Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 04, Issue: 05 (SEP-OCT, 2024)
Available online at http://www.agriarticles.com

Crop Residue Management: Balancing Productivity and Environmental Health

(Anil[1], *Sachin Kumar[1] and Nisha[2])
[1]Department of Agronomy, CCS Haryana Agricultural University, Hisar
[2]Department of Bio-chemistry, Kurukshetra University, Kurukshetra
*Corresponding Author's email: sachinrao2718@gmail.com

Organic matter plays an important role in sustaining the fertility of soils, in recent years, due to intensive cultivation of land, degradation of soil structure and depletion of soil nutrients has occurred. With an increase in crop production, straw and stubble production has been proportionally increasing. Agricultural waste production is increasing day by day at a very alarming rate, which leads to an increase in environmental pollution. The Rice-wheat cropping system is dominating in north India. Due to high yielding varieties of rice and wheat, this resulted in generation of large quantity of crop residue. Straw burning is common in northern India, leading to nutrient loss, it affects the quality of air due to release of $PM_{2.5}$ and emission of several greenhouse gases (CH_4, NO_x, SO_2) which impair human health and it can be detrimental to people having respiratory problems like–asthma, bronchitis, emphysema. Although stubble burning is now a crime under section 188 of IPC (Indian penal code) and APCA (Air and pollution control act, 1981), there is a lack of implementation of these acts. Apart from burning of crop residue, it can be managed in alternate ways including compost manure, livestock feed, biofuel, beverage industry, paper mills, packaging material, wood and so on.

Crop residue management

Crop residue management is a practice of handling and utilizing the left-over part of crop on soil surface after crop has been harvested. Crop residue enhances the availability of nutrients and boosts organic carbon in soil, reduces run-offs and decreases soil evaporation. Effective management of residue encompasses conservation tillage practices, where leftover part is incorporated into top layer of soil without excessive disturbance. Stubble and straw of legumes crops decompose easily due to their low C: N ratio as compared to cereal crops having high C: N ratio and high silica content (e.g., rice). To avoid extra operational costs to manage crop residue, farmers prefer burning of stubble. Burning of stubble causes environmental pollution, depletion of organic carbon in top fertile layer of soil, loss of biological flora and fauna. By adopting proper management practices, farmers can improve soil health, promote sustainable agriculture, conserve natural resources and reduce environmental impacts.

Types of residue

a. **Field residue**– The material left in field after harvesting of crop, includes stalks, straw, leaves, stubble and seed pods. The residue can be directly incorporated into soil or other practices such as zero-till, minimum tillage, strip-till and reduced-till are carried out to maximize the benefit of crop residue in soil.

b. **Processed residue**– The material left after the processing of crops, includes bagasse, husks, chaff, molasses and cobs. They can be used as soil amendment, fertilizers and animal fodder.

Reasons behind stubble burning

Increased mechanization, mainly use of combine harvesters, requires long time for decomposition of crop residue, declining numbers of livestock, shortage of labour during harvesting season, high transportation cost, collection and storage, large volume of residue and due to unavailability of alternative economical methods for crop residue management, farmers are obliged to burn the residues. There are many other reasons for burning of residue, including clearing of fields, pest management, fast method to get rid of residue, weed control and elimination of insect-pests directly or indirectly (by altering their natural habitat). The time period between rice harvesting and wheat sowing is only 15-20 days in north-west India, due to this short gap, farmers prefer to burn the straw and stubble on-farm instead of residue management.

Effects of stubble burning

1. **Air pollution**: stubble burning releases various pollutants into air, including $PM_{2.5}$, PM_{10}, PM_{100}, carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_x), sulfur dioxide (SO_2), polycyclic aromatic hydrocarbons (PAHs), these pollutants have adverse effect on human health which leads to several respiratory diseases and cardiovascular problems.
2. **Soil fertility**: due to modern intensive agricultural practices the level of available N, P, K, is already low in soil and depletion of available nutrients is increased by stubble burning. Long-term burning of residue leads to loss of biomass, potentially mineralized organics and nutrients, reduction in the amount of topmost fertile layer and upsurge soil temperature, which leads to depletion of microbes and flora population.

Strategies for crop residue management

1. **Livestock feed**: crop residue of rice and wheat has been traditionally used as animal feed, supplementing with some additives. Due to low digestibility and unpalatable nature of crop residue, cannot be solely used for feeding. Rice straw has very high silica content (12-16%) and lower lignin content (6-7%). The nutritional value of straw can be increased by physical, chemical and biological treatments, which weaken and break-down the lignocellulose bonds in straw. Wheat straw is utilized as feed for animals, chopped with the help of machine into small pieces. To overcome low digestibility, crop residue is enriched with molasses and urea, also supplemented with green fodders and legumes.
2. **Composting**: Biological process of converting organic waste into compost through microbial activity, resulting into stable, brown colored and humus-rich material which is known as compost, that improves soil fertility, structure and water holding capacity. By composting, farmers can efficiently manage organic waste and reduce amount of chemical fertilizers. Compost can be used in field as soil amendments, mulch to suppress weed growth and regulate soil temperature. All the crop residue is not suitable for composting, residues having high lignin, high C:N ratio takes longer time to decompose as compared to legume crop residue.
3. **Biochar**: A product of pyrolysis, produced by heating of biomass (crop residue and wood), in the absence of oxygen. Biochar is highly porous material, well grained, having large surface area which increases its effectiveness. It acts as a long-term carbon sink, sequestering carbon dioxide from atmosphere and reducing GHGs emission. The addition of biochar to soil can have numerous benefits, including enhancing soil fertility, increases water retention, reduce nutrient leaching and run-offs and absorbing pollutants. However, it is not economically feasible, so cannot be commercialized among farmers.

4. **Bio-energy**: the bioconversion of crop residue into biopower or liquid fuel or electricity. Ethanol is most common cellulose base bio-fuel from cop residue, the process of biochemical conversion involves anaerobic digestion, alcoholic fermentation, and photobiological techniques, where enzymatic break down of polysaccharide into its element sugars and then converted into useful energy. Thermochemical conversion involves gasification, liquefaction, and pyrolysis, where residues are subjected to very high temperature in absence of oxygen to produce biofuel (biochar, bio-oil, syngas). Utilization of bio-energy offers several benefits, such as reduce dependence on fossil fuel for power generation, lowering the emission of GHGs and mitigating climate change.
5. **Gasification**: process comprises heating the residue at 400-500˚C temperature and 33 bar atmospheric pressure in absence of oxygen to produce a mixture of gases. During this process, crop residue transforms into syngas including hydrogen, carbon dioxide, carbon monoxide, methane and hydrocarbons with the presence of gasification agents. Gasification is more efficient as compared to liquification and pyrolysis for producing hydrogen gas.

Techniques	Output
Gasification	syngas
Liquefaction	Bio-oil
Combustion	Electricity
Pyrolysis	Syngas, Bio-oil, Biochar
Transesterification	Biodiesel
Photobiological hydrogen production	Bio-hydrogen
Alcoholic fermentation	Bio-ethanol

6. **Mushroom cultivation**: Mushroom cultivation can be an effectual way to utilize residues and convert them into a valuable food product. The process typically involves breaking down the residues into smaller pieces and then treating them to create favorable conditions for mushroom growth. This can include techniques such as sterilization, pasteurization, or composting to eliminate potential competitors and create a nutrient-rich substrate. Rice and wheat straw are excellent sources for mushroom cultivation. Most grown mushroom–paddy straw mushroom (*Volvariella volvacea*) and white button mushroom (*Agaricus bisporus*).

Machinery for CRM

- Supper straw management system (SMS)
- Happy seeder
- Paddy straw chopper
- Shrub master/ rotatory slasher
- Super seeder
- Bailing machines
- Crop reaper

State-wise crop residue generation, residue surplus and burned

(Crop residue in million tonne)

S.N.	States	Residue generation*	Residue surplus*	Residue burned$
1.	Andhra Pradesh	43.89	6.96	2.73
2.	Arunachal Pradesh	0.40	0.07	0.04
3.	Assam	11.43	2.34	0.73

4.	Bihar	25.29	5.08	3.19
5.	Chhattisgarh	11.25	2.12	0.83
6.	Goa	0.57	0.14	0.04
7.	Gujarat	28.73	8.90	3.81
8.	Haryana	27.83	11.22	9.08
9.	Himachal Pradesh	2.85	1.03	0.41
10.	Jammu &Kashmir	1.59	0.28	0.89
11.	Jharkhand	3.61	0.89	1.10
12.	Karnataka	33.94	8.98	5.66
13.	Kerala	9.74	5.07	0.22
14.	Madhya Pradesh	33.18	10.22	1.91
15.	Maharashtra	46.45	14.67	7.42
16.	Manipur	0.90	0.11	0.07
17.	Meghalaya	0.51	0.09	0.05
18.	Mizoram	0.06	0.01	0.01
19.	Nagaland	0.49	0.09	0.08
20.	Orissa	20.07	3.68	1.34
21.	Punjab	50.75	24.83	19.65
22.	Rajasthan	29.32	8.52	1.78
23.	Sikkim	0.15	0.02	0.01
24.	Tamil Nadu	19.93	7.05	4.08
25.	Tripura	0.04	0.02	0.02
26.	Uttarakhand	2.86	0.63	0.78
27.	Uttar Pradesh	59.97	13.53	21.92
28.	West Bengal	35.93	4.29	4.96
	Total	**501.73**	**140.84**	**92.81**

Initiatives by government for effective management

- **National policy for management of crop residue**: National policy for management of crop residue to overcome challenges associated with agricultural waste and promote sustainable practices.

Major objectives

- Control of stubble burning to prevent its harmful effect on environment and reduce loss of soil nutrients by promoting ex-situ management (Biochar, bio-energy, composting, packing material, paper industry and mushroom cultivation) and in-situ management (soil incorporation, bailing, fodder).
- To create awareness about ill-effects of stubble burning, proper management and utilization of crop residue.

- Formulation and implementation of appropriate policy and law measures to curtail burning of residue.
- **In-situ crop residue management**: the central sector scheme for the promotion of mechanization of in-situ management of residue in states of Haryana, Punjab, Uttar Pradesh and NCR has been implemented from 2018-19 to 2019-20.

Objectives

- To reduce the detrimental effects of residue burning on environment and soil.
- Promoting custom hiring centers (CHC) or farm machinery banks (FMB) for custom hiring of machinery to manage crop residue.

Constraints for CRM in Rice–Wheat Systems

Rice-wheat cropping system is a major cropping system in north India. This system is input-intensive besides that emits larger amount of greenhouse gases. Repetitive puddling in rice fields and deep ploughing of wheat fields may lead to oxidation of organic carbon within soil, which is not favourable for soil environment. A large amount of crop residue was left in the field after combine harvesting has been introduced. Removal of leftover residue from fields is capital and labour intensive, though farmers mostly prefer to burn them rather than management. Residue produced in rice-wheat systems has very limited use for industrial and domestic purposes. Due to very high silica content in rice straw, it cannot be used for the feeding of animals, but wheat straw is used. The decomposition of rice-wheat takes a longer time due to high C: N ratio. Consequently, farmers usually burn the crop residue to get rid of it.

Conclusion

Effective management of crop residues is crucial for sustainable agriculture and environmental safety. It involves adopting practices that promote soil health, minimize waste and mitigate environmental impacts. By implementing a comprehensive national policy for crop residue management, countries can minimize environmental pollution, promote soil fertility, conserve moisture, control erosion and enhance overall agricultural productivity. With proper awareness, incentives, education, infrastructure and collaboration among stakeholders, crop residue management can contribute to sustainable agriculture and support the long-term well-being of both farmers and the environment.