Manual:

HOW TO MAKE BIOCHAR-BASED FERTILIZER FOR IMPROVED FOOD SECURITY AND HEALTH











FAARM ফার্ম

FOOD AND AGRICULTURAL APPROACHES TO REDUCING MALNUTRITION

This manual was developed through the project *Scaling-Up "Biochar-Urine Nutrient Cycling for Health" in Bangladesh* (BUNCH2Scale). This was an Applied Research Fund project in the Food & Business Research Programme of NWO-WOTRO Science for Global Development (Grant number W 08.270.334) and financed by the Dutch Ministry of Foreign Affairs and NWO-WOTRO. The Food & Business Knowledge Platform supported the project by articulating knowledge demands, developing joint knowledge and sharing results.

The BUNCH2Scale consortium consisted of four partners:

- Helen Keller International - Bangladesh Country Office,
- Heidelberg Institute of Global Health - Heidelberg University,
- Ithaka Institute for Carbon Strategies, Switzerland, and
- Centre for International Cooperation - Vrije Universiteit, Amsterdam.

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Preface

We are very happy to present this manual, which results from two projects in Bangladesh that built upon each other to develop a scalable intervention for household-level production of biochar-based fertilizer. Below we give a brief overview, acknowledge funders and provide further information and links.

This manual was developed through the project *Scaling-Up "Biochar-Urine Nutrient Cycling for Health" in Bangladesh* (BUNCH2Scale), funded through the Applied Research Fund of the Food & Business Research Programme of NWO-WOTRO Science for Global Development. The BUNCH2Scale consortium consisted of four partners: Helen Keller International – Bangladesh Country Office, Heidelberg Institute of Global Health – Heidelberg University, Ithaka Institute for Carbon Strategies, Switzerland, and Centre for International Cooperation – Vrije Universiteit, Amsterdam.

BUNCH2Scale was nested within the *Food and Agricultural Approaches to Reducing Malnutrition* (FAARM) project, a cluster-randomized controlled field trial in two sub-districts of Habiganj District, Sylhet Division, Bangladesh. FAARM's aim is to evaluate the impact of a Homestead Food Production program, implemented by the NGO *Helen Keller International*, on nutrition and child growth. In Bangladesh, diets are often deficient in vitamins and minerals. Homestead gardening can provide a source of fresh fruit and vegetables to enrich diets. Besides training and support in home gardening and poultry rearing over three years, families in the FAARM intervention group also received trainings on nutrition and hygiene. Mainly funded by the German Federal Ministry of Education and Research (BMBF), FAARM was initiated at Heidelberg University and then transferred to Charité Berlin. More information on FAARM can be found at: https://iph.charite.de/en/research/climate_change_and_health/faarm/

To address low soil fertility in home gardens within the FAARM project, we partnered with the Ithaka Institute to conduct a feasibility study on biochar-based fertilizer with support from the Leveraging Agriculture for Nutrition in South Asia (LANSA) research consortium funded by UK aid, the *Biochar-Urine Nutrient Cycling for Health* (BUNCH) project. BUNCH2Scale built on BUNCH and scaled up the technology to all FAARM intervention settlements. Additional information, including a scientific paper reporting on yield results from field trials, can be found on our website: https://www.pik-potsdam.de/en/institute/departments/climate-resilience/research-groups/climate-change-and-health/biochar-based-fertilizers.

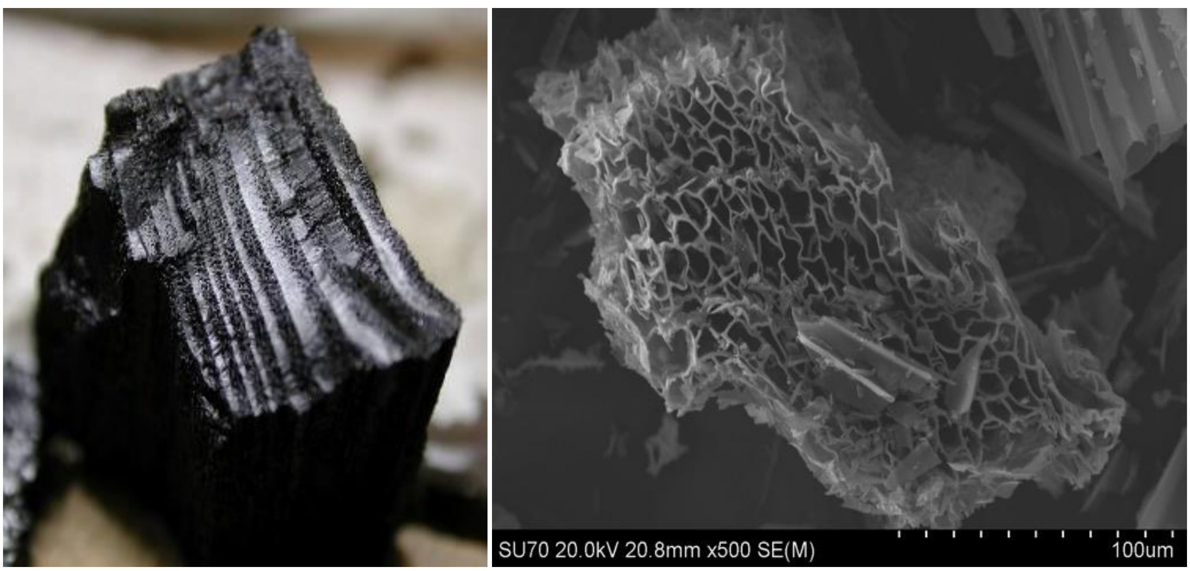
We hope the recommendations in this manual can be useful to others. They have been optimized for our project region in Bangladesh, but could be easily adapted to other settings. If you have any questions, feel free to contact us by writing to schmidt@ithaka-institut.org, jillian.waid@pik-potsdam.de or sabine.gabrysch@pik-potsdam.de.

Jillian Waid, Hans-Peter Schmidt and Sabine Gabrysch
on behalf of the BUNCH and BUNCH2Scale teams

Contents

Why use biochar-based fertilizer?

The FAARM project sought to enable rural households in Habiganj District to produce and consume more micronutrient-rich crops. However, participant households reported poor soil fertility in home gardens as an impediment to production. Commercial mineral fertilizers are not very suitable for eroded tropical soils as soluble nutrients leach to the ground water, resulting in low fertilizing efficiency and ecological damage. Moreover, plant-specific dosage is nearly impossible in garden-scale farming without expensive scales and mathematical skills. Furthermore, commercial mineral fertilizers constitute a substantial expense for poor farmers and their production is energy-intensive and thus contributes to climate change. Organic fertilizers are more environmentally friendly, can be dosed much easier and can be prepared almost for free on a household level.



Piece of biochar (left) and biochar particle under the electron microscope showing its porous structure (Copyright: Ithaka Institute, University of Limerick)

Biochar is a carbon-rich substance obtained when exposing biomass, such as wood, rice straw or fallen leaves, to temperatures above 400°C in the near absence of air (oxygen). This process is called pyrolysis. Usually, biomass pyrolysis is an industrial process that necessitates investments of > 500,000 USD. However, quality biochar can also be produced in low-cost farm-scale devices called Kon-Tiki, using flame curtain pyrolysis. This process enables biochar to be relatively easy to make from a multitude of locally available biomass waste materials such as agricultural residues from crops, wood, twigs, nut shells, dry leaves, animal waste, hay, and even waste from sewage drains.

In the Kon-Tiki, it is not the biomass itself that burns, but the flammable gases that evaporate from the biomass due to the reflecting heat of the fire. In contrast to the conventional burning of biomass which leads to ash, the carbonaceous backbone of the biomass remains intact during pyrolysis. The resulting biochar is very porous and has thus a huge inner surface; it is like a sponge (see the above figure) that can hold nutrients, water, and other substances.

Biochar can be used for multiple purposes, such as waste water treatment, as building material or as additive for animal feed. This manual will focus on biochar as soil amendment and carrier material for fertilizing substances. Biochar improves soil fertility by retaining and exchanging water, nutrients and air. It further acts as a catalyst for bio-chemical reactions in the root zone of plants, reduces nutrient leaching, lessens the effects of salinity and drought, and moderates the level of acidity in the soil. Biochar also sustains the build-up of soil organic matter.

When biochar is used in agriculture, it should never be applied pure but always blended with enhancing organic substances like compost, liquid manure, urine, or fermented kitchen waste as it increases the effectiveness and usability of these fertilizing substances. The mixed fertilizer is then called a biochar-based fertilizer and can be applied to the root zone of crops and trees. Urine, for example, is known to be an excellent fertilizer with at least the same efficiency as commercial mineral nitrogen and potassium (NK) fertilizers but is still underused because of odor and the necessity to mix it with nine parts of water. Biochar soaks up urine and transforms it into a potent odorless solid fertilizer that can be applied without dissolving the urine in water.

In addition to its benefits as a fertilizer, using biochar in soil contributes to mitigating climate change through sequestering carbon in the soil. Biochar can endure in the soil for more than 500 years. It also reduces the leaching of nitrate into the groundwater and the emission of nitrous oxide into the atmosphere (a potent greenhouse gas and contributor to air pollution).

People in multiple countries around the world are using biochar to improve soils. During the FAARM project, the use of organic biochar-based fertilizers improved yields more than 50%, ranging from small increases to over double, depending on the crop type, season, and cultivation methods.

This manual will provide instructions on how to produce biochar in your own backyard and recommendations on how to transform it into a nutrient-rich, low-cost fertilizer using cow urine.

Biochar has the following benefits in agriculture:

1. Improves the efficacy of organic and mineral fertilizers
2. Transforms animal or human urine into an easily applicable fertilizer
3. Improves water and air retention capabilities in soil
4. Preserves carbon in the soil
5. Mitigates damages of salinity and drought and reduces soil acidity
6. Reduces long-term costs of agricultural cultivation
7. Increases agricultural yields

How to make biochar-based fertilizer

To make biochar-based fertilizer, you need (1) solid biomass to make biochar and (2) nutrient-rich substances to enhance the biochar's fertilizing properties.

Ingredients

Solid biomass, for example:

- Dry leaves
- Crop husks
- Straw
- Wood/wood shavings
- Hay

Nutrient-rich substances, for example:

- Cow/human urine
- Animal waste
- Compost
- Chemical fertilizers

Summary of steps

The following is a summary image of the steps required to produce biochar-based fertilizer. The manual will go into detail on each of these steps below.

A: Collect biomass feedstock, e.g., dry leaves and rice straw, from homes or nearby sites.
B: Dig a shallow kiln hole.
C: Arrange the biomass loosely in the kiln, keeping a bit of air at the bottom.

D: Start fire at top of feedstock pile.
E: Once fire is hot (and lower parts of pile are carbonized), slowly add feedstock in layers.
F: Douse carbonized feedstock (biochar) by pouring or stirring water into it.

G: Collect biochar.
H: Mix biochar with urine to create urine-enriched biochar-based fertilizer.
I: Apply urine-enriched biochar-based fertilizer mixed with some compost to the crop root zone.

Detailed production process

1. Gather the materials needed (Step A)

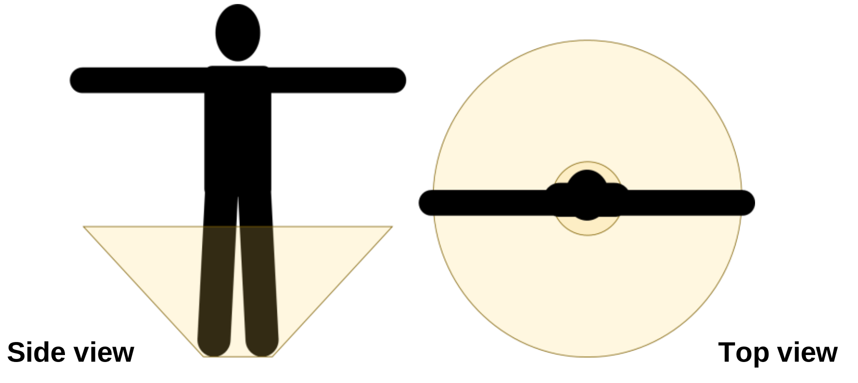
The materials should be selected from what is available at low cost in the nearby area. In a forest-rich area, fallen twigs and wood wastes could be used as feedstock for making biochar. In Bangladesh, however, wood is often scarce and valuable, so dry leaves or crop waste such as rice straw and rice husks can be used instead. Similarly, dried animal waste makes excellent feedstock for biochar, but the waste may be more valuable as fuel or as compost. The biochar-making process does not vary much depending on the material used, but the instructions included in this manual are optimized for small pieces of feedstock – such as rice straw, leaves, and twigs – and not large pieces of feedstock such as tree trunks and large branches. The feedstock should be as dry as possible. The amount of feedstock you gather should be three to four times the amount of biochar you want to have in the end.

In addition to biomass feedstock, gather other nutrient sources such as compost and cow urine. Cow urine can be collected directly from the cow shed using a draining pan as shown in the following images.

Pots can be used to collect urine directly from the cow shed. Adding biochar to the pot will reduce smell.

2. Make a kiln (Step B)

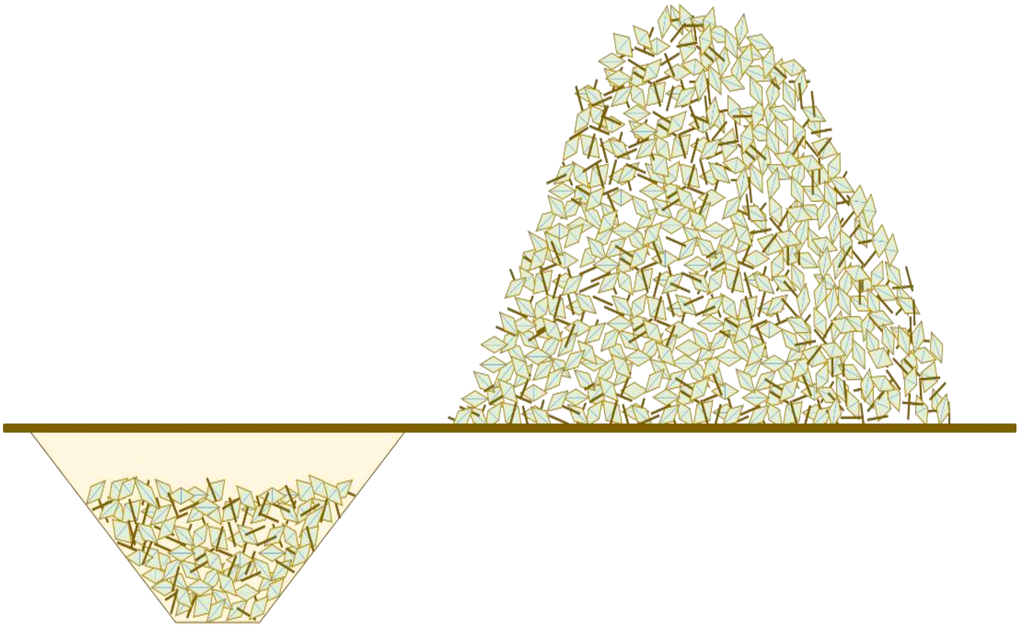
Biochar can be produced in a number of ways, including in ready-made metal cones, but pit kilns can be dug at low cost, produce high-quality biochar, and can be used multiple times. Dig the kiln in an area that is as dry as possible because a wet kiln will slow down the process and produce more smoke. Select a safe and open place so that the fire will not damage anything. To make a pit kiln, dig a shallow hole in the soil that is wider at the opening and narrows to the base. The top of the pit should be around the size of an adult's outstretched arms in diameter (around 1.5 meter diameter) while the depth should be to the lower thigh on an adult (around 0.6 meter deep). The size can be adjusted according to the amount of biochar to be produced. As a rule of thumb, the depth of the pit should be a little less than half of its diameter. The sides should slope gently as shown in the diagram. Thoroughly compact the soil with your feet, a shovel, or a wooden pole. If the soil is sandy, use clay to plaster the pit's walls. After the first fire in the pit kiln, the plaster will become waterproof. Once the pit is dug, ideally add a layer of stones around the rim. This will stabilize the edge and improve safety.



3. Use the kiln (Steps C, D, E, and F)

To aid in the biochar production process, gather a long stick such as a bamboo pole to help you control the fire and easily fix production errors. A longer stick is better than a shorter stick to reduce the chance of being burned.

After collecting a stick, fill the pit kiln only half full with as much feedstock as will fit loosely with little pockets of air in between (see diagram). Do not pack down the feedstock into the pit kiln, just throw it in loosely. Reserve the rest of the feedstock in a pile next to the pit kiln. There should be at least three times more material not in the kiln as in the kiln (see diagram).



Next we must light the kiln. Before lighting the kiln, make sure that children and others are not too close or playing nearby to reduce the risk of injury. Start the fire at the top of the pit kiln. As the top layer of the feedstock burns, it will turn black. When this happens, continuously add new feedstock on the top to the fire. Do this again and again so the fresh feedstock will be heated by the fire and turn into biochar by the heat. The already charred material will remain in the bottom of the kiln.

Do not pack down the material tightly so that air pockets are removed.

If the kiln is working properly, there will be no smoke and the material in the kiln will look black like coal and not grey like ash. If the kiln is working properly, the stick is not needed. However, if you have either of the following problems you can use the stick to help the situation.

If smoke develops, you might be adding too much biomass to the kiln at once and thus snuffing the fire, or the biomass may have been too damp. In these cases, you can use the long stick to “fluff” up the solid biomass so that the fire can get some air and burn hotter again. If smoke develops, be careful when adding new material and not add too much at once, just little by little.

The kiln is not full at the time of firing and a large amount of feedstock is reserved.

Adding biomass piece by piece as the previous biomass is pyrolysed.

No smoke, and the material in the kiln is black. Good production!

Too much feedstock was added at once to the kiln, causing smoke.

Biochar is black.

Ash is grey.

On the other hand, if the biomass is turning grey like ash, you need to add more material to the kiln. Stop adding new biomass if the layer of biochar reaches up to around a hand below the pit kiln rim or once all the available collected biomass has been used up. There should still be some flames when the pyrolysis process is stopped. To prevent it from continuing to burn or glow until the point of ash, the process can be stopped with water or urine.

The liquid should be added slowly from the kiln's edge to extinguish the fire from the bottom to the top. The rising steam within the kiln will clean the biochar pores and increase the biochar's surface area. This will then improve the biochar's ability to hold nutrients. Add more liquid and stir the biochar in the kiln until the biochar is cold enough to touch it by hand. Make sure that all parts are reached before the glowing biochar has turned to ash.

Quenching the fire and collecting the biochar. The collected biochar can be wet or quite dry depending on the amount of water/urine used during the quenching process.

4. Use the biochar (Steps G, H, and I)

After the biochar has cooled, it can be collected and stored or used immediately. The consistency of the biochar will vary depending on the amount of liquid used in the quenching process. Quenched biochar with a drier consistency can be collected and preserved on a mat. With more liquid used, biochar will have to be collected and stored in buckets. If urine is used to quench the fire, the mixture is already prepared.

Otherwise, the biochar is now mixed together with cow urine, an important nutrient source. The biochar removes the unpleasant smell from the urine. Biochar should be mixed with urine using a 1:1 ratio by volume of biochar to urine. Ideally, the biochar-urine mixture is then combined with compost or animal waste to add microorganisms before being used as a fertilizer for crops. Biochar can also be mixed with chemical fertilizers. When blending with mineral fertilizer like urea, dissolve the mineral fertilizer and add biochar until all liquid is soaked into the biochar pores.

Mixing biochar of relatively dry consistency with urine

Applying the fertilizer to the root zone

Biochar-based fertilizers can be applied in vegetable beds, in planting pits for new trees, incorporated in the soil in paddy-rice systems, in bag gardens, or in any other plant-production system. Biochar-based fertilizers always need to be incorporated into the soil, merely applying it on top of the soil is not effective and may be washed away by rain.

Row planting with biochar

For every seed bed of pumpkins, bottle gourds or ash gourds, two liters of biochar should be mixed with two liters of cow urine and placed 10-15 cm below the soil surface before closing the pit with soil and placing the seeds. For row planting: after the row is dug, a layer of biochar-based fertilizer can be applied before the seeds are sown and the row is then covered with soil. When young plants are planted, a half cup of biochar-based fertilizer can be added to the root zone, i.e. to the area around where the plant's roots will grow, in each hole. Applying biochar-based urine fertilizer can also be used in bag gardening (see Annex on page 17).

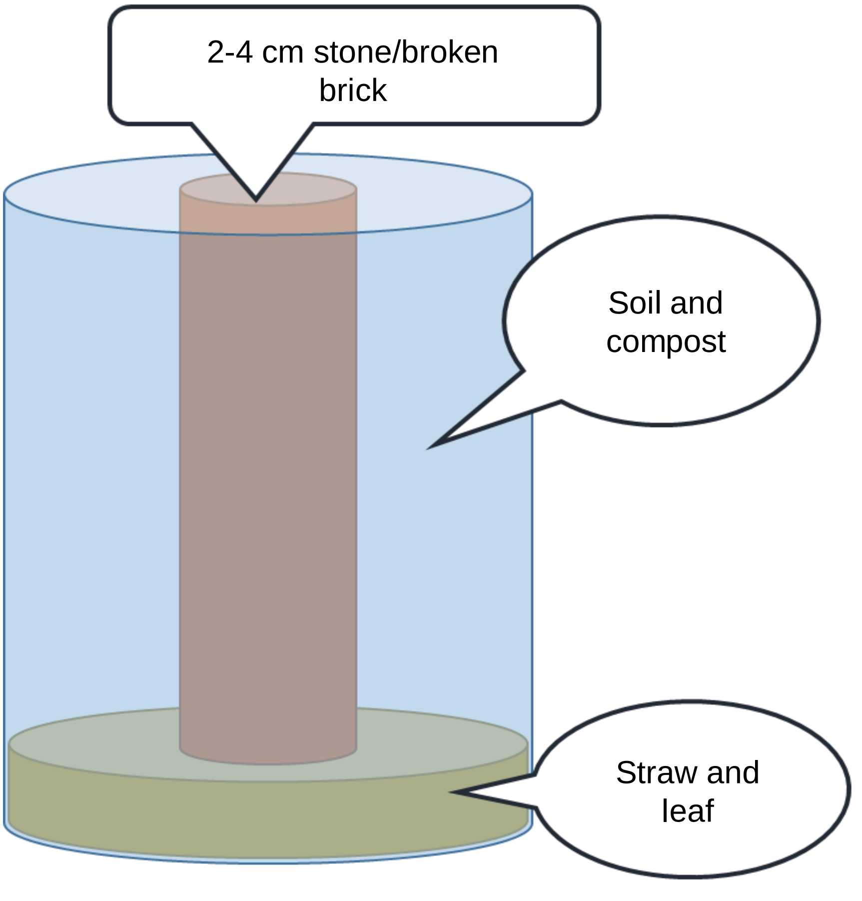
To observe the effect of biochar-based fertilizer on yields, plant one small plot of land in your usual way and another small plot next to it with biochar-based fertilizer. Choose the crop you prefer and make sure to treat the plants in exactly the same way except for the fertilizer. Compare the results yourself!

Annex: Making a bag garden

To make a bag garden you need the following items:

- Burlap or plastic bag like that used for rice
- Things that go into the bag:
    - Brick chips or stones
    - Straw
    - Soil & compost
    - Biochar-based fertilizer
- Tools
    - Pipe
    - Trowel

The structure of the bag is shown below:



Fully open the bag.

Fold in the corners of the bag so that it will sit flat on the ground.

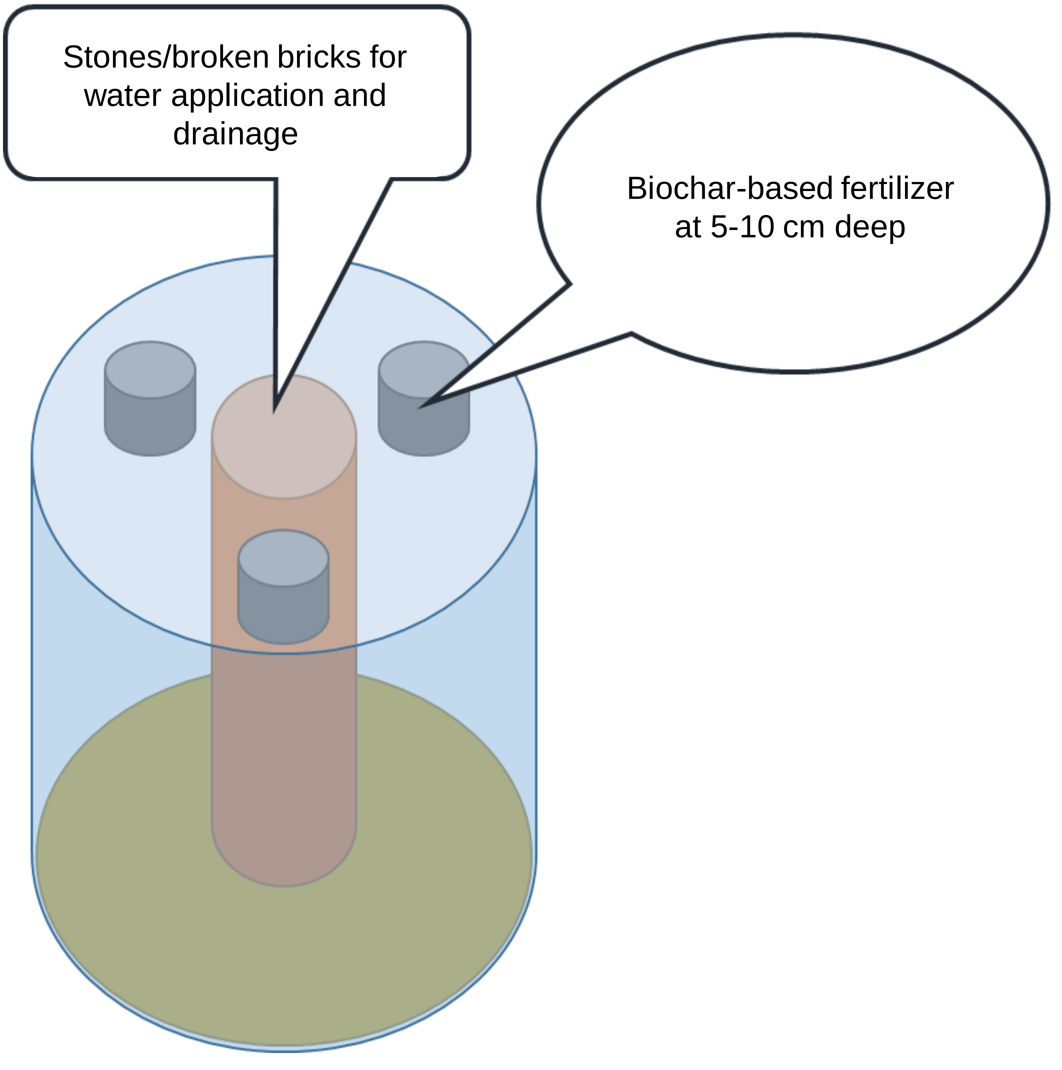
Place straw and leaves in the bottom of the bag.

Push down the straw and leaves using your feet.

Place the pipe in the bag and put soil around the bottom of the pipe to stabilize it.

Place brick chips in the pipe. Continue adding soil and compost around into the bag.

Remove the pipe and the bag garden is completed. For better drainage, the bag garden can be placed upon bricks.



Bag garden seen from above: When planting crops, place them around the bag's periphery and apply biochar-based fertilizer to their root zone.

Contributions and acknowledgements:

This manual results from the work of the teams of FAARM, BUNCH, and BUNCH2Scale.

This included staff from Helen Keller International (Abdul Kader, Jillian L. Waid, and Abul Kalam), Ithaka Institute for Carbon Strategies (Hans-Peter Schmidt and Bishnu Hari Pandit), the James P Grant School of Public Health (Ipsita Sutradhar and Sayema Akter), Heidelberg Institute of Global Health (Sabine Gabrysch, Amanda Wendt, Shafinaz Sobhan), and Vrije Universiteit, Amsterdam (Wendelien Tuijp and Anna Bon).

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