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COMBATING DETRIMENTAL EFFECTS OF RICE STUBBLE BY MICROBES: A REVIEW

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Abstract: Rice is the most important food in the world for humans, feeding people more than any othercrop. Rice is consumed everyday by half of the world's population i.e., 3.5 billion people. It is also known as the staple food across Asia wherearound more than half of the world's poorest people live either as worker or consumer. Wide variety of rice like *Oryza sativa, Japonica and Indica* are also considered significantly important for human nutrition. Rice stubble is the uncut part of the crop after harvest that can be burned and show harmful effects like loss of nutrients from soil, air pollution from smoke, affects soil fertility. Rice stubble burning is causing havoc worldwide by enhancing environmental pollution and degrading soil fertility. To avoid stubble's harmful effects in the environment some recent techniques have been introduced for combating stubble burning like conversion of residue in composting, bioethanol production, gasification, biogas formation etc. some efforts are made to develop techniques of using field residues alternative to rice stubble burning, which are eco-friendly and economically viable. Microorganisms are found to enhance stubble degradation by enhancing decomposition of stubble specifically cellulose, lignin, hemicellulose and lignocellulose degradation. Here in the present review, we shall discuss about the microorganisms which play role in stubble degradation and enhancing soil fertility.

Keywords: Decomposition, Microorganisms, Pollution, Rice, Stubble

STUBBLE BURNING AND HAZARDOUS IMPACTS

After wheat, Rice is considered a dominant grain for world population. Rice has a wide range of adaptation as it can grow in 3.5m below sea level in India. The geographical distribution of rice in the worldwide shows that itcultivated from Manchuria in China and 55˚ North in central Czechoslovakia, on the equator, to 40˚ South in Uruguay and New south Wales in Australia (Mendoza., 2016). Rice is mostly cultivated in those regions that having more than 3000mm rainfall, but it can also becultivated in desert regions having less than 45mm rainfall during its growing season. In India (Sindh Provinces of Pakistan and Punjab) rice growsat more than 33˚C temperature, while the normal seasonal temperature in other countries is not much higher than 20˚C (Baldwin., 2010). For ideal yield and growth, rice requires enoughdistribution of water level during the growing period season and dry during grain filling period season, temperatureshould be enough high during the growing season but at night lower temperatureduring the grain filling period, throughout the growing season solar radiation is

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also needed. Based on several criteria like soil, drainage, water and topography, topography is the study of features and shape of the land surface. The topography of land area refers to its surface features and shape (Mittal *et al*., 2009).This is also known as 'geomorphometry'. Globally, rice harvested area has increased marginally from 121.5 million ha in 1961 to 200.8 million ha in 2016. The rice cultivation environments are classified into different categories like upland, flood prone, rain fed, and irrigated. But every 2 to3 year the average rice yield has doubled from 1.78 to 5.69 Mg ha^{-1} due to the adoption of 'Green Revolution' technologies like application of chemical fertilizers and the use of high yielding rice cultivars. The average rice grows under irrigated conditions, particularly in the region with moderate sun. The agronomic yields show highest degree of instability and depend upon weather changes. *Oryza sativ*a L., is the most grown rice species (Kaur., 2016). Rice has become staple food of an estimated around 3.9 billion people all over the world. About 595 million people suffer from chronic undernourishment diseases globally, and the majority belongs to the developing countries or areas where rice is closely related with the political stability and food security. Rice consumption and production are the highest in Asian population. Rice supplies up to 55% of dietary caloric supply and a considerable part of the protein. In sub-Saharan Africa, the consumption of rice has steadily grown. Some other countries like Latin America regions and Caribbean also show steady rise in rice intake(Dai *et al*., 2010).As we know, rice production takes place all over the world and it is also act as primary source of income. Rice is a special importance for the nutrition. About more than 200 million people are employed in rice production across countries in the developing world andit contains 25-30% of daily calories. Asia is the largest continent for the consumption and production of rice. Rice has become an important dietary staple food.It is a significant part of diet for half of the worldwide population. Rice is composed of 25% of dietary protein and 30% of global diet(Obi., 2016).In world population, total consumption of rice is approximately 500million tonsper year. Worldwide production of rice has been drastically increased due to continuous increase in population growth.India isworld's seventh largest country with a population of 1.32 billion. India shows largest production ofpulses, milk and jute and the second largest production of sugarcane, groundnut, rice, wheat, fruits, vegetables and cotton(Chaudhry and Grover., 2019). Agriculture is the largest source of livelihood in India. Most of the rural families are dependent on the farming. 70% of rural households depend on agriculture for livelihood. India is a bigconsumer (27% of world consumption), producer (25% of global production) and importer of rice (14% of importer) in the world (Van Hung *et al*., 2019).In recent years, many studies have been carried out with the motive to find the effect of rice stubble burning on the air quality. 50-55% of crop residue is burned all over the world, which shows very bad impact on the environment,thus decreasing the air quality. The burning residue shows major environment concern and cause loss of organic compound and plant nutrients (Sood.,2015). Firstof all, we must know what is crop residue or stubble:After harvesting of rice crop the uncut portion of the rice straw that remain attached in the ground is known as crop residue or stubble.It is also known as "parali"(Van Hung *et al*.,2019). Rice residue is formed during the October-November month. Because this is the peak time for rice crop harvesting. We must focus on why farmers burn stubble:In India, farmers leave out 1-2ft tall stubble after harvesting the crop which take more than one and half months to decompose while farmers do not have sufficient time to sow their next cropi.e., wheat. So, farmers found another technique to reduce stubble i.e., stubble burning. Stubble burning is anefficient and cheap way to prepare the soil for wheat, the next crop after rice(Nagendran.,2011).As there is continuous increase in the growth rate of rice in the world, the growth of rice residue or rice stubble also increased. The average annual increase in growth rate of rice residue was around 10-15%. Mechanised harvesting leaves large and massive crop residue or stubble or paraliwhile manual harvesting cut crops close to the ground and leaves fewer residues. Another problem with crop residue is that it needs to be burnt. Unlike, other paddy residues (exceptbasmati variety) are harder to chew, havinghigh silica content and low calorific value make paddy residue unsuitable foranimal fodder use. Stubble burning has several ill effects (Mendoza., 2017). Rice straw is most important renewable biomass by-product such as rice and wheat crop production and exhibits potentiality to converted to "green energy". Mechanism of harvesting crop through harvester has been created a problem of waste management (Albert *et al*., 2017). Presently these waste are disposed off by burning in open air, which creates major environmental problem and disrupt rich soil biodiversity through heating. Straw is composed of lignin, hemicellulose and cellulose. Chemical constitution analysis show that lignin form matrix like structure surrounding cellulose in woody cell walls, which protect the cellulose and hemicellulose from microbial depolymerization (Chen *et al*., 2019). Various methods to breakdown lignin structure in the rice stubble, such as the biological degradation, chemical degradation and thermal degradation. In biological degradation uses of microorganism take place for breakdown lignin structure, in chemical degradation chemicals are used for breakdown of lignin and in thermal degradation or thermal treatment we use heat (Copete *et al*., 2019).

Stubble components and impacts

Stubble burning release black air carbon particulates, like carbon dioxide, sulphur dioxide, nitrogen oxide, carbon monoxide causing high level of atmospheric quality deterioration, human health hazards and nutrient loss from soil (Zhang *et al*.,2009).The dangerous pollutants releasing from stubble burning become a world environmental issue. Emission from crop residue burning (ECRB) is observed after harvesting of rice crop. Crop residue is burned at rice field to reduce handling of it since 1970s. A major problem with crop residue burning (CRB) is ECRB and other pollutants in the atmosphere which shows major effects on air quality and public health(Borah *et al*., 2016). Polycyclic aromatic hydrocarbons (PAHs) are aromatic compounds containing two to eight aromatic rings that are found during incomplete combustion of crop residue. PAHs exhibit a wide range ofchemical-physical properties (Singh *et al*.,2016).Human also play major role in producing PAHs activities:Exhaust from vehicles, residential heating, industrial processes, electric power production, tyresand plastic factories waste product(Mittal.,2009). Open burning of crop is common technique for agriculture residue disposal. Pollutants emitted are CO, hydrocarbons, SO_2, and small amount of NOx(Anasontzis *et al*., 2017). In northern region of India, especially in Haryana, Uttar Pradesh and Punjab large amount of crop residue is produced after harvesting of crop which is removed by burning in open fields (Dubey *et al*., 2016). After burning of crops, high amount of smoke is produced that is seen clearly in the form of thick clouds in the residential area and over the fields (Zhang *et al*., 2011). Chemical agents are also released after stubble burning that affects the human health mainly respiratory system. We all know, respiratory system is major route from where chemical and toxic agents enter the body and cause serious disorders and severe cases that may lead to mortality(Shan *et al*., 2008). Basically, lungs are the first target, because they come in direct contact with air. Air contains more dangerous particles after stubble burning(Pradhan.,2020).The burning of crop residue has severe impacts especially for those suffering from cardiovascular diseases, respiratory diseases. Small children and pregnant women have more chances to suffer from the smoke produced during stubble burning. In recent years, the NCR (National Capital Region) and Delhi have experienced poor quality air in starting winter days or in the month of October-November (Yadav *et al*., 2014).Stubble burning also burn the nutrients present in the soil and cause air pollution. 80-90% of nitrogen, 20% of phosphorus, 25% of potassium and50% of sulphur is present in soil is vanished after crop residue burning (Pradhan.,2020).Burning of rice stubble create number of problems in the environment. The main impact of rice stubble burning on environment include the emission of greenhouse gases (GHGs) that play a major role in creating global warming, increased particulate matter levels (PM), biodiversity of agriculture land is lost, smog that cause health hazards.Another major issue is soil fertility which has been severely affected due to stubble burning (Lohan *et al*.,2018). Rice stubble burning significantly increases the air pollutants quantity in environment such as CO_2, NH_2, NOx, CO, Sox, non-methane hydrocarbons (NMHC),semi-volatile organic compounds (SVOCs), volatile organic compounds (VOCs) (Zhang *et al*., 2011). Rice stubble burning emitted particulate matter in Delhi is 19 timeshigher than from all other sources like garbage burning, industries or vehicle emission. Currently, the government of different countries pays attention to resolving the problem of stubble burning for control of atmospheric pollution. In some countries straw burning is strictly banned.

Rice is a semi aquatic annual plant that having approximately 25-28 species of genus *Oryza*, some genera are wild. Two type of species are important for human consumption: *Oryza glaberrima* and *Oryza sativa. Oryza sativa* first grow insomewhere in India, Myanmar, southeast Asia, China, North Vietnam and Thailand. *Oryza glaberrima* has been trained from wild ancestor *Oryza barthii* by person living in floodplains areas of the Niger River in Africa (Obi., 2016). Today, rice is grown in every continent except Antarctica. In comparison to other species of rice *Oryza sativa* is more widely grown all over the world, including in North and South America and Asia, the middle East, the European Union and Africa. Thousands of Oryza sativa cultivars are grown in more than 152 countries. Rice cultivation can be classified into three cultivatedvarieties, the short/medium grained japonica rice is cultivated in temperate region such as Northern China and Japan, the medium grained japonica rice grown inthe mountainous areas of Madagascar, Philippines and Indonesia, the long grained indica variety grown insubtropical and tropical Asia(IRRI., 2013).Rice is cultivated in a different types of water regimes and soil types, like alkaline, acid sulphur and saline soil (OCED and IRRI., 2013). Rain fed lowland rice is grown in bunded field which are flooded with the rainwater. Irrigated lowland systems where rice is grown in the bunded field can produce three crops per year & nearly three quarters of the worldwide rice production. In recent years, many studies have been carried out with the motive to find the effect of crop residue burning on the air quality. 50-55% of crop residue is burned all over the world, which shows very bad impact on the environment, thus decreasing the air quality.The burning residue shows major environmental concern and cause loss oforganic compound and plant nutrients (Sood.,2015).

Microbiome for Stubble Degradation

Cropping without any nutrient management may decreases nutrient availability in soil for rice. Incorporation of fallow season residues bring no significant yield advantage as compared to burning of rice crop (Singh *et al*., 2016). Rice crop is a staple food in some states for people. Generally, rice grows in subtropical environments with humid and hot climate which helps in the fungal growth and start production of secondary metabolites. Rice cropping system is a common practice in which, harvesting of rice crop takes place by farmers. After harvesting, the crop rice stubble is left in the field and treated the stubble with the microbial degradation technique (Sindhu and Beri., 2008). Degradation of rice crop depends on the microorganism that can colonize and degrade various constituents like cellulose, lignin, hemicellulose and holocellulose. Decomposition is a very complicated process where number of sub-processes and multitude of organismsinvolve and fungi also play important role in the stubble degradation(Wannapeera *et al*., 2008). The problem of degrading cellulose-rich compoundsmay be overcome via consolidated bioprocessing (CBP), where cellulose decomposing microbes could convert the biomass into desired product in a single process (Liou *et al*., 2015). Use of cellulose decomposing microbes through sequential or combined application during co-composting help in degradation of cellulose, but these methodswere not suitable (Wannapeera *et al*., 2008). Some species of lactobacillus were reported for their ability to degrade cellulose or rice straw. Some isolation of nitrogen fixing bacteria from various part of plants and their presence in intercellular and cells in different parts of rice had been reported which help in decomposing of rice stubble (Ross., 2018). Rice strawhas a great distribution of potential for use in production of bioethanol and use in paper industry due to high cellulose content. The degradation of the lignin component effects theutilization of rice straw, leading to the large-scale deposition and inefficient treatment of straw such as burning. But burningcauses a major threat to the natural environment. Recent advancement for the rice straw and lignin involves chemical andphysical treatment. But these methods are less effective than the biological treatment. Biodegradation methods confined the effect of fungi and bacteria on plant. The formation of endophyte resource is important for biodegradation. Endophytes are the inner tissues of healthy/normal plants that are withoutsymptoms of any disease(Wang and Dai., 2011).

Endophytes bring a great interaction with their hosts and produce extracellular enzymes, including lignin catabolic enzyme. Endophytes with ligninolytic activity can decompose plant residues when the plant die (Stone and Bacon., 2000). In current time endophytes is a new microbial resource for the degradation of rice crop. Endophytic fungal strain *Phomopsis sp.* B3 is isolated from *Bischofia polycarpa* are widely used in degradation of crops(Mahadevand Iyer., 2002). Due to the biochemical versatility and the immense environmentally adaptability, bacteria show developing endophytic bacterial characteristics which may provide the variety of benefits such as in lignocellulose biomass degradation (Xiong *et al*., 2014). An endophytic bacterial strain was found to have ability to decompose lignin in rice straw (Koide *et al*., 2016). Methane comes under the product of anaerobic degradation of organic matter in submerged soil.Rice crop show that the production of methane is derived from the degradation of stubble, soil organic matter and root exudates (Yuan *et al*., 2012). Rice straw is the main source of carbon in paddy soil. Incorporation of straw increases the emission of methane from rice field (Liu *et al*., 2014). Rice crops consist of different hemicelluloses (29-37%), lignin (5-15%), cellulose (32-37%) and additionally, contain inorganic components such as silica (Wegner and Liesack., 2016). Polysaccharides serve as a substrate for microbial community that degrades organic matter to carbon dioxide and methane. The process and function of group of microorganisms involved in anaerobic degradation of organic matter in soil (Liu *et al*., 2014). In India around 500 million tons of crop residues are produced every year. Every year one-fourth crop residue produced in India. Rice contributes 30 to 40% of total residues and after harvesting of the rice crop left residue or stubble in the ground is disposed by open field burning. Farmers do not incorporate or retain rice straw in the field due to slow degradation process (Yuan and Conrad., 2012). Some environmental issues or problems associated with stubble burning including micron-sized aerosols, smoke and trace gases that effect the environment and respiratory diseases in human beings are caused by stubble burning. To avoid these issues, farmers need other environment friendly techniques. Microorganisms play important role in degradation of rice residue and providing nutrient solubilization and mobilization by secretion of organic acids. Fungi are efficient at composting of lignocellulosic waste because they are filamentous and have ability to bring prolific spores. Fungi play an important role in the degradation of rice stubble (Chandra *et al*., 2012). Rice stubble is highly rich in lignin, hemicellulose and cellulose. Lignin is a complex aromatic polymers group, irregular three dimensional, amorphous and high branches. The chemical like sinapyl alcohol and hydroxy cinnamyl alcohols are considered the primary building blocks of lignin (Kaur *et al*., 2017). Lignin is an important component of plant cell wall where it provides structural support. Lignin-degrading bacteria are generally occurring slowly, because of lacking penetrating ability. Some lignin-degrading bacteria are *Pseudomonas syringae, Pseudomonas putida, Mycobacterium tuberculosm.* Bacteria like *Paenibacillus, Aneurin bacillus aneurinilyticus* and *Bacillus sp.*are found to degrade kraft lignin (Chaudhary., 2019). Bacteria like *Bacillus pumilus, Ruminococcus flavefacience* and *Cohnella* are major degraders of plant fibre cell walls and also important role for bacteria in lignin degradation and bioproduct formation. Cellulose is an organic polysaccharide compound composed of a linear chain of hundreds of β-linked D-glucose unit. Cellulose is the most abundant organic polymer ofbiomolecules in the biosphere (Mendoza *et al*., 2017). Cellulose is of different types based on their crystalline and non-crystalline, structure and accessibility. Cellulase is a most important enzyme that catalyze the breakdown of cellulose to formglucose, oligosaccharides and cellobiose (Van Hung *et al*.,2019). A wide spectrum of cellulolytic microorganisms like fungi and bacteria help in cellulose degradation. Cellulolytic fungi are the most active agent of decomposition of the organic matter. Soft rot is most known for producing cellulases for example *Trichoderma, Aspergillus niger, Fusarium oxysporum*and *Neurospora crassa*(Borah *et al*.,2016). Cellulolytic bacteria are also producing cellulases in small amount and help in degradation of cellulose. Most cellulolytic bacterial enzymes are produced from *Bacillus, Clostridium, Cellulomonas* and *Acinetobacter*. Hemicellulose is a group of polysaccharides that are found in fibers of plant along with pectin and cellulose. Hemicellulose consistsof heterogeneous group of carbohydrates. Microorganisms are involved in hemicellulose degradation are hemicellulolytic fungi like *Alternaria solani, Botryosphaeria ribis, Rhizopus nigricans and* hemicellulolytic bacterialike*Ruminococcus albus, Streptococcus sp., Bacillus subtilis, Clostridium felsineum* (Sindhu., 2008).

Advancements for combating stubble burning

Agriculture industries share a major role in economic growth of the worldwide. Now a days, in developing countries demand for food has alsoincreased which led to tremendous increases in food production all around the worldwide. Agriculture activities or farming activities increases the quantity of agro-products produced and led to an increase inwaste generation and environmental pollution.Waste productions depend on the culture factors and geographical factors of a country (Nagendran., 2011). These agriculturalactivities have been resulted in complexity in the disposal of agriculture waste and environmental pollution also increased. To reducecomplexity in disposal of agriculture waste and environmental pollution, the national and international agencies are continuously trying to develop policies and creating possible options to manage these wastes (Gupta *et al*., 2017). Various agricultural operations produce waste material. According to the United Nation, agricultural waste includes poultry house, manure,harvest waste, other waste from farms slaughterhouses, fertilizers run off from fields, water, air and pesticides that enter soil (Nagendran., 2011). Harvest waste is basically a crop residue or also known as stubble like rice is harvested from the ground and left residue is known as rice stubble (Hoornweg., 2012). Every year, according to Indian Ministry of New and Renewable Energy (MNRE), our country generates an average of 500-600 Million tons of crop residue. Majority of the rice stubble are used as a fodder, industrial purpose and fuel for other domestic purpose. Agriculture waste portion burnt in India is much larger than the production of agriculture waste in other countries (Ross., 2018). Waste collected from agricultural industry can be utilized in different agro-based and other industrial processing applications. However, processing,transportation and the cost of collection are much higher than the beneficial use of such waste (Sahu *et al*., 2019).

Crop residue: Composition & Decomposing mechanisms

Basically, the general type of crop residues is produced by cereal crops like wheat, rice, maize and sugarcane is also included in this.These field residuesare a natural resource that contributed to the soil fertility through ploughing directly into the soil and soil stability or by composting. Crop residue also increases erosion control and irrigation efficiency. Burning of stubble cause environmental issues, ploughing field residue (Bonnet *et al*., 2008).Biomass of the plant is mainly composed of hemicellulose, lignin, and cellulose with smaller amount of protein extractives, sugars, pectin, chlorophyll, inorganic waste and nitrogenous material. Lignin provides structural support to the plant, and it is almost impermeable. Lignin isresistant to biological degradation and chemical degradation (Perez*et al*., 2002). Crop also contain a non-food-based portion such as straw, husk and stalks categorized under lignocellulosic biomass (Chandra., 2012). Recently, some efforts are made to develop techniques of using field residues alternative to rice stubble burning, which are eco-friendly and economically viable(Kumar *et al*., 2018). Rice stubble is used to meet some alternative purposes such as fodder, animal feed, mushroom cultivation, fuel like bioethanol, packaging, biochar, composting etc. Moreover, acquisition of conservation of agro-based technologies using field residues may prevent the problem of stubble burning or combating stubble burning (Bisen and Rahangdale., 2017). In addition, crop residue also may serve as the ability to improve soil quality, soil health and improve next crop productivity (Kumar *et al*., 2018). The rice stubble burning leads to depletion of valuable resources which could be used as a source of bio-active compounds, carbon, energy for household, feed and small industries. Heat is also generated from crop residue burning which leads to increase in temperature from soil and reduce the level of beneficial microbial population gradually (Pandey., 2019).

Recycling of plant nutrient

It has been studied recently that if crop residue is incorporated in the soil instead of burning and nutrient can be recycled by this process (Sharma *et al*., 2019). Nutritional recycling by diverting the rice straw back into the soil and decreases the dependence on chemical fertilizers in long term process. Recycling of rice straw back to the soil may save upto 29-30% of total fertilizer requirement and 15-18% fertilizer saving possible in the recycling of nutrient crop (Kumar *et al*., 2015). It has been evidenced that rice stubble burning leads to the maximum loss of carbon. If soil organic carbon is increases, microbial growth is automatically increasing. The same in this process, the nutrient reciprocated when rice stubble is mixed in soil instead of burning. Soil carries lots of nutrient content like nitrogen and organic carbon along with other nutrient which helps in the growth of aerobic bacteria and fungi. A long-term process of crop residue incorporation in soil with minimum zero-till resulted in 17-30% higher soil organic carbon (Lohan *et al*., 2017). Recently during 2018-2019 through this process approximately 28 thousand tons of rice straw was saved in Punjab (Sharma *et al*., 2019).

Decomposition and Mulching

Crop residue mulching (CRM) is a technology that involves in covering of 30-40% of the soil surface by crop remnants from the preceding crop at the time of crop emergence. Crop residue mulching (CRM) avoid weed growth by smothering and allelopathy effect (Erenstein., 2002). Crop residue is also used for the thatching, mushroom cultivation, toy making, mat-making and most important thing is making of compost through decomposition. The decomposition process of rice crop residue releases the nutrient through microbial interventions which automatically entre the biogeochemical cycle (Gupta *et al*., 2012).

Rice crop residue are also used as an animal bedding to absorption of urine and heaped in small gaps along with cow dung. 1-4kg of crop residue absorbs 2-4kg of urine. Thus, farmyard manure is produced from such mixture is richwith nitrogen (Gupta *et al*., 2012).Crop residue is also used as an action of consortium of microorganism, produced 3-4 tons of FYM. Thus, crop residue is utilized in more profitable, efficient, and eco-friendly, without harming the environment by burning them. Also protecting the soil by maintaining pH and temperature (Bahadur *et al*., 2015).

Conservational tillage and Zero tillage

Tillage is an agriculture process of soil by mechanical agitation of various types, like stirring, digging and overturning. Using hand tools like picking, shovelling, hoeing, raking and mattock work. Conservational tillage refers to least tillage with low inversion of soil, which provides covering of at least 30-40% of soil surface by the left crop residue (Sommer *et al*., 2012).

This involves minimum tillage operation accompanied with soil covering surface by crop residues and maintain soil moisture by restriction of soil evaporation. Also prevent soil erosion by protecting the soil. Recently also show

Table 1: List of microbes helps in degrading Rice stubble

Sno.	Name of microbes	Strain	Mode of acton	Reference
	Fungi			
1	*Aspergillus flavus*	RPW 1/3 , RPW 1/10	Higher activity of cellobiase, also showed 30% degradation of rice residue, loss of dry mass, biodegradation of cellulose to glucose	Choudhary et al. (2015)
2	*Aspergillus terreus*	RPW 1/6 , RPW 1/9	Higher acitivity of Cmcase , show lignocellulolytic enzyme activity, loss of dry mass, 29% degradation	Choudhary et al. (2015)
3	*Penicillium janthinellum*	RPWM 2/2	Higher activity of Fpase , show lignocellulolytic enzyme activity, loss of dry mass, show 21% degradation	Choudhary et al. (2015)
4	*Aspergillus niger*	RZWM3/1	Higher activity of xylanase , show lignocellulolytic enzyme activity, loss of dry mass	Choudhary et al. (2015)
5	*Trichoderma spp.*	QM6a	Biodecomposer, degrading lignocelluloses, the colour of rice straw changed from light yellow to black indicating degredation process is occur	George E.Anasontzis (2017)
6	*Trichoderma reesei*	RUT-C 30	Degradation of cellulose and hemicellulose, cellulase activity, hydrolatic efficency	George E.Anasontzis (2017)
7	*Trichoderma harzianum*	FEC147, FEC142	Degradation of hemicellulose , cellulase activity	George E.Anasontzis (2017)
8	*Aspergillus tubingensis*	FEC110 , FEC98	Cellulase activity, showed high esterase activity	George E.Anasontzis (2017)
9	*Aspergillus oryzae*	FEC723	Cellulase activity	George E.Anasontzis (2017)
10	*Aspergillus niger*	FEC730	Esterase activity	George E.Anasontzis (2017)
11	*Aspergillus brunneoviolaceus*	FEC156	α-glucuronidase activity	George E.Anasontzis (2017)
12	*Penicillium oxalicum*	FEC385	Degradation of hemicellulose	George E.Anasontzis (2017)
13	*Penicillium simplicissium*	FEC600	Degradation of hemicellulose, Hydrolysis of untreated rice straw	George E.Anasontzis (2017)
14	*Trichoderma virens*	FEC161 , 118	Hydrolatic efficency	George E.Anasontzis (2017)
15	*Trichoderma viride*	ACCC30169	Breakdown the lignin structure in the straw, soluble carbon content	Yankun Cao , Bao-Hong (2019)
16	*Phanerochaete chrysosporium*	ACCC30942	Degradation ratio of cellulose , lignin breakdown	Yankun Cao , Bao-Hong (2019)
17	*Alternaria alternata*	MWM4/7	Higher activity of xylanase and Cmcase	Singh et al. 2012
18	*Trichoderma atroviride*	FEC67	Hydrolytic efficency	A. Sluiter 2012
19	*Trichoderma brevicompactum*	FEC 70	Highest activity of α-glucuronidase activity	J.P. Cairo 2013
20	*Trichoderma asperellum*	FEC 158, FEC 616	Show esterase activity and feruloyl estrase activity	A. Sluiter 2012
21	*Curvularia affinis*	FEC 704	Producing small amount of glucose and xylase	X.L. Li, 2008
22	*Epicoccum sorghi*	FEC 714	Both reported as plant pathogen,	X.L. Li, 2009
23	*Brunneoviolaceus*	FEC 156	Highest α-glucuronidase activity	X.L. Li, 2010
24	*Trichoderma asperellum*	T 203	Show penetrate the roots and colonize the epidermis	J.P. Cairo 2013
25	*Penicillium oxalicum*	MWM4/9 , MWM4/13	Degradation of hemicellulose	James et al. 2010
	Bacteria			
26	*Bacillus pumilus*	B37	Show optimum lignocellulolytic and play important role in decomposition of rice straw	J.S. Ma , X.L. Yang (2013)
27	*Ruminococcus flavefacience*	EC 2.4.1.20	It catalyzes the reversible phosphorolytic cleavage of cellobiose	Sangrila Sandhu, Tushar kanti Maiti (2013)
28	*Clostridium thermocellum*	EC2.4.1.49	It does not act on cellobiose but catalyze the reversible phosphorylytic cleavage of cellodextrin	Sangrila Sandhu, Tushar kanti Maiti (2013)
29	*AMB1 combination of microorganism*	FEC156	Degradation lignocellulolytic enzyme activity	George E.Anasontzis (2017)
30	*Pantoea sp.*	Sd-1	Degradation of lignocellulose, Endophytes with ligninolytic activity can rapidly decompose plant residue	George E.Anasontzis (2017)
31	*Pantoea agglomerans*	Z01, GS1	Chemotaxonomic, biodegradation activity	J.S. Ma , X.L. Yang (2013)
32	*Pantoea ananatis*	4CBJ1	Degradation of lignocellulose, Endophytes with ligninolytic activity can rapidly decompose plant residue	Kim. Et al., 2012
33	*Pantoea agglomerans*	S33	Chemotaxonomic, biodegradation activity	Kim. Et al., 2013
34	*Herbaspirillum seropedicae*	Z67	Chemotaxonomic, biodegradation activity	James et al. 2010
35	*Rhizobium*	ZT33	Show high substantially to straw metabolisation	Maarastawi 2018
36	*Cohnella*	ZT47	Show high substantially to staw metabolisation	Maarastawi 2019

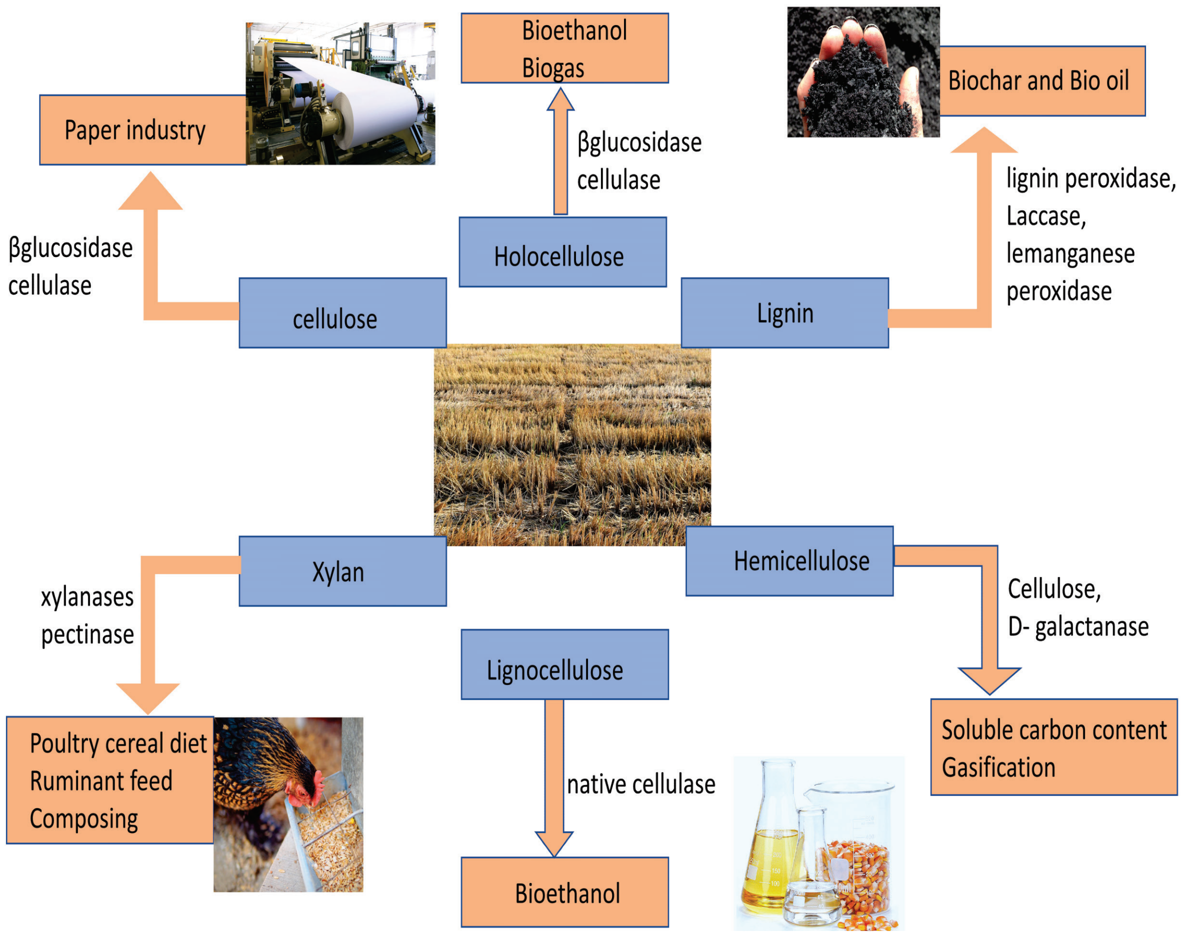

Figure 1: Degradation of stubble by microbes

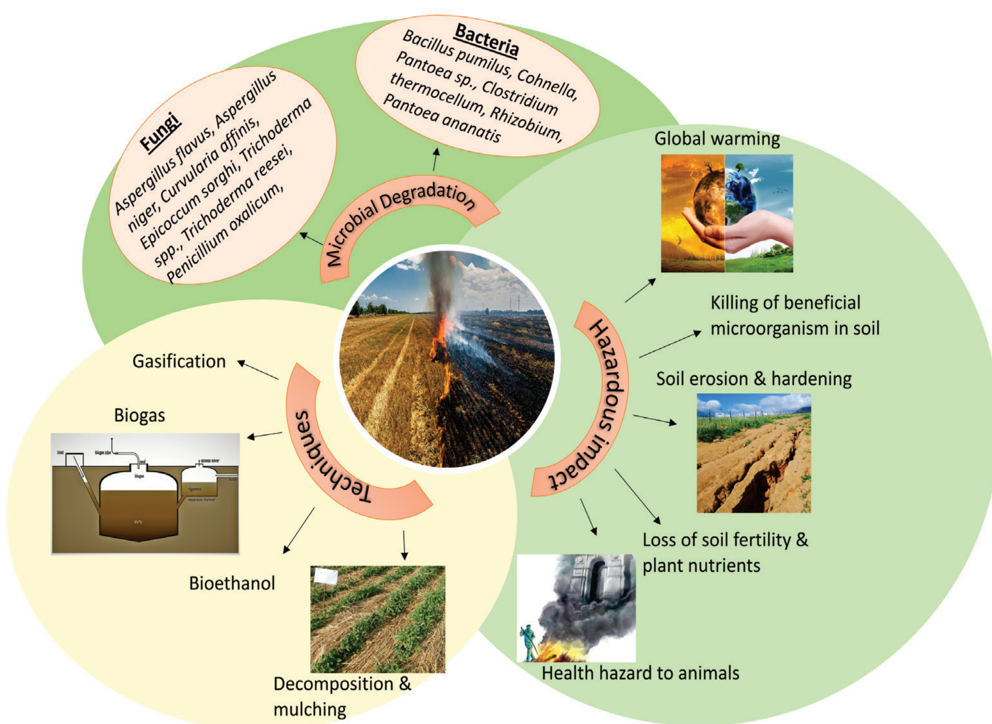

Figure 2. Combating stubble by various resources in the environment.

the crop yield higher in zero tillage than that of conservational tillage (Sommer *et al*., 2012).

Crop Residue Management: Sources of Alternative Energy

Bioethanol

The conversion of crop residueand lignocellulosic wastes intoan ethanol. Ethanol is efficient and safe method of combating the crop residue(Jain *et al*., 2014). This technique exerts a huge impact on increasing living standards and influences the socio-economic development by providing all new avenues for earning income (Riungu *et al*., 2014). This also creates an opportunity to producing a cleaner, safer and more eco-friendly bioethanol. Bioethanol can used as a neat fuel or blended with gasoline for both exporting and domestic use (Pathak *et al*., 2012).

Biochar and biooil

Biochar and biooil are a fine-grainedrich carbon porous product obtained fromthermo-chemical conversion known as pyrolysis at very low temperature(Amonette., 2009). It is a mixture of sulphur (S), nitrogen (N), carbon (C), oxygen (O), hydrogen (H). When high amount of biochar amended into a soil, highly porous nature helps in improving soil surface areaincreases water retention and increases nutrient in soil, leads to crop yield and plant productivity (Singh *et al*., 2015). Many studies show that increases in population of earthworm, decreases fertilizer usage and pH value increase(Lehmann., 2009). Biochar and biooil take control of a high absorbing capacity. Biochar and biooil also used to treat pesticides contaminated soils and heavy metal (Searle and Bitnere., 2017).

Gasification

Gasification is another onesuitable technology to utilizing the crop residue. Gasification is by partial or half burning of crop residue (Verma., 2014). Combustion of crop residue 'producer gas' is generated by thermo-chemical processes and gasses contain some impurities.Producer gas must be purified to eliminate all the impurities before power generation (Pathak *et al*., 2012).

Biogas

Biogas is one more technology to utilizing the crop residue. Biogas technology prepare renewable energy for generation of electricity, lighting purpose and cooking (Sood., 2014). This technology may reduce the combustion of crop residue that harming the environment by producing some gases. Now days, biogas is also used in e-rickshaws to obtain the target of green city (Kumar *et al*., 2018). Biogas is one of the most important plans on weather change in India (MNRE., 2015). About 6000m^3 of biogas to be generated from biogas power plants (CSO., 2014). In India most of biogas-basedplants are present in some of the states like Kerala, Karnataka, Maharashtra (CPCB., 2013).

Conclusion

Rice stubble degradation is a dynamic process undergoing a temporal succession. Some fungal genera were found to be significantly involved in the degradation of straw, while some bacterial taxa immediately decomposed straw. Only small population of the whole fungal and bacterial community was labelled and indicated soil microbial population from rice straw as carbon source either indirectly or directly by degradation products. The most important straw degraders were fungal species some aerobic bacterial. Rotation of crop management contribute to a reduction of methane emission and other harmful gases that may affect human health when rice stubble returnedback to the soil. The rice stubble degradation process is completely aerobic from the starting on even under field condition remains to be evaluated. Microbial degradation of stubble is considered as one of the eco-friendly method to combat stubble and act as a life savour for future generations.

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