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Deterioration of Soil Health Due to Stubble Burning: Solution to its Root Cause

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Abstract
Stubble burning has a great impact on environment, health of soil. The most often burned material is sugarcane leaves, followed by wheat and paddy. One centimeter of soil is heated by burning paddy straw, raising the soil's temperature to 33.8 to 42.2°C. According to reports, the fire steadily reduced soil biological activity and organic matter by eradicating the bacterial and fungal populations necessary for a fruitful soil. Carbon in the ash cannot exist as a food source for the micro-organisms and acts only as a support for them. Thus, the activity of micro-organisms and their population declines which results in disruption of various biological processes in the soil.

Keywords: Deterioration; Soil; Organic matter; Fertility; Stubble

Introduction
In Punjab, more than 500 million tonnes of parali (crop leftovers) is produced annually, 70% of which is originated from cereal crops (rice, wheat, maize, and millets), with rice accounting for 34% and wheat for 22% of this total. The majority of this parali is burnt on farms. An estimated 20 million tonnes of rice stubble are produced annually in Punjab alone, with 80% of that being burnt. A significant quantity of rice crop residue is burnt on farms in places like Punjab and Haryana when it is not used as animal feed. Basic problem with paddy residue is that unlike other crops, which are used as fodder or fuel, it is neither used as fuel nor as a fodder due to high content of moisture and silica. Crop residue burning causes nutritional loss of carbon, phosphate and nitrogen by volatilization. Crop wastes can be recycled in agriculture in a variety of ways, including direct inclusion, mulching, composting, vermicomposting and more. Additionally, it is utilized in the production of biogas, bio-oil, bedding material for cattle, bio-thermal power plants, mushroom farms and biogas. It is also used as dry animal feed. With the increasing demand of food to feed the ever growing population along with increasing the cost of inorganic fertilizer is decreasing the soil fertility. It is necessary to use of renewable and non- renewable sources of input energy (Krishnaprabu, 2019). 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, soil health and crop productivity. On the other hand, it is also 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.

Adverse Impact of crop residue burning on the soil fertility
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%). According to Gadi (2000), one tonne of rice straw burnt released 3kg of particulate matter, 60 kg of carbon monoxide, 1460 kg of carbon dioxide, 199 kg of ash, and 2 kg of sulphur dioxide. Likewise, studies have also shown that the amount of organic matter and nutrient content remain in one tonne 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).

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 these stubbles and fodder are consumed in the fire.

Over the past ten years, scientists and agriculturalists have recommended alternative strategies to prevent crop residue burning. But due to farmers' lack of understanding and social conscience, these measures have not been properly adopted. In this section, information on three such agricultural applications that have either been overlooked or skipped due to various reasons is presented. They are composting, in-situ management of residue and biomass power plants.

Composting

Composting is the natural process of rotting or decomposition of organic matter by micro-organisms under controlled conditions. 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. These techniques also help in higher nutrient uptake, and active nutrient cycling due to enhanced microbial activity in the soil. It occurs in two phases.

Degradation

The first phase of degradation starts with breakdown of easily degradable organics like sugars, amino and organic acids. The aerobic micro-organisms consume oxygen and release carbon dioxide and energy. The first thermophilic phase is dominated by high temperature, high pH and humidity and is essential for activating the micro-organisms and proceeds for several weeks to months. During this phase, it is also ensured that the substrate is properly cooled with sufficient supply of oxygen.

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. 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. Eventually, the biomass is transformed to a material rich in nutrients, which can improve the structural characteristics of the soil.

In-situ management

The National Thermal Power Corporation (NTPC) has lately been instructed by the Indian government to combine crop residue pellets (almost 10%) with coal for the purpose of producing electricity. With a financial return of about Rs. 5500 (77 USD) per tonne of crop leftovers benefited the farmers. Although, these profitable techniques have not yet been implemented. The Indian government only runs a few bio-composting-related programmes. A government effort, the Rashtriya Krishi Vikas Yogna (RKVY), State Plan Scheme of Additional Central Assistance was introduced in August 2007 as part of the Government of India's 11th Five Year Plan. In addition to above, the Ministry of Agriculture of India had developed a National Policy for Management of Crop Residue (NPMCR) (Gadi et al., 2000).

The following are the main objectives of the NPMCR

1. Encourage the development of technology that will maximize crop residue utilization and in-situ management, preventing the loss of important soil nutrients, and broaden the range of industrial applications for crop residue.

2. Create and promote suitable crop machinery for use in agricultural techniques, such as modifying grain recovery equipment (harvesters with twin cutters to cut the straw). It offers discounts and incentives for the purchase of mechanized sowing equipment like the happy seeder, turbo seeder, shredder, and baling machines.
3. Work with the National Remote Sensing Agency (NRSA) and Central Pollution Control Board to monitor crop residue management using satellite-based remote sensing technologies (CPCB).
4. Raise funds for creative ideas and project proposals using a multidisciplinary approach and fund-raising in multiple ministries.

In our study, we tried to find how stubble burning makes our soil health poor. We categorized field into three areas: A1, where stubble burning was common practice; A2, where stubble was moderately burnt and A3, with no stubble burning from last five years. We collected samples of soil and tested pH and organic matter percentage. We compared organic matter of different fields and from that data, it was clear that where stubble was burnt; organic content, microbial activity and pH was low resulting in continuous conversion of soil into infertile land.

Fig. 1. GPS locations of areas with stubble burning

Methodology

The methodology used to collect data was survey method. A survey is data collection tool that lists a set of structured questions to which respondents provide answers on their knowledge and experiences. A questionnaire was prepared for farmers so that their information can be kept safe. It was prepared under the able guidance of my guide teacher. We selected areas to visit, took samples of soil and conversed with 50 farmers through questionnaire. After data analysis results were obtained.

Hypothesis

Retaining stubble may have several advantages for soil productivity and fertility. Retaining stubble can increase labile carbon, which increases the biological fertility of soil. Retaining stubble can maintain microbial activity of soil which enhances biological fertility of soil.

Procedure

***First Phase**:* We visited different areas and nearby fields in different villages. We met farmers and asked them questions. We started writing their opinions, so that we can find results in general. We also wanted to know whether they were aware of latest technologies related stubble burning. Why people prefer to burn the stubble instead of mixing in the soil? We went to

different fields. Some farmers cooperated with us by helping us in solving the problem of stubble burning.

***Second Phase*:** We collected samples of soil from different fields which were burnt by farmers and also collected samples of soil from the fields in which stubble was not burnt from last five years. Then we tested the pH values and fertility of soil .We tried to compare the samples of soil, so that their pH and organic matter percentage could be known.

Third Phase: With the onset of winter, farm fires become rampant in northern Indian states particularly in Punjab and Haryana .Wheat and Paddy are the most prevalent crops in the agricultural states such as Punjab and Haryana. The short period of time between harvesting rice and planting wheat is one of the causes of the stubble burning. The 2009 Punjab Preservation of Sub Soil Act requires that paddy transplantation be scheduled for June 20. This moves up rice crop harvesting from May to June so that a sizable percentage of water is obtained from monsoon rains. Farmers now have just 20–25 days between two crops. Because a delay in seeding wheat would negatively impact the crop, burning crop leftover is one of the fastest and simplest alternatives for farmers. Financial help is not properly provided to each and every farmer and awareness campaigns to demonstrate better residue management practices are not done.

***Fourth Phase*:** We conducted interviews with the farmers. We listened to their problems, the reason to burn stubble and their knowledge of latest technologies .We made them aware about the decreasing pH level of soil and we offered them some sort of solutions of using different machines like happy seeder and Baler. Happy seeder helps in mixing the stubble with the soil. It helps to get rid of problems in a very low cost. Baler is the latest machine which rolls the stubble and uses it for other purposes like production of electricity. But it is very costly. Many farmers can collectively arrange for it and they can even earn money from it.

***Fifth Phase*:** Root cause of the problem was that farmer has lack of time and money for management of stubble. So, we started some sort of innovations to convert paddy straw into compost with homemade material at minimal cost. We were happy to convince farmers with our blue print to grow mushrooms over compost prepared from paddy straw. In this way, farmers can get four crops per year and even marginal famer can earn huge profits.

Tools for Study

To test pH of soil, we used pH solution. The most common method used to estimate the amount of organic matter present in a soil sample is by measuring the weight lost by an oven-dried (105°C) soil sample when it is heated to 400°C; this is known as 'loss on ignition', essentially the organic matter is burnt off.

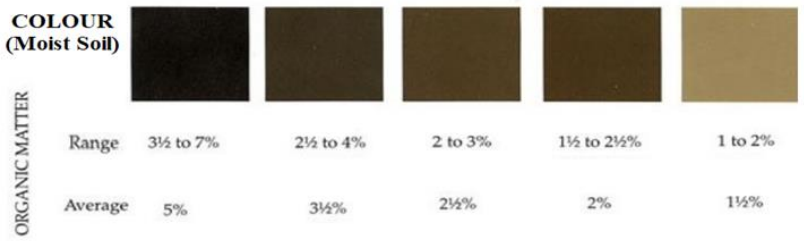

Fig. 2. Change in colour of soil with loss of organic matter

We tracked the activities of various organisms in the soil over time as it relates to breaking down old crop residue using litterbags packed with wheat straw. Micro-organisms and tiny arthropods can decompose the rubbish, thanks to the mesh. The litterbag is retrieved, cleaned, and

measured to determine how much litter vanished due to decomposition after a growth season. Using litterbags makes it simple to keep an eye on a population of soil decomposers.

Data analysis

Table 1. pH, organic matter and microbial activity of soils from different fields

Field	pH	Organic matter (% age)	Microbial activity
Field1	6.5 (stubble burnt)	2.3%	80 DAYS
Field 2	7 (stubble burnt)	3.3%	60 DAYS
Field 3	7.5 (not burnt)	5.2%	45 DAYS

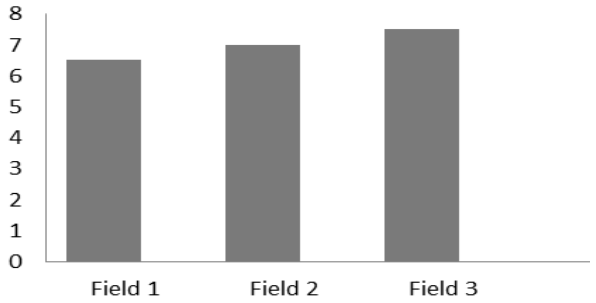

Fig. 3. pH of soil in different categories of fields

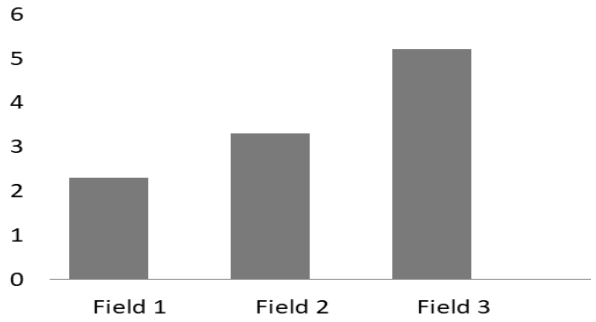

Fig. 4. Organic Matter of soil in different categories of fields (%)

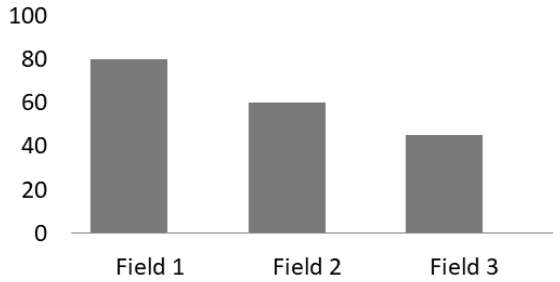

Fig. 5. Microbial activity of soil in different categories of fields

Results and Discussion

Results show that in the field where stubble was burnt every year, fertility of soil was poor. Soil pH plays an important role in availability of nutrients essential for plant growth. In general, optimum availability occurs between a soil pH of 7.2 and 7.5. Low pH results in lower rates of N mineralization, a process dependent on active, viable microbial populations in the soil. It is evident from Fig 3, field in which stubble was burnt; pH of soil was low which made soil acidic. The loss of useful microbes due to heat of stubble burning resulted into slow rate of decomposition of organic matter due to minimize microbial activity (Fig 5). Low content of organic matter is affecting the fertility of soil.

Conclusion

This paper evaluates the knowledge of crop residue management for soil organic carbon, and crop yield. In previous studies, the practice of residue burning or removal were not found suitable for environment. Results of the present study showed that in the fields, where stubble was burnt every year, fertility of soil was poor. Moreover, this study has focused on root cause which is the farmer mentality and his financial status. Instead of enforcing the legislation strictly, the government should encourage and offer need-based support for alternative solutions to end residue burning. A comprehensive program must be outlined by state or Central Government for stubble management. The study showed that returning crop residue to the soil could be beneficial in ameliorating soil and its chemical conditions.

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Author Contributions

SS conceived the concept, wrote and approved the manuscript.

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Competing interest

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Ethics approval

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