Pepper cultivation on a substrate consisting of soil, natural zeolite and olive mill waste sludge-Changes in soil properties

A. Papadopoulos, M. K. Doula*, S. Kosmidis*, A. Assimakopoulou**, A. A. Zorpas*** and C. Kolovos**

** Laboratory of Non Parasitic Diseases, Scientific Directorate of Phytopathology, Benaki Phytopathological Institute, 8 Stefanou Delta Str., 14561 Kifissia, Greece*
(E-mail: a.papadopoulos@bpi.gr)
*** Department of Agricultural Technology, TEI of Peloponnese, Kalamata, Greece*
**** Open University of Cyprus, Faculty of Pure and Applied Sciences, Environmental Conservation andManagement, Laboratory of Chemical Engineering and Engineering Sustainability, Giannou Kranidioti, 33, P.O. Box 12794, 2252, Latsia, Nicosia, Cyprus*

Introduction

Olive oil production is expected to reach a four-year high in the 2021/22 crop year. Moreover, olive mill waste (OMW) management is an issue that has been of concern to the global research community for many years. OMW contains hazardous wastes having high concentrations of phenolic compounds that are difficult to biodegrade. However, recently there is great improvement in the awareness level of citizens, especially of olive mill owners and farmers, in terms of rational management, minimization of environmental impacts, and reuse of OMW in agriculture. It has become clear that there are significant benefits from the reuse of OMW in agriculture. For example, OMW can be a valuable source of nutrients, which has a direct effect on improving soil quality. OMW also contains more than 90% organic matter (OM). Moreover, it increases humified fractions, which constitute a major source of phytonutrients. Nevertheless, OMW management is ultimately waste reuse. For this reason, care should be taken not only to avoid phytotoxic effects on cultivated plants but also for the protection of soil and underground and surface water bodies. A protective measure is the use of active materials as soil additives, such as natural zeolites, which can mitigate the effects of waste addition to soil. The aim of this study is to identify the positive and negative effects of clinoptilolite as a soil additive together with residual sludge from OMW for the cultivation of pepper plants.

Materials and methods

- An 11-week pot experiment was conducted under greenhouse conditions
- Pepper plant (*Capsicum annuum*) was selected for conducting the experiment
- Pepper seedlings were transplanted and grown onto different substrates containing combinations of 0%, 2.5%, and 5.0% zeolite (Z) and 0%, 2.5%, and 5.0% of OMW sludge (AP) (v/v) (Table 1)
- The natural zeolite used, was clinoptilolite
- The OMW sludge used, was obtained from a three-phase olive mill
- Each treatment was composed of 12 replicates arranged in a split-plot design
- Plants were irrigated twice a week and leachates were collected on a weekly basis and further analyzed
- After estimating the nutrient requirements, the plants were fertilized during the 10th week
- After the completion of the experiment, the substrates were collected and analyzed

	OMW (% v/v)	Clinoptilolite addition (% v/v)
Z0AP0	0	0
Z0AP1	2.5	0
Z0AP2	5	0
Z1AP0	0	2.5
Z1AP1	2.5	2.5
Z1AP2	5	2.5
Z2AP0	0	5
Z2AP1	2.5	5
Z2AP2	5	5

Table 1: Sample preparation

Results & Discussion

Samples	EC (mS/cm)	Total N (mg/kg)	Organic matter (%)	Polyphenols (mg/kg)	Available B (mg/kg)	Available Fe (mg/kg)	Exchangeable Na (cmol⁺/kg)	Exchangeable K (cmol⁺/kg)
Z0AP0	1.29 ± 0.03	2.55 ± 0.39	4.12 ± 0.36	118.02 ± 13.23	1.10 ± 0.08	9.41 ± 2.12	0.11 ± 0.02	0.91 ± 0.07
Z0AP1	1.04 ± 0.02	2.88 ± 0.41	5.98 ± 0.22	169.85 ± 19.96	1.57 ± 0.11	14.79 ± 3.15	0.77 ± 0.08	1.12 ± 0.11
Z0AP2	1.38 ± 0.05	3.02 ± 0.63	7.02 ± 0.64	185.11 ± 21.07	1.62 ± 0.23	16.80 ± 2.09	0.89 ± 0.06	1.54 ± 0.18
Z1AP0	1.91 ± 0.07	2.81 ± 0.27	4.10 ± 0.19	127.56 ± 17.94	1.21 ± 0.15	9.61 ± 2.08	0.99 ± 0.07	1.15 ± 0.13
Z1AP1	1.76 ± 0.07	2.73 ± 0.58	6.22 ± 0.21	167.05 ± 22.12	1.47 ± 0.20	17.03 ± 3.11	1.01 ± 0.08	1.61 ± 0.17
Z1AP2	1.79 ± 0.08	2.95 ± 0.64	7.30 ± 0.66	189.29 ± 27.81	1.69 ± 0.19	18.49 ± 4.09	1.14 ± 0.05	1.89 ± 0.23
Z2AP0	2.39 ± 0.11	2.17 ± 0.29	4.19 ± 0.31	129.96 ± 17.33	1.21 ± 0.11	7.92 ± 1.98	1.62 ± 0.12	1.67 ± 0.12
Z2AP1	2.27 ± 0.07	2.91 ± 0.33	6.23 ± 0.47	178.21 ± 26.33	1.53 ± 0.18	17.88 ± 3.51	1.44 ± 0.11	1.80 ± 0.21
Z2AP2	2.32 ± 0.07	2.63 ± 0.19	7.49 ± 0.55	187.01 ± 30.15	1.76 ± 0.22	18.93 ± 3.01	1.40 ± 0.08	2.22 ± 0.34

Table 2: Variations in physicochemical characteristics of treated samples

According to Table 2:

- Increase in the Z percentage of the substrate led to an increase in the EC due to the ions present in zeolite exchangeable sites and mainly Na^+
- Zeolite addition does not improve the N-holding capacity of the substrate
- The concentration of exchangeable potassium was increased with increase in zeolite percentage
- The addition of AP improves the substrate and positively addresses the issue of salt increase
- For the cases of only AP addition, a significant improvement in substrate OM was recorded
- AP addition improved the substrate's available Fe content and the exchangeable K
- Exchangeable Na was increased in the substrate compared to that in the Z0AP0 treatment
- The highest K content was recorded for the case of Z2AP2 treatment
- There was an increase in polyphenol content due to the AP application, while Z did not affect polyphenol concentration significantly

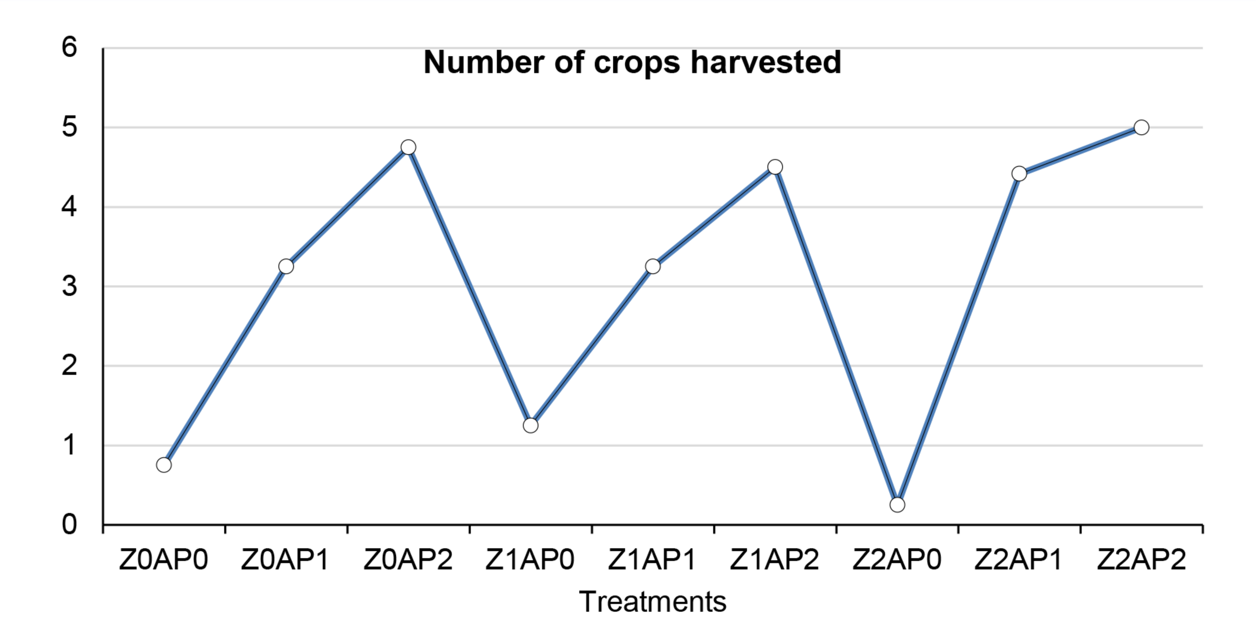
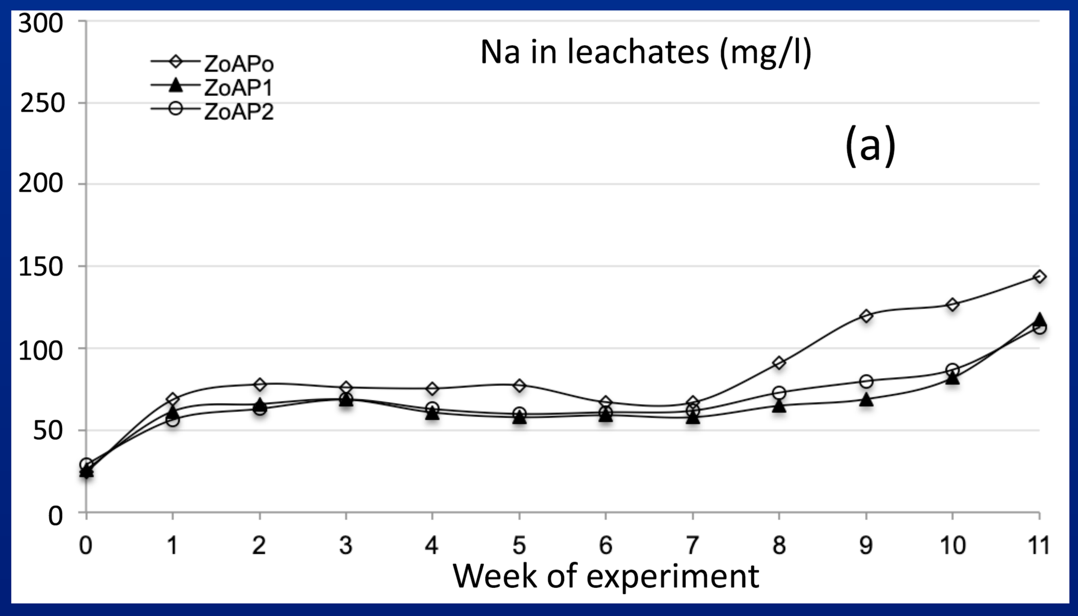
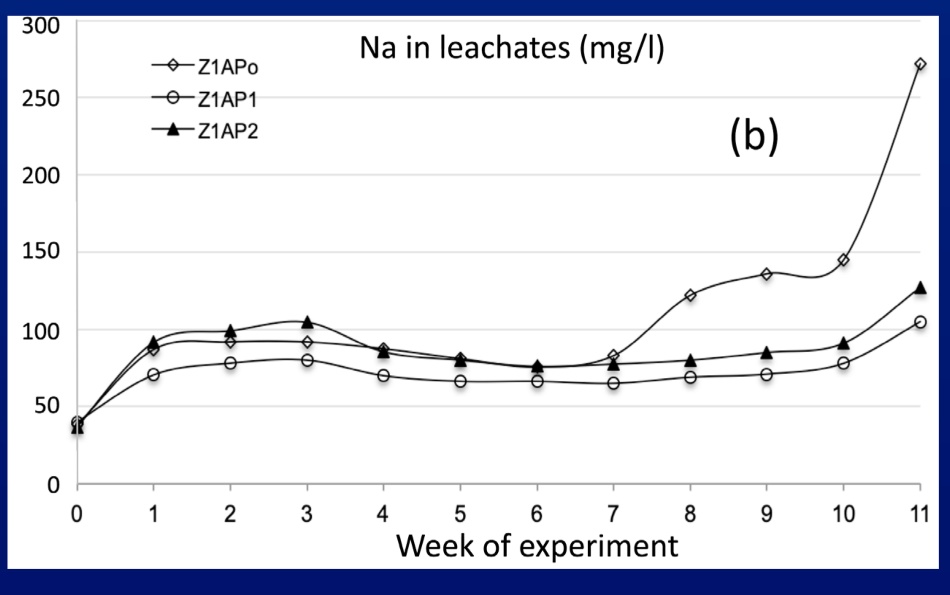


Figure 1: Plants harvested for different treatments (plant survival)

According to Figure 1:

- Z2AP0 treatment yielded the worst result, probably due to sodium concentration
- Z2AP2 treatment resulted in the largest mean number of harvested plants among all studied treatments





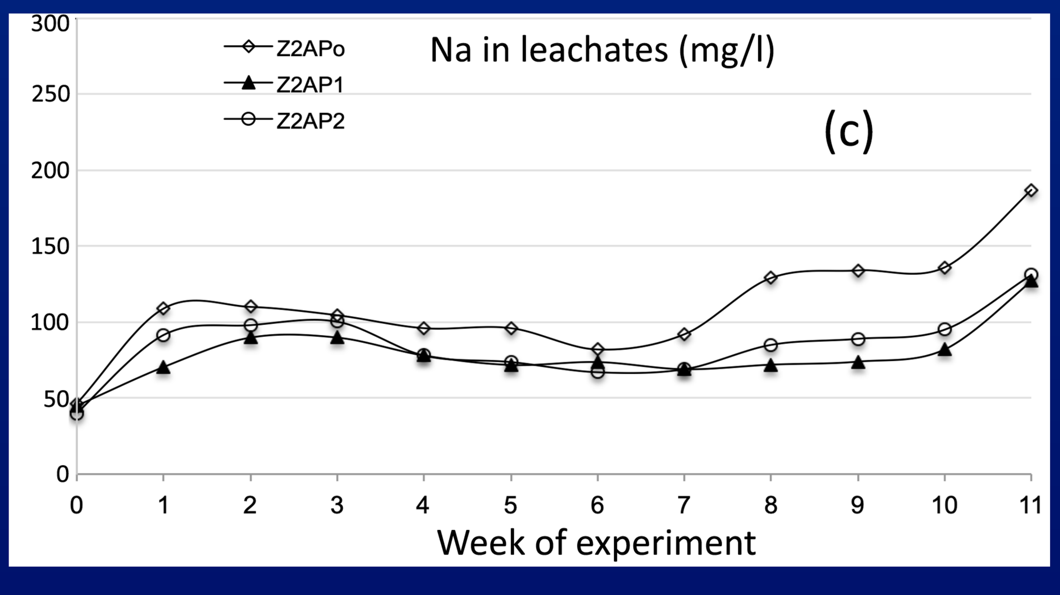


Figure 2 (a,b,c): Sodium measured in leachates for each experimental week and for all treatments

According to Figure 2:

- Z percentage enhanced Na leaching, while OMW inhibited Na leaching

Conclusions

- OMW sludge benefited pepper plants with respect to increase in OM, N, K, B, and Fe
- Clinoptilolite did not appear to have a positive effect on the above properties (except for K)
- Zeolite's synergistic effect improves the stability of the substrate by reducing loss of potassium through leaching and enhancing the soil's ability to retain cations
- The best performance in terms of yield and substrate - leachate properties was observed for the Z1AP1 treatment