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11. Crop Residue Management: Recent Initiatives

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Abstract:

Food production in India between 1947 and 1960 was not sufficient. During this time, Dr. M.S. Swaminathan, the main architect of India's Green Revolution, brought India out of the status of beggar's bowl. As the green revolution continues, there are some weaknesses. One of them is the large amount of agricultural waste associated with crop production. In India, farmers destroy crops by burning to prepare the soil for the next crop. The consequences of burning crops are now felt in the lungs of the people of Delhi.

Therefore, proper management of crop residue has become most important. Earning income from this waste is a good option to prevent farmers from burning the waste. There are many ways to use crop residues for sustainable agriculture and income. Different assets can be created from waste to generate income, making it an essential part of mixed farming. Thus, while the income increases, the agricultural waste problem is also solved. Plant-based fibres have the potential for commercial use in the manufacture of tissue, textiles, pulp and paper, building materials and other composite materials. It has become important to raise awareness among the farming community regarding the importance of crop residues for conservation agriculture and to generate income by adding value. There is no waste in the world unless we treat it as waste.

Keywords:

Crop residue, Surface retention, Mulch, Residue incorporation, Livestock feed, Soil less planting media, Mushroom Cultivation, Sustainable Agriculture.

11.1 Introduction:

The global population is anticipated to reach 8.5 billion by 2030, 9.7 billion by 2050, and over 11 billion by the end of the century [1]. Population growth has led to increased demand for food [2, 3], which has placed enormous pressure on agriculture. In India, food grain production was inadequate in the post-independence era. Dr. M.S. Swaminathan led the Green Revolution during this time [4]. It began in the 1960s and contributed to a rise in the country's food production. The fundamental goal of the Green Revolution was to develop high-yielding cereal varieties (HYVs) to combat poverty and malnutrition [5].

Not to be denied, the Green Revolution was able to alleviate hunger and malnutrition in short term [6]. However, there are also some weaknesses after the green revolution. The most significant of them is the massive production of agricultural waste along with crop production.

Agricultural wastes are waste materials generated from various agricultural operations. Agricultural waste typically includes harvest waste, other farm manure, hazardous waste such as pesticides and insecticides, and processing waste such as packaging material [7]. Crop residues comprise both field residues left in an agricultural field or orchard after harvesting a crop and process residues remaining after the crop has been processed into a marketable resource. Field residues include things like stalks and stubble (stems), leaves, and seed pods. Process residues include sugarcane bagasse and molasses, to name a few [8].

Crop leftovers are produced in vast quantities during crop cultivation. Crop residue recycling offers the advantage of transforming agricultural waste into a usable product that may be used to meet the fertiliser requirements of future crops. Crop residues include a substantial amount of plant nutrients, and their appropriate use will benefit the nutrient management system. Because of the scarcity of plant nutrients in crop fields, the high cost of synthetic fertilisers, and the low efficiency of chemical fertilisers, recycling crop wastes to supply plant nutrients is becoming increasingly important in order to replenish plant nutrients, maintain soil health, and reduce pollution [9].

To maintain sustainable agricultural productivity, it is essential to recycle nutrients from crop residues after harvest. Adoption of effective crop residue management practices is a necessity today.

11.2 Generation of Crop Residues:

According to the Indian Ministry of New and Renewable Energy (MNRE), India produces 500 million tonnes (Mt) of crop leftovers each year on average. According to the National Policy for Management of Crop Residues (NPMCR), the state of Uttar Pradesh produces the most crop residues (60 Mt), followed by Punjab (51 Mt), and Maharashtra (46 Mt), for a total of 500 Mt every year. Cereals (352 Mt) produce the most residues, followed by fibres (66 Mt), oilseeds (29 Mt), pulses (13 Mt), and sugarcane (12 Mt). Cereals (rice, wheat, maize, millet) account for 70% of crop wastes, with rice alone accounting for 34%. The accumulation of massive amounts of agricultural waste is becoming a problem as a result of ineffective crop residue management.

11.3 On Farm Burning of Crop Residues:

Around 93 Mt of plant residues are burned on-farm in the country out of 500 MT of residues produced [10]. According to the IPCC, over 25% of total crop residues were burned on the farm. Paddy fields in Kuttanad, Kerala's rice bowl, are dark today, with some spewing plumes of smoke. In many parts of the world, burning agricultural residues is the most common practice in preparing land for growing another crop [11].

A large amount of crop residues after the harvest of the first crop remained in the field for a long time, and their management is a big challenge for farmers. Therefore, it is very important to look for alternative management practices to use discarded crop residues in a way that does not affect the environment or soil fertility [12].

Crop residue burning is a cause for worry, because it causes air pollution, greenhouse gas emissions, negative health consequences, nutrient loss, increased soil erosion and runoff, negative effects on soil quality, and depletion of soil organic carbon [13].

Burning plant residues on the soil surface degrades the physical, chemical, and biological aspects of the soil, resulting in a deterioration of the soil nutrient budget. They are necessary nutrients for long-term soil fertility.

During the formulation of the National Policy for Crop Residue Management (NPMCR) in 2014, it was anticipated that burning one tonne of rice straw would result in the loss of 5.5 kg of nitrogen (N), 2.3 kg of phosphorus (P), 25 kg of potassium (K), and 1.2 kg of sulphur (S) in addition to organic carbon.

In general, crop residue combustion consumes 80 percent of the N, 25 percent of the P, 50 percent of the S, and 20 percent of the K present in crop residues. The burning of rice, wheat, and sugarcane crop leftovers alone resulted in a loss of around 0.4 MT of nitrogen, 0.01 MT of phosphate, and 0.3 MT of potassium, according to India's main policy-making agency, NITI Aayog. Paddy residue includes 6.1 kg N, 0.8 kg P, and 11.4 kg K per tonne. The intact loss from burning paddy straw is approximately 79.38 kg ha^{-1} N, 183.71 kg ha^{-1} P, and 108.86 kg ha^{-1} K [14]. Crop leftovers must therefore be managed in a sustainable manner to prevent farmers from incurring financial losses.

11.4 Management of Crop Residues:

Crop residue management is possible either by on-farm (in-situ) residue management or off-farm (ex-situ) residue management.

11.4.1 On Farm Residue Management:

In this situation, farm residues are managed directly in the farm field by residue retention, residue integration, or by the use of machinery such as the happy seeder and turbo happy seeder [15]. All of these are in-situ residue management techniques that will improve soil structure, reduce weed intensity, and increase production over farmer methods [16].

A. Surface Retention as Mulch:

Mulching is the practice of covering the soil surface with organic or inorganic materials [17, 18]. This provides a longer time for surface water to be retained, reducing leaching and evapotranspiration. Mulching with organic materials adds organic matter to the soil and will also reduce nutrient losses [19, 20]. Covering topsoil positively regulates soil temperature and thereby increases crop production. After using rice straw as mulch, 15-20% of direct fertilizers can be saved in the subsequent crop [21].

Zero tillage and crop residue mulching were found to reduce input costs with slight yield improvements [22]. 1 kg m^{-2} of organic mulch with a thickness of 10 to 15 cm is sufficient to cover the soil and reduce weed density [23]. The retention of residues in the field will support the organic matter present in the soil and improve the physical properties of the soil [24].

B. Residue Incorporation:

Here, crop residues are completely or partially incorporated into the soil. The above-ground part can be chopped into small pieces and can also be incorporated using machines. Crop residue incorporation increased 1000-grain weight, grain yield, straw yield, harvest index, and benefit cost ratio in the following rice crop [25]. Incorporating plant residues strengthens the soil, helps in nutrient recycling and also improves soil health by increasing soil organic matter [26]. Similarly, residual effect of forage cowpea grown in summer improved the yield of succeeding rice [27]. Rice straw incorporation along with N treatment considerably increased rice and wheat grain production in sandy loam soil in a rice-wheat cropping system. [28]

C. Pusa Decomposer:

Recently, a team of scientists from IARI led by Dr. Livleen Shukhar has developed a bio-degradable capsule called "Pusa decomposer" that has the ability to turn crop stubble into compost in less than one month. These capsules contain crop-friendly fungi that can be dissolved in water before spraying. It is a cost-effective, achievable and practical method to prevent farmers from stubble burning. The capsules cost around Rs. 5, which is feasible for the common man. No negative effects caused by this fungus have been reported yet. It will improve soil fertility, soil productivity and also reduce the need for fertilizer for the succeeding crop. This potential decomposer is being tested in Punjab and Uttar Pradesh. It is an environmentally friendly and beneficial technology that can help to achieve a clean environment [29].

The effect of four residue management practices, viz. residue burning, residue removal, residue treated with PUSA Decomposer and residue treated with *Trichoderma* along with five weed control options namely , two hand weedings @ 30 & 45 DAS, sulfosulfuron @ 25 gm a.i. ha^{-1}, fenoxaprop-p-ethyl + metsulfuron methyl @ 100 g + 4 g a.i. ha^{-1} and brown fertilization fb chlodinofop @ 60 g a.i. ha^{-1} were evaluated on the weed dynamics of late-sown wheat. They reported that the application of PUSA decomposer significantly suppressed the weed flora at 60 DAS and at 90 DAS in the wheat stand.[30]

11.4.2 Off-Farm Residue Management:

Here crop residues are taken off the farm for safe disposal. Packaging and transporting crop residues from the field for safe disposal is only feasible if alternative, efficient and economically viable uses are identified. Off-farm residue management will only be cost-effective, if transported residues can be converted into items that are more profitable.

A. Livestock Feed:

Livestock is essential to poor farmers' livelihoods because it provides economic, social, and food security. In India, plant residues are traditionally used as animal feed. Using these alternative feed sources, replacing part of conventional feed ingredients is a wise way for sustainable animal production. Some of these potential feeds are discussed.

During processing, potato pulp, peels, culls, chips, and pieces, among other things, are created. During processing, around 35% of the total processed potato crop is discarded as waste. The total annual global potato waste is estimated to be 12 million tonnes. In India, around 2 million tonnes of potato waste are produced. The feasibility of using this potato waste to create cow feed combinations were evaluated [31]. A feed made from waste potato chips and pulp was compared to feed available locally. It was shown to have the lowest moisture content (10.07 percent) and could be preserved for a longer amount of time. The feed also has a high pellet durability index because the potato is also used as a binder which identifies the possibility of potato processing waste to partially replace the grain component in feed pellets. In areas where arecanut is grown, the sheaths are usually left unused. Due to their higher lignin content, they will take some time to decompose. The potential of using areca pods as dry fodder for farm animals were evaluated [32]. The dried areca sheaths were cut up and used along with the concentrated mixture as a total mixed ration. It has been found that areca sheaths can completely replace paddy straw because the nutritional value is higher and can improve milk yield.

Cassava peels are a waste product of the tapioca flour industry that is usually thrown away during processing. Supplementing these discarded cassava husks with feed, cattle population were grouped and fed a discarded cassava peel-based feed and milk quality was evaluated [33]. The control group was fed grass and a commercial ration dietary. The results of the study showed significant positive effects for the treatment group in terms of percent protein (2.87%), lactose (4.40%), fat-free dry matter (8.49%) and total dry matter (12.23%) versus control. Therefore, they have a high potential as a feed source to reduce production costs and thereby increase the income of farmers.

Pineapple is a commercially important fruit crop, and its waste disposal is a serious concern because of its high moisture and sugar content, which makes it susceptible to fungus development and deterioration. Converting them into silage can successfully solve this problem. The lactation performance in cows and lambs after feeding pineapple and maize silage were evaluated [34]. The nutritional value of pine apple silage in terms of energy and minerals was found to be superior to maize silage. Milk yield and quality were also found to be improved with pineapple silage, indicating the potential of converting crop residues into silage.

B. Bedding Material:

In Western countries, crop residues are generally not fed to livestock, but are used as bedding, especially wheat straw. While in developing countries, these carbohydrate-rich straws are a valuable resource for farmers as cheap animal feed because there is a shortage of fodder [35].

C. Production of Mushrooms:

Mushroom cultivation is an important source of protein and income for rural meat.

ICAR-CIRCOT has discovered a method for producing oyster mushrooms (*Pleurotus florida and P. ostreatus*) on cotton stalks. In thirty days, one kilogramme of dry cotton stalks can yield around 300 g of fresh oyster mushrooms. In general, two to three mushroom harvests occur each year [36].

A low-cost system for growing oyster mushrooms has been devised using coconut debris such as leaves, stems, bunch waste, leaflets, and so on. Coconut waste is cut into 5-7 cm pieces and steeped in water overnight. The surplus water is drained away, and the substrates are disinfected by steam pasteurisation before being placed in polybags and inoculated with spawn at a rate of 100 g per bag containing 3-3.5 kg of substrate. As an organic supplement, 5 percent sterilised rice bran is added. For 15-20 days, the bags are incubated for spawn run in a mushroom house. After spawning, the plastic cover is ripped and the compact cylinder bed is sprinkled with water two to three times every day. The initial flush of mushroom fruiting bodies appears 5-10 days after opening the bag. Each bed can yield three to four crops. This technology provides work and revenue to many women's self-help groups, unemployed youngsters, and rural residents [37].

The effect of different substrates on the yield of *Pleurotus florida* were reported a high potential for mushroom production using different agricultural plant wastes as substrate material [38]. Oyster mushroom could grow on all substrates used for different treatments. The highest yield (1037.72 g) was achieved with mushrooms grown from sesame crop residue substrates. So, in areas where sesame plant residues are generated in large quantities and pose a threat to the environment, they can be converted as a food source by using them for oyster mushroom production.

D. Biochar from Agricultural Waste Material:

The pyrolysis method is used to create biochar from agricultural waste and weeds. Using a customised portable metal furnace, agricultural biomass may be turned to biochar in two hours with a conversion efficiency of 25-35 percent depending on the kind of biomass. They have the ability to improve soil fertility and agricultural productivity, as well as the efficiency of fertiliser application, water retention, aeration, and soil slope. It also has a large and favourable effect on soil pH. The influence of biochar on bunch yield and bunch features of banana were studied and discovered that biochar application greatly increased banana growth and yield. Biochar @ 10 kg plant^{-1} leads in higher bunch weight, number of hands per bunch, and number of fingers per bunch [39].

E. Banana Fiber from Pseudostem Sheath:

Banana pseudostem is waste material after harvest. Banana cultivation produces 30 million tons of biomass annually, from which 1.5 million tons of fiber can be extracted. Banana pseudostem is the main proportion of banana waste biomass and provides high-quality fiber. The waste generated in the banana pulp extraction plant can be used in hand-made paper production, which will alleviate the problem of pollution along with creating employment opportunities in rural areas [40].

Additionally, it has the potential to be used industrially in the manufacture of food, textiles, pulp and paper, sanitary napkins, reinforced composite materials for automobiles, structural materials for the aerospace industry, and other composite materials [41]. Banana pseudostem fiber had the highest tensile strength, flexural strength and lowest elongation percentage among various natural fibres [42].

F. Bio-Brick:

Rice straw can also be used to make lightweight cement bricks called biobricks that can be used in building construction. Biobricks are an alternative and sustainable building material made from agricultural waste. Biobricks have the potential to generate a new economic model for farmers and contribute to the growth of agriculture-based companies. The biobricks are a carbon-negative, sustainable, and economically viable construction material [43].

G. Soilless Planting Media:

The effect of different growth media on yield and yield characteristics of bhindi were evaluated and reported that different soil less growth media had significant effect on growth and yield characteristics of bhindi. Coirpith compost + FYM (2:1) recorded maximum yield and B:C ratio for bhindi.[44] A similar study was conducted on the effect of different growth media on tomato and coir pith compost + FYM (2:1) reported maximum fruits per plant (23.41), fruit weight (35.43 g) and yield per plant. (883.46 g) [45]. Press mud, a by-product of the sugar industry that is commonly accessible at 2% crushed cane, has physical qualities similar to soil and gives good root anchoring. Because composted press mud supplies critical nutrients to plants, mixing composted and powdered press mud makes a soilless planting media. This soilless planting medium is composed of 50% composted press mud, 25% coirpith, and 25% dry cow dung powder. Dolomite is added to the mixture to balance off its acidity, and neem cake and biocontrol chemicals are also used. Soilless planting media are regularly produced at the ICAR-Krisi Vigyan Kendra in Ernakulam.

H. Briquets:

It is a process in which harvested crop residues are densely compacted, allowing for the replacement of wood as a fuel. Agricultural residues can be managed by converting them into thickened solid biofuels using briquetting technology. By briquetting plant residues, it will be easier for agricultural waste to be transported, stored and used as biofuel [12].

The possibilities of using agricultural waste in the production of briquettes were evaluated. The major generated wastes were used as treatments, viz. rice husks, ground nut shells, cotton husks, coconut husks, coir pith, sunflower stalk, soybean husks, sugarcane bagasse, paddy straw and tea waste for energy production in the form of briquettes. The results show that the calorific value of the briquettes is higher than the calorific value of the raw materials. The input-output ratio was observed to be cost-effective and profitable for the farmers in all parameters.[46]

I. Bio-Waste Utilization for Crop Production:

Kerala Agricultural University has developed feasible technologies for waste utilization. Suchita, created at the College of Agriculture, Vellayani, and Bio-bin, developed at the College of Agriculture, Vellanikkara, have both been established as commercially viable methods for converting bio-waste into bio-manure. These technologies can help manage garbage at its source.

- **Suchitha- Thermochemical Organic Fertilizer:**

"Suchitha" technology is a thermochemical process that can convert biodegradable waste into organic fertilizer. This patented technology of rapid thermochemical processing of biowaste [47] enables the processing of solid waste into organic fertilizer in less than one day in an environmentally friendly manner.

The effect of 'Suchitha' in combination with various organic and inorganic fertilizers on growth and yield of vegetables, viz. tomatoes and okra were evaluated and it was found that regardless of the organic nitrogen source used, the enriched thermochemical organic fertilizer imparted a high total organic carbon status to the growing medium. It was found that irrespective of the organic source of nitrogen used, the fortified thermochemical organic fertilizer imparted a high status of total organic carbon to the growing media. Container grown okra in a growing media with ‘Suchitha’ fortified with farmyard manure out yielded urea-based fortification by 55.96%. Tomatoes grown in growing medium enriched with coirpith compost increased yield by 27.37 percent compared to growing medium enriched with peanut cake.[48]

11.5 Conclusion:

Crop wastes are highly valuable economically as fuel, animal feed, and industrial raw materials. However, crop residue issues vary by region and are linked to socioeconomic requirements. Crop residues are essential for improving soil quality and crop productivity. They contain a large amount of nutrients, so returning plant residues to the soil can save a significant amount of fertilizer. Using plant residues as an important resource for better productivity is a good solution to challenges. The remainder of the crop should be partially or fully used in conservation agriculture to ensure food security in the country, make agriculture sustainable and improve soil quality. Using conservation agriculture practices such as zero tillage and crop residue management such as biochar, incorporating crop residues into the soil and using crop residues as mulch will improve soil quality. In this case, it will increase the productivity of these inputs and help maintain agricultural production levels. A lot of technologies are available for creating wealth from agricultural waste which is generated during agricultural activities, crop harvesting, crop processing, product synthesis etc. The need of the hour is to raise awareness among agricultural communities so that they comprehend the value of crop leftovers in conservation agriculture for the resilience and sustainability of Indian agriculture.

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