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The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(5): 298-305

www.thepharmajournal.com
Received: 05-02-2021
Accepted: 09-03-2021

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Effect of in stubble burning on physico chemical properties of soil, yield and environmental qualities

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Abstract
India is the second largest agro based economy with year round crop cultivation produced a large amount of agricultural waste, including crop residues. It has major environmental issues which causing health problems and also contributing to global warming which leads to ozone depletion. Also it leads to the adversely effect on the nutrient conditions of the soil. It results in the emission of smoke; if smoke is added to the gases that present in the air can cause atmospheric air pollution problems which occur from stubble burning. These gases emission can cause health problems like asthma, chronic bronchitis and decreased lung functions. On the other hand if the proper use of crop residue it is used ad dry fodder of animals, in bio thermal power plants and mushroom cultivations, bedding material for cattle, used for production of bio oil, paper production and also used for bio gas production. Incorporation of crop residues into soil has several positive influences on physical chemical and biological properties of soil.

Keywords: Rice, stubble burning, environment, crop residues, pollution

Introduction

Crop residues are materials left in an agricultural field after the crop has been harvested. These residues are including stalks and stubble, leaves, as well as seed pods (Kaur *et al.,* 2019) [13]. Basically crop residue burning is cheap, easy, convenient and economical method for managing in situ crop residues. Another major benefit of this practice is time saving in clearing the agricultural fields. Because the farmers have very less time between harvest of one crop and sowing the next one. Even though this management measures has creating many problems like health issues and environmental effects. The main environmental issue related with burning of crop residue is air pollution, soil pollution and climate changes. *In situ* crop residue burning adversely affects the soil properties and fertility of the soil (Kaur *et al.,* 2019) [13]. Crop residues may affect the physical chemical and biological properties of the soil. They increase the soil microbial biomass, organic carbon and total nitrogen levels in the soil (Bierke *et al.*, 2008) [3]. Malhi and Kutcher (2007) [18] reported that nutrient loss of carbon, phosphorus and nitrogen by volatilization due to the burning of crop residues in the field. But long term studies in cropping system mainly observed that with the combination of crop residue with inorganic fertilizer resources of nutrients increase the productivity and soil health. Cycling of crop wastes could be used in agriculture in many ways such as direct incorporation, mulching, composting, vermicompost etc. It is also used as a dry fodder for animals and in bio thermal power plants and mushroom cultivations, bedding material for cattle, used for production of bio oil, paper production and also used for bio gas production (R. Rajput *et al*., 2017) [22]. With the increasing demand of food to feed the ever growing population along with increasing the cost of inorganic fertilizer and day by day decreasing the soil fertility. It is necessary to use of renewable and non- renewable sources of input energy Krishnaprabu S. (2019) [23]. Soil is one of the most valuable natural resources of the earth and to maintain its health it is the moral responsibility of mankind. Day by day soil fertility and productivity decreased due to the excessive use of chemical fertilizers and pesticides as well as modern cultivation practices. Use of organic wastes as soil amendment may hold a good potential for improving soil properties and soil health and crop productivity on the other hand it is beneficial for reducing the waste disposal problems. Mostly rice straw is used as a waste organic product whose maximum quantity needs some amount of valuable disposal solution (Swarnima S and Vinay A., 2018) [28].

Generation of crop residues in India

The Ministry of New and Renewable Energy (MNRE, 2009), Govt. of India has estimated that about 500 Mt of crop residues are generated every year (Table 1). There is a wide variability in the generation of crop residues and their use across different regions of the country depending on the crops grown, cropping intensity and productivity of these crops. The generation of crop residues is highest in Uttar Pradesh (60 Mt) followed by Punjab (51 Mt) and Maharashtra (46 Mt). Among different crops, cereals generate maximum residues (352 Mt), followed by fibres (66 Mt), oilseeds (29 Mt), pulses (13 Mt) and sugarcane (12 Mt) (Fig. 2). The cereal crops (rice, wheat, maize, millets) contribute 70% while rice crop alone contributes 34% to the crop residues (Fig. 2). Wheat ranks second with 22% of the crop residues whereas fibre crops contribute 13% to the crop residues generated from all crops. Among fibres, cotton generates maximum (53 Mt) with 11% of crop residues. Coconut ranks second among fibre crops with generation of 12 Mt of residues. Sugarcane residues comprising of tops and leaves, generate 12 Mt, i.e., 2% of the crop residues in India. Generation of crop residues of cereals is also highest in Uttar Pradesh (53 Mt), followed by Punjab (44 Mt) and West Bengal (33 Mt). Maharashtra contributes maximum to the generation of residues of pulses (3 Mt) while residues from fibre crops are dominant in Andhra Pradesh (14 Mt). Gujarat and Rajasthan generate about 6 Mt each of residues from oilseed crops.

Utilization and on-farm burning of crop residues in India

The utilization of crop residues varies across different states of the country. Traditionally crop residues have numerous competing uses such as animal feed, fodder, fuel, roof thatching, packaging and composting. The residues of cereal crops are mainly used as cattle feed. Rice straw and husk are used as domestic fuel or in boilers for parboiling rice. Farmers use crop residues either themselves or sell it to landless households or intermediaries, who further sell them to industries. The remaining residues are left unused or burn ton-farm. In states like Punjab and Haryana, where crop residues of rice are not used as cattle feed, a large amount is burnt on-farm. Sugarcane tops are either used for feeding of dairy animals or burnt on-farm for growing a ratoon crop in most parts of the country. Residues of groundnut are burnt as fuel in brick kilns and lime kilns. The residues of cotton, chilli, pulses and oilseed crops are mainly used as fuel for household needs. The shells of coconut, stalks of rapeseed and mustard, pigeon pea and jute and mesta, and sunflower are used as domestic fuel. The surplus residues i.e., total residues generated minus residues used for various purposes, are typically burnt on farm. Estimated total amount of crop residues surplus in India is 91-141 Mt. Cereals and fibre crops contribute 58% and 23%, respectively and remaining 19% is from sugarcane, pulses, oilseeds and other crops. Out of 82 Mt surplus residues from the cereal crops, 44 Mt is from rice followed by 24.5 Mt from wheat, which is mostly burnt on-farm. In case of fibre crops (33 Mt of surplus residue) approximately 80% of the residues are from cotton and are subjected to on-farm burning.

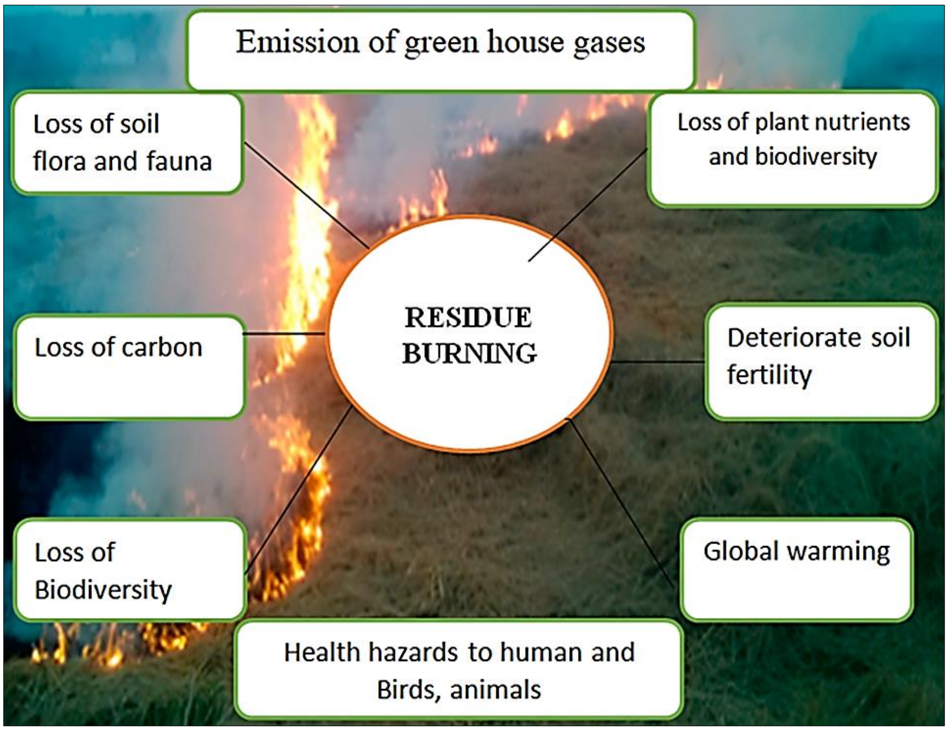

Fig 1: Consequences of crop residue burning

Table 1: Residue generation by different crops in India and the share of unutilized residues in total residues generated by different crops in India

Crops	Residue generation by different crops in India	The share of unutilized residues in total residues generated by different crops in India
Cereal crops	70%	58%
Fibre crops	13%	23%
Oilseed crops	6%	7%
Pulses	3%	2%
Sugarcane crops	2%	2%
Other crops	6%	8%

Characterization of crop residue

Jain A. K. *et al.* (1986) analyzed 10 crop residues to determine the characteristics like bulk density, equilibrium moisture contents at 80% of relative humidity, higher calorific value, fixed carbon, volatile matter and ash contents. In the thermo gravimetric analysis a graph had been plotted between% weight and temperature for a particular heating rate and air flow rate.

Jain A.K. (1997) analyzed the characteristics of thirty four fast growing fuel wood species, agricultural crop residues and agro wastes. Mainly lower heating values, stoichometric formula and stoichometric air fuel ratio were determined. Co-relation models had been developed to predict the characteristics of the biomass and density classification for various bio-mass had been done.

Concluded that 61% of total crop residues in India is produced from straws, remaining 39% includes; sugarcane (23%), stalk (11%), and husk cobs etc. (5%). They further concluded that 64% of the workforce engaged in agriculture with 29.4% contribution to GDP and the characteristics of crop residues differ from region to region because it depends upon agro climatic regions and soil conditions in the country. They further calculated residue production ratio for various crops and suggested to utilize biomass either biochemically or thermo chemically.

Abdul S. P. *et al.* (1999) concluded that in India total biomass consumption for energy was 321 billion kg in year 1991, this is 45% of the total primary energy consumption of the country. Whereas fuel wood contributes 53% of energy needs. Household sector consumes 83% of the total biomass energy. They also given the data of primary conventional energy consumption of 1994-95 and listed the biomass energy resources in India as fuel wood, agricultural residues, energy plantation, animal and other organic wastes, human waste and municipal solid waste (MSW).

Samuelsson R. *et al.* (2006) discussed different methods for the determination of moisture contents of biomass. The first one was determination of moisture content with reference method; drying in an oven at 1050 C until a constant weight (it is accepted as technical specification in CEN TC 335 and is based on Swedish standard SS18 71 70- determination of moisture content- oven dry method) and was compared with other methods like Xylene distillation, freeze drying. It was concluded that significance difference is there at temperature of 800 C and 1050 C and 1300 C. In some cases the discrepancies were explained by the loss of volatile organic compounds during the oven drying step at elevated temperatures.

Sidhu Balwinder Singh *et al.* (2013) evaluated three agricultural residues and one agro industry byproduct (husk) through proximate and ultimate analysis and heating values. The results had been compared with the some previously developed correlation models.

Effects of crop residues on physico-chemical properties of soil

Crop residues plays an important role in improving physico-chemical and biological properties of the soil. It protects the soil loss by wind and water erosion also reduced the runoff and acts as a physical buffer. Even though, due to the addition of straw improves organic matter to the soil favors formation of aggregates and structural stability. Whether incorporation of rice straw with the combination of farm yard manure reduces the bulk density of soil and increases the porosity of the soils. Soil organic matter acts as reservoir for essential plant nutrients, prevents leaching loss, required for growth and increases cation exchange capacity. Continuous use of crop residues increase organic matter content of the soil and also leads to improving the water holding capacity of the soil. Crop residues favors carbon sequestration in soils.

Crop straw application improves soil organic carbon and nutrient content of the soil. The addition of crop residue either partially or completely in the field depends upon the cultivation practices. It is helpful for recycling residue, and the better ration of C: N needs to be corrected by applying extra nitrogen fertilizer at the time of residue incorporation (Yadvinder Singh *et al*., 2005) [32]. In some studies it is also revealed that rice yield was decreased in first 3 years of straw addition 30 days prior to rice planting due to crop residue applied in the field may cause immobilization of soil nitrogen. But later on it did not affect the yield.

Zhang *et al.* (2016) [33] stated that straw incorporation crucially increased the organic carbon content and storage levels as compare to the without use of straw application. Where the increase was probably related with the amount of crop residues incorporated into the soil, as suggested previously (Malhi*et al*., 2011) [19]. Chaudhary *et al*. (2014) studied that retention and incorporation of residue caused a significant increase in total water stable aggregates (15.65%) in 0-15cm depth in surface soil and 7.53% in sub-surface soil (15-30 cm), which showed that the use of crop residue, can enhance 2.1-fold higher water stable aggregates as compared to the other treatments without residue incorporation. Cvetkov *et al*. (2010) [6] showed that the incorporation of farmyard manure enhances more soil organic carbon as compared to residue incorporation in soil under different management systems. Chalise *et al*. (2019) [4] reported the impact of cover crop and crop residue removal on bulk density, Soil organic carbon, infiltration, water retention and productivity. They showed that crop residue enhanced soil organic carbon and decreased bulk density of soil. They concluded when crop residue applied in the field it add soil carbon, soil nutrient by which fertility and crop productivity would be increased. Soil pH, a function of parent material, time of weathering, vegetation and climate is considered as one of the dominant chemical indicators of soil characteristics, identifying trends in change for a range of soil biological and chemical functions such as acidification, salinization, crop performance, nutrient availability and cycling and biological activity (Dalal and Moloney 2000) [7]. Continuous applications of inorganic fertilizers and organic fertilizers have been reported to change soil pH. The magnitude of effects depends on soil type, cropping systems, nutrient management practices and nature of fertilizer materials used. In a Mollisol, continuous cropping of rice-wheat and cowpea for 31 years had no significant effect on soil pH under different fertilizer treatments but slightly increased electrical conductivity (EC) from its initial value of 0.29 dS m-1 to 0.38 dS m-1 in NPK treated plots (Sharma *et al.* 2007) [27]. Futher more application of inorganic fertilizer in an Alfisols decreased soil pH from its initial value of 5.5 to 4.1 in NPK treated plots. Continuous application of organic and inorganic sources of nutrients for 20 years decreased the soil pH by 0.3-0.9 units compared to unfertilized soil (Tirol-Padre *et al.* 2007) [30]. Sharma *et al.* (1998) [25] reported that soil pH was increased or decreased with integrated nutrient management treatments after 31 years compared to initial value. There was no significant effect of various treatments (FYM, NPK, crop residues) observed on soil pH at 0-15 and 15-30 cm soil depth after 35 years of continuous cropping and fertilization (Agarwal *et al.* 2010) [1]. According to Shahrzad K *et al.*, (2014) results revealed that crop residues significantly decline soil pH and the largest increase was observed for *Trifolium* treatment. EC significantly enhanced by affected crop residues application. Dhar *et al*., (2014) [8]. Showed that the application of wheat straw and green manure in soil ph decreased (7.70) and Electrical conductivity was not influenced by the application of organics. Shahrzad *et al*. (2014) revealed an increase in pH and electrical conductivity of soil with the application of crop residues. Anilkumar *et al*. (2012) stated that the incorporation of farm yard manure, wheat straw and green manure along with inorganic fertilizers decline the soil pH and electrical conductivity as compared to the sole application of fertilizers.

Effect of crop residue on yield

Paikaray *et al.* (2001) [24] stated that 80 kg N/ha yield with increased due to the application of wheat residue incorporation. Yield was statistical at par with cowpea in crop rotation and significantly decreased as compared to with residue incorporation statistically similar without organic nitrogen and 120 kg nitrogen per hectare. Thakur *et al.* (1995) [29] revealed that 40kg nitrogen saving per hectare with residue incorporation in field. Inorganic fertilizer, wheat straw and mixture of rice can increase the yield of rice and wheat in rice-wheat cropping systems. Proper crop residue incorporation and fertilizer management practices can decrease nitrogen immobilization into the soil. Sharma (2002) [24] recorded that the use of 40 kg nitrogen per hectare at the time of residue incorporation in wheat crop, and similar percentage of nitrogen used during transplanting and rest at panicle initiation increased straw yield 0.5 1.0 t/ha, grain yield by 0.5-0.7 t/ha nitrogen recovery by 10%.showing residue incorporation was the better result and reported good available Nitrogen content in soil than Nitrogen use along with transplanting. Zhang *et al*. (2016) [33] reported that the addition of straw was a good method for increasing soil fertility and better yield production in semiarid region of China. Guo-Wei *et al.* (2009) [10] stated that 2.65% average of grain yield was increased with addition of crop residue as compared to without use of crop residue. On the other hand, the combination effect of straw on the biomass of yield was better in rice crop. Grain and straw yields of rice were affected significantly. Sole application of wheat straw 5 or 10 t/ha gave better rice grain yield than control. Maximum use of inorganic fertilizer alone, from 50 to 75 and 100% of the recommended dose of Nitrogen, also enhanced crop yield Result stated that the application of both wheat straw and doses of nitrogen improved the grain and straw yields of rice

Effect of organic and inorganic sources of nutrients on soil carbon pools

The level of soil organic carbon (SOC) at a point of time reveals the long-term balance between addition and losses of SOC under continuous cultivation. Alterations in agricultural practices may influence both quantity and quality of SOC and its turnover rates. Dynamics of organic carbon storage in agricultural soils effect global climatic change and crop productivity (Lal *et al.* 1995; Li *et al.* 2007) [15]. The common management practices leading to enhanced SOC status include integrated nutrient management including the use of chemical fertilizers along with organic fertilizers such as manure, compost, crop residues and bio-solids, mulch farming (Lal 2004) [16]. In rice-wheat system, incorporation of rice straw improved soil organic carbon content by 19% and total Nitrogen by 37% over without use of fertilized control. Farm yard manure application enhanced SOC content by 11% and total Nitrogen content by 77%. Combination of both rice straw and Farm yard manure together resulted in highest improvement in soil organic carbon content (34%) and total Nitrogen (90%) showed by (Benbi and Senapati 2010) [2]. Numerous studies have stated that combined use of organic fertilizers and inorganic fertilizers results in increased soil organic carbon under different soil, crop and climatic conditions (Yang *et al.* 2004; Moharana *et al.* 2012) [21, 31]. According to Yang *et al.* (2004) [31] revealed that soil organic carbon content in paddy soil was 40-60% more under integrated use of organic fertilizers and inorganic fertilizers as compared to sole application of inorganic fertilizers. In rice-wheat cropping system continuous use of farm yard manure either sole or in combination with NPK resulted in accumulation of soil organic carbon in surface soil layer as compare to unfertilized control (Moharana *et al.* 2012) [21]. Kumar *et al.* (2012) [14] reported that the long-term effect of organic sources along with fertilizers and found that soil organic carbon was significantly enhanced in soil treated with organic fertilizers and fertilizers in compare to the soil treated with sole application of fertilizers. The incorporation of farm yard manure enhanced soil organic carbon by 48% and 17% than to control and fertilizer treatments, respectively. On the other hand, fertilizers alone also increased soil organic carbon by 26% as compared to unfertilized control. The increase in soil organic carbon with application of inorganic sources is maximum above ground and root biomass than in control plots. Further, with the long-term application of organic fertilizers along with the inorganic fertilizers may be attributed to additional Carbon inputs resulting from return of crop residues into soils.

Burning effects on soil biological activity

So far, very little information on the effects of fire on soil biological life is achieved. It has been reported that the fire gradually decreased soil organic matter and biological activity. One reason suggested for reducing the activity of microorganisms, destroying them by fire. Add organic matter to the soil of the cultivation of plants and micro-organisms in the soil underneath again and areas of soils that have not been exposed to fire. Provided a food source for soil microbe's fire soil organic matter levels are severely reduced. Studies show that about 80% of plant residues by microbial oxidation process and the remaining 20% is converted into organic compounds joins. The cause of the microbial biomass production, or compounds that are easily degraded by microorganisms and increase soil biological activity. When remains are cremated remains about 60% of the amount of its immediately (carbon monoxide) becomes and the remaining 40% of this amount, 32% will be added to the soil microbial processes and their breathing to become the 8% of the organic matter is converted. Carbon in the ash cannot exist as a food source for the microorganisms and act as a support for them. Thus, the activity of microorganisms and population declines and soil biological processes are disrupted. During a test plant debris and ashes from the burnt remains were added to pots containing loamy soil in the laboratory and field capacity for 10 days at 24 ° C and temperature were maintained at the end of the microorganisms was evaluated in pots. Add plant remains much more than adding ash was due to microbial activity. It must be said that the plant remains in the treatment of nitrogen were added to a large amount of nitrogen in the soil due to very high carbon to nitrogen ratio (C/N) was immobile, but the ash was added in the mixture of soil available nitrogen was more Due to the lack of soil microbes use of ash as a source of food. Framed population declined as a result of micro-organisms and nitrogen rather than the plant was established by soil microbes. Incineration plant residues also affect the composition of the population of micro-organisms as plant debris rotting fungi activity is more influenced by bacteria, fungi, much of the population in the soil means soil quality. Leftover food by burning straw mushrooms which is dissipated and the population is low. The balances of the bacteria tend to find it. In addition to the loss of soil organic matter, soil porosity and low permeability. So that the moisture content and soil conditioner and its adverse effect on the fungal population.

Burning of crop residue on the soil surface reduces soil micro-organisms. Wheat straw burning 50 percent of the population of bacteria up to 2.5 cm cut. The amount of soil microorganisms in ground wheat straw burned compared to the land where straw was mixed with soil at about 70 percent. Following the burning of crop residue, bacteria hetero residues in the soil was more than fungi. Burning of crop residue amount and activity of enzymes involved in the cycle of mineral elements in the soil is reduced. In some parts of the world such as the Pacific Northwest burning plant residues, in order to eliminate pathogens of control with chemicals known to NVN an effective and inexpensive. In this region, the burning of wheat straw in the field to reduce the population of different species of pathogenic fungi embankment called pythium by 40 to 50 percent of the province. In some cases, the burning of crop residue on the effect of some chemicals may break dormancy inhibiting seed germination of some seeds, or the loss of it, and such. This reduced wild oat density of 13 of 0.6 square meter plant will be. In another experiment, small grain stubble burning weed density cylindrical ancestral wheat (Aegilops cylindrical) greatly reduced (Einallah Hesammi *et al*., 2014) [9].

Adverse impact of crop residue burning on the environment

The burning of crop residues generates numerous environmental problems. The main adverse impact of crop residue burning include the emission of greenhouse gases (GHGs) that contributes to the global warming, increased levels of particulate matter (PM) and smog that cause health hazards, loss of biodiversity of agricultural lands, and the decline of soil fertility. Crop residue burning considerably increases the quantity of air pollutants such as carbon dioxide, carbon monoxide, Non-methane hydrocarbon (NMHC), volatile organic compounds (VOCs), semi volatile organic compounds (SVOCs) and particulate matter. This basically accounts for the loss of organic carbon, nitrogen, and other nutrients, which would otherwise have retained in soil.

Burning of rice straw causes nutrients loss in soil and affects human health hazards by polluting air. The burning results in huge losses of carbon (almost 100%) Nitrogen (up to 80%), Phosphorous (25%), potassium (21%) and Sulphur (50-60%) (Mandal *et al.* 2004) [20]. According to Gadi, 2003 one ton of rice straw on burning releases about 3 kg particulate matter, 60 kg carbon mono oxide, 1460 kg Carbon dioxide, 199 kg ash and 2 kg Sulphur dioxide. Likewise, studies have also shown that the amount of organic matter and nutrient content remain in one ton of wheat straw before burning is 413 kg of carbon, 11 kg of nitrogen, 1.4 kg of phosphorus 14.5 kg of potash and 1.1 kg of sulphur (Heard *et al.* 2006) [11]. While the product of burning of the stubble are gases and ash and after burning of the straw and stubbles, most of the nitrogen, carbon and sulphur and reduced amounts of phosphorus and potash stored in this stubbles and fodder are consumed in the fire.

Sustainable management practices for crop residue

Alternative measures have long been suggested by scientists and agriculturalists over the past decade to counter crop residue burning, but due to a lack of awareness and social consciousness among the farmers these measures have not been fully implemented. In this section information on three such agricultural applications that have either been overlooked or skipped due to various reasons are presented. They are: composting, biochar, and in-situ management through mechanical intensification.

Composting

Composting is the natural process of rotting or decomposition of organic matter by micro-organisms under controlled conditions (Misra, R.V *et al*., 2003) [36]. As a rich source of organic matter, compost plays an important role in sustaining soil fertility and thereby helping to achieve sustainable agricultural productivity. Addition of compost to the soil improves physio-chemical and biological properties of the soil and can completely replace application of agricultural chemicals such as fertilizer and pesticides. Higher potential for increased yields and resistance to external factors such as drought, disease and toxicity are the beneficial effects of compost amended soil (Misra, R.V *et al*., 2003, Shilev S *et al*., 2006, Lei Z *et al*., 2010) [36-38]. These techniques also help in higher nutrient uptake, and active nutrient cycling due to enhanced microbial activity in the soil.

During composting, the organic matter is acted upon in two phases

(i) Degradation: The first phase of degradation starts with breakdown of easily degradable organics like sugars, amino and organic acids. The aerobic microorganisms consume oxygen and release carbon dioxide and energy. The first thermophilic phase is dominated by high temperature, high pH and humidity, essential for activating the microorganisms and proceeds for several weeks to months (Aladjadjiyan, A., 1992) [40]. During this phase, it is also ensured that the substrate is properly cooled with sufficient supply of oxygen (Beck-Friis, B *et al*., 2000) [41].

(ii) Maturation: The second phase continues for few weeks, with breakdown of more complex organic molecules followed by decrease in microbial population. There is a change from thermophilic to mesophilic phase with a decrease in temperature to 40-45 _C (Aladjadjiyan, A., 1992; Beck-Friis, B *et al*., 2000) [40, 41]. Further at the final stage, temperature declines to an ambient value and the system becomes biologically less active. Finally, a dark brown to black color soil-like material is produced. This soil-like material also exhibits an increased humus content and decreased carbon-nitrogen ratio with a neutralized pH (Misra R.V *et al*., 2003) [36]. Eventually the biomass is transformed to a material rich in nutrients, which can improve the structural characteristics of the soil (Sommer, S.G *et al*., 1999) [43].

Biochar

Biochar is a fine-grained carbon rich porous product obtained from the thermo-chemical conversion called the pyrolysis at low temperatures in an oxygen free environment (Amonette, J *et al*., 2009) [46]. It is a mix of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulphur (S) and ash in different proportions (Masek, O *et al*., 2019) [47]. When amended to soil, highly porous nature of the biochar helps in improved water retention and increased soil surface area. This has made an increased interest in applying charcoal, black carbon and biochar as soil amendment to stabilize soil organic content. These techniques are viewed as a viable option to mitigate the GHG emissions while considerably reducing the volume of agricultural waste. The process of carbon sequestration essentially requires increased residence time and resistance to chemical oxidation of biomass to CO2 or reduction to methane, which leads to reduction of CO2 or methane release to the atmosphere [8, 9]. The partially burnt products are pyrogenic carbon/carbon black and becomes a long-term carbon sink with a very slow chemical transformation, ideal for soil amendment (Izaurralde, R.C *et al*., 2001; McHenry, M.P *et al*., 2009) [44, 45]. It mainly interacts with the soil matrix, soil microbes, and plant roots (Lehmann, J *et al*., 2009) [48], helps in nutrient retention and sets off a wide range of biogeochemical processes. In India currently, the biochar application is limited and mainly seen in in villages and small towns. Based on its wide applicability, it could be more valuable to promote biochar method in India.

Government intervention

Stringent measures to mitigate crop burning and further to regulate crop waste management require involvement of the appropriate Government agencies. Several attempts were made by the Government of India to introduce and educate the agricultural community about the best practices of agricultural proposals were also formulated by environmentalists and Government officials to curb crop residue burning and to promote the usage of alternative sustainable management methods. Some of the laws that are in operation pertaining to crop residue burning are: The Section 144 of the Civil Procedure Code (CPC) to ban burning of paddy; The Air Prevention and Control of Pollution Act, 1981; The Environment Protection Act, 1986; The National Tribunal Act, 1995; and The National Environment Appellate Authority Act, 1997. Particularly, in the states of Rajasthan, Uttar Pradesh, Haryana and Punjab stringent measures have been taken by the National Green Tribunal (NGT) to limit the cropresidue burning (Lohan, S.K *et al*., 2018; Pratap Singh, D *et al*., 2017) [35, 53].

National schemes and policies

The Government of India recently directed the National Thermal Power Corporation (NTPC) to mix crop residue pellets (nearly 10%) with coal for power generation. This helped the farmers with a monetary return of approximately Rs. 5500 (77 USD) per ton of crop residue. These lucrative measures are yet to be in action and it can be profitably exploited by the farmers. Few measures, associated with bio-composting are run by the Indian government. The Rashtriya Krishi Vikas Yogna (RKVY), State Plan Scheme of Additional Central Assistance launched in August 2007 is a government initiative, as a part of the 11th Five Year Plan by the Government of India (Pratap Singh, D *et al*., 2017) [35].

In addition to above, the Ministry of Agriculture of India recently developed a National Policy for Management of Crop Residue (NPMCR) (Gadde, B *et al*., 2000) [50]. The following are the main objectives of the NPMCR, (http://agricoop.nic.in/sites/default/files/NPMCR_1.pdf):

1. Promote the technologies for optimum utilization and in-situ management of crop residue, top revent loss of valuable soil nutrients, and diversify uses of crop residue in industrial applications.
2. Develop and promote appropriate crop machinery in farming practices such as modification of the grain recovery machines (harvesters with twin cutters to cut the straw). Provide discounts and incentives for purchase of mechanized sowing machinery such as the happy seeder, turbo seeder, shredder and baling machines.
3. Use satellite-based remote sensing technologies to monitor crop residue management with the National Remote Sensing Agency (NRSA) and Central Pollution Control Board (CPCB).
4. Provide financial support through multidisciplinary approach and fund mobilization in various ministries for innovative ideas and project proposals.

Conclusion

This review evaluates the knowledge of crop residue management for soil organic carbon, and crop yield. The practice of residue burning or removal doesn't found suitable for environment as well as soil fertility and productivity thus, there is a need to fine tune nutrient management for rice and wheat grown on soils, where crop residues are continuously incorporated. This residue increases the SOC and nitrogen mineralization. The residue has complex effects on physical, chemical and biological properties of soil. Government should promote and provide need based support alternative options to stop residue burning instead of strict law enforcements. The study showed that returning crop residue to the soil could be beneficial; in ameliorating soil chemical conditions.

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