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Crop Residue Management through Utilization : A Review

Ancy G. Martin, Atul Jayapal, Krishna Vikram, Bavigadda Kavya

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ABSTRACT

In India, the production of food grains was insufficient for domestic consumption during 1947 to 1960. The green revolution played a major role in pulling India out from the begging bowl status. This increased production had also increased the accumulation of agricultural waste which is a challenge that is yet to be addressed. Hence, an effective management of these crop residues has become the need of the hour. Generation of revenue from these discarded residues is a feasible option to prevent farmers from burning the residues. The following review gives an insight on various crop residue management options through its utilization thereby generating farm income. There is no waste in the world, unless we treat it as waste.

Keywords Crop residue management, Off farm residue, Sustainable agriculture.

Ancy G. Martin[1]*, Atul Jayapal[2], Krishna Vikram[3], Bavigadda Kavya[4]

[2]Assistant Professor
[1, 2, 3, 4]Department of Agronomy, College of Agriculture, Vellayani, Thiruvananthapuram 695522, Kerala, India

Email: ancygmartin99@gmail.com
*Corresponding author

INTRODUCTION

In India, the internal food production was insufficient in the late 1940s. It was the green revolution that literally pulled India out from the begging bowl status. Even though the green revolution aimed to produce high-yielding grain types to reduce hunger and poverty (Eliazer *et al.* 2019), arguably, some foibles exist. One such is the massive production of agricultural waste with respect to the crop production. According to FAO (2021), a crop residue of 5280 million tonnes is generated in the world during 2020. In India, Uttar Pradesh leads in the generation of crop biomass followed by Punjab and Maharashtra and among the crops raised, rice contributes to 33% of the dry biomass share (Jain *et al.* 2018). For decades, the farmers have been burning crop residues as a cost effective pre-requisite for preparing their fields for the succeeding crop. A lot of ill effects to human health, environment and soil are associated with this burning of crop residues. While burning, a lot of nutrients are lost from these crop residues which could be utilized effectively for crop production. NITI Aayog (2019) has reported that about 1.43 million tonnes of NPK is lost every year due to burning of crop residues. Hence, the crop residues must be managed in a sustainable way to prevent the farmers from burning and also to generate revenue from the discarded agricultural residues.

Crop residues can be defined as any vegetative crop material left on the field after the crop is harvested, pruned or processed. They are the non-economic plant parts that are left in the field after harvest and remains that are generated from packing seed or that are discarded during crop processing. These crop residues can be managed efficiently by recycling and is considered as one of the cleaner options of crop production (Raza *et al.* 2019). Recycling crop residues convert farm waste into useful products. Crop residues contain considerable amounts of plant nutrients, when used wisely, will contribute to the nutrient management system. Crop waste recycling for plant nutrient supply is now becoming essential not only to counteract the ill effects of residue burning, but also for replenishing plant nutrients thereby maintaining soil health (Chatterjee *et al.* 2017).

Methods of crop residue utilization

In general, the crop residues can be utilized in the following ways:

I) On farm residue management

In this, the farm residues are managed inside the farm itself. It is done either by residue retention, residue incorporation and (or) by the use of machineries (Singh *et al.* 2020). These are all *in situ* residue management tactics which improve the soil structure, reduce the intensity of weeds and improves the productivity than farmers' practices (Lal 2004). Different on farm residue options are :

a) Surface retention as mulch

Mulching is the practice of covering soil surface with either organic or inorganic materials (Ghousepeera *et al.* 2020, Santosh and Maitra 2022). The practice of mulching reduces the weed density (Anzalone *et al.* 2010), provides an enhanced time for surface water retention, reducing leaching and evapotranspiration. Mulching with organic materials adds to the organic matter to soil and also reduces the nutrient losses (Anand *et al.* 2020). Kumar *et al.* (2015) observed that it is possible to save nearly 15–20% of fertilizers in the succeeding crop when rice straw is used as mulch. The crop residue retention in the field is observed to promote organic matter in soil and improve the physical properties of the soil (Hiel *et al.* 2018). The soil properties and carbon footprint were found to be enhanced with rice residue mulching (Lal *et al.* 2019). The Zero tillage practice done by farmers automatically retains the mulch in the farm and is reported for a significant conservation of moisture, reduce input cost and a slight improvement in the yield (Wu *et al*. 2021). Abraham *et al.* (2016) studied the effect of different tree loppings on ginger var. Karthika and reported that the use of tree loppings as mulch had significantly improved the yield of ginger. Ginger rhizome yield per plant was significantly higher when mulched with panal tree loppings (653.50 g plant^{-1}). Mathew and Sreekala (2019) studied the effect of mango leaves as mulch on the growth and yield in transplanted ginger (var Karthika) as an intercrop of coconut and found that the plants that received mango mulch @ 30 t ha^{-1} (half at transplanting and half at two months after transplanting) with a basal application of 30 t ha^{-1} of farm yard manure followed by NPK @ 150:100:100 kg ha^{-1} (m_1t_1) produced taller plants with more number of tillers, leaves/plant, shoot weight, fresh yield and dry yield. Thus, in states like Kerala, where significant farm family are homestead farmers, the mulches from trees can effectively be utilized for crop production.

b) Residue incorporation

In residue incorporation, the crop residues are incorporated completely or partially into the soil, mostly by ploughing. The above ground portion may be chopped into small sizes and can also be incorporated using machinery. Nawaz *et al.* (2019) has reported that incorporation of crop residues strengthens the soil, helps in nutrient recycling and also improves the soil health by increasing the soil organic matter. Singh *et al.* (2018) observed an increased 1000 grain weight, grain yield, straw yield, harvest index and benefit cost ratio with crop residue incorporation in the succeeding rice crop. Similarly, Reshma *et al.* (2019) has also observed a residual effect of fodder cowpea raised during summer in improving the yield of the succeeding rice crop. Sharma *et al.* (2020) studied the effect of rice straw incorporation on grain and straw yield of rice and wheat in a sandy loam soil under a rice-wheat cropping system and found that rice straw incorporation along with N application had significantly increased the rice and wheat grain yield against control.

c) Pusa decomposer

Recently, a team of scientists from IARI headed by Dr Livleen Shukhar have developed a bio-decomposing capsule, named as 'Pusa decomposer,' to convert the crop stubbles into compost in under a month. These capsules contain crop-friendly fungus and must be dissolved in water for spraying. It is considered a cost-effective, achievable and practical method for preventing stubble burning. The capsules are cost effective and so far, no negative effects due to this fungus are so far reported. The decomposer is said to improve the soil fertility and productivity, reducing the fertilizer requirement for the succeeding crop. It is an ecologically sound and beneficial technology that will aid in the achievement of a clean environment (Rai 2020). Pachauri *et al.* (2022) evaluated the effect of four residue management practices viz. residue burning (R_1), residue removal (R_2), residue treated with PUSA Decomposer (R_3) and residue treated with *Trichoderma* (R_4) along with five weed management options namely weedy (W_1), two hand weeding's @ 30 and 45 DAS (W_2), sulfosulfuron @ 25 g a.i. ha^{-1} (W_3), fenoxaprop-p-ethyl + metsulfuron methyl @ 100 g + 4 g a.i. ha^{-1} (W_4) and brown manuring fb chlodinofop @ 60 g a.i. ha^{-1} (W_5) on the weed dynamics of late sown wheat . The results revealed that application of PUSA decomposer had significantly suppressed the weed flora at 60 DAS and at 90 DAS in wheat crop.

II) Off-farm residue management

Here, the residues are transported away from the farm for safe disposal. Baling and transporting the crop residues from the field for safe disposal is feasible only when alternate, effective and economically viable usage methods are identified. The off-farm residue management will only be cost effective if the transported residues can be converted to items that are more remunerative. Different off farm residue management measures are:

a) Livestock feed

According to the IGFRI's Vision 2050, India has a net shortfall of 35.6% in green fodder, 10.95% in dry fodder and 44% in concentrate feed materials. By 2050, the demand for dry and green fodder is expected to increase to 1012 mt and 631 mt, respectively. Only 4% of the nation's total cultivated land (8.4 million hectares) is dedicated to growing fodder, and there has not been a significant increase for the past few decades (Dagar 2017, Halli *et al*. 2018, Meena *et al.* 2018). Rice straw is usually given to cattle as feed. Straw, the left-over of the harvested crop, fed to cattle as such, is poor in terms of protein, but has a major content of crude fiber. In the case of legumes, the crude protein and other nutrient contents is better than that of the cereal crop residues (Iqbal 2015, Win *et al.* 2021). Hence, by enriching the crop residues, it can effectively be utilized as components of cattle feed. In areas where arecanut is grown, the sheaths are usually left unutilized. Due to higher lignin content, they take time to degrade. Gowda *et al.* (2012) assessed the potential of using areca sheaths as dry fodder for livestock where dried areca sheaths are shredded and used along with concentrate mixture as total mixed ration. It is found that the areca sheaths can completely replace paddy straw since the nutritive value is more and an improved milk yield and quality is observed from the cattle fed with areca sheath concentrate.

Compound cattle feed can be prepared by partially replacing grain component with the by-products of food waste. Potato processing companies require potatoes of certain specification for their products. The potatoes that do not meet their standards are discarded as waste. Dhingra *et al.* (2013) revealed the prospects of using this discarded potato waste to make compound cattle feed. The lowest moisture content and longest storage period were recorded in the feed produced from discarded potato chips (10.07%). Potato serves both as a feed ingredient and as a binder. This makes the manufactured feed high in pellet durability index, thus exhibiting the potential of potato processing waste to partially replace the grain component in feed pellets. Kerala, one of the leading states in cassava cultivation has an annual production of 3027749.827 tonnes (Farm guide 2023). Cassava peels after use is now discarded as a waste. Cassava peels, a waste product of tapioca flour industry is usually discarded while processing. Studies were made by Pertiwi *et al.* (2019) on supplementation of this discarded cassava peels with feed. Cattle population were grouped and fed with the discarded cassava peel-based feed and the quality of milk was assessed. The study's findings demonstrated that the treatment group significantly out performed the control group in terms of percentages of protein (2.87%), lactose (4.40%), solid non-fat (8.49%), and total solid (12.23%). Thus, the potential for converting cassava peel to a feed source is now opened which can lower the production cost and boost farmer revenue.

Pineapple, one of the commercially important fruit crops of India is having high moisture and sugar content. This makes it susceptible for fungus development, thereby deteriorating the quality, leading to discarding the produce. This discarded product left as an agricultural waste can effectively be converted into silage. Gowda *et al.* (2015) evaluated the lactation performance in cows and lambs after being fed with pineapple and maize silage. The nutritive value in terms of energy and minerals for pineapple silage was found to be superior to maize silage. The milk yield and quality were also found to be improved for pineapple silage suggesting the potential of converting crop residue to silage.

b) Bedding material

In western nations, crop residues, especially wheat straw are typically used as bedding materials for animals. While in under developed nations where there is a shortage of fodder, these carbohydrate-rich straws are significant resources for farmers as a cheap source of nutrition for animals (Goswami *et al.* 2020). After the processing of timber, saw dust, discarded as a crop waste is now being used as bedding for poultry. Paddy straw can be used as bedding in animal shelters, which after use can be recycled through biogas unit. Using saw dust as bedding is known to improve the quantity and quality of milk production as well as animal health. The advantages of bedding components include :

1. Keeps the animal warm in the winters by restricting heat loss.

2. Improves the cleanliness, absorb urine and water and provides overall hygene.

3. Healthy legs and hooves with better reproductive health conditions will ensure higher milk production.

c) Mushroom cultivation

India is primarily an agricultural country, with over 620 million tonnes of agro-waste produced yearly (Singh and Sidhu 2014). A considerable portion of the agro waste being crop residues like rice and wheat straw, saw dust, rice bran. Mushroom production can gain from the use of such agricultural wastes. Singh and Prabha (2017) observed that a total of 39 residues from 26 crops, are used as valuable substrate for mushroom production. The Kerala Agricultural University, Thrissur has releazed an oyster mushroom mutant (var Ananthan) that can be grown in low-cost substrates such as banana pseudostem, sugarcane bagasse, coir pith, saw dust of various soft and hard wood trees, tea waste, tapioca starch waste and water hyacinth. Thomas *et al.* (1998) evaluated the production potential of oyster mushroom from coconut palm wastes viz. bunch waste (spathe + spadices), leafstalk (petiole), leaflets and coir pith (by-product from coir processing industry) and found that when coconut leaf stalk and bunch waste were used as substrates, significantly more edible biomass of mushrooms were produced.

Resmi *et al.* (2021) studied the effect of different substrates on yield of *Pleurotus florida* and found that there is high potential for production of mushroom by using various agricultural plant wastes as substrate material. Oyster mushroom could grow on all the substrates used as treatments. The highest yield (1037.72 g) was obtained with mushrooms grown from substrates of sesame plant debris. So, in areas where sesame plant debris is generated in large quantities and where they pose an environment threat, can be converted as a source of food by using them for the production of oyster mushroom.

d) Bio-waste utilization for crop production

The Kerala Agricultural University has developed feasible technologies for waste utilization. Two systems are developed to convert bio-waste into bio-manure - Suchita developed at the College of Agriculture, Vellayani and Bio-bin developed at

College of Agriculture, Vellanikkara. These technologies are useful in waste management at the source of generation.

e) Suchitha-thermochemical organic fertilizer

'Suchitha', a patented rapid thermochemical biowaste processing technology (Sudharmaidevi *et al.* 2017) enables the processing of solid wastes to organic fertilizer in less than a day. Leno *et al.* (2021) studied the growth and development of vegetables, viz. tomato and okra due to "Suchitha" when combined with different organic and inorganic manures and found that the fortified thermochemical organic fertilizer gave the growth medium a high status of total organic carbon regardless of the organic source of nitrogen utilized. Smart bio bin, Gee bin. Bokashi bucket and Solwearth organic waste converter machines can be successfully used in crop residue management.

f) Soil less planting media

Urban agriculture is fast cementing its place in this post covid scenario. In urban areas where there is scarcity of soil for agriculture, crops can be raised in soil less media prepared from agricultural biowastes. This nutritionally enriched mixture serves as an excellent planting media for agriculture. Cuckoorani and Thomas (2015) studied the effect of different growth media on yield and yield attributes of bhindi and found that different soil less growth media had significant influence on growth and yield characters of bhindi. Coir pith compost + FYM (2:1) recorded maximum yield and B:C ratio for bhindi. Similar results were also reported by Soumya and Usha (2015) who observed the effect of different growth media on tomato and found that coir pith compost + FYM (2:1) recorded maximum fruits per plant (23.41), fruit weight (35.43 g) and yield per plant (883.46 g). Dr Pushparaj Anjelo and Shinoj Subramanian of KVK, Ernakulam, developed a soil less planting media from composted press mud, coir pith and cow dung powder and has enriched it with neem cake and biocontrol agents. This media has a better moisture retention capacity, better crop root anchorage, enhanced nutritive value and can be reused more than three times.

g) Biochar

The crop residues can be converted into biochar as an alternative to crop residue burning. Biochar is a carbonaceous material that is obtained by the thermochemical decomposition of biomass by heating agro-wastes under oxygen limited conditions. Being a high carbon compound, biochar has low bulk density, high porosity and high-water holding capacity which makes it a suitable material for water and nutrient management (Punnoose and Anitha 2015, Nihala and Rani 2020). Biochar produced from the agricultural wastes contains 1.35–1.62% N, 0.22-0.51% P and 0.89-1.30% K (Pati and Panda 2021). When biochar is applied to the soil as an amendment, it is found to increase soil fertility, soil organic carbon, reduce GHGs and increase fertilizer use efficiency (Nematian *et al.* 2021). Sainath *et al.* (2020) studied the effect of biochar on the bunch yield and bunch characters of banana and found that the growth and yield of banana was significantly improved with application of biochar. Biochar @ 10 kg plant^{-1} added with 75% of soil test-based results produced higher bunch weight, number of hands per bunch and number of fingers per bunch.

III) Miscelcaneous uses

Apart from recycling the crop residues back to agriculture, different value-added products can be created from these discarded wastes to generate income, thereby making it a component of integrated farming system. Thus, the agricultural waste problem is managed as well as income can be generated.

a) Banana fiber

Natural fibers derived from plants, including banana, coir, sisal, jute, kenaf, and many more, have been tested for use in industry. Given that bananas are one of the most popular fruits consumed worldwide, banana fiber is the most significant of them. The banana plant's many components, including the fruit, fruit peel flower bud, leaves and pseudostem, can be used for a variety of industrial applications. The main source of banana waste biomass and a source of high-quality fiber is the pseudostem. It may find use in manufacturing sanitary napkins, textiles, pulp and paper, food, reinforced composite materials for cars, building materials, aerospace, and other composite materials (Ghosh *et al.* 2020). Balda *et al.* (2021)

studied the mechanical properties of various natural fibers and have reported that banana pseudostem fiber had the highest tensile strength, flexural strength and lowest elongation percentage.

b) Areca/jute/glass fiber reinforced hybrid composite plates

Scientists and technicians have now set their interest in using natural fibers from plants like cotton, jute, and other crops in packaging, low-cost housing and other structures. The use of hard cellulose fibers has been encouraged by the growing interest in introducing cheap, renewable, and environmentally friendly reinforcing materials. The hybrid fibers are a desirable substitute due to their inexpensive price, light weight, and density (Dinesh *et al.* 2019).

c) Paper from paddy straw

Kriya labs (a start-up incubated at IIT Delhi) has developed a sustainable technology which is soon to be made available to the public, that can convert agro-wastes like paddy straw into pulp. This pulp can then be used to make products like paper, plates and cups that are not only completely biodegradable, but are also a lot cheaper than their plastic counterparts. It is reported that from one tonne of paddy stubble about 500 kg of pulp can be produced. The pulp from the waste can be sold @ Rs 45 per kg. It can be utilized for production of cups, plates cardboards, bio-foams and certain furniture items. Based on reports, around 50% of the paper sector in Punjab uses straw, which minimizes burning and environmental damage (Kumar and Singh 2020).

d) Bio-brick

Rice straw can also be used for the production of light weight cement bricks called as bio-bricks that are used in the construction of buildings. Bio-bricks was developed as an alternative and sustainable building material that is made up of agricultural waste. Bio-bricks can create a new economic model for farmers and lead to the development of agriculture-based industries. Rautray *et al.* (2019) has reported bio-bricks as a carbon negative, sustainable and economically viable material for construction. Decorative wall panels can also be made from banana pseudostem fibers. In China, rice straw is used to produce bricks which reduce energy consumption and waste from rice harvesting (Liang *et al.* 2020). There are reports that native rice straw blended with bricks has strong compression strength, good heat transmission coefficients, and low cost. Native rice straw mixed bricks are ideal for environmentally friendly construction since it's used as wall insulation while saving energy. (Chen *et al.* 2018, Garas *et al.* 2009). Adobe brick, one of the most significant and historic building materials still in use today, which is created by combining organic materials with mud, water, straw, or other fibers that can be added to boost composite strength. (Trang *et al.* 2021). In high-temperature regions, using adobe bricks in construction purposes offers many advantages, such as being durable, fireproof, non-toxic, biodegradable, low thermal conductivity, and low sound transmission levels through walls (Babé *et al.* 2020, de Castrillo *et al.* 2021).

e) Briquetting

The process of briquetting which is compacting the agricultural residue left after harvest allows for substitution of wood as a fuel. Using briquetting technology, agricultural waste may be managed by converting them into densified solid biofuels. It is simpler to transport, store, and use (Setter *et al.* 2020). Patil (2019) studied the possibility of utilizing agricultural wastes into briquetting production. The major wastes generated were used as treatments viz. rice husks, ground nut shell, cotton husks, coconut husks, coir pith, sunflower stalk, soya bean husk, sugarcane bagasse, paddy straw and tea waste for energy generation in the form of briquettes. The results revealed that the calorific value briquettes is higher than those of raw materials. The input and output ratio ware observed as cost-effective and profitable in all parameters for the farmers. Rahaman and Salam (2017) produced briquettes from rice straw using the cold densification method and revealed that the energy consumed for making briquettes accounted for only 5.6–7.5%. Yank *et al.* (2016) developed a low-cost manual press generating a pressure of 4.2 MPa to produce biomass briquettes from rice husks in the context of a rural village.

f) Electricity generation

The increasing demand for energy and gradual depletion of non-renewable energy sources requires a shift to reliable renewable energy resources. Biogas plant has the maximum potential for electricity generation (Jiang *et al.* 2019). According to Ravindra *et al.* (2019) and Logeswaran *et al.* (2020), crop residues which are a replenishable and reliable energy source, can generate about 10% of the country's total energy production. Energy production is 19.34% from wheat straw, 5.32% for barley straw, 40.46% for corn stalk, 25.03% for sunflower stalk, 3.17% for rapeseed straw and 6.67% for soybean straw.

Indian perspective

The use of plastic products has become the part of the day-to-day life of the people. Due to this exorbitant use, the safe disposal of the plastic waste is a concern. The agricultural residues which are now being discarded as waste, can be put to good use as a replacement for the plastic products which potentially is a revenue generation activity through value addition.

Coir geotextile : A Government of Kerala initiative

The canals and streams in Kerala are all undergoing a makeover, with a 'golden drape' falling over their enticing slopes and curves of the banks. Coir geo textile is an eco-friendly, fabric made from woven coir (from coconut husk fiber), that is used to check soil erosion during the rains. It is spread over the banks of the water bodies like ponds, and the walls of the streams, bunds, farms and canals to protect the soil and conserve water.

CONCLUSION

Crop residue is regarded as a crucial component in achieving sustainable agriculture since it significantly improves the physical, chemical and biological characteristics of the soil, increases soil fertility and increases crop yield. It is important to investigate how agricultural residues may be used in a variety of industries, including those that produce compost, manures, animal feed, and textile composites and non-wovens. To raise awareness among farm communities and to persuade them to appreciate the significance of crop residues for revenue production through value addition has become the need of the hour.

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