings (PD) and olive mill wastewater (OMW), on the other hand the **OW compost** is consisting of GW, PD, OMW and olive-waste, for manure for manure, has been supplied from a farm in the Sefrou region.

- ***Soil:*** Three types of soils were used: the first has been fertilized since 2018 (S_1), the second never fertilized (S_2), and the third corresponds of the field located at Douar Aghlabou Aguorar in Sefrou, usually fertilized by NPK fertilizers (S_3).

- ***Irrigation water***: two wells were employed; wells of FSDM- Fez and wells in Douar Aghbalou Aguorar.

2.2. *Methods of Materials characterization: AFNOR*

- ***Organic amendements*** [18-20]

All materials were characterized by measurement of the parameters: pH, electrical conductivity (EC), humidity (% H), dry matter (% DM), kjeldhal nitrogen (NTK), organic matter (% OM), total organic carbon (TOC), C/N ratio, fertilizing elements and metallic elements according to AFNOR standards.

The maturation of substances OMW and OW evaluated by measuring their polyphenol content, humic acid formation (E_4/E_6), germination index (GI) and polyphenols.

- ***Irrigation water*** [21]

The well water was taken and analysed by measuring pH, Electrical conductivity, Chemical Oxygen Demand (COD), ammonium (NH_4^+), sulphides (S^{2-}), sulphates (SO_4^{2-}), nitrate (NO_3^-), nitrite (NO_2^-) and ortho-phosphate (PO_4^{3-}) ions in according with AFNOR standards.

- ***Monitoring the effect of the amendment on the soils***

It was held by measurements of the same physicochemical parameters of the soil characterization as a function of the assimilation time of the amendments during 10 days (t_1), then after harvest of the radish (t_2 = 45 days), and of the potato (t_3 = 90 days). The effect of soil quality on the two crops was studied by measuring their production parameters; caliber and yield.

- ***Statistical Studies***

All measurements were subjected to a three-way ANOVA analysis of variance for soil, assimilation time, and type of organic amendment without repetition, using Fisher's F test to verify the equality hypothesis of means at the risk threshold of 5%. The result is noted significant when $p < 0.05$. The statistical processing is carried out with Statgraphics 18 software.

3. Results and Discussions

3.1. Physico-chemical Characterization of Organic Amendments

The Physico-chemical characterization of organic amendments M and OW (Table 1) reflects that they are mature, stable, have no phytotoxic effect, and fully meet the requirements of the NFU44-051 standard relating to the quality of urban composts [18].

Table 1. *Physico-chemical characteristics of the used amendments*

Parameters	OW	OMW	M	Standard NFU44-051B [18]
pH	7.95	7.63	8.57	6.5-8.5
EC (mS.cm^{-1})	2.69	4	3.87	ND
H (%)	16.7	12	20	>30
DM (%)	83.3	88	80	>30
OM (%)	56.65	62.95	74.68	>20
TOC (%)	29.82	33.13	37.72	ND
TKN (%)	2.59	3.15	2.97	0.88
C/N	11.51	10.51	12.7	>8
Polyphenols (mg/L)	6.5	7.5	0	ND
Minerals and fertilizers mg / Kg				
Na	8505	36225	10485	ND
K	88680	8410	85460	ND
Ca	14.83	7.79	6.71	ND
P	1.75	3.52	2.39	ND
Mg	2.9	2.2	3.16	ND

Both amendments are rich in the mineral elements calcium, potassium, phosphorus, magnesium, and sodium which play an essential role in improving soil fertility and consequently in the development and growth of plants.

3.2. Physico-chemical Characterization of Soils before the Amendment

The results of the Physico-chemical characterization of the soils studied for the cultivation of radishes and potatoes are represented in Table 2.

Table 2. *Physico-chemical characteristics of the used soils*

Parameters	S_1	S_2	S_3	Standards [19,20]
pH	7.13	7	6.88	ND
CE mS.cm^{-1}	0.264	0.236	0.198	ND
H (%)	13	13	16	ND
MS (%)	87	87	84	ND
MO (%)	10	4	8	3.6-6.5
COT (%)	5.26	2.1	4.21	ND
NTK (%)	0.525	0.176	0.103	ND
C/N	10.01	11.93	40.09	11-15
Minerals and fertilizers mg / Kg				
Na	54540	52560	36720	0.3-0.7
K	54470	36130	48100	0.15-0.25
Ca	46.29	104.84	38.1	5-8
P	0.62	0.5	0.69	ND
Mg	5.22	4.62	4.91	1.5-3
Metal trace elements mg / Kg				
Cu	0.057	0.056	0.062	ND

Before the amendment, all three soils were almost neutral. These types of soils are very suitable for growing radishes (6 <pH <7). However, for the potato, the soil had to be slightly acidic (4.5 <pH <6.0). They are rich in mineral elements, especially magnesium, calcium, sodium, and potassium. The organic matter of S_1 and S_3 soils exceeds the required value by standard NF-EN 14259 thanks to their amendment previously, respectively by the compost OMW and fertilizers for old crops. This promotes the availability of essential nutrients for plant growth and good microbial activity. The C/N ratio for S_3 exceeds three times the required standard for fertile soil (AFNOR 2015), which leads to good mineralization of organic matter.

3.3. Physico-chemical Characterization of Well Water

The physicochemical characterization of the irrigation water (Table 3) reveals that the water from the two wells meets the Moroccan irrigation water standard [21] and does not present any risk for the soil-plant system.

3.4. Maturity Tests for OMW and OW Composts

The maturity verification tests for M and OW composts (Table 4) reflect that they are characterized by germination indices greater than 50 and a high presence of humic acid evaluated by the spectroscopic test of the ratio (E_4/E_6) which is greater than 5. This proves the stability and non-phytotoxicity of the two composts.

Table 3. *Physico-chemical composition of well water*

Well water	pH	CE (mS cm^{-1})	NO_3^- (mg L^{-1})	NO_2^- (mg L^{-1})	NH_4^+ (mg L^{-1})	SO_4^{2-} (mg L^{-1})	S^{2-} (mg L^{-1})	PO_4^{3-} (mg L^{-1})	DCO (mg L^{-1})
FSDM	7.11	120	0.8	0.011	1.087	0.5	0.076	0.22	93.05
Field	7.3	253	1.1	0.016	1.102	0.57	0.09	0.31	124
NM Irrigation water (SEWE 2007)	6.6 à 8.4		1.5	-	-	250	-	-	-

Table 4. *Maturation tests for amendments OMW, M, and OW*

Parameters	OW	OMW	M	NFU44-051 (AFNOR.2015)
IG (%)	71.45	60.61	0	> 50
E_4/E_6	3	2.33	0.2	< 5

3.5. Comparative Study of the Effect of Organic Amendments on Soil Quality

The physicochemical parameters of the three studied soils S_1, S_2, and S_3 were followed according to the time of their assimilation of three types of amendments: two composts, OMW and OW, and manure M (figures 1 to 8). A statistical study by ANOVA was carried out to evaluate the significant effect of the amendments on each parameter characterizing the composition of the soil.

3.5.1. pH

Analysis of the graphs in Figure 1 shows that the addition of amendments increased the pH of soil from neutral to slight basicity to a maximum reached after radish harvest (45 days) for S_1 and S_3. After the potato harvest (90 days), the soils amended by the OW compost recorded a notable increase in pH for S_3 and to a lesser degree for S_1 and S_2 respectively. In fact, a pH in the region of 8 does not prevent obtaining acceptable harvests; in the case of the potato, it prefers slightly acidic soils in principle [22]. The three amendments have the same effect for S_3; the OMW compost is more assimilated by S_1, and that of olive waste by S_2. These variations are similarly true due to the difference in the initial compositions of soils, amendments, and irrigation water. Also, the geographical location of the soils and their orientation allow optimum solar contributions necessary for the retention of nutrients, their texture favoring places of exchange and permeability.

3.5.2. Electrical Conductivity

In figure 2, the curves show that the electrical conductivity of all the soils increased as a function of time for all the amendments thanks to their richness in fertilizers. Manure and OMW compost acted more favorably on the mineral load of soils due to their high organic matter composition in comparison with OW compost which is mineralized and has released ions; since the electrical conductivity of the soil represents the size of the reservoir that allows reversibly storing certain cationic fertilizing elements (potassium, magnesium, calcium, etc.), they promote good circulation of salts in the soil, and consequently promotes seed germination and stimulates plant development [23,31].

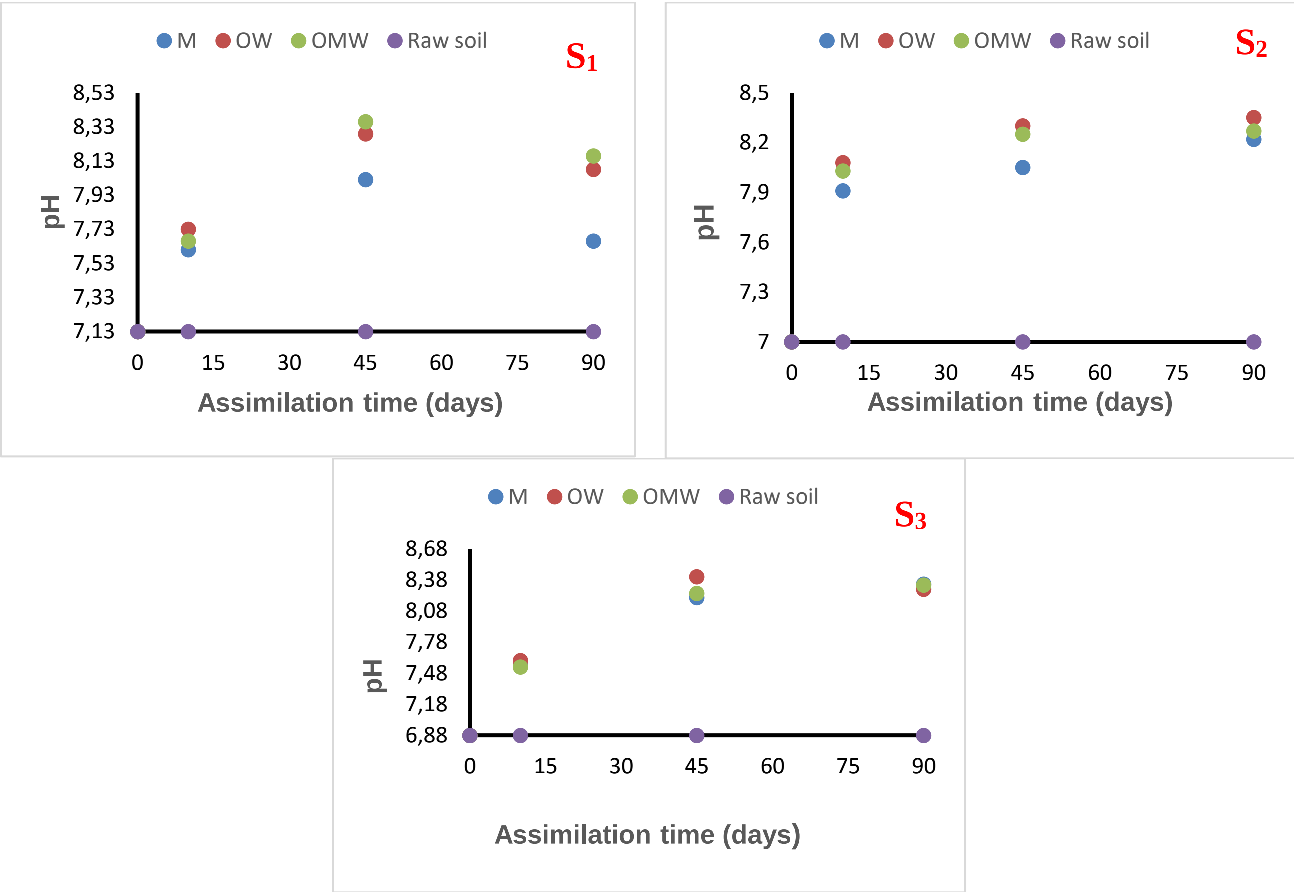

Figure 1. pH of Soil as a function of the assimilation time of amendments

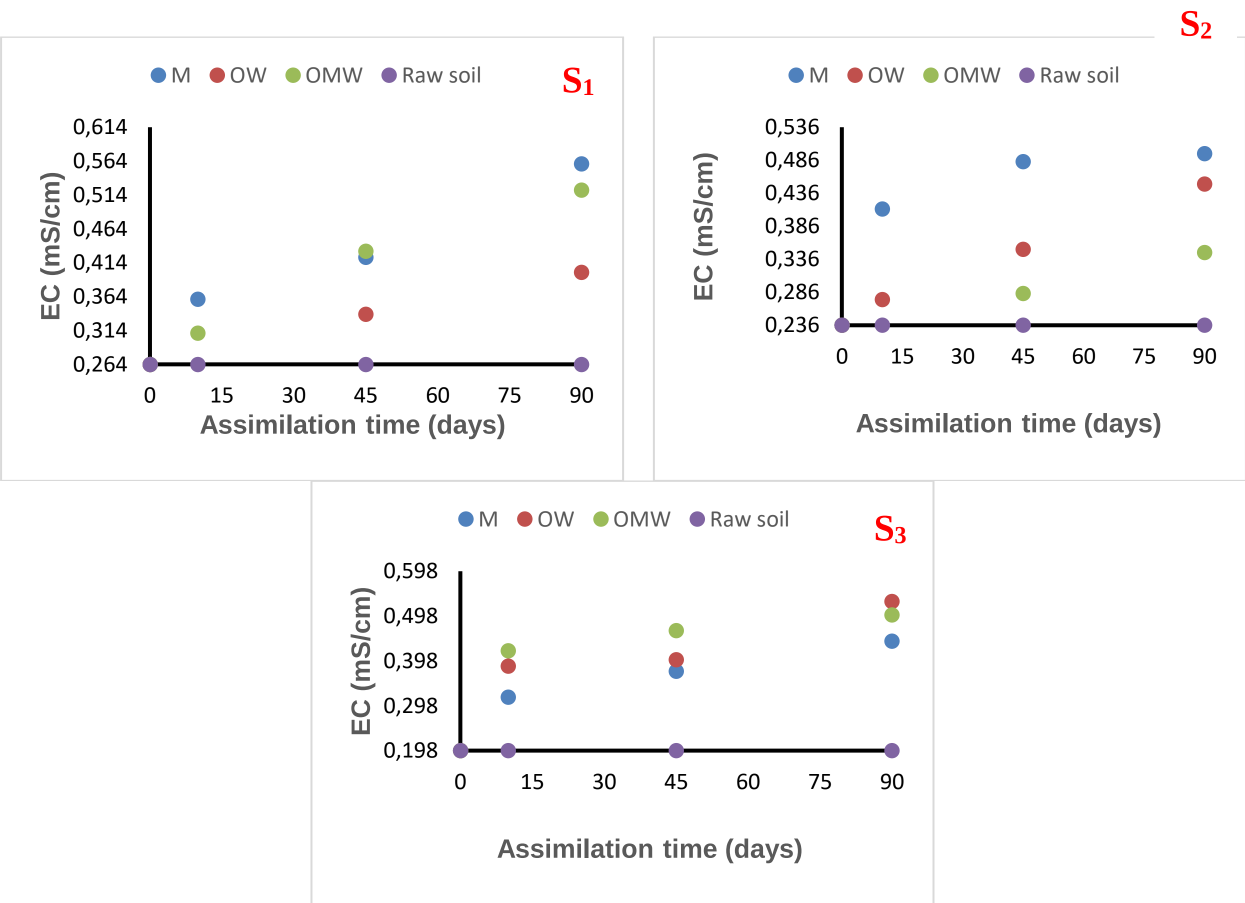

Figure 2. Electrical conductivity of soils as a function of the assimilation time of amendments

3.5.3. Humidity

The curves, in Figure 3, demonstrate the decrease in moisture of almost half of the three soils for different types of amendments until radishes are harvested (45 days) as well as the potato (90 days). This can be explained on one hand by the changing climate conditions, excessive use of chemical fertilizers, irregular mode of irrigation, water consumption by crops, or the nature of the soil. On the other hand, water absorption by the microorganisms responsible for transporting necessary elements to crops [24].

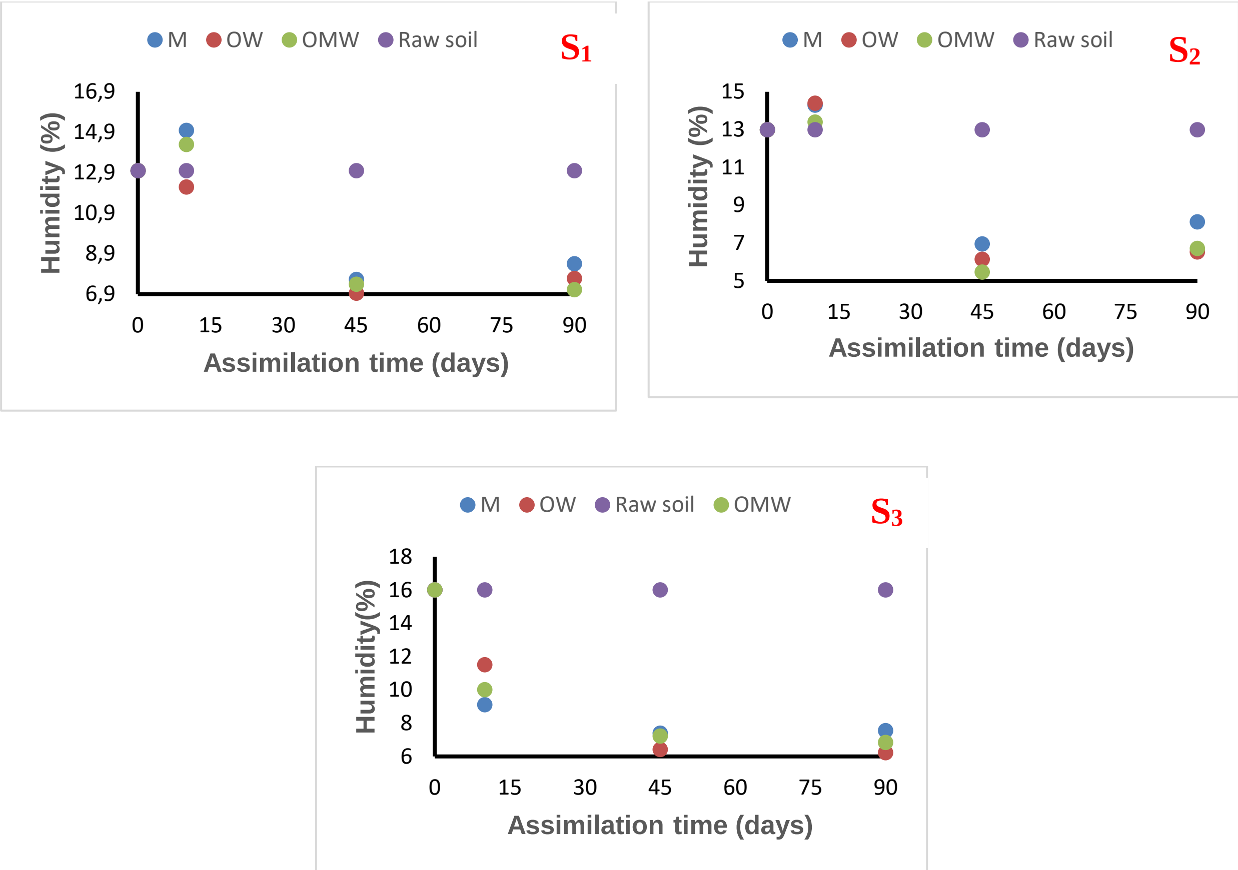

Figure 3. Soil humidity as a function of the assimilation time of the amendments

3.5.4. Dry Matter

Figure 4 shows that the addition of amendments slightly reduced the rate of dry matter on the 10th day of OMW amendment to olive waste for soils S_1 and S_2 because they were initially low in organic matter, then an excessive increase after harvesting radish (45 days) and to a lesser extent of the post-harvest potatoes (90 days). In fact, the higher this content, the more the mixture is concentrated, the drier and richer in nutrients. As for the S_3 soil and all soils amended with compost OW for 10 days, the dry matter increased slightly; then, it has known an increase after the harvest of radishes (45 days) and at a lower degree of the after harvest potatoes (90 days). This is probably due to the difference in the nature and texture of S_3 soil in the field compared to S_1 and S_2 soil, and also to the consumption of the necessary elements for the growth of the potato as it is a more demanding crop than that of the radish [25].

3.5.5. Organic Matter

The curves of Figure 5 represent the monitoring of organic matter OM as a function of the addition of the amendment. An increase in OM for all soils after 10 days of their amendment with compost or manure, then a decrease for all soils was recorded to varying degrees after harvesting both radishes and potatoes. This is mainly due to the transmission of OM from soil particles to crops through the activity of microorganisms. For the soil, OM constitutes an energy contribution and a contribution of biogenic elements necessary for the activity of a large number of organisms (flora, microflora, and fauna of the soil) thanks to its composition in elements C, N, H and O as well as K, Na, Ca, Mg and Mn cations present in composts [26]. It should be noted that for S_3 soil, manure and OW compost have a weaker action than OMW compost which has been well absorbed by undergoing stabilization given its availability in polyphenols which react with proteins and reduce their microbial degradation and thus nitrogen releases which attributed to the increase in organic matter. For S_2 soil amended with OW compost or manure, the OM rate increased significantly after 10 days of assimilation and then decreased after harvesting the radish (45 days). This is due to the good composition of the OM in OW composts which interacted advantageously with the soil which has never been amended. After the potato harvest (90 days), OM remained almost constant for soils amended by M and OW compost and stabilized for manure

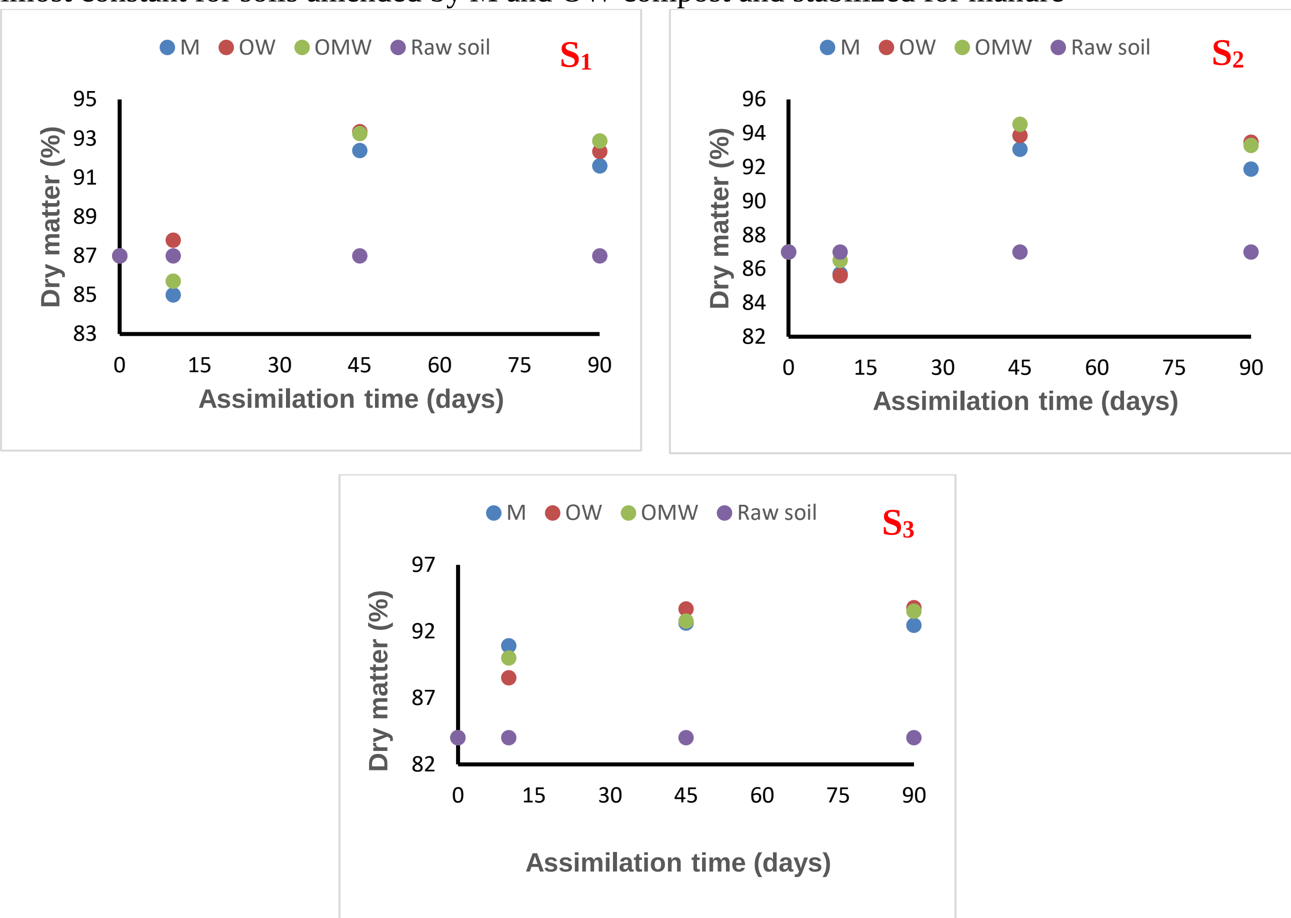

Figure 4. Dry matter of soils as a function of the assimilation time of the amendments

3.5.6. Total Organic Carbon

In Figure 6, the curves record the same direction of evolution of TOC as that of OM. The TOC increased during the first 10 days of amendment of the three soils with organic amendments OMW, OW, and manure M. After potato harvest, the TOC of soils S_1 and S_3 decreased, while S_2 soil marker an increase of TOC with OMW compost until harvesting radish. These oscillations are possibly due to the nature of the soil which did not allow the rapid assimilation of the components of OMW compost.

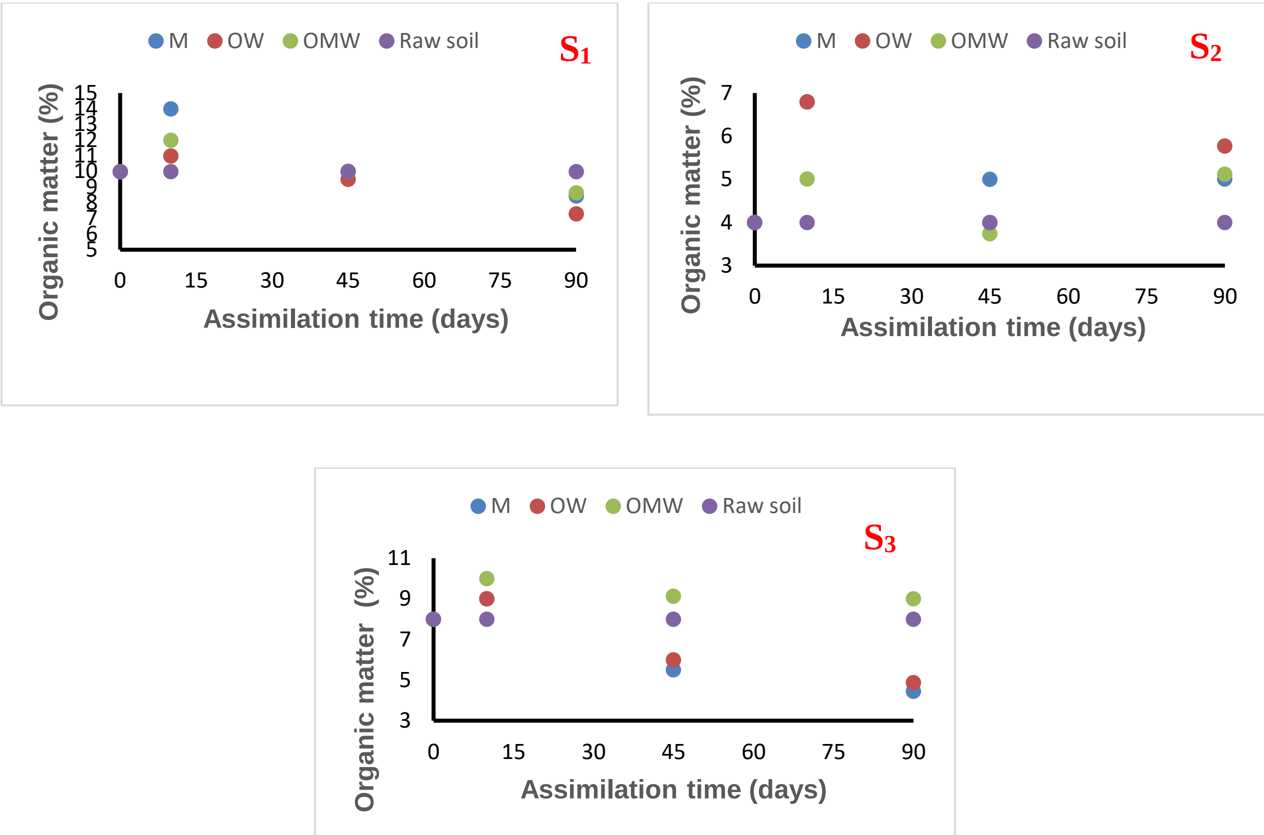

Figure 5. Organic matter of soils as a function of the assimilation time of amendments

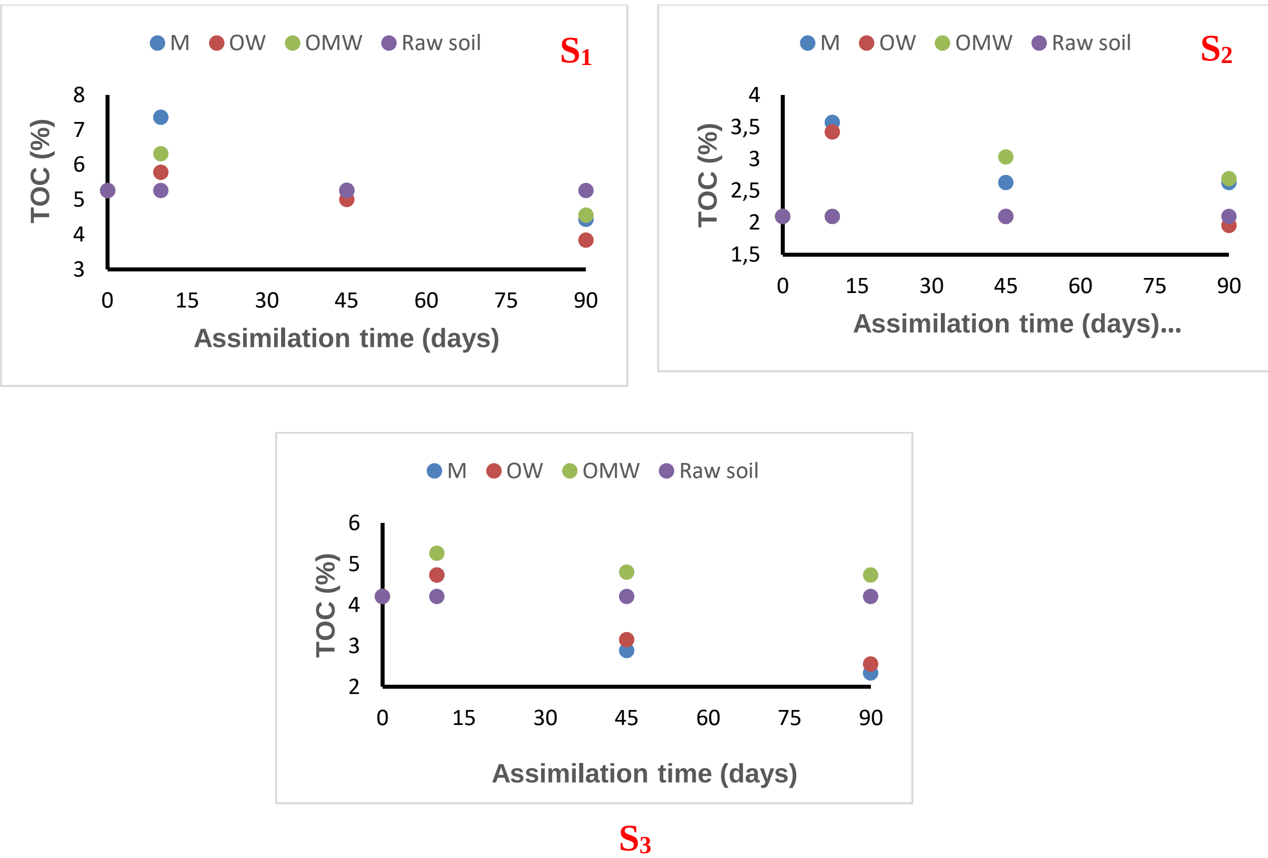

Figure 6. Total organic carbon of soils as a function of the assimilation time of amendments

After harvesting the potato for 90 days, the TOC stabilized respectively in soils S_2 and S_3, resulting in the consumption of carbon, contained in the organic amendments, by the crops. It is manifested by their developments since TOC is an essential constituent of organic soil matters (50%), followed by oxygen, hydrogen, and sulfur [27].

3.5.7. Nitrogen Kjeldhal

Figure 7 shows that Kjeldhal nitrogen, reflecting the content of non-oxidized nitrogen compounds (mainly organic nitrogen and ammoniacal nitrogen), increased after 10 days of the amendment of the three soils with all OMW and OW composts and the manure. This is also due to their high nitrogen content which plays a decisive role in improving the fertility of soil [25]. After harvest of radish or potato, the NTK of soil decreased due to its consumption during crop development for soils (S_1) and (S_2). The three amendments had almost the same effect on the soil (S_3). Good assimilation was observed for S_1 and S_2 soils with OW and OMW compost respectively.

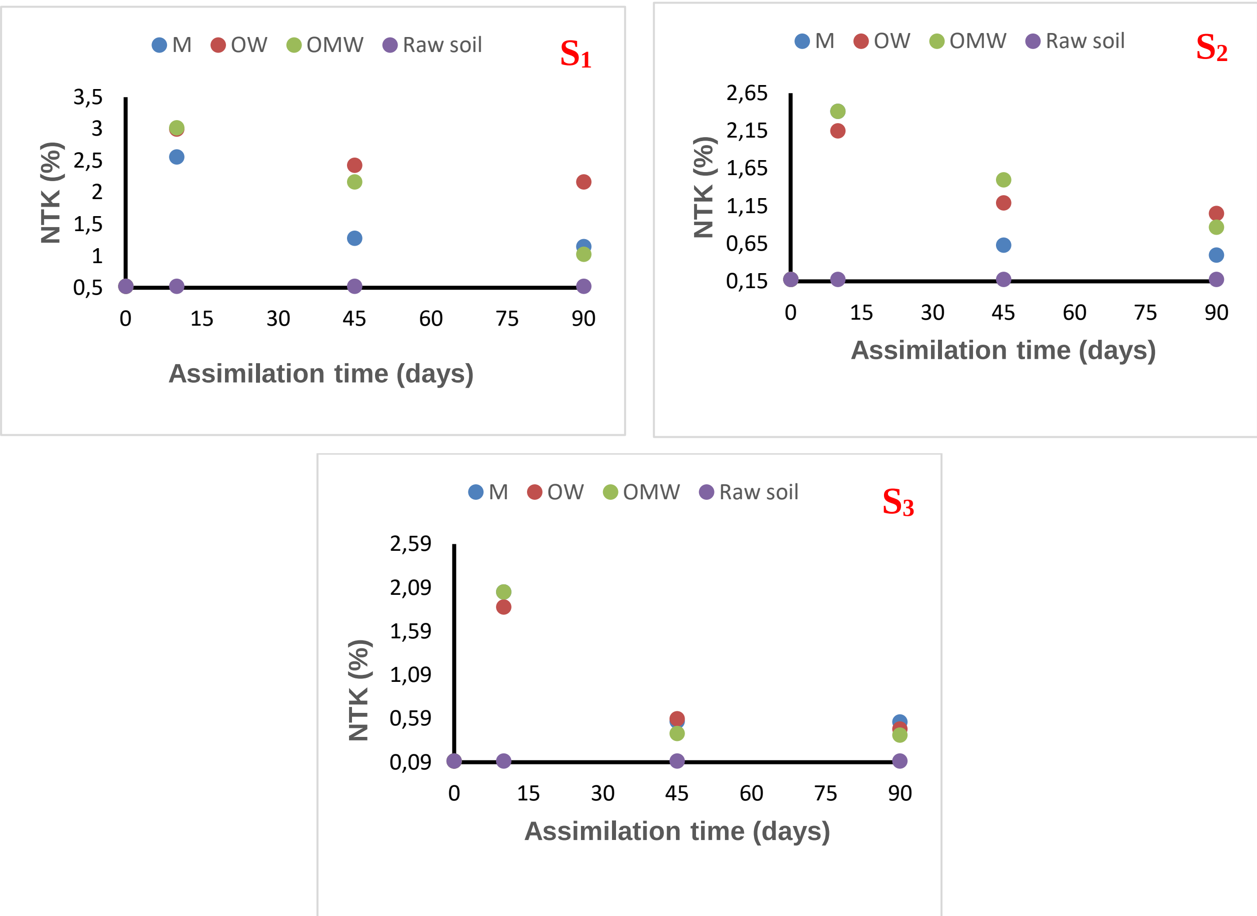

Figure 7. Kjeldhal nitrogen in soils as a function of the assimilation time of amendments

3.5.8. C/N Ratio

The curves, in figure 8, demonstrate that the value of the C/N ratio decreased for all the soils with the different amendments, especially the S_3 soil after 10 days of the amendment, which fell respectively from 40.1 to 2.30 and 2.81 with the organic amendments OW and OMW. After harvesting the radish and the potato, the amendments have almost the same effect for the three soils by a slight increase or stabilization of the C/N ratio with a few fluctuations. This proves that the contribution of amendments accelerates the degradation of organic matter and therefore the rapid growth of crops. It has been shown that the lower the C/N ratio, the faster mineralization occurs.

In fact, the C/N of the soil varies fundamentally as a function of the C/N of the plant organic matter [22, 30]. Statistically, analysis of variance at the 5% threshold showed that the amendments had no significant effect on soil humidity. However, they have a highly significant effect on the other physicochemical parameters of the 3 soils: pH, electrical conductivity, humidity, dry matter, organic matter, total organic carbon, nitrogen kjeldhal, and the C/N ratio; the p- values are less than 0.05. Consequently, improving the composition of the soil strongly depends on the type and quality of the organic amendment.

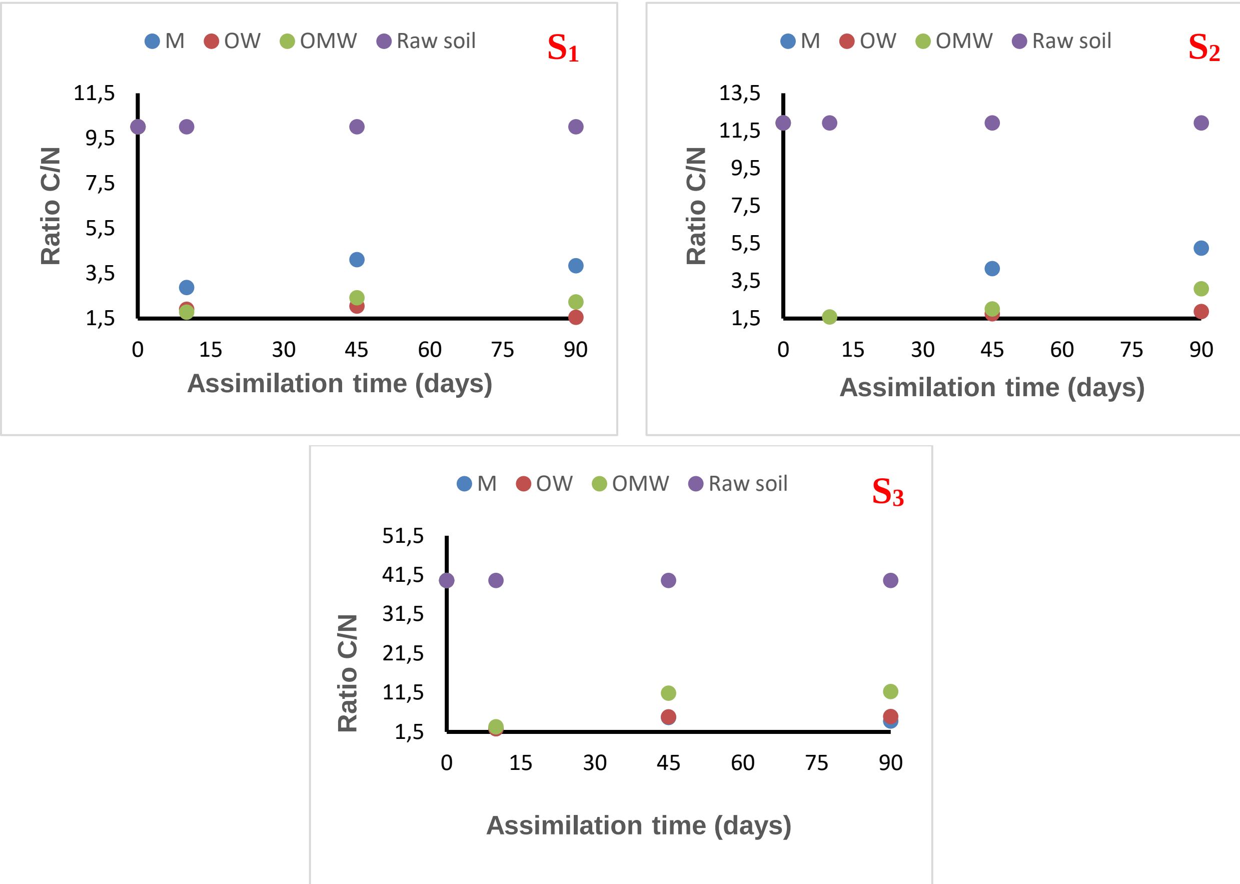

Figure 8. C/N ratio of soils as a function of the assimilation time of the amendments

3.6. Effect of Soil Quality on Radish and Potato Production

The quality and yield of crops are conditioned by several factors including the quality of the soil and the organic amendment [26,28]. The effect of S_1, S_2, and S_3 soils amended by three types of amendments: two composts OMW and OW, or manure M took place by measuring the production parameters at the end of the harvest: size and yield.

3.6.1. Caliber of Crops

The size of the radish was assessed by measuring the length and diameter in cm (Figure 9). The potato in three dimensions: small (2.15 to 3 cm), medium (4.1 to 5.75 cm), and large (6.15 to 8.65 cm) (Figure 10). The results show that the S_1 soil, previously amended by the OW compost, produced 16 and 14.88% of the largest diameter and length radishes, which are respectively 4.6 and 4.27 cm, while potatoes have three caliber dimensions: 8.8 cm, 5.4 cm, and 3.5 cm with proportions of 26.62%, 16.33%, and 10.59% respectively. This is explained by the high load of the S_1 soil in OM, OC, and nitrogen kjeldhal; subsequently, a lower C/N ratio which participated in the fertility of the soil and the growth of legumes. In fact, organic matters undergo biological transformations in the soil that lead to their mineralization and the release of mineral elements such as nitrogen, phosphorus, sulfur, potassium, and trace elements, which become available to plants stimulating their development [29].

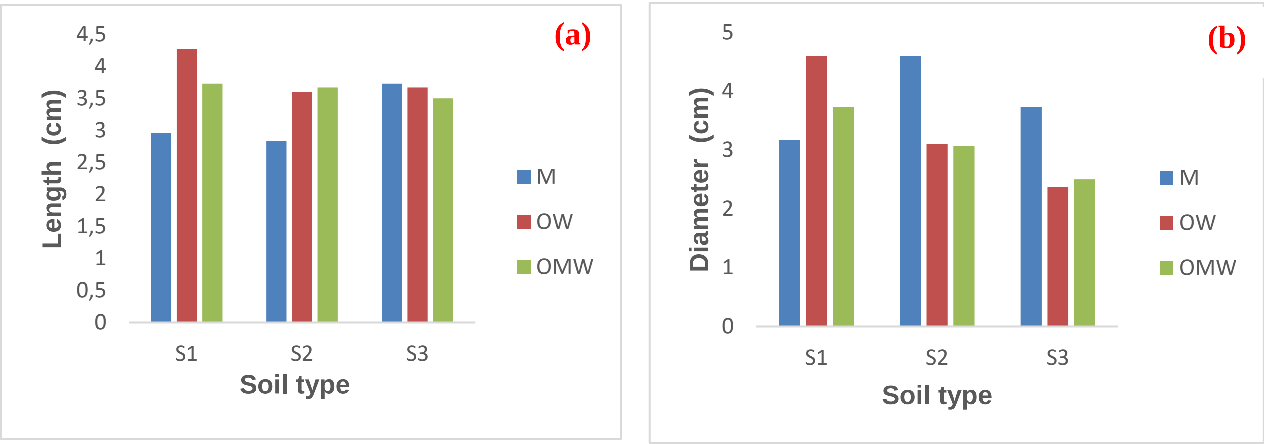

Figure 9. Radish size according to soil types and amendment: length of the radish (a) diameter of the radish (b)

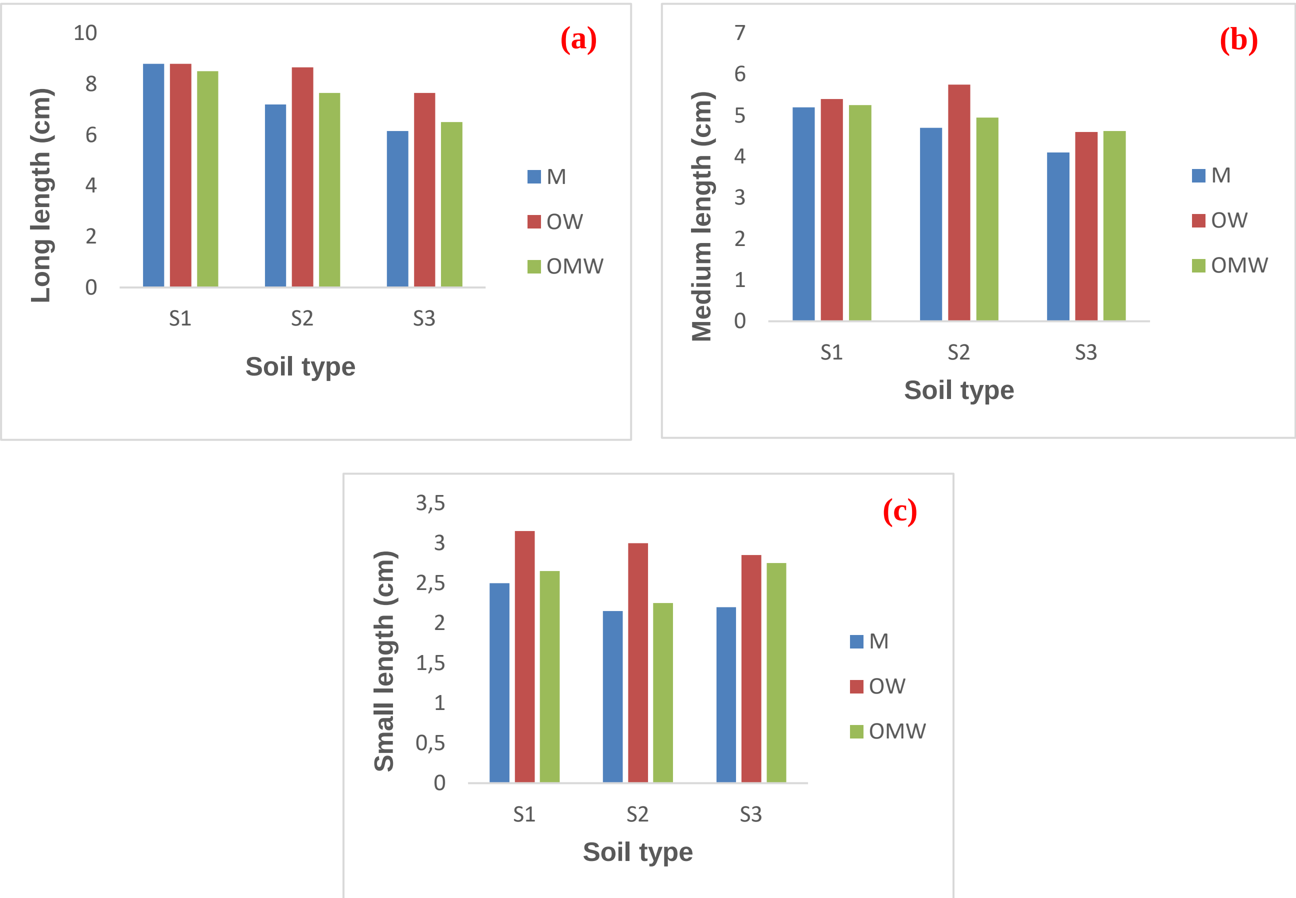

Figure 10. Size of the potato according to the types of soil and the amendment: long length (a) medium length (b) and short length (c)

3.6.2. Crop Yield

The results of total crop yield of radish and potato as a function of soil types and amendments are shown in Figure 11.

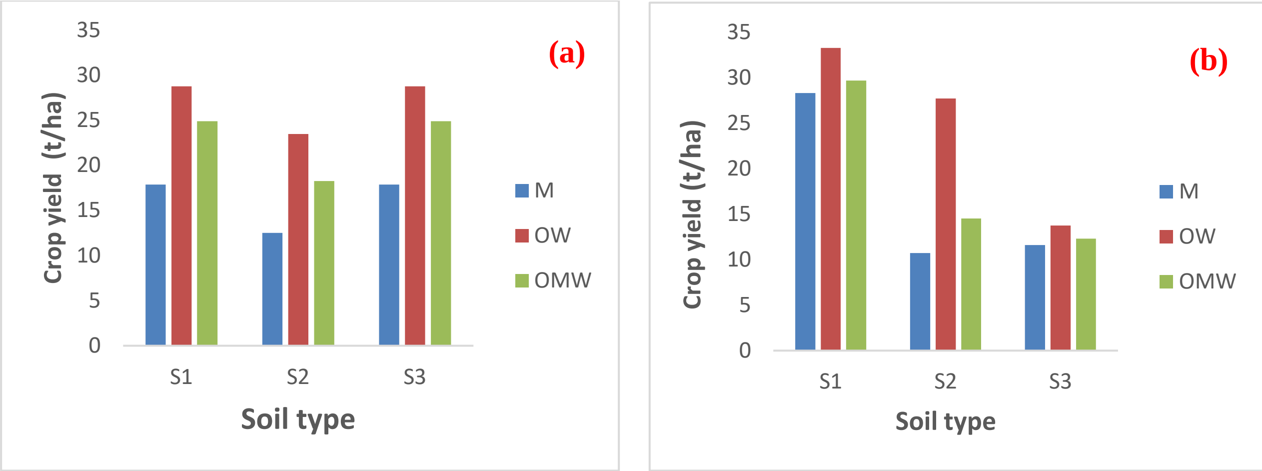

Figure 11. Total agricultural yield of radish (a) and potato (b) according to soil types and amendments

The results present that the highest rates were for S_1 soil, previously amended by OW compost, both for radish (28 t / ha) and potato (33.1t / ha) against 23.47 t / ha and 27.71t / ha produced by the soil (S_2) freshly amended by OW compost. This can be explained by the availability of essential nutrients in the OW compost which are transmitted to the soil as the nutrients: potassium and calcium which acted in favor of the soil by improving its quality and its agricultural yield. All the results prove that the best productions were harvested with S_1 soil, previously amended by OW compost, which is sufficiently rich in fertilizing elements and stabilized organic matter useful for the formation of humus and provides the soil a nutrient mixture rich in phosphorus [17,29] compared to soils S_2 and S_3.

4. Conclusion

The work carried out on the test of the effectiveness of two organic amendments based on olive oil by-products: olive mill wastewater (OMW) and olive pomace (OP), and their effects on three soils: raw S_2, amended for 2 years S_1, and field S_3 on the cultivation of two vegetable gardens: radish and potato led to the following conclusions:

- The amendments used are of good quality, stable, and meet the NFU 44-051 standard.
- Irrigation water has no harmful effect on the plant-soil system.
- Soils (S_3) and (S_2) are very poor in organic matter, nitrogen, and total organic carbon, on the other hand, the soil (S_1) is characterized by a remarkable rate of these elements. This result confirms the positive effect of OW compost on the physical and chemical properties of the soil, which increases over time; something which has contributed to the improvement of agricultural production of radish and potato crops.

After ten days of the amendment, the organic composition of the three soils was improved according to the type of amendment added in the following descending order:

$$S_1 + OW > S_1 + OMW > S_2 + OW > S_3 + OW > S_1 + M > S_2 + M > S_3 + OMW > S_3 + M > S_2 + OMW$$

For S_2 soil amended with OMW compost, 10 days were not sufficient for the degradation of the compost and its assimilation by the soils. The amendment activity did not begin only after planting radish and potato. After harvesting of the two crops, the composition of soils S_1 and S_3 in OM and TOC decreased compared to their initial composition. While that of nitrogen has increased slightly. For soil S_2, the organic composition increased slightly after amendment and then decreased after cultivation while remaining with a similar composition to the initial. For the three soils amended by OW compost, the production parameters of radish and potato are markedly improved. The lowest results are obtained for S_2 soil amended by OMW compost and S_3 amended by manure.

Compost with olive waste, wastewaters, and wet pomace, could therefore be an organic fertilizer, to ensure the presence of the necessary nutrients in the soil and consequently replace partially the chemicals used which degrade the quality of Moroccan soil.

References

[1] P.D Blanco, L.A Hardtke, C.M Rostagno, H.F Valle, G.I Metternicht Soil Degradation in Peninsula Valdes: Causes, Factors, Processes, and Assessment Methods. In Late Cenozoic of Península Valdés, Patagonia, Argentina. *Springer Earth System Sciences*, (eds.), P. Bouza, A. Bilmes. Springer, Cham p.p. (2017) 191-213.

[2] A.E Johnston, P.R Poulton The importance of long-term experiments in agriculture: their management to ensure continued crop production and soil fertility; Rothamsted experience. *European Journal of Soil Science* 69, (2018) 113–125.

[3] MAPDR: The Ministry of Agriculture, Fisheries, Rural Development, Water, and Forests. The development department of production chains (2016).

[4] M. Sabir, and E. Roose Restauration des sols cultivés mais dégradation des parcours par l'élevage au Maroc (2015).

[5] IFA: International Fertilizer Industry Association. Retrieved from https://www.fertilizer.org/ (2018).

[6] L. Dong-Po et Z.J WU, Impact of chemical fertilizers application on soil ecological environment. *Le journal d'écologie appliquée* 19 (5): (2008) 1158-1165.

[7] I. Aviani, Y. Laor, S. Medina, A. Krassnovsky and M. Raviv Co-composting of solid and liquid olive mill wastes; Management aspects and the horticultural value of the resulting amendments organiques. *Bioresource Technology*. 101, (2010) 6699-6706.

[8] W. Abid, E. Ammar, M A. Triki, M. Ben Abbou, M. El Haji Gestion et valorisation des margines par co compostage avec les déchets verts et amendements des sols agricoles pour l'amélioration des rendements Brevet déposéa l'Office Marocain de la Propriété Industrielle et Commerciale. (2015).

[9] L M. Brito, I. Mourao, J. Coutinho, S R. Smith Co-composting of invasive Acacia longifolia with pine bark for horticultural use. *Environmental Technology*. 36, (2015) 1632-1642.

[10] S.Y. Choy, K. Wang, W. Qi, B. Wang, C.L. Chen, J Y Wang Co-composting of horticultural waste with fruit peels, food waste, and soybean residues. *Environmental Technology*. 36, (2015) 1448-1456.

[11] W. Abid, S. Magdich, I B. Mahmoud, K. Medhioub, E. Ammar Date Palm Wastes Co-composted Product: An Efficient Substrate for Tomato (Solanum Lycopersicum L) Seedling Production. *Waste and Biomass Valorization*. 9, (2018) 45–55.

[12] C.S Akratos, A.G Tekerlekopoulou, I.A Vasiliadou, and D.V Vayenas Chapter 8- Co-composting of olive mill waste for the production of soil amendments. *In Olive Mill Waste*, C.M. Galanakis, (2nd ed.), (Academic Press), pp. (2017) 161-182.

[13] A. El Mastour Valorisation des déchets oléicoles dans la filière de compostage. Master Thesis (2018). Sidi Mohammed Ben Abdellah University, Morocco, Fez.

[14] Z. Majbar Traitement des margines par un procédé couplant l'électrocoagulation et l'adsorption sur des charbons actifs de la sciure de bois d'eucalyptus et leur valorisation par la filière de compostage des déchets vinicoles. Doctoral Thesis (2019). Sidi Mohammed Ben Abdellah University, Faculty of Sciences - Morocco, Fez.

[15] K. Lahlou Valorisation des boues dans la filière de compostage : élaboration et application. Doctoral Thesis (2019). Sidi Mohammed Ben Abdellah University, Faculty of Sciences - Morocco, Fez.

[16] F. Aftiss Apport de la matière organique sur le rendement du sol : Test d'application ». Master Thesis (2017). Sidi Mohammed Ben Abdellah University, Faculty of Sciences - Morocco, Fez.

[17] K. Lahlou, M. Ben Abbou, Z. Majbar, Y. Zaytouni, O. Karzazi, F. El-Hajjaji, M. Taleb, M. El Haji, and Z. Rais Recovery of sludge from the sewage treatment plant in the city of Fez (STEP) through the composting process. *Journal of Materials and Environmental Sciences*. Vol 8, (2017) 4582-4590.

[18] AFNOR. Matières fertilisantes et support des cultures. Compendium on CD ROM Reference 31845271 CD, ISBN (2015): 978-2-12-184271-4.

[19] AFNOR. Evaluation de la qualité des sols, volume 1 : méthodes d'analyses chimiques, volume 2 : méthodes d'analyses physiques et biologiques. (2004) E210-58.

[20] AFNOR. Qualité des sols – Pédologie. Compendium on CD ROM Reference 3213171 CD. ISBN (2014): 978-2-12-213171-8.

[21] SEWE (2007): Secretary of State to the Ministry of Energy, Mines, Water, and the Environment.

[22] C.S.A Ballot, G. Mawussi , W. Atakpama, M. Moita-Nassy , T.M Yangakola, I. Zinga, S. Silla, W. Kpérkouma, G. Dercon, B. Komlan, A. Koffi Characterization physicochemical soils to improve productivity of cassava (Manihot esculenta Crantz) in the region of Damara in south-central of Central African Republic. *Agronomie Africaine* 28 (1): (2016) 9 – 23.

[23] D. Jendoubi, T. Houcine, M. Moussa Suivi des effets des amendements organiques (fumier ovin et fumier camelin) sur les propriétés chimiques de sol dans les régions arides Tunisiennes (Dar Dhaoui and El Fjé – Médenine). *Revue des Régions Arides* – (2014) Special issue- n° 35.

[24] OMARFA: Ministry of Agriculture, Food and Rural Affairs Retrieved on 19 August 2020. From http://www.omafra.gov.on.ca/

[25] A. Getahun, D. Muleta, F. Assefa, S. Kiros, M. Hungria Biochar and Other Organic Amendments Improve the Physicochemical Properties of Soil in Highly Degraded Habitat. *European Journal of Engineering Research and Science*, (2020) Vol. 5, No. 3.

[26] N.N Adolphe, M.K Gustave, M.T Remy, M.M Angel, and N.N Dieudonné Influence de l'apport des matières organiques sur la culture de poivron (Capsicum annum L.) Cultivé sur un sol sableux à Kabinda, province de Lomami, en République Démocratique du Congo. *International Journal of Innovation and Applied Studies*. ISSN 2028-9324 (2020) Vol. 29 No. pp. 613-618.3

[27] N.T Akedrin, B.B.N.B Voui, O.F Akotto, S. Ake Effets de six légumineuses spontanées les plus répandues dans les jachères naturelles sur la fertilité des sols dans la région de Daloa (Côte d'Ivoire). *International Journal of Biological and Chemical Sciences*. (2020) 14(3): 1052-1064.

[28] Y.P Sagna, S. Diedhiou, A.O.K Goudiaby, Y. Diatta, M.D Diallo, I. Ndoye Effet des amendements organiques sur le développement du riz (Oryza sativa L.) dans les basfonds sulfato-acides en zone sud-soudanienne au Sénégal. *International Journal of Applied Biosciences*. 144 : (2019) 14831 – 14841.

[29] K. Lahlou, F. Elmadani, M. Ben Abbou, O. Karzazi, F. El-Hajjaji, M. Taleb, A. Chetouani, M. El Haji, Z. Rais Effects of sludge compost as an amendment on the morphological responses and on production parameters of radish and potato. *Moroccan Journal of Chemistry*. 7 N°2 (2019) 320-336.

[30] Y. M'Sadak, M. A. Elouaer Physico-chemical characterization of growth substrate-based poultry methacompost for better use in Tunisia. *Moroccan Journal of Chemistry*. 4 N°2 (2016) 339-351.

[31] H.Mikdame, B.El hafidi, N.Mtarfi, M.Ben Abbou, F.Z.ElMadani, Z. Rais Energy valorization of olive waste water, their sludge and treatment by methane production. *Moroccan Journal of Chemistry*. 7 N°2 (2019) 383-391.