

Review Article

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Crop Residue Management for Sustainable Agriculture

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ABSTRACT

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India is facing various challenges in agriculture sector for sustaining soil fertility and food grains production, besides environmental degradation and food security of the country in the event of ever increasing demands of food grains production with limited cultivable land. Cultivable land and maintaining its soil fertility are one of the major tasks which supports about 17.6% of its population and leads to fact that, our natural resources are under considerable strain. Food grains are a major source of energy and are thus vital for food and nutritional security. Besides, technological advances and use of machinery for crop harvesting leave behind large quantities of crop residues, which is burnt by farmers as cheap and easiest method with misconception that, burning of crop residues enhances soil fertility and helps in control weeds, insects and pests. From various studies, it is concluded that burning of crop residues result in heavy loss of organic carbon as well as soil nutrients, emits large amount of submicron aerosols and trace gases like Carbon dioxide (CO₂), Sulphur dioxide (SO₂), Carbon mono-oxide (CO) and smoke, thereby posing problem to environment and human health hazards. As per Ministry of New and Renewal Energy, about 500 Mt of crop residues are generated annually in India, used as animal feeding, soil mulching, composting, uses in mushroom production etc. As such, crop residues have tremendous plant nutrients, however, a large quantity of the crop residues (about 93 Mt) is burnt on-farm and primarily to clear the field for sowing of the successive crop and farmer also burn due to shortage of labour farmer can't be able to manage the residues, so they simple burn it (NPMCR, 2019). Crop residues also act as an alternate host for many of the insect, pest and diseases (Cox *et al.*, 2004). In view of above, efforts were made to collect the data and suggest various technical and policy options for crop residue management to prohibit crop residue burning, enhancing soil fertility besides prevention of environmental degradation. The major recommendations includes, incorporation of crop residue in to the soil, adoption suitable crop rotation as recommended by ICAR or in Soil Health Care provided to the farmers, promotion of alternate competitive methods of utilizing residues in Small Scale Industries for use of crop residue/rice straw in paper/board/panel and packing material and biomass power plants establishment in Public Private Partnership mode to ensure economic return to the farmers and sustaining soil fertility and food grains production, besides prevention of environmental degradation in the country.

Introduction

The growing demand for food in various countries has led to huge increase in food production around the world. Hence, agro-based activities represent profitable businesses for both developed as well as developing countries. The crowd of agricultural activities increases the amount of agro-products produced and this has been led to an overall increase in environmental

pollution and waste generation. Large stretches of wasteland have been converted to arable lands due to developments in modern agro-technologies, water management systems and large-scale agrochemical deployment (Nagendran, 2011).

These measures have been resulted in global environmental pollution and increased complexity in the disposal of agricultural wasted. However, the national agencies are

continuously developing policies and possible options to manage these wastes, which include their conversion to reusable resources.

Crop residues are parts of the plants and left in the field after crops have harvested and threshed. The recycling of crop residues has the advantage for converting the surplus residues into useful product for meeting nutrient for soil microorganism as well as succeeding crops. Crop residues are a source of organic carbon for soil microorganisms and also contribute to plant nutrients. In India still a surplus of 140 Mt out of which 92 Mt is burned each year (NPMCR, 2019).

Crop residues retention on the soil surface, resulted reduces run-off as well as soil erosion and can decrease soil evaporation and land preparation costs (Lal, 1989). In India there are 500-550million tones (Mt) of crop residues are produces annually (MNRE, 2009). Mostly farmer's remove wheat straw used for feeding for animals. However, management of the rice straw is a major challenge task because high silica content so poorly feed for the animals. Combine harvester leaves behind a swath of loose rice straw, which interfere the operations of the seed drill used for sowing of wheat. To avoid these problems farmers burns their crop residues (90-140 Mt annually). From the farmers' point of view, burning may be seen as the best management practices for disposing of crops residues. It is not only a cost-effective method but it acts as an effective practices incest pest control (Dobermann and Fairhurst, 2002). (Gadde *et al.*, 2009) estimated that the burning of rice straw contributed 0.05% of the total amount of greenhouse gas emissions in India, which not only lead to loss of the huge amount of biomass, i.e. organic carbon, plant nutrients, but also cause adverse effect on soil properties chemical and biological physical as well as soil flora and fauna.

So there is a need to adopt a suitable ways and means to manage this valuable resource. Crop residues incorporation in soil to maintain and restore soil fertility (Pituello *et al.*, 2016).

Why we needed for crop residue management?

Management of crop residue due to mostly Indian farmer burned their crop residues. Approximately 730 Mt of biomass was burned annually in Asia and 18% of that is from India (Street *et al.*, 2003). Burning of crop residue create following problems.

Loss of nutrients

It is estimated generally crop residues of different contains 80% of Nitrogen (N), 25% of Phosphorus (P), 50% of Sulphur (S) and 20% of Potassium (K). It is also estimating that burning of one tonne of crop residue account for loss of the nutrient 5.5 Kg Nitrogen, 2.3 Kg phosphorus, 25 Kg potassium and 1.2 kg sulphur besides, complete loss of organic carbon and polluting atmosphere and increase greenhouse gas emission led to climate change. If the crop residues are incorporated or retained the soil itself, soil gets enriched above mention nutrient, particularly with organic carbon and also meets food for soil microorganism and plant nutrient.

Impact on soil properties

Heat from burning of residues elevates soil temperature causing death of beneficial soil organisms. Burning of the crop residues immediately increases the bicarbonate extractable P content, but there is not build up nutrients in the soil profile. Frequent residue burning leads to complete loss of microbial population, though the effect is temporary, as the microbes regenerate after a few days.

Repeated burning in the field also reduces level of N the nutrient and C and potentially mineralizable N in the upper (0-15 cm) soil layer.

Emission of greenhouse gases (GHG)

Burning of residues emits a significant amount of Green House Gasses (GHGs). About 70%, 7% and 0.7% of C present in rice straw is emitted as carbon dioxide (CO₂), carbon monoxide (CO) and methane (CH₄), respectively, while 2% of N in straw is emitted as nitrous oxide (N₂O) upon burning. This lead to increase greenhouse gas emission.

Why farmer burn their crop residues?

The Ministry of Agriculture attributes the increase in the on-farm crop residues burning to the shortage of the human labor. Reported that 80% of the crop residues burning took place during the post-harvest period of April-May and November-December months. The reason behind this is attributed to the crop patterns used to ensure a higher economic return which leaves limited time between two consecutive crop cultivations. Some farmers even resort to a cycle of three crops a year with a short gap between harvesting and sowing of the next crop. Crop residues also act as an alternate host for many of the insect, pest and diseases (Cox *et al.*, 2004).

Crop residue – types

Field residues

Field residues are those residues left in an agricultural field after the crop has been harvested. These residues include stalks and stubble, leaves and seed pods. The residue can be ploughed directly into the ground, or burned first. In contrast, no-till, strip-till or reduced tillage in agriculture practices are

carried out to maximize crop residue cover. Good management of field residues can increase the efficiency of irrigation and control of soil erosion.

Process residues

Process residues are materials left after the crop have been processed into a usable resource. These residues include husks, seeds, bagasse, molasses and roots. They can be used as animal fodder and soil amendment, fertilizers and in manufacturing.

Nutrient content in crop residues

Crop residues are a potential source of plant nutrients and their beneficial effects on soil fertility and productivity can be harnessed by recycling them into the soil that on an average 30–35% of applied nitrogen and phosphorus and 70– 80% of potassium accumulate in the crop residues of food crops. About 40% of N, 30–35% of P, 80–85% of K, and 40– 50% of the S uptake by rice remains in the vegetative parts at maturity. Similarly, about 25–30% of N and P, 35–40% of S, and 70–75% of K uptake is retained in wheat residue. Moreover, crop residues are the primary source of organic matter (as C constitutes about 40% of the total dry biomass) which is indispensable for sustaining agricultural ecosystems. However they depend upon the soil conditions, crop management, variety as well as season determine the nutrient concentration in crop residues (Table 1).

Crop residue potential in India

The Ministry of New and Renewable Energy, Govt. of India (2009) has estimated that about 500 Mt of crop residues are generated every year. The generation of crop residues is highest in UP (60 Mt) followed by Punjab (51 Mt) and Maharashtra (46 Mt). Among different crops, cereals generate maximum

residues (352 Mt), followed by fibers (66Mt), oilseeds (29 Mt), pulses (13 Mt) and sugarcane (12 Mt). The cereal crops contribute 70% while rice crop alone contributes 34% and wheat ranks second with 22% of the crop residues (Table 2).

Challenges for management of crop residue

- Huge volume of crop residue.
- Collection & Storage.
- Time window between harvesting and sowing of two(next)crops.
- Utilization of crop residue.
- Cost-effective mechanization, awareness and availability of appropriate machinery.

Management of crop residues

Balling and removing the straw

Surplus straw from agriculture may be used for a number of useful purposes such as livestock feed, fuel, building materials, livestock bedding, composting for mushroom cultivation mushroom production is one of the areas with great potential for exploitation of forest and agricultural residues (Gregori *et al.*, 2007). Bedding for vegetables such as cucumber, melons etc. and mulching for orchards and other crops.

Soil mulch

Direct drilling in the surface mulched residues is a practice that leaves crop residues from a previous crop on the soil surface without any form of incorporation. Surface retention of residues helps to protecting the fertile soil surface against wind as well as water erosion. (Thorne *et al.*, 2003). The large volume of residues remaining on the surface often leads to machinery failures, thus affecting sowing of seeds of the following crop. Farmers usually follow this practices where no- till or conservation tillage practices are prevalent. Surface retention of some or all of the

residues may be the best option in many situations. It suppresses the weed growth (Bilalis *et al.*, 2003). Residues decompose slowly on the soil surface, increasing the organic carbon and total nitrogen in the top 5-15 cm of the soil, while protecting the surface soil from erosion. Retention of crop residues on the soil surface increased the soil NO₃-concentration by 46%, nitrogen uptake by 29%, and yield by 37% compared to burning. It maintains the soil temperature (Lenka *et al.*, 2012). Retention, however, provides habitat. For both harmful as well as useful organisms in one hand, and on the other it provides C substrate for heterotrophic N-fixation, increase microbial activity, soil C and N, and reduce fertilizer N requirements for rice. The faster decomposition and release of nitrogen to the soil is possible if this is treated with urea and applied during field preparation.

Crop residues incorporation

Crop residues may be incorporated partially or completely in the soil depend upon methods of cultivation. Straw incorporation can increase crop yield (Yang *et al.*, 2016) Ploughing is the most efficient residue incorporation method. Incorporation of rice residues before sowing of wheat compared to incorporation of wheat straw before rice planting is difficult due to low temperatures and the short day interval between rice harvest and wheat sowing. Unlike removal or burning of crop residues incorporation of residues increases SOM and soil nitrogen, phosphorus and potassium contents. In few studies, wheat yields were lower during the first one to three years of rice straw incorporation 30 days prior to wheat planting because of immobilization of soil nitrogen in presence of crop residues with wide C/N ratio, but in the later years, straw incorporation did not affect wheat yields adversely. In contrast, rice straw incorporation gave significantly higher wheat yields of 3.5 t ha⁻¹ as compared to the 2.91 t

ha⁻¹ with straw removal. Crop residues, which contain abundant organic carbon and mineral nutrients, are important sources of organic matter that can be returned to soil for nutrient recycling and for improving soil physical, chemical, and biological properties (Kumar and Goh, 2000).

cereal straw is the immobilization of inorganic N and its adverse effect due to N-deficiency. Incorporation of rice straw into the soil after its harvest leads to slow down the decomposition process and soil inorganic nitrate is immobilized, reducing the nitrogen uptake and yield of subsequent wheat crops by about 40% (Table 3).

The major disadvantage of incorporation of

Table.1 Nutrient content in crop residues

Crop Residues	Nutrient content (%)		
	N	P ₂ O ₅	K ₂ O
Rice	0.61	0.18	1.38
Wheat	0.48	0.16	1.18
Maize	0.52	0.18	1.35
Sugarcane	0.40	0.18	1.28
Pulses	1.60	0.51	1.75

(Source:- Reddy and Reddy., 2003)

Table.2 Crop residue potential in India crop wise

Crops	Residues (Mt)
Cereals	352
Pulses	13
Oilseeds	29
Sugarcane	12
Fibers	66

Source - The MNRE, Govt. of India (2009)

Table.3 State-wise (major states) crop residue generated, residue surplus and burned in India

States	Residue generation (Mt)	Residue surplus (Mt)	Residue burned(Mt)
Uttar Pradesh	59.97	13.53	21.92
Punjab	50.75	24.83	19.65
Maharashtra	46.45	14.67	7.42
Andhra Pradesh	43.89	6.96	2.73
Karnataka	33.94	8.98	5.66
West Bengal	35.93	4.29	4.96

Source - The MNRE, Govt. of India (2009)

Due to straw incorporation, wheat yield depression (mean of 10 years) decreases from 0.54 t ha⁻¹ to 0.08 t ha⁻¹ with the application of N @ 60 and 180 kg ha⁻¹, respectively. The combined uses of rice or wheat straw and fertilizer can, however, increase the yield of rice and wheat in rice-wheat cropping systems.

Farmers often apprehend to optimum for incorporation of the rice residues before planting of wheat because of the fact that nitrogen is temporarily immobilized for the following wheat crop, reducing its productivity. Of course, proper nitrogenous fertilizer management practices can reduce nitrogen immobilization due to incorporation of crop residues into the soil. These practices included suitable method, time, and rate of nitrogen fertilizer application (i) placement of N fertilizer below the surface soil layer that is enriched with carbon after incorporation of crop residue (ii) application of nitrogenous fertilizer at a higher rate than the recommended rate, and (iii) application of nitrogen 15-20 kg ha⁻¹ as starter dose with straw incorporation increases yields of wheat and rice as compared to either burning of straw or its incorporation into the soil (Singh *et al.*, 2004).

The recycling of crop residues has the great potential to return a considerable amount of plant nutrients to the soil. The yield of crops stagnation consequently upon due to declining soil organic carbon is a major threat to this system. Therefore it is a great challenge to the agriculturists to manage crops residues effectively and efficiently for enhancing sequestration of carbon and maintaining the sustainability of production. Crop residues management practices are also important as machines are being increasingly used for harvesting of grains and this mechanical harvesting leaves huge amount of crop residues in the field. There are several options for management of crop residues: mulching, incorporation in the soil and surface retention etc. Every management options have its advantages as well as disadvantages. Now it is the location, soil and situation, which will

govern the practice to be selected. Of course, intensive research is required to solve this problem of managing rice residues. Sometimes surface retention may be the best option for sustainable agriculture. For sowing/ planting of subsequent crops having rice residues, both stubbles and loose straw in the field needs to be managed, for that intensive investigation in different crops growing areas is required. In long term incorporation of crop residue increase the soil physical, chemical and biological properties. No tillage technology may be adopted which is fitted to the location and soil condition. Incorporation of crop residues in soil is the best option as well as ecofriendly management practices for sustainable agriculture.

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