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Project title: Improving Soil FERtility in Arid and semi-arid regions using Local organic DAte palm residues

D5.3 Report on the presentation and analysis of the results of the pot experiments

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The main pot experiment was conducted by URCA and is described in a paper accepted for publication, a submitted paper and two papers in preparation.

The paper accepted for publication in the journal Soil Use and Management (preprint DOI: 10.2139/ssrn.4936387) is:

Nitrogen budget and barley response to organic amendments in a sandy soil under simulated arid climate

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The paper submitted for publication in the journal Pedobiologia is the following one.

Response of nitrogen-cycling functional genes to biochar, compost, and their mixture in sandy soils under arid conditions

Authors: M. El Mazlouzi[1], E. Le Guyader[1], A. Guillaneuf[1], P. Girods[2], S. Abiven[3,4], B. Marin[1], M. Gommeaux[1], X. Morvan[1]

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The papers in preparation are hese one.

Nutrients leaching losses and barley uptake in response to organic amendment from date palm residue

Authors: El Mazlouzi M*, Le Guyader E*, Guillaneuf A, Marin B, Gommeaux M, Morvan X, et al. To be completed

Changes in the speciation of phosphorus during compost mineralization in simulated arid-soil cultivation experiment

Authors: El Mazlouzi M et al. To be completed

This experiment investigated the effects of organic amendment (compost and biochar) application on barley response, soil properties and the dynamics of soil nitrogen in the context of arid systems. The specific objectives of this study were to assess i) the role of date palm biochar on nitrogen retention/transformation in the soil, ii) the availability of nitrogen for the plant in the presence or absence of external nutrient inputs, iii) the extent of nutrient loss due to leaching compared to plant uptake, and iv) the changes in the abundance of microbial communities involved in nitrification and denitrification.

In order to reproduce a similar texture to that found mainly in Saharan regions, natural soil collected in the semi-arid region of Murcia, Spain, was mixed to washed quartz sand to a proportion of 1/4 original soil and 3/4 washed sand.

The compost was produced by Palm Compost (Biskra Chetma, Algeria) from crushed date-palm residues mixed with sheep manure (70:30 in volume) over a three-months period. The biochar was produced from slow pyrolysis (2 h at 450 °C) of date-palm leave rachis, collected in the Murcia, region, Spain. Both products were characterized.

Six treatments where soil with/without organic amendments was the substrate for barley growth, in addition to an unamended uncultivated soil. Experimental soil columns of 19 cm diameter and 35 cm depth (14 kg of soil/column) were prepared with organic amendments mixed, where applicable, in the upper horizon (17.5 cm) of the soil and unamended soil in the lower horizon (17.5 cm). The cultivated columns included 4 replicates of each of the 6 following treatments: unamended control soil, soil + biochar, soil + urea, soil + biochar + urea, soil + compost, soil + biochar + compost.

The experiment was conducted in controlled-climate chambers. The air temperature, air specific humidity and radiation were set to correspond to average hourly values determined over five years (2017-2021) during the period from January to April in the El Atilet oasis in Kebili, Tunisia.

Irrigation was carried out manually by flooding the columns every 7-10 days with a 5 cm layer of domestic water, similar to the used method by farmers in the oases. The irrigation water was analysed to account for the N it contains in the budget.

Leachates were collected after each watering event and analysed. Plant development was monitored weekly (number of tillers, height and phenological stage) and aboveground biomass was estimated from a subsamble of plants at tillering stage and from the harvested material at the end of the experiment. The plant shoot and grain nutrient contents were also determined after harvest. Soil samples were analysed for the nutrient stock and for the abundance of microbial communities involved in nitrification (quantitative PCR estimation of the number of copies of ammonia monooxygenase subunit A gene for bacteria and archaea) and denitritrification (nitrite reductase and nitrous oxide reductase), in addition to fungal and bacterial abundance.

The leachate and soil analyses allowed for calculations of N balance and N use efficiency.

Compost (either alone or in combination with biochar) significantly increased initial soil levels of available P (Olsen), exchangeable K and Na in the topsoil and the effect on P and K was still present after barley cultivation, suggesting a long-lasting effect of compost addition. Both organic amendments improved SOC stocks at the end of barley cultivation. N leaching occurred mostly during the 1st month of the experiment, with NO_3^- as the dominant leached N form whereas NH_4^+ was the dominant extractable N form in initial amended soils, indicating an intense nitrification activity. P leaching was low for all treatments, whereas compost caused a significant leaching of K, Na and Cl. For Na and Cl, leaching also occurred mostly during the 1st month whereas for other elements it continued throughout the experiment.

The development of barley was highly improved by the addition of compost (in quantity though not in grain N concentration) but slightly decreased by biochar if applied alone. Nitrogen use efficiency was lower in soils amended with compost. Compost provided N in a highly soluble and rapidly available form, which led to increased N leaching.

The application of organic amendments did not cause a large variation in the fungi to bacteria ratio but a significant increase in ammonia-oxidizing archaea and bacteria was observed for compost-amended soils, as well as of the abundance of organisms involved in denitrification. The application of biochar amendment might contribute to reduce N loss in the form of N_2O and N_2.

In addition, a detailed investigation of phosphorus concentrations and chemical forms in the soils of this experiment was conducted. Phosphorus (P) availability is a limiting factor for crop production in arid agroecosystems. Application of date palm biochar and compost can directly affect soil P availability by altering both the amounts and forms of P present. However, the speciation of P in biochar, compost and biochar/compost mixtures and their transformation after application to soil in arid agroecosystems are not fully elucidated.

While soil extraction methods can be used to evaluate the amount of plant available P in soils, it is also important to determine the P speciation, as it can provide insight to the processes that occur in

soil after application of amendment. P speciation determination was performed using more direct approaches, such as P K-edge X-ray absorption near-edge structure (XANES) spectroscopy to the SOLEIL synchrotron. This technique allows direct identification of P species in soils without the need for an extraction step that could potentially alter the chemical state of P in the sample. A proposal was successfully submitted to the SOLEIL synchrotron and a week of beamtime was allocated on the LUCIA beamline.

The objectives of this study were to i) identify the different forms of P in biochar, compost, and biochar/compost mixtures produced from date palm residues prior to their application to soil to quantify P availability contents in each OA, and ii) determine and compare the P transformation in soil after the application of these OA into the studied sandy soil cultivated with barley.

The study's expected outcomes include the identification of the dominant chemical P species in biochar, compost, and biochar/compost mixture produced from date palm residues. This will determine if there is any added value in mixing compost with biochar. Identification of the dominant chemical P species will help in assessing their reactivity and availability for plants. Another expected result is the determination of P transformations after the application of OA in a sandy soil. By studying the changes in P speciation, it will reveal how the initial forms of P in the OA influence its dynamics in the soil. This information is crucial for understanding the fate of P in soil and its potential impact on plant uptake. Results have been acquired in September 2024 and their analysis is still in progress.

These results, comforted by additional experiments performed by UMKB and UB, indicate that the application of biochar, if alone, is of little agronomic benefit in the studied soil and climate conditions. Contrarily, the application of compost improved plant nutrition but it is necessary to ensure its quality when considering repeated applications, to prevent the risk of soil salinization through the release of soluble salts.