DRY SEASON PLANTATION FRAMEWORK AND TRAINING MANUAL

Food and Agriculture Organization (FAO)
Cox's Bazar

July 2021

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Foreword

Bangladesh is a tropical country in South Asia with a high population density experiencing rapid depletion of natural resources. Forest cover loss with a high rate of biodiversity degradation is a deep concern for this region considering the pace of erosion at the genetic base (of flora and fauna). The sudden humanitarian crisis at Cox's Bazar also exerts additional pressure on the natural resource base. Increased dependency on natural resources for food, fodder, and firewood widens the gap of loss and gain by the natural ecosystem over the last decades. Forest regeneration capacity cannot cope with the pace of forest extraction. A good number of initiatives have been taken by the government to halt the pace of degradation and to heal the loss incurred through a wide range of causes. Besides, as part of the humanitarian responses, development partners supported rehabilitating the degraded vulnerable areas inside and outside the camp areas with the massive reforestation program. However, the rehabilitation initiatives need to be accelerated considering the necessity to rejuvenate the degraded areas.

The conventional plantation window limits the process of the reforestation work as it mostly depended on the monsoon rain that lasts for a few months. The high dependency on water and excessive expulsion from the underground reserve to address the local need make the water resource a scarce commodity in this region both for household uses as well as for irrigation. To overcome all the impediments and keep the pace of reforestation round the year, FAO in close collaboration with the forest department and research institutes, developed an improvised mechanism for continuing the reforestation work round the year. The developed system not necessarily reduces the nutrient competition by the tree seedlings at the succession stage but also helps in reducing the demand for irrigation water regularly for doing plantations beyond the plantation window.

The support from the development partners and the FAO's mandate in the generation of knowledge through the field research and practices paved the way for rejuvenating the degraded land in such protracted conditions. The finding of the field experiment and the guideline developed thereafter will help in replicating at the national and regional levels contributing to the year-round plantation.

Acknowledgement

This book is an outcome of the field research, knowledge generation and ecosystem restoration initiatives undertaken by the Food and Agriculture Organization of the United Nations (FAO) in collaboration with Bangladesh Forest Department and IOM, WFP.

Numerous stakeholders, government bodies, academic institution and individual experts contributed to the assessment in different phases. We acknowledge sincere gratitude to Bangladesh Forest Department of the Ministry of Environment, Forest and Climate Change (MoEFCC) for overall guidance and support.

FAO acknowledges the enormous contribution of Mohammad Mosharraf Hossain, FAO National Dry Season Plantation Expert and Mr. Mahmudul Hosen, FAO Dry Season Plantation Field Supervisor from the Institute of Forestry and Environmental Sciences of University of Chittagong.

FAO is grateful to Cox's Bazar field office team including Marco De Gaetano, Rajib Mahamud, Md. Tanjimul Alam Arif, and Mondal Falgoonee Kumar for their role in coordination and technical support for the project. The invaluable technical guidance of Mr. Kenichi Shono, Forestry Officer, FAO Head Quarter helped the field team in successful field implementation.

FAO is also grateful to all the people worked in the plantation sites both inside and outside the camp areas for their enormous effort in the field implementation, monitoring and post planting care and maintenance. We highly appreciate the role of the Chief Conservator of Forest, Mr. Safiul Alam Chowdhury for allocating forest land to conduct this experiment and also to the Refugee Relief and Repatriation Commissionner and the Depty RRRC for theirsupport inside the camp plantation. Special thanks goes to the Cox's Bazar South Forest Department officials namely to Md. Humayun Kabir, Divisional Forest Officer, Md. Sohal Rana, Assistant conservator of Forest and Md. Moinul Islam, Forest Ranger of Shilkhali Range along with many other field officlas in this process.

Finally, FAO acknowledges the support from Government of Japan, Global Affirs Canada and Embassy of the Kingdom of Netherland for the financial assiatnce to implement this innovative approach on restoring the degraded forestland affected by the human interferences

Background

In the tropical environment of Bangladesh, the start of the traditional planting season coincides with the rainy spell of monsoons roughly between April and May. The planting season lasts till the start of the dry winter season usually till late September or early October. As in winter, the topsoil dried out and the seedlings suffer from the water stress at the initial root growth stage and wilt leading to failure of the plantation, for which normally, plantation activities are discontinued during the dry months of the year between October and March. The odds of water stress during initial seedling establishment are higher in the hilly terrains as the soil water table in hilly terrains tends to diminish much faster as rainfall ceases compared to flatlands. Therefore, plantation activities in hill forest areas in the dry season have never been thought of. Against this backdrop, innovating dry season plantation techniques is inevitable for several reasons.

Firstly, under the gloomy realities of ongoing severe and undeterred deforestation in forests all over the country the increasing pressure to restore the forest cover for ensuring the reemergence of lost ecosystem services, climate change mitigation and for the stable environment – it becomes increasingly important to think outside the box to enhance temporal window of plantation drives by.

Secondly, some sites become inaccessible during the rainy season for a host of factors and can only be safely and conveniently planted during the dry season as during the dry season, the forest sites become more accessible and easier to manage in terms of weeds to prepare the sites for plantation and execute the plantation itself with primary care in the absence of weed growth.

Thirdly, the actors in plantation activities face hurdles in making preparations for plantation projects for permissions, site selection, approvals, site preparation, logistics, and so forth. This pushes the start of plantation activities towards the end of planting season. Accordingly, they often plant trees hurriedly while the dry season starts which limits the success of plantations.

Fourthly, there are places in the tropical region including in Bangladesh where the amount of rain is sparse. Accordingly, even during the wet months, the soil remains relatively dry and planting these sites require dry season plantation modalities Especially, in the Barind area of Bangladesh, the dry soil makes successful plantations difficult to achieve and the dry season technique can be a lucrative proposition. It is, therefore, highly relevant to try out options for dry season plantation to elevate the number of trees planted each year and the number of areas brought under restoration drives with a higher survival percent of seedlings.

The problem statement and avenues for innovation

The most critical part of a dry season plantation modality is to ensure a stable supply of water to seedlings at the initial root establishment stage. If the seedlings can be supplied with enough moisture to settle at the site, the start of rain of the following monsoon ensures their vigorous growth to outperform the weeds and ground vegetation which becomes a major issue as the rain starts. Accordingly, innovative soil moisture management for the dry spell of the year only for the first year of the plantation becomes the main concern to design a dry season plantation modality. The main aspects of innovations for a dry season plantation become irrigation, enhancement of soil moisture retention ability, equitable sharing of soil moisture among the seedlings, making the irrigation needs as low as possible to address the cost issue. Topsoils in many deforested areas became infertile due to the loss of nutrients. Hence, besides moisture management in these sites the management of nutrients requires attention. Naturally, any innovation that addresses both issues with a single solution will be more desired and cost-effective. On the other hand, some unconventional plantation techniques have some inherent elements to make them candidates for being adapted as a dry season planation modality.

FAO Cox's Bazar facilitated the innovation of dry season plantation modalities based on three approaches. **The first approach** involves the application of moisture conservation cum nutrient supplementing materials while planting to ensure moisture availability with low-frequency irrigation and soil amendment. as well as slow irrigation devices. **The second approach** involves the use of slow irrigation devices to suppress weeds while ensuring the availability of moisture to seedlings with irrigation at long intervals. **The third approach** was to adapt the Miyawaki model of plantation to render it as a dry season modality in hilly terrain. These approaches have been field-tested successfully at Shilkhali and Rohingya refugee Camp 19 – both were challenging and barren sites.

This training manual contains step-by-step instructions to understand and implement these three approaches. The step-by-step instructions are given with illustrations as a self-help guide to demonstrate the components involved with each of these approaches so that the interested stakeholders and implement the dry season plantation approach that suits their requirements.

A simple **dry season plantation framework** for the implementation of these approaches is proposed.

The dry season plantation framework

Among the innovative dry season approaches trialed in Cox's Bazar, following the general dry season plantation framework as depicted in table 1, the plantation-related decisions can be made with confidence.

Table 1: The general framework for dry season plantation

Approaches	Moisture conservation	Sourcing	Secondary benefits	Nutrition material	Site	Species and seedlings	Plantation type	Irrigation
Approach 1	Biochar	It can be prepared onsite, can be sourced by creating local entrepreneurship, or commercially sourced	Biochar enhances soil properties, it can help in long term carbon storage from waste material charring	Compost, Vermicompost, Cow dung, commercial fertilizer (use of commercial fertilizer is discouraged)	Any plantation site – plain or hilly - is suitable for application of this option for dry season plantation.	Monospecific plantation or mixed species plantation, the mixed plantation is recommended. The root condition of the seedlings must be checked. Seedling with cut taproots is not recommended.	Existing arrangements (square, triangular, etc.) can be adapted but the hexagonal arrangement is recommended with varying spacing lower or higher than 2m depending on the size and purpose.	Depending on the site condition it can have a frequency of few days to one week or more.
	Cocopeat	It can be prepared from waste coconut husks, can be sourced by engaging youths in waste management, can be sourced from green coconut sellers, can be sourced from commercially from industries that depend on coconut husk.	Cocopeat also adds to soil carbon and nutrient pools besides helping to prevent wastage of this valuable resource	DO	DO	DO	DO	DO
	Water hyacinth compost	Water hyacinth compost can be prepared onsite, can be prepared by creating local entrepreneurs	Water hyacinth is a big problem in many places, for example, at Kaptai lake. Using this material can convert this nuisance into a resource. It adds to the forest soil nutrient pool.	DO	DO	DO	DO	DO
Approach 2	Cocoons	Local artisans, commercial vendors. with develop a large-scale application – the price will become comparable to earthen tobs. Plastic cocoons can be made at a lower cost but the use of unsustainable material is discouraged.	Cocoons can be reused if properly collected after the establishment of seedling just after the first rain. Cocoons can create very good local employment and entrepreneurship. These can be used in home gardens as well.	Compost, Vermicompost, Cow dung, commercial fertilizer (use of commercial fertilizer is discouraged)		DO	Square, a triangular or hexagonal arrangement can be used. But spacing has to be kept at least 2m or more depending on the budget for the cocoon.	Irrigation frequency can be few weeks to one month depending on site and management of cocoons against evaporation loss
Approach 3	Adapted Miyawaki plantation	All the materials needed (waste biomass including rice husk, rice straw, vegetable market residue, sawdust, wastes from poultry farms, waste branches or leaves or twigs and other similar materials) can be locally sourced or sourced commercially.	The Miyawaki method ensures the creation of a lush forest cover within a short period besides helping big initial carbon storage and subsequent enhancement of soil carbon pool.	Compost, Vermicompost, Cow dung, commercial fertilizer (use of commercial fertilizer is discouraged)	Suitable for relatively flat land. When used in slopes in hilly terrains it should be done with care not to destabilize the slope.	As many varieties of indigenous species as can be sourced should be planted at random. Seedling with cut taproots isn't recommended.	In this method a packed close spacing, a random arrangement is used,	Irrigation at 3-7 days intervals can be adapted depending on the materials used and site condition.

General guidance for dry season planting

Site and season

The site for the plantation needs to be selected at least 3 months before the plantation as preparation and sourcing depend on the site. The site should be carefully cleared from weeds which can be composted to add to soil nutrients if done at least 40 days before the planting. The use of fire is discouraged. The preparation for planting should start well before the dry season so that plantation can be implemented without delays after the onset of the dry season. However, the approaches can be used throughout the dry season. The seedlings should be raised according to the time of plantation. The approach used also dictates the site. For example, Approach 3 should not be used in steep terrains. Approach 2 can be used in steep terrain if transportation of cocoons does not become a limiting factor.

Site selection is important for dry season plantation as it dictates the use of materials for moisture conservation and soil amendments, selection of species, level of interventions needed with manpower and budget. In the beginning, it is better to select sites where there is the availability of surface or groundwater for low-frequency irrigation since the main barrier to dry season planting is water shortage for plants during the initial establishment and growth phase. Moreover, the transportation of materials for the plantation and site cleaning requirements are among the factors to be considered in selecting sites.

It is better to avoid very sites at high elevations, on steep slopes, or sites having poor accessibility as the frequent movement for irrigation may require. However, with the development of more dependable techniques of water conservation which may offer the advantage of single irrigation for the plant to survive through extreme moisture conservation, with the availability of materials and devices to offer planting without disturbing slope stability – these factors may not remain limiting and any kind of site may become amenable to dry season plantation.

Site condition assessment

The factors associated with site conditions should be taken into consideration with care. Major site factors which need consideration including slope, aspect, existing vegetation, soil condition, presence of shade, interferences, etc. should be considered.

Prevention of soil movement

If the dry season planation site is prone to erosion, we may need to check soil movement by planting bamboo, cane, etc., and by creating physical barriers across the gullies by using poles and sticks from

the cleared undergrowth is necessary if there are gullies at the site which are prone to erosion in the rainy season (as was the case with the dry season plantation trial site at Shilkhali).

Water source

As dry season plantations will need irrigation despite the innovations to reduce the frequency at which irrigations are to be done, it is necessary to plan regarding the source of water to be used for low-frequency irrigation. As the frequency varies depending on the approach adopted, the amount of water needed will also vary. It should be kept in mind that the availability of water in the available sources will diminish as the dry season progress.

Materials and other logistics required

Depending on the condition and size of the selected site upon determination of the materials and devices needed, it is desirable to determine the total amount of each of the materials and the devices required. Whenever feasible, determining the resource requirements in advance will assist in sourcing these locally to create income opportunities for local people and the use of local waste materials. However, the most important thing is, if not done in advance, the sourcing may become a challenge in implementing the plantation at the right time. Especially, if any device such as cocoons is used, as these are not readily procurable from market sources, it is to be arranged much in advance. A list of materials that are used for different purposes is shown in table 2 by categorizing them into mandatory and non-mandatory groups.

Table 2: The list of materials needed for the dry season plantation.

Essentials	**Minor items**	**Ornamental items**	**Safety items**	**Others**
Seedlings	Legume seeds	*Grass tiles*	Nylon net	Watering pipe
Sticks	Jute net	Cane seedlings	Dry bamboo	Pump
Cow dung	Jute rope	Bamboo seedlings	GI wire	Small trolley
Compost	*Rice straw*		Safety helmets	Bamboo basket
Cocoon	*Sawdust*		Safety gloves	
Biochar			First aid box	
Cocopeat				
Water hyacinth				

** Items in italic are required only for approach 3 i.e., adapted Miyawaki dry season plantation.

Material sourcing

As there are many options to source the materials, emphasis should be given to source them locally to ensure the local people find synergy with the plantation activities and can indirectly take part by

becoming providers of materials. Adequate time should be given to them so that materials can be obtained just when needed at a reasonable cost with proper quality checking.

Selection of species

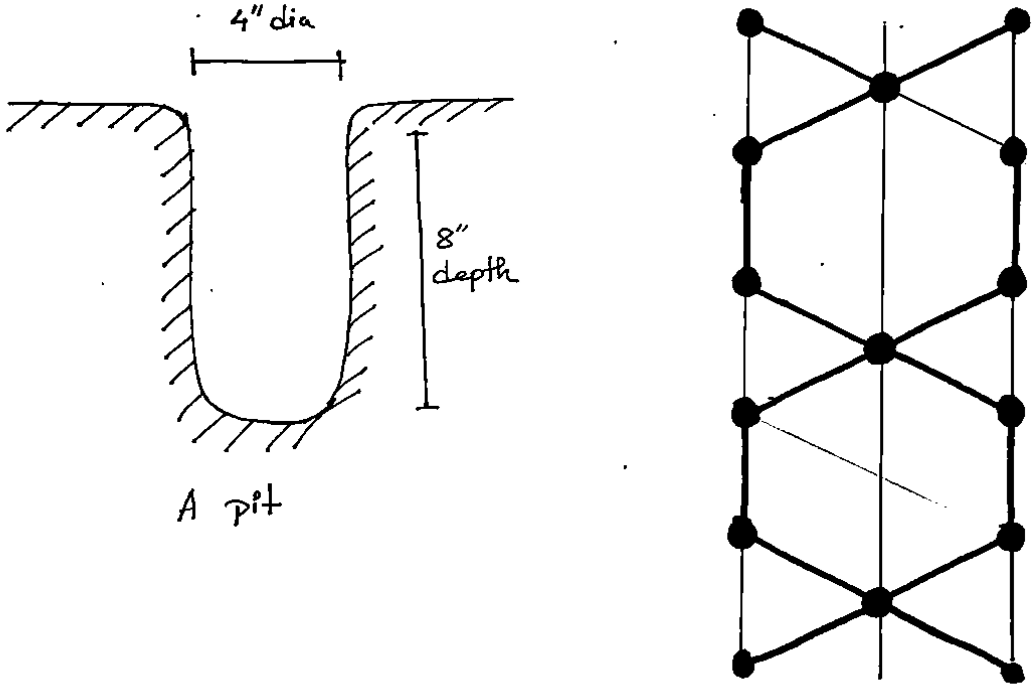
It is one of the main determinants in any plantation. A mixed dry season plantation is preferable to ensure a synergistic relationship among species. In the dry season plantation trial based on which this manual was developed, six indigenous species Arjun (*Terminalia arjuna*), Bohera (*Terminalia bellirica*), Chikrassi (*Chukrasia tabularis*), Kalojam, Neem (*Azadirachta indica*), and Telsur (*Hopea odorata*) were selected and their performances were excellent. In the adapted Miyawaki trial 17 indigenous species were used with good performance. However, as there is no comprehensive data on the dry season performance of major species, this trial has made the selection based on the availability of seedlings locally, the vigor of the seedlings, and the information available on their performance under water stress. In general, for dry season plantation, it is preferable to use a mixture of evergreen and deciduous species with a higher emphasis on evergreen.

Selection of seedlings

It is better to use indigenous species locally available or reported to occur in the area. The seedlings selected should be from reliable sources with good vigor as sturdy seedlings have a better chance of survival in dry season plantations. Also, it is desirable to raise the seedlings near the plantation site to avoid damages during transportation as well as the unnecessary cost involved therein. Seedlings should be sturdy, without cut tap roots. Using old and larger seedlings is discouraged as the moisture requirement of these seedlings tends to be higher which increases the risk of failure of the plantation.

Staking and Pitting following hexagonal plantation layout

One innovative option trialed for the development of the dry season plantation techniques included in this manual was the ***hexagonal plantation*** arrangement to ensure the better sharing of moisture and nutrient amendments among the seedlings. Also, the hexagonal plantation arrangement gives the trees more sturdiness against toppling by winds and ensures better safety for seedlings against landslide-related damages. Moreover, the hexagonal arrangement allows the accommodation of more seedlings at the same plot of land than the usual square plantation format used in plantation activities in the country. The hexagonal layout can be done quite easily with the help of an improvised hexagonal jute rope net having 1.8 meter long sides giving seedling-to-seedling spacing of 1.8 m.



Sketch 1: Hexagonal arrangements for dry season plantation and the pit dimension for approaches 1 and 2

For establishing a dry season plantation, hexagonal plantation arrangement is not mandatory. Depending on the site condition and preference of the stakeholder square, rectangular or triangular arrangments are also equally useable.

Staking is to be done following the layout to demarcate the locations of pits. After staking according to the layout, 8-inch deep and 4-inch diameter pits should be dug at six corners and the center of each hexagon.

Planting

Planting is done following the standard method as outlined with the description of approaches.

Care and maintenance

Irrigation

- After planting, regular irrigation is mandatory in the first week for all approaches except those of cocoons which were filled up when the water level fell depending on the site condition.

- In subsequent weeks, a routine frequency of irrigation was maintained. In cocoons, the trial maintained an 8-days interval. In the case of cocopeat, water hyacinth compost and charcoal, irrigation was done every 4 days.

Sowing nitrogen-fixing legumes

This is an optional but very important approach to spread seeds of nitrogen-fixing leguminous species and/or Pigeon pea locally known as Arhar (*Cajanus cajan*) and Dhaincha (*Sesbania bispinosa,)* in the plantation site to enrich the soil with nitrogen, to suppress the weeds, to make the fragile site more stable against rain and air erosion while conserving soil moisture by creating a cover over the barren soil. As these are shallow rotted plants, there was no competition for moisture and nutrients between them and the planted seedlings. Moreover, upon completion of life cycles, they add to the soil nutrient through decomposition.

Spot weeding

After several weeks of the plantation, if weeds became visible, a spot wedding should be done to ensure the survival and optimum growth of the planted seedlings by avoiding competitions.

Small check dams for erosion control

If there are gullies already formed at the site, check dams can be constructed by using sticks and jute nets or similar materials to check further erosion and loss of the plantation. Earth, weeds, and poles from site clearing operations were used for the purpose.

Monitoring for diseases

Seedlings are to be routinely monitored for the onset of any disease and paste. During the first three months, no such incidence was observed.

Data collection and monitoring

The seedling survival, the leaf falls and leaf flushes, changes in heights and collar diameters, condition of weeds have been routinely recorded. After planting, one record was taken for all plots on randomly selected seedlings. These seedlings have been measured twice at varying intervals over the next three months to get an idea about the performance of the treatments, performance of the seedlings, and their variations with slopes, etc.

Protection and fencing

At sites near localities or with frequent grazing, fencing should be provided especially for Approach 3 since cocoons are amenable to theft and damages. Temporary fencing for the first few months is suggested by using locally available fencing materials The materials from site cleaning, if usable, can

be a good choice. Also, taking measures for establishing a natural fence, in the long run, is desirable by using bamboo and cane species around the perimeter of the plantation plot. The use of bamboo needs to be regulated and species are to be carefully chosen.

Steps in dry season plantation

Steps involved in all the three dry season plantation approaches are given below with illustrative sketches and photographs as required.

Approach # 1: The use of soil amendment for moisture conservation

Preparation of soil amendments for moisture and nutrients

Three different types of soil amendments were tried besides moisture retention cocoon devices:

- Biochar
- Cocopeat
- Water hyacinths compost

Biochar

However, *Biochar* can be made by using a traditional charcoal kiln or portable charcoal kiln from waste biomass materials including the debris from site cleaning. If biomass materials from the local municipalities or waste generation sites can be used, the circular flow of nutrients back to the forest can be attained while solving the waste management issues. Local entrepreneurship can be fostered to produce biochar, which has a big market besides requirements for dry season plantations, as a means of alternative livelihood for people dependent on the forest to enhance the possibility of success of plantations. It can also be sourced from commercial suppliers but the quality of biochar should be tested.

Cocopeat

Cocopeat can be made from waste coconut husks and green coconut shells which are abundant almost all over the country especially in coastal areas like Cox's Bazar. Sourcing of cocopeat from local manufacturers can become a livelihood option for forest-dependent people to refrain from being agents of deforestation. Besides, the use of this waste material will create a value chain for the wastes and will help in making the environment cleaner. Coconut husks or green coconut shells upon drying can also be a feedstock for making good quality charcoal.

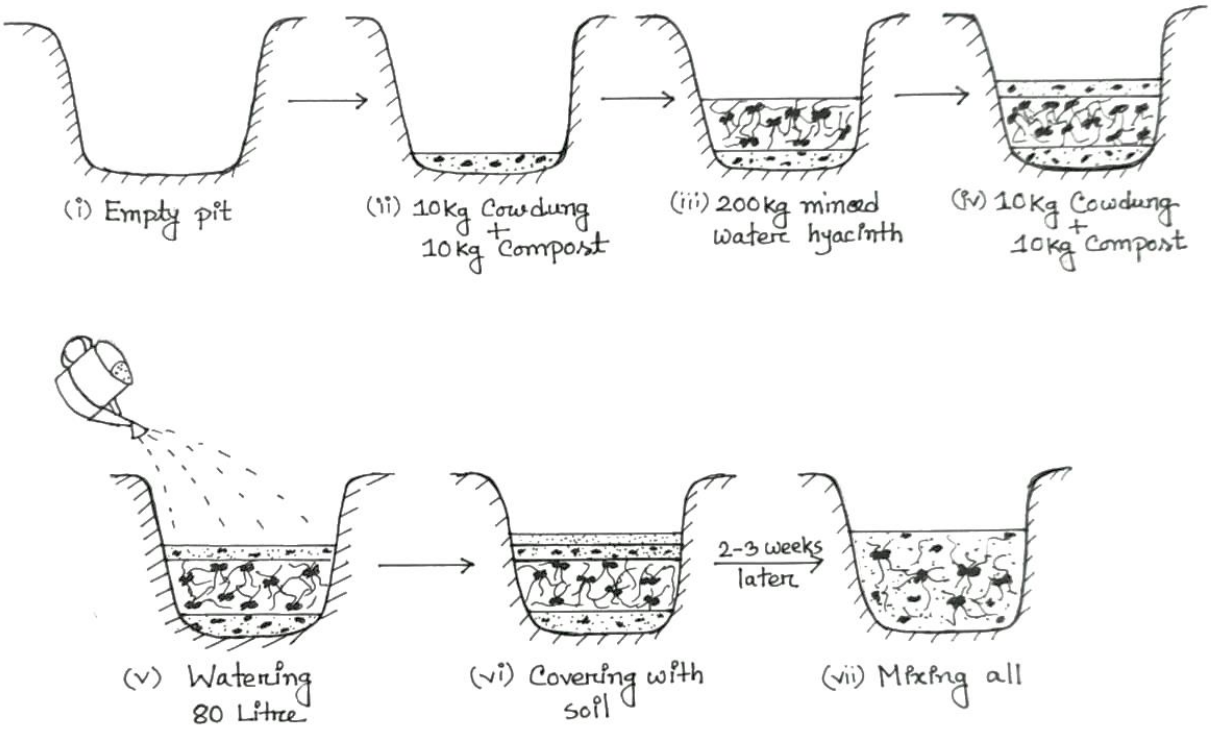
Compost from water hyacinth

Water hyacinths are a problem all over the country as it hampers the primary productivity of inland water bodies. It is a big issue at Kaptai lake due to rapid growth and the cost involved in their cleaning. However, it has some commercial uses as a raw material in the cottage industry.

Water hyacinth can be converted into compost at or near plantation sites or can be composted near its sources and the resulting compost can be transported to the plantation site. The latter option is more preferable from transportation volume and cost consideration.

Plate 1: Preparation of water hyacinth compost on-site.

As it is fibrous in nature and spongy, it has the inherent capacity to retain a substantial amount of moisture. And, being soft and mainly leafy green makeup, it is easily decomposable. Therefore, the application of compost from water hyacinth creates multiple opportunities – solving water hyacinth nuisance and keeping water bodies clean for other uses, a livelihood option for local people to produce this compost, and returning lost nutrients from the soil while using the compost to improve soil moisture retention capability.



Sketch 2: The step-by-step guide to preparing water hyacinth compost.

The water hyacinth compost was prepared by following the procedure as outlined in Plate 1 and Sketch 2.

- Collected required amount of water hyacinths (in trial 200 kg was used) and mince into pieces
- Dig a 6 ft deep and 4 ft diameter pit (). [for 200 kg water hyacinth]
- Add 10 kg of cow dung and 10 kg of compost at the bottom of the pit and mix thoroughly to enhance the composting process, a
- Add 200 kg of thoroughly sliced water hyacinths added to the pit.
- Again, add a mixture of 10 kg cow dung and 10 kg compost at the top
- Add 80 liters of water [200 Kg water hyacinth] by using a waterfall
- Cover the pit with soil
- Routinely monitor the decomposition.
- After four-six weeks, the water hyacinths compost can be collected.

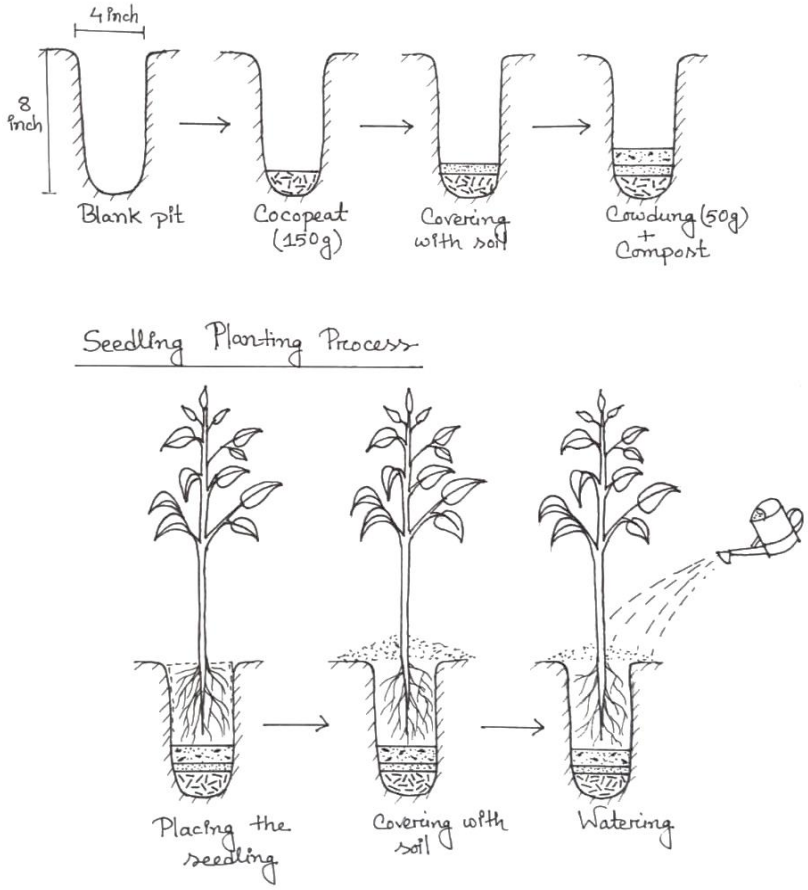
Application of soil amendments

After staking and pitting following the plantation arrangement, moisture conserving and soil amendment materials needs to be applied to each pit.

Cocopeat

Sketch 3 illustrates the process as described below:

- Add 150 gm of cocopeat at the bottom of each pit.
- Add a layer of soil was added as a buffer between roots and cocopeat above the cocopeat layer to avoid direct and sustained exposure of seedlings' roots with water as cocopeat is a moisture retention material
- Add water
- Leave the pit for few days before planting

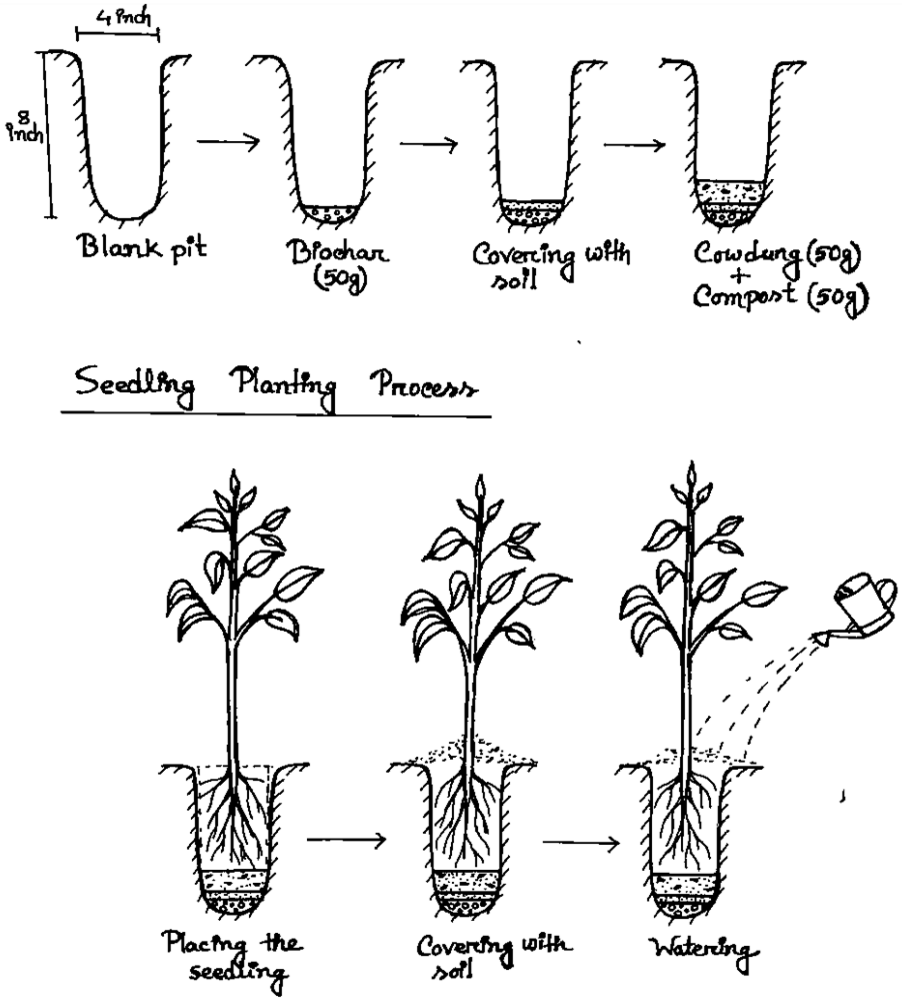


Sketch 3: Application of cocopeat as a soil amendment for moisture conservation.

Biochar

Sketch 4 illustrates the process as described below:

- Add 50 gm of biochar at the bottom of each pit. Biochar has a higher water holding capacity per unit mass than cocopeat for which, one-third the amount of cocopeat is proposed in the case of biochar.
- Add a layer of soil as a buffer between roots and biochar above the biochar layer to avoid direct and sustained exposure of seedlings' roots with water as biochar is a high moisture retention material.
- Add water
- Leave the pit for few days before planting

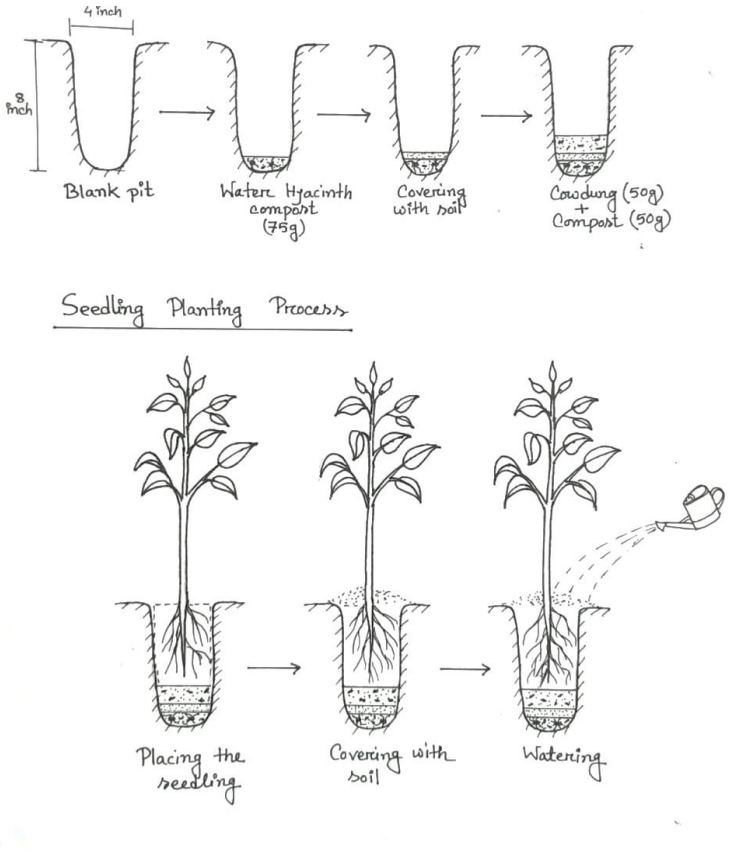


Sketch 4: Application of biochar as soil amendment for moisture conservation

Water hyacinth compost

Water hyacinth compost requires to be characterized in terms of moisture-holding capacity and nutrient content, if possible, before application. This will help determine the irrigation regime. Sketch 5 illustrates the process as described below:

- Add 75 gm of compost at the bottom of each pit
- Add a layer of soil as a buffer between roots and water hyacinth compost above the water hyacinth compost layer to avoid direct and sustained exposure of seedlings' roots with water as water hyacinth compost is a high moisture retention material.
- Add water
- Leave the pit for few days before planting



Sketch 5: Application of biochar as soil amendment for moisture conservation

Application of cow dung and compost

- Add 50 gm cow dung and 50 gm commercially available compost to each peat for all amendments.
- In the hexagonal arrangement, the center pit of the hexagon can be kept vacant and a bulk amount of Cow dung and compost can be added for sharing with all seedlings in the hexagon.
- Alternatively, compost and cow dung can be used in a circular trench around each pit as additional nutrients for sharing among seedlings if the site condition allows.

Planting seedlings in pits with moisture conservation materials

In pits containing the treatments of moisture conservation and soil amendment materials, the seedlings can be planted by removing the polybags and placing them into the pits followed by filling up the pit with soil. The steps involved are:

- Remove polybags from the seedlings
- Carefully plant the seedlings following standard technique without damaging the roots
- Apply adequate moisture after planting
- Tie with the stake to save polybags from wind through
- Spread cocopeat / dried materials from slashed debris available onsite the base of the seedlings to serve as mulch and to add to the soil nutrient gradually
- Check the seedling condition and provide irrigation at a regular interval based on requirements

Approach # 2: Use of the slow irrigation device - Cocoon

Cocoons are moisture conservation devices of varying designs for slow irrigation. Cocoons can be made of a range of materials including plastics, paper, earth, wood, or metals. These can be used aboveground or belowground depending on the purpose. In the Shilkhali dry season plantation trial, we have used earthen cocoons of our design, manufactured by local potters for applications aboveground. Our single-use earthen cocoons design can be adapted for both above- and below-ground applications, for both hilly land or plain land. The cocoons as used are shown in **plate 2**.

In terms of dimension used in the trial based on which this manual has been prepared, the total height with lid was 8.5 inches and without a lid was 7.5 inches, with a top diameter of 13 inches. The cylindrical opening at the center through which the seedlings are protruded was 5 inches in height and 4 inches in diameter. The lid covered the face with an opening for protrusion of the seedlings. At the bottom, there was a perforated low wall to tie a fabric wick and a small notch on the top of the cylindrical opening to pass the wick and put it into the soil for slow removal of water from the cocoon into the soil.

Plate 2: Earthen cocoons used as slow irrigation devices for dry season plantation trials.

Steps involved in planting with cocoon

In the case of cocoons, seedlings are planted following the same standard method, and cocoons are placed after the seedlings are planted. Some steps need to be followed before the setting up of these cocoons as given below:

a) Testing the cocoons

Cocoons are earthen devices and may have cracks and other defects developed during manufacturing or transportation. Therefore, before field application, the first step is to test the cocoons. Testing can be done by keeping 2.5 to 3 liter of water in the cocoons and leaving them for one hour and check them for leakages of water (Plate 3). Cocoons, which leaked water due to cracks, were separated, marked as defective, and send back to the supplier for replacement or repair. The remaining cocoons are considered as fit for field applications.

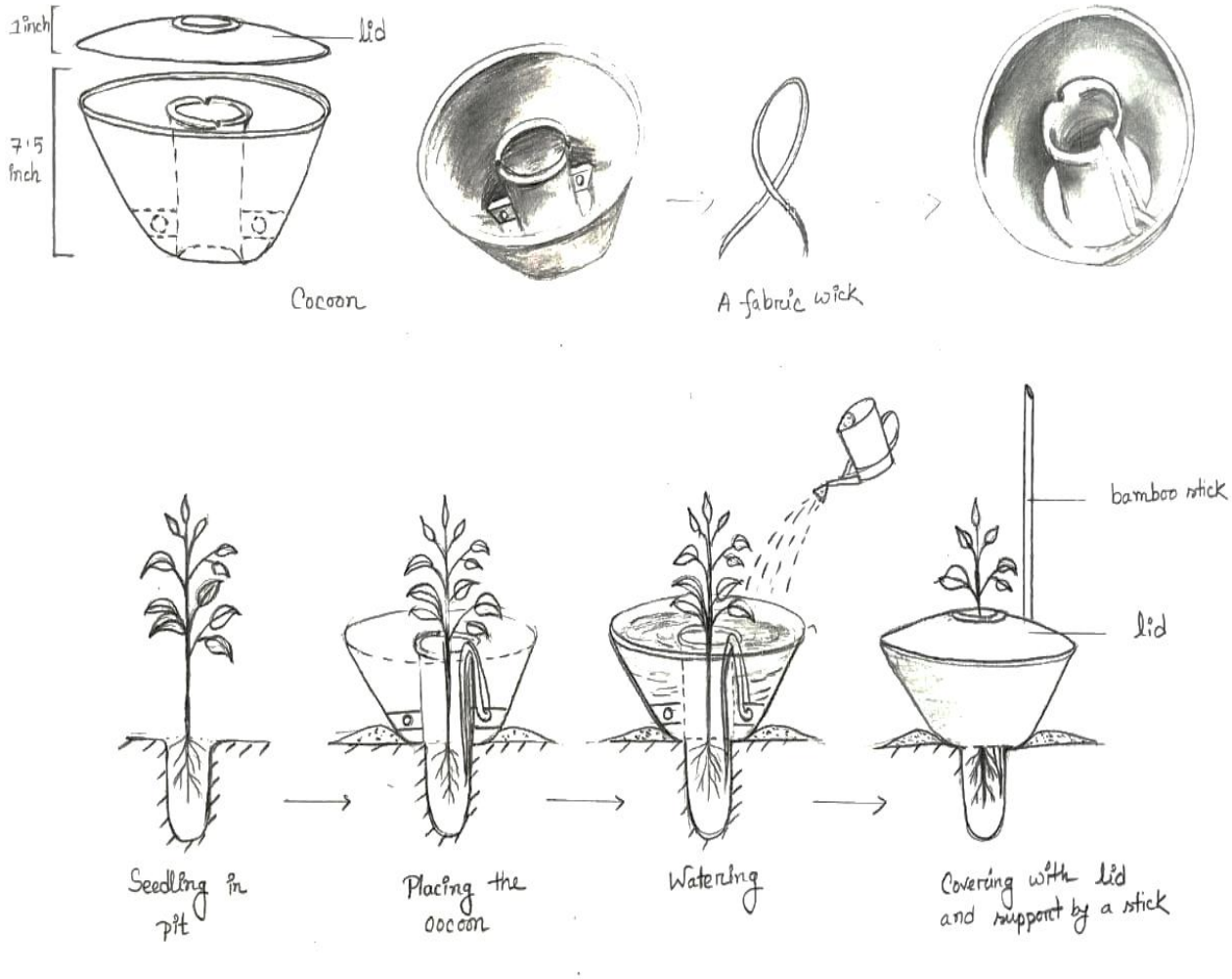
Plate 3: Testing the cocoons for cracks and defects through the water leakage test.

b) Adding wicks

- A light thick cotton wick, usually used in kerosene lanterns in rural areas in Bangladesh can be added by attaching them to the small perforation designated for the purpose at the bottom of the cocoons and pass them over a cylindrical opening

over the notch. In selecting the wicks, the thickness and the materials need to be optimized based on the site condition. Think wicks make the irrigation slower and the cocoons can supply water for weeks and thick ones can remove water faster and cocoons may need to be filled up more frequently.

- The wicks are to be dipped into the soil at a distance from the base of the seedlings so that the water inside cocoons can easily and slowly rise through the wicks by capillary action and reach the soil irrigate the soil and maintain favorable soil moisture for the seedlings through capillary force.



Sketch 6: The cocoons in the upper panel and the method of placing cocoons in the lower panel.

Plate 4: Placement of cocoons – the slow irrigation device for dry season plana

c) Placing the cocoons:

- The cocoons are then placed (Sketch 6 and Plate 4) by keeping the seedlings emerging through the cylindrical opening of the cocoons.
- The cocoons are to be placed on the ground by taking extra care of the spot to ensure the stability of the cocoons as the plantation plots used for cocoons were located on moderate to steep slopes.
- When necessary, some sticks can be used around the outer edge of the cocoons as support to avoid toppling off the cocoons.

d) Checking evaporation loss from cocoons:

- After placement, cocoons should be covered with lids to avoid direct evaporation loss.
- The use of shading and covering materials such as jute net, plastics, or straw over the lid of the cocoon can reduce the loss of water due to evaporation
- If all precautions are taken, a cocoon can ensure moisture supply for a seedling for about four weeks. In the case of the dry season plantation trial at Shilkhali at Cox's Bazar, wicks of medium thickness were used.

Approach # 3: Adapted Miywakai method

This approach is based on the Miyawaki plantation method which aims to rapidly cover small to large tracts of relatively flat land areas with a mixture of different plant species of different canopy classes in a dense arrangement upon extensive soil amendment procedures for enrichment and retention of moisture and nutrient for attaining a natural forest-like vegetation cover both in structure and function.

Plate 5: Dry season Miyawaki plantation establishment in pictures.




Adaptations to Miyawaki method for the hilly terrain dry season plantation

- In this adapted Miyawaki method, a mixture of compost fertilizer, biochar, cocopeat, water hyacinth compost, dried and crushed water hyacinth, rice husk, and sawdust can be used which are different from the material mix used in traditional Miyawaki plantations.
- Also, unlike the Miyawaki method, the soil-amending materials are applied to the pits dug for seedlings. In Miyawaki, usually, the entire site is excavated to about 1 m depth.
- In contrast to the Miyawaki method, in this approach, the materials need to be preprocessed so that seedlings can be planted with a minimum time gap between materials application and actual plantation.
- Seedlings can be planted very densely at a random arrangement with spacing around 0.5 m.
- After plantation, the entire site should be covered with dried rice straw or cocopeat or sawdust or rice husk or a combination thereof as mulching materials that also add to the soil nutrient pool and suppress the growth of weeds at the initial stage.

The steps followed in the successful establishment of the dry season plantation under the adapted Miyawaki method is outlined below:

Application of materials

Application of soil amending materials

In each pit apply 300 gm of soil amendment materials. An example mixture may contain the following components. A different mix of similar materials can also be tried.

a) Biochar: 50 gm
b) Cocopeat: 100 gm
c) Dry water hyacinths: 20 gm
d) Water hyacinth compost: 30 gm
e) Rice husk: 50 gm
f) Sawdust: 50 gm

Application of cow dung and compost

Usually, as per the principle of the Miyawaki method, after the application of soil amendments, there is a time gap before planting to allow them to decompose. To save time by enhancing the decomposition, 50 gm cow dung and 50 gm compost can be added to each pit. In addition to enhancing decomposition, it assured the availability of nutrients to plants at the initial stage of the plantation.

The general guideline section guidance for other necessary steps.

Cost-benefit estimation for the field implementation

Alike all the off-season facility costs higher than usual, the dry season plantation is not an exception. Considering the technical aspects and the methods for ensuring moisture conservation during the dry period which requires some improvised technique, costs higher than the conventional practices. In developing the method, different particles were used to ensure soil moisture. Depending on their performances and availability in the market, the price of those items varies. The experiment also followed the conventional tree plantation method that requires regular irrigation to estimate the difference between the improvised and conventional practices. The following graphs depict the costs from field preparation to 3 months maintenances of the planted seedlings. The comparison shows higher cost involvement with the installation of cocon while the other methods perform better with almost simiar cost to the conventional practices. However, the added soil amendment treatment through the developed technique ensures better performence with more nutrient that boost the initial growth, helps the tree seedlings to compete with other weeds and grasses during the succession period.

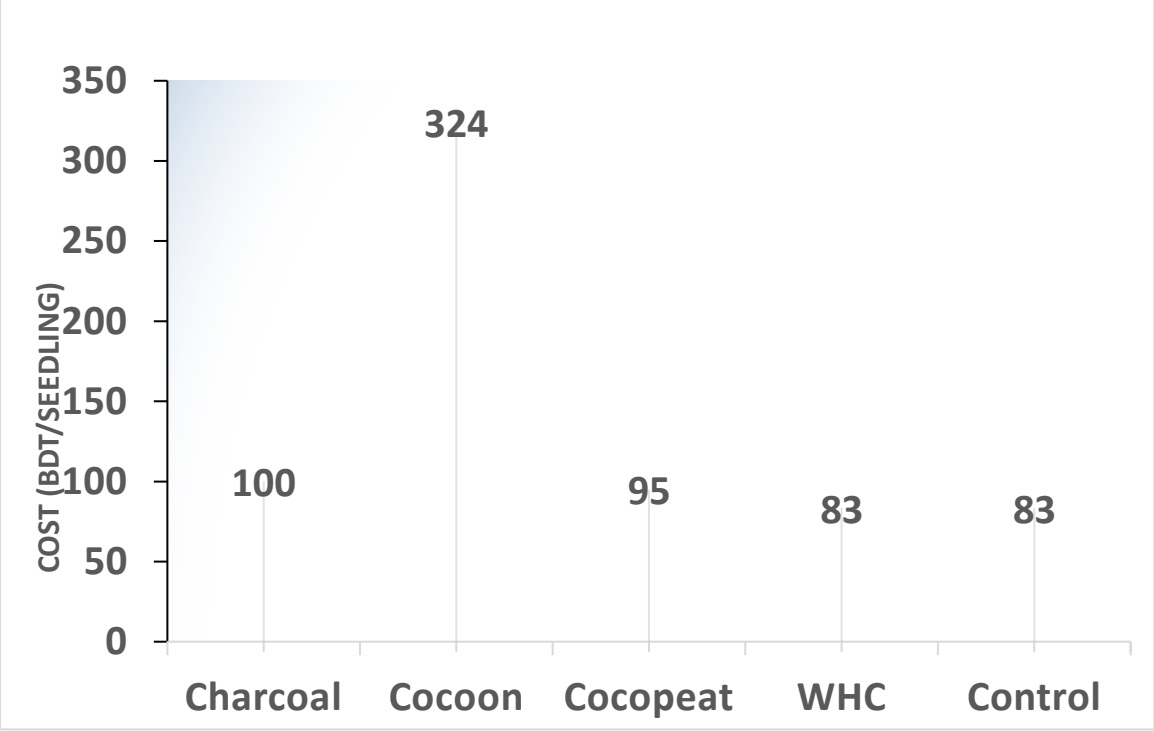


Figure 1: Essential material plus labour cost