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INTEGRATED CROP RESIDUES MANAGEMENT FOR A SUSTAINABLE AGRICULTURE: ONLY ANSWER TO THE STUBLE BURNING – A REVIEW

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Abstract

India, as an agriculture-based country, produces more than 500 million tons of crop residues annually. There is a common practice, existing in various states of India, of stubble burning after the grain harvest from crops such as wheat, paddy etc., despite imposed Governmental restrictions over it. This is done over years by the farmers primarily to avoid he cost of clearing of the field from crop remnants. However, this leads to huge environmental pollution relating with increasing load of particulate matters and greenhouse gases in the air, that become instrumental to cause hazards to human and animal health, global warming and climate change. It also affects the soil health adversely, inducing direct loss of macro- and micro-nutrients from soil and reducing soil microbial population and its diversity which are responsible for major route of nutrient transformation in soil. Recently, efforts are being made to develop techniques of using crop residues alternative to stubble burning, which are economically viable and are eco-friendly. The stubbles may be used efficiently to meet some alternative purposes such as animal feed, fodder, fuel like bioethanol, biochar, packaging, mushroom cultivation, composting etc. Moreover, adoption of conservation agriculture-based technologies using these crop residues may avoid the problems of stubble burning. Additionally, left-over crop residues may serve as the unique component to improve soil health and quality, and thus, to increase crop productivity, without becoming a responsible factor for environmental pollution. This approach, ultimately, must bring about sustainable agriculture and its resilience.
***Keywords*:** Crop residues, residue management, conservation agriculture, carbon sequestration, stubble burning.

Introduction

India is an agriculture-based economy. In its different agroclimatic zones, variety of crops are cultivated regularly with a production of 95.8, 106.6, 21.6, 20.7, 352.2, 10.4, 16.5, 25.3 million tons (Mt) of wheat, rice, maize, millets, sugarcane, fiber crops (jute and cotton), pulses and oilseeds (MoA, 2018). With such a large quantity of harvested products, it is quite natural that a huge volume of crop stubbles is produced. Total quantity of crop remnants produced in India has been estimated as approximately 500-550 Mt of crop residues per year and out of this, nearly 15.9% residue is burnt on farm (MoA, 2012, Kumar and Dwivedi, 2018a; Kumar *et al.* 2018b; Kumar *et al.*, 2018c; Kumar and Dwivedi, 2018d; Kumar and Purnima *et al.*, 2018e; Kumar and Pathak, 2019f; Kumar *et al.* 2019g). It has been observed that within quantity of total burnt residue on the field, rice straw contributes maximum (40%) followed by wheat straw (22%) and sugarcane trash (20%). During 2017, gases emitted from burning were found to be CO (8.57 Mt), CO_2 (141.15 Mt), SO_x (0.037 Mt), NO_x (0.23 Mt), NH_3 (0.12 Mt) (MNRE, 2018), and particulate matters (PM) of different sizes in the air. The WHO standard for permissible levels of $PM_{2.5}$ in the air is 10 µg/m^3, and according to the India's National Ambient Air Quality Standard, the permissible level for $PM_{2.5}$ is set at 40 µg/m^3 (Siddique and Kumar, 2018h; Siddique *et al.*, 2018i; Pathak *et al.*, 2017j; Prakash and Kumar, 2017k; Kumar and Mandal, 2014L; Kumar *et al.*, 2014m; Kumar *et al.*, 2014n; Kumar, 2013o; Kumar and Dwivedi, 2015p). But at present air pollution has reached to such an extent that most of the metropolitan cities in India show the PM2.5 several folds more than the Indian standards. As for example, Delhi recorded a mean value of 98 µg/m^3, which is at least twice more than the Indian standard and ten times higher than the WHO standard (Zehra, 2017). The annual contribution of $PM_{2.5}$ due to burning of paddy residue in the Patiala district of Punjab was estimated to be around 60 to 390 mg/m^3. Stubble burning becomes instrumental for air pollution due to release of particulate matters along with other noxious gases in the air and thus it is considered as a major environmental concern from the point of its contribution to global warming as well as human health hazards. Composting, biochar production and mechanized farming are used as cost-effective sustainable techniques to retain the nutrients as well as to enhance carbon sequestration in the soil, that diminishes the gravity of the stubble burning issue (Bhuvaneshwari *et al.*, 2019). Numerous measures to curb the residue burning issue have been taken through direct Governmental interventions. One of such measures is the promotion of sustainable soil and crop management method by converting crop residue into energy. However, increasing air pollution level in Delhi and surrounding areas due to the stubble burning from Punjab and Haryana in recent years raises the question over the successful implementation of these measures (Gogia *et al.*, 2014q; Kumar, 2014r; Kumar *et al.*, 2012s; Mishra *et al.*, 2012t; Kumar *et al.*, 2011u; Kumar *et al.*, 2011v; Kumar and Pathak, 2016w; Pathak *et al.*, 2016x).

On-farm stubble burning comes from the idea of easy clearance of the field without any further financial investment and to prepare the field for the succeeding crop quickly. Moreover, it controls pest also (Dobermann and Fairhurst, 2002). In north-west India for rice-wheat cropping system, the period left in between the rice harvesting and wheat sowing is very short (15-29 days). Due to shortage of time and scarcity of manpower, the farmers use combines which leave a layer of chopped portions of rice straw residues on the soil surface. This further worsens the situation and makes it difficult to harvest the chopped harvested residues. Thus, to avoid cost for harvesting straw as well as their transportation cost, farmers adopt the practice of rice straw burning *in situ.* Farmers face a big challenge to incur the cost involved in the process of removing and space involved to store the residues for future use. Moreover, swathes of rice straw residues left on the soil surface by the combine harvester cause the seed drilling operation difficult during planting of succeeding crop, wheat. To get rid of this problem, farmers usually burn these residues which account for nearly 90-140 Mt annually (Bisen and Rahangdale, 2017) at the cost of various unwanted output such as air pollution, nutrient deficiency in soil, reduced crop productivity, human and animal health hazards, etc. Stubble burning causes emission of noxious gases such as CO, CO_2, CH_4, NO_x, SO_2, etc. leading to depletion of the stratospheric ozone layer and release of particulate matters and various hydrocarbons in the air leading to human health hazards, loss of plant available nutrients causing a decline in soil fertility and crop productivity (Pandey, 2019). This practice of burning ultimately creates scarcity of fodder and thus, makes a hike in fodder price. Therefore, it becomes a challenge to handle the crop residues in an effective and profitable manner. Apart from using the residues for the purpose of animal feed, fodder, bioethanol, biochar, packaging, mushroom cultivation, composting etc. (Maher, 1991; Sidhu and Beri, 2005; Bisen and Rahangdale, 2017), conservation agriculture may serve as the best option to manage the residues in such a manner that this eco-friendly process will come out to be an alternative to burning and will promote sustainable agriculture and its resilience because this approach enhances the carbon retention in soil.

Crop Residue Burning and Environment

The soots released, and the smoke generated during the stubble burning impairs the surrounding atmosphere causing human and animal health problems. The greenhouse gas emission of carbon dioxide, methane and nitrous oxide is accelerated by crop residue burning, which plays a significant and pivotal role in accelerating global warming (Kumar *et al*., 2018y; Kumar *et al*., 2018z; Kumar *et al*., 2018aa; Kumar *et al*., 2018bb; Kumar *et al*., 2018cc). Apart from this, essential nutrients are lost from the surface soil. Nearly 80 % of N, 25% of P, 21% of K, and 60% of S may be lost from soil due to burning (Raison, 1979; Ponnamperuma, 1984; Lefroy *et al*., 1994). The stubble burning leads to wastage of valuable resources which could be used as a source of carbon, bio-active compounds, feed and energy for rural households and small industries. Heat generated from the burning of crop residues elevates soil temperature and consequently active beneficial microbial population with their diversity is reduced significantly, impacting adversely on the nutrient transformation in the soil. As a result, the succeeding crops suffer from nutrient deficiencies. Although the effect is temporary and the microbial population is recovered within a certain period, but repeated burnings may exhibit permanent effect on the population of soil microorganisms making the soil unfertile due to reduction in organic matter content accompanied with significant reduction in nutrient mineralization in the soil. Burning of crop residues results in the emission of a significant amount of Green House Gasses (GHGs), releasing about 70%, 7% and 0.7% of C present in rice straw in the form of CO_2, CO and CH_4, respectively and 2% of N as N_2O (Pandey, 2019). Thus, the process of burning plays directly a significant role in global warming and in turn, climate change. Burning of one tons paddy straw reportedly releases 5 kg Nitrogen (N), 2.3 kg Phosphorus (P), 25 kg Potassium (K), 1.2 kg Sulphur (S) into the atmosphere (NPMCR, 2014; Kumar *et al*., 2019) and avoidance of straw burning adds the commensurate value of nutrients to the soil.

Crop Residues Management: Agricultural Practices

Recycling of plant nutrients

It has been estimated that if rice straw can be incorporated in the soil instead of its burning, nutrients are recycled in terms of INR 410.87/ton of rice straw (Sharma *et al*., 2019). Nutrient recycling by diverting the straw back to the soil reduces dependence on chemical fertilizers in long-term. Recycling of crop residue was found to save approximately 29% of total fertilizer cost in a rice-wheat cropping system (Naresh *et al*., 2017; Sharma *et al*., 2019) and 15-20% direct fertilizer savings may be possible in the succeeding crop after using the rice straw as a mulch or incorporating into the soil (Kumar *et al.,* 2015). It has been evidenced that stubble burning leads to maximum loss of C (100%) accounting nearly 0.97 tons C/acre and N (90%) from soil accompanied with relatively low degree of loss of P (25%), K (20%) and S (60%) (Kumar *et al.,* 2019). If soil organic carbon (SOC) content is increased, microbial growth is generally enhanced as organic carbon supplies energy and nutrients to them. The same has been reciprocated when crop residue is mixed with soil instead of its burning, soil is enriched with organic carbon and nitrogen along with other nutrients and an increase in nearly 5–10 times more of aerobic bacteria and 1.5–11 times more of fungi was observed. A long-term (10 years) crop residue incorporation in soil with minimum to zero-till resulted in 17-25% higher SOC (Lohan *et al*., 2017). Recently during 2018, through intervention of Confederation of Indian Industry (CII) in Punjab, >27 thousand tons of rice straw were saved from burning and approximately 25 thousand tons of rice straw were incorporated into the soil to maintain a sustainable agriculture (Sharma *et al*., 2019).

Decomposition and mulching

Crop residue mulching (CRM) refers to a technology that involves in covering of 30% of the soil surface by crop remnants from the preceding crop at the time of crop emergence. Through the smothering and allelopathy effects, mulching usually prevents the weed growth (Erenstein, 2002). However, the crop residues may also be used for mushroom cultivation, thatching, mat-making and toy making and most importantly for making compost through their decomposition. The decomposition of crop residues through microbial interventions releases the nutrients which ultimately enter the biogeochemical cycle. Crop residues are usually used as animal bedding to absorb urine and subsequently are heaped in pits along with cow dung. One kilogram of straw absorbs nearly 2-3 kg of urine. Thus, the farmyard manure which is produced from such mixture is enriched with N. By the action of consortium of microorganisms, three tons of FYM may be produced from the rice stubbles released from one-hectare land within a period of 75-90 day (Pathak *et al*., 2012). Thus, waste biomasses are utilized in a more efficient, profitable and eco-friendly way, without impacting adversely on the environment by burning them. On the contrary, they improve soil physical, chemical and biological properties by acting as buffering agent and protecting the soil from alteration of soil pH and temperature, source of nutrients for plant and microorganisms, increasing water and nutrient absorbing capacity of soil, reclaiming the problematic soils etc., and ultimately improve crop yield (Bahadur *et al*., 2015).

Conservational tillage and zero tillage

Conservational tillage refers to low tillage with limited inversion of soil, which promotes covering of at least 30 % of the soil surface by left-over plant residues. This practice, involving in minimum tillage operation accompanied with covering soil surface by crop residues, conserves soil moisture by restricting soil evaporation, controls soil erosion by protecting the soil particles from the impact of air and water and suppresses weeds. It has been observed that crop yields were higher in zero tillage with residue management than that in conventional tillage. In conventional tillage nearly 55% of the seasonal precipitation was reported to be lost by soil evaporation. On the other hand, zero tillage with residue management exhibited negligible evaporation loss (Sommer *et al*., 2012).

Crop Residues Management: Source of Alternative Energy

There has been a trend observed in recent years to utilize biomass along with solar or wind energy as an alternative renewable energy source and as substitute to the fossil fuels. The added advantage of using biomass for energy generation includes its storability, cost-effectiveness, end eco-friendly nature (Pathak *et al.*, 2012). Alternative arrangements of various energy resources and reserve are also discussed recently in India (Kumar *et al.*, 2019). However, crop stubbles are of low bulk-density and low energy yielding product (per unit weight basis) and thus, their transportation cost becomes a major constraint in using them to generate energy.

Bioethanol

The bioconversion of agricultural residues and lignocellulosic wastes into ethanol is also considered as a safe and efficient method of disposing the organic farm residues. This exerts a major impact in increasing living standards and influencing socio-economic development by creating new avenues for earning additional income (Riungu *et al*., 2014). This also provides an opportunity to produce a safer, cleaner, more eco-friendly bioethanol which can be blended with gasoline or used as a neat fuel and may be projected for both domestic use and exporting. Various crop stubbles may produce bioethanol in the range of 382 to 471 l/t of dry matter (Pathak *et al.*, 2012). However, the high cost of hydrolytic enzyme, cellulase and unavailability of the commercially efficient fermenting microorganisms hinder it to be marketable in India. More studies are needed in this respect.

Biochar and biooil

Biochar produced from pyrolysis of crop residues helps in carbon sequestration and in mitigating greenhouse gas emission and thus, shows a direct hold on climate change. Biochar possesses a high absorbing capacity. Thus, its addition to soil facilitate to increase nutrient and water holding capacity of soil, ultimately leading to increase in plant productivity and crop yield. This is also used to remediate heavy metal or pesticide contaminated soils (Singh *et al*., 2015). During pyrolysis thermal disintegration of crop stubbles produces vapours which on condensation gives rise to bio-oil possessing calorific value of 16-20 MJ/kg (Pathak *et al*., 2012). Although production of bioethanol or biochar shows a promising method to use the crop stubbles efficiently, use of the crop residues to stabilize and increase the levels of SOC (Searle and Bitnere, 2017) should be equally considered, which provides the scope of not spending energy for residue removal from the field.

Gasification

One more convenient method to utilize the crop residues is the gasification that involve in the partial combustion of crop residues. In this method, ‘producer gas’ is generated through thermo-chemical processes. However, ‘producer gas’ should be purified to remove its impurities before power generation. One ton of biomass can produce 300 kWh of electricity (Pathak *et al*., 2012).

Biogas

Biogas technology provides renewable energy for electricity generation, cooking and lighting purpose, minimizing the crop residue burning with a decline in environmental pollution. It may also prove an alternative for e-rickshaws to achieve the target of green city (Kumar at al., 2018). Biogas production is one of the important action plans on climate change in India (MNRE, 2011; 2015). Commercially about 5000 m^3 of biogas per day was reported to be generated from biogas power plants with a power generation capacity of 5.5 MW (CSO, 2014). In India most of the biogas-based power plants are found in the states of Maharashtra, Kerala and Karnataka (CPCB, 2013). Recently new biogas technologies are developed to use paddy straw and other crop residue other than dung and vegetable waste (Verma, 2014; Sood, 2015; Urja, 2016). This adds up a new feather and a dimension to the development of alternative renewable green energy through bio-methanation technology using crop stubbles instead of its burning. This technology is capable to generate significant quantity of biogas from tons of agricultural residues and to generate job opportunities for the farming communities.

Conclusion

It is assumed that India will become the most populous country by 2050 in the world. It will be a major challenge to ensure food security for all as well as to keep the environment safe and pollution-free. But if the practice of stubble burning is continued as it is practiced today, it will further worsen the situation, exerting adverse effect on the soil fertility and thus, crop productivity will not meet the requirement of the burgeoning population. Moreover, quality of environment will be depleting to a greater extent affecting human and animal health. Therefore, sustainable agriculture should gain pivotal importance in delivering a better ecosystem while offering a better livelihood to the increasing population. Farming with good soil and crop management practices provides a proper direction to meet the future challenges of food, water and energy requirement, to mitigate degradation of natural resources and to prevent the climate change. Crop residue is considered as important input components to obtain sustainable agriculture because crop residue improves the physico-chemical and biological properties of soil, enhances soil fertility and hence, increases the crop productivity. It has potential to partially, although not completely, substitute the chemical fertilizers and thus, minimizes their adverse effects on the environment. Thus, crop residues, apart from their uses as industrial raw materials, fodder, biofuel, play a significant role in conservation agriculture to deliver a sustainable and resilient agriculture to ensure the country's food security. At this moment, Indian agriculture is urgently in need of promoting conservation agriculture technologies and ensuring their availability among the farmers. Capacity building and awareness about ill effects of crop residue burning and its effective utilization and management is the present day need of Indian agriculture and this could be availed by organizing training among the farmers with efforts to make them convinced to think that stubbles are not mere waste products but service providers for productive agro-ecosystems.

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