In-situ management of paddy stubble through microbial bio-degradation

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Abstract. After the harvest of crop, the disposal of the rice stubbles remains a notable area of interest in all the growing areas of rice. The present review paper explores and highlights an effective strategy of decomposing the decomposers of the paddy stubble. Due to the increasing production of rice, there is an increase in rice crop residues and stubbles production. Conventional methods of management of paddy involve burning, surface retention, mulching, bailing, incorporation/amalgamation and direct removal. However, there are certain environmental challenges by using available agricultural implements. Thus, this current study demonstrates strategic management of the paddy crop residue for a sustainable environment. The developed eco-friendly methods will render new dimensions for the application of the post harvested residues. The review paper will be significant for sustainable management of the wastes of the paddy crop and hence strategic decomposition method, which will be beneficial for the society, farmers as well as the environment

1 Background of the study

Rice (*Oryza sativa*) is perceived to be the most pivotal staple food for a majority of the population of humans, in particular the Latin America, South Asia and East Asia, the West Indies and Middle East [1]. Rice, a grain, is discerned to be second-highest production after maize (corn) in terms of production [2]. Furthermore, a large amount of waste byproduct is observed besides the rice seed production. Majority of the waste byproduct is the rice straw residue [3]. In addition to this, disposition of the imperative amount of agricultural waste takes place by the conventional method of burning or by mulching in the paddy fields [3]. Consequently, severe forms of challenges are faced by the farmers and the environment if they are not handled adequately [4]. Furthermore, if residues in the field are left open without any strategically or effectively form of management, it results into the spreading of various diseases, initiating from the rice straw, for example, the stem disease thereby encouraging the pest breeding, particularly of the rats. Hence, burning technique is not perceived to be an effective way of dealing with the byproduct wastes, since it results negatively to the environment [5].

Over the past few years, rice production is dwindling that are attributed to the degradation of soil due to the techniques wherein the puddling is linked with the declining nature of organic matter amendment to the soil, decreased form of soil fertility, persistence of unbalanced nutrients, incompetent management of

nutrient and crop, inappropriate practices of the application of fertilizers and severe shift in the climatic parameters [6]. The production of the crop residues in large quantities and thereby consists of a plentiful but underutilized reservoir of renewable biomass in agricultural form.

Burning of agricultural byproducts in the field is asserted to be an easy and cheap method for the disposal of excess paddy. Additionally, the process of burning appends to increase in soil erosion, air pollution, and decrease in the productiveness of the herbicides that are soil applied like isoproturon [7, 8]. Furthermore, respiratory problems are caused, and fog incidences increase during the burning of the crop residue [5]. Thereby, the rice (paddy) disposal is a serious concern due to its colossal bulk material and slow degradation rate. Furthermore, utilization of residues cannot be as animal feed due to low protein, low digestibility, high content of silica and lignin. The straw is disposed of through open-burning due to many problems, thereby resulting in severe problems associated with environment as well as a menace to public health. Majority of the residues of the crop left out after the harvest are used as cattle feed in countries that are developing, while in the countries that are developed, the residues are burnt in situ.

The rice straw comprises majority of the cellulose (36-37%) and hemicellulose (23-24%) encrusted by lignin (15-16%) along with a small quantity of protein, thereby making it high in the ratio of C: N and hence is

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resistant to the decomposition of microbes compared to the straws of wheat and barley [9, 10]. Thus, lignocellulolytic microbes are utilized effectively to make the process economically viable and sustainably efficient. The rice straw compost is primarily applied to the fields of rice in Japan for improving soil fertility and the yield of the crop [11].

2 Research aims and objectives

The present study is aimed at ascertaining the significance of biodegradable decomposition of the paddy stubble by employing in-situ decomposition technique for maintaining an eco- friendly environment. The aims and objectives include:

- To explore and highlight the environment-friendly management of paddy stubble using biodegradation methods.
- To determine the existing challenges in the paddy stubble decomposition through microbial biodegradation.
- To identify the significance of situ decomposition of paddy stubble.
- To explore the advantages of situ decomposition of paddy stubble.

3 Literature review

3.1 Bio-decomposition of crop residue

Several biological processes of decomposition take place in the crop residue [12]. The microbes in the soil feed upon the C present in the crop residue and also require N for the process [13]. However, more concentration of the C in comparison to the N would result in the soil microbes taking more time in breaking down of the organic material and using of soil N in order to do their work. Studies have proved that utilization of the organic wastes as soil amendment might render good promises for improvement of the soil health and thereby also reduce the waste disposal issue [14, 15]. A study also affirmed that the use of the application of the microbial consortia for the paddy straw is an effective and strategic move for the treatment [15]. Apart from this, it was confirmed that availability of the soil nutrients also increased particularly N, K and organic carbon when the straw is applied with the microbial consortia. Although in the fields, direct association of the residues of agriculture solves the issues pertaining to burning, however, because of the difference in the short time occurring between the rice harvesting and wheat sowing, it is not feasible [5]. Moreover, according to a study long term based observed experiments asserts and highlight that although incorporation of agricultural residue improves the health of the soil significantly, however, the subsequent yields of crops decreases due to the allelochemical and microbial phytotoxins production and immobilization of nitrogen that is available [16].

3.2 Microbial biodegradation

According to a study, the process of Composting is one of the most well-known and effective technologies for the management of agricultural residues [5]. These residues are of potent source several benefits such as improved soil health and fertility which leads to increased agricultural productivity and soil biodiversity. In order to undergo composting by the use of microbes, it is essential that the raw material has a ratio (C: N) in the range of 30 and 35 and the content of moisture is discerned to be in between 55 to 65% of the residues for ensuring microbial appropriate conditions in order to decompose and transform into organic matter from the crop residues [17]. Many microorganisms have been manifested with activities of cellulose including various fungal and bacterial forms of strains comprising of both the aerobic and anaerobic. A study asserted that *Chaetomium*, *Myrothecium*, *Trichoderma*, *Fusarium*, *Aspergillus*, *Penicillium*

and *Trichonympha*, *Clostridium*, *Butyrivibrio fibrisolvens* and *Bacteroides succinogenes* are some of the bacterial and fungal species accountable to the activity of degrading [18]. In another study, it was asserted that a microbial consortium comprising *Aspergillus nidulans*, *Trichoderma viride*, *A. awamori* and *Phanerochaete chrysosporium* was rendered in the process of composting of various crop residues with poultry droppings and rock

phosphate (%) which produces nitrogen enriched phosphocompost within two months [19]. Mesophilic microorganisms like bacteria *Pseudomonadaceae*, *Enterobacteriaceae*, *Streptomycetaceae* and *Erythrobacteraceae* families govern the mesophilic phase of composting which grow in the temperature range of 15 to 35 degree Celsius and thereby utilize the soluble compounds such as sugar, amino acids and lipids [20]. After metabolic activities these generate exothermic reactions and increase the composting temperature up to 65 to 85 degree Celsius and this phase is called thermophilic phase. A study demonstrated that *Pseudonocardiaceae* and thermo- monosporaceae and possess hydrolytic enzyme degrading lignin, cellulose, hemicelluloses and proteins [21]. A thermophilic consortium fungi of *A. nidulans*, *Scytalidium thermophilum* and *Humicola* sp was found very useful and beneficial soybean trash and rice straw decomposition [22]. At low temperature, the composting was accelerated by some psychrotrophic microbial consortium comprising *Eupenicillium crustaceum*, *Paceliomyces* sp. *Bacillus atrophaeus* and *Bacillus* sp., was employed for biodegrading rice straw [23].

3.3 Methods of eco-friendly management of paddy stubble

The eco-friendly management of paddy stubble generally encompasses conventional and modern

stubble use. There is need for new innovations and proposals that more private players are encouraged for setting up facilities locally which could put stubble in use. Also, various new technologies available all around the world need to be studied and adopted accordingly. Fungi among the microbial agents forms the most essential form of group and thereby shows colonization on solid substances very quickly. Fungi hence has a vital function in the bio-degeneration of the organic forms of wastes that are lignocellulosic in nature. Many researchers demonstrated the lignocellulolytic activity of several fungal species. Studies have been carried about the *Fusarium sp.*, the *Aspergillus terreus*, the *Paecilomyces fusisporus*, the *Micromonospora* and the *Coriolus versicolor* [24, 25]. Some researchers concluded that the lignocellulolytic microorganism is perceived to be strategically associated technology in order to accelerate the degradation potential of lignocellulose in agriculture wastes [9]. It further manifested that *R.oryzae*, *A.oryzae* and *A.fumigatus* mixed culture can further be suggested for the paddy straw degradation and quality compost production with a greater population of macronutrients.

3.4 Eco-friendly management of paddy crop residue

A study explores and highlights an alternative technology known as Happy Seeder technology providing an effective measure in order to manage the residues of rice [26]. Furthermore, the technology enables drilling of wheat directly in residues of standing as well as loose forms [27]. Some studies concluded various alternatives of in-situ like crop residues management by zero-tiller machine, double disc coulters, straw choppers for cultural agriculture adoption and practice, thereby showing reduction in the rice and wheat rotation residue burning [28]. A research, affirmed and highlighted the eco-friendly management of the paddy crop residues for a sustainable environment and development. The research highlights the eco- friendly methods for the management of the residues providing a new dimension for the application of the post harvested residues [29]. A study conducted by Zafar (2018) explored the significant use of rice straw and husk into an efficient source of energy. The husk of rice is discerned to be productive form of stubbles in the countries producing rice in great amount. Studies have explored efficient usage of rice husk in the generation of power through the route of steam or gasification [30]. There has been the applicability of combustion boilers of rice straw along with the steam turbines for producing heat and electricity. Even the end products i.e. fly ash, and bottom ash is perceived to have economic values, thereby used in cement manufacturing and brick manufacturing, road construction and embankments, etc. In a recent study by Institute and Enertimee Company for researching the feasibility of establishing rice straw power plant an

advanced system of biomass combustion, Organic Rankine Cycle (ORC) was employed [31].

The applicability of rice straw in the production of biogas using anaerobic digestion was also perceived in the study. Apart from this, the rice straw renders applicability in the industry of mushroom also at varying levels. The mushroom paddy straw, *Volvarella volvacea* is discerned as stress-free mushrooms for cultivating due to the short incubation period [32]. According to the studies conducted, the applicability of production of mushroom renders high productivity of about 5-10% [33, 34]. Also, one of the significant substances is rich in carbon, biochar and can be produced using the rice straw [35]. The paddy straw effective recycling using the microorganism degeneration may play a significant role in grain and straw productivity enhancer. A study asserted by Dobermann and Fairhurst stated that good amount of nutrients is contained in the rice straw. One ton of the straw is discerned to comprise of 0.5-0.8% N, 0.16-0.27% P_2O_5 , 1.4-2.0% K_2O , 0.05-0.10% S and 4-7% Si on dry matter basis [6]. Also, the paddy stubble finds its applicability in the bed material during the winter for the cattle and is a traditional, conventional and regular form of practice in India. This bedding material formed from the residues of paddy renders an improved ability of milking pertaining to quantity and quality thus contributing udder health and relaxed sleep for the cattle [36]. Moreover, it can be processed for the compost by alternative forms of methods through the applicability of microbial organism and amendments on the farm itself [37].

3.5 Burning issues of paddy residue management

According to a study, the burning of the residues in open renders to be a common form of practicing in Asia [38]. Majorly, the burning of the paddy crop takes place using in-situ. The practice of burning of the residues of paddy causes substantial amount of air pollution and also kills microorganisms and soil insects that are advantageous. Thereby, the soil borne injurious pathogens and pests are killed due to burning practice [39]. The paddy stubbles or residues further grounds greenhouse gas emissions and other pollutants that are gaseous such as NO_3 , SO_2 , HCl and to a smaller extent dioxins and furans [40]. It further acts as a significant source of the particles of aerosol such as (PM10) and (PM2.5), thereby affecting the quality of the air locally and radiation budget [41, 42, 43]. Consequently, because of the abovementioned burning issues in the open field, there is an urgent need for the farmers to adopt eco-friendly management of the rice stubbles. Additionally, the Rice-Wheat Consortium scientists are continuously encouraging farmers in cutting down the practice of burning paddy stubbles. A study conducted by researchers focus on the management of paddy related issues of burning; the paper also focuses on assessing and managing from the paddy residue concerning utilization, approximation and generation

of energy [28]. Hence, by demonstrating the population magnitude because of paddy burning and its further effect on the health of the soil, environment and human health.

4 Research gap

In the study of the paper titled 'Syntrophic microbial system for ex-situ degradation of paddy straw at low temperature under controlled and natural environment', the methods that are focused upon include the intensification of the process of compost at low temperature, isolation of psychrotrophic microbes and characterization for lignocellulosic hydrolytic potential. The main limitation is that the research study was specifically aimed for research at a low temperature. The study concluded that the psychrotrophic microbial consortia can be used in composting of agriculture-based residue, thereby helping in the enhancement of soil fertility and decrease in the pollution of the environment caused due to the agricultural residue burning.

The study namely 'Burning issues of paddy residue management in north-west states of India', focuses on the composition of common organic wastes in nature using the isolates selected individually and as a consortium. The C/N ratio of each substrate led to the gradual reduction to 25–30:1 within 120 days and thereafter remained constant. The NH_4^+ and NO_3^- ion concentrations reduction also reflected the maturity in compost after 120 days whose pH was perceived to be 7.0 ± 0.2 , and the PO_4^{3-} ion concentration was high throughout the decomposition process. The main limitation of the study is that it is confined to the states of north-western India. Especially, optimization of the process of composting was described using isolates consortium from soil that was composted.

A full paper on 'Ecofriendly Management of Paddy Crop Residues for Sustainable Environment and Development' was studied thoroughly to carve out the research gaps. The paper explores and highlights the eco-friendly methods of managing residue of post-harvest. It provides the alternative of utilizing the paddy crop residue. It also explores the microbial degradation thereby accelerating using different amendments. The results emphasized that the sustainable utility and efficient management of stubble proves to be vital for the society as a whole by enhancing the fertility of the soil, economy and reduction in the level of pollution. The large-scale practical implications of the study are yet to be checked.

The study on 'Crop residues management with conservation agriculture: Potential, constraints and policy needs', discussed the economical utility of crop residue as livestock feed, industrial raw material and fuel, following the conservation agriculture. The paper asserted that the policy, research and development in decomposition of paddy stubble can serve as a great deal to manage the crop residue. It is a proposed research that asserts to be implemented by the government officials for sustainable and resilient form

of Indian agriculture. The effective ways of farming and conservation of agriculture with crop residue as an integral component can be a potential solution.

5 Summary and discussion

The residues or stubbles forms the threshed consolidated part of the rice plant which is left in the field post-harvest. These undesirable residue demands disposal effectively and strategically. In conclusion, it has been affirmed by different studies that residues form great values of economy, including fuel, feeding of livestock, and other raw materials. However, complications occurring contrary with the management of the residues of crop still remains an issue. Through the review of the literature, it is intended that if the stubbles are not returned back into the soil fields, it may then lead to soil mining for majorly known nutrients and may also render a balance which is net negative as well as deficiencies that are multi-nutrient in the subsequent crops. Consequently, this is the primary factor for the decline in the production of the cropping system of rice and wheat. Subsequently, an efficient way is needed for accomplishing residues of these crops for stability and sustainability is of the system. The paper also acknowledged the various techniques of managing the post harvested residues of crop such as burning, surface retention, incorporation, mulching, domestic or industrial fuel bailing. Through this review paper, it can be proposed that the government should encourage such viable technologies machine through subsidies so that more farmers can exercise during farming. The review of the literature also highlights the conservation of agriculture using various promising technologies to manage paddy residues and the promotion of conservation agriculture [28]. Review of the literature further highlights a gap, and through this current paper intends to fill the gap. The applicability of decomposed paddy crop using the microorganism and the organic and inorganic amendments results in safe and green technology for the management of post-harvest stubbles or residues. Furthermore, limited efforts have been rendered in exploring various constraints in the adoption of this technology and further suggestions thereof. From the studies it has been explored and highlighted that the eco-friendly management of the stubbles renders a new dimension in the form of bedding material for the cattle, packaging, fodder, material for packaging, biogas, fuel, production of paper, cultivation of mushroom, electricity generation from the bio-thermal power plants and a resulting sustainable environment.

In Spite of farmers getting aware about the adverse effects of burning paddy straw at the farm level, the farmers are still forced because of the lacking of economically viable and accepted forms of machinery and alternatively nature of residues of paddy. The other options of the in-situ techniques like crop residue management by straw choppers, double disc coulters, zero-till machine are needed in the practice and adopting sustainable friendly agriculture in different

parts of the world, which will thereby diminish the burning of residues while rotation of rice-wheat. Therefore, promoting the practices of organic recycle and considerations for benefits to the farmers will assure prevalent sojourn practices commencing polluting and wasting of resources that are potential. Thus, knowing the fact that burning practice causes carbon dioxide, sulphur dioxide, nitrous oxide and carbon monoxide, zero- tillage and happy seeder technology promising technologies offering advantages like controlled weeds, maintained moisture content and controlled pollution. Through this current review paper, the research affirmed at ascertaining the notable significance of the biodegradable decomposition of the paddy stubble by employing in-situ decomposition techniques for the maintenance of the eco-friendly environment [44].

The study asserted the adoption of zero-tillage based technology thereby improving in the benefits of the farmer, livelihood and thereby poverty reduction [45]. From the various studies mentioned above, it is discerned that Happy Seeder Technology is an alternative form of technology which is viable to the burning taking place in the open fields and tends to save approximately USD 23 in the preparation costs of field on an average in comparison to conventionally prepared plots [46]. Additionally, the paper asserts with the exploration and highlighting of the environment-friendly management of the paddy stubble decomposition through the microbial biodegradation. Various studies were scrutinized determining the current challenges in the paddy stubble decomposition through microbial biodegradation. Thereby, the review paper identified the significance of the situ decomposition of the paddy stubble and hence the advantages of utilizing such sustainable friendly management of the rice (paddy).

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