# Biochar: classification, effects to plants and practical application.

## 1. Soil improvement by biochar application

### 1) What is biochar?


Biochar is a charcoalized material made from biological resources. And it has gained international recognition in recent years because it has a positive impact on plants and is effective in improving the environment. This content aims to describe standard application of biochar for soil improvement purpose and to create suitable condition for plants growth.

In Japan, biochar and ash have long been used for soil improvement. We can find such description in Encyclopedia of farming published in 1697. Rice husk charcoal, charred at 350-500 degree C, have long been used as traditional soil improvement materials in rice farming. Research on the agricultural use of wood charcoal began in the 1980s, and the Forestry Agency organized the Wood Carbonized Component Multi-Use Technology Research Association for five years from 1985. Also, in 1986, charcoal was designated as a soil improvement material by the Soil fertility promotion law, as it has the effect of improving the permeability of soil.

### 2) Types and characteristics of biochar

- **Classification by raw materials: Wood, bamboo, plant shells (rice husk, soybean pod, corn cob, etc.)**

Woody raw materials can be classified according to tree species and parts such as bark and branches. There is no significant difference in quality between hardwoods and softwoods, but in the parts, the bark is rich in potassium and silica. In addition, since there is a possibility that preservatives and paints may remain in construction waste, it is not preferable as a raw material.

There is a lot of species in bamboo family but after charcoalized, almost no difference among them, rich in potassium and silica compared to tree species.

Plant shells include rice husk, corn cob, stalks of plants, cut grass. Rice husk charcoal contains about 15% silica.

- **Classification by production method: White charcoal, black charcoal, rice husk charcoal, burn & off charcoal**

Biochar changes its properties depending on the temperature of the production.

In white charcoal production, air is supplied in the final step to raise the temperature of the charcoal. The temperature of the charcoal reaches 900 degree C or more. This refinement process makes white charcoal dense and heavy. Because of these characters, the improvement effect of the physical property of soil is considered to be small.

The carbonization temperature of black charcoal is about 500 ° C to 650 ° C, that lead to good water retentivity and air permeability, therefore it has a high soil improvement effect.

Rice husk charcoal (RHC) is produced at a lower temperature than black charcoal, about 350 ° C. to 500 ° C. In general, charcoal is alkaline, but RHC may be acidic because acidic functional groups may be attached to the surface of it.

Burn & Off charcoal (BOC) is produced by a simple method. It is forced to extinguish and cool by spraying water after burning well. In general, although the carbon content is low, the mineral contained in the ash can be expected to be effective as a fertilizer.

- **Classification by shape: powdery, chipped, molded**

The shape of the biochar includes the shape of the raw material itself and the shape made by processing after the carbonization. From the viewpoint of soil improvement, powdery or chipped charcoal is suitable for agriculture. However, when used for trees such as pine, relatively big shape of molded biochar may be used.

## 2. Chemical & physical properties of biochar and its compatibility with micro-organisms

### 1) Effect on pH of soil

Although biochar exhibits alkalinity (pH 9 to 11), the pH of carbon itself is originally neutral and alkalinity is attributable to metal oxides contained in biochar. Therefore, it is possible to neutralize its pH value by watering. Plants those prefer acidity need to be careful, as mixing biochar make the soil alkaline at first. In addition, it is effective to mix biochar in order to neutralize acid soil.

### 2) Influence on Electric Conductivity (EC)

When biochar is mixed into soil, EC tends to rise up due to the effect of metal oxides contained in biochar. If EC is raised too much, Water absorption function of plants may be impaired, so it is necessary to manage EC carefully when mixing in soil of high salinity.

### 3) Retention capacity for water and nutrient

Since biochar is porous and can maintain a certain shape, it is possible to create a gap in the soil by mixing the biochar into the soil, and to retain water in it. Furthermore, since water can be retained in the hydrophilic macropores of biochar, it can greatly contribute to the improvement of water retention capacity. Although biochar itself does not contain a fertilizer component, its high water-holding capacity makes it possible to achieve high nutrient retention capacity and supply fertilizer component to plants efficiently.

### 4) Air permeability

As with water retention, the gap in the soil made by biochar also serve as vents, which are highly effective in preventing root rot of plants.

### 5) Compatibility with soil microorganisms

Since biochar is burned at high temperature, bacteria attached to the raw material are killed out. Furthermore, since biochar does not contain organic matter, bacteria and mold can't propagate on the surface of biochar, and it is almost sterile until organic matter comes in. On the other hand, since most of biochar is highly alkaline, microorganisms that enter the biochar in the soil are often useful bacteria and actinomycetes. Furthermore, since macropores of biochar has appropriate water retention and air permeability, fine roots of plant can enter into it easily, VA bacteria symbiosis with roots, nitrogen-fixing bacteria that help absorb plant fertilizer components, etc. can be selectively grown.

## 3. Principles of biochar application

### 1) For sowing and seedling

In sowing and seedling, elongation of healthy root is prioritized than growing plant body above ground. The seedling culture medium using biochar is highly effective in improving physical properties, and can create an optimal environment for growing root.

Generally, mixing 20 to 40% of biochar against soil quantity of sowing or seedling bed. Biochar is usually mixed with seedling bed uniformly, but in case of preventing root rot, a large amount of biochar is mixed in the bottom of the pot. For crops that prefer acid soil, increase initial irrigation to prevent the damage of high alkaline.

**2) For ridge farming**

For ridge farming, apply 10 to 20% of biochar against the volume of ridge before making it up, then stir the soil and make the ridge.
(soya bean, corn, sweet potato, potato, etc.)

**3) For planting hole**

In case of planning the seedling in the hole of 30 cm diameter, 15 cm depth, apply biochar of 1 to 2 lither of biochar before planting to accelerate the growing of plant.
(Tomato, eggplant, cucumber, etc.)

**4) For sowing seeds in line**

In case of sowing seeds in the line, mix biochar to the line of 20 distance and 15cm depth, at 10 to 30% against soil volume then sow the seeds on it.
(Carrot, Japanese spinach, etc.)

In order to recover the condition of tree, dig ditch of 30cm width and 15cm depth under the edge of crown and embed biochar solely or with soil of same volume.
(Pear, plum, persimmon, pine, etc.)

**5) For spreading**

In the field of cereals such as rice and wheat, spread 10 to 40 m3 of biochar per 1ha uniformly. In order to prevent biochar flowing out from paddy fields, it is necessary to cultivate the biochar before plowing. Biochar is also utilized to prevent weed growing by scattering on the water surface after puddling because of mulching effect.
(Rice, wheat, etc.)

**6) Mixing with top layer of soil**

For trees those fine root gather at top soil, scrape it 10cm deep below the branches and mix biochar 10-30% against that soil volume, then return it.
(Plum, apple, pear, etc.)

**7) For pot cultivation**

Ornamental plants are often cultivated in the same soil for a long time, and the density of the roots is high. Therefore, the soil used for these must be excellent in water retention and air permeability.

Mix biochar 10-30% against soil volume of pot. In order to prevent root rot, biochar may be intensively applied to the bottom of the pot.

**8) For hydroponic cultivation**

In recent years, hydroponics cultivation has become widespread mainly on fruit vegetables such as tomatoes, cucumbers and eggplants. There are some methods. Ordinally, it's applied for ridge farming but also for small amount of soil in bag or container. In any case, using biochar is effective from the viewpoint of improving the capacity of water retention and permeability, but we should consider nutritious content of biochar for applying in case hydroponic liquid contains much nutrients. For ridge faming, mix 10-20% of biochar against soil volume of the ridge. For bag & container those contains only small quantity of soil, mix 10-50%. We can use only biochar instead of soil in this hydroponic cultivation.

## 4. Examples of Biochar application to major crops

In this section, the amount of biochar is described in volume. This is because the application rate must not be changed by the water contained in the biochar, and in an actual field, you can work easier in measuring by volume than weight.

### 1) Cereals and beans

- **Paddy rice**

For seedling, apply 20-40% of biochar against soil volume of seedling bed and irrigate with a large amount of water to lower pH degree. Don't use biochar instead of soil for covering seed because it will float up. For paddy field, spread biochar 10-40m3/ha before plowing with water to prevent flowing it out from paddy field.

- **Soya bean, corn**

Apply 1-20% of biochar against ridge soil with stirring and make the ridge. For groove farming, apply 30% of biochar against volume of groove 20cm width and 15cm depth where seeds or seedlings will be planted.

**2) Leafy vegetables**

・ **Spinach, cabbage, Chinese cabbage etc.**

Mix 20% biochar in line of 15cm depth and 20cm distance then sow the seeds on it.

**3) Fruit vegetables**

・ **Cucumber, tomato, eggplant**

Apply 1-2 litter of biochar by mixing with the soil of planting hole, 30cm diameter, 15cm depth.

・ **Strawberry, tomato**

For hydroponics, biochar can be mixed up to 50% of the soil, but there are also cases of 100%. For pot cultivation, about 30% of biochar is mixed with the cultivation soil. For open field cultivation, biochar is mixed at 20% to whole cultivation ridge.

**4) Root vegetables**

・ **Sweet potato, potato**

Make a high furrow and mix biochar at 10-20%, then plant seedlings or seed potato. Biochar powder may also be applied to the cross section of seed potato.

・ **Japanese radish, carrot**

Mix biochar at 20% against ridge and sow seeds.

**5) For trees**

・ **Pear, apple, plum**

Dig groove of 30cm width and 20 depth under the edge of crown and mix 30% of biochar against soil there or scrape the soil 10cm deep below the branches and mix biochar 10-30% against that soil volume, then return it.

・ **Pine**

Dig 4 holes of 30cm diameter and 50cm depth under the edge of crown and mix 50-100% of biochar with soil then return it to the holes.

**6) Cut flowers**

・ **Chrysanthemum, rose, carnation, Nadeshiko, etc.**

About 20% biochar is uniformly mixed with the cultivation soil in the cultivation pot. Similarly, in the case of cultivation bed, 20% biochar is mixed.

## 5. Biochar and organic fertilizer

Since biochar is porous, mixing it with cow dung or chicken dung can greatly improve the water retention and breathability required for fermentation as compost. In addition, since the macropores of biochar have an effect of growing microorganisms, fermentation is promoted. Moreover, since biochar is not decomposed by microorganisms, a stable effect can be maintained during the fermentation period. Well fermented compost containing biochar is an excellent agricultural material that has not only a fertilizer effect but also improvement effect.

**1) Effect of biochar in compost production, fermentation promotion, deodorization effect**

Mixing about 20% biochar with raw materials of composts such as cow dung and chicken dung are effective in promoting fermentation and deodorizing.