Indian Farming **64**(12): 9–12, 18; March 2015

Low-Cost Portable Kiln

for Biochar Production from On-Farm Crop Residue

G. Venkatesh[1], Ch Srinivasa Rao[2], K.A. Gopinath[3] and Sammi Reddy[4]

ICAR-Central Research Institute for Dryland Agriculture, Hyderabad 500 059

HUGE quantities of unused crop residue in India are becoming an issue of concern due to inefficient crop residue management practices. The Ministry of New and Renewable Energy (MNRE), Govt. of India has estimated the surplus crop residue availability at about 120–150 million tonNEs/annum. Of this, about 93 million tonnes of crop residues are burned each year by farmers. For more effective utilization and disposal of crop residue, a novel and alternate way is gaining importance on use of thermo-chemical process (slow pyrolysis) to convert crop residue into "biochar". Biochar production helps to reduce the weight and volume of crop residue and make the product easier to handle compared with that of fresh and uncarbonized crop residue. Currently, however, very little biochar is produced and utilized in modern Indian agriculture. Use of crop residue for producing biochar for improving soil quality as well as crop productivity in the Indian farming systems may be ecologically promising.

Need for Recycling of Crop Residue into Biochar

- To improve soil health through efficient use of crop residue as a source of soil amendment/ nutrients
- To improve soil physical properties viz. bulk density, porosity, water holding capacity, drainage etc, through incorporation of biochar
- Substantial amounts of carbon can be sequestered in soils in a very stable form
- Addition of biochar to soil enhances nutrient use efficiency and microbial activity
- To enhance soil and water conservation by using the biochar in rainfed areas
- Minimize reliance on external amendments for ensuring sustainable crop production
- Mitigation of greenhouse gas emissions by avoiding direct crop residue burning by farmers
- To enable destruction of all crop residue borne pathogens

Constraints in Recycling of Crop Residue

- Unavailability of farm labour, higher wage rates for collection and processing of crop residue
- Lack of appropriate farm machines for on-farm recycling of crop residue
- Inadequate policy support/ incentives for crop residue recycling

Biochar Production – A Novel Strategy for Efficient Recycling of Crop Residue

Carbonization of crop residue by thermo-chemical conversion process (slow pyrolysis) at low temperatures (~350–600°C) in an environment with little or no oxygen yields a highly stable carbon compound known as biomass-derived black carbon or 'biochar'. The main quality of biochar is its carbon-rich, fine-grained, highly porous structure and high surface area, which makes it an ideal soil amendment to increase the rate of soil carbon sequestration, soil fertility and crop yield.

Biochar can be produced at scales ranging from large industrial facilities down to the individual farm and even at the domestic level through a distributed network of small facilities that are located close to the crop residue source. Small facilities to produce biochar are less complicated than larger units. Biochar production protocols are yet to be standardized in India. To make biochar technology popular among the farmers, it is imperative to develop low cost biochar kiln at community level or at individual farmer's level. Hence, a low cost portable biochar kiln was developed at ICAR-CRIDA, Hyderabad to produce biochar from crop and agroforestry crop residue.

Burning of unusable and surplus crop residue is a major concern in India. Thermo-chemical (slow pyrolysis) conversion of crop residue to biochar appears to be a novel and sustainable strategy to address the concerns associated with crop residue management, long term C sequestration and improving soil health and productivity, especially in terms of improving the sustainability of the agricultural system. Biochar from crop residue is one of the oldest soil amendments and has ancient orgins, which has been aptly, termed as Amazonian Dark Earths or Terra Preta de Indio. Biochar has received much attention recently as a tool for countering climate change.

A Brief Description of the CRIDA Biochar Kiln

In designing the kiln, both the requirements of controlling the loading rate and rate of partial pyrolysis periods to stop the process when all of the crop residues have been converted to biochar have been addressed. Biochar kiln functions on direct up-draft principle with bottom ignition. The biochar kiln consists of a metal cylinder modified from a ready-made oil drum of about 0.21 m^3 capacity based on a single barrel design of vertical structure with perforated base. At one end of the cylinder, a square shaped hole of 16 cm x 16 cm is formed for loading the crop residue, which can be closed at the end of conversion by a metal lid (about 26 cm in length and 26 cm in width) with a handle (110 cm). The other end of the cylinder is marked with alternating and staggered vents of 16, 16 and 8 numbers in first, second and third equidistant concentric circles from rim for uniform heat transfer through the crop residue by primary air movement. This perforated portion of the cylinder has a central vent of about 2.5 cm radius to hold wooden pole or metal rod, to create a central vent. A strip of metal is welded with handles at around 3/4th height of kiln, to serve as lifting jack.

Key Features of the CRIDA Biochar Kiln

Portability: Easy mobility of the kiln to the source of crop residue and with access to most remote places helps to reduce collection, handling and transporting expenses.

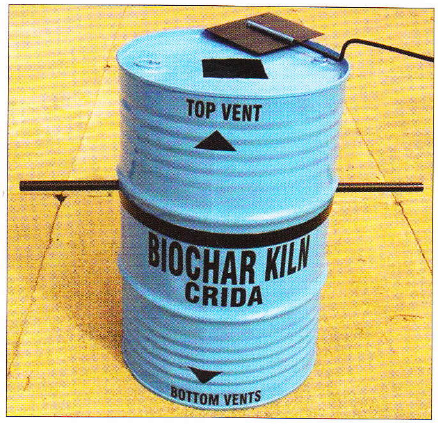
Simplicity: Farmer-friendly, easy-to-understand, convenient-to-use, minimize operational labour costs.

Adaptability: Designed for non-competitive and surplus crop residue.

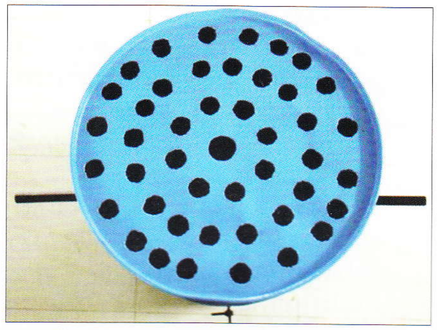
Affordability and Durability: Least expensive kiln (approximate cost: ₹ 1200/-) to match the needs of the small and marginal farmers and kiln can be operated for multiple batch process.

Thermo-Chemical Conversion of Crop Residue to Biochar

The steps involved in preparation of biochar from different crop residue by using the CRIDA biochar kiln are as (in the process shown).

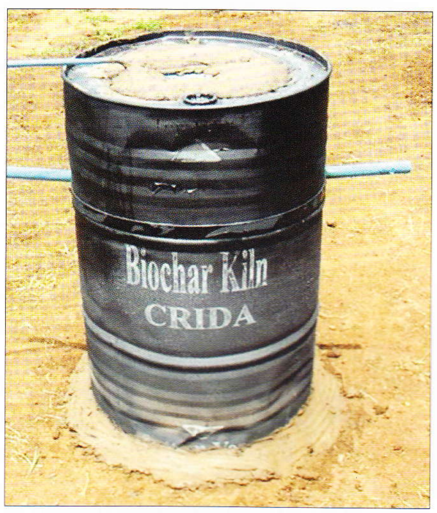


Whole view of the kiln with top vent



Bottom view of the kiln with vents

Low cost portable biochar kiln to produce biochar at farm level



View of the sealed kiln during cooling period

Create a central vent in the kiln with pole
↓
Load the kiln with freshly chopped and sundried bioresidue with gentle shaking
↓
Mount the kiln on raised stones
↓
Bottom ignition with dried grasses for 3-4 minutes (carbon neutral)
↓
Blue exhaust (350-450°C) is the target and stage
↓
Close the top vent with metal lid to develop backward pressure
↓
Transfer the kiln to flat ground to prevent primary air ingression through bottom vents
↓
Seal the edge of the top lid and circumferential bottom edges of the kiln
↓
Cooling off by heat loss
↓
Remove seal and unload the biochar
↓
Cure the biochar
↓
Grind, seive and store the biochar

Flow chart for biochar production process

Properties of Biochar Prepared from CRIDA Biochar Kiln

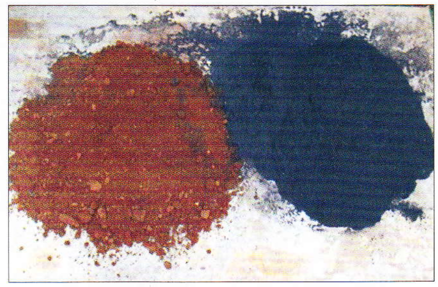
The potential of the CRIDA biochar kiln was investigated by converting the different crop residue into biochar. The operational process parameters *viz.* loading rate and partial pyrolysis period were standardized for production of biochar from crop (maize, castor, cotton and pigeonpea) and agroforestry (*Gliricidia* twig, *Eucalyptus* bark, *Pongamia* shell, *Eucalyptus* twig and *Leucaena* twig) residue on a small scale to suit farmer. In this technology, grey color exhaust was correlated to 350-400°C and blue color exhaust to 450-500°C as corresponding internal kiln temperature range for determining the end stage. Biochar composition varies according to type of crop residue (Table 1 and 2).

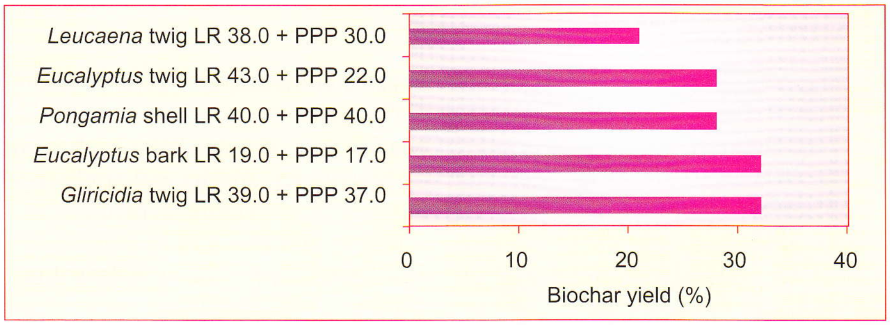
Handling of Biochar

Biochar is more susceptible to wind and water erosion. During transportation, measuring and soil incorporation of fine biochar, drifting losses can be significant; precautions must be taken to minimize the losses by mixing thoroughly the measured quantity of biochar with some amount of carrier like native soil. Incorporating biochar well into soil

Table 1. Properties of biochar produced at the end stage of biocarbonization

Property	Trend
Proximate	Volatile matter content decreased, fixed carbon and ash content increased biochar yield varied with temperature range
Ultimate	– Total N, P, K, Ca, Mg, Fe, Cu, Mn and Zn contents got concentrated in biochar from crop residue – CEC, pH and EC varied with temperature range – The maximum water holding capacity and available water capacity of the biochar was enhanced – Higher total carbon content in the biochar signifies its potential to sequester substantial amounts of carbon in soil over shorter period. The order of total carbon (%) content is 71 > 65 > 56 > 51 for pigeonpea, cotton, castor and maize biochar, respectively.





Biochar yield from different agroforestry residue using CRIDA biochar kiln (LR- Loading rate-kg/kiln; PPP- Partial pyrolysis period-minutes)

Mixing biochar with native soil as carrier

will minimize surface runoff with water after heavy rainfall events, and/ or wind erosion.

In the biochar field study at CRIDA, Hyderabad, broadcast method was adopted for uniform topsoil mixing with biochar. Biochar with native soil (carriers) mix was broadcasted with the onset of southwest monsoon after primary soil preparation and incorporated to a depth of 10-15 cm by using hand hoe. Incorporation can be done with any implement that is used to incorporate FYM, lime, or other amendments, such as hand hoes,

Uniform top soil mixing

Table 2. Operational parameters for four different biochar products, order of conversion and basic properties

Operational parameters	**Conversion order to biochar products**	**Basic utility properties**
Loading rate (kg/kiln): 8.7 Partial pyrolysis period (min.): 15.00 Biochar yield (%): 29.3		Total Organic Carbon (g/kg): 520.0 Total Inorganic Carbon (g/kg): 2.5 Total Nitrogen (g/kg): 13.4 Total Phosphorous (g/kg): 4.0 Total Potassium (g/kg): 4.7 MWHC (%): 590.51 CEC (C mol (p+) kg^{-1}): 16.9
Loading rate (kg/kiln): 10.8 Partial pyrolysis period (min.): 11.30 Biochar yield (%): 26.9		Total Organic Carbon (g/kg): 710.0 Total Inorganic Carbon (g/kg): 5.7 Total Nitrogen (g/kg): 9.8 Total Phosphorous (g/kg): 4.6 Total Potassium (g/kg): 4.0 MWHC (%): 382.84 CEC (C mol (p+) kg^{-1}): 46.28
Loading rate (kg/kiln): 15.0 Partial pyrolysis period (min.): 17.00 Biochar yield (%): 24.4		Total Organic Carbon (g/kg): 577.0 Total Inorganic Carbon (g/kg): 15.0 Total Nitrogen (g/kg): 12.0 Total Phosphorous (g/kg): 2.0 Total Potassium (g/kg): 4.0 MWHC (%): 374.89 CEC (C mol (p+) kg^{-1}): 31.09
Loading rate (kg/kiln): 18.0 Partial pyrolysis period (min.): 16.00 Biochar yield (%): 35.0		Total Organic Carbon (g/kg): 720.0 Total Inorganic Carbon (g/kg): 31.6 Total Nitrogen (g/kg): 14.4 Total Phosphorous (g/kg): 4.1 Total Potassium (g/kg): 4.1 MWHC (%): 385.27 CEC (C mol (p+) kg^{-1}): 14.0

Physical properties	Chemical properties	Biological properties
Decreases bulk density, improves soil workability, reduces labour and tractor tillage and minimizing fuel emissions	Liming effect provides net carbon benefit compared to standard liming	Enhances the abundance, activity and diversity of beneficial soil bacteria, actinomycetes and arbuscular mycorrhiza fungi
High negative charge of biochar promotes soil aggregation and structure	Enhances the fertilizer use efficiency, reduces the need for more expensive fertilizers and improves the bioavailability of phosphorus and sulphur to crops	High surface area, porous structure and nutrient retentive capacity of biochar provides favorable microhabitats by protecting them from drought, competition and predation
Positive effect on crop productivity by retaining plant available soil moisture due to its high surface area and porosity	Reduce leaching of nutrients and prevents groundwater contamination	
	Carbon negative process, stable carbon, longer residence period and reduces Green House Gas emissions from soil	

spades, animal draft plows, harrows, disking, rotary hoes or chisel tillage depending on the size of field and scale of the farming operations.

Quantity and Frequency of Biochar Application

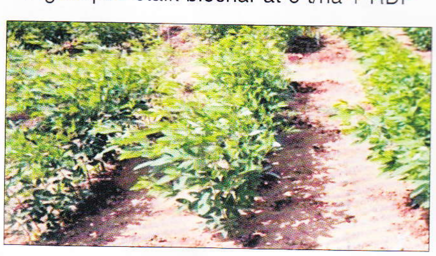
Availability of crop residue, soil type, crops, nature of biochar, application rate of biochar, labor, time and the preference of the farmer may determine to employ one-time application of large quantity or frequent application of smaller quantity. Biochar is not substitute for fertilizer. Adding biochar with necessary amount of inorganic nutrient can enhance the crop yield. Biochar is stable in nature compared to manures, compost and other soil amendments; therefore, biochar does not need to be applied with each crop. Beneficial effects of biochar can improve with time over several growing seasons in the field.

Crop Responses to Biochar Addition

- Results of field trial showed that the alternate year application of either pigeonpea stalk biochar @ 6 t/ha with recommended dose of fertilizers (50-20-00 kg N, P_2O_5, K_2O/ha) or cotton stalk biochar @ 3 t/ha with recommended dose of fertilizers produced higher pigeonpea grain yield of 1484 and 1400 kg/ha, respectively compared to control (454 kg/ha).
- Three years of experimentation on residual effect of different types of biochar in Alfisols under maize revealed that application of maize stalk biochar was proved better than biochar prepared from castor, cotton and pigeonpea stalks in influencing the maize yield. Application of maize biochar @ 4 t/ha with RDF (120-60-60 kg N, P_2O_5, K_2O/ha) + 5 t FYM/ha to maize produced comparatively less yield in the first year (12% decrease over RDF alone) but it gave higher yield in second (135% increase over RDF alone) and third year (126% increase over RDF alone) after application.


Pigeonpea stalk biochar at 6 t/ha + RDF


Pigeonpea stalk biochar at 3 t/ha + RDF


Recommended dose of fertilizer (RDF)


Unamended control

Benefits of Biochar Incorporation in Soil

Transforming a low-value crop residue into a potentially high-value carbon source and its soil application has several important benefits.

Soil Carbon Sequestration Potential of Biochar

It has been estimated that about 7.8 Mt of biochar could be produced annually from maize, crop residue of castor, cotton and pigeon pea by using CRIDA biochar kiln. Based on the total carbon percentage in the respective biochar, it is estimated that its application can sequester about 4.6 Mt of total carbon annually in soil, making it a carbon sequestering process. This would increase soil fertility and crop yields in the long term.

Cost of Biochar Production

Biochar production process should be economically viable and sustainable. The total cost of the CRIDA biochar kiln comes at ₹ 1200/- per unit. An expenditure of ₹ 100/- per unit is required for maintenance during lean season. The cost of production of biochar per kg has been worked out on the basis of crop residue load per kiln and its conversion efficiency into biochar. All aspects from on-farm crop residue preparation, handling and operation of the kiln, pounding, sieving and packing of biochar were considered for cost estimation. On an average, the production cost of one kg of biochar from maize, castor, cotton and pigeonpea crop residue was ₹ 17.0, 14.0, 17.0 and 10.0, respectively. The cost estimates for

(Continued on page 18)

sectors, are also relied on. To some large degree, this situation arises as the large-scale global market farms have no alternative but to participate.

- *Government and industry regulation*: A wide range of quotas, marketing boards and legislation governing agriculture impose complicated limits, and often require significant resources to navigate. For example, on the small farming end, in many jurisdictions, there are severe limits or prohibitions on the sale of livestock, dairy and eggs. These have arisen from pressures from all sides: food safety, environmental, industry marketing.
- *Real estate prices*: The growth of urban centers around the world, and the resulting urban sprawl have caused the price of centrally located farmland to skyrocket, while reducing the local infrastructure necessary to support farming, putting effectively intense pressure on many farmers to sell out.

What is to be Done?

Policy can be, and is, extremely important for the fate of family farming. Although family farming can survive highly adverse conditions, positive conditions can help family farming reach its full potential. Precisely here resides the enormous responsibility of policy, that is, of state apparatuses, multinational forums (like the FAO, IFAD and other UN organizations), but also of political parties, social movements and civil society as a whole. By securing rights and by investing in infrastructure, research and extension, education, market channels, social security, health and many other aspects, investments of family farmers themselves can be triggered. Strengthening rural organizations and movements is equally of utmost importance. We have to keep in mind that family farmers, wherever in this world, are trying to find and unfold new responses to difficult situations. Thus, identifying successful responses, building on novel practices, communicating them to other places and other family farmers and interlinking them into strong processes of change must be important items on our agenda. In short, a lot is to be done. The good news, though, is that every step, including every little step, is helpful.

SUMMARY

Family farming includes all family-based agricultural activities, and it is linked to several areas of rural development. Family farming is a means of organizing agricultural, forestry, fisheries, pastoral and aquaculture production which is managed and operated by a family and predominantly reliant on family labour, including both women's and men's. Family farms and the countries in which they operate are diverse in many ways and the solutions offered for them should be tailored for this diversity.

[1&4] Principal Scientists, Agronomy, [2] Director, [3] Scientist, Plant Physiology at ICAR Research Complex for Eastern Region, Patna(Bihar)

Low cost portable Kiln for Biochar Production...

(Continued from page 12)

biochar production is affected by several factors viz. availability of family labour, quantity of on-farm availability of surplus crop residue, demand for biochar and weather conditions to run biochar kiln.

The Recommended Practices for Use of Biochar in Agriculture

- Use freshly harvested and under-utilized dry crop residue for biochar production.
- Avoid use of crop residue grown on toxic chemical and heavy metal contaminated site.
- Co-locate the kiln unit to crop residue generating locations to provide a management solution and minimize handling and transportation costs.
- Operate the CRIDA biochar kiln unit in an open area with lots of atmospheric air circulation ideally away from any structures.
- Keep sufficient water source close by and do not open the kiln unit during cooling period.
- Let fresh biochar be 'cured' overnight by exposure to open air
- Store as whole biochar outside under shelter, away from buildings, in a cool, dry well-ventilated open spot and grind to powder just before its use.
- Transfer the biochar to application site in a sealed container or in a closed plastic bag.
- To avoid biochar loss by wind, apply biochar as close to ground as possible on mild windy day to avoid drift or on a day with a mild precipitation to dampen and lay on the soil surface until following tillage operations.
- Use protective clothing such as insulated gloves or gunny rags, masks or cloths whenever possible while handling kiln and biochar.

SUMMARY

A large amount of surplus crop residue is typically subjected to on-farm burning which leads to significant emissions of greenhouse gases to the atmosphere causing adverse impact on environment as well as soil fertility. A low cost portable biochar kiln developed at ICAR-Central Research Institute for Dryland Agriculture, Hyderabad would enable the small and marginal farmers to produce biochar from surplus crop residue rather than burning. Biochar produced from different crop and agroforestry residues were characterized and found suitable to be used as soil amendment. Field experiments were conducted to study the effect of biochar application on soil health and crop yields under rainfed conditions. Thus, there is a need to discourage on-farm burning of crop residue by creating awareness among small and marginal farmers about the relatively new approach and positive impact of biochar on soils and crops.

[1] Scientist, [2] Director, [3] Senior Scientist, [4] Head, Division of Resource Management, CRIDA, Hyderabad