



Deep Water Culture Aquaponic Unit: Step by Step Description

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Summary

Aquaponics is the integration of recirculating aquaculture and hydroponics in one production system. The Deep Water Culture (DWC) is one of the three common methods of aquaponics being utilized at present, generally implemented at large-scale operations.

This technology provides a detailed explanation of the main components of this method and a step by step guide to constructing a DWC.

Description

In a deep water culture method, also known as the raft method or floating system, the nutrient-rich water is circulated through long canals at a depth of about 20 cm while rafts (usually polystyrene) float on top.

Plants are supported within holes in the rafts by net pots. The plant roots hang down in the nutrient-rich, oxygenated water, where they absorb large amounts of oxygen and nutrients which contribute to rapid growth conditions.

This method is the most common for large commercial aquaponics growing one specific crop (typically lettuce, salad leaves or basil) and having high stocking density of fish (up

to 10 and 20 kg of fish per cubic meter of the fish tank). However, it can be adapted to a low stocking density of fish production.

1. Components of the Deep Water Culture Aquaponic Unit (DWC)

1.1 Water flow

In the deep water culture unit described in this technology, water flows by gravity from the fish tank, through the mechanical filter, and into the combination biofilter/sump. From the sump, the water is pumped in two directions through a (Y) connector and valves. Some water is pumped directly back to the fish tank.

The remaining water is pumped into the manifold, which distributes the water equivalently through the canals. The water flows, again by gravity, through the grow canals where the plants are located and exits on the far side. On exiting the canals, the water is returned to the biofilter/sump, where again it is pumped either into the fish tank or canals. The water that enters the fish tank causes the fish tank to overflow through the exit pipe and back into the mechanical filter, thus completing the cycle.

The flow rate of the water entering each canal is relatively low. Generally,

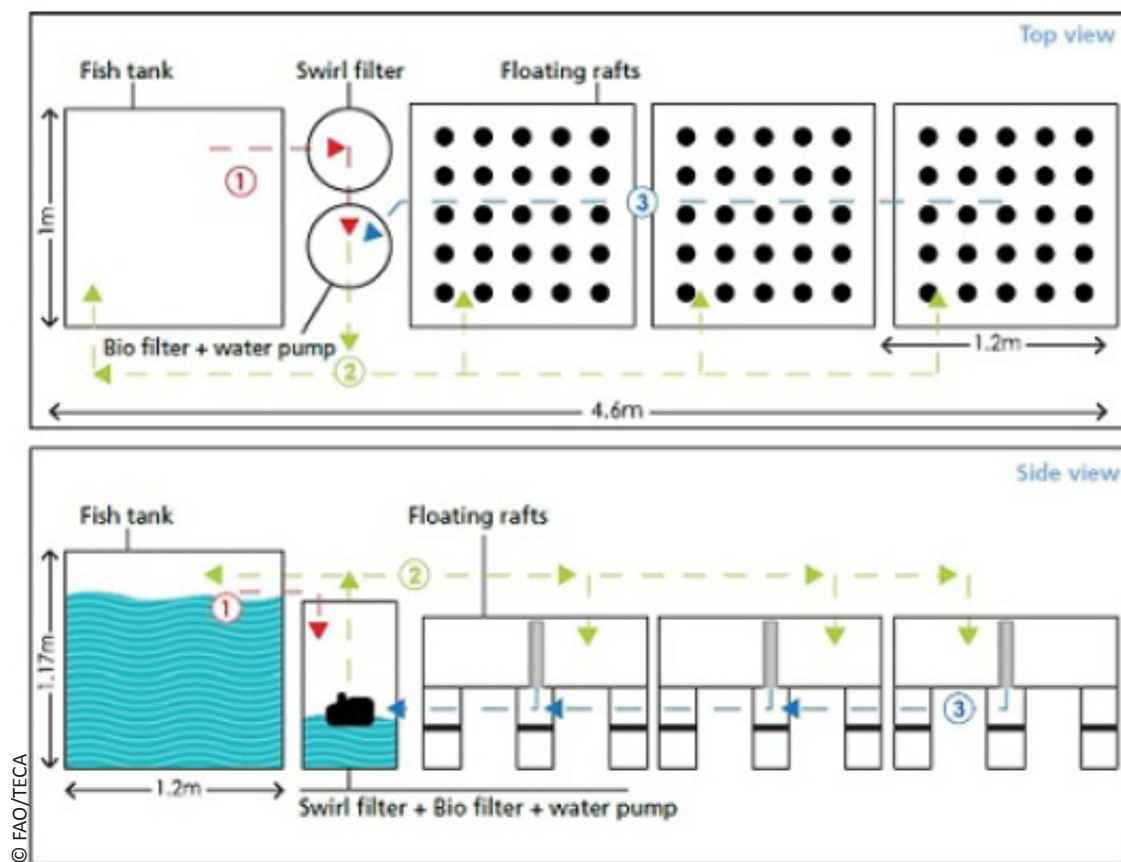
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Figure 1: Water flow diagram



every canal has 1 to 4 hours of retention time. Retention time is a similar concept to turnover rate and refers to the amount of time it takes to replace all the water in a container. For example, if the water volume of one canal is 600 litres and the flow rate of water entering the container is 300 litres/h, the retention time would be 2 hours (600 litres divided by 300 litres/h).

However, when a low stocking density of fish (i.e. 1 to 5 kg of fish per one cubic meter of the fish tank) is used, the DWC can be designed without using external filtration containers, mechanical or biological.

In this system, water flows by gravity from

the fish tank straight into DWC canals, passing through a very simple mesh screen. Water is then returned either to a sump and pumped back to the fish tanks, or directly to the fish tanks without a sump. Water in both the fish tanks and canals is aerated using an air pump. The fish waste is broken down by nitrifying and mineralizing bacteria living on the plant root surface and the canal walls. To procure additional mineralization and biofiltration, and to avoid waste accumulation of solids at the bottom of the canals, a simple mesh screen with a basket of pea gravel or clay balls can be positioned just above the water level where the water exits the fish tank.



1.2 Filtration

Two types of filters need to be constructed using the first technique: first, a physical trap to catch the solid wastes, and then a biological filter for nitrification. The designs described in this publication use a mechanical swirl filter to trap particulate wastes, with periodic venting of the captured solids. On exiting the swirl filter, the water passes through an additional mesh screen to trap any remaining solids and then reaches the biofilter. The biofilter is well oxygenated with air stones and contains a biofiltration media, usually Bioballs®, nylon netting or bottle caps, where the nitrifying bacteria transform the dissolved wastes.

With insufficient filtration, the DWC units would clog, become anoxic and exhibit poor growing conditions for plants and fish alike. When a stocking density of fish is used, the system can be designed without filters, as described in the previous section.

1.3 DWC grow canals

Canals can be of variable lengths, from one to tens of metres, enabling an adequate nutrient supply due to the large volume of water used in this system. As far as the width is concerned, it is generally recommended to be the standard width of a sheet of polystyrene, but it can be multiples of this.

However, narrower and longer canals enable a higher water speed that can beneficially hit the roots with larger flows of nutrients. The choice of width should also consider accessibility by the operator. The recommended depth is 30 cm to allow for adequate plant root space.

Similar to fish tanks, canals can be made out of any strong, inert material that can

hold water. For small-scale units, popular materials include fabricated Intermediate bulk containers (IBC) plastic containers or fibreglass. Much larger canals can be constructed using wood lengths or concrete blocks lined with food-grade waterproof sheeting. If using concrete, make sure it is sealed with non-toxic, waterproof sealer to avoid potential toxic minerals leaching from the concrete into the system water. The retention time for each canal in a unit is 1 to 4 hours, regardless of the actual canal size.

This allows for adequate replenishment of nutrients in each canal. Plant growth will definitely benefit from faster flow rates and turbulent water because roots will be hit by many more ions; whereas slower flows and almost stagnant water would have a negative impact on plant growth. Aeration for DWC units is vital.

In a densely planted canal, the oxygen demand by the plants can cause dissolved oxygen (DO) levels to plummet below the minimum. Any decomposing solid waste present in the canal would exacerbate this problem, further diminishing DO.

Thus, aeration is required. The simplest method is to place several small air stones in the canals. The air stones should release about 4 litres of air per minute, and be arranged every 2 to 4 square meter of canal area. In addition, Venturi syphons can be added to the water inflow pipes to aerate the water as it enters the canal.

Finally, the Kratky method of DWC can be used, which consists in leaving a space of 3 to 4 cm between the polystyrene and the water body inside the canal. This allows air to circulate around the top section of the plant roots. This approach removes the need for air stones in the canal as sufficient amounts of oxygen in the air are supplied



to the roots. Another advantage of this method is the avoidance of direct contact of the plant stems with water, which reduces the risks of plant diseases in the collar zone. Moreover, the increased ventilation as a result of the increased airspace favours heat dissipation from water, which is ideal in hot climates.

Do not add any fish into the canals that could eat the plant roots, e.g. herbivorous fish such as tilapia and carp. However, some small carnivorous fish species, such as guppies, mollies, or mosquito fish, can be used successfully to manage mosquito larvae, which can become a huge nuisance to workers and neighbours in some areas.

2. Planting in a DWC unit

As mentioned previously, this method involves suspending plants in polystyrene sheets, with their roots hanging down into the water. The polystyrene sheets should have a certain number of holes drilled to

fit the net cups (or sponge cubes) used for supporting each plant. The amount and location of the holes are dictated by the vegetable type and the distance desired between the plants, where smaller plants can be spaced more closely.

Seedlings can be started in a dedicated plant nursery in soil blocks or a soilless medium. Once these seedlings are large enough to handle, they can be transferred into net cups and planted into the DWC unit.

The remaining space in the net cup should be filled with hydroponic media, such as volcanic gravel, rockwool or Lightweight Expanded Clay Aggregate (LECA), to support the seedling. It is also possible to simply plant a seed straight into the net cups on top of the media. This method is sometimes recommended if vegetable seeds are accessible because it avoids the transplant shock during replanting.

Figure 2: Fish tank and concrete blocks placement





When harvesting, be sure to remove the whole plant, including roots and dead leaves, from the canal. After harvest, the rafts should be cleaned but not left to dry so as to avoid killing the nitrifying bacteria on the submerged surface of the raft.

Large-scale units should clean the rafts with water to remove dirt and plant residues and immediately repositioned in the canals to avoid any stress to the nitrifying bacteria.

3. Step by Step guide to constructing a DWC unit

3.1 Preparing the fish tank

Please follow the same procedures described in the TECA Media Bed Aquaponic Unit (Section 1 and 2).

3.2 Preparing the mechanical separator and biofilter

Please follow the same procedures described in the TECA Nutrient Film Technique (Section 1-4).

3.3 Making three DWC canals from two IBC Tanks

Please follow the same procedures described in the TECA Media Bed Aquaponic Unit (Section 4)

3.4 Initial steps in building a DWC system

Follow the steps contained in the previous sections to set up the fish tank, the mechanical separator, the biofilter and three DWC canals from two IBCs. Once completed, proceed to assemble the DWC canals. For the DWC system, the cut IBC bed used as a sump tank in the media bed unit can be used as the forth canal. Extra blocks and plumbing are required to install the forth canal.

3.5 Assembling the DWC canals

Place the concrete blocks according to the distances described in Figure 11.2:1a. The fish tank should be raised up about 15 cm; do so by using concrete blocks. Then, place the three grow beds (including the metal support frames) on top of the blocks as shown in Figure 2:1b. (Make sure the grow beds are secure on top of the blocks. If not, slightly adjust the layout of the blocks underneath).

3.6 Preparing the drainage pipes into the biofilter

The following materials are needed to make three drainage pipe units:

Figure 3: Drilling location on the barrel





- 24 cm of PVC pipe (25 mm) x 3;
- Barrel connectors (25 mm) x 3;
- PVC adaptor, female (1 inch – 25 mm) x 3;
- PVC elbow, female (1 inch – 25 mm) x 1;
- PVC T-connector (25 mm – 1 inch [female] – 25 mm); and
- Rubber washer (25 mm).

Take each DWC canal and mark their centre points at the bottom of the canal. Drill a 25 mm diameter hole at each centre point and insert the 25 mm barrel connector (25 mm) with the rubber washer placed

inside the grow bed. Tighten both sides of the connector using a wrench (see Figures 3: 2-4). Screw the PVC adaptor, female (1 inch – 25 mm) on to the barrel connector (25 mm) inside the tanks and then slot the standpipe into the adapter. Make sure to cut five longitudinal slots on the upper end of the standpipe to prevent the pipe from clogging (Figures 4: 5–6).

Next, connect the PVC elbow, female (25 mm – 1 inch) to the end of the barrel connector underneath the DWC

Figure 4: PVC adapter connected to the barrel connector

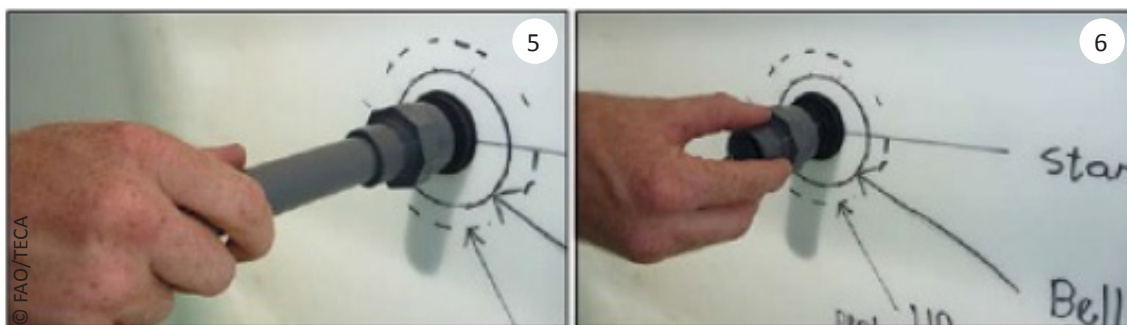


Figure 5: PVC elbow connection

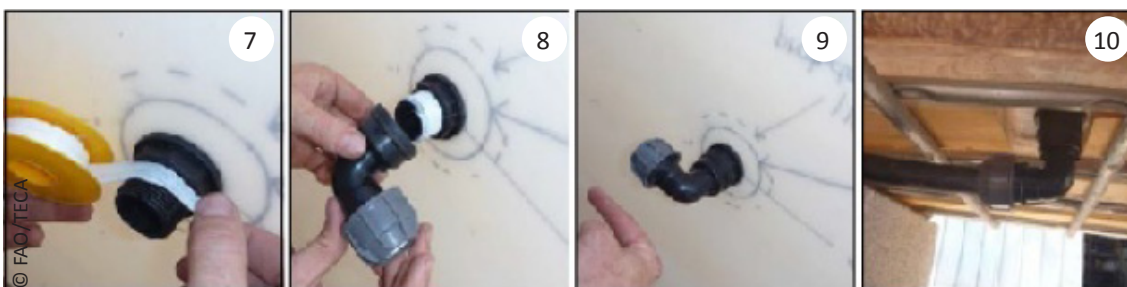


Figure 6: Connection between canals A, B and C

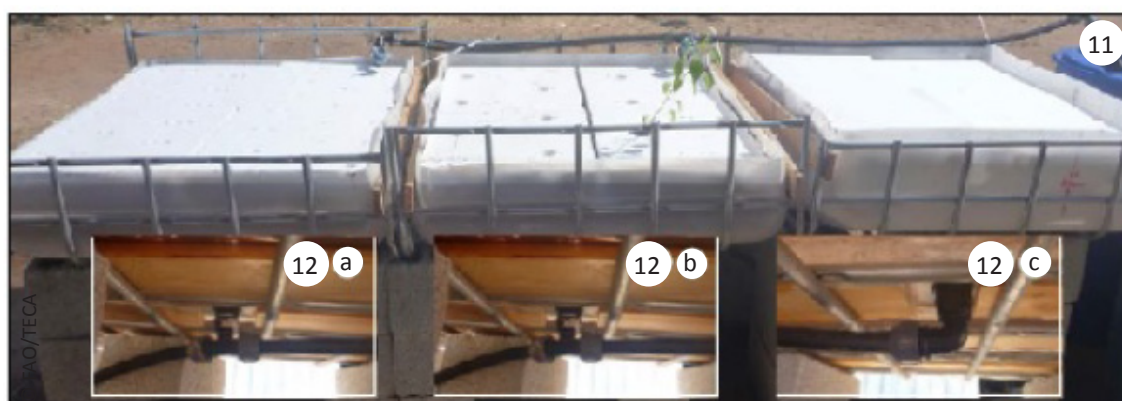




Figure 7: Connections between the tanks

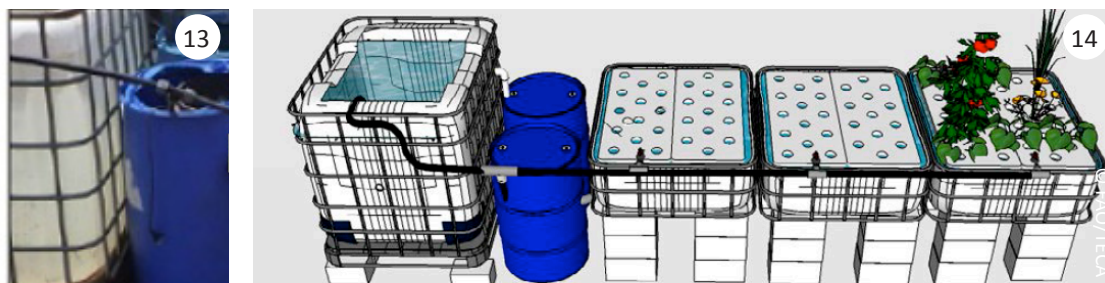


Figure 8: the Submersible pump is placed at the bottom of the biofilter barrel



Figure 9: T-connector

canal that is farthest from the fish tank (Figures 5: 7–10). Then fix the remaining two PVC T-connectors (25 mm – 1 inch [female] – 25 mm) to the barrel connectors underneath the other two canals.

Take three pieces, every 1 m in length, of PVC pipe (25 mm) and connect the elbow to the two T-connectors underneath the canals (Figures 6: 11–12).

Finally, drill a 25 mm hole into the side of the biofilter barrel using the circular drill bit at least 15 cm below the standpipe height in the canals and insert a barrel connector (1 inch) in it. Then, connect a PVC elbow (25 mm – 1 inch) to the barrel connector and then take one more piece of PVC pipe (25 mm) and connect the PVC elbow (25 mm – 1 inch) where it exits the biofilter to the final T-connector underneath the tank A and slot the other into the 25 mm hole in the biofilter (Figures 7: 13–14).



3.7 Adding the submersible pump

For this unit, the submersible pump is placed at the bottom of the biofilter barrel (Figures 8: 15–16). Water is pumped from there into two locations: the three DWC canals and the fish tank. 80 percent of the water flows to the fish tank while 20 percent flows into the plant canals. The taps are used to control the water flow at each location (Figure 9: 17).



Figure 10: T-connector connecting the fish tank with the canal



Figure 11: Water flow into each canal

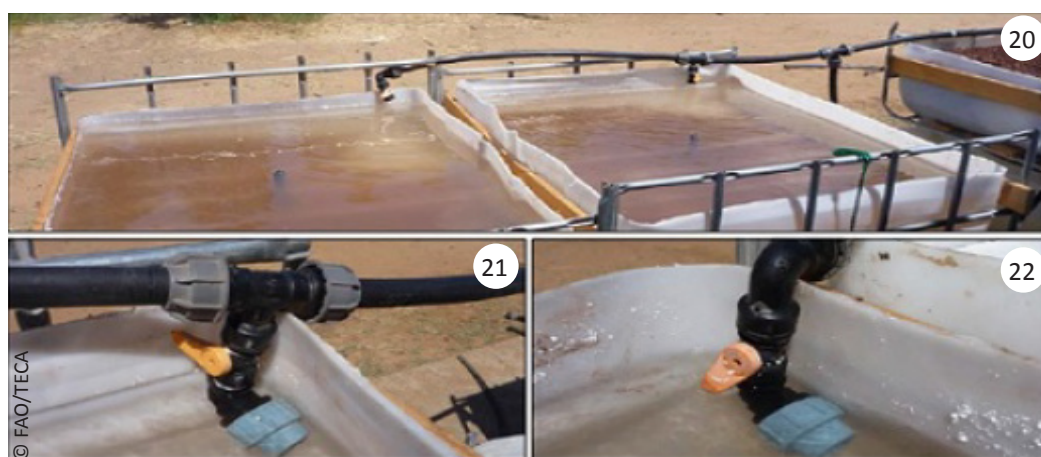
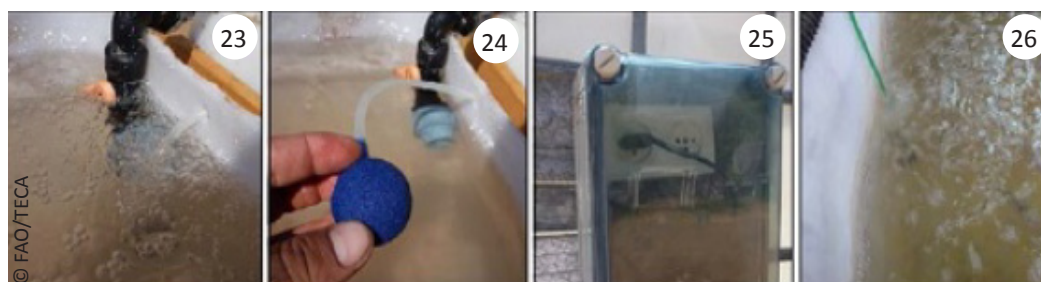


Figure 12: Connect the pipes to the metal frame with plastic cable ties





3.8 Pumping to the fish tank and DWC canals

Connect the submersible pump to a length of polyethylene pipe (25 mm) pipe length using an adaptor (1 inch female – 25 mm), or any other connection that fits the pump. The pipe should be at least 1 m long. Place a T-connection (25 mm) at the end of the pipe allowing water to flow to the fish tank and the canals (Figure 10: 18). Attach a pipe (25 mm) to one end of the T-connection long enough to reach the fish tank. Use flexible pipe if possible as this removes the need for elbow connections, which reduce the pumping capacity of the pump

(Figure 10: 19). Attach a tap (25 mm) to the end of the pipe to control the water flow into the fish tank. Next, take about 3.5 m of polyethylene pipe (25 mm) and attach one end to the remaining exit of the T-connection (25 mm) coming from the pump in the biofilter. Then, take the 3.5 m pipe and lay it along the DWC canals. At each canal, add a T-connector (25 mm – three-quarter inch – 25 mm), a tap (three-quarter inch male – three-quarter inch female), and a PVC elbow (25 mm – inch male) allowing water to flow into each canal at an angle (Figures 11: 20–22). At the final canal furthest from the fish tank using a PVC elbow (25 mm – three-quarter inch

Figure 13: Planting hole size

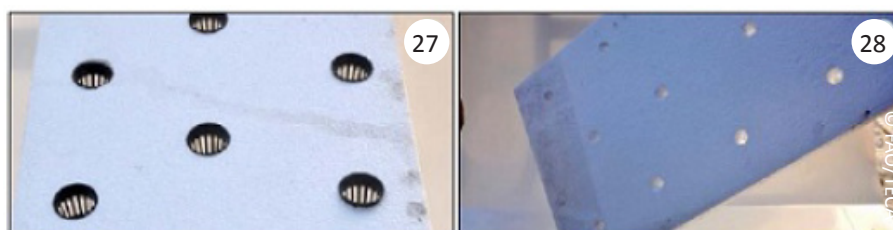
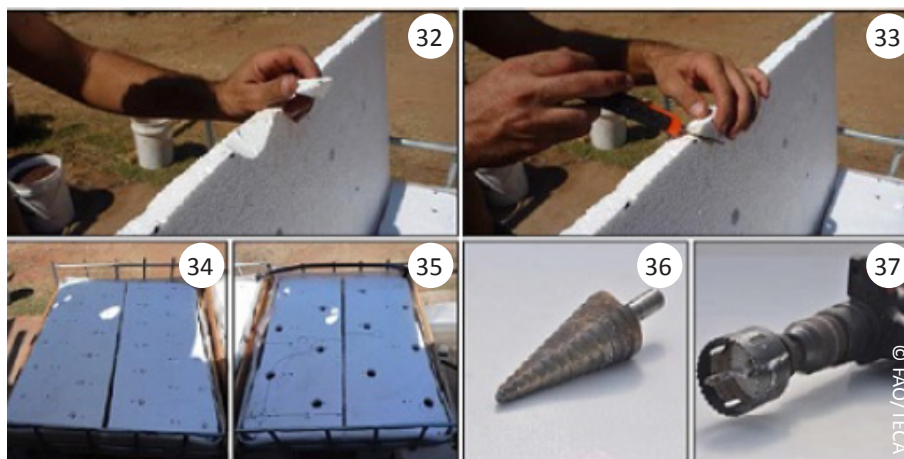


Figure 14: Polystyrene cutting and placement



Figure 15: Plant holes preparation





female) instead of the T-connector. Be sure to secure the pipes to the metal frame by means of plastic cable ties.

3.9 Installing the air pump and stones

For this unit, the air pump is used to integrate air into the DWC canals. The air pump should be placed into a protected box at the highest point in the system (ideally attached to the side of the fish tank) (Figure 12: 25).

Take 4 to 6 m of 8 mm air pipe. Attach one end to the air pump and lay the rest of the 8 mm pipe along the side of all the DWC canals. On each tank, drill an 8 mm hole just

below (1 to 2 cm) the top and slot the 8 mm pipe into each hole.

Attach the air stones to the 8 mm pipe and place them next to the inlet water stream to ensure full oxygen saturation in the canal. Repeat the same air pipe connection for the fish tank (Figures 12: 23, 24 and 26).

3.10 Making the rafts

- Key principles and rules of thumb for making the polystyrene rafts: All water in the canals should be fully covered (no exposure to light).
- Choose polystyrene sheets that are at least 3 cm thick to hold the weight of the

Figure 16: Fish tank filled with water



Figure 17: Secure pipes with plastic cable





Figure 18: Planting process with cups

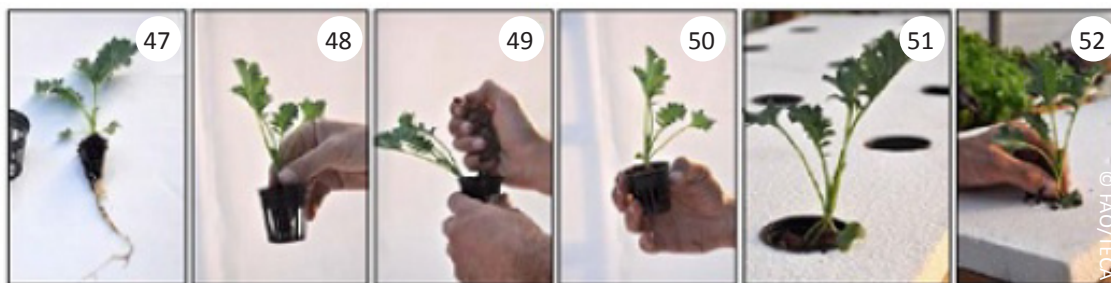


Figure 19: Finished system



vegetables.

- The polystyrene must not release any toxins to the water (make sure it is safe for food production or food-grade quality). Painted plywood can also be used.
- Plant hole sizes and spacing are dependent on the type of vegetables to be planted.
- The planting hole size can range from 16 mm (for planting seedlings directly into the rafts without cups (Figure 13: 28)) to 30 mm. This depends on the size of the net cups available (Figure 13: 27).

Place the polystyrene on top of the DWC canals and mark the edge lines. With a knife, cut the outline of the canal (Figures 14: 29–31). Drill the plant holes

(Figures 15: 34–35) using a circular drill bit (Figures 15: 36–37). Along with planting holes, make sure to cut one hole for the standpipe of each canal (Figures 15: 32–33).

3.11 Final checks

Once all parts of the system are in place, fill the fish tank, both filters and DWC canals (Figures 16: 38–43) with water and run the pump to check for any leaks in the system. If leaks appear, fix them immediately where they arise by:

- tightening the plumbing connections;
- checking all uniseals and taps for both filters;
- reapplying Teflon to threaded connections; and
- making sure all valves are in their ideal position.



Secure all the remaining pipes with plastic cable ties (Figures 17: 45–46).

Finally, check the flow rates of the water flowing into each DWC canal. Knowing that the volume of each canal is about 300 litres, the ideal flow rate for each canal should be 75 to 300 litres per hour.

Water inflow can be measured by using a stopwatch and an empty 1-litre plastic bottle (Figure 17: 44). At 75 litres/hour the 1-litre bottle should fill up in 48 seconds, at 300 litres/hour in 12 seconds.

Once all the leaks are fixed, and the water is flowing through all components of the unit, begin cycling the unit by using ammonia to stimulate nitrifying bacteria colonization.

Planting process with (Figures 18: 47–51) and without cups (Figure 18: 52).

This technology is part of a series on other TECA technologies and practices about Aquaponic units:

- Designing an Aquaponic unit (FAO-TECA ID 8350);
- Media Bed Aquaponic Unit – Step by Step

Description (FAO-TECA ID 8395);

- Nutrient Film Aquaponic Unit – Step by Step Description (FAO-TECA ID 8396); and
- Management of the Aquaponic Systems (FAO-TECA ID 8398).

4. Further reading

- FAO. 2014. Small-scale aquaponic food production - Integrated fish and plant farming. <http://www.fao.org/3/a-i4021e.pdf>
- FAO. 2015. 7 rules-of-thumb to follow in aquaponics. <http://www.fao.org/zhc/detail-events/en/c/320156/>

5. Agro-ecological zones

- Tropics, warm
- Tropics, cool/cold/very cold