Chapter

Nutrients Deficit and Water Stress in Plants: New Concept Solutions Using Olive Solid Waste

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Abstract

Great efforts were deployed by researchers to mobilize water resources while is becoming rarer and to control with efficiency the water besides nutrient needs for the plant. Autonomous water and nutritional anti-stress device for plants (AWANASD) based on the recovery of rainwater patented by Medhioub et al. fits into this general framework. Scientific efforts were also dedicated to preserve the environment and minimize energy consumption through using agricultural waste materials in different fields. This chapter provides a new concept based on the use of the olive solid waste in AWANASD as water storage and nutrient elements for plants giving rise to the new system called AWANASD-OSW.

Keywords: stress, water, nutrient, olive solid waste, device

1. Introduction

Climate change and the excessive needs of human activities impact the water resource [1] and consequently its availability notably for the big water use of agriculture sector activity [2]. It accounts for 69% of global withdrawals [3], 2021. The irregularity of rainfall distribution and the faster and increasing water demand by 50% by 2030 [4] threat considerably some regions in the world. So, it is important to realize that in arid environments, challenges of preserving and saving water are crucial for achieving the Millennium Development Goals [5]. As the agriculture sector is the largest consumer of water, several researches and achievements aim to save water and ensure the minimum nutrient requirements for optimal growth of crops.

Reference to [3], **Table 1** resumes some irrigation systems based on saving water use. In fact, these irrigation methods have their advantages and disadvantages but all of them require water sources, storage tanks, installation, etc. and incorporating nutrients under different forms.

Agricultural sector activity is on the other side a source of renewable and valuable waste. Many research works were carried out to enhance this green waste in the different fields enjoying their specific performances mainly thermal, lightness, and its organic material characteristic. In France, regarding the fight against climate change and the strengthening of resilience in the face of these effects, deputies adopted an amendment (No. 7012) relating to the use of bio-based materials in construction. It indicates that from January 1, 2028, bio-based materials must be

System	Description	Reference(s)
Clay pot irrigation	A clay pot is buried and filled up with water to irrigate the plants placed around it. Water seeped through its wall, will be absorbed by the roots of the plants.	[6]
Drip irrigation	Water and nutrients are delivered to the field in pipes called "drip system lines" containing smaller units called "drip systems." Each drip system emits drops containing water and fertilizer, which allows a uniform application of water and nutrients directly to the root zone of each plant, over an entire field.	[7]
Continuous irrigation	It uses a porous tube qualified as a semipermeable membrane (SPM). It delivers slowly and continuously water directly into the plant root zone.	[8]
Hydrophilic polymers or hydrogels	Hydrophilic polymers or hydrogels were small granules that function like sponges: They retain water up to 500 times their weight with rain or watering then it will be released later slowly and in very small quantities when it is incorporated into the soil.	[9–15]

Table 1.
Overview of some irrigation methods.

used in at least 25% of renovations and constructions ordered by the public institute [16]. All green waste can be used as well in agriculture. It can be turned into humus and nutrients, which are essential for soil life and plant development.

Our contribution in this chapter will be divided into three sections—the first one will review the new concept of irrigation method based on the recovery of rainwater given by [3], called autonomous water and nutritional anti-stress device (AWANASD) for plants; the second section is reserved to introduce the process of obtaining the olive solid waste (OSW), its fields of application and its physical and chemical characteristics. The last section gives a new vision to improve AWANASD by the use of OSW as the main component to respond at the same time to the minimum of water and nutrients required to the plant.

2. Autonomous water and nutritional anti-stress device (AWANASD)

The new concept of AWANASD, given by [3] (Video 1: https://vimeo.com/user163271525/review/665174900/0954b75438), is a genius new concept inspired by the ancient clay pot method of irrigation. The bottom line of AWANASD is collecting rainwater then storing them temporarily with soluble nutrients enrichment and delayed water transfer to the plant. It's a regular cyclical of water storage and transfer in order to overcoming the water stress of the plant in drought periods taking advantage of the rainy season (**Figure 1**).

AWANASD is made up of three compartments—the first one is a rainwater receiver exposed to open air and designed to filter and convey the collected water to the second compartment; the latter is buried in the soil near the maximum root density of the plant and in which the temporary storage water is enriched by nutrients. This water will forward to the last compartment which is the key piece of AWANASD. It has a defined permeability to ensure a deferred daily volume rainwater outflow and consequently, it will fill the lack of water needed to plant survival in the dry season. The calculated permeability is related to multiple parameters mainly the climate of the target crops region.

AWANASD will be able to spare the underground water tables from intensive exploitation and eventually from the poor-quality water [17]. It also reduces water consumption [18] and water loss by evaporation and deep percolation [19] and consequently improper management of water resources [20].

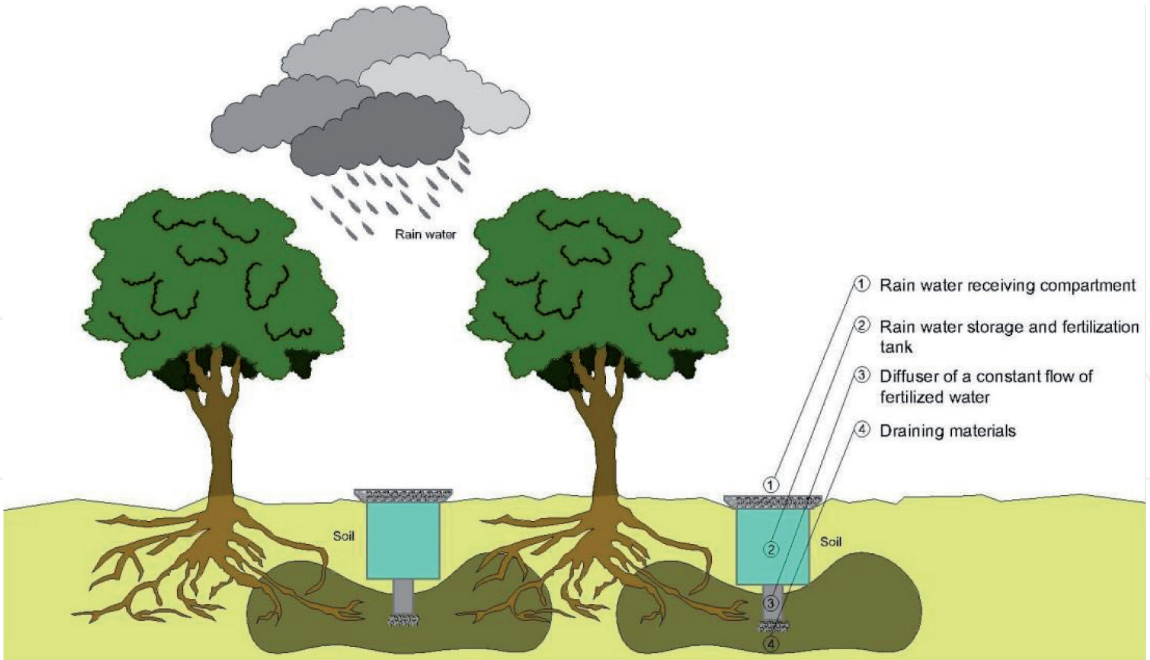

Figure 1.
Simplified AWANASD function.

The analytical model of AWANASD is based on the next water balance equation:

$$inflows\ volume = change\ in\ storage\ volume + outflows\ volume \quad (1)$$

More numerical details were shown in Ref. [3].

3. Olive solid waste: origin, valorization, and characterization

3.1 Introduction

According to the International Olive Council, the olive sector takes great importance in the economics of a large number of countries (**Figure 2**) and had tripled its production in the last 30 years [22]. The annual production of table olive for the period 2018–2019 was closed at 3 million tons [22]. This would indicate that the sector is expanding. As a consequence of the activity of this sector, large volumes of waste and by-products are generated. Among these agriculture wastes, those resulting from classic pressure processes, batch processes (super press), and continuous processes (centrifugation).

3.2 Oil extraction process

3.2.1 Classic or traditional process

In classic (traditional) extraction units, the oil extraction process consists of the following different steps (**Figure 3**):

- Grinding: It is carried out by granite stone grindstones, which rotate in a tank whose floor is also made of stone. This grinding is carried out manually or through an animal. This step, therefore, makes it possible to obtain a paste that contains solid matter and fluids (oil and water from vegetation).

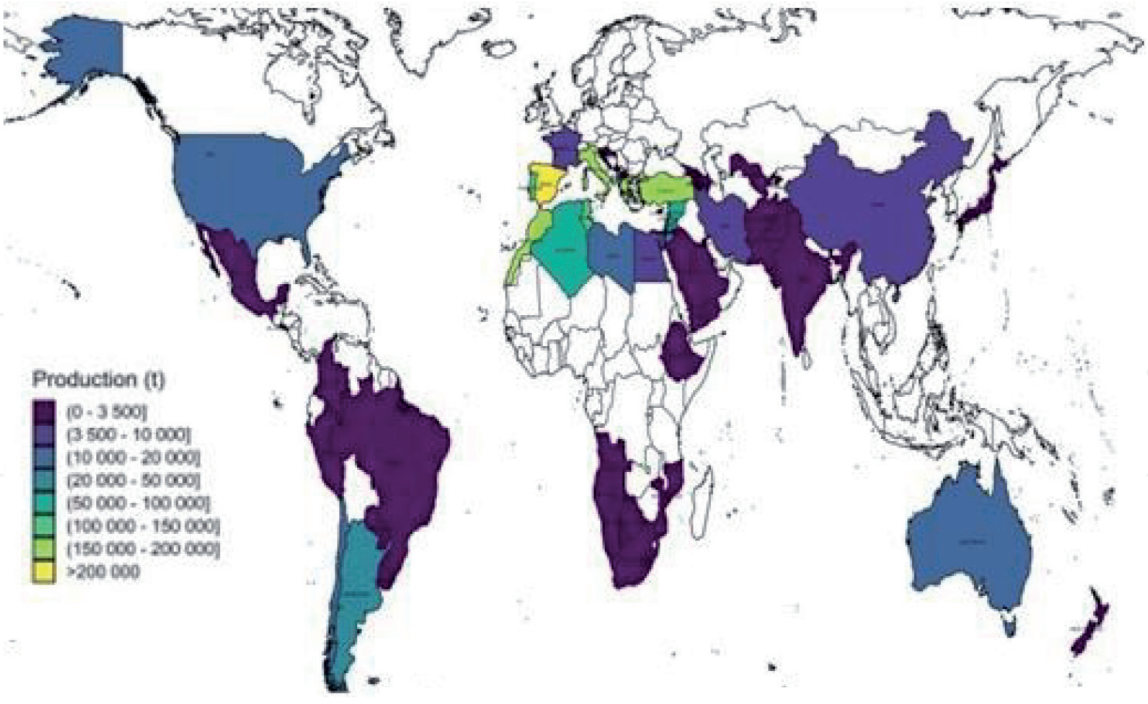

Figure 2.
World olive oil production, 2018/19 crop year [21].

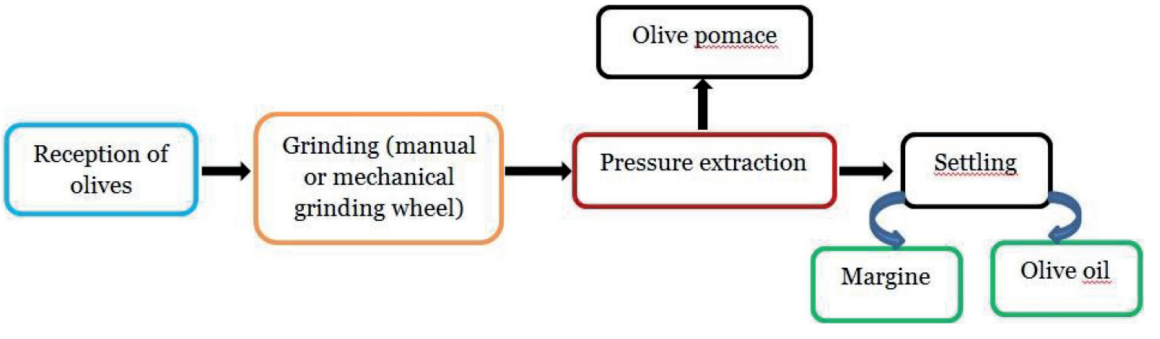

Figure 3.
Classic press and super press extraction systems.

- Phase separation: The pulp produced is placed on scourtins (fiber discs plants). Then, oil extraction is carried out by pressure. The pressing generates a solid by-product called olive pomace. These olives pomaces are the residues solids recovered following the first pressing or centrifugation. They are made up of residues of the skin, pulp, almond, and fragments of olive pits.

- A separation by settling of the liquid phases (oil and vegetation water) is performed. This separation takes place in the open air in cement, earthenware, or clay containers. A liquid by-product was generated at the end of this step, called vegetable waters. It is the brown aqueous liquid residue that separated from the oil by sedimentation after pressing or centrifugation. This liquid has a pleasant smell but a bitter taste. This effluent relatively rich in organic matter constitutes a pollution factor that creates a real problem for the olive industry.

3.2.2 Batch process or super press system

The olives received in the traditional oil mills go directly through the following steps:

- Grinding: It is carried out by grinding wheels. The grinding wheels used for grinding are slightly off-center with respect to the axis of rotation, which increases the possibility of crushing olives.

- Mixing: This step releases as much oil as possible. Raclettes bring back permanently the dough under the grindstones which then play the role of kneading machines. The dough is obtained after about half an hour.

- Phase separation: The dough is then placed in a layer approximately 2 cm thick on nylon fiber discs (the mats), themselves stacked on top of each other around a central pivot (called a needle) mounted on a small carriage. The set is placed on a hydraulic press piston which allows the dough to be subjected to a pressure of the order of 100 bars. The liquid phase flows into a tank. The pomace stays on the scourtins. This operation takes approximately 45 minutes. Then, each scourtin is cleared of its pomace by tapping it as when cleaning a carpet.

- Decantation: The oil, having a lower density than that of water, goes back to the area. This is the natural settling. However, this method is almost no longer used, due to its slowness and the difficulty in separating the oil from the water vicinity of the interface between the two fluids. These are vertical plate centrifuges that today make it possible to separate olive oil from vegetable waters (**Figure 3**).

3.2.3 Continuous process

There are two types of the continuous extraction process—three-phase centrifuge system and two-phase centrifuge system.

3.2.3.1 Three-phase centrifugal extraction system

The olives, once received, undergo preliminary treatments, such as stripping, stone removal, and washing to have good oil quality.

- Grinding: This is carried out by mechanical disc or hammer grinders. These grinders can work continuously; the dough is obtained almost instantly.

- Mixing: The dough is poured into a stainless-steel tank moderately thinned with water lukewarm, in which a spiral or worm turns, also in stainless steel.

- Phase separation: This consists of separating the solid part (pomace) from the fluid (vegetable waters). The kneaded paste is injected by a pump into a centrifuge whose axis is horizontal (horizontal settling tank).

- Decantation: Vertical centrifuges with plates are used which make it possible to separate olive oil from vegetable waters [23]. This extraction process is illustrated in **Figure 4**.

3.2.3.2 Two-phase centrifugal extraction system

The olives undergo the same stages of stripping, stone removal, washing and grinding, mixing, and settling as those of the previous three-phase system.

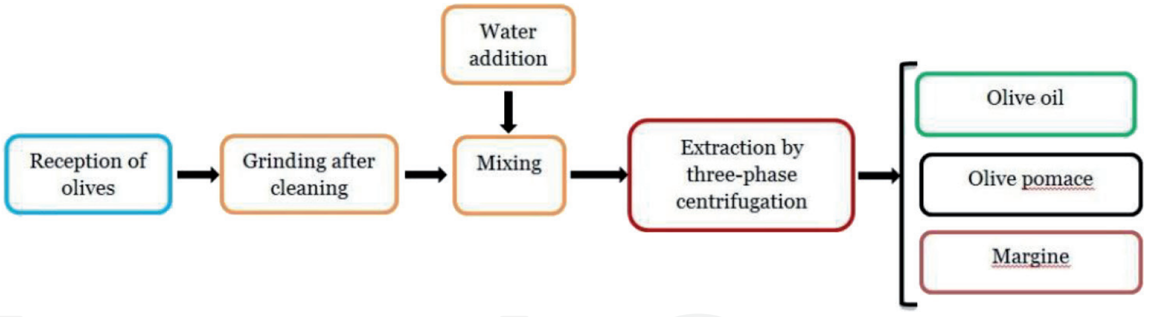

Figure 4.
Three-phase centrifugal extraction system.

However, this olive oil extraction process works with a new decanter with two-phase centrifugation (oil and moist olive pomace) which does not require the addition of water for the separation of oil and solid phases containing pomace and the vegetable waters. This two-phase decanter allows for slightly higher oil yields than those obtained by the conventional three-phase decanter and the press system. In addition, it does not increase the volume of vegetable waters.

Figure 5 shows the different stages of olive oil extraction by a two-phase centrifugal extraction system.

3.3 Valorization of olive pomace

As a renewable by-product source further its high added-value, the olive solid waste was valued in different areas. **Table 2** summarizes the most important uses. Each of these uses will be detailed succinctly later in the text.

3.3.1 Combustion of stone and whole stone

The olive stone is a biomass fuel that has low N and S percentages [24] with a minimum environmental impact. The important power heating combustion is converted to electrical sector and for heating buildings [25]. Rodrıguez et al. [34] and Arvanitoyannis et al. [46] detailed more in their study the thermal treated olive stone used.

3.3.2 Activated carbon from olive stone

Activated carbon was used in many fields (mining, pharmaceutical industries, food, etc.) [27, 28]. Activated carbon from olive stone is mainly used for the removal of contaminants, such as arsenic [47] or aluminum [48], odors, unwanted colors, and tastes [49].

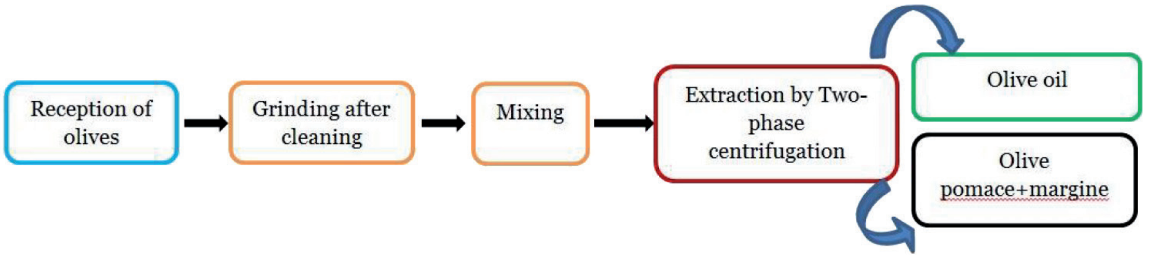

Figure 5.
Two-phase centrifugal extraction system.

Application	Raw material	Pretreatment	Application sector	References
Combustion	Stone and seed	Dried	All industries residential and commercial	[24–26]
Activated carbon	Stone and seed	Pyrolysis activation	Food, chemical, petroleum, nuclear, mining, pharmacological industry	[27–32]
Bio-oil	Stone and seed	Pyrolysis	Wide field of industries	[33]
Furfural	Stone and seed	Acid hydrolysis	Wide field of industries as solvent	[34]
Plastic filled	Stone	Grinding	Plastic and construction	[35–38]
Abrasive	Stone	Grinding	Cleaning	[39]
Cosmetic	Stone	Grinding	Cosmetic	[40–42]
Animal feed	Stone and seed	Grinding	Food	[43]
Resins	Stone and seed	Pyrolysis or liquefaction	Electrochemical	[44, 45]

Table 2.
Overview of some OSW uses.

3.3.3 Liquid and gas products from olive stone pyrolysis

Olive stone pyrolysis gives interesting bio-oil and gas products [33].

3.3.4 Furfural production

There are many processes to produce furfural such as acid hydrolysis of xylose and some of which present the olive stone. Several industrial uses of furfural are performed, such as solvent or as a base for synthesizing its derived solvent [34].

3.3.5 Olive stone as a plastic filled

The olive stone as a natural and biodegradable raw material [35, 36] was already studied to prepare a friendly environment product then a certain plastic structure by mixing it with a certain polypropylene to produce a new thermoplastic polymer [37].

Figure 6.
Olive composition.

3.3.6 Olive stone as an abrasive

The interested proprieties of olive stone in terms of resistance to rupture and deformation confers an abrasive quality that let it wide use in the industrial sector [39].

3.3.7 Olive stone in cosmetic

Olive stone is incorporated as a component in many products to aid in skin exfoliation [40, 41].

3.4 Characterization

3.4.1 Composition of the olive

The olive composition depends on its variety (**Figure 6**), soil, and climate [23]. The contents olive is composed of epicarp (2–2.5% of weight) which is in fact the skin of the olive. It is covered with a waxy material, the cuticle, which is waterproof, then, the mesocarp (71.5–80.5% of weight) [50] which is the pulp of the fruit. It is made up of cells in which the drops of fat that will form olive oil will be stored, during the "lipogenesis" phase and finally, the endocarp or the stone (17.3–23% of weight).

3.4.2 Physical proprieties of olive solid waste

The olive solid waste (OSW) used in the tests reported in this chapter (**Figure 7(a)** and **Table 3**) was obtained from a three-phase centrifugal extraction process from "Botria oil" Tunisian company mills. After a centrifugal separation of the husk residue, the extracted olive solid waste (OSW) underwent a natural drying process in an open shelter.

The tested OSW showed 605 and 1490 kg/m^3, respectively to bulk and relative density and 24-hour water absorption capacity of 11.5%. **Figure 7(b)** shows its particle-size distribution.

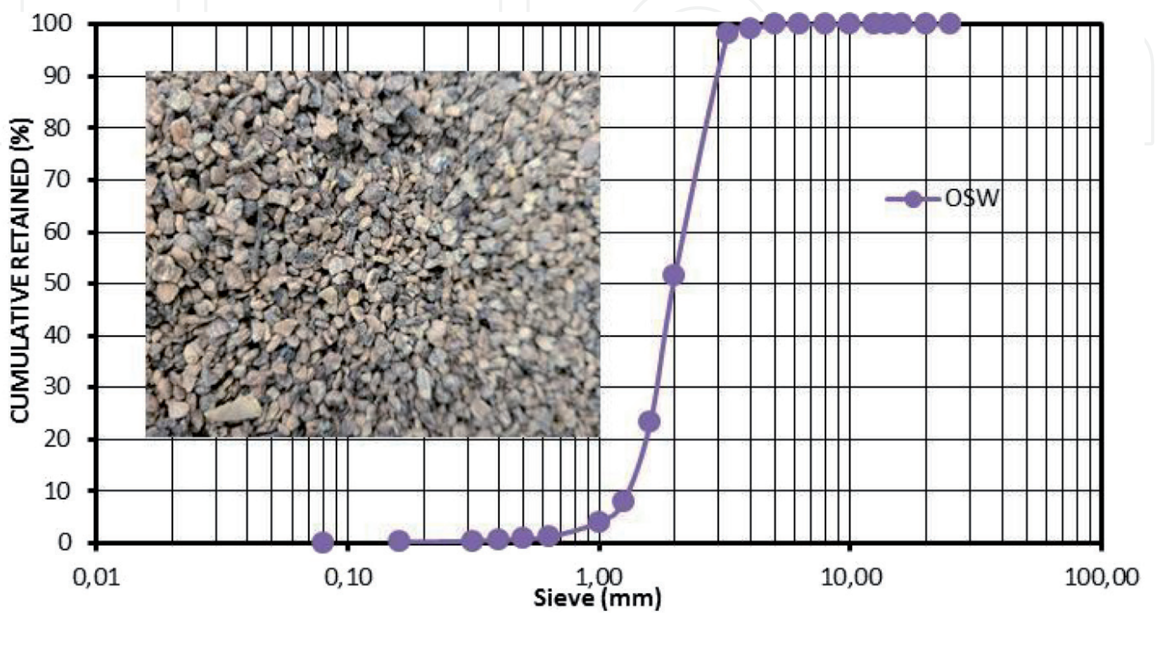

Figure 7.
Olive stone. (a) Sample used for testing. (b) Grain size distribution.

t (mn)	0	15	30	60	90	120	180	240	360	1440	2880
M_0 (g)	178	178	178	177	171	182	178	179	177	175	177
M_f (g)	178	257	272	293.1	295	318	319	324	325	330	336
V_0 (ml)	279	279	279	279	279	279	279	279	279	279	279
V_f (ml)	279	338	345	351	360	369	373.5	376	379	383	390
W (%)	0	44	53	66	73	75	79	81	84	89	90
f (%)	0	21	24	26	29	32	34	35	36	37	40

Table 3.
Water and profusion of OSW as a function of the immersion time.

3.4.3 Olive solid waste behavior in water

The organic nature and the porous structure of solid waste cores have been the subject of a specific study of their behavior in the presence of water and as a function of the immersion time. The following procedure has been adopted while not losing sight of RILEM recommendations [51]:

- Weigh 200 g of a raw OSW
- Dry the OSW sample in a 105°C oven and for 24 hours (until a constant mass of less than 0.1% is reached)
- Weigh the dried sample (M0)
- Place it in a graduated test tube and note the corresponding volume (V0)
- Fill the test tube with water and put the dried OSW sample in it until a given time t.
- Net volume (V_f) and weight (M_f) of wetted OSW corresponding to time t
- Repeat the above operations for each time t equals to 15, 30, 60, 90, 120, 180, 240, 360, 1440, and 2880 mn)

Table 3 shows all measured values.
The water content W is given by Eq. (2).

$$w = \frac{M_f - M_0}{M_0}(\%) \tag{2}$$

The volume occupied by a given weight of dry OSW material increases at the same time as its humidity. This phenomenon is, therefore, called profusion. This is characterized by expansion coefficient f (expressed in %; Eq. (3)) as the increase in the volume corresponding to a given humidity compared to the volume occupied by the same quantity of bio-sourced but in the dry state [52]:

$$f = \frac{V_f - V_0}{V_0}(\%) \tag{3}$$

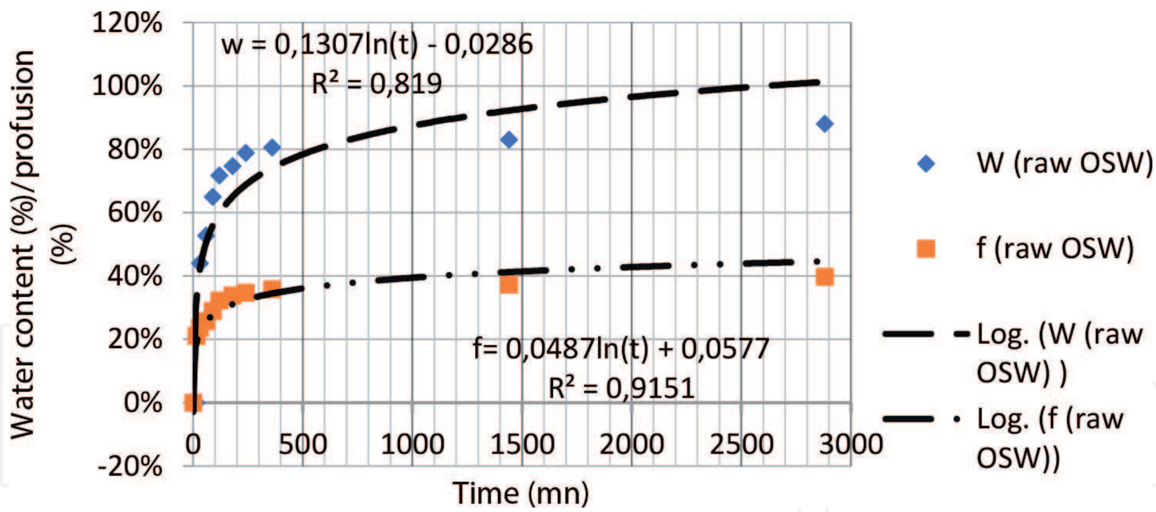

Figure 8.
Water content and profusion function of time of OSW.

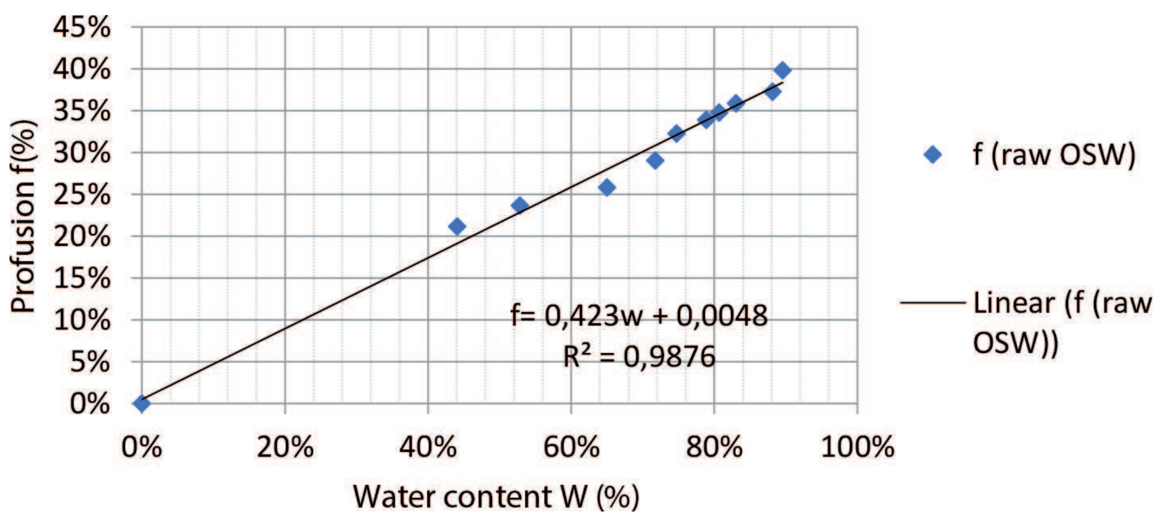

Figure 9.
Profusion function of the water content of OSW.

	Unit	Raw OSW	A	B	Mean	OSW after dissolving in water	A	B	Mean
N*	%		0.915	0.854	0.884		0.581	0.49	0.536
Mineral matter	%		4.72	5.2	4.96		1.06	1	1.03
Calcium*	mg/kg		0.276	0.277	0.276		0.159	0.132	0.146
Phosphor*			0.021	0.014	0.017		0.009	0.009	0.009
Potassium*			0.019	0.017	0.018		0.012	0.01	0.011
Sodium**			0.044	0.035	0.039		0.055	0.059	0.057
Copper**			7.488	7.186	7.337		4.893	4.695	4.794
Zinc**			7.289	4.284	5.786		5.06	6.792	5.926
Manganese**			10.28	9.482	9.883		3.395	3.496	3.446
Iron**			335.9	364.7	350.3		67.009	66.426	66.718

*Macronutrients.
**Micronutrients.

Table 4.
Elementary chemical elements in the raw and dissolving OSW.

Figure 8 shows by using regression equation the approximation curves and their equations of the water content and profusion function of time. We note that, according to correlations coefficients R^2, the two equations reflect well the tendency of W and f with time. We note as well that water saturation and the maximum profusion of OSW begin after 4 hours. In addition, we deduce the relation between w and f shown in **Figure 9**.

3.4.4 Chemical proprieties of olive solid waste

ICP technique, short for "Inductively Coupled Plasma" was used for measuring the content of an inorganic element in a sample. This technique is applicable to all types of elementary chemical elements.

The results of ICP sample analysis of OSW for two samples (A and B) were given in **Table 4**.

4. Olive solid waste used in AWANASD: a new concept for nutrients deficit and water stress

Adding to its organic material, the physical and chemical proprieties of OSW let confer it a potential and interesting material not only for its ability to stock water on it around the double of its weight but it is a useful nutrient element for plants even not with a big quantity but it can be required to thwart certain nutrition deficit. Medhioub et al. [3] gave a design of AWANASD for the governorate of Sfax (Tunisia). This design consists of filling the third compartments of AWANASD with grains sand of 3 mm in diameter to reach permeability equal to 10–7 m s[1] to give a water flow of 0.4 L day[1] at a depth of about 1 m. Nevertheless, the authors did not specify which and how the nutrient should be done. So, our proposed device concept named "AWANASD-OSW" is a new version of AWANASD which can be

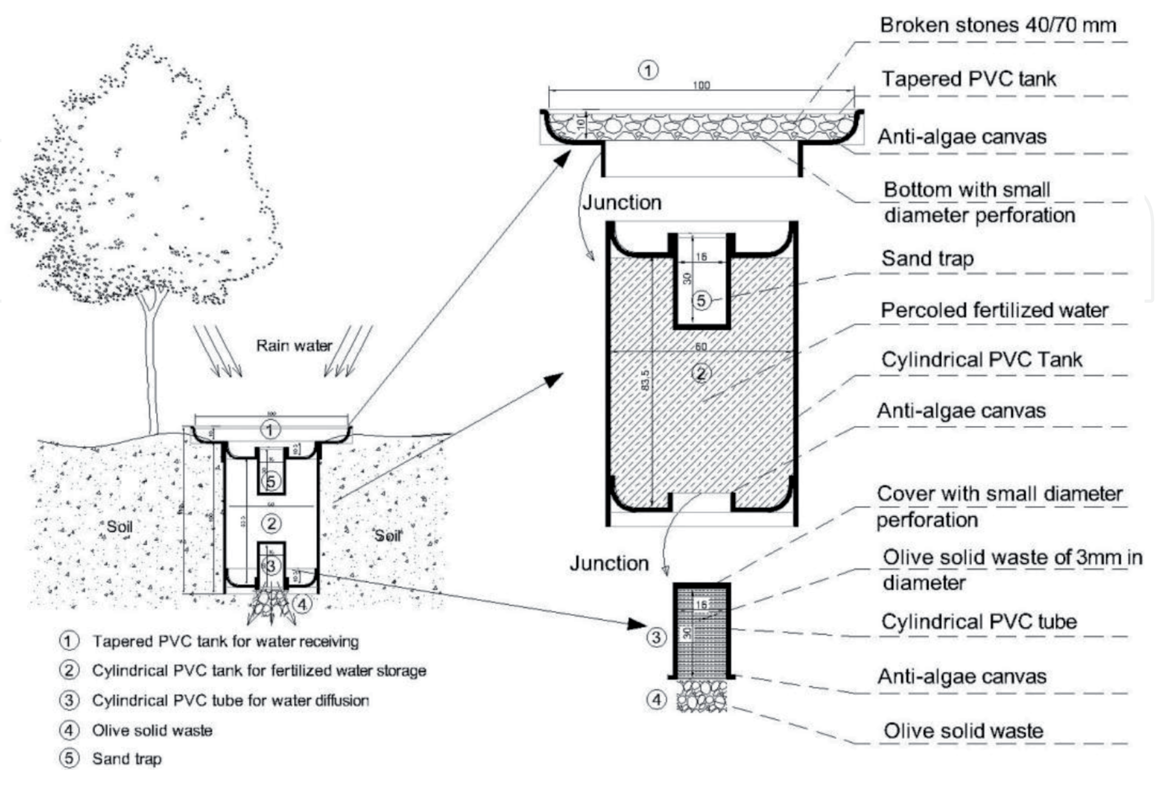

Figure 10.
AWANASD-OSW design.

applied to the same location. AWANASD-OSW includes the same number of compartments of AWANASD (**Figure 10**) and ensures the goal of delayed water transfer to the roots of plants. However, the third compartment which is a cylinder (32 cm height; 16 cm of diameter) will be filled by a specific volume of OSW (V_{OSW}) having a similar sand particular diameter. This is given by equation Eq. (4):

$$V_{OSW} = {}^{V_s}\!/_{f} * 10^{-3} \left(m^3\right) \quad (4)$$

where Vs is the sand volume equal to $6410^{-3}(m^3)$; f is the profusion of OSW taken for the maximum of water content (40%).

5. Conclusion

As it is a living organ, a plant's need is nutrition and a water supply. Different technical methods have been developed and applied to meet this need. The reliability of these methods varies in degree of performance. The recent one called AWANASD is given by Medhioub et al. [3], ensuring the minimum water flow and nutrition during drought months at the level of the maximum concentration of roots.

AWANASD applied for Sfax governate concluded the use of grain sand with a specific diameter to ensure the objective of delayed water transfer but it did not mention the nutrition issue. Our AWANASD-OSW new concept fully incorporates the said system but replaces the grain sand with olive solid waste with the same granulometry.

This renewable agriculture waste material has interesting physical and chemical properties besides its characteristic as a biodegradable organic material. It allows the release in the presence of water of nutrients for plants in addition to its role of water store.

A full-scale experimental device must be set up not only to ensure the expected theoretical performances but also to assess its longevity.

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