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YIIFSWA-II
Yams for Livelihoods

Manual for seed yam production in hydroponics system

Morufat Balogun, Norbert Maroya,
Beatrice Aighewi and Djana Mignouna

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Cover: Fully developed yam in Hydroponics at Nwabudo Seeds Ltd, Umuahia, Nigeria

Contents

Acronyms

BS	Breeder Seed
CS	Certified Seed
DSH	Drip System Hydroponics
EC	Electrical conductivity
FS	Foundation Seed
HS	Hydroponics System
NT	Nutrient Temperature
pH	Hydrogen Ion concentration
SNVC	Single node vine cuttings
SH	Screenhouse
TDS	Total Dissolved Solutes
TIBS	Temporary Immersion Bioreactor System
YIIFSWA-II	Yam Improvement for Income and Food Security in West Africa (Phase 2)

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Introduction

The purpose of this manual is to make available an instructional document for setting up a low-cost HS for the production of seed yam. Depending upon the budget constraint and intentions of the user, this system can be scaled-up or scaled-down in terms of the amounts of materials technology (Appendix 1 & 2) and automation used.

Hydroponics is from the Greek word 'hydro' meaning 'water' and 'ponos' meaning 'labor'. This definition is broad and is synonymous with soilless culture: plant cultivation in only water containing nutrient, or any inert substrate (gravel, vermiculite, perlite, and rockwool). Therefore, the HS achieves target nutrient levels in foods, product is free of harmful chemicals and pesticides in routine soil culture, and does not impact the environment negatively. Among several numerous types of HS available, the YIIFSWA II project has standardized the DSH for seed yam production. This type uses drip lines to irrigate or fertigate the plants. The system harnesses and consolidates on the novel high ratio propagation technologies developed in YIIFSWA and YIIFSWA II, including tissue culture (Balogun et al., 2017, 2018, 2020), aeroponics (Maroya et al., 2017), and single-node vine cuttings to generate clean stock plantlets and scale- up their propagation *in vitro* and *ex vitro* (Aighewi et al., 2015). All classes of seed yam can be produced using HS depending on what was initially planted. This ranges from Breeder to Foundation to Certified seed.

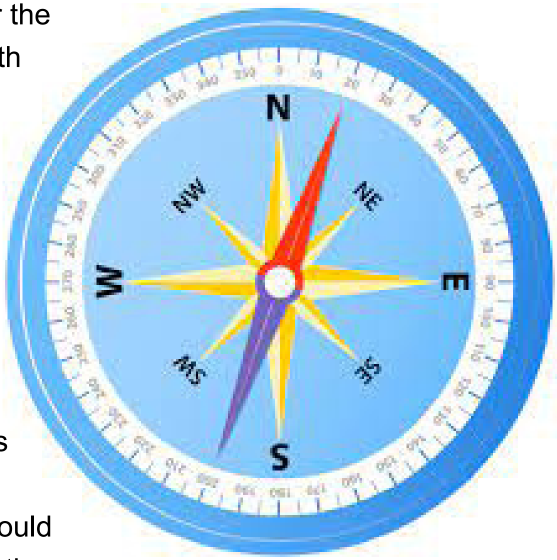
Fertilizers are very important for the plants because they are the sources of substances that contain plant nutrients (Appendix 3) such as Nitrogen (N), Phosphorus (P), and Potassium (K) facilitating the plants growth. Fertigation is the injection of calculated amount of fertilizers used for soil amendments, water amendments, and other water-soluble products into an irrigation system. Fertigation is related to chemigation, the injection of chemicals into an irrigation system.

The last general meeting with all the YIIFSWA-II project partners operating in Nigeria was held on 7 May 2021 through the Microsoft Teams under the leadership of Dr Lawrence Kent of the Bill and Melinda Gates Foundation. During the meeting, we were all informed by Context Global Development, in collaboration with their consultant Sakina, that they are developing a blended liquid fertilizer that will be used for seed yam production in HS. This blended fertilizer will be available before the end of the project. It will be a very good development to facilitate the use of fertilizers by the private seed companies. To accelerate this process, Taskforce No 4 (headed by Mark Nelson and composed of Jason Nickerson, Norbert Maroya, and Beatrice Aighewi) was established. Pending the successful finalization and availability of the blended liquid fertilizer, we are proposing in this manual the use of the current nutrients, individually weighed in a combination of seven different fertilizers and one source of micronutrients (Appendix 3-6). These fertilizers have effectively and efficiently worked for the hydroponics in YIIFSWA-II Project since 2018 up to date.

Location and orientation for your DSH

Your choice of location for your DSH depends on the class of seed you plan to produce. Early generation seed (Breeder and Foundation) will do well in an aphid-proof SH, while a home garden or field (isolated from other yam crops) is fine for certified seeds.

Although it is good for the SH to be oriented north to south (NS) – from the back of the SH to the front – to allow good lighting by the east-west solar radiation, this will not hold where heat is a challenge. If the breeze is strong, trees should be planted as wind breakers and should be located away from the strong direction of the wind. It should also be well-spaced away from other buildings allowing it to receive sufficient breeze. A tunnel SH design is usually too hot for the West African environment. A roselle design is good and will allow good ventilations. However, it is necessary to install air cooling systems or vents for better cooling.



The SH should have a changing room/section, foot-dips, greenhouse coat hangers, and preferably with wash hand basins having hand sanitizers. It can be placed inside (at the center or on the side) of the SH.

Factors that affect the fertigation in HS include the quality of ***water to use for the nutrient solution and the type and composition of substrate used in the HS. In terms of water quality, the specific factors are:***

- **pH of the water available (acidic or basic) for use in the nutrient preparation in tank**

  The pH is the measure of the activity of hydrogen ion (H+). The normal range of surface water pH ranged from 6.5 to 8.5 and for ground water is 6.0 to 8.5. Water with pH below 7 is considered acidic water and water with pH above 7 is considered basic water.

- **Electrical conductivity of water**

  The EC of a water is the measure of its capacity to conduct electricity. The unit on conductivity is Siemens per meter (S/m) or micron Siemens per centimeter (µS/cm). Drinking water has an EC between 200-800 µS/cm and rainwater has an EC between 2 -100 µS/cm.

- **Composition of some key mineral elements in water**

  The quantity of mineral elements, such as Calcium (Ca), Magnesium (Mg), Sodium (Na), K, Iron (Fe), etc. can affect the types and quantities of fertilizers to use in preparing the nutrient solution.

Any material that provides support to the plants can serve as substrate. The less nutrient-rich, the more the nutrients reaching the plants can be standardized as prepared by you. Examples include cocopeat, perlite, rice husk, river sand, carbonized rice husk, and composted rice husk variously combined and used in hydroponics by IITA. For nutrient-rich substrates, the added fertilization should be reduced (e.g. composted rice husk). However, the substrate should be chemically analyzed to know the profile of nutrients available in it to determine the required external addition of nutrients for a specific situation.

Step by step procedures

Installing plant troughs

These can be wooden troughs or plastic basins preferably rectangular or buckets (Plate 2.1). For the wood:

1. Construct a metal stand of 1.5 m (B) x 3 m (L) x 1m (H).
2. Construct wooden troughs of 1.5 m (B) x3 m (L) 0.3 m (depth).
3. Make one drainage hole at the bottom of each trough following the slope of the ground (Plate 2.2).
4. At the top of the troughs, add 1.5-2 m long wooden frame to serve as stakes support for the yam plants.
5. Put the wooden trough on the metal stands.
6. Allow at least 0.4 m space around each trough so plants can be reached from any direction.
7. A 24 m x 8m SH can house eight wooden troughs with at least 0.5 m around each trough.
8. Line with plastic tarpaulin sheets to create a water-proof barrier at the bottom and sides (Plate 2.3).
9. Name or label each trough or bucket (A, B, C, D, E, etc.)
10. Construct an office/nutrient preparation room 2 m x 4 m space housing a table and chair for placing items like logbooks, pH meters, thermometers, data loggers, weighing balances, fertilizer bags, and tape for well-known water.

Plate 2.1. Plastic buckets arranged for use in HS.

Plate 2.2. Bottom drainage in HS trough.

Plate 2.3 Wooden troughs lined with tarpaulin.

Installing irrigation and fertigation lines	
1. Construct steel structure scaffold stand (2 m (L) x 2 m (B) x 3 m (H)) and locate inside or outside the SH (Plate 2.4). 2. Obtain two water reservoirs (330 L water and 1000 L nutrient capacity). 3. Commit one to water for irrigation and the second one for nutrient (fertigation). 4. Purchase drip irrigation tapes with specified spacing, 10 cm within rows (companies can customize for you). 5. You will need a plumber to install the line for you to connect to the reservoirs using PVC connectors with valves, PVC pipes, end caps, elbows, T-joint, air valve, and gum (Appendix 1). 6. The plants can be gravity-fed if the water reservoir is high enough (4-5 m higher than the plants) to give the desired pressure. Otherwise, 1 hp pump will efficiently feed the plants. 7. Connect the 1 hp pump to the two reservoirs and to the drip lines to provide enough pressure in the emitters. 8. It is best that each plant has its own drip point, so your tape spacing should be equal to your plant spacing. 9. Lay the drip lines 15 cm apart in rows. 10. Brace the drip lines mid-length of the trough with wood to prevent sagging (Plate 2.5). 11. Note the volume delivered per unit time per drip emitter provided by the manufacturer.	 Plate 2.4. Scaffold with reservoirs for water and nutrient solutions.  Plate 2.5 HS troughs with installed drip lines.

Substrate preparation

1. Determine the volume of your container using L X B X H or by measuring water into it.
2. The volume of substrate should cover up to two-thirds of the volume of the container.

Cocopeat

1. Buy washed and buffered cocopeat (manufacturer-certified that pH is 6-7, EC <1.0ms/cm) (Plate 2.6).
2. If EC is below 0.5 mS/cm or lower, then the coir does not have to be buffered.
3. To buffer yourself, block the drain off of the trough.
4. Dissolve 1.6 kg Calcium Nitrate in 200 L water for 15 blocks of cocopeat for 450 L capacity trough.
5. Drench in the buffering solution for 24 hours for the buffer to take full effect and for optimum results.
6. Rinse the cocopeat two times by letting all the water run-off to get the buffered cocopeat.
7. Increase aeration by mixing with 20 L perlite (Plate 2.7) for 15 blocks of cocopeat.
8. Disinfect by drenching in 40 g Mancozeb and 22.8 ml Cypermethrin for each block of cocopeat for 24 hours (Plate 2.8). One percent sodium hypochlorite (one volume of commercial bleach in 2.5 volumes of water) can also be used, especially if reusing the cocopeat for the second time.
9. In the trough, flush with pH-adjusted nutrient solution three times and drain for 24 hours before planting.

Plate 2.6. Cocopeat blocks.

Plate 2.7. Perlite.

Plate 2.8. Disinfection of HS substrate.

Composted rice husk

(The hard protecting covering of rice grains, which can be obtained from local rice mills)

1. The powdery rice husk is best.
2. Arrange rice husk in heaps of about 1 m high or as convenient.
3. Wet the heap of rice husk thoroughly with water to facilitate the fermentation process.
4. Cover the heap and allow the temperature within the pile of rice husk to rise. The temperature in the middle of the heap will rise rapidly and peak at 68-70^{o}C in four to five days before dropping to ambient conditions.
5. Add water to rice husk and mix the husk well every four days ensuring that those at the outer parts of the old heap get into the middle of the new one.
6. Continue the curing process until the temperature within the heap stabilizers at about 24^{o}C even after turning in the rice husk.
7. If there is a possibility of having obnoxious weed seeds mixed with the rice husk, steam sterilization should be done.
8. At the end of the process, cover the rice husk during the rainy season to prevent leaching or bag and store for later use.
9. Plant seedlings in HS troughs containing compost rice husk (Plate 2.9 & 2.10).

Plate 2.9. Cuttings freshly planted in rice husk.

Plate 2.10. Plants growing in rice husk substrate.

River Sand

1. Sand has no mineral nutrients, no buffering capacity or CEC.
2. Source sharp river sand from a stream (Plate 2.11).
3. Sieve sand to remove large particles of stone and dirt.
4. Wash under running water to further remove dirt.
5. Disinfect the sand by soaking in 0.5% percent (5000 ppm) sodium hypochlorite (NaOCl) for 10 minutes.
6. Rinse five to six times with water to remove NaOCl residues.
7. Put on a raised rack with holes to allow the sand to drain for 24 hours before use.
8. Plant vine seedlings as for earlier substrates (Plate 2.11, 2.12 & 2.13)

To prepare NaOCl solution

- Sodium hypochlorite is contained in household bleach (3.5 percent per volume).
- To get 0.5 percent NaOCl: For each liter of household bleach that contains 3.5 percent NaOCl, add 7 L of water to get a solution with 5000 ppm of NaOCl.

Plate 2.11. Sharp sand from a river.

Plate 2.12. Freshly planted cuttings in sand (sandponics).

Plate 2.13. Plants growing in sand.

Carbonized rice husk

Carbonized rice husk is obtained with the incomplete burning of rice husk. It is a very good media, which makes pulling out of the seedlings for transplanting easy, increases carbon content, and creates an initial porosity in the substrate.

Complete carbonization gives ashed rice husk which is also a good substrate.

1. Make a chimney-like metal.
2. Start a small fire with coal and put the carbonizer on top of the fire.
3. Pour rice husk to cover the carbonizer from outside (Plate 2.14).
4. Throw coal into the carbonizer as needed through the metal pipe to keep the fire burning.
5. When all of the rice husk has turned black, remove the carbonizer.
6. Allow cooling for 24 hours before use (Plate 2.15).
7. It does not require sterilization at first use.

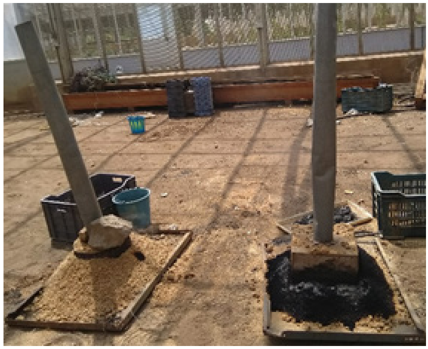


Plate 2.14. Carbonization of rice husk.

Plate 2.15. Carbonized rice husk.

Nutrient preparation

1. Purchase your nutrients from reliable sources (Appendix 8).
2. Check that nutrients have not passed the expiry date.
3. Do not store nutrients in the SH, but in a storeroom with temperature not higher than 27°C.

4. It is good if you can get a master-blend or composite, otherwise measure individually (Appendix 3).
5. Prepare fresh nutrient every 1-2 weeks as it should not be stored for a long time.
6. Wear disposable gloves when preparing nutrients or handling plants.
7. Take pH of the water before adding nutrients.
8. Ensure the spirit level of balances are reached before weighing.
9. Ensure all weighing bowls are clean and dry before use.
10. Ensure that labels on each trough (variety, planting date, seed class to be harvested, plant population, and trough label) are clear. If not, re-label using a permanent marker.
11. Label the bowls for each nutrient and always weigh the nutrients into the labelled bowl.
12. Dissolve each nutrient component separately.
13. Use strainer when pouring dissolved nutrient into the nutrient reservoir to avoid particles from entering the solution. Wash strainer before and after each use.
14. Pour stock solution as recommended into reservoir and mix the solution with a clean plastic pipe. Make up to final volume.
15. Record substrate and SH temperature every morning, mid-day, and evening (fixed time daily).
16. Dissolve all nutrients (Appendix 4) completely .
17. Never feed the plants with nutrient having pH below 5.
18. EC of nutrient mix should range from 800 to 2000 µS/cm to favor the plants.
19. Take pH, TDS, EC of nutrient solution, and the drain-off from substrate every day and record in a logbook.
20. Alert and review in case of extremes.

Planting and general maintenance

1. Sanitize your hands with 70 percent alcohol and put on sterile gloves and nose masks.
2. Wear SH overall.
3. Listen to the sound of the pumps when working to detect irregularities.
4. Check that the drip emitters are in place in the troughs; delivering solution not burst, leaking, or blocked.
5. Clean troughs (lined with tarpaulin) before any major planting operation with one percent hydrogen peroxide or 15 percent commercial bleach.
6. Use forefinger to make 2.5 cm deep holes at 10 cm intervals on the prepared, disinfected substrate (Plate 2.16).
7. Select and carefully transplant vigorous, clean seedlings of desired class (Breeder or Foundation) and plant in the holes made (Plate 2.17).
8. If planting mini-tubers, pre-sprout in carbonized rice husk at room temperature (Plate 2.18).
9. Fertigate after planting by switching on the pump for a pre-determined duration.
10. Insert sprouted mini-tubers into holes made and fertigate as scheduled.

Plate 2.16. HS substrate with holes ready for planting.

Plate 2.17. Planting in HS.

Plate 2.18. Pre-sprouted mini-tubers for planting in HS.

11. Run hydrogen peroxide solution every two weeks through the system by adding 800 ml of 30 percent hydrogen peroxide into 400 L of nutrient in reservoir and irrigate for the same duration to clean the drip lines.
12. Put up twines as stakes for each plant and direct young plants to twines as they grow (Plate 2.19, 2.20 & 2.21).
13. Clean the tarpaulin edges with 70 percent alcohol (7 L of water made up to 10 L with water) every week.
14. Check the plants for mealybugs every morning and evening.
15. If mealybugs are found, spray plants with Ampligo (100g/L Chlorantraniliprole, 50g/L lambda -cyalothrin). Use a 15ml sachet of Ampligo in 20 L of water in a knapsack sprayer. The 20 L should be divided into three and applied to one trough containing 150-200 plants.
16. Prepare and hang a fertigation/irrigation chart in the SH or on each trough.
17. Charts should be marked by a responsible personnel when fertigation is done (Appendix 7).
18. Fumigate SH every two weeks.

Plate 2.19. Trellising yam growing in HS.

Plate 2.20. HS substrate with holes ready for planting.

19. Hang a fumigation schedule (Appendix 8) and tick when done. Spraying should be in the evening (from 4 pm).
20. Hang insect traps on each trough to indicate level of insect presence in the SH.
21. No food items are allowed in the SH.
22. Keep entrance door locked and never open the two doors at the same time.

Plate 2.21. Planting in HS.

Harvesting from hydroponics

1. You can harvest both vines and tubers after 12 weeks and 20 weeks, respectively.
2. For vine harvesting, tag vigorous, apparently clean and non-symptomatic plants
3. Cut single node vines in the morning or late in the evening.
4. Root in topsoil (heat-sterilized if Breeder) or coco peat + perlite in trays or nursery bags or pots.
5. Irrigate with water or fertigate with nutrient, as needed.
6. The seedlings should be ready for field or planting in bigger pot after four to six weeks (Plate 2.22).
7. Do not irrigate two days before harvesting tubers.
8. Carefully dig out the tubers and place on top of the substrate to air-dry for two days (Plate 2.23).
9. Treat with Mancozeb (7 g) and Karate (2 ml) per liter of water and allow to air dry.
10. Store in the cold room at 16-18oC.
11. To initiate sprouting, move into room temperature storage six to eight weeks before required planting.

Plate 2.22. Vine cut from HS and rooted in trays

Plate 2.23. Tubers harvested from HS.

Appendices

Appendix 1. Materials needed for the installation of 10 pieces of wooden troughs

S/N	Drip system hydroponic system with plywood	Qantity
1	¾ Threaded elbow	25
2	¾ Threaded nipple	10
3	1"X ¾" threaded r/socket	5
4	¾ Threaded union connector	10
5	1" Threaded plug	5
6	1" Threaded nipple	5
7	1" Hp pedrollo pump machine	2
8	1000 Liter tank	1
9	4000 Liter tank	1
10	1" Threaded foot valve	10
11	1" Threaded union connector	10
12	¾ Threaded pipe	17
13	¾ Iron stock cock	5
14	¾ Threaded tape	10
15	4" Pvc pipe	2
16	4" Pvc plain elbow	3
17	2" Pvc pipe	1
18	2" Pvc plain elbow	5
19	Plumber putty	1
20	Abro gum	2
21	Silicon sealant	1

	Iron stands for trough	
S/n	Materials	Quantity
1	2" X 2 " angle iron	68 Length
2	Cutting disc	5 Pcs
3	Grinding disc	2 Pcs
4	Electrode	2 Packet
	Metal scaffold for storex tanks	
S/n	Materials	Quantity
1	3"X3" angle iron	3 Length
2	2" Galvanize pipe	1 Length
3	1 ½ Galvanize pipe	2 Length
4	Electrode g10	1 Packet
5	Cutting disc	3 Pcs
6	1" X 1" galvanize mesh	1 Sheet

Appendix 2. Sources of hydroponics supplies

Some contacts to points-of-sale for materials for PBT production

Region	Address
Africa	**Farmsquare** Bola-Ige Junction, Off Liberty Road, Ibadan, +2348135196537 info@farmsquare.ng **JubailiAgrotec** **Nigeria:** Industrial Area 1 and Ext, Cadastral Zone: C16, Plot no. 918 Idu, +2348128600001 Gh**ana**: Nkoransa Off Obuasi Road, Near Friends Eye Clinic, Kumasi Mobile: +233540121225 **Afri-Agri products Ltd** 4 Metal Box Road Ogba Industrial Scheme Ikeja, Lagos, +2349090402800 Welcome to Afri Agri Products Ltd. | Afri Agri (afri-agri.com) **AgriTropic** No.7A Niger street Malam Kato park, Kano, Nigeria. +2348034149810 www.agritropicnig.com **Dizengoff** Dizengoff House Plot 328, Block 12 Ogunusi Road, Omole Housing Estate, Phase 1, Lagos www.baltoncp.com/nigeria/ No. 2 Feo Eyeo Street North Industrial Area P. O. Box 3403, Accrawww.baltoncp.com/ghana/
Outside Africa	www.hortamericas.org http://www.greenhousemegastore.com/category/flats-trays-inserts http://www.duboisag.com/

Appendix 3. Types of fertilizers needed for mother plants growth in hydroponics troughs

The seven types of fertilizers and micronutrients used constantly by IITA for mother plants production in hydroponics system are listed below.

- Three types of nitrogen fertilizers
  1. Ammonium Nitrate (NH_4NO_3) prohibited in Nigeria
  2. Calcium Nitrate ($Ca(NO_3)_2$)
  3. Potassium Nitrate (KNO_3)
- Three types of potassium fertilizers (including Potassium Nitrate cited in Nitrogen fertilizers)
  1. Potassium Sulphate (K_2SO_4)
  2. Potassium Phosphate (KH_2PO_4)
- Two types of phosphorous fertilizers (incl. Potassium Phosphate cited in Potassium fertilizers)
  1. Triple Super Phosphate
- One type of Magnesium fertilizer
  1. Magnesium Sulphate ($MgSO_4$)
- Micro-nutrients fertilizer
  1. Terratiga Chelate Mix

Appendix 4. Quantity and calculation of dosage needed for each type of fertilizer for hydroponics

Below, the fertilizers are arranged by source of nutrient (N, P, K) and the calculation of the weight is given per 200 L of water. The formula of each fertilizer corresponds to a weight. Below is a step-by-step calculation of the molecular weight of the fertilizer using the formula and the milliequivalents per liter (me/l).

1. Ammonium Nitrate $\{NH_4NO_3\}$: N=14; H=1 O=16

   14+(1x4) +14+(16x3) =14+4+14+48= 80g

2. Potassium Nitrate $\{KNO_3\}$: K=39; N=14; O=16

   39 +14 +(16x3) = 39+14+48= 101g

3. Triple Super Phosphate $Ca\{H_2(PO_4)\}_2$: Ca = 40; H=1; P=31; O=16

   40 + {(1x2) +31+(16x4)}x 2 = 40+{2+31+64}x2
   = 40+(97x2) = 40+194=234g .

In this formula you have two times PO_4 then the molecular mass for one PO_4 is 234g/2=117g.

What is the me/l of Potassium Sulphate (K_2SO_4): ?

Conversion of molecular weight in milliequivalents per liter (me/l): A unit for expressing the concentration of chemical constituents in terms of the interacting values of the electrically charged particles or ions in solution.

The milliequivalent of the fertilizers molecular weight are calculated as:
Ammonium Nitrate $\{NH_4NO_3\}$ = 80g/1000=0.08 me/l (g)
Potassium Nitrate $\{KNO_3\}$ =101g/1000 = 0.101me/l (g)
Triple Super Phosphate $Ca\{H_2(PO_4)\}_2$ = 117g/1000=0117me/l (g)

Appendix 5a. Table of milliequivalent per liter of the fertilizers used

Nitrogen (N)	1me/l (g)
Ammonium Nitrate	0.08
Potassium Nitrate	0.101
Calcium Nitrate	0.118

Phosphorus (P)	1me/l
Mono Potassium Phosphate	0.136
Triple super phosphate	0.117

Potassium (K)	1me/l
Potassium sulfate	0.087
Potassium Nitrate	0.101
Mono Potassium Phosphate	0.136

Magnesium	1me/l
Magnesium Sulfate	0.247

Appendix 5b.

S/N	Fertilizers used in Hydroponics by IITA	Quantity (grams)	Me/l weight	Me/l used	Quantity of each nutrient (type of fertilizer) in 200 l
1	Ammonium Nitrate – {NH_4NO_3}	8	0.08 g	0.5 me/l	0.08 x 0.5 x 200 = 8 g
2	Calcium Nitrate – {$Ca(NO_3)_2$}	47.2	0.118 g	2 me/l	0.118g x 2 x 200 =47.2g
3	Potassium Nitrate {KNO_3}	46.46	0.101 g	2.3 me/l	0.101g x 2.3 x 200 = 46.46g
4	Potassium sulphate – {K_2SO_4}	55.68	0.087 g	3.2 me/l	0.087g x 3.2 x 200= 55.68g
5	Potassium Phosphate {KH_2PO_4}	39.44	0.136 g	1.45 me/l	0.136g x 1.45 x 200 = 39.44 g
6	Triple Super Phosphate – TSP	11.70	0.117 g	0.5 me/l	0.117 g x 0.5 x 800 = 11.7g
7	Magnesium Sulphate {$MgSO_4$}	12.35	0.247 g	0.25 me/l	0.247 g x 0.25 x 800 = 12.35 g
8	Terratiga Chelate	5	Fe (7,15%), Mn (3.22%), B (1.58%), Zn (1.28%); Cu (0.3%)		

Notes: These critical and specific calculations have helped to maintain the pH of the nutrient solution between 6.5 to 5.5 from the beginning up to finishing the solution. That is what allows you to know the quantity of fertilizers to use.

- *Ammonium nitrate was used to have NO_4 instead of NO_3 only. In case there is no Ammonium Nitrate (case of Nigeria), it is possible to have NO_4 by using Ammonium Phosphate NH_4PO_3 or Ammonium Sulphate $(NH_4)_2S0_4$)*

These quantities can vary with the water composition of some locations. It is good to start with some quantities below the one listed and appreciate the performance of the plants.

Appendix 6. Fertigation and irrigation scheduling

Fertigation and irrigation regimes are location-specific due to different weather conditions.

To maintain a proper watering regime, information on the monthly temperature and humidity range of your environment must be obtained. This will determine how 'thirsty' your plants will be or how quickly your substrate becomes 'dry' and requires water. Yam is intolerant to flooding so substrate at about 80 percent water holding capacity (field capacity) is preferred. This is the amount of water in the substrate after water is removed by gravity following water saturation. You need to standardize what 70 percent field capacity of your substrate 'feels like'.

To determine the field capacity (FC) of your substrate:

1. Fill a bucket with 10 L of dry substrate and weigh.
2. Place the bucket on a saucer to catch drained out water.
3. Using a measuring cylinder, add water gradually until excess water is drained out.
4. Record total volume of water added (denoted as X) until drained.
5. Re-weigh the bucket.
6. Measure volume of water drained (denoted as Y).
7. Calculate for field capacity (denoted as Z) using formula Z = X-Y.
8. Calculate 70 percent of Z (denoted as Z70) using formula Z70 = Z * .70.
9. Take another dry substrate and add Z70. This is your target feel (TF), indicating when your substrate moisture content is just right.

Appendix 6. Contd.

10. Determine the volume of water delivered per emitter per minute according to manufacturer specifications and multiply this by the number of emitters per trough.
11. Determine for how many minutes you will irrigate to deliver Z70 to your volume of substrate. Check for TF and adjust the frequency of fertigation or irrigation as weather changes
12. Example: If X=30 and Y=10, then X-Y = Z = 20
    70% of 20 = 14.
    Add 14 ml to your substrate to give the TF.
    If your dripper emits 2 ml per minute and you have 7 emitters per trough, then you require one minute to deliver 14 ml (2 x 7).

At Ibadan, TF was achieved at 2 minutes fertigation time, where there are 20 emitters per trough delivering 36 ml per minute to 50 plants every two days in the wet season. This goes up to 6 minutes during the drier season when temperatures range between 28°C and 38°C, respectively.

Notes: *Fertigation is better in the evenings due to a longer period of coolness overnight. However, early morning fertigation is also fine. Sediments in the nutrient tank mean that the plants are not getting the nutrients. These nutrients should dissolve well and the tank must be washed before preparing fresh batch of nutrients every 7 to 10 days. When there are no emitters available, use a watering can instead to measure the required amount of nutrient and add to troughs as scheduled.*

Appendix 7. Trough (name or number for identity) Fertigation/Irrigation Chart

September 2021

October ⮞

Sun	Mon	Tue	Wed	Thu	Fri	Sat
			1 Nutrient for 2 minutes	2	3 Nutrient for 2 minutes	4
5 Nutrient for 2 minutes	6	7 Nutrient for 2 minutes	8	9 Nutrient for 2 minutes	10	11 Nutrient for 2 minutes
12	13 Nutrient for 2 minutes	14	15 Nutrient for 2 minutes	16	17 Nutrient for 2 minutes	18
19 Nutrient for 2 minutes	20	21 Nutrient for 2 minutes	22	23 Nutrient for 2 minutes	24	25 Nutrient for 2 minutes
26	27 Nutrient for 2 minutes	28	29 Nutrient for 2 minutes	30		

Appendix 8. Fumigation chart (to be completed by responsible staff)

Date	Day	Done by (Name)	Signature
25 September	Friday		
09 October	Friday		
23 October	Friday		
06 November	Friday		
20 November	Friday		

References

Aighewi, B., R. Asiedu, N. Maroya, and M. Balogun. 2015. Improved propagation methods to raise the productivity of yam (*Dioscorea rotundata* Poir.). Food Security 7: 823–834.

Balogun, M., N. Maroya, J. Taiwo, C. Ossai, A. Ajayi, P. Kumar, O. Pelemo, B. Aighewi, and R. Asiedu. 2017. Clean Breeder Seed Yam Tuber Production using Temporary Immersion Bioreactors. IITA, Ibadan, Nigeria. 66 pp. ISBN 978-978-8444-89-3.

Balogun M., N. Maroya, C. Ossai, A. Ajayi, B. Aighewi, and R. Asiedu. 2018. Breeder seed yam production from soil to soilless systems: Yam hydroponics. In Proceedings: 18th Triennial Symposium of the International Society for Tropical Root Crops. 22 -25 October 2018, International Center for Tropical Agriculture (CIAT) Cali, Colombia.

Balogun M., N. Maroya, B. Aighewi, O. Chukwunalu, A. Ajayi, J. Taiwo, L. Kumar, D. Mignouna, and R. Asiedu. 2020. YIIFSWA Working Paper Series No 8. Evolvement and advances in the hydroponics system for clean seed yam production. IITA, Ibadan, Nigeria. 15 pp

Maroya, N., M. Balogun, B. Aighewi, J. Lasisi, and R. Asiedu. 2017. Manual for Clean Foundation Seed Yam Production Using Aeroponics System. IITA, Ibadan, Nigeria. 68 pp. ISBN 978-978-8444-88-6.