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D5.8 Synthesis of the influence of organic amendments on oasis agroecosystems to improve their resilience to climate change

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The various laboratory experiments and field trials conducted in the ISFERALDA project investigated the links between production processes and properties and field effects of date-palm based organic amendments compost and biochar. They enable to make recommendations concerning the production and application of these products.

Organic amendments production

For compost, a comparison between composts produced by the Association pour la Sauvegarde de l'Oasis de Chenini (ASOC, Tunisia) and by Palm Compost (Algeria) revealed important differences, and their analysis enable to draw up recommendations as regards the production process. Notably, Rock-Eval analysis revealed significant differences in their organic matter signature. ASOC compost was very close to fresh plant material whereas Palm Compost compost was more mature and closer to literature data for compost.

Setting the windrows on a concrete platform or in concrete cases, or simply on sheets, rather than directly on the natural soil would reduce the high mineral matter content by reducing mixing with soil particles and covering the windrows might reduce the intake of wind-transported particles. Covering might also reduce water evaporation, thus the amount of water used and in turn the commensurate quantity of soluble salts brought into the compost. To this purpose, a permanent roof or a temporary cover with sheets would seem appropriate. Investment cost, notably equipment such as the date-palm waste shredder, would be lighter to bear by groups of farmers.

Resorting to the water with the lowest salt content that is locally available should be favoured. In areas where significant seasonal fluctuations in the quality and salt content of well-water (generally higher at summertime, up to several g/l), production of the compost when the quality of the water is better might be recommended.

Keeping the salt content of the compost as low as possible has two advantages. The first one is to optimize the maturation process (not interfering with microbial processes). The second one is to limit the supply of salt to the soil the product is applied to, which is of paramount importance in arid and semi-arid zones. Also, avoiding an excessive supply of water to the windrows reduces the risk of leaching and loss of a part of the fertilizing compounds of compost.

For biochar, the lots produced in the laboratory by URCA differed by the amount of dioxygen in the pyrolysis chamber, whereas the date-palm feedstock and pyrolysis temperature (450 °C) were identical. This temperature is well-suited to create porosity in the size-range compatible with the availability of water to the plants. Biochar also did not display hydrophobicity, and functional groups that contribute to the cation-exchange capacity, and thus nutrient retention, are preserved at this mild temperature.

The biochars produced at different oxygen levels exhibited similar sorption-desorption behaviour, all releasing significant amounts of Ca, K, Mg and Na, and similar and low Na-retention patterns. Although the retention of plant nutrients by biochar has not been investigated in-depth, these results suggest that a precise control of the anoxia level in the pyrolysis chamber, which is difficult to regulate with artisanal or even industrial methods, is not of primary importance, provided combustion of the feedstock is avoided.

The greenhouse-gases (GHG) budget of the production and application of date-palm based organic amendments should also be considered. For the production of compost, values cited in the literature are generally close to 50% organic matter mineralization during the process. The values obtained in the ISFERALDA experiments are lower, with an estimated mineralization of 7-27% over the 3-months composting period. It is not possible to discriminate the contribution of the different components of the compost (date-palm waste and manure) to OM mineralization.

Effects of organic amendments in laboratory and field experiments

In the laboratory, biochar clearly improves the water retention of the sandy soil, whereas compost has no significant effect on that property. Pot and field cultivation experiments compared the effects of biochar and compost to unfertilized soil as well as to an optimal chemical fertilization fulfilling completely the plant requirements for nitrogen (pot), in addition to phosphorus and potassium (field). Chemical fertilizers have the highest barley yield in the field, but compost clearly improves the yield compared to unfertilized soil (+30%) and performs better than chemical nitrogen fertilizer (urea) in the pot experiments. The possible high salt content of compost does not seem to impede its rapid mineralization once mixed in the soil. Grain protein content, at 6-7%, is not improved by compost alone although it improves the grain yield.

Biochar slightly enhances the fertilizing effect of compost or chemical fertilizers on plant nutrition whereas it has no effect if used alone. Biochar demonstrated, however, an important and sustained release of potassium, and its combination with a nitrogen and phosphorus source (compost or chemical fertilizer such as urea) fulfils plant requirements.

The effect of compost on plant nutrition, notably through the supply of nitrogen, is very clear in the first months after application but diminishes quickly thereafter (although the estimated gross mineralisation was only 17% over 4 months of incubation). The supply of phosphorus from compost is more sustained. The second year after application, a small effect of compost remains though the grain yield is only approximately 15% higher than unfertilized plots.

In the case of flood irrigation, an important loss of nitrogen from the compost, mostly in the form of nitrate, occurs due to the leaching of the excess irrigation water. In these conditions, optimal plant development requires an additional source of nitrogen to take over compost at grain filling stage, for example urea, to obtain a satisfactory gross yield but also a high quality of grains. Optimization of irrigation methods would, in addition to water savings, help prolonging the fertilizing effect of organic amendments over time and reduce nitrate accumulation in superficial aquifers.

Compost enhances the development of microbial communities involved in nitrogen mineralization, mineralization and denitrification, but the addition of biochar to compost can reduce nitrogen loss caused by the denitrification process.

Contribution of organic amendments to the circular economy

In-grove production and application of date-palm based biochar might fully contribute to the circular economy. The production of date-palm waste is estimated to be 1.5-2.4 ton/ha/yr. According to the biochar yield observed in our experiments, this would correspond to a biochar production of 0.5-0.8 ton/ha/yr. At the applied dose of 10 ton/ha, this means that the application of biochar to a given area requires gathering and treating the waste from 12-20 times larger zone on a given year. Conversely, purely local recycling of date-palm waste would take 12-20 years (if all waste is dedicated to this) to produce enough biochar to apply to a given area entirely. The laboratory and field experiments showed that biochar is mostly made of very stable organic matter and is not easily degraded in the soil. The corresponding amount of carbon (62%, corresponding to 6.2 ton/ha) can be considered as sequestered in the soil on the long term. Our experiments have, however, not permitted to estimated losses of biochar particles through wind erosion or infiltration, which would require renewal of the application. Preventing biochar loss due to hydric erosion requires a good incorporation of this low-density material into the soil, to avoid floating biochar particles to be taken away with irrigation water.

The compost making requires 70% of date-palm and 30% of manure, date-palm waste production is thus sufficient for a compost production of 1.7-2.7 ton/ha/yr, provided manure is available in sufficient quantities and at a reasonable cost. The laboratory and field experiments suggest a compost application dose of 36 ton/ha (higher doses would not improve plant development and yield pose an increased risk of nitrogen leaching). At this dose, purely local recycling of date-palm waste would take 13-21 years (if all waste is dedicated to this) to produce enough compost to apply to a given area entirely. This duration is very similar to the similar estimation for biochar, though the estimated persistence of biochar is much longer than that of compost.

No data have been collected over the course of the ISFERALDA project concerning the cost of in-grove production of biochar or compost. Data have been collected from biochar or compost producers, but they are partial because the producers were very wary not to disclose confidential data, in a context of a to-date very limited niche market.

Promoting the production and use of biochar and compost by groups of farmers or associations, in addition to the reduction of possible investment costs, would enable sharing experiences, especially to ensure product quality by monitoring processes, resorting to complementary analyses and interpreting their results, if need be, in the primary objective that amendments are not noxious to the agroecosystems at the chemical and biological levels.