Project Number: 1567

Project Acronym: ISFERALDA

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

D5-4 Report on the presentation and analysis of the results on the influence of OAs on soil water retention

Authors : Maxime GOMMEAUX[1],

1: University of Reims Champagne-Ardenne, 51100 REIMS, FRANCE

Note: This deliverable replaces the "Report on the presentation and analysis of the results of the rainfall simulations" after cancellation of initially planned rainfall simulation experiments and replacement of the corresponding task.

The main experiments addressing the influence of biochar and compost on soil water retention were conducted by URCA and are described in a paper published in the journal *Forests* **2024**, 15, 304. https://doi.org/10.3390/f15020304:

Influence of Date Palm-Based Biochar and Compost on Water Retention Properties of Soils with Different Sand Contents.

Authors: Elie Le Guyader[1], Xavier Morvan[1], Vincent Miconnet[1], Béatrice Marin[1], Mohamed Moussa[2], Diego S. Intrigliolo[3], María José Delgado-Iniesta[4] , Pierre Girods[5] , Sebastien Fontana[6], Mahtali Sbih[7], Belkacem Boumaraf[8] , Aissa Tirichine[9], Victor Kavvadias1[0] and Maxime Gommeaux[1]
Groupe d'Etude sur les Géomatériaux et Environnements Anthropisés (GEGENA UR3795),

1 Université de Reims Champagne-Ardenne, 51100 Reims, France
2 Eremology and Combating Desertification Lab. (LR16IRA01), Institute of Arid Regions, Medenine 4100, Tunisia
3 Desertification Research Center (CIDE) (CSIC-UV-GVA), 46113 Moncada, Spain;
4 Department of Agricultural Chemistry, Geology and Edaphology, University of Murcia, Campus Espinardo, 30100 Murcia, Spain
5 Laboratoire d'Études et de Recherche sur le Matériau Bois (LERMAB), INRAE, University of Lorraine, 88000 Epinal, France;
6 Institute Jean Lamour, University of Lorraine, UMR 7198 CNRS, 54000 Nancy, France;
7 Laboratory for Improving Agricultural Production and Protection of Resources in Dry Areas, University of Batna, Algeria;
8 Laboratory of Promoting Innovation in Agriculture in Arid Regions, University of Mohamed Khider, Biskra 07000, Algeria;
9 National Institute of Agronomic Research of Algeria, Touggourt 30200, Algeria;
10 Department of Soil Science of Athens, Institute of Soil and Water Resources, Hellenic Agricultural Organization DEMETER, 14123 Lykovrisi, Greece

The rationale for these experiments is that soils of arid and semi-arid regions generally have low water retention properties due to their high sand and low organic carbon contents. In this context, the production of organic amendments from date palm residues and their application in soil might constitute an effective solution to improve the water retention properties of soils. In turn, this practise might contribute to optimizing the use of water resources in irrigated areas.

The soils used in these experiments were collected in eastern Spain (region of Murcia). The first soil was a cultivated sandy loam from Cañada de Gallego (GPS coordinates 37°1′30′′N, 1°24′47′′W) and the second soil was a natural silty loam from Saladares del Guadalentín (37°0′23′′N, 1°1′39′′W). Soil samples were air-dried, sieved at 2 mm, packaged in plastic boxes and stored at room temperature until use.

In order to investigate the effect of grain size distribution on the magnitude of the effect of OA on soil water retention, the natural soils were artificially enriched with coarse sand in different proportions. Washed quartz sand (grain size distribution in mass: 0.5–1.0 mm: 56%; 1.0–2.0 mm: 44%) was added to the natural soils to a final proportion of 2/3 original soil and 1/3 sand (in mass) as well as to a final proportion of 1/3 original soil and 2/3 sand.

The compost used was produced by the "Association pour la sauvegarde de l'oasis de Chenini" (ASOC) in Gabès, Tunisia. The making process includes mixing about two-thirds date palm residues (Phoenix dactylifera L.), in volume, and one-third sheep manure. Composting time is approximately 5 months, during which the compost is regularly wetted and aerated (see D5-2 for more information). Compost was then air-dried and stored at room temperature until the experiments.

In order to produce biochar, date palm residues (rachis) were collected in the Murcia region. After fragmentation, they were submitted to slow pyrolysis under a constant nitrogen flow at a temperature of 450 °C ± 5 °C for two hours (after a temperature rise of 4.9 °C min^{-1}) at the LERMAB laboratory (Épinal, France). The biochar was then ground in an automatic mortar and sieved at 1 mm.

Soil and OA samples were then characterized. Original soil analyses included granulometry (Robinson's pipette method), organic carbon content (sulfochromic oxidation), carbonate content, cation exchange capacity (Metson method), pH and electrical conductivity (at a ratio of 10 g of soil to 50 mL of deionized water). Compost analyses included organic carbon content, pH and electrical conductivity (same conditions as for soils) and particle size distribution (by sieving with mesh sizes of 4 mm, 2 mm, 1 mm, 0.5 mm and 0.2 mm). Biochar analyses included total carbon content (combustion and elemental analyser), mineral content (after 6 h of heating at 550 °C in a muffle furnace), potential cation exchange capacity (after pH adjustment to 7 and washing of samples until electrical conductivity was < 0.2 $mS.cm^{-1}$), pH and electrical conductivity (at a ratio of 5 g of soil to 50 mL of deionized water), BET specific surface area (by physisorption of dinitrogen at 77 K after outgassing for 12 h at 350 °C) and hydrophobicity (by water droplet penetration time).

Amended and unamended soil water retention capacity was determined after measuring soil water content using pressure membrane apparatus at nine different matric potentials, ranging from the saturation to the permanent wilting point. Soils samples were placed in rubber cylinders (approximate volume 21 cm^3) and saturated with distilled water by capillarity. Pressure was then applied, corresponding to the targeted matric potential and an equilibration time of 7 days was observed. The soil water contents were then determined gravimetrically by subtracting the soil mass before and after drying (at 105 °C for 48 h).

The natural soils studied differed notably by their textures though both were alkaline and relatively poor in organic carbon. Their soluble salt content was moderate to high. Differences in clay content were reflected by differences in cation exchange capacity. The compost had a neutral pH while the biochar had a very alkaline pH. The compost's mineral content was high considering this type of product. The biochar's high potential CEC was not correlated with its low surface area. Sand-supplemented soils had a sand content up to 85%.

Briefly, the results showed that biochar was more efficient at improving soil water retention than compost. In most cases, biochar-amended soils had higher soil water content than unamended or compost-amended soils. Furthermore, the higher the sand content was, the more pronounced the effect of organic amendments on water retention was. The effect of compost addition (if alone) was weak, likely due to its properties and notably its high mineral and soluble-salt content (revealed by its high electrical conductivity). Soil sand supplementation increased the differences between the OA-amended soils and unamended soils. Available water capacity was increased by up to +80% in the most favourable case (a sandy loamy soil enriched with 2/3 sand and amended with biochar), compared to the unamended soil. When comparing these results with existing literature, it must be kept in mind that previous studies frequently used hydrophobic biochar, supplemented to soils that were already rich in organic carbon, contrarily to our study on both aspects.

This demonstrated that sand content influences the effect of OA application. Thus, coarse textured soils such as those in Saharan desert regions might benefit greatly from the application of biochar from date palm residues, with an important improvement of their water retention properties. Applied on a broader scale, such practises might play a role in the optimization of irrigation.