BRAINSTORMING WORKSHOP ON RICE RESIDUE BURNING IN MANIPUR – ISSUES AND STRATEGIES FOR SUSTAINABLE MANAGEMENT

31st January, 2018
Imphal, Manipur

Souvenir

Organized By -

INDIAN ASSOCIATION OF HILL FARMING, MEGHALAYA

In Collaboration With -

ICAR RESEARCH COMPLEX FOR NEH REGION, MEGHALAYA
AND
CENTRAL AGRICULTURAL UNIVERSITY, IMPHAL

Co-sponsored by -

NATIONAL BANK FOR AGRICULTURE AND RURAL DEVELOPMENT, MANIPUR RO
TRIBAL SUB-PLAN, GOVERNMENT OF INDIA
DIRECTORATE OF ENVIRONMENT, GOVERNMENT OF MANIPUR
DEPARTMENT OF AGRICULTURE, GOVERNMENT OF MANIPUR

सत्यमेव जयते

INDIAN ASSOCIATION OF HILL FARMING Estd: 1987

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CENTRAL AGRICULTURAL UNIVERSITY 1993

NABARD

souvenir

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National Bank for Agriculture and Rural Development, Manipur RO

Tribal Sub-Plan, Government of India

Directorate of Environment, Government of Manipur

Department of Agriculture, Government of Manipur

Souvenir

Brainstorming Workshop on

RICE RESIDUE BURNING IN MANIPUR – ISSUES AND STRATEGIES FOR SUSTAINABLE MANAGEMENT

January, 2018

Compiled and Edited By

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CHIEF MINISTER
MANIPUR

Message

It gives me immense happiness to learn that ICAR Research Complex for NEH Region, Meghalaya; Central Agricultural University, Imphal and Indian Association of Hill Farming, Meghalaya are organizing a one day Brainstorming Workshop on "Rice Residue Burning in Manipur – Issues and Strategies for Sustainable Management" on 31st January, 2018 at Imphal, Manipur.

Burning agriculture residues leads to air pollution and increase in black carbon, which contribute to regional and global climate change. Burning of paddy straw in the field also results in nutrient depletion in the soil, kills the beneficial flora and fauna and adversely affects the nutrient budget of the crop apart from giving severe severe health hazards.

I am confident that the proposed workshop will address all these challenges and come out with a meaningful strategy to convert the waste in to wealth.

I wish the event a grand success.

(N. Biren Singh)

Yumnam Joykumar Singh, IPS
Deputy Chief Minister
Manipur

सत्यमेव जयते

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Message

I am very happy to learn that a Brainstorming Workshop on "Rice Residue Burning in Manipur – Issues and Strategies for Sustainable Management" is going to be organized jointly by ICAR Research Complex for NEH Region, Meghalaya; Indian Association of Hill Farming, Meghalaya and Central Agricultural University, Imphal on 31st January, 2018 at Imphal, Manipur.

Burning of rice residue is a common practice in North East India, especially in Manipur. Instead of burning in to ashes, if this huge amount of biomass can be converted into resources, it will not only solve the problem of environmental pollution, but also will provide much needed organic manure for the farmers.ensure additional profit to the farmers.

I am confident that the deliberation in the workshop will lead to an appropriate action plan through science towards solving problems of rice residue burning in Manipur.

I wish a grand success to the organizers and that the workshop provides knowledge and technique for management of rice stalk after the harvest for the farmers of North East in particular those of Manipur state.

(Yumnam Joykumar Singh)
16/1/2018

V. Hangkhanlian
Minister (Agri/Vety)
Manipur

Message

It is great pleasure for me to learn that Indian Association of Hill Farming, Meghalaya, the ICAR Research Complex for NEH Region, Meghalaya and the Central Agricultural University, Imphal and are jointly organizing a Brainstorming Workshop on "Rice Residue Burning in Manipur – Issues and Strategies for Sustainable Management" on 31st January, 2018 at Imphal, Manipur and to mark the occassion, a souvenir is also being published.

The use of paddy straw in Manipur is now practically nil owing to the drastic decrease of cattle population which used them as fodder. The use of this material in other small purposes like house building is also no longer practised. As done in other parts of India, in Manipur and some other N.E. States, burning of straw after harvesting is rapidly becoming the method of disposing this material of great value as natural manure. Instances of high pollution and the resultant imminent health hazard have been facing by us - more severely this year.

It is high time the general public are aware of the harmful effect of burning straw. In this regard, this workshop will provide the most efficient strategy for the purpose. I do believe, the scholar and the scientists of the organizing institutions will successfully convince the population through this workshop.

I wish all success to the workshop and the publication of the souvenir.

V. Hangkhanlian
(V. Hangkhanlian)

Th. Shyamkumar
MINISTER
MAHUD, Town Planning, Forest & Environment,
Horticulture, Soil Conservation
Manipur

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Message

I am very delighted to note that ICAR Research Complex for NEH Region; Indian Association of Hill Farming and Central Agricultural University is going to organize a Brainstorming Workshop on "Rice Residue Burning in Manipur – Issues and Strategies for Sustainable Management" to be held on 31st January, 2018 at Imphal, Manipur. One the same day, a Souvenir is being published to highlight the occasion.

In North East India, significant amount of rice residue are burnt after harvesting and thrashing. Crop residue burning contributes to atmospheric pollution that has serious implications on environment, soil, human health as well as state economy due to release of large amount of air pollutants. One of the major aims of the workshop is to promote entrepreneurship on feed block, secondary agriculture and transportation cushioning material etc. as a possible means of residue management.

I am confident that the event would provide an avenue for all stakeholders covering researchers, academicians, state government official, KVKs, NGOs and farmers to discuss the topic in detail and come out with a meaningful solution.

I hope the mission of the organizers will go a long way and I wish their endeavour a grand success.

(Th. Shyamkumar)

CENTRAL AGRICULTURAL UNIVERSITY
IROISEMBA, IMPHAL - 795 004, MANIPUR (INDIA)

Prof. M. Premjit Singh,
Vice-Chancellor

Tel : (0385) 2415933 (O)
Gram : AGRIVERSITY
Fax : 2410414

Message

I am happy to know that Indian Association of Hill Farming, Meghalaya in collaboration with ICAR Research Complex for NEH Region, Meghalaya and Central Agricultural University, Imphal and are organizing a Brainstorming Workshop on "Rice Residue Burning in Manipur – Issues and Strategies for Sustainable Management" on 31st January, 2018 at Imphal, Manipur.

Farmers in Manipur burn rice residue in their field after harvesting and thrashing due to lack knowhow about its alternative uses like composting, mushroom cultivation, mulching etc. A meaningful policy intervention with dedicated technology dissemination programme on these aspects would definitely alleviate the problem of rice residue burning which causes air pollution and resource degradation. I am sure that the workshop will cover multifaceted utilization of rice residue and will come up with a sustainable roadmap.

I wish the workshop a grand success.

16/01/2018
(M. Premjit Singh)

Manipur University
Canchipur
Imphal - 795003
Manipur, India

Prof. Adya Prasad Pandey
Vice-Chancellor

Message

It is undeniably a great pleasure to know that a Brainstorming Workshop on "Rice Residue Burning in Manipur – Issues and Strategies for Sustainable Management" is going to be organized jointly by ICAR Research Complex for NEH Region, Meghalaya; Indian Association of Hill Farming, Meghalaya and Central Agricultural University, Imphal on 31st January, 2018 at Imphal, Manipur.

In Manipur tonnes of rice residues are burnt by the farmers every year. Burning of crop residue contributes heavily to atmospheric pollution and also leads to degradation of natural resources including biodiversity. In North Eastern states like Manipur the issue of air pollution due to rice residue burning has not come up in bigger way due to large forest cover. But with ongoing deforestation at rapid rate, soon atmospheric pollution is expected to become a major concern. Ample options are available for management of rice residue in a sustainable manner, only we need to devise a meaningful strategy in a farmer friendly way which can be taken up by the State Government to formulate a policy.

In this regard, the workshop is a right step not only for working out economically viable alternatives to residue burning but also ensuring a green environment to our future generation.

I congratulate the organizers for such initiative and wish the event a grand success.

29.1.2018
(Adya Prasad Pandey)

DR SUHEL AKHTAR, IAS
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Government of Manipur

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Message

I am delighted to learn that ICAR Research Complex for NEH Region, Meghalaya; Central Agricultural University, Imphal and Indian Association of Hill Farming, Meghalaya are organizing a one day Brainstorming workshop on "Rice Residue Burning in Manipur – Issues and Strategies for Sustainable Management" on 31st January, 2018 at Imphal, Manipur.

Open agricultural crop residue burning releases huge amount of pollutants in the atmosphere, which includes aerosols and hydrocarbons which not only degrade the atmospheric quality but also affect the climate and ultimately the human health. Burning is the easiest and economical option for management of rice straws and generally paddy straw biomass burning is practiced by farmers for clearing of their agricultural land, control of weeds and nutrients regeneration. However, instead of burning it may be used as a source of energy and raw materials for many enterprises for example, mushroom production. From time immemorial, paddy straw has been serving as an indispensable component of rural livelihood. With the entry of various cheap and durable synthetic products the importance of paddy straw use for various purposes is now diminishing. Moreover, due to increasing labour cost and decreasing agricultural workforce farmers are reluctant to invest on straw collection and storage. Due to lack of awareness or non availability of suitable technologies burning of straw is generally practiced everywhere in Manipur. In this age of growing issues about environmental pollution, we can no longer compromise environmental safety and sustainable for increasing crop productivity.

This brainstorming workshop on the aspect of Rice Residue Burning in Manipur in North East region, especially in Manipur is taking place at the right time to discuss about the present scenario of rice residue burning. Hopefully, it shall bring forth appropriate strategies to be taken up to ensure sustainable recycling and eco-friendly solution for this problem.

I wish the Workshop a grand success.

23/1/18

(Dr. Suhel Akhtar)

Ph. Rajendra Singh
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Message

I am happy to know that ICAR Research Complex for NEH Region, Umiam, Meghalaya; Indian Association of Hill Farming, Meghalaya and Central Agricultural University, Imphal and are jointly organizing one day Brainstorming Workshop on "Rice Residue Burning in Manipur – Issues and Strategies for Sustainable Management" on 31st January, 2018 at Imphal, Manipur and a souvenir is also bring published on this occasion.

About 2.2 lakh ha area of rice is cultivated in the state. It is a common practice of burning of rice straws and other agricultural wastes in preparation for the next crop season in the state. It contributes to the degradation of soil properties besides more to air pollution than vehicle emission.

It is the right juncture to organize such workshop with a view to create awareness among different stakeholders towards sustainable way of rice residue management for transforming the waste in to wealth.

I wish the organization of workshop and publication of souvenir a grand success.

Rajendra
(Ph. Rajendra Singh)

भारतीय कृषि अनुसंधान परिषद
उत्तर पूर्वी पर्वतीय क्षेत्र अनुसंधान परिसर, उमियम, मेघालय
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
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Message

It is great pleasure for me to learn that Indian Association of Hill Farming, Meghalaya; ICAR Research Complex for NEH Region, Meghalaya and Central Agricultural University, Imphal are jointly organizing a Brainstorming Workshop on "Rice Residue Burning in Manipur – Issues and Strategies for Sustainable Management" on 31st January, 2018 at Imphal, Manipur.

Burning of rice residue in Manipur is a serious challenge for agriculture as well as environment sector. Blazing the piles of paddy straw leads to rapid increase in hazardous gases in the environment which again poses threat to human health. Recently we heard about the air pollution in New Delhi due to burning of rice residue in Western India. Hence, if we educate the farmers about the ill effects of rice residue burning as well as their alternative uses, definitely this problem can be solved in a sustainable manner. The workshop is a right and timely step towards this goal.

I hope the Workshop will have many discussions and interactions which are focused on rice straw burning in the North East India and its sustaonable solution. The outcome of the workshop will definitely serve as the guiding force for the farmers, policy makers and other stakeholders. I wish the event a grand success.

(Narendra Prakash)

Dr. I. Meghachandra Singh
Pr. Scientist & Joint Director i/c
ICAR Research Complex for NEH Region
Manipur Centre, Imphal

From the Desk of Convenor

Burning of paddy stubbles after harvesting has become a trend with zero tillage cultivation of rabi rapeseed mustard in Manipur. Recently with the application of the mechanical threshing machines the damaged straws are burnt as these are not fit for cattle and other purposes. Farmers burn the rice residue because the removal of rice residue from the field has cost implications. Without some technological interventions to make the rice residue removal less costly or to make it's alternative uses more profitable, it likely that this trend in residue burning may continue. Hence, it is highly essential to mitigate the impacts due to the burning of rice residues in the open fields and its consequent effect on soil, environment and living organisms. With this background, the Brainstorming Workshop on "Rice Residue Burning in Manipur – Issues and Strategies for Sustainable Management" is being organized on 31st January, 2018 at Imphal, Manipur by the Indian Association of Hill Farming. ICAR Research Complex for NEH Region, Manipur Centre is extremely privileged to host this important event.

We hope that the Brainstorming Workshop will provide a great opportunity to bring together multi-disciplinary scientific team, academicians, policy makers, line departments, financial institutions, KVKs, NGOs, students, farmers, media and other stakeholders to a common platform for sharing their problems, findings and ideas to formulate a meaningful strategy for sustainable way of rice residue management. The recommendations of the event will be published as policy document for sustainable rice residue management in Manipur in particular, North Eastern region and also outside the region in general.

On behalf of the organizing committee, I extend my heartfelt gratitude to our sponsors, invited speakers, experts, delegates, representatives from NGOs, media and specially our farmer friends for their valuable contributions to the workshop. I also thank all the committee members for their sincere efforts in organizing the event successfully. We hope that this brainstorming workshop will provide an effective stimulus to fulfill the ultimate goal to serve the human kind and all forms of lives on the earth.

(I. Meghachandra Singh)
Convenor

Dr. Anup Das
Pr. Scientist & HOD (Crop Production)
ICAR Research Complex for NEH Region
Umiam, Meghalaya

From the Desk of Organizing Secretary

In agriculture, crop residues serves multiple ecosystem services like acting as source of nutrients and energy for limitless soil biota and crop plants, major buffer to regulate soil temperature and importantly conserving soil and soil moisture and acting primary as source of cattle feed, bedding materials for livestock and poultry, etc.. Moreover, these plant biomass also helps in carbon-sequestration by trapping atmospheric CO_2 and thereby, contributing to mitigating global warming. In contrary, unprecedented and unthoughtful burning of crop residues relentlessly pollute the environment and result in global warming that has negative impacts on entire biodiversity including crops, soil and human health. Every year huge amount of rice crop residues are burnt in north India leading to unwarranted environmental pollution. In Manipur also, around 0.5 million tonnes of rice residues from ~ 2.2 lakh ha rice area is being burnt every year leading to generation of pollutants such as ~ 6864 tonnes of particulate matter, 31680 tonnes of CO, 770880 tonnes of CO_2, 1848 tonnes of NO_x and 1056 tonnes of So_2.

However, this enormous amount of rice residues can be collected and diverted to serve multiple essential ecosystem services. Rice residue can be easily used for preparation of house hold or community based compost and vermicompost or it can be judiciously used as efficient mulching materials or it can act as transport cushioning of delicate and perishable packaging materials, making feed blocks and bedding materials for livestock, a good media for mushroom cultivation and feasible substrate for biofuel, and paper and pulp board manufacturing etc.

In this backdrop, the objective of the present brainstorming workshop on “Rice residue burning in Manipur - Issues and Strategies for Sustainable Management” is to create awareness among various stakeholders of agriculture especially farmers, policy makers and to identify possible reasons for rice residue burning in Manipur through participatory interactions. All researchers, policy makers, extension functionaries and farmers come together and put-forth all ideation, deliberate and brainstorm to bring out some sustainable management options for rice residue management which are acceptable and feasible to hill farmers.

The organizers are highly grateful to all the esteemed delegates and participants specially farmers for making it possible to attend the brainstorming workshop and extending their contributions wholeheartedly for science and societal cause.

(Anup Das)
Organizing Secretary

BRAINSTORMING WORKSHOP ON "RICE RESIDUE BURNING IN MANIPUR – ISSUES AND STRATEGIES FOR SUSTAINABLE MANAGEMENT"

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Content

Content

MULTIPLE USE OF RICE RESIDUE FOR SUSTAINABLE AGRICULTURE

Narendra Prakash

Director
ICAR Research Complex for NEH Region, Umiam, Meghalaya

Rice (*Oryza sativa* L.) is the lifeline of Asia. More than 90% of the world's total rice cropis produced in Asia. Rice-based cropping systems are the most productive agroecosystems in Asia and produce the most food for the most people. Along with grain yield, these systems generate large amounts of crop residue.Rice straw is an important crop residue that is produced in large amount in India India. If rice straws are used for bioethanol production a huge energy requirement of country could have been me. However, technological backstopping and infrastructure is the major challenge (Kim and Dale 2004). An increasing proportion of rice straw is burned in India leading to environmental pollution, global warming and health hazards. Open-field burning of crop residues is recognized as a major contributor to reduced air quality and human respiratory ailments, particularly in China and northwestern India, which represent major irrigated rice ecosystems in Asia (Bijay-Singh et al. 2008).Thus, there is increasing interest in alternative and multiple uses of rice residues as source of energy, crop nutrients, substrate for compost making, livestock feed, mushroom production and so on.

Rice straw and husks are two types of residues from rice cultivation that have potential in terms of energy. One of the principal reasons for the preferred use of husk is its easy procurement from rice mills. In the case of paddy straw, however, its collection is a tedious task and its availability is limited to harvest time. Technologies for energy use of straw must be efficient to compensate for the high costs involved in straw collection.

Continuously burning can reduce soil quality and make land more susceptible to erosion. Smoke from burning also contributes to increased carbon dioxide levels in the atmosphere and hence contributes to global warming.

There has been increased realization that crop residues are a resource constituting a readily available source of nutrients and organic material for rice farmers. About 40% of the N, 30–35% of the P, 80–85% of the K, and 40–50% of the S absorbed by rice remain in the vegetative parts at maturity (Dobermann and Fairhurst, 2000).

Conservation agriculture (CA) is recognized as agriculture of the future, the future of agriculture. To harness the full potential of CA, not only residue will have to be used as soil surface mulch but also rice will have to be brought under zero tillage. Ensuring good seed germination and crop stand establishment are major challenges to be addressed with CA and crop residue management. Agronomic productivity and profitability are high with use of CRs in conjunction with no tillage in CA. Rice residue adds 35-45 kg N ha–1 and is a key consideration when attempting to optimize N fertility in conservation tillage systems. One factor that continues to be a problem in high residue no-till farming systems is N management. Hence, first few years, about 20% higher N fertilizer may be needed. In CA system, broadcasting N onto the residue covered surface is an inefficient method of application because of the potential for immobilization by surface residues and volatilization losses of N. Thus, placing the fertilizer in bands below the C-enriched surface soil that results from surface placement of CRs can overcome volatilization and N immobilization problems to a great extent.

The rice straw can be used as mulch for other crops. The beneficial effects of this practice to improve crop yields at comparable irrigation regimes and saving of irrigation water and fertilizer nitrogen at comparable yields have been reported in several crops. The magnitude of yield gain in different crops ranged from 4 to 29% and saving of irrigation water from 7 to 40 cm. The variation in yield response to mulching depended upon the atmospheric temperature, frequency and amount of rainfall and soil texture. The response is more under high temperature, low rainfall year and on coarse texture soils.

Biochar is produced via the burning of waste biomass at 300-600ºC in the partial or complete exclusion of oxygen, a process is known as pyrolysis. Due to the relatively stable biological state of biochar, its production for soil application has been proposed as a way of diverting waste biomass carbon from a rapid to a slow carbon-cycling pool in soil. Enormous quantities of rice straw, rice husk and other surplus residues available in India could potentially be pyrolysed to produce bioenergy, thereby reducing field burning and the use of fossil fuels, and the biochar by-product could help to improve soils, avoid methane emissions, and sequester carbon in soils (Singh and Sidhu, 2014).

The rice residue as fodder for animals is not a very popular mainly because of the high silica content in the rice residue. Total production of residue of paddy is almost 30 million tonnes for the total livestock of 464,472 thousands. Thus the consumption of paddy residue per livestock stands at 0.06 t/animal. Highest imbalance of livestock and consumption is noted in Rajasthan with zero consumption per animal. Other such low ranked state with least consumption rate is Madhya Pradesh, Himachal Pradesh, Maharashtra and Sikkim. In north, Punjab has got highest ratio of consumption, followed by Kerala and North Eastern state Tripura and Manipur. Uttar Pradesh has highest concentration of livestock which is followed by Rajasthan, Madhya Pradesh and Maharashtra. The residue is found highest in West Bengal and Arunachal Pradesh.

The availability of crop residue in India is about 500 million tonnes of which about 352 mt is from cereals. About 34% of this residues are from rice alone. The surplus CRs (i.e., total residues produced minus the amount used for various purposes) are typically burned on-farm. Of the 82 Mt of surplus CRs nearly 70 MTs (44.5 Mt rice straws and 24.5 Mt wheat straws) are burned annually. The availability of crop residue is highest in Uttar Pradesh followed by Maharashtra, Bihar, Rajasthan and Andhra Pradesh. Excepting Assam almost all the north Eastern States and Kerala have least availability of crop residue. As in the case of availability, the highest requirement of crop residue is in Uttar Pradesh and thus the requirement per animal (0.99 t/animal) and per animal availability of the state is also high (0.07 t/animal). States like Punjab, Haryana and Bihar has higher per animal availability as compared to other states of India.

Another use of rice residue that is being encouraged by various institutions and departments is the use of rice residue for generation of electricity. Apart from the generation of electricity for supply to state grid to meet the ever-increasing demand for energy in the state, the plant also reduces the Green House Gases (GHGs) emissions.

The farmers of the state have been advised to use paddy straw as bedding material for cross bred cows during winters as per results of a study conducted by the Department of Livestock Production and Management, College of Veterinary Sciences, Punjab Agricultural University. It has been found that the use of paddy straw bedding during winter helped in improving the quality and quantity of milk as it contributed to animals' comfort, udder health and leg health. Paddy straw bedding helped the animals keep themselves warm and maintain reasonable rates of heat loss from the body. It also provides clean, hygienic, dry, comfortable and non-slippery environment, which prevents the chances of injury and lameness. Healthy legs and hooves ensure enhancement of milk production and reproductive efficiency of animals. The paddy straw used for bedding could be subsequently used in biogas plants. The use of paddy straw was also found to result in increased net profit of Rs. 188–971 per animal per month from the sale of additional amount of milk produced by cows provided with bedding. The PAU has been demonstrating this technology to farmers through training courses, radio/TV talks and by distributing leaflets.

Paddy straw can be used for the cultivation of Agaricusbisporus, *VolvariellaVolvacea* and Pleurotus spp. One kg of paddy straw yields 300, 120–150 and 600 g of these mushrooms, respectively.Paddy Straw Mushrooms (*VolvariellaVolvacea*) also known as grass mushrooms are so named for their cultivation on paddy straw used in South Asia. Paddy Straw is high temperature mushroom grown largely in tropical and subtropical regions of Asia, e.g. China, Taiwan, Thailand, Indonesia, India, and Madagascar. In Indonesia and Malaysia, mushroom growers just leave thoroughly moistened paddy straw under trees and wait for harvest. This mushroom can be grown on a variety of agricultural wastes (the cultivation method of this mushroom is similar to that of *Agaricusbisporus*) for preparation of the substrate such as water hyacinth, oil palm bunch waste, dried banana leaves, cotton or wood waste, though with lower yield than with paddy straw, which is most successful. Paddy straw mushroom accounts for 16% of total production of cultivated mushroom in the world.

The paddy straw is also being used in conjunction with wheat straw in 40:60 ratios for paper production. The sludge can be subjected to bio-methanization for energy production. The technology is already operational in some paper mills, which are meeting 60% of their energy requirement through this method. Paddy straw is also used as an ideal raw material for paper and pulp board manufacturing.

Rice straw is also having very good potential for soil health management. The technical measures are ‘straw incorporation’ and ‘straw mulching’. In both these measures, the residue is incorporated in the field itself and is thus used to increase the nutrient value or fertility of the soil. The second measure is more useful as there is no weeding in this process and it is less expensive.

Another study (Singh 1992) reveals that, incorporation of paddy straw in soil immobilized native as well as added fertilizer N and about half of the immobilized N was mineralized after 90 days of straw incorporation. Straw and N application alone or in combination increased biomass carbon, phosphates and respiratory activities of the soil. Microbial biomass carbon and phosphate activities were observed maximum at 30 days of straw decomposition. In field trials, incorporation of paddy straw 3 weeks before sowing of wheat significantly increased the wheat yield at Sonepat district in a clay loam soil while no such beneficial effect was observed in a sandy loam soil at Hissar (Singh 1992).

The incorporation of the straw in the soil has a favorable effect on the soil’s physical, chemical and biological properties such as pH, Organic carbon, water holding capacity and bulk density of the soil. On a long-term basis it has been seen to increase the availability of zinc, copper, iron and manganese content in the soil and it also prevents the leaching of nitrates. By increasing organic carbon it increases bacteria and fungi in the soil. In a rice-wheat rotation, Beri et al. (1992) and Sidhu et al. (1995) observed that soil treated with crop residues held 5–10 times more aerobic bacteria and 1.5–11 times more fungi than soil from which residues were either burnt or removed.

Due to increase in microbial population, the activity of soil enzymes responsible for conversion of unavailable to available form of nutrients also increases. Mulching with paddy straw has been shown to have a favorable effect on the yield of maize, soybean and sugarcane crops. It also results in substantial savings in irrigation and fertilizers. It is reported to add 36 kg per hectare of nitrogen and 4.8 kg per hectare of phosphorous (6 g of Nitrogen and 0.8 g of phosphorous per kg of paddy straw) leading to savings of 15–20 % of total fertilizer use.

Bio-oil is a high density liquid obtained from biomass through rapid pyrolysis technology. It has a heating value of approximately 55 % as compared to diesel. It can be stored, pumped and transported like petroleum based product and can be combusted directly in boilers, gas turbines and slow and medium speed diesels for heat and power applications, including transportation. Further, bio-oil is free from SO_2 emissions and produces low NO_2. Certain Canadian companies (like Dyna Motive Canada Inc.) have patented technologies to produce bio-oil from biomass including agricultural waste. Though their major experience is with bagasse, wheat straw and rice hulls, feasibility of this technology with paddy straw needs to be assessed.

Agricultural requirement for power is highest during June to September for the purpose of paddy cultivation. Biomass, such as agricultural residue, bagasse, cotton stalks, rice husk, etc., is emerging as a viable source of power for rural electrification in India. Direct burning of such waste is inefficient and leads to pollution. When combusted in a gasifier at low oxygen and high temperature, biomass can be converted into a gaseous fuel known as producer gas. This gas has a lower calorific value compared to natural gas or liquefied petroleum gas, but can be burnt with high efficiency and without emitting smoke. The advantages of utilizing crop residue over and above the conventional resources are that such residue is renewable, readily available and can be used successfully by burning in boilers with the efficiency of 99 %. Further, they are available at low cost as compared to that of coal while ash contents is much less (as compared to 36 % ash content of coal) and at the same time the calorific value of both, coal and paddy straw are comparable, i.e., 4,200 and 3,590 kcal/kg, respectively. Additional income to the farmers from the sale of straw is an added advantage.

The transportation of biomass is one of the key cost factors for its use as a source of renewable energy. Decentralized energy systems provide an opportunity to use biomass to meet local energy requirements that are, heat and electricity. In contrast to straw, the use of rice husk for energy has been realized faster. One important factor is that rice mills can use husk to serve their internal energy requirement. As an alternative, rice millers could sell the husk to a power-plant operator. The propagation of rice husk use for energy was accelerated by energy providers, who deal with a relatively small number of rice millers for supplying husk, which is an easier task than dealing with thousands of farmers supplying paddy straw.

Paddy straw can either be used alone or mixed with other biomass materials (the latter is called co-firing or co-combustion) in direct combustion. In this technology, combustion boilers are used in combination with steam turbines to produce electricity and heat. In thermal combustion, air is injected into the combustion chamber to ensure that the biomass is completely burned in the combustion chamber. Fluidized bed technology is one of the direct combustion techniques in which solid fuel is burned in suspension by forced air supply into the combustion chamber to achieve complete combustion. A proper air-to-fuel ratio is maintained and, in the absence of a sufficient air supply, boiler operation encounters various problems.

In straw combustion at high temperatures, potassium is transformed and combines with other alkali earth materials such as calcium. This in turn reacts with silicates, leading to the formation of tightly sintered structures on the grates and at the furnace wall. Alkali earths are also important in the formation of slags and deposits. This means that fuels with lower alkali content are less problematic when fired in a boiler (Jenkins et al. 1998). The byproducts are fly ash and bottom ash, which have an economic value and could be used in cement and/or brick manufacturing, construction of roads and embankments, etc.

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MICROBES FOR RICE RESIDUE MANAGEMENT – OPTIONS AND STRATEGIES

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Introduction

Rice (*Oryza sativa*) is the most important staple food for a large part of the world's human population, especially in East and South Asia. It is the second highest grain after maize (corn) in terms of worldwide production. After China, India is the second largest producer of rice in the world. In north east states of India, it is the main source of carbohydrate. Besides producing rice seed, it also produces a large amount of waste byproduct of which one is rice straw residue. According to Foreign Agricultural Service (FAS) in 2016-17 around 105 million tonnes of rice harvested from 44 million hectares of rice plantation area in India. Roughly 130 million tonnes of rice straw produced in every planting season. Among current options available to farmers for rice residue management before next crop sowing are: (1) in situ incorporation in the soil using rotavator or is mulched in the rice fields and (2) in situ open field burning.

But if these wastes are not properly handled, will cause many problems to farmers as well as to the environment. If rice straw is left in the field without proper management, it can cause the spreading of disease, which originates from the rice straw, such as stem disease and can also encourage the breeding of pests, especially rats. Burning is not the best way to deal with such waste, as it is harmful to the environment. Burning of crop residues result in emission of noxious air pollutants and greenhouse gases along with particulate matter and hydrocarbons which affect the atmospheric chemistry. Crop residues are good source of plant nutrients and organic matter (40% of the total dry biomass constituted by C) and are important for stability of agricultural ecosystems.

So, one of our goals of this work was to find an alternate biological method to the current practice of open field burning of crop residue by farmers. For this use of microbes for accelerating decomposition of crop residue and humification of cellulosic material in the soil by using consortium of fungus and bacteria was done. Moreover, mixed cultures can have greater influence on substrate colonization because of the higher production of enzymes and resistance to contaminant microbes as compared to pure cultures. Although, residue degrading microbes are already present in soil but their population vary greatly from place to place and field to field depending on the management, edaphic and environmental conditions.

Waste Decomposer: Answer to Stubble Burning

The main cause of concern among the rural population in developing countries is the management of agricultural and municipal solid waste. The present practice is usually to burn these residues or to leave them to decompose. To overcome this problem National Centre of Organic Farming, Ghaziabad developed a product called Waste Decomposer. It is a consortium of few beneficial microorganisms which is isolated by Dr. Krishan Chandra in 2004 from "desi" cow dung and took 11 years to standardize the mass multiplication technique at the farm level. Waste decomposer works as biofertilizer, biocontrol agent, and as well as soil health reviver. It can also be used in various ways such as quick composting of bio wastes, drip irrigation (Microbigation), foliar spray as biopesticide against most of the plant diseases for all types of agriculture and horticulture crops, in-situ composting of crop residue and seed treatment.

Salient Features of waste decomposer

- Simple and Reliable
- Ready to use (within 5 days)
- Longer shelf-life (3 years)
- Recommended for all crops
- Better crop response
- Works as a great component for clean India Movement (Swachh Bharat Mission) by converting bio-waste into organic Manure
- Low cost (only Rs. 20 per bottle)
- More than 1 lakh metric tonne organic manure could produce from 1 bottle per year by farmers.

Mass multiplication of Waste Decomposer

Waste decomposer is given to the farmers in small bottles and they themselves mass multiply this product without using any sophisticated technique.

Process of Mass multiplication

- Take 2 kg jaggery and mix it in a plastic drum containing 200 litres water.
- Now take 1 bottle of waste decomposer and pour all its contents in a plastic drum containing jaggery solution.
- Mix it properly with a wooden stick for uniform distribution of waste decomposer in the drum.
- Cover the drum with a paper or cardboard and stir it every day once or twice.
- After 5 days the solution of drum turns creamy in colour and ready to use.

Note: Farmers could prepare the waste decomposer solution again and again from the above formed solution. For this, 20 litres of waste decomposer solution is added to a drum with 2 kg of jaggery and 200 litre water added. Again it will be ready in 7 days.

Mass multiplication of Waste Decomposer

Solution can be used again and again from the above formed mixture. For that, 20 Litres of the above solution is added to a drum with 2 kg of jaggery and 200 Litres of water. And in such a way this can be used again and again.

No Structure, Pit or equipment require

Composting with Waste Decomposer is very much cost effective, as this technique demands neither standard structure nor essential parameters which are compulsory in other composting methods. Therefore, the farmer could save the entire costing supposed to be spent on the structures and process. In case of composting other than with Waste Decomposer, require standard structure like brick lining, bottom line concrete, pit, trench, bins etc and many other parameters like heap size (height, length, and width), covering with plastic/jute material, ventilating stacks etc. Better composting and good quality compost is not expected without maintaining standard structure and essential parameters with the so far existing methods of composting. But composting with the Waste Decomposer technology could produce high quality compost despite any standard structure and essential parameters.

Quick Composting

- The mass multiplied solution of waste decomposer is used to decompose bio-waste into organic manure.
- 18-20cm thick layers of 1 ton bio-wastes such as agricultural wastes, kitchen wastes, cow dung etc. are piled on the ground.
- Wet the waste with solution of waste decomposer.
- Again another 18-20cm thick layer of bio-waste is spread and again wet with waste decomposer solution.
- The above processes are repeated till the piling goes 30-45cm higher.
- Turn the pile at every 7 days interval for uniform composting and add more solution at every turning.
- Maintain 60% moisture during the entire period of composting. If required again add solution.
- The compost gets ready to use after 30-40 days.

In Situ Composting of Crop Residue

- Sprays the mass multiplied waste decomposer liquid solution on the post-harvest stalks of crop plants then flooded with water and leave it for few days.
- After few days black spots will appear on the crop residue which shows that the decomposition starts.
- The above prepared 200 litre waste decomposer liquid solution can be used for 1 acre /0.4 Ha. crop residue as in-situ composting.
- Process of decomposition can be enhanced by shredding the crop residue and repeat spray of waste decomposer liquid solution which results in improvement soil health.

Healthy Compost

Compost which gets ready by using waste decomposer is dark brown in colour, no foul smell, not warm, dry, and very good in quality having high organic carbon content and other nutrient content.
It doesn't attract flies and insects and no foul smell, which is, in fact, a good sign for healthy composting. Generally, in case of so far, existing composting lot of complication are noticed by farmers and surrounding people which are offensive to the community living in the area of

composting, some of the notable complaints with existing composting methods are, 1. Foul smell, 2. Matted leaves or grass clippings aren't decomposing, 3. Stinks like rancid butter, vinegar or rotten eggs, 4. Odor like ammonia, 5. Attracts rodents, flies, or other animals, 6. Attracts insects, millipedes, slugs, etc, 7. Fire ant problems and etc. But if the Waste Decomposer Technology is adopted, there will be zero percent offensive and recurring management problems. Due to this healthy composting features, it is very much adaptive in for kitchen and terrace gardening.

Waste decomposer microorganism was demonstrated to be an excellent candidate for lignocellulose degradation in this work, showed more robust growth, stronger spore production, faster secretion of lignocellulose-decomposing enzymes and better pH tolerance. These features make this product unique to convert all types of waste into good compost.

Additional uses of Waste Decomposer

Waste decomposer not only decomposes the bio-wastes, but it can be used in multiple ways.

1. As Biopesticide and Biofertilizers : The mass multiplied liquid waste decomposer culture is diluted in the ratio of 1:40 with water and applied as a foliar spray to control pest and diseases. It can control all types of soil borne, foliar diseases, insects, and pests.

2. Drip irrigation : For the revival of soil health and as biofertilizer for the crop, waste decomposer is used during irrigation in the field by mixing the mass multiplied solution with water. 200 litres of waste decomposer solution is enough for 1 acre land.

3. Seed Treatment : Simply spray/sprinkle the waste decomposer solution uniformly over any type of seeds. Leave the treated seeds under shade for 30 minutes. After 30 min. the seeds are ready for sowing. Various seed borne diseases are controlled by waste decomposer.

4. Foliar Spray : The mass multiplied liquid waste decomposer culture is diluted in the ratio of 1:10 with water and applied as a foliar spray to control pest and diseases.

Multi-potent efficiency of Waste Decomposer

1. Disease Management : Waste Decomposer has a great potential to control a variety of fungal bacterial and viral diseases effectively in different crops. Waste Decomposer application eliminates the usage of all pesticides/fungicide/insecticide since it controls both root diseases and shoots diseases.

2. Crop quality and yield : Waste Decomposer is a promising tool for good quality of crop and high yields. It was reported by the farmers that usage of Waste Decomposer in their fields has resulted in the luxuriant growth of the crop.

3. No Chemical Fertilizer : No chemical fertilizers (like urea, DAP, MOP etc) are required for growing crops when the Waste Decomposer is applied in organic fields. Waste Decomposer technology is an alternate for all the chemical fertilizers.

5. Effect of Waste Decomposer on Soil : Waste Decomposer application changes the biological and physico-chemical properties of soil, thereby soil becomes favorable for plant growth. The biological properties of the soil seemed to changed tremendously in terms of increase in beneficial macro and micro soil biota, as well as innumerable quantity of earthworms in the field.

6. Effect on Seed Germination : Waste Decomposer seed treatments help to control soil borne diseases and also enhances plant growth and yield as it got the ability to alleviate biotic stress (seed and seedling disease caused by soil borne pathogens) and abiotic stresses (osmotic, salinity, chilling, or heat shock).

7. Promising tool for Swachh Bharat Abhyian : Waste Decomposer has become a prominent tool in Hon'ble Prime Minister Flagship programme Swachh Bharat Abhiyan as the single bottle of Waste Decomposer has the efficiency of converting more than 1 lakh metric ton of bio-waste. As result, it was widely used in Swachhta Pakhwara which held from 16 to 31 May 2017, where in 64 Mandis (including 16 model mandis) 148 campaigns were organized across India and Waste Decomposer technology was demonstrated and this initiation has gathered great momentum for composting. Waste Decomposer is also used in cleaning toilets and reduction of the foul odour generated from toilet/septic tanks especially in villages. This characteristic feature very much admirable and drives Swachh Bharat Abhiyan to reap its benefits by making the village environment clean in terms of foul odour.

Success Stories

Since the launch of Waste Decomposer more than 5 lakh farmers have used it and revived their soils/fields and all of them witnessed no crop damage by pests and have got the good yields. It is often said by the farmers that the input cost has reduced to zero and their income is doubled by the usage of Waste Decomposer, the success stories can be seen on youtube channel of Dr. Krishan Chandra. Some of the success stories published on youtube are given as links below:

For more information on use of Waste Decomposer, in regional languages, please click the below given youtube link :

https://www.youtube.com/watch?v=CpDoYhkYT2c&t=33s (Hindi)
https://www.youtube.com/watch?v=uUxQP5LxGL8&t=80s (Hindi)
https://www.youtube.com/watch?v=4kWT7uooiLE (Hindi)
https://www.youtube.com/watch?v=HE23HxzpEb0 (Hindi)
https://www.youtube.com/watch?v=MWWnyir8gRo (Hindi)
https://www.youtube.com/watch?v=GutOBQQhODY&t=22s (Hindi)
https://www.youtube.com/watch?v=MWWnyir8gRo (Hindi)
https://www.youtube.com/watch?v=yM4aCHtTRc8 (Hindi)
https://www.youtube.com/watch?v=X0Gj-8YqYoI (Hindi)
https://www.youtube.com/watch?v=4_SnTCiT1RE (Hindi)
https://www.youtube.com/watch?v=_ePRyiT44kU (Hindi)
https://www.youtube.com/watch?v=j1tUvXSq608 (Hindi)
https://www.youtube.com/watch?v=OEeJRqrIFtY (Hindi)
https://www.youtube.com/watch?v=IdocnmFcvvI (Hindi)
https://www.youtube.com/watch?v=96wDnHUETEI (Hindi)
https://www.youtube.com/watch?v=Vprh13OcsTI (Hindi)
https://www.youtube.com/watch?v=HjTe2deMHZI (Hindi)
https://www.youtube.com/watch?v=Qq91JqX0wAo (Punjabi)
https://www.youtube.com/watch?v=75rjEXm-OVA&t=32s (Kannad)
https://www.youtube.com/watch?v=DIsrK-jcOm4&t=31s (Manipuri)
https://www.youtube.com/watch?v=2HS_gxafMeY (Assami)
https://www.youtube.com/watch?v=Fdikauc3a_o (Assami)
https://www.youtube.com/watch?v=7gcSe9nECH8
https://www.youtube.com/watch?v=04Qds-WrE94 (Oriya)
https://www.youtube.com/watch?v=Huq7r7qFYDI (Oriya)
https://www.youtube.com/watch?v=y43M_66473Q (Nagaland)
https://www.youtube.com/watch?v=UqX6D9eyw_E&spfreload=10 (Marathi)
https://www.youtube.com/watch?v=oxGBveUzjsM (Telugu)
https://www.youtube.com/watch?v=TtJiPNcv29k (Telugu)
https://www.youtube.com/watch?v=X8U0Mob8HSc (Telugu)
https://www.youtube.com/watch?v=Yff6m1B2L7I (Telugu)
https://www.youtube.com/watch?v=zxbjfjrNDQw (Telugu)
https://www.youtube.com/watch?v=yq9C5pgK8Lw (Bengali)
https://www.youtube.com/watch?v=CpDoYhkYT2c (English)
https://www.youtube.com/watch?v=GutOBQQhODY (English)
https://www.youtube.com/watch?v=K592iMuxKl0 (English)
https://www.youtube.com/watch?v=45neaDyR8SE (English)
https://www.youtube.com/watch?v=EVWjarcZ8rQ (English)
https://ncvid.com/video/waste-decomposer-an-experience.html

Findings of Waste Decomposer Efficiency in Crop Residue Management by ICAR-IIFSR, Modipuram

The ICAR-IIFSR, Modipuram has given its findings regarding the efficiency of Waste Decomposer by carrying research for two months. Dr. N. Ravi Shankar, Principal Scientist and his team comprising of Dr. Debahsis Dutta, Senior Scientist, and others studied the efficiency of Waste Decomposer by treating the Wheat, Rice and Sugar cane residue with it under laboratory and pot culture techniques and found that the decomposition of the residue is done just in one month. Dr. Ravi Shankar said that they are in a process to analyze all the biochemical compositions of the decomposed material shortly. The Waste Decomposer was procured by ICAR-IIFSR of their own interest due to its popularity among the farmers.

For this study they obtained waste decomposer from National Centre of Organic Farming (NCOF), Ghaziabad and evaluated its efficacy of decomposition of wastes such as rice straw, wheat straw and sugarcane trash through lab and pot culture experiments. The basic characterization of Waste Decomposer was also done at NPOF centre, Narendrapur (West Bengal).

Characterization of Waste Decomposer

The pH, organic carbon and microbial parameters were analysed at different days. It was found that pH was in the range of 4 to 6 while organic carbon in the range of 0.40 to 0.60 (Fig 1 & 2). The microbial load indicated waste decomposer was having cellulose & xylan degrading bacteria besides the phosphorus and Potassium solubilizes which contributes for enhanced decomposition of residues (Table 1).

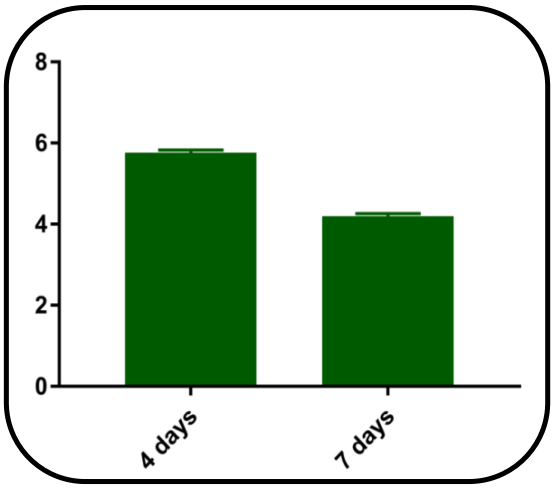

Fig 1. pH

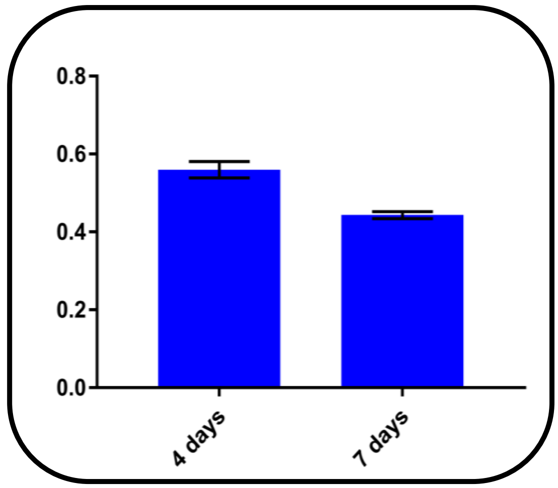

Fig 2. Organic carbon

Table: Population of micro-organisms in Waste Decomposer

Type of bacteria	Bacterial population
Cellulose degrading bacteria	$10.0x10^7$
Xylan degrading bacteria	$2.4x10^6$
PSBs	$2.0x10^7$
KSBs	$8.0x10^4$

Nutrient release during decomposition

Nutrient release and decomposition pattern in different residues was studied at ICAR-IIFSR, Modipuram with different combinations of residues, water, decomposer, FYM and mulching. The details of the treatment evaluated with 4 replications are given below. It was found that carbon mineralization and soil available nitrogen was higher under waste decomposer applied treatments in all the residues from 42 days onwards (Table 2 & Fig 3-5). Waste decomposer could able to enhance the decomposition rate of all the residues and also makes available nitrogen, phosphorus and potassium from soil due to presence of cellulose degrading bacteria besides phosphorus and potassium solubilizes.

Treatment	Rice residue	Wheat residue	Sugarcane residue
T_1	Rice residue + Water	Wheat residue + Water	Sugarcane residue + Water
T_2	Rice residue + Water + Waste decomposer	Wheat residue + Water + Waste decomposer	Sugarcane residue + Water + Waste decomposer
T_3	Rice residue + Water + FYM	Wheat residue + Water + FYM	Sugarcane residue + Water + FYM
T_4	Rice residue + Water + Waste decomposer + FYM	Wheat residue + Water + Waste decomposer + FYM	Sugarcane residue + Water + Waste decomposer + FYM
T_5	Rice residue + Water + Waste decomposer + mulching	Wheat residue + Water + Waste decomposer + mulching	Sugarcane residue + Water + Waste decomposer + mulching

Table 2. Soil available nitrogen (kg/ha) due to decomposition

Treatments	30 days	42 days	54 days
RICE			
T1	179.80	142.16	150.53
T2	163.07	142.17	**175.62**
T3	196.53	175.62	175.62
T4	175.62	137.98	167.25
T5	150.53	**200.70**	**188.16**
WHEAT			
T1	179.80	171.43	179.80
T2	179.80	133.80	**183.98**
T3	175.62	150.53	175.62
T4	204.88	146.35	171.44
T5	137.98	**213.25**	**150.53**
SUGARCANE			
T1	171.44	158.89	167.25
T2	150.53	142.17	**183.98**
T3	163.07	146.35	196.52
T4	209.07	163.07	179.80
T5	175.62	**225.79**	**175.62**

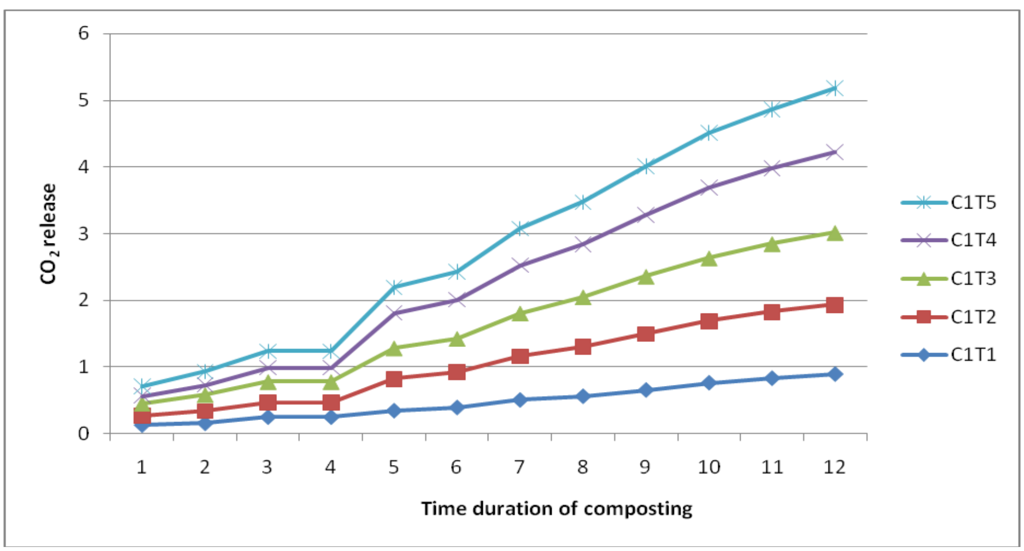

Fig 3. CO2-C release due to waste decomposer addition in rice residue (1=24 hrs, 2=4 days, 3=10 days, 4=21 days, 5=28 days, 6=35 days, 7=42 days, 8=49 days, 9=56 days, 10=63 days, 11=70 days, 12=77 days)

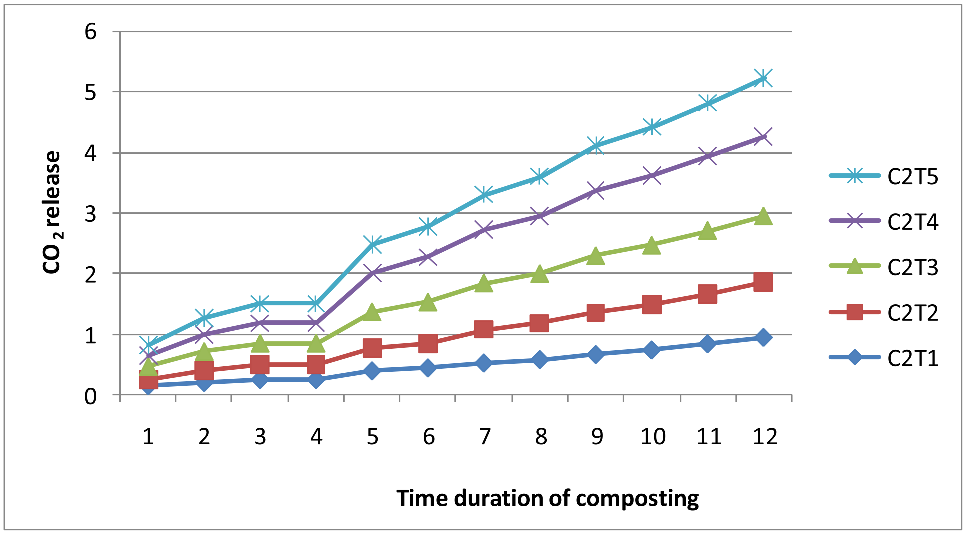

Fig 4. CO_2-C release due to waste decomposer addition in wheat residue (1=24 hrs, 2=4 days, 3=10 days, 4=21 days, 5=28 days, 6=35 days, 7=42 days, 8=49 days, 9=56 days, 10=63 days, 11=70 days, 12=77 days)

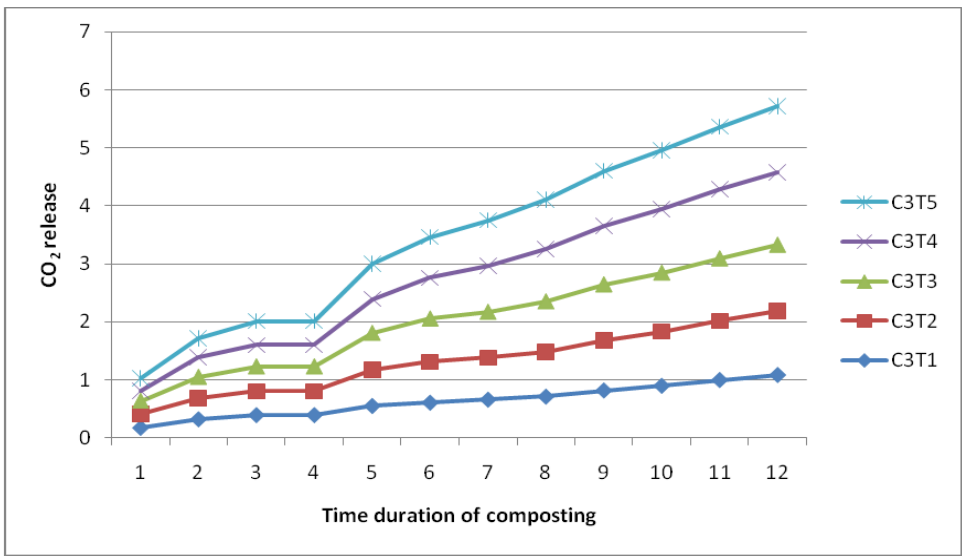

Fig 5. CO2-C release due to waste decomposer addition in Sugarcane trash (1=24 hrs, 2=4 days, 3=10 days, 4=21 days, 5=28 days, 6=35 days, 7=42 days, 8=49 days, 9=56 days, 10=63 days, 11=70 days, 12=77 days)

Further evaluation of waste decomposer through on-station and farmers field is in progress through NPOF centres of Coimbatore (Tamil Nadu), Karjat (Maharashtra) and Narendrapur (West Bengal).

Conclusion

So if agricultural soils and crop residue subjected to waste decomposer treatment for several years would likely acquire a significant layer of organic matter that would reduce the need for commercial available chemical fertilizer applications. This would represent an increase in soil fertility and lead to maintained or increased crop yields while lessening external fertilizer applications. Increased organic matter would also increase soil porosity, water holding capacity, aeration and fertilizer retention.

PRACTICES OF BURNING RICE STUBBLE IN ZERO TILLAGE RABI CROPS – MERITS & DEMERITS

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Rice is the staple food of India. It is the major crop produced in the country and occupies 43.57mha with an average production of 104.32 mt (2015-16) and productivity of 2381kg/ha. India is one of the world's largest producers of rice, accounting for 20% of all world rice production. Due to this, India is self sufficient in feeding its entire population. In Manipur also rice is the only dominant staple food crop occupying an area of 2.2 lakh ha producing about 11 lakh tonnes of straw (9 lakh tonnes in the valley & 2 lakh tonnes in the hill). However, what happens with the straw left after harvesting of paddy? What do farmers do to the bigger tons of paddy straw left? Combine harvester leaves behind a swath of loose rice residues, which interfere with operations of the seed drill used for planting wheat. A large amount of rice residue is annually produced in the rice growing countries. Moreover, the adoption of mechanized farming has resulted in leaving a sizeable amount of rice straw in the field after harvesting the grain. (Mandal *et al.*2004). Total amount of crop residue produced in India is estimated at 350 x 10^{6} kg yr^{-1}, of which rice residue constitutes about 51%and that of wheat residue constitutes about 27%(Lal and Kimble, 2002).Management of rice straw is a major challenge as it is considered to be a poor feed for the animals due to high silica content.Despite such huge amounts of rice straw generation, farmers in the country are yet to realize the potential of this agro-waste in terms of manure and as a profitable raw material for various industries.

Farmers use different straw management practices as per the situation. These practices include: a) burning of rice residue after the rice harvest in order to prepare the field for next crop specially wheat, improve tillage efficiency and reduce the need of herbicides and pesticides to control for diseases, weeds and pests; b) removal of rice straw and its use as animal feed, fuel for cooking purposes, and for manufacturing paper, and hardboard c) incorporation of residue into the soil through use of appropriate farm machinery such as the rotavator and disc harrow and d) surface retention and mulching to protect the fertile surface soil against wind and water erosion. During the last 2 decades, with the popularization of mechanize farming in the state, rice straw burning is becoming a common phenomenon. However, the purpose of burning in Manipur is different to that of North Western India. In the three districts of Manipur viz. Imphal West, Thoubal&Bishnupur rice residues are burnt to facilitate zero tilled repeseed cultivation. The residues are scattered over the field and burnt before sowing seeds with the assumption that the ashes served as rooting medium for the germinated seeds as well as mulches for conserving soil moisture. However, the harmful effects of rice residues burning is not properly known among the farmers of Manipur and yet to be realized.

Rice straw burning in the fields

Rice straw burning and its consequences

Straw burning especially of rice is a common practice for residue management and weed control in Northern India (Mishra *et al.* 2014). Rice residue has to be burned, removed or incorporated into the soil in order to prepare fields for the next crop.The most favored residue management practice in terms of total rice area is complete burning of rice residue followed by removal of rice residue. The need to prepare fields for the succeeding crop specially wheat crop results in hasty burning of rice residue.The primary reason for burning rather than incorporation for enriching the soil is absence of any suitable residue management practice.

A majority of farmers reported an increase in the burning of rice residue after the entry of the 'combine harvester'. This technology allows farmers to harvest their rice crop more quickly and efficiently but leaves straw on the ground. Since labor is very busy at the end of the rice season in harvesting rice and sowingwheat, this machine encourages farmers to burn rice residue in the field (Ahmed and Ahmad, 2013). Farmers burn rice residue also because many believe that it has a beneficial effect on yields. The literature on burning, however, suggests that burning straw after harvesting rice can have both positive and negative effects on soil quality in the short and long run.Burning increases the availability of some nutrients such as phosphorus and potassium in the short run (Erenstein, 2002) and new research suggests that it may increase the productivity of the crop in the next season (Haider, 2012) However, it can also result in the loss of plant nutrients such as nitrogen, potash, sulphur (Gupta *et al*., 2004; Heard *et al*., 2006) and negatively affect the local microbial population and organic carbon (Heard *et al*. 2006).Many research findings show that long-term burning decreased the microbial population of the soil permanently, severely declining the bacteria population involved in nitrification (Raison, 1979; Biederbeck *et al.* 1980).One of the advantages of burning is that it clears the land quickly of residues before the next crop is established, thus facilitating seed germination and establishment. Burning also kills soil borne deleterious pests and pathogens. Phosphorus and potassium showed increased trend in top soil layer due to straw burning while most important plant nutrient i.e. nitrogen decreased in soil samples taken from burnt straw field (Mishra *et al.* 2014).

A growing major concern regarding residue burning emerges from its effects on air pollution and climate change.It is estimated that one tonne rice residue on burning releases 13kg particulate-matter, 60kg CO, 1460kg CO_2, 3.5kg NO_2, 0.2kg SO_2, causing nutrient losses, and serious air quality problems affecting human health and safety. When burnt, the residues instantly generate as much as 13 t of CO_2 ha^{-1}, contaminating the air, depriving the soils of organic matter. Incomplete combustion of biomass such as agriculture residues generates black carbon (Kante, 2009) which is the second largest contributor to global warming after carbon dioxide (UNEP, 2009: Chung *et al.* 2005, Ramanathan and Carmichael, 2008).Burning of rice straw causes gaseous emission of 70% CO_2, 7% CO, 0.66% CH_4, and 2.09% N_2O (Gupta *et al*. 2004). The field burning of crop residues is a major contributor to reduced air quality (particulates, greenhouse gases) and impacts human and animal health both medically and by traumatic road accidents due to restricted visibility in North West India.The peak in asthmatic patients in hospitals in North West India coincides with the annual burning of rice residue in surrounding fields (Yadvinder Singh *et al*. 2010b).

So, although there are some short-term benefits of burning crop residues, there arelong term detrimental effects on soil quality, human health and environment.

Alternate management options of rice straw:

The rice residues can be put to various other uses, if managed properly with the active support of Govt. and other stakeholders and can be used in several useful alternative ways. Various alternatives are being proposed for the use of straw instead of burning it. Retention or incorporationis the most beneficial residue management practice. It has many advantages like, it sustains the productivity of soil as it can hold and supply the nutrients, reduce soil erosion from water and wind, act as mulch to conserve soil moisture and modify soil temperature and improve physical condition of soil (Mehta *et al.* 2013).

Straw mulching in rapeseed-mustard

Mulching of rice residues in zero tillage rapeseed enhances the germination percentage by conserving soil moisture during the lean period of rainfall in winter.Crop residue shows immense potential in terms of residue incorporation in conservation agriculture. Residue retention significantly increases the amounts of mineralizable C and N in the soil compared to situations where the residue is repeatedly burnt.

Continuous retention of high C/N ratio residues (cereal grain residues such as in continuous no till and intensive annual cropping) increases microbial activity in the soil, but not the size of the biomass. This increased activity ensures rapid decomposition and turnover of organic matter, resulting in greater amounts of available nutrients over time (Mishra *et al.* 2014).The significance of recycling the organic resources for replacement of plant nutrients and the residues also contain appreciableamount of secondary and micronutrients. (Verma and Pandey, 2013).

Surplus straw from agriculture may be used for a number of useful purposes such as livestockfeed, fuel, building materials, livestock bedding, composting for mushroom cultivation, and bedding for vegetables such as cucumber, melons etc. and mulching for orchards and other crops(Mandal *et al.* 2004). Spreading and incorporation of straw, however, are labour-intensive tasks, and farmers consider burning to be more expedient.Incorporation of rice residue into the soil is safe ecofriendly practice without any adverse effect on crop yield, and it gradually improves soil organic carbon, phosphorus and potassium contents (Prasad *et al.* 1999) but it leads to some problems as higher cost (compare to burning), increase weed carryover,difficulty of tillage, and increased GHG emission due to flooding while rice cultivation (Summer*et al.* 2003).

Another promising method of utilization of straw is to treat straw so as to produce a useful feed for ruminants such as sheep, beef and dairy cattle. Treatments with sodium hydroxide or ammonium compounds make straw cellulose more available to ruminants for energy conversion.

Rice straw potentially may be collected and used as fuel to make gas and electricity. Other possible products are methane, alcohol, furfural, fuel, oil, and charcoal.The collected crop residues can be effectively utilized in preparation of briquettes which is a renewable source of energy. Biochar is produced via the burning of waste biomassat 300-600ºC in the partial or complete exclusion ofoxygen, a process is known as pyrolysis. Due to therelatively stable biological state of biochar, itsproduction for soil application has been proposed asa way of diverting waste biomass carbon from a rapidto a slow carbon-cycling pool in soil. In the past few years, there has been growing interest in the use of synthetic biochar as an amendment worldwide.

Straw biochar

Application of synthetic biochar in soil may provide a novel soil management practice because of its potential to improve soil fertility, enhance soil carbon, mitigate soil greenhouse gas emissions, reduce leaching of nutrients and chemicals, increase fertilizer use efficiency, and enhance agricultural productivity (Lehmann *et al*. 2006, Chan *et al*. 2007). Enormous quantities of rice straw, rice husk and other surplus residues available in the NW region of India could potentially be pyrolysed to produce bioenergy, thereby reducing field burning and the use of fossil fuels, and the biochar by-product could help to improve soils, avoid methane emissions, and sequester carbon in soils.

Remedy to rice straw burning

A joint effort is under way by Indian and US scientists to end the harmful practice of rice and wheat straw burning in Punjab and convert the crop residue into a product of value to benefit the farmers.The Indo-US team expects to simultaneously address the farmers' agony and environmentalists' concern by introducing a century-old thermo-chemical process called "torrefaction." This is a low-cost process that turns organic waste into "biochar", a kind of charcoal from biomass. The process requires no external energy and consumes all the smoke-causing emissions from the agricultural residue. Once the prototype is validated, it will be tested in India using locally available feedstock such as rice straw, Chandra Prakash, a biotechnologist and one of the Indian promoters of this project, told. "This technology, therefore, has the potential to reduce the contribution of rice straw burning to smog formation in cities, at the same time turning the agricultural waste valuable as a solid fuel (as a charcoal or coal substitute) that can increase farmers' income," Prakash said, adding that the technology would eventually be deployed in Haryana too and would also be employed to check the scourge of farmers in the two states burning the residue of the wheat crop.

When this solution is widely scaled, it is expected to contribute to a reduction in urban smog by lowering emission sources in the rural agricultural areas. "In addition, this process is expected to mitigate greenhouse gas emissions and so help India meet its low-carbon goals." Among the beneficiaries are Punjab farmers who can potentially get Rs 6,000 ($92) additional income per acre through selling the straw.

Conclusions

Rice residue burning has emerged as a serious policy concern in recent years because of its impact on soil and human health and the environment. However, without some technological innovations to make rice residue removal and wheat field preparation less costly, it is likely that this trend in residue burning will continue. There is a need to create awareness among the farming communities about the importance of crop residues in sustainability and its various other uses as mentioned above. Farmers who are burning their residue should be given some form of incentive to move them towards rice residue incorporation, which is the next best alternative.

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MANAGEMENT OF RICE RESIDUE FOR SUSTAINING SOIL HEALTH IN CONSERVATION AGRICULTURE

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Introduction

Rice is the staple food for Asian people, occupies majority areas of cultivable land in this part of the world and accounted for three quarters of the world rice production (Yadvinder*et al*., 2005).As far as India is concerned,rice is cultivated in an area of 43.5 million ha (mha) (27.23% of the arable land) with a production of 104.4 million tonne (mt)and approximately 156.6 mt of rice straw is produced during 2015-16 (Indiastat 2016).The total amount of crop residue generated in India was approximately 350 mt per year of which rice residue accounts for about 51% (178.5 mt) (Mandal*et al*., 2004). Rice is the principal food crop of the northeastern region (NER) of India cultivated on an area of about 3.5 M ha with an average productivity of 1.78 Mg ha^{-1} (Layek et al., 2017). Like, rest of the paddy growing states of India, the north eastern part of the country also generates approximately 10.7 mt of total rice straw. Paddy residue in general is parts of the plants left in the field after the removal of the economic part i.e. grains. It includes both the stubble left standing during the harvest process and the leaves and stems left over after threshing (Bijay-Singh *et al*., 2008). These residues at times have been regarded as waste that require disposal and are often burned in the field, which is a cost effective method widely practiced (Romasanta*et al*., 2017). Rice residue burning has advantages *viz*. elimination/killing of many pest and pathogens, less laborious than straw incorporation, allows rapid and complete residual removal, ease in farm operations, etc. but has many disadvantages from an environmental perspective *viz*. loss of soil nutrients, reduction in biodiversity, reduction on organic carbon content, emission of greenhouse gases in the atmosphere, air quality, etc. (NAAS 2017). Due to the large rice cultivated area, burning rice straw has become one of the main sources to air pollution, where the large losses going into the atmosphere up to 80% N (Dobermann and Witt, 2000), 25% of P and 21% of K (Ponnamperuma, 1984) and 4-60% S (Lefroy*et al*., 1994).Rice crop residue burning to the tunes of millions of tonnes by farmers in north western India in early winter months is major contributor to air pollution and smog in national capital Delhi and is in news for several years. As per some estimates, about 2.2 lakh hectare rice in being cultivated in valley lands of Manipur out of which rice residue from about 60% area (1.32 lakh hectare) is being burned in the months of December after rice harvesting. As per rough estimate, the average rice straw yield in Manipur is around 5.5 t/ha and out of which 20 cm stubbles kept in-situ in field which may contribute for around 2 t/ha. So, about 3.5 ton of rice residue is being burnt per hectare area and if this happened over 1.32 lakh area, about 4.62 lakh ton of rice residue is being burnt every year in Manipur. It is estimated that one tonne rice residue on burning releases 13 kg particulate matter, 60 kg CO, 1460 kg CO_2, 3.5 kg NO_x, 0.2 kg SO_2. So, from rice residue burning in Manipur itself is generating approx. 6006 tonnes of particulate matter, 27720 tonnes of CO, 674520 tonnes of CO_2, 1617 tonnes ofNO_x and 92.4 tonnesof SO_2 every year.

It is widely reported that that as high as around two-thirds to three-fourths of the rice residue are being burnt mainly due to uneconomical options available to farmers for any alternative use of the same (Kumar *et al*., 2015). Farm waste must be properly managed for obtaining positive effects on soil, crop and environment. Rice straw have of great use value as livestock feed, fuel and industrial raw material. Burning of rice residue reduces the availability of feed to livestock mainly cattle and buffaloes, which is already in short supply by 40% (Kumar *et al.*, 2015). Keeping in view the increasing problems associated with paddy stubble burning, there is a need to adopt ways and means to manage this valuable resource. It has become now realized that they are important natural resources and not waste. Recycling of crop residues will help in converting farm waste into useful resource for maintaining the health of soil, plant and environmental quality thereby improving the overall agro ecological system. This enormous amount of rice residue can be managed well with the active support of Govt. and other stakeholders of the region and can be used in several fields. Rice residue can be used preparation of compost and vermicomposting, mulch material, transport cushioning, feed blocks, bedding material for cattle shed, mushroom cultivation, roof thatching, biogas (anaerobic digestion), furnace fuel, biofuel, and paper and pulp board manufacturing etc (NAAS 2017). By adopting these economically viable alternative optionsof using rice residue, residue burning can be minimized to a significant extent.

Status of rice residue production in North East India

Paddy is the main crop for North Eastern India and the total rice straw generation in the eight states of it is approximately 10.7 mtwhich is 6.85% of the country during 2015-16(Table 1) (Indiastat).The straw production is highest in Assam (7.68 mt) followed by Tripura (1.19 mt). As far as Manipur is concerned, it is the 3rd largest (0.51 mt) rice straw generation state in the north east.

Table 1. Area, production and productivity of paddy grain and straw in North East India

State	Area ('000' ha)	Grain production ('000' tonne)	Grain productivity (kg/ha)	*Straw production ('000' tonne)
Arunachal Pradesh	12	204	1584	306
Assam	2485	5125	2062	7688
Manipur	237	339	1429	509
Meghalaya	110	301	2726	452
Mizoram	37	62	1671	93
Nagaland	201	319	1586	479
Sikkim	11	13	1230	20
Tripura	270	795	2946	1193
Sub-total	3480	7158	15234	10737
India	**43499**	**104408**	**2400**	**156612**

*Based on residue to product ratio of 1.5:1 (Sidhu *et al*., 1998)

Reason behind rice residue burning

Burning of crop residues in the field is a common practice in many countries which is mainly done for the purpose of preparing the fields for the next crop rapidly and inexpensively (Gadde*et al.*, 2009).Burning of straw is the cheapest and easiest way for removing large loads of the produced rice straw as compared to costly operation ofincorporation of rice residue within soil (Lal, 2008).Presence of straw in the field complicates the process of ploughing as straws often got caught or struck in the plough machinery causing damage to the machinery and hence increased farm operating cost.Other causes of rice residue burning are unavailability of location specific suitable machines to seed through the rice residue, shortage of labor for gathering and removing of rice straw from the field, lack of awareness about the importance of crop residues and ill effects of burning, etc.The use of combine harvester for harvesting of crops like rice, wheat, etc. has been increasing at a tremendous rate and it leaves behind a swath of loose residues which is difficult to collect, which interfere with the operations of farm machinery like seed drill(Naresh, 2013). It is widely perceived that farmers find burning of the residue the easiest and the most economical way of getting rid of the residues (Kumar *et al*., 2015).Many farmers considered rice straw as agricultural waste and should be removed and cleared from the fields for sowing the next crop in succession. Thus, farmers resorted to take the easiest way out and the cheapest means to clean up the fields i.e. straw burning.

Impact of residue burning on soil

Rice residue contain 0.63% N, 0.19% P and 1.38% K on dry weight basis is (Das *et al*., 2008).So, crop residue is not a waste but rather a useful natural resource if used properly. Burning of rice straw results in losses of 80% N, 25% P, 21% K, 4-60% S and air pollution in the form of CO_2 depriving the soil of its precious organic matter (Mandal*et al*., 2004). Residue removal can therefore have a significant effect on depleting soil nutrient. Burning of straw raises the soil temperature up to 33.8-42.2^{O}C in surface layer upto1.0 cm depth. Fungal and bacterial populations decreased immediately by more than 50% as a result of residue burning.The amount of nutrient loss due to burning of crop residue depends on the method used to burn the straw. If the harvesting has been mechanized, all the straw remains in the field and is rapidly burned *in situ*; thus losses of P, Kand S are small.However, in areas, where the straw is heaped within or away from field, the ash is usually not spread on the field resulting in large losses of minerals (Dobermann and Fairhurst, 2002).

Impact of residue burning on environment

Burning of crop residue causes severe pollution of land, water and air. Open field burning of rice straw releases a large amount of pollutants like SO_2, NOx, including toxic gases such as CO, dioxins and furans, volatile organic compounds, carcinogenic polycyclic aromatic hydrocarbons, as well as inhalable fine particles (Fig. 1) (Oanh*et al*., 2011) and also contributes to formation of atmospheric brown cloud that affects local air quality, atmospheric visibility and earth's climate (Kanokkanjana*et al*., 2011). It also contributes to global warming through emission of greenhouse gases such as CO_2, CH_4 and N_2O (IPCC, 2013).Incomplete combustion of biomass also generates black carbon (Kante, 2009) and is the second largest contributor to global warming after CO_2 (UNEP, 2009). Increased concentration of black carbon and other pollutants, observed in high Himalayas is expected to enhance glacier melting (Nakajima, 2009).Biomass burning and crop residues account for about 18% of global emissions (FAO, 2002).

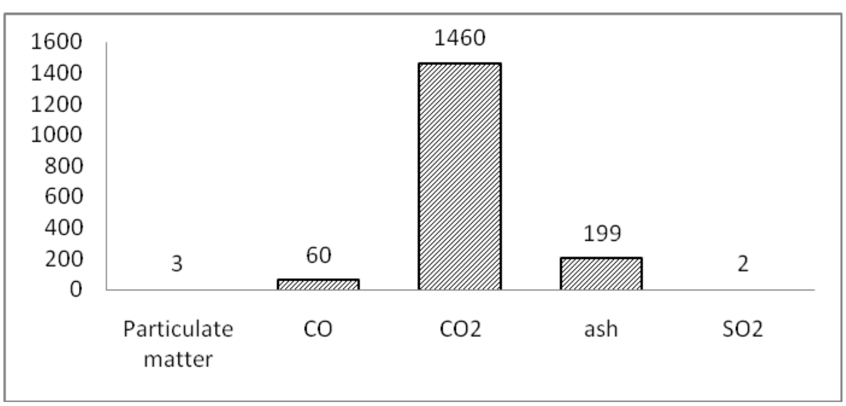

Fig 1. Quantity of different pollutants emitted while burning one tonne of crop residue

(Source: Gupta *et al*., 2004)

Impact of residue burning on health

Air pollution resulting from residue burning can have severe impact on health of both human and animals. The gaseous emissions degrade the air quality and caused a range of health hazards like asthma, bronchitis, cough, eye and skin irritation,lung and heart diseases, etc. The smoke and black shoot generated during burning decreases the visibility which may lead to increased chances of traumatic road accidents resulting in increased individuals' disease mitigation expenses and also affecting ones' working capacity. Burning of crop stubbles result in the emission of harmful chemicals like polychlorinated dibenzo-p-dioxins, polycyclic aromatic hydrocarbons and polychlorinated dibenzofurans and these pollutants have toxicological properties and are carcinogenic in nature (Gadde*et al*., 2009). Most of the population of North Indian states live in rice growing areas and are exposed to air pollution due to mass burning of rice residue. The same may be true for the areas of Manipur and other adjoining areas, where, rice residue burning is increasing day by day.

Alternative management practices to rice reduce burning

Burning of crop biomass causes deterioration in soil, air and water quality. Some management options of rice residue to reduce field burning are given below;

- *Fodder for animals*: Rice straw can be used as fodder for animals preferably after mixing with leafy vegetables and grasses.
- *Bedding material for animals:* Use of paddy straw as bedding material especially during winter helps in improving the quality and quantity of milk as it contributed to animals' comfort, udder and leg health and hygiene. Healthy legs and hooves ensure enhancement of milk production and reproductive efficiency of animals and resulted in increased net profit of Rs. 188-971 per animal per month from the sale of additional amount of milk produced by cows provided with bedding (Kumar *et al*., 2015).
- *Substrate for mushroom cultivation:*Rice straw can be used for cultivation of a variety of mushrooms like *Agaricusbisporus*, *Volvariellavolvaceae* and *Pleurotus* spp.
- *Incorporation of rice straw in the soil:* Incorporation of paddy straw in the soil favorably affects the soil's physical, chemical and biological properties.
- *Conversion to manure:*Rice straw can be converted to valuable manure either through composting or vermicomposting. National Centre of Organic Farming, Ghaziabad developed a very low cost microbial formulation (waste decomposer, Rs. 20/tonne of rice residue) for enhancing degradation of rice residues (within 40-50 days) and preparation of high quality compost.
- *Mulching:* Rice straw can be effectively used as mulching material for growing *rabi* crops. Experiments conducted in ICAR Research Complex for NEH Region, Umiam revealed that application of rice residue as a mulch @5t/ha increase the leaf relative water content (LRWC) of lentil grown in rice fallow. Number of primary and secondary branches of lentil was influenced by various resource conservation practices and significantly higher values for these parameters were recorded with mulching as compared to residue removal. Mulching recorded significantly higher lentil seed yield than 20 cm standing stubble and residue removal.

- *Maintaining longer rice stubble in field:* Harvesting of rice at 40 cm standing stubble can helps in improving the growth of succeeding lentil, pea and toria under rainfed condition and can reduce the generation of rice residue after harvesting. Experiments conducted in ICAR Research Complex for NEH Region, Umiam revealed thatlentil seed yield grown under no till systems after rice was maximum under 40 cm standing stubble (1.84 t/ha) followed by 20 cm standing stubble (1.60 t/ha) as compared to control (1.36 t/ha). (Das *et al.*, 2017).
- *Raw material in industries:* Rice straw is used for manufacturing of paper, straw board, ropes, baskets, etc.
- *Thatching:* Rice straw is used as a thatching material in villages.
- *Packing material:* Rice straw can also be used as packing material for transport of goods to avoid breakage or spoilage.
- *Electricity generation:* Generation of electricity is an attractive option but, at present, only seven-biomass energy plants have been installed in Punjab and six more are in the pipeline. However, these biomass energy plants produce large amount of ash and there is a serious challenge for its disposal (NAAS 2017).
- *Bio-oil and gasification:* Technologies to produce bio-oil (pyrolysis) and gasification are still under research and development to make them economically viable. Moreover, collection (baling) and removing the rice residue from the fields for use in biomass based energy plants is counterproductive for the soil health mission of Government of India. (NAAS 2017))

Residue management for sustainability of the production system

Retention of rice residue in soil surface, incorporation (*in-situ*) in soil as well as composting (*ex-situ*) are the promising on-farmmanagement options to address the issue of burning as well as maintaining soil health and long-term sustainability of Rice based cropping system (NAAS 2017). However*,* these techniques are are energy and cost intensive, and time is a constraint for following them properly. For example, incorporation of rice residue within soil needs 2-3 extra tillage, and one additional irrigation. There is a need for initial extra dose of N to hasten its decomposition. However, with the invention of proper machinery and waste decomposer developed by National Centre for Organic Farming, Ghaziabad, it is possible to fasten the decomposition of rice residue.

Rice straw is rich in nutrients especially K (Table 2). So, incorporation of rice straw encouraged recycling of nutrients. Besides, crop residues are also an important source of soil organic matter (as C constitutes 40% of total dry biomass) which can improve soil properties such as nutrient availability, water retention, cation exchange capacity, etc. As a result of crop residues incorporation within the soil, nutrients and organic matter content in soil increased and need of fertilizer from external sources is reduced.

Table 2. Nutrient content of paddy straw and amounts removed by one tonne of straw

Parameter	N	P	K
Content in straw (% dry matter)	0.63	0.19	1.38
Removal with 1 tonne of straw (kg)	6.3	1.9	13.8

This results in loweringthe cost of production andchances of water pollution (Sarwar*et al*., 2008). So, crop residues if managed properly can serve as an important component for the stability of agricultural ecosystem. Many studies reported positive effects of residue retention/incorporation in conservation agriculture (Das *et al*., 2008). Crop residue retention on the soil surface in combination with no tillage initiates processes that lead to improved soil quality and overall enhancement of resource use efficiency (Sangar and Abrol, 2006). No till combined with residue retention results in more C sequestration than conventional tillage which favored higher earthworm population (Govaert*et al*., 2006). (Das *et al*., 2008) revealed that *in situ* residue management resulted in higher population of bacteria, *Rhizobium*, and phosphorus solubilizing microorganisms compared with organic and inorganically managed soils of the same farm (Table 3). Ghosh *et al.* (2010) reported that performance of no till pea in rice fallow was better under 75% rice residue retention (only panicle harvested) followed by 50% rice residue retention (50% crop residue cut) and complete removal of residues. In case of complete removal of rice residue, the seeds of pea germinated but failed to grow thereafter due to insufficient soil moisture. Improvement in yield and higher soil organic carbon, soil microbial

Table 3. Soil microbial population (cfu/g dry soil) as influenced by in situ residue management, organic and inorganic fertility management

Management practices	Bacteria	Rhizobium	Phosphorus solubilizing bacteria
In situ residue management	129 9 × 10^4	61.6 × 10^4	39.9 × 10^4
Organic management	67.5 9 × 10^4	31.2 × 10^4	26.0 × 10^4
Inorganic management	18.4 9 × 10^4	5.7 × 10^4	7.1 × 10^4

biomass carbon and dehydrogenase activity in no till and residue retention/incorporation plots as compared to residue removed conventional till plots as noted by Ghosh *et al*. (2010) (Fig 2 and Fig 3).

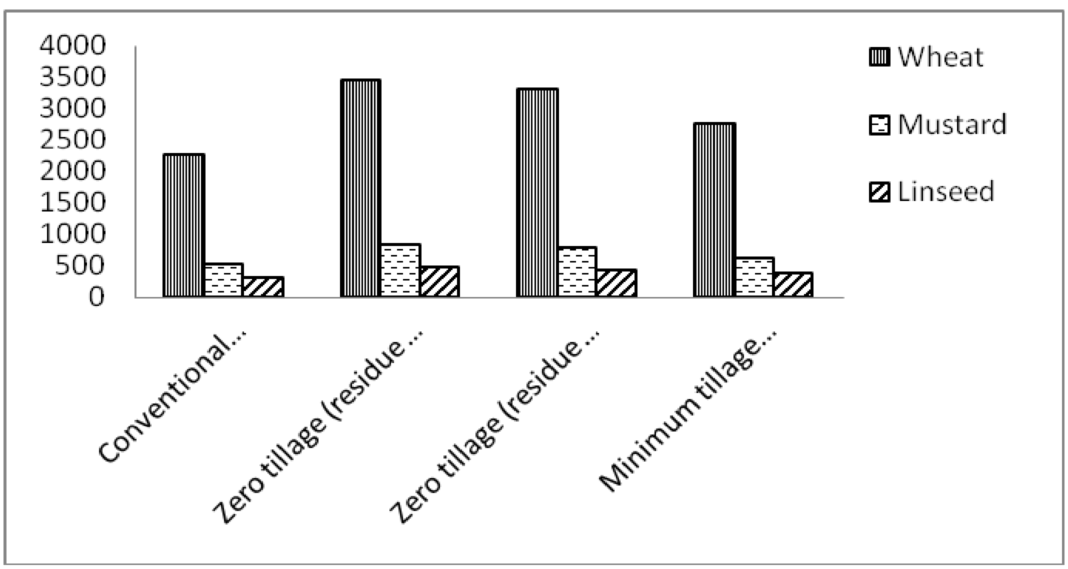

Fig 2. Grain yield (kg/ha) under different tillage practices (at the end of four cropping cycles)

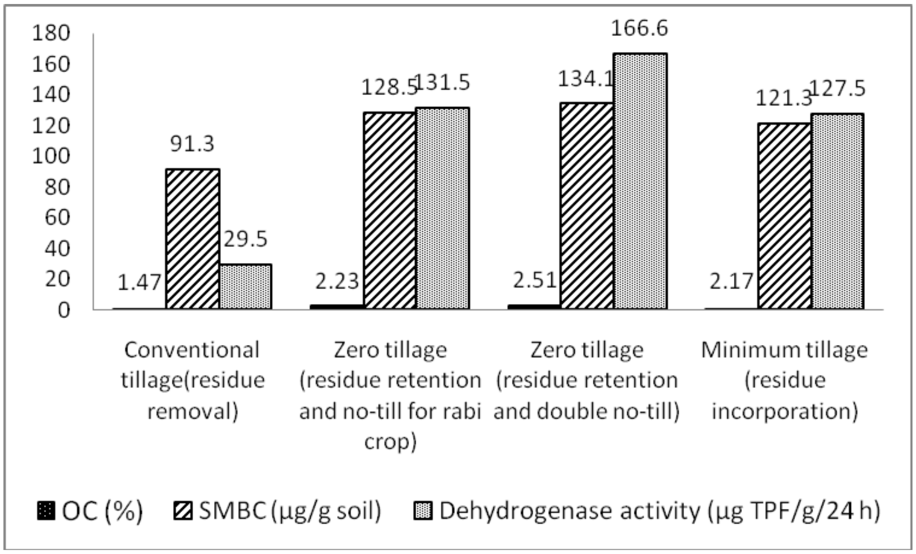

Fig 3. Organic carbon (OC), soil microbial biomass carbon (SMBC) and dehydrogenase activity under different tillage practices

Double no till practice in rice-based system was cost-effective, restored soil organic carbon, favoured biological activity, conserved water and produced better yield, which were 70.75, 46.7 and 49% higher compared to conventional tillage Ghosh *et al*. (2010). Residue management practices had significant impact on soil organic carbon (SOC). The dehydrogenase activity (DHA) and soil microbial biomass carbon (SMBC) were significantly affected by rice stubble management practices. Among the different residue management practices, maximum DHA and SMBC was recorded in soils under 40 cm standing stubble (2.09 µg/g/hr and 160.41µg C/g dry soil 2) followed by 20 cm standing stubble as compared to residue removal. Rice residue management practices had significant impact on soil physical parameters i.e. bulk density, water holding capacity (WHC) and infiltration rate (IR). Least bulk density was recorded with 40 cm standing stubble followed by 20 cm standing stubble and residue removal at 0-15 cm soil depth. The 40 cm standing stubble recoded higher WHC and IR as compare to 20 cm standing stubble and residue removal in both the years (Das *et al.*, 2017).

Super straw management system (SMS)-fitted combines and Turbo Happy Seeder in rice-based cropping systems

Turbo Happy Seeder is recognized as a significant technological innovation for *in-situ* residue management (Sidhu et al. 2015). The Turbo Happy Seeder has proven to be extremely useful and step forward for developing viable solution to rice crop residue burning (NAAS 2017).For efficient sowing of wheat using Turbo Happy Seeder, the loose rice residue need to be uniformly spread across the field, but the traditional combine harvesters put the loose residues in narrow swath. Harvesting of rice by super SMS fitted combine harvesters allows concurrent sowing of wheat, which saves time, energy and one irrigation by utilizing the residual moisture of rice fields. Most importantly, it dispenses the need for crop residueburning**.** This valuable eco-friendly innovation is an attractive option for adoption by the farmers (NAAS 2017).

Conclusion

In the sustainable agricultural system, it become a fact that, “waste is not waste but is the misplaced resource”. Considering this, paddy residue which is considered as the waste at farmer’s perspective must be properly managed at farm level to reduce its negative effect on the farm and environment.

It requires both the scientific and extension intervention to manage the paddy residue on a sustainable basis. There exists ample possibility and opportunity for the farmers to use economically viable alternative option to residue burning through concurrent use of various environmental as well as farmer friendly options. A cost effective *in situ* management of paddy residues can save a considerable amount of fertilizers resulting in reduction of cost of production, contamination of soil and water. It can be achieved through technological breakthrough and should be diffused to the society by adopting suitable extension machinery. A converged effort of all the stakeholders including policy makers should adjoin their shoulders for sustainable management of paddy residue.

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Indiastat 2015-16 State/season wise area, production and productivity of rice in India http//indiastat.com

STATUS OF RICE CULTIVATION AND VIABLE OPTIONS FOR RICE RESIDUE MANAGEMENT IN MANIPUR

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Introduction

Manipur is an important state of the north eastern Indiacovering an area of 22,327 sq. km. It is surrounded by Nagaland to the north, Mizoram to the south, and Assam to the west; Burma lies to its east. Agriculture is not onlythe main source of livelihood of the overwhelming majority, but also a tradition and away of life that moulds the socio-economic status of the people.More than half (52.19 percent) of its population depend upon the agriculture sector, especially the rice cultivation. The Gross Cropped Area (GCA) is 3.3 lakh hectares (12.98 per cent). Around 90 percent of GCA of the state is covered by rice and average cropping intensity is accounted at 143.26 per cent in 2011-12 (Singh and Mishra 2015). This indicates that the average ratio of rice area sown is found to be 1.5 times annually in the state. Directorate of Rice Development, Patna, Government of India, ranked Manipur as 8th in the country with productivity 2369 kg/ha in 2006-07.

Status of rice cultivation in Manipur

Rice is cultivated in 9 districts of Manipur. Out of which 4 districts are under high productivity and rest 5 districts are in low productivity groups. Triennium average area of high productivity group (yield more than 2,500 kg/ha) comprising of 4 districts was 1.11 lakh hectares, which was 60.3% of triennium average area (1.84 lakh hectares) under rice in the state. Triennium average production was 3.31 lakh tonnes, which was 80.7% of triennium average production (4.10 lakh tonnes) of rice in the State. Triennium average productivity of high productivity group comprising of 4 districts was 2,982 kg/ha as against 2,228 kg/ha triennium average productivity of the State.

Triennium average area of low productivity group (yield 1,000-1,500 kg/ha) comprising of 5 districts was 0.73 lakh hectares, which was 39.7% of triennium average area (1.84 lakh hectares) under rice in the State. Triennium average production was 0.79 lakh tonnes, which was 19.3% of triennium average production (4.10 lakh tonnes) of rice in the State. Triennium average productivity of low productivity group comprising of 5 districts was 1,082 kg/ha as against 2,228 kg/ha triennium average productivity of the State.

About 60% of total area under rice in the State is concentrated in high productivity group and accounts for about 80% of total rice production in the State. Triennium average productivity of the State is 2,228 kg/ha, which is about 14% higher than triennium average productivity of the country.

Table1: Area, Production & yield of Rice in Manipur, during 2015-16

Crop	Area ('000 ha)	Production ('000 MT)	Productivity (t/ha)
Pre Kharif Paddy	42.00	168.19	4.00
HYV Paddy	106.18	233.50	2.20
Jhum Paddy	78.82	90.79	1.15
Terrace Paddy	10.00	15.66	1.57
Total paddy	**195.00**	**339.95**	**1.74**

Table2: District wise Area, Production and yield of Rice in Manipur, during 2015-16

District	Rice		
	Area (000 ha)	Yield (t/ha))	Production (000 t)
Senapati	12.10	1.60	14.44
Tamenglong	27.45	1.25	34.37
Churachandpur	29.12	1.14	33.14
Chandel	10.03	1.23	12.3
Ukhrul	10.12	1.21	12.2
Imphal East	36.65	2.95	108.09
Imphal West	43.45	2.56	111.27
Bishnupur	33.33	2.62	87.25
Thoubal	34.75	2.74	95.08
Manipur	**237.0**	**2.14**	**508.14**

Source: Department of Agriculture, Manipur

The role of environment on rice farming economy stilloccupies some significant impacts of rice production in the state.Based on the rice agro-ecosystems prevailing in NEH Region, rice may also be classified as hill or slope land rice, valley or flat land rice and low lying semi-deep water and deep water rice. Hill or slope rice is grown in hill slopes either in the *jhum*field as rainfed upland direct seeded rice or in terraces as rainfed or irrigated wetland transplanted rice grown on higher altitude up to 2500 m MSL. Valley or flat rice is grown in flat land either as rainfed upland direct seeded rice or rainfed wetland direct seeded rice with sprouted seeds or rainfed wetland transplanted rice or irrigated wetland transplanted rice. Semi deep water or deep water rice are generally adapted to semi-deep water (say from 0.5 to 2.0 m) and deep water conditions (more than 2.0 m). This rice is generally direct seeded before monsoon rains.

Rice based cropping system is most predominant in NEH region with exception of Sikkim with maize as important crop. Field experiments conducted by the research Institutes, Universities and KVKs indicated possibility for quantum jump in rice productivity by adopting high yielding varieties, adequate amount of fertilizer and manure, weed management and plant protection measures. Almost all the rice area is under rainfed condition. Farmers mostly practice direct seeding or random transplanting and transplant older seedlings with 3 to 5 seedlings/hill. Adequate establishment methods, selection of good quality seeds of HYVs, seed treatment along with a good nursery practice is the key to success in rice production (Anup Das et al., 2012).

Table 3.Average area, production, productivity, requirement, excess/deficit and % excess/deficit of NEH states from the year 2006-07 to 2010-11.

States	Area (in lakh ha)	Production (in lakh tonnes)	Productivity (kg/ha)	Requirement (in lakh MT)	Excess(+)/ Deficit(-) (in lakh MT)	Excess(+)/ Deficit(-) %
Arunachal Pradesh	1.232	1.836	1493	2.143	(-)0.307	(-)16.72
Manipur	1.765	4.062	2293	4.219	(-)0.157	(-)3.87
Meghalaya	1.072	2.035	1901	4.594	(-)2.559	(-)125.75

Mizoram	0.495	0.367	767	1.691	(-)1.324	(-)360.76
Nagaland	1.721	3.043	1761	3.070	(-)0.027	(-)0.89
Sikkim	0.138	0.224	1630	0.942	(-)0.718	(-)320.54
Tripura	2.482	6.430	2591	5.690	(+)0.740	(+)11.51
NEH states	8.905	17.997	2021	22.349	(-)4.352	(-)24.18

Source: Directorate of Rice Development, Ministry of Agriculture, Govt. of India.

Per capita consumption of rice: 155 kg/person/year (www.rice.ws)

Population: As per 2011 census.

The average rice productivity in the NEH states varies from 767 kg/ha in Mizoram to 2591 kg/ha in Tripura with a total rice deficit of about 4.35 lakh metric tonnes. To be self sufficient in rice for the NEH states, rice production is to be increased by 24.2 % from the present level of production. As the availability of land area for rice cultivation in NEH Region has become a limiting factor, increasing the level of productivity wherever possible by adopting the best available rice production technology to meet the ever increasing demand of rice has now become a great concern(Rohinikumarsingh, 2012).

Residue Management in Agriculture

Agriculture production in India is concentrated in a vast agricultural net cropped area of 143 m ha where nearly producing 252.22 million tonnes out of which 104.3 million tonnes of rice and 93.5 million tonnes of wheat are produced annuallyduring 2015-16.There is enormous potential of recycling these residues in the crop production systems. Total amount of crop residue produced in India is estimated at 350 x 10^6 kg per yr, of which wheat residue constitutes about 27% and that of rice about 51% (Lal and Tandon, 2002, Krishna et. al., 2004). Among these residues, a large portion of about 140 million tonnes burnt 40% of all crop residue burning is attributable to Paddy Straw, 22% to Wheat Residue and 20% to Sugarcane in the fields to clear it from fields after harvest of the proceeding crop (Mehta *et al*., 2018).Traditionally, most of the paddy stubbles are burnt in fields during October–November. India now has a second season of crop residue burning April–May from wheat and other *rabi* crops.

In 2008, about 620 million tons of rice straw and about 125 million tons of husks (referred to as "residues") were produced in Asia alone, and this quantity is increasing every year. In most places, these residues have no commercial value and are disposed off in various ways. In intensive systems, where two or three crops are grown each year, the time for residue decomposition is very short and the remaining residues may disrupt soil preparation, crop establishment, and early crop growth. Although residue retention is essential for sustainable soil management of non-rice crops and mixed croppings systems (rice-upland crops), research in long-term experiments has shown that complete residue removal has no negative consequences for the productivity, sustainability, and soil health of intensive double and triple-cropping rice systems.However, where practiced, burning of rice residues causes severe air pollution in some regions. The alternative, residue incorporation into the soil, in turn causes methane emissions from rice fields, contributing to climate change.

High yields and intensive land use in irrigated rice-based cropping systems result in production of huge quantities of crop residues, which Asian farmers often burn.The rapid introduction of combine harvesters is a game changer as combines spread rice straw in the field, which gives options in collecting them. Manual collection is unprofitable because of the high labour cost. Incorporation in the soil is also not possible in systems with two to three crops per year because the turnaround time is too short for decomposition. These constraints lead widely to farmers burning the rice straw directly in the field, causing the release of greenhouse gas emissions and human health problems. The field burning of crop residues is a major contributor to reduced air quality and human respiratory ailments in intensive rice production areas of Asia, especially in north-western India and portions of China (Nguyen et al 2008, Streets et al., 2003).There is immediate need to realize the importance of the residue management and an immediate priority is implementing uses of crop residues that avoid burning (Nguyen et al., 2008). One option is incorporation of residues into fields to supply subsequent crops with essential plant nutrients, thereby saving fertilizer, and to supply C, thereby maintaining or building soil fertility (YadvinderSingh et al., 2005).

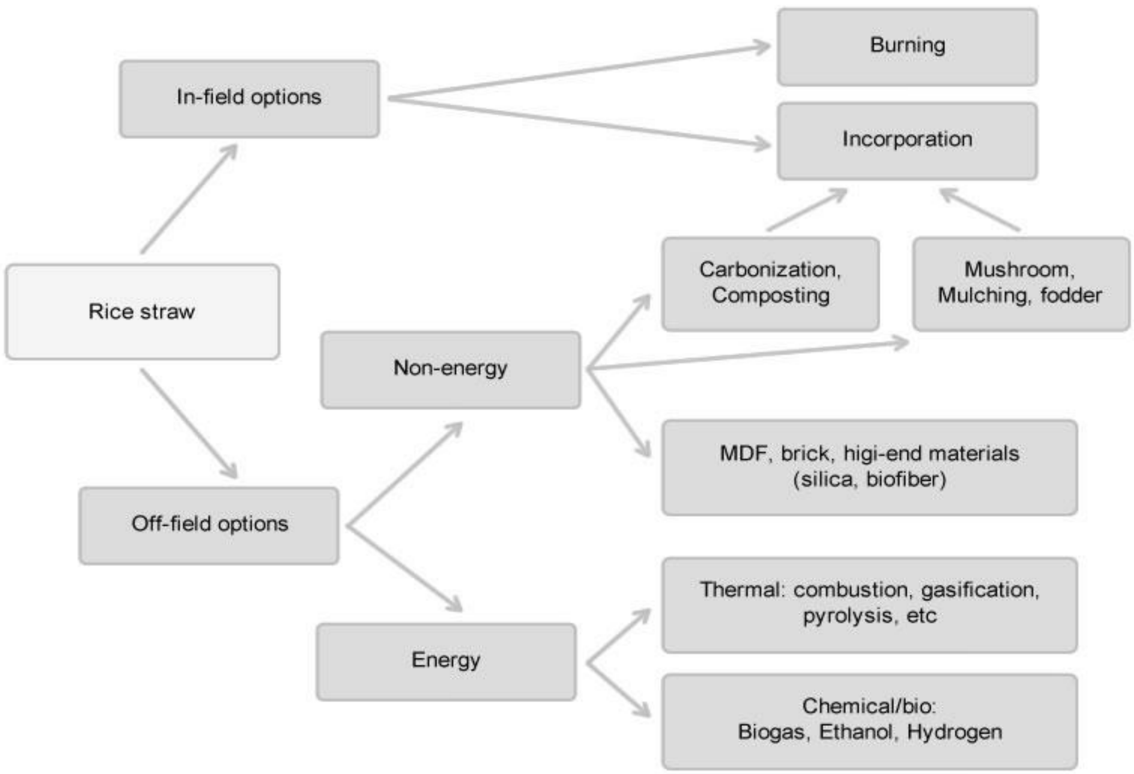

Figure 1. Options for rice straw management and use

Alternate uses of paddy residues

- ***Incorporation of paddy residue into the soil***

Rice crop residues may be incorporated partially or completely into the soil depending upon methods of cultivation (DormaarandCarefoot, 1996). Ploughing is the most efficient residue incorporation method. Singh et al. (2004) reported N immobilization into soil when paddy residue was immediately incorporated before sowing of wheat crop. The decomposition of paddy straw during the wheat seasonleads to release of 6-9 kg N/ha. Thus, wheat productivity was sustained when N fertilizer was applied asper recommended rates. Mandal et al. (2004) studied the effect of different crop residue management practices onthe physio-chemical properties of the soil for 7 years and reported increase in organic C, available N, P, Kand total N, P, K in soils where paddy was incorporated into soil as compared to straw removal orburning (C R Mahata, 2018).Residue incorporation along with N application not only helps in attaining more Ca& K to avoid sodium uptake to elevate the salinity or sodicity but also helps in mineralization and mobilization of essential plant nutrients apart from adding organic matter to improve soil fertility (Syed IshitiqueHyder et al., 2012).

Establishing sustainable agricultural practices together with the restoration of functional food webs for integrated pest management and nutrient cycling has become a major focus of current rice research. Decomposition of rice straw is an important process regulating energy flows and nutrient cycles in rice paddies (Gracia*et al*., 2013). There isimmediate necessity to focus on the establishment of a functional decomposer community which is essential in the development of practices for sustainable agricultural management in rice dominated landscapesin Manipur. The decomposition dynamics (interactions between microbes and invertebrates) as well as detritivore community assembly in flooded rice ecosystems has to be standardized which perhaps will be the technology and best solution to the disposal of the rice straw which is a major problem at present.

In fact the three main factors are important for efficient residue decomposition in rice-based cropping systems: (1) crop residue factors (like C/N ratios and lignin concentration), (2) edaphic factors (soil properties like moisture content), and (3) management factors. For a long-term sustainable improvement of management practices in paddy fields, it is crucial to understand the ways in which these often interacting factors influence the decomposition of rice straw (Singh Y et al., 2005)

Incorporation of rice straw into paddy soil improperly and ineffectively can result in a decrease in production efficiency and an increase in greenhouse gas emissions (GHGE) (Sander et al 2014). Some farmers, however, do not practice incorporation because of the slow decomposition rate of rice straw, which may not be completed within the short turnaround time of less than three weeks before the next rice cropping season. At IRRI monitored the total carbon dioxide equivalent (CO_2-eq) per ha converted from $CH_4$and N_2O in a rice crop season with straw incorporation emitted about 3,500 kg CO_2-eq per ha. This amount of GHGE was almost 1.5 times higher than the amount emitted from the practice of rice straw removal. Thus to speed up the decomposition rate of rice straw, use of fungal inoculums (Goyal and Sindhu 2011, Ngo et al 2012) helped foster its decomposition in the soil in Vietneum using specially designed machine to harvest and chop rice straw in addition to spraying of inoculum in the straw (*Trichoderma*).

- ***Used as a cattle feed in some areas during lean period of fodder availability***

Rice straw is considered to be a feed for animals owing to its high silica content (Mandal*et al*., 2004) the use of is restricted to only few parts of the country.Because of the limited nutritive value of the rice straw (low crude protein and digestibility) it should be used as only replacement for the part of the forage in ration. It should not be used as a complete ration. However, paddy straw will be a source of fodder during lean period of fodder availability. Increasing the conscious against the burning of straw due to environmental impacts awareness is increasing among the farmers to be blended and fortified with other feeds to be uses as cattle feed.

The major challenges to use it as cattle feed are like palatability like cattle prefer to eat if the time between baling the straw should be less than 10 days after harvest. Rice straw is considered to be a feed for animals owing to its high silica content (Mandal*et al*., 2004) of 8-14 % which is indigestible and reduces the digestibility of the feed. It contains crude protein content of 2-7% on dry matter basis needs to protein supplements to meet the protein requirements of cattle. It also contains oxalates decreases the absorption of calcium (Dineal*et al*., 2002).

- ***Used as mulching materials for the succeeding crops***.

The retention of crop residues as mulch on soil surfaceconserves soil water, moderates the thermal regimes, suppressesweeds and improves fertility, which in turn help in improving cropyields and may result in saving of irrigation water.The straw mulchingof crops has been useful in both irrigated and rainfed environments (Mehta C R., *et al*., 2018).

- ***Used for composting to prepare compost using different microbial consortia***

The abundance of rice straw as an organic waste can be converted to fertilizer throughout the process of composting. Composting was the first concept for using effective microorganisms (EM) in environmental management. Crop residues and animal wastes have been effectively composted to produce bio-fertilizers (MohdLokman, *et al*., 2013). Although organic fertilizers, including rice compost, are often low in major nutrients such as nitrogen (N) and phosphorus (P), they can be highly beneficial because they contain micronutrients, enzymes and micro-organisms that are often not found in inorganic fertilizers. Rice straw is rich in potassium (K).

- ***Used as a media for growth of mushrooms***

Mushroom cultivation is a profitable agri-business enterprise which literally produces food from rice and wheat straw while facilitating the proper eco-friendly disposal of this straw. The paddy straw mushroom, *Volvariellavolvacea* , is considered to be one of the easiest mushrooms to cultivate with its short incubation period of 14 days (Reyes 2000). Using rice straw for mushroom production can yield about 5–10% of mushroom products (50–100 kg of mushroom per 1 ton of dried straw) (Zhang et al 2002 and Ngo 2011). On the other hand, cultivation of the oyster mushroom *Pleurotus* spp. offers an on-farm technology for the bio-conversion of poor-quality straw into nutritious food products. This not only helps in providing nutritional security to the farmers, but also helps in the doubling of the farmers income.

- ***Utilized to prepare rope by twining straw and packaging materials***.

Rice straw is fibrous and has good strength to be coiled together to make ropes which has very vast uses among the farmers. Some farmers use this ropes to pack the temporary grain storage structures made out of bamboo for sealing the storage structures. This acts as a better packaging material in addition to providing support to the storage structure. Further it can also be used as a packaging material to delicate items like glasses, equipment, marble tiles, cardboards and other high value goods to protect them during transportation.

- ***Rice residues are also used in the extraction of silica and also used as industrial material in extraction of paper***

It can be successfully synthesize silica particles from rice straw waste using simple extraction method. This can be done by heating and extracting rice straw waste into basic solution. The extracted solution was then put into acid solution and heated to remove the remained solvent. The aggregated silica particles with sizes of about 200 nm were successfully produced which has no. of industrial uses. (A B D Nandiyantoet al., 2016).

Silica rich plant material has the potential of transforming the electrochemical properties of acidic soils that reduces P fixation; improves base retention and increase the soil pH. Therefore, retention or incorporation of particularly the rice residues can manifest all the benefits of liming acidic soils. This is a common practice with most Indian farmers in the hills where acidic soils are found. Benefits of rice crop residues incorporation as soil amendments (as substitute for liming material) can also be tested in high rainfall regions of eastern India and Bangladesh, where acidic soils are commonly found and deficiencies of Zn, B and P are at times quite acute.

About 30% of India's paper is made from agricultural residue and/or non-wood fibers like rice residues and so on.

- ***Biochar production and utilization***

Biochar, a carbon-rich product, is used as soil amendment to improve soil productivity, carbon storage, and filtration of percolating soil water (Lehmann and Joseph 2009). It is produced by the thermal decomposition of organic materials or biomass under a limited supply of oxygen at temperatures from 500 to 700°C.

Using rice straw to produce *biochar* has huge potential. Also, carbon sequestration in the application of biochar helps GHG emissions in the atmosphere. Reduction in emissions associated with using biochar as soil amendment is higher than the fossil fuel offset in its use as fuel (Gaunt and Lehmann 2008).Despite its huge potential, however, the processing of *biochar* requires energy for carbonization and for transportation of rice straw and *biochar* products. There is still a need for scientific evaluations for the feasibility of *biochar* production from rice straw and utility by farmers in terms of energy balance and economic benefits.

- ***Rice residues can be converted into biogas***

Rice straw and cattle dung are arranged layer by layer in the digester. The ratio of the layers of rice straw to cattle dung is 4:1 based on the weight with the specified moisture content (MC). Feedstock with 1.6 tons of chopped straw (15–18% MC) and 0.4 ton of cow dung (30–40% MC) is fed into a batch digester with a retention time of 100–120 days. Biogas is generated on the 7th day after feeding, with average yield of 4–5 m^3biogas per day in about 100 days. Methane content is about 65%. In addition to the outputs, about 0.4 ton of digestate is obtained and used as organic fertilizer.

Major impact of residue burning

Rice straw is a by-product produced when harvesting paddy. Each kilogram of milled rice produced results in roughly 0.7-1.4 kilos of rice straw depending on varieties, cutting-height of the stubbles, and moisture content during harvest. Rice straw is separated from the grains after the plants are threshed either manually, using stationary threshers, or more recently, by using combine threshers.

An exhaustive study conducted by IIT Kanpur in 2015 study attributes 17% of PM10 and 26% of PM2.5 emissions in Delhi to biomass burning in winter (Mukesh and Onkar, 2016). Crop Residue Burning also results in large-scale loss of nutrients – 100% of carbon, 80–90% of the nitrogen, 25% of the phosphorus, 20% of the potassium and 50% of the sulphurBurning crop residue in one year alone results in the loss of 1.43 million tonnes of nutrients from the top soil layer(Mehta *et al*., 2018).

Table 4: Effects of Paddy Straw Burning

	Nutrient Loss	kg/t	kg/ha
1	Nitrogen	5.5	33.0
2	Phosphorus (partial in burning)	2.3	13.8
3	Potash (Negligible in burning)	25.0	150
4	Sulfur	1.2	7.2
5	Micro-nutrients	10-20	60-120
6	Soil organic carbon	400	2400

(Source: Presentation of Dr. C R Mehta, Project Coordinator, AICRP on FIM,CIAE,Bophal)

The cultivation of high yielding varieties of paddy has helped in ensuring the food security in the states and country by at the same time has resulted in the production of huge quantities of the crops residues. Due to shortage of labour force for harvesting, it is harvested using mechanical harvesting using combined harvesters. In the major rice growing states like Punjab and Haryana about 23 million tonnes of straw is burnt out of 30 million tonnes of straw. However the farmers prefer to burn straw due to lack of time (2-3 weeks) after harvest of paddy to prepare next crop. In some areas of Manipur, farmers burn the residues to bring down the moisture content along with easy straw disposal in the paddy field for next *rabi* pules and oil seed crops to be grown. Unlike wheat and maize straw, rice straw is not suitable for feeding to cattle due to higher silica content (Arora and Sehagal, 1999). The requirements of the cattle feed are met from other cattle feeds and forages. So burning seems to be the easiest and cheapest method of the straw disposal to the farmers at the cost of environment.

Thus one of the biggest problems facing humankind in recent years is the environmental pollution resulting from industrial wastes and living materials (Yang et al., 2004). Uncontrolled burning is often considered the most cost-effective disposal method for such by-products (Nehid*et al*., 2003). This seasonal and highly localised massive burning generates excessive air pollution that lowers air quality. Recently problem of smog was observed in and around Delhi due to massive burning of straw by farmers. This has become a serious health concern for citizens and authorities (Nehid*et al*., 2003) in all rice growing regions in addition to this loss of nutrients form the cultivated soils, drastic reduction in loss of soil biota. However, the search for new techniques for controlled combustion of rice residues without causing damage to the environment or the best way is to convert it into a useful materialsto mitigate the environmental concerns is a major challenge.

Management of Paddy Straw – some important options.

In view of the bad impacts of faulty disposal of rice straw there is a need to manage huge quantity of paddy residue through different farmmachinery options. Therefore, evaluation and popularization of technologies at farm level needconcentrated efforts of researchers through farmers' participatory approach of technology evaluationand dissemination.

Mechanization Alternatives of Paddy Residue Management

The mechanization alternatives of paddy residue management can be broadly classified into followingtwo groups.

1. **In-situ management of paddy straw**

Incorporation of paddy residue into the soil using

- Conventional tillage methods
- Straw chopping and mixing using tillage tools

Using Tractor Mounted Paddy Straw Chopper-cum-spreader which is now being used in Punjab state.This machine harvests thestubbles, chops them into pieces and spreads on the field in singleoperation. The machine consists of a rotary shaft mounted with"Inverted Gamma" type blades to harvest the straw and a cylindricalunit to chop it. The paddy straw left over by combine harvester can bechopped and mixed into the soil under flooding condition with oneoperation of rotavator. The field can be directly sown using no-till drilland strip-till drill after 15-20 days depending upon type of soil.

Retention of paddy straw as mulch on soil

- Sowing of wheat using Happy seeder
- Straw chopping and sowing of wheat using spatially modified no-till drill

The benefits of minimum and no tillage technologyare well known in terms of economics, timeliness of sowing and watersaving over conventional tillage practices. However, direct drilling isdifficult in combine harvested field. The main reasons are accumulationof loose straw in furrow openers of seed drill, traction problem of drivewheel and non-uniformity of seed placement under heavy trashy conditions (Shukla et al., 2002; Anonymous, 2010).

To overcome these problems, Punjab Agricultural University, Ludhiana developed a machinenamed as Happy seeder which can directly sow wheat in a combine harvested paddy field withoutremoval or burning of straw. It consists of a straw management rotor which cuts and chops the straw infront of furrow openers and guides the cut material between the sowing tynes thus leaving a clear spacefor sowing while leaving the chopped straw as mulch in between the seed rows.Direct drilling of wheat on combine harvested field and pressing of straw as mulch using tractor operated implements like happy seeder. This can also be tried for other crops with necessary modifications which can suit to the cropping systems of Manipur after harvest of rice.

The uniform distribution of loose straw is a pre-requisitefor smooth operation of Happy seeder, the Punjab AgriculturalUniversity, Ludhiana has developed a bruiser type strawmanagement system (Super SMS) and attached to the rear side ofcommercial combine harvester just below the straw walkers andbehind the chaffer sieves.It chops and spreads the loose strawcoming from the straw walker and sieves in the working width ofcombine harvester in a single pass. (Anonymous, 2010)

Removal/collection of paddy straw

The alternative uses of straw like feeding cattle, making of hay and silage and hay, subjecting excess straw to composting and other alternative uses. However removal, collection and storage are very important stages straw management. This can be done using the following ways

- Farm residue collector
- Baling of paddy straw
- Collection of whole straw using head feed combine

Use of Straw Bales

- Bio mass based power plants
- Cardboard/paper making/packing
- Mulching in orchards and crops
- Animal fodder
- Other possible uses
    - Mushroom production
    - Biogas plant
    - Bale geyser
    - Compost making
    - Bio-char making

Economics of Paddy Straw Management

The cost of operations for different mechanized paddy straw management and *rabi* crop sowing practices and their comparative cost economics are reported in Table.

Option		Package/Practice	Cost, Rs/ha
Residue retention as straw mulch	I	Super SMS + Happy Seeder	2875
	II	Super SMS + Spatial drill	2600
	III	Stubble shaver + Happy seeder with press wheels	3330
Residue incorporation	I	Chopper/mulcher + Wet mixing (Rotavator) + spatial/No till drill	5045
	II	Chopper/mulcher + Reversible MB Plough + Rotavator + Planker + spatial seed drill	8264
Residue collection	I	Stubble Shaver + Rake + Baler	5252
Burning		Stubble Shaver + Harrow/cultivator (2-3) + Planker + Seed drill	5500-6000

Source: Adopted from Dr. C R Mehta presentation on Status of farm mechanization for paddy cultivation presented in the national seminar on 'Sustainable rice production technology for increasing the farmers income on 20-21 Jan., 2018.

Government Initiatives for straw management

- Government of Punjab has notified "New and Renewable Sources of Energy Policy - 2012" to promote off-site gainful utilization of crop residues for power generation.
- Slow adoption of straw management machinery
    - High initial cost and operating cost of machinery and
    - No strict compliance to check burning of crop residues in field.
- Promote resource conserving technologies (RCTs) - zero till seed cum ferti drill, roto till drill, Happy seeder etc for sowing and straw combine, hay rake and baler for management of harvested crop residues.
- Need for creating awareness of its bad effects among farmers.
- Discourage burning through incentives and technology transfer.

Source: Parmod Kumar, Surender Kumar and Laxmi Joshi, 2014, Policies for Restricting the Agriculture Residue Burning in Punjab, Socioeconomic and Environmental Implications of Agricultural Residue Burningpp: 117-131(online spinger book)

Conclusion

- Linking farmers' interests with a sustainable improvement of agricultural practices in compliance with nature conservation is one of the future challenges to stabilize or even increase yields while preserving biodiversity and natural landscape structures.
- Treating rice hulls/straw as source to derive silica rather than a waste cansolve the disposal problems confronting Indian growers and further improve airquality. Silica produced would have added a value to the underutilised by-product andminimise the waste disposal problems in the rice industry
- The resource conserving technologies (RCTs) that can be used for management ofcrop residues include zero till seed cum ferti drill, roto till drill, Happy seederetc for sowing and strawcombine, hay rake and baler for management of harvested crop residues
- The tractor drawn PTOoperated straw baler can be used for efficient collection of paddy straw from field in the form of baleswhich can be easily transported.
- Thus it needs concentrated efforts of researchers and extension functionaries for the sensitizing the farmers about the management options for safe disposal of rice crop residues.

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BURNING OF RICE RESIDUE: HAZARDS AND SOLUTIONS

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Manipur, being a hilly ecosystem, agriculture is the mainstay of the people. Agriculture is practised for sustenance and not for commercial activities. The cultivated area of the state approximates to 10% of the total geographical area (Economic Survey Manipur, 2017). Rice is the principal source of food for the state. Rice production accounts for 433.32 thousand tonnes covering an area of 175.16 thousand hectares in the year 2015-16. The valley region (Bishnupur, Imphal East, Imphal West and Thoubal districts) covers about 88.94 thousand hectares with a production of 254.40 thousand tons and 2.85 t ha^{-1} productivity whereas the hilly region (Chandel, Churachandpur, Senapati, Tamenglong and Ukhrul) covers 86.22 thousand ha with a production of 178.9 thousand tons and 2.74 t ha^{-1} productivity (Economic Survey Manipur, 2017). Total paddy straw production is estimated to be about 628.31 thousand tons (368.88 and 259.43 thousand tons from valley and hilly areas, respectively). With the increasing of rice production, the amount of rice residue produced as a by-product, is generated doubled which can be used for many purposes. However, farmers routinely burn their straw in-situ as a method to clear fields prior to initiating mechanized land preparation or after harvesting causing a range of environmental pollution problems.

With the evolution of mechanisation for harvesting the rice crop, burning of rice residues become a major problem as it poses a great threat to the environment. There are various problems faced by farmers on technical, financial and management front on rice residue management. The problems are non- availability of suitable technologies for processing the straw, increased use of combine harvester for crops resulting in long stubbles in the field interfering with tillage and seeding operations for the next season, high cost including labour and transportation cost involved in removal of straw from the field (Roy and Kaur, 2015). Therefore, it has become imperative to understand the reasons for rice residue burning and option driven opportunities to utilize the hidden potential.

Hazards of burning rice residue

Conventionally, rice straw was used as fodder for livestock and used as building materials. However, the increase in size and productivity of paddy areas has led to a huge excess of rice straw. Removing the rice residues from the field is a labour-intensive process. The foremost reason for burning is that the farmers are not aware of hazardous impact of burning rice residues on health and environment. In addition, labour-intensive while collection and lack of knowledge and expertise for converting this so called waste into valuable product is the major factors which compelled farmers to burn the rice residues. Open-field burning is certainly a controversial topic and requires a thorough understanding of its effects.

From the farmers' point of view, burning may be seen as the effortless way for disposing of rice straw. It is not only a cost-effective method but it acts as an effective pest control procedure (Kadam et al., 2000; Dobermann and Fairhurst, 2002). It is also seen as a way of preparing the soil for the next crop as well as releasing nutrients contained in the residue for the next crop cycle (Gadde *et al.*, 2009). Farmers also opined that the decomposition rate of rice residue is very slow and does not complete within short period (less than 3 weeks) before the next cropping season so incorporation practice of rice residues in field causes problems to the farmers while preparing for the next season crop. This led the farmers to burn the residues/stubbles as it was found to be the easiest way for clearing the field for the succeeding crop. Some think burning is a quick, easy and cheap method as all unwanted husk, plants and shrubs get destroyed. Some believe that fire may return nutrients to the land. But burning husk on ground destroys the nutrients in the soil, making it less fertile. Heat generated by stubble burning penetrates into the soil, leading to the loss of the moisture and useful microbes. Thus adversely affecting the soil. It kills natural nutrients and bacteria that help rejuvenate soil. However, burning the residues create atmospheric pollution at a drastic phase.

a. Rice residue burning leads to emission of air pollutants causing hazard to people's health. Open burning of rice residue contributes to global warming through emissions of greenhouse gases (GHGs). Hence, burning causes release of toxic pollutants like methane (CH_4), carbon monoxide (CO), volatile organic compound (VOC) and carcinogenic polycyclic aromatic hydrocarbons. Burning of rice straw emits 0.7-4.1 g of CH_4 and 0.019-0.057 g of N_2O kg^{-1} of dry rice straw (Jenkins *et al*., 2003 and Oanh *et al*., 2011).
b. The smoke produced formed a thick blanket of smog. Smog formed of the smoke can increase the levels of pollutants by manifolds in the air, creating breathing troubles and other respiratory disorders. After release in the atmosphere, these pollutants disperse in the surroundings, may undergo physical and chemical transformation and eventually adversely affect the human health. Frequent rice residue burning may contribute to the formation of the brown clouds that affects the local air quality, atmospheric visibility and earth climate.
c. Farmers think discarding the rice residues by burning it is an effortless way as it gets destroyed all the unwanted debris. They believed that burning of rice straw may return nutrients to the land. But burning rice residue on ground destroys the nutrients in the soil, making it less fertile. Heat generated by residue burning penetrates into the soil, leading to the loss of the moisture and useful microbes. Thus adversely affecting the soil. It kills natural nutrients and bacteria that help rejuvenate soil.
d. Burning of rice residue leads to the loss of nutrients as nearly 25% nitrogen and phosphorus, 50% sulphur and 75% potassium uptake from the soil are retained in soil residues (Gadde et al. 2009). It is estimated that burning of 1 ton of rice residue accounts for loss of 5.5 kg nitrogen, 2.3 kg phosphorus, 25 kg potassium and 1.2 kg sulphur, besides organic carbon.
e. Husk has high prolific value. Rice husk is unusually high in ash, which is 92-95% silica, highly porous and lightweight, with a very high surface area. Its absorbent and insulating properties are useful in many industrial applications, such as acting as strengthening agent in building materials. Husk is also produced as fuel for processing paddy, production through direct combustion or gasification. It is also used as cattle feed. Burning stubble would be a waste of such utility.

Table 1. Major pollutants emitted during crop residue burning

Category	Pollutants	Source
Particulars	SPM (PM100)	Incomplete combustion of in organic material, particle on burnt soil
	RPM (PM10)	Condensation after combustion of gases and incomplete combustion of organic matter
	FPM (PM 2.5)	

Gases	CO	Incomplete combustion of organic matte
	NO_2	Oxidation of N2 in air at high temperature
	N_2O	
	O_3	Secondary pollutant, form due to Nitrogen Oxide and Hydrocarbon
	CH4/Benzen	Incomplete combustion of organic matter
	PAHS	Incomplete combustion of organic matter

SPM Suspended particulate matter; PM particulate matter; FPM fine particulate matter Source Singh et al. (2008)

Estimated pollution due to residue burning and nutrient losses

Burning of farm waste causes severe pollution of land and water on local as well as regional and global scales. It is estimated that burning of paddy straw results in annual nutrient losses to the tune of 3.85 million tonnes of organic carbon, 59,000 t of nitrogen, 20,000 t of phosphorus and 34,000 t of potassium at the aggregate (Kumar et al., 2014). Gadde et al. (2009) estimated that the burning of rice straw contributed 0.05%, 0.18%, and 0.56% of the total amount of greenhouse gas emissions in India, Thailand and the Philippines, respectively. The event which brought rice straw burning to front page news in Malaysia was the car accidents the smoke from the straw caused on highways which were situated close to paddy areas (Malaysian Society of Social Science, 2004). Similarly various accidents also happened in capital of India, New Delhi during end of 2017 due to paddy straw burning smoke. One tonne of straw on burning releases 3 kg of particulate matter, 60 kg of CO, 1,460 kg of CO2, 199 kg of ash and 2 kg of SO_2 (Gupta et al. 2004). According to Gupta et al. (2004), burning of crop stubble increases the temperature in the soil up to 33.8–42.2 ^{0}C.

Estimated pollution due to residue burning and nutrient losses in Manipur

In the year 2017, while surveying in Manipur of 360 people in both the valley and hilly regions, it was found that 80 percent from valley and 65 percent from hill farmers burnt their paddy straw. It is estimated that out of 628.31 tonnes/ annum paddy straw approximately 463.7 tonnes burnt per annum (295.10 and 168.6 thousand tons from valley and hill, respectively). In Manipur, the estimated losses of Carbon, Nitrogen, Phosphorus, Potassium and Sulphur due to burning of rice residues were 11112.96, 2.55, 1.07, 11.59 and 0.56 tonnes annum^{-1} respectively (Table 1). We have also estimated pollution generated in Manipur by paddy straw burning i.e. 1391.20, 27824.01, 677050.90, 92282.97 and 927.46 kg annum^{-1} Particulate matter, Carbon monoxides, Carbon dioxide, Ash and Sulphur dioxide, respectively (Table 2).

Table 2. Estimated nutrients loss from paddy straw burning from Manipur

Nutrients loss from paddy straw burning	Valley (tonnes annum^{-1})	Hill (tonnes annum^{-1})	Total (tonnes annum^{-1})
Carbon	708.25	404.71	1112.96
Nitrogen	1.62	0.93	2.55
Phosphorus	0.68	0.39	1.07
Potassium	7.38	4.22	11.59
Sulphur	0.35	0.20	0.56

Table 3. Estimated pollution generated due to paddy straw burning in Manipur

Pollution generated due to paddy straw burning	Valley (kg annum^{-1})	Hill (kg annum^{-1})	Total (kg annum^{-1})
Particulate matter	885.31	505.88	1391.20
Carbon monoxides	17706.24	10117.77	27824.0
Carbon dioxide	430851.80	246199.10	677050.90
Ash	58725.70	33557.27	92282.97
Sulphur di oxide	590.21	337.26	927.47

Solutions to cease burning rice residue

Rice residue has greater potential for multiple uses. It can be used alternatively. Despite having many positive outcomes both economically and environmentally, still farmer's burn paddy straw and not going for alternate usage of straw. We note that residue disposal is problem only when the wheat crop follows a rice crop and the turn-around time between the rice harvest and the sowing of wheat is very short. But in Manipur, monocropping is practiced and farmers are not in the need to prepare the fields quickly for next crop.

Incorporating the straw back into the soil is the best use of residue, practically an unpopular one with farmers. Its advantage is that it builds up organic matter in the soil as well as returning the nutrients contained in the straw back to the soil (Singh, 2001). Some studies suggest that non-burning of residue in long run can improve soil properties and improve residue incorporation including nitrogen intake (Verma and Bhagat, 1992), increase soil organic matter (Sidhu and Beri, 1989; and Gupta *et al*., 2004), microbial biomass and potential for nutrient recycling leading to high crop yield (Prasad *et al.,* 1999; Hartley and Kessel, 2005; Ganwar *et al*., 2006; and Malhi and Kutcher, 2007). Thus, there appears to be a consensus that in the long run incorporation of residue, as compared to burning, improves the soil quality.

Another best use of rice residue is as animal feed by conversion of residue into livestock fodder. Converting residue into milk and meat will add more value than using it as fuel. Humans cannot digest straw at all, but cattle, sheep, goats have four-stage stomachs that digest up to half of it. Goats have the toughest stomachs and best digestion rates. Treatment with urea, alkalis or molasses can improve the digestibility and calorific value of straw.

Zero-till farming is another alternative which sows successive crop without removing the stubble. Tractor-mounted happy seeders, rotavators, and straw-reapers simultaneously cuts rice stubble and sow successive seeds, depositing the cut stubble on top as mulch. The farmers should also be encouraged to adopt conservation farming systems. The other possible alternative is by providing stubble collecting machines to farmers to collect stubble or by subsidizing/availing the stubble collecting machines at rent.

Another alternative which has received much attention is the removal of the straw from the field and its use for other economic activities. Common suggestions include using straw rice to produce energy. In most cases, it would not be cost-effective for the straw to be transported too far away from the paddy farm. The most prospective way of using paddy straw is to recycle it through composting and vermi compositing processes (Pramanik et al., 2007). Likewise, paper is also another viable option of using paddy straw as it involves minimal cost (Atchison, 1974). Various other economically viable alternatives are mushroom cultivation, hay as animal feed, paper and board making, packaging materials, as a fuel in brick kilns, handicrafts (Lal, 2005; Liu *et al.*, 2010; Delivand *et al*., 2012; Li *et al*., 2012; Kanokkanjana & Garivait, 2013; Nguyen *et al*., 2013; Park *et al*., 2014; Qian *et al*., 2014).

Also, conversion of rice straw into cellulosic ethanol is another strategy which has high economic viability. India needs 105 crore litres of ethanol for mandatory five percent blending but as per recent report, the oil companies are getting access only to one-third of ethanol from domestic sources at the rate of rupees 45 to 47 litre^{-1}. Once the rice straw is converted into ethanol at a competitive cost, it would be very beneficial for industrial application. The oil companies can invest in such refineries which generate ethanol through rice straw as part of their corporate social responsibility policy to reduce the negative impacts of open field burning of paddy straw (Biotechnology Industry Research Assistance Council, 2013).

There are various ongoing, long-term efforts at diversification of cropping techniques, such that crop residue burning can be effectively prevented. This is being attempted through cultivation of alternate crops (apart from rice/paddy and wheat) that produce less crop residue and have greater gap periods between cropping cycles.

Conclusion

The on field impact of burning includes removal of a large portion of the organic material, denying the soil an opportunity to enhance its organic matter and incorporate important chemicals such as nitrogen and phosphorus, as well as, loss of useful micro flora and fauna. The off-field impacts are related to human health due to general air quality degradation resulting in aggravation of respiratory (like cough, asthma, bronchitis), eye and skin diseases. Fine particles also can aggravate chronic heart and lung diseases and have been linked to premature deaths in people already suffering from these diseases. Clouds of ash and smoke can travel more than thousand kilometres and create an obstinate and non-clearing clouds. Smog formed of the smoke can increase the levels of pollutants by manifolds in the air, making it difficult to breathe. After release in the atmosphere, these pollutants disperse in the surroundings, may undergo physical and chemical transformation and eventually adversely affect the human health. Frequent paddy straw burning may contribute to the formation of the brown clouds that affects the local air quality, atmospheric visibility and earth climate. The black soot generated during burning also results in poor visibility which could lead to increased road side incidences of accident. It is thus essential to mitigate impacts due to the burning of agricultural waste in the open fields and its consequent effects on soil, ambient air and living organisms.

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RICE RESIDUE BURNING – IMPACTS ON AIR QUALITY AND GREENHOUSE GAS EMISSION

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Introduction

Rice is a widely grown crop that leaves a substantial quantity of plant residues in the field such as roots, stubbles, and straw. Processing through milling also produces large amount of residues. It is estimated that 242, 97, 22, and 11 Mt of rice straw residues are produced per year in China, India, Thailand, and the Philippines, respectively (Gadde *et al*., 2009). After harvest, rice straw is either scattered in the field, accumulated in piles, or baled and sold for other purposes such as for mushroom production, thatching for rural homes, residential fuel for cooking, ruminant fodder, stable bedding, paper making, etc.However, a large portion of the crop residues is not utilized and left in the fields. These materials at times have been regarded as waste materials that require disposal, but it has become increasingly realized that they are important natural resources and not wastes. Due to inadequate knowledge regarding the significance of crop residues, they are often burned in the field (Samra*et al*., 2003). Agricultural open field burning is widely practiced in the rural areas and suburbs to dispose of biomass waste (Yevich and Logan, 2003). Several reasons favor burning of crop residue including cleaning and field preparation for the next crop, meeting domestic energy requirements, fertilizing the field with ash and offering the pest control (Huang *et al*., 2012). Farmers resort to burning of crop residue for burning because it is the quickest, easiest and economical option to manage the large quantities of crop residues and prepare the field for the next crop well in time. Owing to lack of awareness or non-availability of suitable technologies it is generally practices everywhere.

India being an agrarian country generates a huge quantity of agricultural wastes every year which is expected to increase in future as with the growing population to meet the need to increase the productivity. The Ministry of New and Renewable Energy (MNRE, 2009), Govt. of India has estimated that about 500 Mt of crop residues are generated every year. The generation of crop residue is highest in Utter Pradesh (60 Mt) followed by Punjab (51 Mt) and Maharashtra (46 Mt). The cereal crop (rice, wheat, maize, millets) contributes to 70%, while rice crop alone contributes 34% to the crop residues (MNRE, 2009: Pathak., 2006). The disposal of such a large amount of crop residues is a major challenge. Usage of the rice straw is considered to be a poor feed for the animals owing to high silica content.

Potential Impact of Rice Residue Burningon Air Quality

Biomass burning is a global phenomenon and is an important contributor to poor air quality worldwide (Yang *et al.*, 2008).Open-burning of rice straw in the field is of incomplete combustion in nature; hence, a large amount of air pollutants such as CO (Carbon monoxide), NH_3 (Ammonia), NOx (Oxides of Nitrogen), SO_2, NMHC (Non-methane hydrocarbon), volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) are emitted and is the largest source of particulate matter (PM) like elemental carbon and smoke in the global tropospherereposing threat to human health and the potential to alter global air quality (Launio*et al*., 2013; Zhang *et al.*,2008, 2011).

Intensive burning of agricultural wastes in many Asian countries may substantially contribute to the formation of Atmospheric Brown Cloud (ABC) that affects local air quality, atmospheric visibility, and Earth's climate (Kanokkanjana *et al*., 2011; Tipayarom and Oanh, 2007). Concentration levels of particulate matter of varying sizes are greatly affected by types of agricultural crop residue burning; however the total distribution of the particulate matter remains almost constant (Awasthi*et al*. 2011). Researchers found that most of the particulate released due to agriculture crop residue burning (ACRB) are Respirable Suspended Particulate Matters (RSPM) which are smaller than 10 microns (PM_{10}), and easily enter into the lungs, causing lower respiratory and heart problems (Hauck *et al.* 2004). Table 1 shows the emission of air pollutants from open burning of rice residues.

Table 1: Emissions of air pollutantsfrom Open Burning of Rice Residues

Name of the pollutant	Emissions from open burning of rice straw			
	EF (g/Kg dry matter)	India (Gg)	Thailand (Gg)	Phillipines (Gg)
CO (Carbon Monoxide)	34.70	386	290	282
NMHC (Non-methane Hydrocarbons)	4.00	45	33	32
NOx (Nitrogen Oxides)	3.10	35	26	25
SO_2	2.00	22	17	16
TSPM (Total Suspended Particulate matter)	13.00	145	109	106
Fine particulate matter ($PM_{2.5}$)	12.95	144	108	105

EF: Emission Factor, Gg: Giga gram *(Adapted from Gaddeet al. 2009)*

Badarinath *et al*.2009 studied the variations in CO, O_3 and black carbon aerosol mass concentrations associated with Atmospheric boundary layer (ABL) over tropical urban environment in India. They suggested significant raise in CO and BC concentrations during early morning hours. A study conducted by Singh *et al.* 2010, observed that levels of SPM, SO_2 and NO_2 increases during the burning months (October–November) with the meteorological parameters especially wind direction, precipitation and atmospheric temperature playing the main role.

Potential Impact of Rice Residue Burning on Greenhouse Gas Emission

Besides emitting significant quantity of air pollutants, rice residue burning releases greenhouse gases like CO_2 (Carbon dioxide), N_2O (Nitrous Oxide), CH_4 (Methane) in considerable amount contributing to the greenhouse effect which heats the atmosphere through absorption of thermal radiation. Biomass burning emissions have both the positive and negative effects on climate.It represents a significant source of chemically and radiatively important trace gases and aerosols to the atmosphere, thereby resulting in a large perturbation to global atmospheric chemistry (Crutzen and Andreae, 1990). This change in composition of the atmosphere may have a direct or indirect effect on the radiation balance of earth affecting its climate and contributing to global climate change (Streets *et al.*, 2003; Koppmann*et al.*, 2005).While smoke and aerosol particles scatter sunlight or reflect it directly back to space, thereby having a cooling effect on the atmosphere, black carbon particles (PM), however, have a warming effect due to absorption of incoming radiation. Smoke particles are also a major source of cloud condensation nuclei (CCN) (Kaufman and Nakajima, 1993). Clouds, which consist of a higher number of smaller droplets reflect more radiation back into space, and as the clouds are less likely to produce rain, cloud coverage may also increase (Crutzen and Andreae, 1990). However, smoke emissions do not only have a cooling effect on the atmosphere, but a warming one as well. (Kaufman *et al*., 1992). Other than these direct effects, indirect and semi-direct effects of biomass burning emissions have also been detected, whereby aerosols modify the microphysical and hence the radiative properties and amount of clouds (e.g., the increase in cloud coverage due to the larger number of CCN, or its decrease due to the increase in temperature resulting from the absorption of incoming radiation by EC (elemental carbon) particles (IPCC, 2001). Table 2 shows the emission of the three greenhouse gas emitted from open rice residue burning.

Table 2: Emissions of greenhouse gases from Open Burning of Rice Residues

Name of the pollutant	Emissions from open burning of rice straw			
	EF (g/Kg dry matter)	**India (Gg)**	**Thailand (Gg)**	**Phillipines (Gg)**
CO_2 (Carbon Dioxide)	1460	16,253	11,850	11,850
CH_4	1.20	13	10	10
N_2O	0.07	1	1	1

EF: Emission Factor, Gg: Giga gram *(Adapted from Gaddeet al. 2009)*

Burning of 253 Tg, of dry residue biomass in 2010 is estimated to emit 22.4, 24.4 and 26.1 Tg of carbon;0.30, 0.33 and 0.35 Tg of nitrogen oxide;4.18, 4.59 and 4.86 Tg carbon dioxide equivalent of greenhouse gases (GHG, viz., CH4 and N2O; which is over 1% of the Indian agriculture sector GHG emissions); 2951, 3,240 and 3,431 Gg of CO; and 120.8, 132.9 and 140.6 Gg NOx emissions in 1994, 2005 and 2010, respectively(Shivraj*et.al.,* 2010).Shivraj*et al*., 2010 have calculated the methane emission from field burning of crop residue. The FBCR in India in the year 2000 contributed an estimated 1.8% and 13.6% of the Asian and Indian CH4 emissions from all types of biomass burning, taking into account the estimates of Streets *et al*., 2003. The total Indian FBCR CH_4emissions are estimated as 88.6, 132.7, 149.6, 156.4, 164.2 and 174.0 Gg for the years 1980, 1990, 1994, 2000, 2005 and 2010, respectively. Rice, wheat and sugarcane together accounted for about 73.3, 110.4, 126.0, 136.6, 136.1 and 148.6 Gg in the years 1980, 1990, 1994, 2000, 2005 and 2010, respectively.
Biomass burning, in general, continues to be associated with largeinformation gaps and uncertainties, especially for the developing world regions like the Indiansub-continent. Stress should be given to the urgent need for biomass burning studies inthe Indian region.

Management options

Rice residue burning is not the suitable option for the crop residue management. Appropriate technologies for managing the crop residue should be developed. Management options include recycling (incorporation, surface retention and mulching), and baling and removing the straw (for use in other purposes), while, its incorporation shows the better result for soil fertility and crop production point of view. Adoption of technologies for harnessing energy from crop residues such direct combustion, gasification, carbonisation, ethanol production, liquefaction, bricking and pyrolysis, should be encouraged. It will not be only reducing the atmospheric pollution and climate problem but also helpful to fulfil the energy demand with improve the economic condition of the country.Following strategies may be implemented to achieve the adoption of the abovementioned management options:

1. Outreach and public awareness campaigns must be created amongst the farming communities to highlight the negative repercussions of crop biomass burning and importance of crop residues

incorporation, recycling, usage for maintaining sustainable agricultural productivity and over air quality. Kisan camps, trainings and workshops through various print media, television, radio jingles may be promoted as awareness options.

2. Ban on rice residue burning: crop residue burning was notified as an offence under the Air Act of 1981, the code of criminal Procedure, 1973 and various appropriate Acts. In addition, a penalty is being imposed on any offending farmer. Village and block-level administrative officials should be strictly engaged for the enforcement. Stringent monitoring and enforcement mechanism through the use of remote sensing/GIS technology-use of real time satellite imagery, along with village/local level enforcement teams with the aim of achieving zero incidence rate of crop residue burning, through prevention and penalisation.
3. Establishment of a larger number of biomass-based power projects utilising greater amounts of paddy straw is needed. Manipur has few to no operational biomass-base power plants.
4. Creation of a market for paddy straw, along with a mechanism for commercial procurement of paddy straw for use in biomass based power projects, as fuel in brick kilns and in production of ethanol. Establishment of bio-refineries for utilization of paddy straw is another viable alternative.

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UTILITY OF RICE RESIDUE IN HORTICULTURE SECTOR

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Introduction

Indian agriculture produces about 500-550 million tones of crop residues annually. A large portion of these crop residues, about 90-140 million tones annually, is burnt on farm primarily to clear the fields to facilitate planting of succeeding crops (NAAS, 2012). The problem of on farm burning of crop residues has intensified in recent years due to use of combines for harvesting and high cost of labourers in removing the crop residues by conventional method.

These days, burning of paddy straw is a common practice due to lack of options to dispose of the straw. Although, the Government has recommended that farmers should take it to the nearest biomass plant. But practically, it is costly for farmers due to distance of biomass plant and high transportation cost. Therefore, the easiest way is to burn it, this had enveloped the sky with polluted air in Punjab, Haryana and other parts of the country. In 2012, the US' National Aeronautics and Space Administration (NASA) released a satellite image of Punjab and Haryana showing fires across millions of hectares of agricultural fields in the region (Fig 1; Anon., 2012). The smog and haze had affected not only burning areas but also the adjoining states particularly Delhi which is situated 100 km south. Burning of crop residues leads to plethora of problems; emission of green house gases such as carbon dioxide, methane, and nitrous oxide adding to global warming; loss of plant nutrients such as N,P,K, and S; adverse impacts on soil properties and wastage of crop residues. The burning of straw kills soil microorganisms, earthworm and other living body in the soil due to heated land and harming soil productivity and worsening global climate change. Furthermore, the smog causes respiratory ailments in humans and animals besides raising other health issues. It is a paradox that burning of crop residues and scarcity of fodder co-exists in this country, when fodder prices have surged significantly in recent years. It is estimated that one hectare of paddy field produces 2.6 tonnes of straw, which can in turn be used in horticultural activities and production cost will also be reduced.

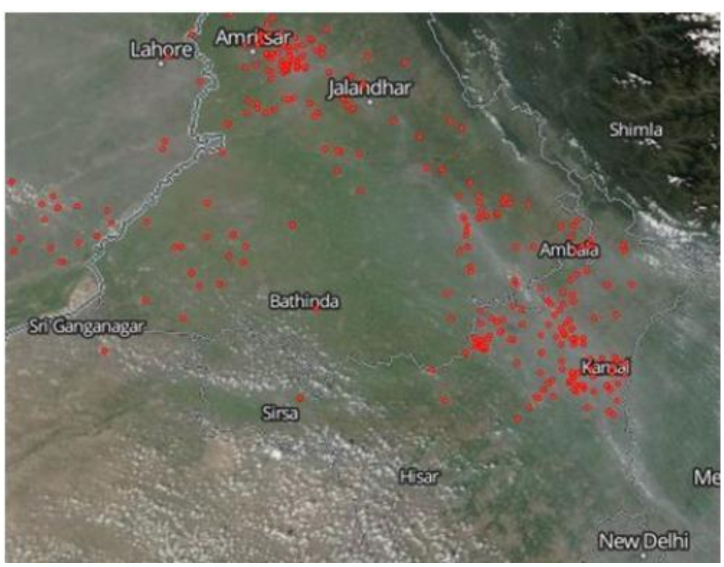

Fig 1. NASA imagery depicting fires on agricultural lands in Punjab and Haryana (Anon., 2012)

1. Mushroom cultivation : Paddy straw is a good source of input for preparing substrate for mushroom cultivation. Paddy straw substrate is prepared by composting. Mushrooms are capable of breaking down organic material that other microorganisms cannot decompose. The common field mushroom and many other types of mushroom (Agaricus spp.) grow well on compost made from rice straw. Mushroom production can generate a good income for farmers, and utilize surplus manpower in rural areas. The organic matter left over after mushrooms have been cropped on rice straw can be recycled onto cropland as organic fertilizer. The translation of mushroom cultivation into economic benefits livelihood improvement using paddy straw, for instance more than 20 marginal farmers run over 100 mushroom farms in Israne and in Puthar, Punjab the total annual turnover from mushroom farming is over Rs 2 crore (Anon., 2015).

2. Compost and manure preparation : The nutrient content in rice straw is presented in Table 1. This makes the straw suitable for developing as compost to improve soil fertility. On dry weight, the moisture content would loss around 14%-16%. Straw incorporated would build up soil carbon as well as soil nitrogen returning valuable nutrients to the ecosystem (Nguyen et al., 2013).

Furthermore, the composted rice straw is reported to contain 33% carbon and 1.9% N and, the carbon: nitrogen ratio was 18 (Imagawa et al., 1989) in addition digestible organic matter (51.5%), cellulose (47.2%), lignin (3.0%) and soluble phenolic compounds (4.3%) (Gina, 2013). On burning rice straw large losses of nitrogen and small losses of potassium occurs. Rice straw can be added to field as straw itself, or as compost depending on the local field itself. The integrated use of both inorganic and organic sources of substrates enhances the efficiency of both the substances to maintain soil productivity and enhances the soil ability to meet the total nutrient requirement of crop to achieve sustained yield. Incorporation of rice straw into soil with decomposing fungi and plant growth promoting rhizobacteria led to improvement in the production of eggplant cv. Black Balady, as well as, reduce the amount of mineral fertilizers and avoid one of the most serious environmental air pollution (Black Cloud), caused by burning rice straw annually (Abd El-Aziz et al., 2015).

Returning of crop residue into soil improves soil through its potential influence on reducing risks of soil erosion; stabilizing soil structure and improving tilth; reducing soil bulk density; storing or recycling nutrients; improving water retention and transmission properties; providing energy for microbial processes; increasing cation exchange capacity and enhancing agronomic productivity (Lal, 2005). Composting is also very suitable for growing fruit plants and vegetables and general horticulture-use (Rosmiza, 2012). Around 61.5% of rice straw in Japan is ploughed into the field for general organic compounds to also encourage the activity of micro-organisms (Matsumura et al., 2005). Several countries such as Taiwan of up to 56.9% of the rice harvest and South Korea (46.0%) have previously successfully developed and utilized rice straw as a compost (Table 2) (Devendra & Sevilla, 2002).

Table 1. Nutrient content in rice straw

Nutrient content	Percent (%)	Nutrient content	Percent (%)
Nitrogen (N)	0.65	Magnesium (Mg)	0.20
Phosphorus (P)	0.10	Calcium (C)	0.30
Potassium (K)	1.40	Iron (Fe)	0.035
Zink (Zn)	0.003	Manganese (Mn)	0.045
Sulphur (S)	0.075	Copper (Cu)	0.0003
Silicon (Si)	5.5	Boron (B)	0.0010

Source: Ismael et al. (2013)

Table 2. Rice straw utilization in Asian countries

Country	Rice straw utilization	Percent (%)
Bangladesh	Livestock feed, compost, biogas	74.4
Korea	Compost	46.0
	Biofuel	20.0
	Livestock feed	15.0
Thailand	Livestock feed	13.0
	Compost	5.0
	Raw material (sell)	1.5
	Biofuel	0.2
	Others activities	0.3
China	Rural energy (electricity)	53.6
	Livestock feed	28.0
	Fertilizer	15.0
	Paper making	2.1
	Reused on the farm and collected for other purposes	16.2
Japan	Livestock feed	11.6
	Compost	10.1
	Animal bedding	6.5
	Combustion	4.6
	Erosion control	4.2
	Mulching	4.0
	Incinerator	3.1
	Handicraft	1.3
	Processed	1.1
	Other activities	0.3
India	Biogas	28.0
	Other activities (livestock feed and roof)	49.0
Taiwan	Compos	56.9
	Livestock feed	11.0
	Biofuel	5.1
	Other activities	22.1
Philippines	Livestock feed, mulching, mushroom growth medium	5.0
Malaysia	Livestock feed, compos, erosion control, mushroom growth medium, paper making	1.0

Source: Rosmiza et al. (2014)

3. Mulching in crop production : Straw also can be used as a mulching material. Spreading of rice straws over the fields help in conserving soil moisture in hot and dry climates by reducing evaporation. It also helps in moderate soil temperature throughout seasons. The mulched straw when decomposed improves soil microbial activities that enhance soil fertility. Furthermore, straw also has the capability of influencing pest populations in the field such as snails and to check weed growth. When straw is incorporated into the soil, it will sequester organic carbon content in the soil, increasing its fertility and also storing carbon. More importantly, not burning straw will reduce black carbon emissions, which is a short-lived climate pollutant. Unlike carbon dioxide, black carbon does not have a long life in the atmosphere, but it is a potent greenhouse gas. Not releasing black carbon into the atmosphere will, therefore, bring quick climate benefits. Rice farmers in Punjab and Haryana can be big players in the climate change story. These advantages should be used for vegetables, fruits and horticulture more generally. This can increase the value of straw and create additional income for farmers.

4. Post harvest management : Paddy straws are used in post harvest management of several horticultural products. Rice straws have high surface area and are light weight. They posses insulation quality and are normally used as cushioning and lining materials for packing and transportation of harvested products such fruits and vegetables. There are environmental friendly and do not adversely affect the environment like synthetic packing materials such as thermocol, plastic, etc.

5. Nursery management : Nursery plants are very tender and require handling with care. Paddy straw may be used as roofing materials over nursery beds/ area to provide shade to plants. Nutrients in paddy straw allow it to be used as a medium for seed germination and also grass growing. The seedling on attainment proper stage may be transplanted to field. Paddy straw is also used to wrap the earthen ball of the saplings and other delicate planting material like vegetable and ornamental flower seedlings before packing.

6. Crop diversification : Crop diversification in rice based cultivation refers to a shift from the regional dominance of rice crop to regional production of a number of different crops, to meet ever increasing demand of cereals, pulses, vegetables, fruits, oilseeds, fibres, fodder, grasses etc. This system will help to improve soil health and to maintain dynamic equilibrium of the agro-ecosystem. Immediately after harvesting of rice, line sowing of pulses, oilseeds (soybean, til) may be adopted through zero tillage technology. CRIDA, Hyderabad showed that in dryland ecosystems, where only a single crop is grown in a year, it is possible to grow a second crop with residual soil moisture in the profile under conservation agriculture with soil cover with crop residues.

7. Other uses : Paddy straw may be used as fuel. About 1 ton of rice paddy can produce 100 KWh of power. The bye product is rice husk ash, which has an economic value and can be used in cement and brick manufacturing, construction of roads and embankments, etc. When husk is burned under control temperature, it forms husk ash. Rice husk ash is used as partial replacement of ordinary Portland cement in concrete (Small quantity), saving on cost.

Rice straw is mainly used as a source of fodder for the livestock. With the biological treatments and use of certain organic chemicals, its digestibility and nutrient value can be increased..

Constraints

1. Lack of awareness among farmers: Farmers are not much aware about the various potential use of paddy straw towards tangible and intangible benefits. They usually consider it as a waste other than using as a feeds for livestock.
2. Financial problems: Farmers usually have economic problems to start any new venture with paddy straw based input materials for instance mushroom cultivation.
3. Penetration of technology: Using straw in mushroom cultivation or nursery management requires technological inputs. But farmers lack technological know-how to fully utilize the resource.
4. Lack of interest: Burning stubble is easy for farmers instead of putting it to some other use. Processing and utilizing it in other forms require stringent inputs.

5. Lack of environmental concerns: Those who burn stubble are less concerned about its adverse effects on the environment.

6. Stubble difficult to be used as fuel: Rice straws are difficult to burn in most combustion furnaces, especially those designed for power generation. The primary issue concerning the use of the rice straws and other bio mass material for power generation is fouling, slagging and corrosion of the boiler due to the alkaline and chlorine components of the ash.

Conclusions

There are several options such as animal feed, composting, energy generation, bio-fuel production and recycling in soil to manage the residues in a productive and profitable manner. Use of crop residues as soil organic amendment in the system of agriculture is a viable and valuable option. A policy should be developed with a goal to promote multiple uses of crop residues in the context of conservation agriculture and prevent their on-farm burning. The policy and development programmes such as creating awareness, human resources development, providing incentives through investment, subsidies and compensation, developing and disseminating technologies and implementing legislation should be put into practice to promote the use of crop residues. All stakeholders, i.e., farmers, supply and value chain service providers, researchers, extension agents, policy makers, civil servants, consumers need to be engaged in understanding and harnessing the full potential of using crop residue for sustainability and resilient of Indian agriculture.

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EFFECT OF RICE STRAW RESIDUE BURNING ON SOIL MACRO AND MICRO ORGANISM

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Soil as a unit of an ecosystem

An ecosystem is a community of living organisms in conjunction with the nonliving components of their environment (things like air, water and rocks and minerals that make up the soil), interacting as a system. These biotic and abiotic components are regarded as linked together through nutrient cycles and energy flows.Ecosystems are divided into terrestrial or land-based ecosystems, and aquatic ecosystems in water. These form the two major habitat conditions for the Earth's living organisms. In an ecosystem, a number of species interact with each other to maintain the energy cycle needed to keep the ecosystem balanced.

Soil is one of the most valuable abiotic factors in an ecosystem because everything that lives on land depends directly/indirectly on soil. Soil affects types of plants that can grow in an ecosystem which directly impacts the types of other organisms that can live there. If the soil quality changes in any of its properties, the ecosystem will also change.

Soil Properties and their Interrelationships

Soil is a dynamic entity where complex interactions among its biological, chemical and physical components take place. Healthy soils occur when their biological, chemical, and physical conditions are all optimal, enabling high yields of crops. When this occurs, roots are able to proliferate easily, plentiful water enters and is stored in the soil, the plant has a sufficient nutrient supply, there are no harmful chemicals in the soil, and beneficial organisms are very active and able to keep potentially harmful ones in check as well as stimulate plant growth.

Soils host a complex web of organisms which can influence soilevolution and specific soil physical and chemical properties. For instance earthworm activity increases infiltration rate, or microbial activity decreases soilorganic matter due to mineralization.Soil biological properties are also interconnected with other soil physical andchemical properties; e.g. aeration, soil organic matter or pH affect the activity ofmany microorganisms in soils which in turn perform relevant activities in carbonand nutrients cycling.

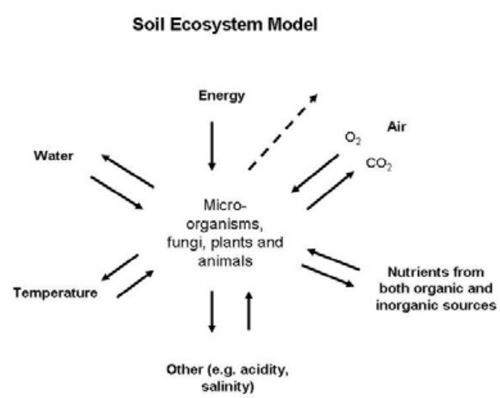

Figure 1: Soil ecosystem model

Thus, changes in soil properties due to management can significantly affect biologicalproperties in soils, some of them being extremely sensitive to soil management; e.g. soil microbial activity can be greatly increased by improved drainage,liming or organic amendments. That is why some soil biological properties can beused as indirect indicators of appropriate soil management and good soil quality, like soil respiration rate or some enzymatic activities that can be derived fromliving organisms in soil.

Soil as a carbon sink

Soil is a large reservoir of carbon, with about 60% organic carbon in the form of soil organic matter (SOM), and the remaining inorganic carbon in the form of inorganic compounds (e.g., limestone, or $CaCO_3$). It is estimated that SOM stores about twice as much carbon as the atmosphere, and about three times more than forests and other vegetation (Lal, 2004). Soil carbon sequestration is the removal of CO_2 from the atmosphere through plant photosynthesis, and storage as long-lived, stable forms of soil organic matter that is not rapidly decomposed. Changes in soil organic carbon levels can have significant affects on atmospheric CO_2 levels. Each 1% increase in average soil organic carbon content could reduce atmospheric CO_2 by up to 2% (Anonymus, 2009).

SOM originally comes from atmospheric CO_2 that is captured by plants through the process of photosynthesis. When plants die and decompose, some CO_2 is sequestered in the soil, while some is released back to the atmosphere. The primary way to store (sequester) carbon in the soil is to add organic soil amendments such as compost or animal manures.

Benefits of soil carbon sequestration

In addition to reducing current atmospheric CO_2 levels, increasing soil carbon sequestration can provide other benefits for soil quality, the environment, and agricultural production:

- Increased agricultural productivity
- Improved soil structure
- Increased soil fertility
- Increased water holding capacity
- Increased infiltration capacity
- Increased water use efficiency, due to reduced moisture loss from runoff, evaporation, deep drainage below the root zone
- Improved soil health resulting in higher nutrient cycling and availability
- Reduced fertilizer (N, P) needs over the longer term

Soil type is significant to soil carbon sequestration as well. Soils with higher clay content sequester carbon at higher rates. Most of the potential soil carbon sequestration takes place within the first 20 to 30 years of adopting improved land management practices. With most practices, the highest rates of sequestration are achieved in the intermediate term, with lower or even negative rates in the short term.

Soil Organic Matter and Soil Health

The term "Soil organic matter" (SOM) has been used in different ways to describe the organic constituents of soil. The soil organic matter (SOM) is comprised of multiple components, including:

- Plant and animal residues recently incorporated into the soil by field operations or by earthworms and other macro-organisms
- The soil life itself
- Active organic matter, including recently-dead soil organisms, root exudates, and partially decomposed materials that remain available for further utilization by soil life
- Stable organic matter, which is protected from further decomposition because it is physically integrated into soil aggregates or it has become chemically resistant.

Soil organic matter (SOM) and specifically soil organic carbon (SOC) are known to play important roles in the maintenance as well as improvement of many soil properties.The amount of SOC that exists in any given soil is determined by the balance between the rates of organic carbon input (vegetation, roots) and output (CO_2 from microbial decomposition. Organic matter and soil life play central roles in soil health and fertility. In natural plant communities, the daily consumption and assimilation of organic residues by soil organisms provides the primary source of plant nutrition. Without regular inputs of organic (carbonbased) materials derived from photosynthesis and other life processes, soil organisms go hungry and the soil's capacity to support agriculture and provide ecosystem services degrades.

Principal functions of SOM in soils

The functions of SOM can be broadly classified into three groups: biological, physical and chemical.

Functions of Soil Organic Matter

Biological Functions

- Provides source of energy (essential for biological processes)
- Provides reservoir of mutrients (N, P, S)
- Contributes to resilience of soil/plant system

Physical Functions

- Improves structural stability of soils at various scales
- Influences water-retention properties of soils and water holding capacity
- Alters soil thermal properties

Chemical Functions

- Contributes to the cation exchange capacity
- Enhances ability of soils to buffer changes in pH
- Complexes cations (enhanced P availability), reduces concentrations of toxic cations
- Promotes binding of SOM to soil minerals

Rice residue management

Agricultural residues are the biomass left in the field after harvesting of the economic components i.e., grain. Large quantities of crop residues are generated every year, in the form of cereal straws, woody stalks, and sugarcane leaves/tops during harvest periods. Processing of farm produce through milling also produces large amount of residues. These residues are used as animal feed, thatching for rural homes, residential cooking fuel and industrial fuel. However, a large portion of the crop residues is not utilized and left in the fields. The disposal of such a large amount of crop residues is a major challenge. India ranks second in paddy production in the world after China (Anonymous 2015).

Straw is the only organic material available in significant quantities to most rice farmers. About 40 percent of the nitrogen (N), 30 to 35 percent of the phosphorus (P), 80 to 85 percent of the potassium (K), and 40 to 50 percent of the sulfur (S) taken up by rice remains in vegetative plant parts at crop maturity.Straw is either removed from the field, burned in situ, piled or spread in the field, incorporated in the soil, or used as mulch for the following crop. Each of these measures has a different effect on overall nutrient balance and long-term soil fertility.

Straw Removal: Removal of straw from the field is widespread in India, Bangladesh, and Nepal, which explains the depletion of soil K and Si reserves at many sites. Straw can be used as fuel for cooking, ruminant fodder, and stable bedding or as a raw material in industrial processes (e.g., papermaking). In the process, some or all of the nutrients contained in straw may be lost to the rice field.

Straw Incorporation: Incorporation of the remaining stubble and straw into the soil returns most of the nutrients and helps to conserve soil nutrient reserves in the longterm. Short-term effects on grain yield are often small (compared with straw removal or burning) but long-term benefits are significant. Where mineral fertilizers are used and straw is incorporated, reserves of soil N, P, K, and Si are maintained and may even be increased.

Table 1. Nutrient content of rice straw and amounts removed with 1 tonne of straw residue.

	N	P_2O_5	K_2O	S	Si
Content in straw, % dry matter	0.5-0.8	0.16-0.27	1.4-2.0	0.05-0.10	4-7
Removal with 1 tonne straw, kg/ha	5-8	1.6-2.7	14-20	0.5-1.0	40-70

Source: Dobermann and Fairhurst, 2002

Burning: Burning causes almost complete N loss, P losses of about 25 percent, K losses of 20 percent, and S losses of 5 to 60 percent. The amount of nutrients lost depends on the method used to burn the straw. In areas where harvesting has been mechanized (e.g., Thailand, China, and northern India), all the straw remains in the field and is rapidly burned in situ; therefore, losses of S, P, and K are small. In Indonesia and the Philippines, straw is heaped into piles at threshing sites and burned after harvest. The ash is usually not spread on the field, and this results in large losses of minerals.K, Si, calcium (Ca), magnesium (Mg)leached from the ash piles. Burning causes atmospheric pollution and results in nutrient loss, but it is a cost-effective method of straw disposal and also helps reduce pest and disease populations that may occur due to reinfection from inoculum in the straw biomass.

The burning of stubble, contrasted with alternatives such as ploughing the stubble back into the ground has a number of consequences and effects on the environment.

Stubble burning:

- Quickly clears the field and is cheap
- Kills weeds, including those resistant to herbicide
- Kills slugs and other pests
- Can reduce nitrogen tie-up

However, it has a number of harmful effects on the environment:

- Loss of nutrients
- Pollution from smoke
- Damage to electrical and electronic equipment from floating threads of conducting waste
- Risk of fires spreading out of control.

Table 1: Impacts of rice straw disposal methods

Disposal method	Fertility	Air Quality	Soil Carbon Sequestration
Burn	-	-	-
Incorporate	+	0	+
Roll	+	0	+
Bale & Remove	-	0	-
Burn & Flood	-	-	-
Incorporate& Flood	+	0	+
Roll& Flood	+	0	+
Bale/Remove& Flood	-	0	-

Source: Kessel and Horwath, 2001 (+ positive impact, - negative impact, 0 no impact)

Table 2 : Carbon mission coefficient for agricultural residue burning

Biomass type	CH_4	CO_2	CO	Reference
Emission factor (g/kg)				
Agricultural residue Wheat straw 156722 Rice straw	2.70 7.37±2.72 5.32±3.08	1515±177	92±84 156±22 82±20	Andreae and Merlet, 2001 NPL (www.nplindia.org/) NPL (www.nplindia.org/)

Table 3: Comparison of all-India emissions from rice and wheat residue open burning in 1994 and 2000 (Gg)

Year	CH_4	CO	N_2O	NO_x
1994	102	2138	2.2	78
2000	110	2305	2.3	84

Source: Gupta*et al*., (2004) CURRENT SCIENCE, VOL. 87, NO. 12

Burning rice straw in India

Depending on the crops grown, cropping intensity and productivity in different regions of India, there is a large variability in generation and end use of these crop residues. In the northern states of India, a large portion of paddy straw is subjected to burning (Sood, 2013) in fields primarily to clear them prior to the sowing of wheat crop. Out of 82 Mt surplus crop residues from the cereal crops, 44 Mt is from rice crop which is mostly burnt on-farm (Derpsch and Friedrich, 2010 and Pathak *et al.,* 2010).

Table 4: End use of paddy straw

Author	Disposal pattern
Badarinath and Chand Kiran (2006)	75–80 % area is machine harvested ¾ or 75 % of straw is burnt
Venkataraman *et al.* (2006)	30–40 % straw burnt (IGP)
Sidhu and Beri (2005)	81 % of paddy burnt and 48 % of wheat burnt, fodder (7 % of rice and 45 % of wheat), rope making (4 % of rice and 0 % of wheat), incorporated in soil (1 % of rice and less than 1 % of wheat), miscellaneous (7 % each of rice and wheat)
Sarkar *et al.* (1999)	75 % combine harvested and 100 % burnt
Average	75 % of paddy is burnt

Paddy is grown on an average area of around 30 lakh hectares in Punjab. After wheat, it is the biggest crop in the State. After harvest, around 19.7 million tonnes of paddy straw is left on the fields and has to be disposed of to make way for wheat. Of this, 70-75% of paddy straw is burnt in open fields to clear the land for sowing wheat or other crops — it is the quickest and cheapest way of getting rid of the residue. In Punjab, of the total paddy straw, nearly 4.3 million tonnes is consumed in biomass-based projects, paper, or cardboard mills and animal fodder, while a small portion is managed through other systems such as machinery and equipment. The rest of the 15.4 million tonnes of paddy straw is burnt on the fields (Anonymus, 2017).Contrary to this, there is no burning of paddy straw in West Bengal and it is used for various other purposes such as cattle feed, thatching for rural houses, fuel for residential cooking and industry, mulching material, etc. (Anonymous 2014a).

Table 5: Status of paddy straw management in Burdwan, West Bengal

State	**West Bengal (n=60)**
Activities regarding paddy straw management	Percentage (%)
Burning	0
Mulch materials	13.33
Animal feed	100
Compost making	16.66
Mushroom production	58.33
Happy seeder/Zero tillage	1.66
Incorporation	16.66
Thatching	91.66
Packing material	41.66
Fuel purpose	80

Source: Roy and Kaur, 2015

Effect of rice straw burning on soil

Farmers burn stubble and excess vegetation for a variety of reasons, not just simply to remove straw and duff. Burning cereal crop residues after harvest can somewhat reduce diseases where straw serves as a host to pathogens. Burning also results in changes in soil temperature, soil moisture, and nutrient availability. Some long and short-term studies have been completed to determine the effects that burning has on soil quality.

Dormaar*et al.* (1979) found that a number of soil properties were permanently affected by long - term burning of crop residues including decreases in organic matter, total nitrogen, carbon nitrogen ratios, extractable carbon, polysaccharides, ammonium, and available phosphorus. Biederbeck *et al*. (1980) reported that the heat from burning residue only penetrated the soil to a depth of 1.5 inch. This means that many insects and diseases that are soil borne or overwinter in the soil are not affected by burning. Additionally, research is also consistent in findings that burning increases the erodibility of the soil, reduces water intake of the soil, and increases soil density (reducing porosity). Tung *et al*. (2014) studied that rice straw burning method (dispersive and intensive) on rice field increased the soil temperature, especially at the topsoil layer. The soil temperature caused by intensive was higher than dispersive burning.

Table 6: Impact of rice straw burning on soil temperature

Burning methods	**Layer (cm)**	**Temperature (°C)**	
		Preburning	**Post burning**
Dispersive	0-2	30.2	75.5±1.32
	4-6	4-6	45.5±3.5
	8-10	26.0	30.0±0.87
Intensive	0-2	30.2	89.0±1.50
	4-6	28.5	82.0±2.29
	8-10	26.0	41.0±0.5
LSD	0-2	-	3.58
	4-6	-	7.50
	8-10	-	1.79

Source: Tung *et al*., 2014

Table 7. Effect of Crop Residue Management on Organic C and Total N Content of Soil under the Rice-Wheat Cropping System

Reference	Type of crop residue	Duration of study (Years)	Residue management	Organic C (%)	Total N (%)
Beri *et al.*, 1995	Rice straw in Wheat and Wheat straw in Rice	10	Removal Burned Incorporated	0.38 0.43 0.47	0.051 0.055 0056

Table 8. Effect of crop Residue Management on Soil Fertility of a loamy sand soil over 11 years of the Rice-Wheat Cropping System at Ludhiana (Beri *et al*., 1995)

Soil property	Crop Residue Management		
	Burned	Removed	Incorporated
Total P (mg kg^{-1})	390	420	612
Total K (mg kg^{-1})	17.1	15.4	18.1
Olsen P (mg kg^{-1})	14.4	17.2	20.5
Available K (mg kg^{-1})	58	45	52
Available S (mg kg^{-1})	34	55	61

Sourse: Sidhuand Beri, 2008

Table 9: Nutrient losses due to burning of rice residues in Punjab, 2001–2002

Nutrient	Concentration in straw (g/kg)	Percentage lost in burning	Loss (kg/ha)
C	400	100	2,400
N	6.5	90	35
P	2.1	25	3.2
K	17.5	20	21
S	0.75	60	2.7

Source: Singh *et al.* (2008)

Most research has shown that short-term burning (somewhere between seven to fifteen years of burning) has little measurable effect on overall soil health and crop production. Where burning is prolonged over periods in excess of 15 years, soil quality is measurable with a final result of reduced yields.

Effect on Soil biological properties:

Crop residues provide substrate, and C and N for growth and activities of soil microorganisms. These organisms also compete with plants for available nutrients, including those released from residues by decomposition. Soil microbial biomass (SMB) is affected by the residue management practices. Many workers reported a decline in microbial biomass when residues are burnt. Residue incorporation resulted in more microbial activity than residue removal or burning. Many research findings show that long-term burning decreased the microbial population of the soil permanently. It takes several months to 5 years to recover.

Table 10: Total soil nitrogen (N) pool size (pounds/acre) as affected by 5 years of incorporating or burning straw, winter flooding and no winter flooding fields

Treatment	Soil N pools				
	Inorganic N	Microbial biomass	Light fraction	Mobile humic	Total soil N
Burn/flood	16.2	62.2	40.2	493	1930
Burn/no flood	11.5	66.3	43.8	455	1974
Incorporated/flood	16.0	79.8	47.3	536	1927
Incorporated/no flood	13.7	86.6	52.7	522	1940
P values					
Straw	0.039	0.003	0.095	0.109	NS
Flood	0.055	NS	NS	NS	NS
SxF	NS	NS	NS	NS	NS

Source: Bird *et al*., 2002

Bhattacharjee *et al*., (2013) showed that various approaches of rice stubble utilization had very distinct effect on the microbial biomass carbon (MBC) and nitrogen (MBN) content in wheat rhizosphere soil. In general the decreasing importance of these additives to increased MBC and MBN values was in the order: Stubble+PC+NK>Stubble+PC+K> Inoculatedvstubble+NPK> Inoculated stubble+PK>stubble+NPK>Stubble+PK> Burnt stubble+PC+NK> Burnt stubble+NPK, indicating that stubble burning could not significantly increase biomass carbon and nitrogen in soil. Thus, higher microbial biomass could be through residue incorporation than their removal and/or burning.

Table 11: Rice stubble utilization in relation to microbial biomass carbon (µg g^{-1}) in wheat rhizosphere at different stages of wheat growth

Stages Treatments	Crown Root Initiation	Tillering	Internode elongation	Flowering	Harvest	Mean
Burnt stubble + NPK	54.34g	74.63g	124.4h	171.1g	144.7f	113.827h
Burnt stubble + PC + NK	82.44f	98.03f	152.5g	199.2f	178.9e	142.202g
Stubble + PK	116.6e	156.1e	198.4f	253.6e	231.3d	191.183f
Stubble +NPK	136.9d	181.9d	225.5e	265.4e	245.8cd	211.109e
Inoculated Stubble + PK	147.1d	211.3c	250.6d	295.5d	263.0c	233.505d
Inoculated Stubble +NPK	183.6c	221.5c	274.8c	318.6c	287.6b	257.214c
Stubble + PC + K	207.0b	253.6b	295.6b	342.2b	305.1b	280.688b
Stubble + PC +NPK	231.4a	268.9a	323.5a	370.3a	334.5a	305.739a
Mean	144.918	183.236	230.661	277.001	248.852	

Source: Bhattacharjee *et al*., (2013)

Table 12. Rice stubble utilization in relation to microbial biomass nitrogen (µg g^{-1}) in wheat rhizosphere at different stages of wheat growth

Stages Treatments	Crown Root Initiation	Tillering	Internode elongation	Flowering	Harvest	Mean
Burnt stubble + NPK	5.95g	7.65h	14.0h	19.0h	16.2f	12.546h
Burnt stubble + PC + NK	9.10f	11.1g	17.0g	22.0g	20.1e	15.885g
Stubble + PK	13.0e	16.8f	23.1f	28.0f	24.9d	21.152f
Stubble +NPK	15.0d	19.9e	25.1e	30.1e	27.1c	23.420e
Inoculated Stubble + PK	16.9c	23.1d	27.8d	33.0d	30.1b	26.191d
Inoculated Stubble +NPK	19.8b	25.1c	30.1c	36.0c	31.9b	28.584c
Stubble + PC + K	23.3a	28.0b	33.0b	38.0b	34.9a	31.427b
Stubble + PC +NPK	25.0a	29.9a	36.0a	41.1a	36.9a	33.790a
Mean	16.003	20.201	25.760	30.894	27.764	

Source: Bhattacharjee*et al*., (2013)

Bhattacharjee *et al*., (2013) also reported that Stubble+PK was similar to burnt stubble+NPK and the later was at par with Inoculated stubble+PK but Inoculated stubble+PK was significantly better than Stubble+PK. This implied that inoculation of biodegrading culture having greater microbial biomass enhanced the urease activity in soil. It also revealed that stubble+NPK was similar to stubble+PC+K and burnt stubble+PC+NK. However, burnt stubble+PC+NK was significantly better than stubble+PC+K indicating that fertilizer N in the burnt stubble+PC+NK increased the urease activity.

Table 13. Rice stubble utilization in relation to urease activity (µg NH_4^+ g^{-1}soil ha^{-1}at 30^0C) in wheat rhizosphere at different stages of wheat growth

Stages Treatments	Crown Root Initiation	Tillering	Internode elongation	Flowering	Harvest	Mean
Burnt stubble + NPK	67.74d	73.88c	98.69c	129.4c	115.0bc	97.032ef
Burnt stubble + PC + NK	84.95bc	94.96b	111.1bc	150.6b	124.2ab	113.2c
Stubble + PK	76.91c	43.48d	112.3b	133.0c	109.8cd	95.078f
Stubble +NPK	98.25a	108.1a	120.0b	127.4c	98.95d	110.5cd
Inoculated Stubble + PK	88.63b	107.3a	116.6b	107.5d	85.06e	101.0e
Inoculated Stubble +N PK	88.98b	110.6a	136.2a	157.0b	132.3a	125.0b
Stubble + PC + K	83.73bc	94.85b	116.1b	131.4c	109.5cd	107.1d
Stubble + PC +NPK	105.9a	115.4a	119.6b	203.7a	109.6cd	130.8a
Mean	86.89	93.64	116.3	142.38	110.5	

Source: Bhattacharjee *et al*., (2013)

Bhattacharjee*et al*., (2013) also revealed that a substantial amount of nitrogen was fixed by the heterotrophic non-symbiotic N fixing bacteria being stimulated by the incorporated stubble in wheat field. The influence of stubble blended with fertilizer NPK was greater than the burnt stubble + NPK, indicating that stubble had greater impact on the growth and activity of bacteria to fix atmospheric N. Stubble on decomposition produces oxidisable carbon molecules which in turn utilized by heterotrophic non-symbiotic nitrogen fixers as energy source for nitrogen fixation.

Table 14. Rice stubble utilization in relation to nitrogen fixing power (mg N g^{-1} of sucrose g^{-1}soil) in wheat rhizosphere at different stages of wheat growth

Stages Treatments	Crown Root Initiation	Tillering	Internode elongation	Flowering	Harvest	Mean
Burnt stubble + NPK	7.34d	8.55f	9.65c	9.07de	7.91f	8.504d
Burnt stubble + PC + NK	8.30c	9.48bcd	9.77c	9.41cde	8.72cd	9.134c
Stubble + PK	8.97ab	9.86ab	10.8ab	10.2ab	9.24ab	9.826b
Stubble +NPK	7.43d	9.31cd	9.54c	8.87e	8.35de	8.700d
Inoculated Stubble + PK	8.83ab	9.72abc	11.3a	10.6a	8.92bc	9.871b
Inoculated Stubble +N PK	8.53bc	8.72ef	10.4b	9.49cd	8.22ef	9.079c
Stubble + PC + K	9.16a	10.1a	11.3a	10.6a	9.65a	10.2a
Stubble + PC +NPK	7.62d	9.17de	10.4b	9.85bc	8.41de	9.088c
Mean	8.271	9.364	10.409	9.769	8.674	

Source: Bhattacharjee*et al*., (2013)

Table 15. Impact of rice straw burning on soil microorganisms (CFU/g soil)

Burning methods	Layer (cm)	Bacteria		Actinomycetes		Fungi	
		Pre-burning	Post-burning	Pre-burning	Post-burning	Pre-burning	Post-burning
Dispersive	0-2	$5.0x10^6$	$2.4x10^5$	$2.7x10^5$	$5.1x10^4$	$4x10^3$	$8.8x10^2$
	4-6	$4.2x10^6$	$8.2x10^5$	$7.0x10^4$	$2.5x10^3$	$2x10^3$	$6.4x10^2$
	8-10	$5.0x10^5$	$4.6x10^5$	$2.7x10^3$	$2.5x10^3$	$1.8x10^3$	$1.5x10^3$
Intensive	0-2	$5.0x10^6$	$2.0x10^4$	$2.7x10^5$	$4.9x10^3$	$4x10^3$	$1.2x10^2$
	4-6	$4.2x10^6$	$1.1x10^5$	$7x10^4$	$2.2x10^3$	$2x10^3$	$2.1x10^2$
	8-10	$5.0x10^5$	$1.4x10^4$	$2.7x10^3$	$2x10^3$	$1.8x10^3$	$1.0x10^3$
LSD			$2.24x10^5$		$6.09x10^3$		$2.85x10^2$

Source: Tung *et al*., 2014

Conclusion

Crop residues, usually considered a problem, when managed correctly can improve soil organic matter dynamics and nutrient cycling, thereby creating a rather favourable environment for plant growth. Residue burning causes nutrient and resource loss and adversely affects soil properties. The most viable option is to retain residue in the field; burning should be avoided. The recycling of crop residues has the advantage of converting the surplus farm waste into useful product for meeting nutrient requirement. It also maintains the soil physical and chemical condition and improves the overall ecological balance of the crop production system.They are important natural resources and not wastes.

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USE OF RICE RESIDUE FOR MUSHROOM CULTIVATION

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Food grain production in India increased from 50 million tonnes (Mt) in 1947 to 273.4 Mt in 2017, by a factor of 5.5. The rate of increase of production of food grains has surpassed that of the population growth, especially since mid-1960s with the onset of the green revolution. The per capita food grains production was 145 kg for the population of 344 million in 1947. The per capita grain production is 204 kg for the population of 1340 million in 2017. With increasing agricultural production, there is resulting increase in crop residues. Estimates of crop residues production in India have been made since 1990s (Lal, 1995). Current estimates of production of crop residue in India range from 510 to 836 Trillion g per yr with an average of 664 Tg per year. Of these, contributions of crop residues by cereals range from 332 to 433 Trillion g per year. Among cereals, rice is an important source of crop residues and other by-products. India produced 122 Trillion g of paddy rice in 2012, and it operates 125,000 rice mills.

Adverse Impacts of Burning of Crop Residues

In-situ burning of crop residues has been done by farmers to prepare the fields for next crop. Farm mechanization especially in harvesting and threshing of paddy, has made this practice more widespread. Although it is quick, easy and convenient method of disposing off unwanted crop residue, it has numerous disadvantages especially in the present context of climate change. Burning of crop residues and biomass burning (forest fires for clearing *jhum* fields) contributes to emission of greenhouse gases (CO_2, N_2O, CH_4) residues including CO, NH_3, NOx, SOx, non-methane hydrocarbons (NMHC), and volatile organic compounds (Irfan *et al*., 2014).

Research on this issue in the state of Punjab, India's breadbasket, has established that burning one ton of straw, releases about 3 kg of particulate matter, 60 kg of carbon monoxide, 1,460 kg of carbon dioxide, 199 kg of ash and 2 kg of sulphur dioxide. The resultant haze and low-hanging clouds of smoke, exacerbated by low temperature and slow wind speed, are a lethal health hazard, posing serious risks to health of the people and increases existing diseases. It also leads to poor soil health by eliminating essential nutrients. It is estimated that burning of 1 t of rice straw accounts for loss of 5.5 kg nitrogen, 2.3 kg phosphorus, 25 kg potassium and 1.2 kg sulphur leading to soil fertility loss.

In addition to adverse effects on soil health and risks of accelerated erosion along with erosion-induced impacts on quality of water (non-point source pollution) and wind (dust storms), emission of soot (black carbon) and other gases seriously impact human health. The very recent impasse in the national capital over the quality of breathing air leading to debates, policy change and introspection may be recalled. The practice of burning post-harvest plant stubble in the agricultural fields of Punjab has received international attention with the National Aeronautics and Space Administration, NASA releasing satellite images showing large number of fires over millions of hectares of agriculture fields of Punjab obscuring most of the Punjab region of India. This has caused severe ill effects. Researchers found that most of the particulates released due to agriculture crop residue burning are smaller than 10 microns and easily enter into the lungs, causing heart problems. The exposure to smoke emitted from crop residues burning has adverse effects on pulmonary functions especially of children and expectant mothers.

Judicious utilization of agricultural waste is important to improving the environment while creating another income stream for rural communities. Crop residues, in India and elsewhere in developing countries, have numerous traditional and modern competing uses. Traditionally, crop residues are used for cattle feed, cooking fuel, home construction, and making household products. Nowadays, there are many ways of using solid waste to generate income/energy. According to the Ministry of New and Renewable Energy, Govt. of India (Mazumdar, 2013), 1700 MW of energy will be generated from urban organic solid waste (1500 from MSW and 225 MW from sewage) along with 1300 MW of energy from industrial waste (http:// www.eai.in/ref/ae/wte/wte.html). Shehrawat and Sindhu (2012) expressed that although farmers are aware of the potential of using waste as an energy source, there is a need for implementation of community-based projects.

Rice being the staple crop of the state, it is estimated that an area of one hectare of rice in Manipur, 4000 kg (800 bundles of about 5 kg each) of rice straw are produced. In Manipur, farmers burn the paddy straw mainly use to produce ash for spraying in the vegetable crops especially in potato cultivation to increase the tuber yield (high content of K). If rice straw is left in the field without proper management, it can lead to spreading of diseases and pests, as primary inoculum from the rice straw, such as stem disease / stem borers and can also encourage the breeding of pests, especially rats. A management strategy that does not involve burning while generating sustainable income would be highly benefitting-farmers and environment.

In Manipur, there is tremendous potential at the individual farmer's level/ community level that is beneficial for income generation while being absolutely safe for the environment through mushroom cultivation. In India, three mushrooms namely white button mushroom (*Agaricus bisporus*), oyster mushroom or dhingri (*Pleurotus species*) and paddy straw mushroom (*Volvariella volvacea*) are widely cultivated by using paddy straw as substrate. There has been tremendous increase in mushroom production during the last few decades with the development of new improved technology. Thus, instead of burning of paddy straw after harvesting of rice, it can be used judiciously for cultivation of highly delicious mushroom to get higher income for the farmers.

Cultivation of edible mushrooms with agricultural residue like paddy straw is a value added process to convert a material, which is otherwise a non-consumable waste to a nutritious superfood that has no cholesterol and loaded with vitamins and minerals in the shortest period of time possible. It represents one of the most efficient ways by which this residue can be recycled.
Important edible and commercially cultivated mushroom in Manipur using paddy straw as substrate is discussed below.

A) **Cultivation of *Pleurotus spp.*:** Oyster mushroom is widely cultivated in Manipur. This mushroom is also known as "Wood fungus" and in India commonly called "Dhingri". Some of the commercially cultivated species of oyster mushroom in Manipur are
   1. *Pleurotus sajor caju*
   2. *P. ostreatus*
   3. *P. sapidus*
   4. *P. flabellatus*
   5. *Hypizygus ulmarius* etc.

Out of the above mentioned species, *P. flabellatus* and *Hypizygus ulmarius* is grown in summer and remaining are cultivated in winter.

Method of Cultivation

1. **Selection of paddy straw, cleaning, chopping, sterilization and soaking in water:** Paddy straw having light yellow colour, not more than 18 months, free from disease infection and rain free are preferable. Before chopping out the paddy straw, mouldy leaf portion should be removed by the hand combing. Chopped the cleaned paddy straw into pieces of 2-3 cm using chop cutter or sickle. After chopping the paddy straw, it should be soaked into cold water for 6-12 hrs by adding carbendazim @ 7 gm/100 L and 125 ml formaldehyde to wipe out the or micro-organisms present in the straw. Ideal time for soaking is 8 hrs with clean water. Soaking time can be only 30 mins if we used hot water for sterilization. It is advisable that all the equipment should be sterilized with alcohol. Excess water should be drained out till the moisture content of the straw was about 80 per cent (while squeezing the straw with pressure, water should not come out from between fingers indicating 70-80 % moisture).
2. **Preparation of spawn and selection of spawn:** Mother culture should be collected from highly reliable sources to avoid preparation of inferior quality of spawn. After getting the mother culture, it should be regularly sub culture for future used in slant or plate containing media. This sub culture can be used for spawn preparation. For preparation of spawn, fresh culture should be made on plate containing media. When the plate is fully covered with the mycelial growth, it should be made into small pieces into circles using cork borer. One piece containing mycelial growth can be used for preparation of spawn of weighing 250-500 gm of sterilized partly cooked rice grains. All the operations should be done inside the laminar air flow to avoid contamination. Thus, spawn is ready for used after 7- 15 days. Ideal spawn should be white mycelial growth and free from any contamination mainly by *Trichoderma sp.* (Light green colour discoloration) and Bacillus infection (White viscous in nature). Spawn should not be more than 20-30 days old.
3. **Spawning:** Spawning means adding of chopped out rice straw with 80 % moisture along with spawn into polythene sheet. Size of polythene bags is not restricted and depends on individual convenience. The ratio of straw with spawn is 10:1. Layer spawning is recommended. In layer spawning, a layer of paddy straw is placed at the bottom of the polythene uniformly and then spread the spawn proportionately. Around 250-300 gm of spawn is enough for spawning of one bag. It should be repeated till 3-5 layers with covering the last layer with some loose straw. The polythene should have perforated hole of 0.5-1 cm diameter for good aeration. The mouth of the polythene should be tight up with a thread and then, placed in the mushroom house either by hanging or in the rakes. The mushroom house should have enough moisture and should be completely dark for initiation of mycelial growth and development of fruiting body and well ventilated room. Watering should be done regularly to keep the house moist in condition. After 10-15 days of spawning, white cottony mycelial growth will fully covered the polythene. After 2-3 days small pin head will appears and is ready after harvest after 2-3 days.
4. **Harvesting:** Proper way to harvest mushroom is by twisting the stipe with hand so that no portion should be left out in the bed to prevent the rotting and contamination while watering. At least 3 harvesting can be done from one polythene bag yielding 2.5-3.0 kg of fresh mushroom in proper management system. Summer type of mushroom is ready to harvest 5-10 days earlier as compared to winter type.

Instead of burning the rice straw, farmers can properly harvest the straw and can be heaped at free space. They can either sell to mushroom growers or they can start mushroom cultivation which will boost their socio-economic condition. With proper training they can become skilled in mushroom cultivation. This will ensure income and nutrition security for their family also. Being favoured by the congenial climate, year round cultivation of mushroom cultivation in Manipur can be taken up by any farmer at the individual level or self-help groups can also be formed for women/interested growers at the community level. Value added products of mushroom can also be prepared such as pickles or dried mushroom which increases the shelf-life and value of the product.

Economics

The cost of cultivation of *Pleurotus* mushroom is shown in the following table, highlighting the amount invested during first establishment and the profit earned.

Non-recurring		
A.	Land	**Own**
B.	Cropping shed	**Own**
C.	Cost of flooring and rack preparation	**Rs. 10,000/-**
D.	Machine and equipment	**Rs. 13,100/-**
	1. Sickle	Rs. 300/-
	2. Hand Sprayer	Rs. 1,600/-
	3. Plastic water reservoir (500 l×2)	Rs. 9,000/-
	4. Plastic tub	Rs. 350/-
	5. Plastic sheet	Rs. 100/-
	6. Small sprayer	Rs. 250/-
	7. Plastic tray (2 nos.)	Rs. 600/-
Recurring		
E.	Margin Money for working capital	**Rs. 15,200/-**
	1. Paddy straw @ Rs. 15/ bundle (200 no.)	Rs. 3,000/-
	2. Spawn @ Rs. 30/ pkt of 300gm. (200 no.)	Rs. 5,000/-
	3. PP plastic bags @ Rs. 5/pc (200 no.)	Rs. 1,000/-
	4.Chemical L.S	Rs. 1,000/-
	5.Water and electrical Energy L.S.	Rs. 2,000/-
	6. Product labelling & plastic	Rs. 1,200/-
	7. Miscellaneous	Rs. 2,000/-
F.	Salary/ labour wages (2 months)	**Rs. 18,500/-**
G.	Depreciation 5% and interest at 12% on non –recurring (23100x5/100x12)=96.25x2	**Rs. 192.50/-**
H.	Interest 3% per month for two months (Rs. 56,300 x 3/100) = Rs.1, 689 x 2	**Rs. 3,378/-**
I.	Total cost (1st year) = C+D+E+F+G+H	**Rs.59,870.50/-**
J.	Anticipated Yield @ 3kg/bag (Rs.150 /kg) (3x200x150)	**Rs.90,000/-**
K.	Return for 1st year= Rs. (90,000-59,870)	**Rs. 30,130/-**
FOR SECOND YEAR		
L.	**Total cost of production: E+F+G+H**	**Rs. 36,770/-**
M.	**Anticipated yield**	**Rs. 90,000/-**
N.	**Benefit: Rs. (90,000-36,770)**	**Rs. 53,230/-**

* The size of mushroom house is 15'X 20' X 12' (200 bags capacity)

The growing numbers of mushroom growers in Manipur is a testament to the usefulness of this simple zero pollution technology to ensure sustainable income, food and nutrition security for the farmers. At the same time, mushroom production is a sustainable approach for utilizing the paddy straw for ensuring additional profit and generate employment with less investment.

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SUSTAINABLE USE OF CROP RESIDUES INCLUDING PADDY STRAWS AS LIVESTOCK FEED

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Paddy straw is a major field-based residue undergoes field burning in most parts of the rice producing states of the country like Punjab, Haryana, North eastern states including Monipur. This waste the energy resulting high fuel prices and demands for reducing greenhouse gas emissions as well as air pollution. To avoid these burning issues of crop residues like rice straws management of agricultural waste for their alternate uses is being practiced and promoted. These include use of rice residue as fodder for livestock, crop residue in Bio thermal power plants and mushroom cultivation, rice residue used as bedding material for cattle, production of bio-oil, paper production, bio-gas etc. Besides, it can be use in soil as mulching, energy technologies and thermal combustion (Kumar, 2015).

Livestock production is a major component of the agricultural economy of developing countries like India. In mixed farming system livestock production especially, ruminants have lagged behind in productivity because of factors like low genetic potential, poor health management and imbalance feeding (Singh et al., 1997). With the deterioration of natural range lands due to the overgrazing, and the tendency to divert better feeds to crop residues like straws, stovers, bhusha, khadbies etc become the prominent feeds for the small holder livestock farmers especially in the ruminant production system. However, the major limitation of feeding these crop residues includes bulkiness and poor nutritive values.

In the western part of the world livestock production has become more intensive and the traditional human foods have become the row materials for animal production. But, in South Asian countries like India, livestock production is entirely different from the system in western countries. Whatever food grains are produced here are used for human consumption and we are unable to fed livestock with traditional human foods and feeding of animals are mostly dependent on poor quality roughages (fibrous crop-residues) with little or no grazing. This system of feeding cannot meet the nutrient requirement of animal for growth and production, because the crop-residues are very poor in nutritive values (little or no DCP, poor in TDN and contain high silica and crude fiber with lignin) and animals cannot fully utilize these for their productive purposes. However, these can be treated by various methods to improve their nutritive values and thereby obtain more and more production from our livestock overcoming their inherent limitations like low digestibility, low crude protein content, poor palatability and bulkiness. The methods includes manipulation of their physical forms, supplementation with other feeds, up-grading with urea, ammonia etc.

i) Manipulation of physical form of crop residues: The treatment of poor quality roughages like straws to improve nutritive value was started as early as 1895 by Lehman. Indeed, efforts are in progress to find out a simple and economic treatment process for the small and marginal farmer. The various simple and economic physical methods of treatment of these poor quality roughages to improve the physical forms and nutritive values of crop-residues includes Chaffing and grinding, Water soaking and boiling, steam treatment with or without pressure etc. Some chemical treatments with the use of NaOH, $Ca(OH)_2$, Ammonia, urea etc have also been tried in different areas with best finding in terms of growth and production in dairy animals through urea treatments that also adopted by farmers in India as well as other parts of the world. The techniques can be describe as follows-

ii) Urea treatment of poor quality roughages: As per the research conducted in NDRI, Karnal to improve the nutritive values of paddy straws with urea used 100kg of paddy straws with 90% DM, 3-4kg urea and 50 liters of clean drinking water. For preparation of the product at first approximately one quintal of straw (chopped or un-chopped) is spread over a circle of about 2 metres radius on a clean dry floor. Then over the straw sprinkle the solution of 3-4 kg of urea after dissolving it in 50 litres of water. The straw layer is then pressed thoroughly by feet to make the stack more compact.

Then, another straw layer of one quintal is then spread over the previous layer and then the solution of 3-4kg of urea dissolving in 50 litres of water should sprayed over the straw layer. The same procedure is repeated till the last layer of straw (up to 25 quintals) to be treated with urea. Then the stack should be covered with polythene sheet or banana leaves or untreated straw for at least 3 weeks. During this 3 weeks of period the urea used will first hydrolysed to ammonia which will penetrates in to the straw fibres and breaks the lingo-cellulogic bonds and cellulose and hemi-cellulose of the treated roughages will be easily hydrolyzed by rumen microbial enzymes. Hence, treatment of poor quality roughages with urea, increased not only the digestibility and palatability of the roughages, but also increases its crude protein contents.

The desire quantity of treated straws as per daily requirement is exposed first for an hour to remove the smell of the ammonia gas before being offered to the animals. Experiment conducted at NDRI, Karnal reported not only increase in palatability and digestibility but also increase the DCP and TDN percentages from zero to 4-5 and 38-40 to 48-50, respectively. The treated straw can be chaffed and then mixed with little quantity of green fodder, if possible and then fed to the animals. 5-6 kg of treated straw can meet all the requirements of energy and proteins for an adult yak or dry cattle. In case of lactating dairy animal 4-5kg of treated straw can be reduces the amount of concentrate by 0.5 to 1kg with increasing milk yields by 1-1.5kg.

Molasses, at the rate of 5-10% can also be used for increasing productive performances of the animals and the desire amount of molasses have to be mixed first with the urea solution before spaying on to the spread straws (**urea-molasses enrichment of straws**).

iii) Supplementation of poor quality roughages with limiting nutrients: Feeding limiting nutrients in the form of concentrates, special minerals, protein or some green forage does supplementation of poor quality roughages which aims at one or a combination of two distinct objectives-

a) Feeding for a positive associated effect: In this approach small quantities of supplements such as minerals or protein are used to enhance rumen fermentation leading to increased intake and digestibility. The primary objective of this is the utilization of available roughages which implies only a low levels of animal production e.g. survival feeding which is essential and valuable in many tropical farming systems.

b) Substitution supplementation: It aims to reach a desired level of animal production with moderate to high levels of supplement, often by substituting a part of the basal feed in the ration. This supplementation can even be done at the expense of optimum biological processes in the rumen, as in the case of feeding high concentrate rations. Significantly higher DM intake and also

DM and OM digestibility have been observed with increasing levels of concentrate supplementation in cattle ration. Sharma *et al*. (2006) reported significantly higher DM, DCP and TDN intake along with increased milk yield through increasing dietary supplementation levels of cakes in lactating buffaloes.

Methods of supplementation:

i) Feeding straw mixed with green leguminous fodder or tree leaves @ 75:25 can maintain the body weight of the animals. At 50: 50 ratios it can maintain growth and lactation.

ii) **Poor quality roughages mixed with feed ingredients**: when straw is fed with supplementation of concentrate mixture and green grass it can maintain the growth in growing animals. The ration mentioned below could serve the average daily gain (g/day) up to 550g in crossbred cattle.

Straw	4.0kg
Concentrate mixture	2.0kg (16% DCP and 70% TDN)
Green grass	2.0kg

iii) Pre-treatment or up-grading with Urea/Ammonia: The use of cereal straws for ruminant feeding is essentially constrained by its low voluntary intake and digestibility resulting losses in productions. Hence, effort has been directed to up-grading through treatment with urea or ammonia solutions (Dolberg, 1992). Ammonization of wheat/rice straw almost doubled the crude protein content from 3.9-4.1 to 8.1-8.5% due to retention of ammonia nitrogen content, which normally considered the minimum necessary in the diet for adequate intake, digestive activity of the micro-organisms and maintenance of live weight. In this method 2kg of urea first dissolve in 10litres of water in addition with 10 kg of molasses and the mixture sprayed over 100kg of straws uniformly, dried up under the sun and fed to the animal on free choice basis.

iv) Densification of crop residues for better utilization: Poor quality roughages along with some conventional high quality fodder and concentrates in the form of Complete feed blocks i.e. in densified form can cater to the needs of livestock of varying production levels especially during winter when greenery complete perishes from the scenario of the yak rearing areas or also during some natural calamities like draught, flood etc. Studies conducted by ICAR-NRC on Yak showed on an average adult yaks lose approximately 25–30% of their total body weight in winter, putting them at risk. It has been suggested that complete feed block feeding over the traditional grazing as a supplementary feeding could ensure the optimum productivity of yaks during winter.

Complete feed block?

Complete feed block is an intimate mixture of processed ingredients including roughage and concentrate parts designed to be the sole source of feed for animals in compressed form. It may be square, circular or quadrangular depending on the type of dye used in the machine. Complete Feed Block Technology (CFBT) is the latest development in the direction to exploit the potential of locally available animal feed resources besides using non-conventional feed resources in a better way that makes livestock farming an economically viable.

The technology: The processed feed ingredients inclusive of roughage and concentrate are mixed in a uniform blend and compressed at high pressure, ensuring the supply of diet of same composition. Roughages (mostly crop residues like paddy straw, wheat bhusha, stovers, jungle grasses etc) form an essential and major component of ruminant diet. They are available seasonally; hence their storage becomes necessary for use during off season. Due to low bulk density (65-70 kg/m^3), require large storage space and poses problems in handling, storage and transportation which becomes among major constraints in their feeding to livestock.

Densification of these feed resources tremendously reduce storage space, which in turn save significant amount of money incurred as transportation charges and drastically curtails the cost of storage. CFB feeding also reduces the problems of nutrient deficiencies in livestock fed on poor quality feed resources by allowing a synchronous and fractionated supply of all essential nutrients for attaining maximum production potential. There is possibility of incorporation of un-conventional feed ingredients like tree leaves etc and some chemicals like tannin neutralizing agents e.g. polyethylene glycol (PEG) and anthemantics medicines

Advantages of feeding Complete Feed Block in ruminants:

- ✓ **Improved nutrient intake:**
  CFB feeding improves dry matter intake (DMI) in all ruminant species compared to other feeding systems by about 10-20%. It also reduces the loss of valuable dry matter and thereby prevents environmental pollution

- ✓ **Better nutrient utilization:**
  CFB feeding ensures intake of intended proportion of roughages & concentrates by animals, thus not permitting faster or selective eating. Improves utilization of poor quality roughage, as concentrate particles are closely attached to roughage feed particles due to high pressure employed during compression

- ✓ **Economical aspect:**
  - Due to low bulk density (65-70 kg/m^3), require large storage space and posses problems for paddy straws in handling, storage and transportation creating major constraints for livestock feeding. Densification tremendously reduce storage space, which in turn save significant amount of money incurred as transportation charges and drastically curtails the cost of storage.
  - Minimizes the risk of road accidents and is convenient as it saves time and labour due to ease in handling & feeding.

- ✓ **Establishment of feed banks:**
  - Paddy straws instead of burning during harvesting can be stored in block form, which may be utilized in shortfall year during which prices of feed ingredients increases to the maximum extent. Paddy straw based CFBs may be highly useful in establishing feed banks by the Government to solve the problem of feeding livestock during natural calamities like flood, draught, snowfall etc.

✓ **Improved keeping quality of feeds:**

- Crop residues after harvesting stored conventionally either on tree tops or ground whereby precious nutritional resources are exposed to vagaries of weather.
- Reduces the risk of fire hazards.
- Reduces shattering of lighter leafy nutritious matters, leaching by rains, mould growth, decomposition of biomass, fire hazards etc that drastically lowers nutritive values of roughages
- The block making prevents disintegration of valuable nutrients and thus CFBT is a simple and efficient technique for long term conservation as animal feed resources.

The experiment conducted by Baruah *et al*., 2012 at Mandala (10,000ft msl) under ICAR-NRC on Yak, Dirang reported compensatory growth and performances of growing yaks on both tree leaves and paddy straw based CFBs.

v) Ensiling: The nutritive value of poor quality roughages can also be improved by **making silage**, though the process in general used for green fodders. Ensiling is the forage conservation techniques by which we can preserved green forages through controlled or induced anaerobic fermentation retaining its moisture content and the product is called as **Silage**. The best silages are moist to touch, soft but not slimy and fragrant. For ensiling of paddy straws, poor quality roughages are mixed first with other succulent fodder such as maize, berseem, water hyacinth, poultry litter etc and then keep in a Silo to allow it for *Lactobacillus* and other beneficial microbial growth to create anaerobic condition which finally produce lactic acid and make cellulose and hemi-cellulose more soluble. After 4-6 weeks this feeds become suitable for feeding livestock during scarcity. To prepare good quality silage we need one Trench/Bunker/cylindrical type silo (container used for silage making) besides good quality fodder with sufficient moisture. Generally, crops with thick stems are conserved as silage, but any crop having sufficient soluble carbohydrates and moisture to produce good quantities of lactic acid may be use for silage making. The most commonly used silage crop in India are maize, sorghum, sudan grass, bajra, hybrid napier etc.

Ensiling paddy straws with fruit factory waste and poultry droppings at different levels for a period of at least 4 weeks produces good silages. The fruit by-products like apple pomace, citrus peels etc are rich source of soluble carbohydrate with little protein containing when added with poultry droppings contains sufficient quantity of nitrogen and chaffed paddy straws for a period of 4 weeks will improves the feeding values of paddy straws through increasing fermentation. Paddy straw, poultry dropping, green grass and molasses in the ratio of 40:40:10:10 on dry matter basis form very good silage (Baruah *et al*, 1983) and is highly relished by the animals. However, to reducing the burning issue of the country immediately after harvest of seeds retaining their sufficient moisture content (minimum 65%) can also be proceed for silage making with or without mixing with leguminous fodders.

Conclusions

Paddy straws, the major field-based residue of rice production system undergoes field burning in most parts of the country resulting loss of energy and demands for reducing greenhouse gas emissions as well as air pollution. Feed scarcity during winter for high lender and due to natural calamities like flood, draughts etc are the major constraints in most of the developing countries like India, where livestock production is a major component of the agricultural economy. To address these issues management of agricultural waste like paddy straws alternate uses are being practiced and promoted. Feeding paddy straws in ruminants is one of the best among these alternatives. However, the major limitation of feeding these residues includes their bulkiness and poor nutritive values. Technology applications like supplementation of concentrate mixture, urea treatment, densification, ensiling etc has the capacity to meet these challenges and could reduces the burning issues of the crop residues including paddy straws and thereby better utilization resulting improvement in their productivity.

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RICE RESIDUE: A SUSTAINABLE SOURCE FOR BIOENERGY

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Introduction

In India, paddy is cultivated in about 43.95 million hectares producing about 106.54 million tonnes of rice and approximately 160 million tonnes of straw with a ratio of 1:1.5 for rice grain to straw produced. Punjab produced 11.27 million tonnes of rice, which is 10.6 per cent of all India's total production for the year 2013–14 and produced a total of 16.90 million tonnes of paddy straw. Of the paddy straw produced, some part is used as a fuel for modern biomass power plants, brick kilns, cardboard making, mushroom cultivation, and some portion is used to fuel for domestic biomass cook stoves in rural areas. Portions of the paddy straw that remain uncollected in the fields due to a combined harvesting technology can ploughed back into the fields, without burning. It will serve as beneficial manure for the upcoming crops. Flooded rice fields also add up additional methane, a potential greenhouse gas produced by the bacterial community under anoxic conditions. But, due to surplus paddy straw and problem associated with its collection, farmers burned it in the open fields to quickly prepare the field for sowing the next crop. In fact 668 t paddy straw could produce theoretically 187 gallons of bioethanol if the available technology is adopted at commercial level. However, an increasing proportion of paddy straw due to increased area and production undergoes field burning. This waste of energy seems inapt, given the high fuel prices and the great demand for reducing greenhouse gas emissions as well as air pollution. As climate change is extensively recognized as a threat to development, there is a growing interest in alternative uses of field-based residues for energy applications. There are primarily two types of residues from rice cultivation that have potential in terms of energy—straw and husk. Although the technology of using rice husk is well established in many Asian countries, paddy straw as of now is rarely used as a source of renewable energy. One of the principal reasons for the preferred use of husk is its easy procurement, i.e., it is available at the rice mills.

In the case of paddy straw, its collection, transport and storage are tedious tasks and its availability is limited to harvest time only. The logistics of collection transport and storage could be improved through baling but the necessary equipment is expensive and buying it is uneconomical for most rice farmers. Thus, technologies for energy use of straw must be efficient to compensate for the high costs involved in straw management.

Power/Electricity Generation

Rice straw base combustion

Boilers and steam turbines are commonly used for biomass power projects. The technology is well known and reliable. In straw combustion at high temperatures, potassium is transformed and combines with other alkali earth materials such as calcium. This in turn reacts with silicates, leading to the formation of tightly sintered structures on the grates and at the furnace wall. Alkali earths are also important in the formation of slag and deposits. This means that fuels with lower alkali content are less problematic when fired in a boiler. Rice straw can either be used alone or mixed with other biomass materials in direct combustion, whereby combustion boilers are used in combination with steam turbines to produce electricity and heat. The energy content of rice straw is around 14 MJ per kg at 10 percent moisture content. The by-products are fly ash and bottom ash, which have an economic value and could be used in cement and/or brick manufacturing, construction of roads and embankments, etc. Straw fuels have proved to be extremely difficult to burn in most combustion furnaces, especially those designed for power generation. The primary issue concerning the use of rice straw and other herbaceous biomass for power generation is fouling, slagging, and corrosion of the boiler due to alkaline and chlorine components in the ash. Europe, and in particular, Denmark, currently has the greatest experience with straw fired power and CHP plants. Because of the large amount of cereal grains (wheat and oats) grown in Denmark, the surplus straw plays a large role in the country's renewable energy strategy. Technology developed includes combustion furnaces, boilers, and superheat concepts purportedly capable of operating with high alkali fuels and having handling systems which minimize fuel preparation. Whole bales are pushed into the combustion chamber and the straw burned off the face of the bale. However, the newer Danish plants have moved away from whole-bale systems to shredded straw feed for higher efficiency. For pulverized coal co-firing, the straw usually needs to be ground or cut to small sizes in order to burn completely within relatively short residence times (suspension fired systems) or to feed and mix upon injection with bed media in fluidized bed systems.

Rice husk based gasification

India is one of the world's largest producers of white rice and brown rice, accounting for 20% of all world rice production. Every year approximately 120 million tons of paddies are produced in India. This gives around 24 million tons of rice husk and 4.4 million tons of rice husk ash every year. The use of rice husk for electricity generation in efficient manner is likely to transform this agricultural by-product or waste into a valuable fuel for industries and thus might help in boosting the farm economy and rural development. India is the second largest rice producer in the world. For smaller projects, gasification would seem to be an appropriate solution. As with boilers, straw alkalinity and slagging are matters of concern for gasifiers. In addition, operating the gasifier at the relatively lower temperatures required to prevent agglomeration of the ash results in a tarry, low quality, producer gas. In Southeast Asia, biomass gasification projects have been based around updraft gasifiers supplied from China and India that can be described as "basic" and lack sophisticated controls. The gas produced is not sufficiently cleaned prior to use, necessitating frequent engine maintenance. As a result, these projects have historically experienced very low availability to the extent that they become commercially unviable. Decommissioned and abandoned biomass gasification equipment litters the countryside. Large numbers rice husk based gasifiers has been evaluated and installed in Bihar.

Power generation: There are different methods to generate electricity from rice husk. Within some powerful ways of electricity generation, following is power generation through the rice husk gasification. This entire system is designed in such a way that it evolves complete zero emission. The first step is biomass storage in it rice husk is placed for processing. It reserves the rice husk. Once the reserve is done, it is than passed on to the gasifier and here some chemical reactions are done so that syngas can be produced for use. Different types of gasifier are available in the market. The cheapest gasifiers is downdraft gasifier even this gasification chamber generates product gas with very low tar content. In it, at the top of gasifier biomass fuel is kept. Then as the fuel moves downward, it reacts with air (the gasification agent). The major processes are described further below.

***Downdraft gasification*:** In downdraft gasifier gas and the solids flow in the same downward direction. The actions involved in the full process are drying, pyrolysis and combustion also known as gasification. In Downdraft Gasifier System, the controlled intake of air (oxygen) is fed into the chamber containing downward movement of biomass material. After going through the process, the producer fuel gas is finally collected and drawn off at the base of this Gasifier. It is an efficient technique which has the capacity to process the biomass containing the moderate moisture (up to 30%). About 5 to 10 minutes time is needed to ignite the combustion and bring the plant to an operative temperature. Downdraft Gasifier is best suitable for the applications where the temperature control is critical, and the cleaner fuel gas is required. These Gasifiers can be used in those applications where moderate temperature is required up to 1100^{o}C.

Purification unit: With the help of dry type purification unit the process of purification can be turned more environmental friendly. In it for water purification no gas is required, which resultantly created no water pollution; even the processing of gas is completed in chamber thus the reverse effect to area through gas is prevented. With this the components like No liquid tars, no desertion of dirty water with ammonia and other gases makes the process and environment pollution free. To maintain this type of system minimum cost is required because of no slug. While the presentation of Production its efficiency is to the maximum because of the gas being recoverable and could be reused for drying the rice husk or heating the gasifier. This process is highly suitable and convenient as it allows turbine to generate electricity.

Turbine and generation unit: This unit is the power generation section of the system. Here the syngas collected from the purification system is used for generation of electricity. Two types of turbines can be used: gas turbine or steam turbine. If steam turbine is to be used, it will require a boiler where water will be heated and made steam using syngas and the efficiency will not be so high. So here it is best to use gas turbines. The efficiency of gas turbine is far better than the previous process. Here in this process, the syngas is taken into the combustion chamber, mixed with air and then combusted. It produces flue gas, which is flown through the blades of the turbine. The turbine is required up to 1100^{o}C.

Biomethanation of paddy straw

The anaerobic digestion technology is a most efficient way in terms of energy output/input ratio for handling biomass resources to produce energy and bio-fertilizer. Biomethanation of paddy straw presented here consists of actual field experimental data taken from demonstration scale biomethanation plant at Fazilka, Punjab (Ramchandra, et al, 2017). He reported that paddy straw is pulverized for its size reduction to 3–5 mm. The average capacity of paddy straw pulverization unit is 1.0 tonne/h. The unit is powered by an electric motor of 75.0 kW, that consumes nearly 94 kWh energy per hour of operation. This unit also consists of a pulverized paddy straw collection system followed by aspirator system for the collection of dust generated during the pulverization process. The aspirator unit is powered through electrical power of 30 kW, which consumes 37.5 kWh energy per hour of operation. Biomethanation is carried out in two anaerobic digesters (designed in house) of 3,400 m^3 water volume capacity. The pulverized paddy straw substrate is fed to the two digesters through the feeding unit using pumps. No external heating source is provided in the digester as the annual mean temperature in the area lies within mesophilic range. Loading rate was kept constant at

6.75 tonne / day to maintain 8–10 per cent TS in the digester, while the digester was maintained at a hydraulic retention time of 30 days. The digested slurry was passed through two horizontal solid–liquid separating machines with a slurry handling capacity of nearly 8.0 m3/h. The system is able to separate solid material at the rate of nearly 600 kg/h having a moisture content of about 65 per cent. The separated liquid is recycled to prepare paddy straw substrate in a blending tank. Table 1 shows the initial parameters of conducting continuous feed anaerobic digestion of paddy straw. C/N ratio of the pretreated paddy straw was maintained by adding urea at a rate of 18–20 g/kg of paddy straw on a dry basis. The digester was fully charged with fresh cow dung for startup and feeding of paddy straw was gradually started,

Table 1: Biomethanation parameters

S. N.	Parameter	Details
1.	Operation cycle	Continuous
2.	Hydraulic retention time (HRT)	30 days
3.	Operating temperature	33-38 ±1^{0}C
4.	Adjusted C/N ratio	~20
5.	Substrate concentration Total solids concentration (TS) Volatile solids concentration (VS)	 10% (100.0g/L) 7.5% (75.0g/L)

To reduce the hydrogen sulphide level in biogas below 50 ppm for engine operation the scrubber unit has been used. An electric motor having 5.5 kW power is used to circulate the biogas in the scrubbing unit. The total power consumption in hydrogen sulphide scrubbing unit has been 11 kW, which utilizes 13.75 kWh energy per hour of operation. Power generation unit consists of 1.0 MW 100 per cent biogas. The generator produces 1.2 MW per hour electrical energy through a three-phase 415 V alternator. Ten tonne/d of paddy straw is pulverized and fed to anaerobic digesters, which produce nearly 3,800–4,000 m^3 of biogas per day with methane and carbon dioxide content in the range of 50–55 per cent and 40–45 per cent, respectively. The hydrogen sulphide content in produced biogas varies from 500 to 600 ppm. Average specific biogas production has been found in the range of 390–440 m^3/tonne of total solids fed to the plant.

Energy and cost– benefit analysis of biogas production

For the energy balance, calculations are made from the point of paddy straw pretreatment for biogas production. From Tables 2 and 3, it is evident that the conversion of paddy straw to biogas via pulverization achieves a net positive energy of 655 kWh/tonne and cost benefit of `6,916/ tonne of paddy straw. It was revealed that the use of rice straw for biogas production can generate a positive net energy balance between 70 per cent and 80 per cent. This shows that pretreatment of paddy straw is necessary to reap a higher methane yield. The pretreatment followed by biomethanation will enable the economically competitive use of paddy straw for energy generation. This will lower the negative environmental impact during burning of paddy straw in open fields.

Table 2: Energy analysis of paddy straw-based biogas power production

Particulars	Power consumption (kWh/h)	Operating time, h	Total power consumption, kWh10 tonne
Energy input			
Paddy straw pretreatment (pulverization)	94.00	10.00	940.00
Substrate feeding unit	23.00	10.00	230.00
Hydrogen sulphide scrubbing unit	13.75	10.00	137.50
Bio-fertilizer unit	13.37	10.00	137.50
Total energy input (kWh)	-	-	1,445
Energy output (kWh)	-	-	8,000
Net energy gain (kWh)	-	-	6,555
Output/ input	-	-	5.5

Table 3: Cost-benefit analysis of paddy straw-based biogas power production

Particulars	₹/ 10 Tonne paddy straw	Rate (₹/ Unit)
Output electricity (8000 kWh)	60,000	7.5 kWh
Bio-fertilizer (5.0 t)	35,000	7.0/ kg
Input paddy straw cost	-15,000	1,500/ tonne
Paddy straw pretreatment (pulverization)	-7,050	-
Substrate feeding unit	-1,725	-
Hydrogen sulphide scrubbing unit	-1,031	-
Bio-fertilizer unit	-1,031	-
Net benefit	69,163	-
Output/ Input	3.6	-

Total energy of biogas

It is evident from Table 4 that the total obtainable energy yield from biomethanation route is 30 per cent more than bioethanol route. If all the surplus paddy straw biomass, which accounts for 160 million tonnes in Punjab, is brought to biomethane production, it will produce energy equivalent to 30.60 Mtoe and upon converting it to bioethanol, it will produce energy equivalent to 21.39 Mtoe.

Table 4: Biomethane and bioethanol potential of paddy straw

S. N.	Energy route	Yield/tone paddy straw (kg/t)	Total energy yield (GJ/t)	Electricity equivalent* (kWh/t)	Petrol equivalent(l/t)
1.	Biomethane	144.32	8.000	777.00	166.60
2.	Bioethanol	188.57	5.600	544.25	116

*Power generation efficiency is 35%

Biofertilizer

The manure used as substrates at biogas plants go through a process of decomposition during change in material characteristics. The physical and chemical change that takes place in biogas reactor produces a modified fertilizer in the form of slurry with significant increase in ammonia nitrogen content. The obtained digestate further dried for agriculture applications with silica rich biofertilizer.

Bio-ethanol from paddy straw

Rice straw is an attractive lignocellulosic material for bioethanol production since it is one of the most abundant renewable resources. It has several characteristics, such as high cellulose and hemicelluloses content that can be readily hydrolyzed into fermentable sugars. But there occur several challenges and limitations in the process of converting rice straw to ethanol. The presence of high ash and silica content in rice straw makes it an inferior feedstock for ethanol production. One of the major challenges in developing technology for bioethanol production from rice straw is selection of an appropriate pretreatment technique. The choice of pretreatment methods plays an important role to increase the efficiency of enzymatic saccharification thereby making the whole process economically viable. The present review discusses the available technologies for bioethanol production using rice straw.

Ethanol production from alkali treated rice straw was investigated by simultaneous saccharification and cofermentation (SSCF) using commercial cellulose and 3 different yeast strains viz., Saccharomyces cerevisiae HAU-1, Pachysolen tannophilus and Candida sp. individually as well as in combination at varied fermentation temperature and incubation time. Dilute alkali (2%) pretreatment of straw resulted in efficient delignification as observed by low residual lignin (12.52%) with 90.6% cellulose and 28.15% hemicellulose recovery. All the 3 yeast strains were able to produce ethanol form alkali treated rice straw and overall ethanol concentration varied from 5.30 to 24.94 g/L based on different fermentation time and temperature. Ethanol production from different yeast strains combinations revealed maximum ethanol concentration of 23.48 g/L after 96 h incubation at 35ºC with P. tannophilus individually and 24.94 g/L when used as co-culture with saccharomyces cerevisiae. Rice straw contains cellulose: 37%, hemicellulose:24% & lignin 14%. 1 kg rice straw has 350 g of cellulose which depends upon variety and the geographical location. This can theoretically yield 220 g /283 ml ethanol. Rice straw (collected locally) washed and despoiled by froth-floatation in water, air dried and chopped into small pieces. Partially delignified using 4 % NH_4OH at 15 bar &120 ^{0}C for 20 min in an autoclave at a volume ratio of 5:4 washed with hot water repeatedly till free from alkali. NH_4OH treated rice straw is dipped in 1% sulphuric acid and autoclaved at 120 ^{0}C for 15 min at 15 bar. It is done by using acid or enzyme catalyst or a combination of these two {Acid hydrolysis: 3 % sulfuric acid solution and {Enzyme hydrolysis: Cellulose (liquid) enzyme (ROSSARI BIOTECH). Optimum pH ranges: 4.5 - 6 in 2 M citrate buffer at 45^{0}C over a period of 24 hrs.

Production of ethanol from rice straw

Basic concept

Rice straw consists of three main components, cellulose, hemicellulose and lignin. Technologies for conversion of this feedstock to ethanol have been developed on two platforms, which can be referred to as the sugar platform and the synthesis gas (or syngas) platform. The basic steps of these platforms are shown in Fig. 1. In sugar platform, cellulose and hemicellulose are first converted to fermentable sugars, which then are fermented to produce ethanol. The fermentable sugars include glucose, xylose, arabinose, galactose, and mannose. Hydrolysis of cellulose and hemicellulose to generate these sugars can be carried out by using either acids or enzymes (Drapcho et al., 2008).

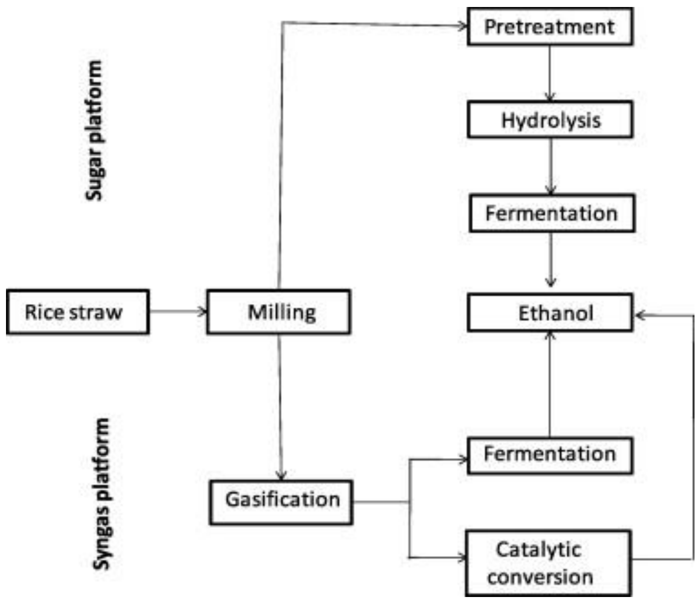

Fig. 1. Basic concept of ethanol production from rice straw.

Physical pretreatment: *Physical pretreatment will increase the accessible surface area and size of pores, and decrease the crystallinity and degrees of polymerization of cellulose. Commonly used physical treatments to degrade lignocellulosic residues include steaming, grinding and milling, irradiation, temperature and pressure.*

Chemical pretreatment: *Enzymes cannot effectively convert lignocelluloses to fermentable sugars without chemical pretreatment. The most promising chemicals for pretreatment of rice straw include alkali and ammonia.*

Enzymatic hydrolysis: Enzymatic hydrolysis is the second step in the production of ethanol from lignocellulosic materials. It involves cleaving the polymers of cellulose and hemicellulose using enzymes. The cellulose usually contains only glucans, whereas hemicellulose contains polymers of several sugars such as mannan, xylan, glucan, galactan, and arabinan. Consequently, the main hydrolysis product of cellulose is glucose, whereas the hemicellulose gives rise to several pentoses and hexoses (Taherzadeh and Niklasson, 2004). However, high lignin content blocks enzyme accessibility, causes end-product inhibition, and reduces the rate and yield of hydrolysis. In addition to lignin, cellobiose and glucose also act as strong inhibitors of cellulases (Knauf and Moniruzzaman, 2004). Various factors influencing the yields of the lignocellulose to the monomeric sugars and the by-products are, e.g., particle size, liquid to solid ratio, type and concentration of acid used, temperature, and reaction time, as well as the length of the macromolecules, degree of polymerization of cellulose, configuration of the cellulose chain, association of cellulose with other protective polymeric structures within the plant cell wall such as lignin, pectin, hemicellulose, proteins, and mineral elements.

Recent advances in enzyme technology for the conversion of cellulosic biomass to sugars have brought significant progress in lignocellulosic ethanol research. Enzymatic hydrolysis is usually carried out under mild conditions, i.e., low pressure and long retention time in connection to the hydrolysis of hemicellulose. Valdes and Planes (1983) studied the hydrolysis of rice straw using 5–10% H_2SO_4 at 80–100 °C. They reported the best sugar yield at 100 °C with 10% H_2SO_4 for 240 min. Yin et al. (1982) studied the hydrolysis of hemicellulose fraction of rice straw with 2% H_2SO_4 at 110–120 °C, where they succeeded to hydrolyze more than 70% of pentoses. Valkanas et al. (1998) carried out hydrolysis of rice straw with different acids with varying concentrations (0.5–1% H_2SO_4, 2–3% HCl and 0.5–1% H_3PO_4) and they found that after 3 h retention time, rice straw pentosans converted to a solution of monosaccharides, suitable for fermentation. Roberto et al. (2003) studied the effects of H_2SO_4 concentration and retention time on the production of sugars and the by-products from rice straw at relatively low temperature (121 °C) and long time (10–30 min) in a 350-L batch reactor. The optimum acid concentration of 1% and retention time of 27 min was found to attain high yield of xylose (77%). The pretreatment of the straw with dilute sulfuric acid resulted in 0.72 g g^{-1} sugar yield during 48 h enzymatic hydrolysis, which was higher than steam-pretreated (0.60 g g^{-1}) and untreated straw (0.46 g g^{-1}) (Abedinifar et al., 2009). When they increased the concentration of substrate from 20 to 50 and 100 g L^{-1} sugar yield lowered to 13% and 16%, respectively.

The kinetics of glucose production from rice straw by *Aspergillus niger* was studied by Aderemi et al. (2008). Glucose yield was found to increase from 43 to 87% as the rice straw particle size decreased from 425 to 75 µm, while the optimal temperature and pH were found within the range of 45–50 °C and 4.5–5, respectively. The study shows that the concentration and rate of glucose production is depend on pretreatment of rice straw, substrate concentration and cell loading. Enzymatic hydrolysis of alkali assisted photocatalysis of rice straw resulted 2.56 times higher hydrolysis rate than that of alkali process (Kun et al., 2009) whereas, ammonia treated rice straw resulted an increase of monomeric sugars from 11% in the untreated to 61% (Sulbaran-de-Ferrer et al., 2003). Hydrolysis efficiency of lignocellulosic biomass increases when combination of enzymes such as cellulase, xylanases and pectinases are employed rather than only cellulase (Zhong et al., 2009) but the cost of the process increases drastically even though from ecological point of view it is highly desirable.

Fermentation: The cellulose and hemicellulose fraction of rice straw can be converted to ethanol by either simultaneous saccharification and fermentation (SSF) or separate enzymatic hydrolysis and fermentation (SHF) processes. SSF is more favored because of its low potential costs (Wyman, 1994). It results in higher yield of ethanol compared to SHF by minimizing product inhibition. One of the drawbacks of this process is the difference in optimum temperature of the hydrolyzing enzymes and fermenting microorganisms. Most of the reports states that the optimum temperature for enzymatic hydrolysis is at 40–50 °C, while the microorganisms with good ethanol productivity and yield do not usually tolerate this high temperature. This problem can be avoided by applying thermo-tolerant microorganisms such as *Kluyveromyces marxianus*, *Candida lusitaniae*, and *Zymomonas mobilis* or mixed culture of some microorganisms like *Brettanomyces clausenii* and *Saccharomyces cerevisiae* (Golias et al., 2002; Spindler et al., 1988).

ICAR-CIAE, Bhopal has developed an laboratory scale ethanol production plant Biodiesel production plant as shown in Fig. This is batch type biodiesel production plant suitable for bioethanol production from lignocelluloses biomass like paddy maize etc. The capacity of plant is 5 l per batch and cost of the unit : ₹ 1,20,000/-. However the production cost of ethanol is very high i.e, ₹ 250/l. the operating cost: ₹ 20-25/kg.

Paddy Straw Pellet/briquette for Improved Cook stove

Farm-collected paddy straw biomass is dried and pulverized for palletization. Paddy straw was air dried for five days followed by drying in hot air oven at 105±1°C for 12 hours and pulverized. Pulverized paddy straw was mixed with standard binder and pellets were made by a pelletizer of capacity 100 kg/h. Thermal efficiency of the improved biomass cook stove was found to be 36.11±0.38 percent when fuelled by paddy straw pellets which is equivalent when the same stove is fuelled with other fuels. The average value for CO_2 equivalent was found to be 648.76 kg/tonne of paddy straw pellet. The value shows a significant decrease in emissions when compared to CO_2 equivalent emissions from burning one tonne of paddy straw in the open field which comes to be 2,150 kg CO_2e/ tone,

ICAR-CIAE, Bhopal has developed a paddy briquetting machine. The machine comprises of feeding hopper, screw auger, die and power unit as shown in Fig. Feedstock for briquetting machine has been prepared by mixing paddy straw and other crop residues in 70:30 ratio and binder (cow dung at 20 per cent of total biomass). The raw material is conditioned before feeding to hopper. The moisture content of feedstock for briquetting is maintained in the range of 50-60 per cent by adding water. During feeding the speed of screw auger of briquetting machine is maintained at 350 RPM. The density of produced briquettes was obtained in the range of 520-550 kg/m^3.

The briquettes exhibit excellent resistance to shattering and it was durable as well. The calorific value of paddy straw briquettes is 3600 kcal/kg. The developed briquetting machine having output of 50-60 kg/h.

Technological constrains

There are some obstacles which causes difficult to implement such kind of power plant in India. Some of the obstacles are;

Collection, transportation and storage: To avoid inconsistency of fuel in scarcity time lots of space is required to store the fuel. Storage as bale requires collection of straw from field and its transportation.

Silica and ash: The high content of ash, alkali, and potassium in rice straw causes agglomeration, fouling, and melting in the components of combustors or boilers (Baker 2000, Jeng et al 2012).

Lignin: The high silica content of rice straw causes the components in processing machines, such as the chopper or grinder, to wear out. The lignin walls in rice straw hampers digestibility, which reduces the efficiency of bio-energy conversion processes (Klass 1998).

Washing/wet storage: It has been demonstrated that leaving straw exposed to rain in the field before collection significantly reduces its alkalinity. For efficient combustion or gasification the moisture content of the straw needs to be kept low. Wet storage of the biomass is another option for reducing the straw alkalinity. The leachate from the process must be collected for disposal or other use however. This technology is probably best used in conjunction with anaerobic digestion.

Torrefaction*:* Pretreating the rice straw by torrefaction makes the biomass a much easier fuel to densify and burn or gasify. It also allows for more efficient storage and increases the possibility for mixing with other types of biomass.

Efficiency of power plant: plant is not as efficient as generation of electricity from conventional power plant.

Finally

While the technical difficulties in utilizing rice straw as a fuel for electricity production are considerable, they are not insurmountable. As with most agricultural waste, the biggest obstacles to overcome involve the collection, transportation and storage of the biomass. Getting farmers interested in taking the time and effort to collect the straw is a challenge. Further, once the suppliers have a captive customer for the straw, the price of that straw will invariably increase. This is regardless of the terms of any fuel supply agreement.

Conclusion

Paddy straw burning is a serious concern in India and has been driving the attention of policymakers and researchers. The authors did in-depth study for best utilization of paddy straw for sustainable energy production and to reduce resulting emissions in terms of GHGs equivalent. The analysis of power generation, by combustion and biomethanation, ethanol production and pelleting/briquetting from paddy straw revealed that each route of energy conversion is most efficient in terms of obtainable useful energy and global warming potential as per the appropriate technological intervention in region. The power generation data showed that the biomethane results into electricity generation of 777.0 kWh/ tonne of paddy straw with output/ input energy ratio of 5.5. However, bioethanol production potential analysis showed an electricity equivalent of 544.25 kWh/tonne of paddy straw. Nevertheless, bioethanol is a ray of hope in competing with existing petrol-based motor vehicles but biomethane provides an added advantage of reaping extra energy from the same amount of paddy straw and on the other hand providing valuable manure for sustainable agriculture. The pelletized paddy straw can be used in improved biomass cook stoves to meet thermal cooking energy requirement as the results showed in reduction of indoor air pollution as compared to open field burning. The palletization of paddy straw for improved cook stove showed net global warming potential reduction of 2,459 CO_2 e kg emissions/tonne. The energy available from rice straw can be suitably used to supply clean and green cooking fuel, power generation as well as vehicular fuel applications depending upon the need in the vicinity.

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STRATEGIES FOR RICE RESIDUE MANAGEMENT THROUGH MECHANIZATION

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Manipur one of the north eastern states of India covers an area of 22,327 km^2 is basically an agrarian state where more than half (52.19 %) of its population depend upon the agriculture, especially the rice cultivation which is the most important crop in both the hill and valley areas of the state. The gross cropped area (GCA) within the state is 3.3 lakh hectares (12.98%) and around 90 percent of GCA is covered by rice and average cropping intensity is accounted at 143.26 % in 2011-12 (GoM, 2012). This implies that the average ratio of rice area sown is found to be 1.5 times annually. In term of rice yield level, as per the Directorate of Rice Development, Patna, Government of India, Manipur ranked 8th in the country with 2369 kg/ha in 2006-07. Though rice area had slightly declined from 1.6 lakh hectares in 1995-96 to 1.4 lakh hectares in 2002-03 (GoI, 2013) after 2002-03, it increased and recorded 2.2 lakh hectares in 2011-12. Despite this, demand for rice crop has increased significantly in the recent past, much higher than its supply capacity (Singha, 2013).

The area production and yield of rice for the state of Manipur from the year 2010-11 to 2014-15 and in each district is presented in Table 1 (Directorate of Economics and Statistics, Manipur). The production of rice for Manipur for the year 2014-15 was estimated at 4.82 lakh tonnes as against 4.77 lakh tonnes in 2013-14. Among the districts, Imphal East District had the highest production of rice with 91.40 thousand tonnes (18.95 %) which was followed by Imphal West with 79.92 thousand tonnes (16.57 %). The lowest was recorded in Tamenglong District having only 20.19 thousand tonnes (4.19 %) during the year 2014-15.

Table 1. Area, Production and Yield of Rice in Manipur

Year/District	Area ('000 ha)	Production ('000 tonnes)	Yield (kg/ha)
2010-11	168.78	377.37	2235.81
2011-12	172.83	387.17	2240.18
2012-13	175.04	426.50	2436.59
2013-14	176.47	477.05	2703.29
2014-15	178.20	482.25	2706.23
Senapati	19.64	48.46	2467.32
Tamenglong	9.62	20.19	2098.75
Churachandpur	29.83	48.51	1626.29
Chandel	9.85	33.58	3410.26
Ukhrul	10.16	25.81	2540.04
Imphal East	26.54	91.40	3443.68
Imphal West	21.20	79.92	3770.09
Bishnupur	21.65	69.47	3208.25
Thoubal	29.71	64.91	2184.94

Generation of paddy residue in Manipur and adverse consequences of on-farm burning

With the increase in rice production in the state, it is natural that a huge volume of crop residues (paddy straw) are produced both on-farm and off-farm. The paddy residue generated in the year 2006-07 was estimated as 2 lakh tonnes (Lok Sabha Unstarred Question No. 726, dated on 24.11.2009). Total crop residue generated in the state accounts to about 9 lakh tonnes (MNRE, 2009) and about 0.21 Mt/yr (based on IPCC coefficients) and 0.07 Mt/yr (Pathak et al. 2010) of the crop residues were burnt during 2008-09. However, farmers are still continuing with the old practice of in-field straw and stubble burning. Open-field burning of paddy straw may effectively removes large volumes of biomass and helps control weeds and a variety of pests and diseases.

However, the advantages of burning are offset by the disadvantages. With the advent of mechanized harvesting, farmers have been burning in-situ large quantities of paddy residues left in the field as these interfere with tillage and seeding operations for the subsequent crop, causing loss of nutrients and soil organic matter (SOM). Many farmers chop-off the rice stubbles with a stubble shaver, dry them and burn completely to facilitate timely planting of subsequent crop leading to all kinds of environmental pollution. Thus, one option is burning despite the large losses (up to 80%) of nitrogen (Raison, 1979), 25 % of phosphorous and 21 % of potassium (Ponnamperuma, 1984), and 4-60 % of Sulphur (Lefroy et al. 1994). This practice also causes significant air pollution and killing of beneficial soil insects and microorganisms. Paddy straw burning also affects the regional air quality as it was recently witnessed from rose in air pollution to alarming levels in Delhi due to open-field burning of straw in the neighbouring state of Delhi. The open burning of residue in the fields results in the burning of trees in addition to adjoining standing crops. The ash left after burning is a very good adsorbent. This ash lying on the surface of the soil, if not mixed properly adsorbs the applied weedicides, which results in decreased efficacy of herbicides. Therefore burning of rice residue is not advisable.

Paddy residue management for alternate uses

Keeping in view the increasing problems associated with paddy stubble burning several initiatives for its proper management have been taken up.

Incorporation of straw in soil : Crop residues may be incorporated partially or completely into the soil depending upon methods of cultivation. Ploughing is the most efficient residue incorporation method. It returns most of the nutrients and helps to conserve soil nutrient reserves in the long term. The incorporation of straw in soil has a favourable effect on the soil's physical, chemical and biological properties such as pH, organic carbon, water holding capacity and bulk density of the soil. These practices increase hydraulic conductivity and reduce bulk density of soil by modifying soil structure and aggregate stability. On a long-term basis it has been seen to increase the availability of zinc, copper, iron and manganese content in the soil and it also prevents the leaching of nitrates. By increasing organic carbon it increases bacteria and fungi in the soil. Mulching with paddy straw has been shown to have a favourable effect on the yield of maize, soybean and sugarcane crops. It resulted in substantial savings in irrigation and fertilizers. It was reported that an addition of 36 kg per hectare of nitrogen and 4.8 kg per hectare of phosphorous (6 g of Nitrogen and 0.8 g of phosphorous per kg of paddy straw) had shown savings of 15–20 % of total fertilizer use (Beri et al., 1992; Sidhu et al., 1995).

Surface retention and mulching : Direct drilling in surface mulched residues is a practice that leaves straw residues from a previous crop on the soil surface without any form of incorporation. Surface retention of residues helps in protecting the fertile surface soil against wind and water erosion. The large volume of residues remaining on the surface often leads to machinery failures, thus affecting sowing of seeds of the following crop. Farmers usually follow this method where no-till or conservation tillage practices are prevalent. Surface retention of some or all of the residues may be the best option in many situations. Retention of residues on the surface increased soil NO^{3-} concentration by 46%, N uptake by 29%, and yield by 37% compared to burning (Bacon, 1987; Bacon and Copper, 1985a; Bacon and Copper, 1985b).

The rice straw can be collected and used as mulch which has favorable effect on the yield of some crops such as maize, soybean and sugarcane crops. It also results in substantial saving in irrigation water. Rice straw mulching in the no-till sown wheat with the newly Happy Seeder is recommended where cutting, lifting and spreading the standing rice stubbles and loose straw along with sowing in one operation is done.

Baling and removal of residue : Surplus straw from agriculture may be used for a number of useful purposes such as livestock feed, fuel, building materials, livestock bedding, composting for mushroom cultivation, bedding for vegetables such as cucumber, melons etc. and mulching for orchards and other crops.

Composting: The crop residues have been traditionally used for preparing compost (Fig. 1). For this, crop residues are used as animal bedding and are then heaped in dung pits. The use of paddy straw bedding during winter helped in improving the quality and quantity of milk as it contributed to animals' comfort, udder health and leg health. Paddy straw bedding helped the animals keep themselves warm and maintain reasonable rates of heat loss from the body. It also provides clean, hygienic, dry, comfortable and non-slippery environment, which prevents the chances of injury and lameness. It also ensures enhancement of milk production and reproductive efficiency of animals. In the animal shed each kilogram of straw absorbs about 2-3 kg of urine, which enriches it with N. The residues of rice crop from one hectare land, on composting, give about 3 tons of manure as rich in nutrients as farmyard manure (FYM). Indian Agricultural Research Institute (IARI), New Delhi, has successfully developed a biomass-compost unit for making of good quality compost.

This mechanized unit efficiently uses waste biomass and crop residues generated in the IARI farm. The decomposition process, which is hastened by a consortium of microorganisms, takes 75-90 days. During the year 2010-11, the unit prepared about 4000 tons of compost and in the subsequent year it increased to over 5000 tons. The use of paddy straw was also found to result in increased net profit of Rs. 188–971 per animal per month from the sale of additional amount of milk produced by cows provided with bedding (Department of Livestock Production and Management, College of Veterinary Sciences, Punjab Agricultural University).

Fig. 1. Preparation of improved quality compost from crop residues

Livestock feed: Rice residues are traditionally utilized as animal feed as such or by supplementing with some additives. However, being unpalatable and low in digestibility, it cannot form a sole ration for livestock. The residues have low-density fibrous materials, low in nitrogen, soluble carbohydrates, minerals and vitamins with varying 10 amounts of lignin which acts as a physical barrier and impedes the process of microbial breakdown. To meet the nutritional requirements of animals, the residues need processing and enriching with urea and molasses, and supplementing with green fodders (leguminous/non-leguminous) and legume (sunhemp, horse gram, cowpea, gram) straws.

The total production of residue of paddy in Manipur is almost 2 lakh tonnes for the total livestock of 971 thousands. Thus the consumption of paddy residue per livestock stands at 0.21 t/animal which is the highest among the North Eastern states (Lok Sabha Unstarred Question No. 726, dated on 24.11.2009).

Bio-oil production: Bio-oil can be produced from crop residues by the process of fast pyrolysis, which requires temperature of biomass to be raised to 400-500 ^{o}C within a few seconds, resulting in a remarkable change in the thermal disintegration process. About 75% of dry weight of biomass is converted into condensable vapours. If the condensate is cooled quickly within a couple of seconds, it yields a dark brown viscous liquid commonly called bio-oil. The calorific value of bio-oil is 16-20 MJ kg^{-1}.

Gasification: Gasification is a thermo-chemical process in which gas is formed due to partial combustion of crop residues. The main problem in biomass gasification for power generation is the purification of gas for removal of impurities. The rice residues can be used in the gasifiers for ‘producer gas’ generation. In some states, gasifiers of more than 1 MW capacity have been installed for generation of ‘producer gas’, which is fed into the engines coupled with alternators for electricity generation. One ton of biomass can produce 300 kWh of electricity.

The gasification technology can be successfully employed for utilization of paddy residues in the form of pellets and briquettes. The generated ‘producer gas’ is cleaned using bio-filters and used in specially designed gas engines for electricity generation.

Biochar production: Biochar is a high carbon material produced through slow pyrolysis (heating in the absence of oxygen) of biomass (Fig. 2). It is a fine-grained charcoal and can potentially play a major role in the long-term storage of carbon in soil, i.e., C sequestration and GHG mitigation. However, with the current level of technology, it is not economically viable and cannot be popularized among the farmers. However, once all the valuable products and co-products such as heat energy, gas like H_2 and bio-oil are captured and used in the biochar generation process, it would become economically-viable. There is a need to develop low cost pyrolysis kiln for the generation of biochar to utilize surplus crop residues, which are otherwise burnt on-farm.

Fig. 2. Low-cost pyrolysis kiln for preparation of biochar

ICAR Research Complex for NEH Region has procured the unit for biochar production (Srinivasarao et al. 2013). The unit is capable of converting up to 300 kg/h of woody biomass into biochar (Fig. 3).

Fig. 3. Biochar preparation using continuous biochar production unit at ICAR RC NEH, Barapani: wood chips collected in drums (A); continuous biochar production unit (B); feeding the biochar unit with wood chips (C); Firing the smoke with a torch (D); initial smoke from biochar unit (F); and wood chips burning inside main reactor (F)

As already discussed in the above section the different management options which can be taken in proper utilization of paddy straw, further a proper decision making can be implemented regarding the management plan. IARI (2012) has suggested the following guidelines to be considered.

- The amount of crop residue generated in the region
- Availability of crop residue during each season
- Priority of competing uses of residues
- Impacts on the availability of technologies
- Infrastructure and equipment availability o for management of crop residues

A model plan given in Table 2 may be used as a guideline for managing crop residues at local and regional scales (IARI, 2012)

Table 2. Model plan for managing crop residues at local and regional scales

Query	Response	Crop Residues Management Options
1. Can crop residues be used for conservation agriculture? If the answer is No, move to query 2	Yes	• Retain it on soil surface • Used drill for sowing with residues (e.g. Happy Seeder) • Follow conservation agriculture for all crops in rotation
2. Can it be used as fodder? If the answer is No, move to query 3	Yes	• Leaves stubbles in field • Enrich fodder with supplements (e.g. urea and molasses) • Use manure in conservation agriculture
3. Can it be used for biogas generation? If the answer is No, move to query 4	Yes	• Leaves stubbles in field • Adopting modern composting technique • Use slurry in conservation agriculture

4.	Can it be used for composting? If the answer is No move to query 5	Yes	• Leave stubbles in field • Adopt modern composting technique • Use compost in conservation agriculture
5.	Can it be used for bio-fuel generation? If the answer is No, move to query 6	Yes	• Leaves stubble in field • Install biomass-fuel plant • Use liquid slurry in conservation agriculture
6.	Can it be used for electricity generation If the answer is No move to query 7	Yes	• Leave stubbles in field • Install biomass energy plant • Use ash in conservation agriculture
7.	Can it be used for gasificaton? If the answer is No move to query 8	Yes	• Leave stubbles in field • Install biomass gasifier • Use ash in conservation agriculture
8.	Can it be used for biochar making?	Yes	• Leave stubbles in field • Install biochar kiln • Use biochar in conservation agriculture

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Mechanization – Management of residues in the field

In the state of Manipur, cultivation of rapeseed and mustard after paddy is being practiced and promoted by different organization to transform from mono-cropped rice cropping system to doubled cropped rice-rapeseed cropping system. Various sowing techniques have been practiced in zero tillage cultivation of rapeseed and mustard in Manipur viz. as relay crop, sowing seeds after burning straw; and sowing seeds with straw mulching.

To achieve proper management of paddy crop residue, there is a range of mechanization options which includes sowing through soil surface residues without burning the paddy straw and stubbles, raking and baling of paddy straw, chopping of stubbles and mulching in soil, making of feed blocks for cattle from paddy straw.

Machinery for sowing

Manual hand tools and implements

Jab Planter: A jab planter (Fig. 4) appears to be a promising tool that could enable the small-scale farmer work with improved timeliness and reduced drudgery (Ukatu, 2001). It is an easy-to-operate dibble instrument used in various types of soil, including untilled soil with stubble and tilled soil with or without residues from previous crops. They are suitable for very small holdings and are available with both seed and fertilizer (Johansena *et al*., 2012). This machine enable to seed into mulch-covered no-tilled soil effectively. They were designed to manage residue whilst seeding and fertilizing in no-tilled soils. So, they normally have discs to cut through the surface residue and furrow openers to place the fertilizer and seed. However, disc penetration in wet residue and hard soil can be a limitation.

Fig. 4. Jab planter

Li Seeder: Li seeder (Fig. 5) is a typical manual seeder for no-till seeding of maize and soybean. It can be used on small farms under a wide range of conditions including wet soils. The operating handle contains the seed and a shoulder bag carries the fertilizer. Through a chopping action the seeder can plant one or more seeds simultaneously, while fertilizer can be applied separately and the amount is adjustable. The total weight of Li seeder is 2.2 kg and the working efficiency is 0.2-0.3 ha/day/person.

Fig. 5. Li seeder

Animal operated sowing machine

Angled single disc seed drill: It is designed basically for planting maize. It can be pulled by an animal as a two-row seed drill (Fig. 6). It has an adjustable depth gauge wheel to control the planting depth from 20 mm and 50 mm, 400 mm angled discs to cut crop residue and two press wheels to firm the seed drill and controls operation through a beam.

Fig. 6. Angled single disc seed drill

Tractor operated sowing machine

ACIAR-Rogro tined seed drill: No till planters for two-wheeled tractors are becoming increasingly demanded in Asian and African Conservation Agriculture (CA) systems such as ACIAR Rogro, strip-tillage machines (Esdaile, 2011). ACIAR-Rogro tined seed drill (Fig. 7) is a three-row tined planter with adjustable row spacing. Attempt has been made on alternative soil engaging components, in addition to the standard chisel tine that has been fitted to date. These include double offset and single disc openers adjustable for offset and tilt.

Fig. 7. ACIAR-Rogro tined seed drill

Happy Seeder: Crop residue management planters including of Turbo Happy Seeder (Fig. 8) have been designed specifically to deal with heavy rice residue (up to 10 ton/ha) and for direct seeding immediately after the rice harvest without the prior removal or burning of paddy straw. This machine combines stubble mulching and seed drilling functions into one machine. Mulched crop residues improve soil health and add organic matter to the soil. The Turbo Happy Seeder has a set of straw management flails immediately in front of the chisel tine openers. These clear the straw and allow direct seeding to take place before the residue falls back to cover the soil.

Fig. 8. Happy seeder

Stubble star double disc opener ***Daybreak' single disc opener***

Fig. 9: Tine and disc opener for minimum soil disturbances

Tine and Disc Openers

Single and double disc opener: There is also an option towards selection of tine and disc openers such as Stubble Star double disc opener, 'Daybreak' single disc opener technology, (Fig. 9) etc. to reduce soil disturbance during the seeding process. The discs of stubble star double notched disc opener are angled at 7° to each other and have an undercut angle of 3.5° to improve soil conditions in the base of the furrow (Desbiolles, 2011).

Machinery for Straw Collection and Mulching

Straw rake: A straw rake (Fig. 10) is an agricultural rake used to collect paddy straw into windrows in the field for later collection (e.g. by a baler or a loader wagon). A straw rake may be a simple hand operated hand tools or equipment operated by the tractor (Fig. 11). A hand operated garden rake is also developed by Division of Agricultural engineering, ICAR Research Complex for NEH Region, Umiam, Meghalaya to carry out windrowing of scattered material in the field. Tractor drawn paddy straw rakes are of two types. First one consists of simple tines which are attached to the frame and second one consists of wheel rakes, gears chain and sprockets etc. This type of equipment is attached to the rear end of the tractor. The wheel rakes are powered by the tractor PTO. After using straw rake, the windrowed straw in the field are collected by the baler or wagon

Fig. 10. Hand operated straw rake

Fig. 11. Tractor operated hay rake

Baler: A baler may be used to compress a cut and raked crop (such as paddy straw) into compact bales that are easy to handle, transport, and store. Several different types of balers are commonly used, each producing a different type of bale – rectangular or cylindrical, of various sizes, bound with twine, strapping, netting, or wire. These machines collect the windrowed straw made by the straw rack and make the bales. The most common type of baler in industrialized countries today is the round baler (Fig. 12). It produces cylinder-shaped "round" or "rolled" bales.

In rectangular baler, each baler is bound with half dozen or trings of twine, which are then knotted. Such bales are highly compacted and generally eigh somewhat more than round bales. Rectangular bales are easier to transport than round bales, since there is little risk of the bale to roll off the back of a flatbed trailer. The rectangular shape also saves space and allows a complete solid slab of straw to be stacked for transport and storage.

Fig. 12. A round bale

In the storage, these types of baler can be stack similar to brick thereby creating a strong and stable structure. Small size bale can be loaded manually to the wagon. While the large size bale need bale spike to load the bale to the wagon and carry to storage.

Paddy straw chopper shredder/mulcher: Paddy Straw Chopper Shredder (Fig. 13) is used to chop the paddy straw and stubbles left after combine harvesting and spreads the chopped straw evenly in the field. The machine in a single operation chops the paddy stubbles and spread it on the ground. The chopped and spreaded stubbles are then easily buried in the soil by the use of single operation of rotavator or disc harrow and decayed after irrigation. This machine can be of two types. They are either mounted type or trailed type. The mounted type consists of a rotary shaft mounted with blades named as flails for harvesting and chopping the paddy straw. Power to rotary shaft is provided from tractor PTO through a gear box and belt pulley drives. Counter rows having serrated blades are mounted inside the concave which further assist in chopping the straw. The trailed type tractor operated paddy straw chopper with combine type/flail type cutting mechanism and double cylinder serrated chopping mechanism with concave.

Fig. 13. Paddy Straw Chopper

Machinery for making densified feed block

Stationary Animal Feed Block Formation Machine: Stationary animal feed block formation machine (Fig. 14) is useful for making animal feed blocks of size 20 cm x 20 cm by mixing crop residues with essential nutritional elements. The machine is powered by 25 hp electric motor and has the capacity of 250 kg/h. It is also available in 125 kg/h capacity with block size of 10 cm X 10 cm operated by 10 hp electric motor.

Fig. 14. Stationary Feed Block Formation Machine

The self-life of the feed blocks is more than one year, very economical to transport to distant places.

Mobile Feed Block Machine: Mobile feed block machine (Fig. 15) useful for making animal feed blocks of size 15 cm X 15cm, powered by 6 hp diesel engine (air cooled), capacity 100-125 kg/h. It is easy to transport of fodder to any suitable place and useful to make block. The mobile unit is mounted on a four-wheel trolley of 3 m X 1.5 m size and can be transported to the place of availability of fodder.

Fig. 15. Mobile Feed Block Machine

Constraints of mechanized paddy crop residue management

Mechanization usually involves a lot of investment. So, a smallholder with, typically, under two hectares of land, will be reluctant to be the sole investor in a machine which has the potential to operate over a much larger area. As the farmers of the state are mostly economically backward, costly machines are not affordable and will militate to adopt such machinery. The poor smallholder families in the state who are struggling to emerge from subsistence farming will usually have difficulty in amassing the resources necessary for machinery purchase. Furthermore, local availability of machinery for crop residue management is extremely limited. Therefore, local dealers and suppliers should be encouraged whenever possible as there is tremendous scope for this type of machinery. Above all, the most attractive option to improve access by smallholders to mechanization would be to offer the service from well-equipped and well trained local service providers. Further technical training should be conducted predominantly on practical in the field level e.g. calibration of machines, routine maintenance, servicing, etc. of these crop residue management machinery.

Conclusions

To avoid burning of rice stubble, management of agricultural waste for alternate uses should be practiced and promoted. Keeping in view the increasing problems associated with crop stubble burning, several initiatives for its proper management have been discussed. These include use of rice residue as fodder, crop residue in bio-fuel, gasification and biochar production, rice residue used as bedding material for cattle. Other uses include incorporation of paddy straw in soil, soil retention and mulching. The recycling of residues with these initiatives has the great potential to return a considerable amount of plant nutrients to the soil in the rice based crop production systems. Different mechanization techniques in sowing with no till, straw collection and mulching as well as for making densified block could help in further management of these residues with minimal human power requirement and short time. All stakeholders viz, farmers, supply and value chain service providers, researchers, extension agents, policymakers, civil servants and consumers need to be engaged in understanding and harnessing the full potential of these valuable resources for sustainability and resilience of the agriculture within the region.

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VALORIZATION OF RICE STRAW: POTENTIALITY AS BIOCHAR AND BRIQUETTES

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Rice is the major food grain of India in term of area, production and consumer preference. In 2016-17 India produced about 105 million tonnes of rice accounting for 23% of global production being the largest producer in the world after China[1]. The state wise production of rice has been depicted in Fig 1. Rice production is labour intensive and most of it is consumed by the harvesting and threshing process. To reduce labour requirement and timely harvesting of the crop, combine harvester is the most common for mechanized harvesting. Combine harvesters leave all straws and chaffs on the field which creates hindrance while sowing of next crop. Collection, transportation and storage of straw are energy and cost intensive. For this reason, farmers burn them in the field which is easiest way to get rid of the straw and they also add residual carbon and ash to the soil. However, burning of rice straw causes emission of gases like CO, CO_2, CH_4, N_20, NO_x, NMHCs and aerosols which pollutes the local environment[2]. In 2009, estimated emission of CO_2, CH_4, N_20, CO, NMHCs, NO_x and SO_2 from burning of rice straw alone was 16,253, 13, 1, 386, 45, 35, and 22 MMT, respectively[3]. Further, burning also causes residual nitrogen loss of 40-80% and residual sulphur loss of 40-60%. The heat of burning also kills the beneficial microbes at the top layer of soil[2].

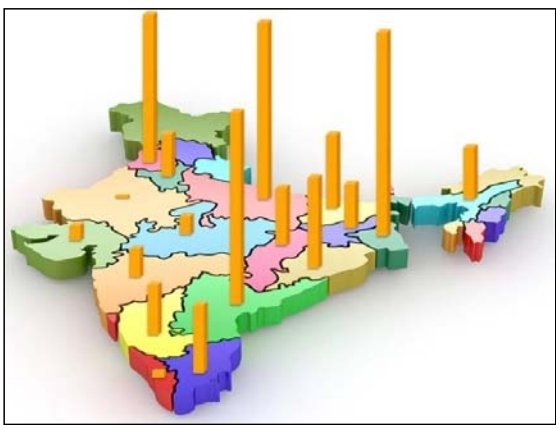

Fig 1. State wise production of rice in India in 2011-12

Total production of rice straw in 2016-17 was estimated to be 158 MMT considering a straw-grain ratio of 1.5. Major constituent of rice straw is hemicelluloses (30-35%) followed by cellulose (21-31) and lignin (4-19%) (Table 1). Being a lingo-cellulosic biomass rice straw has potentiality to be used as a source of bio-energy to replace fossil fuel. Various routes for conversion of rice straw to bio-fuel have been suggested by Mandal et al.[4]. Production of high density binderless briquettes is one of them. Rice straw can also be utilized to produce biochar as byproduct of pyrolysis to recycle into the soil thereby to increase soil carbon pool[5]. Calorific value (15-17 MJ/kg) of rice straw is substantially good as compared to other fuel biomass and thus it ensures good quality of briquette production. Bulk density of loose straw is approximately 150 kg/m^3 which is the cause of higher energy input in handling and storage. Rice straw can be easily converted to briquettes[6]. Briquetting is a good alternative when storability is concerned as it takes very less space to store. Briquettes are considered good fuel for gasifiers, brick industries and co-firing with coal due to their uniform size and shape with high energy density. Biochar as a soil conditioner played a much more important role in improving crop growth than as a fertilizer itself in Ultisol. The improvement of crop growth was due to increase in pH and CEC.

Table 1. Properties of rice straw[6]

Properties	Value
Heating value, MJ/kg (dry basis)	17.14
Proximate analysis (wet basis, wt.%)[15]	
Moisture	8.25
Ash	12.26
Volatiles	66.24
Fixed carbon	13.21
Thermogravimetrical analysis(TGA), wt.%	
Hemicellulose	30–35
Cellulose	21-31
Lignin	4-9

In this article, a short account has been presented describing the process and energy involved in conversion of rice straw to briquettes and biochar. Table 2 presents the brief account of energy input/output for briquetting and pyrolysis. For collection, transportation, drying, elevating and lighting energy consumption is about 833 MJ for a tonne of straw. For collection, a baler having 0.26 ha/h capacity has been considered as it is the most common baler used in the country. With a straw productivity of about 6 t/ha and single bale of 25 kg with density of 150 kg/m^3 time requirement for 40 bales will be 0.64 hours. Fuel consumption will be approximately 3.20 l. As in transportation, for a distance of 20 km with a trolley of two tonne capacity attached with a tractor will consume 4.5 l of fuel and 4 human-hours. For conveying, drying, elevating of bales and lighting of farm house, man power; diesel and electricity requirements are 2 human-hours, 12.8 kW-h and 6 l, respectively. So, altogether to bring and store rice straw in form of bales we need approximately 840 MJ/t of energy[4].

Table 2. Energy input/output scenario of rice straw conversion

Operations	Energy input (MJ/t)	Energy output (MJ/t)
Briquetting	1513	16435
Pyrolysis	5040	18540

Note: Energy contained in rice straw not considered

A lot of electrical energy is required in the process of briquetting. Straws are loosened from bales and then chopped with a straw chopper. Then these are grinded to small size usually between 1 – 2 mm followed by compressing in a high pressure briquetting machine. All these operations need very high electrical input. For chopping, grinding and briquetting a total of 76.5 kW-h/t of electricity need was observed. Thus total energy consumption in briquetting was 1513 MJ/t[4]. A typical briquetting plant installed by ICAR-Central Institute of Agricultural Engineering, Nabibagh, Bhopal at Mana village near Bhopal is shown in Fig. 2. It consists of a hammer mill grinder with a capacity of 200 kg/h, a feeding screw conveyor and a briquetting plant of 500 kg/h capacity. The briquettes from this plant are produced with a true density of 1100 – 1200 kg/m^3 and calorific value of 17 – 20 MJ/kg (Table 3). A conceptual schematic of rice straw based energy centre has been depicted in Fig. 3.

Fig. 2 Briquetting plant at Mana village near Bhopal (Courtesy: CIAE)

Pyrolysis is the thermochemical process where biomass is heated externally in absence of oxygen. In the process, biochar, bio-oil and product gases are produced. For pyrolysis, major energy need is in heating the reactor which is mostly done electrically and partly by the product gas which is rich in CO, CH_4 and H_2. Minor energy need is for pumping of the cooling water and feeding the biomass to reactor. A screw pyrolysis reactor with its components has been depicted in Fig. 3. For a tonne of rice straw pyrolysis energy need was estimated to be 5040 MJ.

Energy output for both processes also has been presented in Table 3. In pyrolysis, 340 kg of biochar is produced which contains about 70% carbon which is 238 kg of carbon. This carbon is recalcitrant in nature and can be stored in soil for a very long time which otherwise would be released to atmosphere as CO_2 if only burnt. In briquetting about 95% biomass is converted to biomass, % 5 being the losses. Thus total output energy from a tonne of rice straw is 16435MJ with a calorific value of 17.3 MJ/kg.

Table 3. Rice straw conversion to biochar and briquettes

Name of the process	Process conditions	Product	Output/t of straw	Energy MJ/kg	Total energy output, MJ/t
Densification and briquette production	Densification of smashed rice straw using piston mould at 85 kg/cm^2 pressure and 150 °C temperature.	Briquette	950 kg	17.3	16435
Pyrolysis and Biochar production	Pyrolysis of rice straw in inert environment at 450°C.	Biochar Product gas Biooil	340 kg 200 kg 280 kg	28.0 4.5 29.0	9520 900 8120

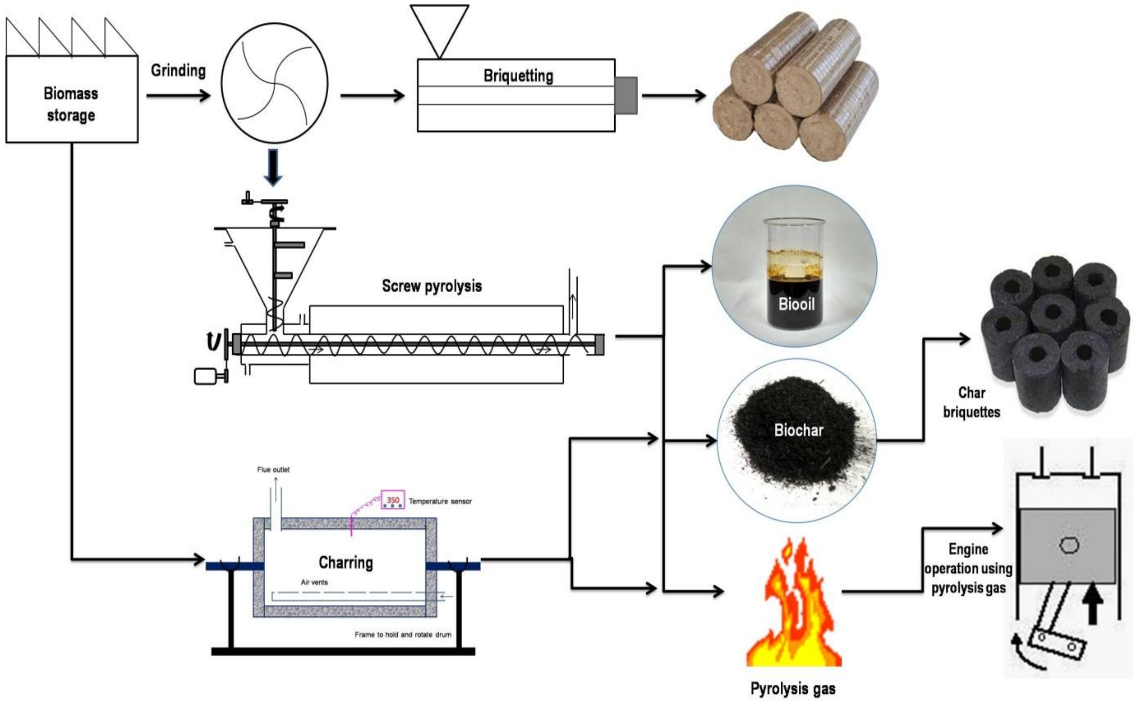

Fig. 3 schematic of proposed rice straw based energy centre

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ORGANIC MANURES FROM RICE RESIDUE

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The burning of the straw is a serious environmental issue in many Asian countries. The damage caused by the soot in the atmosphere is considered very serious. This not only degrades the atmospheric quality but also affect human health. Burning is an easiest and economical option for management of rice straws. Generally paddy straw biomass burning is practiced by farmers for clearing of their agriculture land, control of weeds, nutrient regeneration, however instead of burning it may be used as the raw material for compost production. Compost is the relatively stable product that results after decomposition of organic materials may be crop residues or animal manure where carbon (C) is reduced and other nutrients are concentrated yielding a better organic fertilizer. Although organic fertilizers, including rice compost, are often low in major nutrients such as nitrogen (N) and phosphorus (P), they can be highly beneficial because they contain micronutrients, enzymes and micro-organisms that are often not found in inorganic fertilizers. Rice straw compost usually contains relatively low amounts of major nutrients but they are rich in potassium (K). Income gains resulting from a healthy crop are the most immediate return. But more importantly, the soil benefits from continued use of paddy straw compost in the long term. Results include improved soil texture and tilth, better aeration and water-holding capacity, increased fertility and liming potential of the compost. Because rice straw is composted and not burnt, less carbon dioxide is released into the atmosphere. Compost reduces the need for chemical fertilizers which contaminate surrounding water bodies and encourage algae blooms that compete with fish for oxygen. Additionally, as farmers gain self-reliance they become less dependent on off-farm inputs.

Table 1: Nutrient content of rice straw and cattle manure on fresh weight basis.

Organic material	C (%)	N (%)	P (%)	K (%)	Ca (%)
Rice straw	41	0.5-0.8	0.05-0.1	0.3-2.0	0.03-0.17
Fresh cattle manure	8-10	0.4-0.6	0.1-0.2	0.4-0.6	0.2-0.4
Composted cattle manure	30-35	1.5	1.2	2.1	2.0

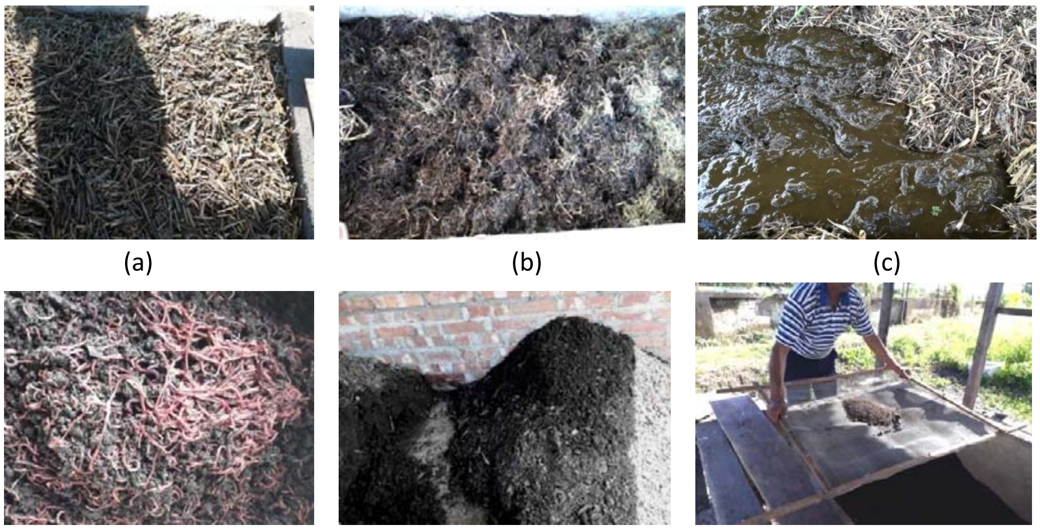
Methods of paddy straw composting

A. Sole Paddy Straw Composting

As the C:N ratio of the paddy straw is very high, composting with only paddy straw may not get much success. Rice straw is rich in C and poor in N. Its C/N can vary from 50 to 150, which limits the composting process. This high C/N can be decreased by increasing the basal N content of rice straw by external application. For quick conversion of paddy straw into compost addition of incorporation of nitrogenous materials like cow dung, urine, poultry dropping, oilseed cakes etc. may be necessary. The mixture containing 70% rice straw produced the most suitable compost in terms of maturity and nutrients.

B. Paddy Straw Vermicomposting

Vermicomposting of paddy straw involves three steps; Pretreatment of composting materials, Composting and Residue disposal. Straw is required to cut into smaller pieces (preferably 5 cm) for enhancing decomposition process. The separated material should be spread in a layer of maximum of 1 foot to expose to sun for a day. To control insect pest infestation, if any, neem formulation can be used. This helps in killing some of the unwanted organisms and removes foul smell. Then the material should be mixed with cowdung slurry, made a heap covered with clothes or left on ground for 4/5 weeks for partial decomposition. This partially decomposed material is now ready for vermicomposting.



(a) (b) (c)

(d) (e) (f)

Figure 1: Steps during Vermicomposting (a) Cutting of paddy straw (b) Pre-decomposition (c) Application of cow dung slurry (d) Worm addition /composting (e) Short exposing to sunlight (f) Sieving

Methods of Vermicomposting

1. ***Pits below the ground*****:** Pits made for vermicomposting are 1 m deep, 1.5 m wide and 2 m long (Fig. 2). The length varies as required. At the bottom of the pit, a vermibed has to be created for the earthworms. This is done by placing 15-20 cm thick layer of good loamy soil above a thin layer *(i.e.,* 5 cm) of broken bricks and sand. Earthworms are introduced in the soil layer where they will inhabit. About 100 earthworms will constitute an optimum inoculating density for the above size of the pit. Handful lumps of fresh cattle dung are then placed at random over the vermibed. The compost pit is then layered to about 5 cm with dry leaves or hay. The pit may be covered with coconut or palmyrah leaves to protect worms from birds. After 30 days of decomposition, wet partially decomposed paddy straw is spread over the partially decomposed organic layer to a thickness of about 5 cm. This has to be repeated twice a week. The heap have to turn over or mixed periodically using a hand tool without disturbing the vermibed in which the worms live. Addition of organic wastes can be repeated till the pit is nearly full. The pit has to be kept moist for another 30-45 days. During this period, the material in the pit has to be turned over occasionally without disturbing the

2. ***Heaping above the ground*****:** The waste material is spread on a polythene sheet or cemented floor and then covered with cattle dung (Fig. 3).

3. *Tanks above the ground*: Tanks made up of different materials such as normal bricks, hollow bricks, asbestos sheets and locally available rocks are adopted for vermicompost preparation (Figure 4). At the base of pit/tank, a layer of broken bricks is to be placed, followed by coarse sand.

Figure 2. Vermicomposting in Pits

Figure 3. Vermicomposting in Heaps

Figure 4. Vermicomposting in Tanks

Figure 5. HDPE woven vermibed

The thickness of layer should range between 5-7.5 cm, for drainage of excess water. At second layer, chopped waste materials should be placed. The thickness of layer should be about 30 cm well suited for aeration. Third layer should be of 15-30 days old cow dung with the thickness of about 20-30 cm which acts as reserve food for earthworms. Fourth layer or top layer should have partially decomposed paddy straw up to thickness of 30-40 cm. Earthworms are introduced in between the layers @ 350 worms per m^3 of bed volume and covered with moist gunny bag. The beds are maintained at about 40-50% moisture content and a temperature of 20-30° C by sprinkling water over the beds. If moisture is high, dry cow dung or more straw should be mixed in the substrate. Sprinkling of water should be stopped before 3-4 days of harvesting to allow the worms to go down because of the drying of surface layers and the compost is then harvested, dried in shade and packed.

4. *High Density Poly Ethylene woven vermibed*: Nowadays low cost HDPE woven vermibed (12x4x2 feet) can replace the cemented structures (Figure 5). It is a tough new generation vermiculture bed for producing superior grade vermicompost and vermiwash, rearing earthworms for organic farming. These beds represent the future in modern compost technology, which is smart choice for all organic agriculture that benefit from the higher yields resulting from vermicompost.

For rapid vermicompost production, undiluted urine can be used for moistening paddy straw during the preliminary composting period (before the addition of worms.). After the initiation of worm activity, urine can be diluted with an equal quantity of water. This simple technique can yield vermicompost with a higher N content. Moreover, worms have been found to become very active and vermicompost can be harvested at least 10 days early.

C. Through Mushroom Spent Straw Waste

The mushroom spent paddy straw waste is a very good raw material for composting and vermicomposting. This spent compost is very much suitable for utilising directly for vermicomposting or composting. Most of the original compounds in the paddy straw have been already degraded.

D. IBS Method of Rapid Paddy Straw Composting

Ordinary composting, which requires three months for complete decomposition, is too slow for farmers who plant two or three rice crops a year. The IBS rapid composting method (named after the Institute of Biological Sciences at the University of the Philippines, Los Banos), speeds up the process with a compost fungus activator, *Trichoderma harzianum*. The activator complements soil microbes as a source of waste cellulose decomposers, thereby increasing the number of decomposers and the rate of decomposition so that farmers can use the compost sooner. Rapid composting requires rice straw, nitrogen-rich materials like animal manure and the activator *Trichoderma harzianum*. A combination of three parts carbon to one part nitrogen substrate is best. If animal manure is difficult to obtain, it may be replaced with leguminous plants such as Azolla and Sesbania. The Process of rapid composting is described below.

- At harvest time, rice straw is heaped to one side of the paddy. It saves labour later to have one compost pile for each paddy instead of one central pile.
- Rice straw is soaked overnight in irrigation water or in the rain until saturated.
- A simple platform is made in the middle of the paddy (size is relative to the size of the paddy).
- A layer of saturated rice straw 10-15 cm thick is loosely piled on the platform.
- On top of the layer, one or two handfuls of the activator is broadcast (25 kg /ha).
- Straw is alternately layered with the activator until all the straw has been used.
- Manure and nitrogenous plants are put on top of the straw layers. The nitrogen substrate is 15-25% of total composition.
- The compost is covered (with plastic, banana leaves, or coconut fronds) and heats up within 25 hours.
- The compost must be moistened frequently to compensate for evaporation.
- The compost is left unturned and matures within one month. It is ready for use when the pile has cooled and is 30% of its original size.

Rapid composting turns a problem into a solution by using formerly wasted rice straw to benefit the soil. The process fits into farmers' busy planting schedules and can help to make them more independent of chemical inputs purchased externally.

Possible Drawbacks

Rapid composting, like composting in general, often means more work for the farmer. Labour inputs can be reduced by composting in the paddy and in small heaps that are easily transportable. A reliable supply of *T. harzianum* is critical to facilitate the rapid decompostion process. Contaminants reduce the effectiveness of the activator and may cause skin irritations. Also, limited manure supply may result in compost with low N content.

E. ICRISAT Method of Rapid Paddy Straw Composting

Dr. O.P. Rupela, Soil Microbiologist, ICRISAT, Patancheru has developed this. It is an aerobic composting method using a native soil fungus. This method is designed to be a rural enterprise for the educated unemployed youth. This eco-technology will save huge volumes of rice and wheat straw that are being burnt in parts of India,Vietnam, Sri Lanka, Philippines and Indonesia. The compost has been found to contain 1.7 to 2.1 per cent nitrogen, 1.3 to 1.5 per cent phosphorus and 1.4 to 1.6 per cent potassium. In this method the following steps are to be followed.

- Dry rice straw should be bundled into convenient sizes of 5 to 10 kg each, and dipped in a soaking solution for two to three minutes.
- The soaking solution is prepared by mixing one ml of fungal (*Aspergillus awamori*) spore suspension and one gram of urea for every litre of water.
- With each soaking, the dry straw bundle will soak up to 1.5 times its weight of the solution. For instance, a 10-kg bundle will use up about 15 litres of the solution.
- The wet straw bundle should be drained over a polythene sheet spread over a sloping surface for about 20 minutes to facilitate the drained solution and it can be collected and re-used.
- The well-drained bundles are sprinkled with 6 per cent powdered rock phosphate and placed layer by layer over dried twigs. The dried twigs will help in aeration between the soil and the straw layers, to form a large heap of 5 metres length, 1.5 metres width and 1.5 metres height.
- Each of such large heaps will accommodate about 500 kg dry straw soaking 750 litres of the solution. The whole heap is then covered with a 20 to 30 cm layer of untreated straw to retain the moisture.
- Care should be taken to maintain the moisture regimen of the heap. To penetrate the interior layers, an indigenously designed injection-pipe lance is used. It is thrusted into the heap and allowed to deliver 10 to 40 litres of water a minute.
- The first watering is done on the 7th day and about 100 litres water is added. On the 15th day, the heap is turned well, and about 240litres is added.
- On the 20th day about 150 litres of water is added, and the final turning and watering is done on the 30th day, when about 200 litres of water will be required.
- The temperature in the center of the heap reaches 60 degrees Celsius within four days. The base of the heap remains 4 to 6 degrees Celsius above the ambient temperature. On the 45th day, the entire heap will be completely composted, which is indicated by sweet, earthy smell, and the dark colouration of the straw. The straw strands will still be visible, but will break easily. The soft compost will then be ready for application in the field.

F. Composting of rice straw with effective microorganisms (EM)

Effective micro-organisms (EM) consist of common and food-grade aerobic and anaerobic micro-organisms: Photosynthetic bacteria, Lactobacillus, Streptomyces, Actinomycetes, Yeast, etc. The EM solution functioning as accelerator reduces the composting period from 1-3 months. The application of EM is suitable to increase the mineralization in the composting process. It is reported that the application of EM in compost increases the macro and micronutrient content. The compost applied with EM has more N, P and K content compared to compost without EM. The Fe in compost with EM is much higher than in the compost without EM (Jusoh et al. 2013). The final resultant compost indicated that it was in the range of the matured level and can be used without any restriction.

- Pile the mixtures with the ratio as follows: 50% rice straw + 30% goat/cattle manure + 20% green waste, in which10 kg of rice straw was mixed with 6 kg of goat/cattle manure and 4 kg of green waste.
- Use commercial EM preferably containing lactic acid bacteria, yeast and phototrophic bacteria.
- For the activation of EM, one part EM microbial inoculants and one part of molasses were mixed with 20 parts of chlorine-free water.
- Store for three to five days in an air tight expandable container for fermentation. Release the built up gas released once daily.
- For piles apply EM @ 5% EM solution to constitute 20% of the amount of water to be added to a given mixture.
- Add water until the moisture content reached 60% (wet basis) in the composting mixture.
- To retain the moisture and prevent excessive loss of heat, the heaps of composting material were then covered using plastic sheets (maintain at 50–60% by the addition of water throughout the active composting period by frequent checking.
- Turn the mixture at 3-day intervals to maintain porosity and compost for 90 days.

Advantages of converting straw into compost

- Compost contains a range of micronutrients and microorganisms that are beneficial to crop growth and soil health, and which are not usually contained in inorganic fertilizers.
- Composting concentrates the nutrients in otherwise poor quality rice by-products.
- Nutrients in compost are released slowly and are less likely to be lost by leaching.
- The high temperatures generated in composting (above 55^{o}C) keep pathogen levels low and reduce the viability of weed seeds contained in the compost material.
- Once compost is ready to use, it is easy to handle (it is fairly stable and has little odour).
- Organic wastes are widely available on farms.

Disadvantages of converting straw into compost

- Collecting and piling straw wastes, turning compost heaps and spreading compost in the field may require a lot of labour.
- Farmers may need to apply a lot of compost to obtain enough nutrients to achieve high yields. For high-yielding crops, inorganic fertilizers are usually needed as well as compost.
- Compost usually only contains 1/20th to 1/30th the N content of common inorganic fertilizers.
- Not all of the nutrients in compost are available to crops during the year of application (compared to 100% availability of N in ammonium fertilizer, for example).

Characteristics of straw for good quality compost

- Paddy straw should be free from severe disease and pest infestation.
- Paddy straw should be stored with minimum moisture percentage.
- For reducing the volume of straw, use of paddy straw baler machine is recommended.

DO NOT include these materials while composting:

- Plants infected with disease or a severe insect attack where eggs could be preserved or where the insect themselves could survive in spite of the compost pile's heat.
- Ivy, succulents and certain pernicious weeds such as morning glory and buttercups; and grasses which spread by rhizomes such as quack grass. These may not be killed by the heat of decomposition and can choke out other plants when compost is used in the garden.
- Cat, dog and bird manures, which contain pathogens harmful to human. These pathogens are not always killed in the heat of the compost pile.
- Meat and fish leftovers, bones, or greasy fatty foods such as oils, butter, and cheeses.
- Diseased or insect-infested plants should not be turned in.

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BRAINSTORMING METHOD: FROM THEORETICAL TO PRACTICAL PERSPECTIVE FOR CREATIVE SOLUTION

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Brainstorming is a kind of training method to promote group creativity, so that all aspects of a problem can be visualized and as many solutions as possible can be generated within a given period. "Spontaneity" and "creativity" are two main elements for brainstorming. The ideas given by the participants are recorded so that everyone can see them. When a large number of suggestions are made, the group is asked to reflect on them and evaluate their merits and demerits. A reasonably small number of worthwhile final solutions may emerge from this evaluation. In the recent time, brainstorming becomes the common jargon amongst the scientific fraternity for mobilizing a large number of stakeholders around a common problem. Ironically, it is organized in the same way as workshop, seminar etc. instead of following the prescribed methodology for conducting it. Indian Association of Hill Farming, Meghalaya in collaboration with ICAR Research Complex for NEH Region, Meghalaya and Central Agricultural University, Imphal is organizing one Brainstorming Workshop on "Rice Residue Burning in Manipur – Issues and Strategies for Sustainable Management" at Research Complex for NEH Region, Manipur Centre, Imphal. This paper is an attempt to delineate the intricacies of brainstorming to be adopted during the above said workshop. For the present work, the entire brainstorming session has been divided into four phases (Fig. 1). The outcome in terms of aim, objective and goal of the brainstorming workshop on Rice Residue Burning in Manipur is given in the Key Box 1.

Key Box: 1

Outcome of the brainstorming workshop

Aim: *Sustainable solution of rice residue burning issue in Manipur.*

Objective: *To prepare a clear cut policy/working document on sustainable management of rice residue alternative to burning in short and long term.*

Goal: *Phase wise reduction of rice residue burning in Manipur through social awareness and technological intervention.*

Phase I

In this phase only few expert from the research institutes, state government and other stakeholders will present the current situation of rice residue burning in the Manipur. The participants will be exposed by the glance of facts and data on the issue. This will work as the unfreezing moment for the participants.

Phase II

This phase will help us to identify the real cause behind the rice residue burning in Manipur. A question "Why farmers are burning the rice residue?" will be presented to the participants. Each participant will be asked to give one idea at a time on the question raised.

All the ideas will be documented on the board without any judgment at that moment. A participant may be encouraged to build the idea on other person's previous idea. This process will continue till the exhaustion of ideas. Now the evaluation of all ideas will be done in participatory mode. The ideas will be evaluated based on the merit and demerit of the idea and it will help in narrowing down the problem to the exact few reasons for the rice residue burning in Manipur.

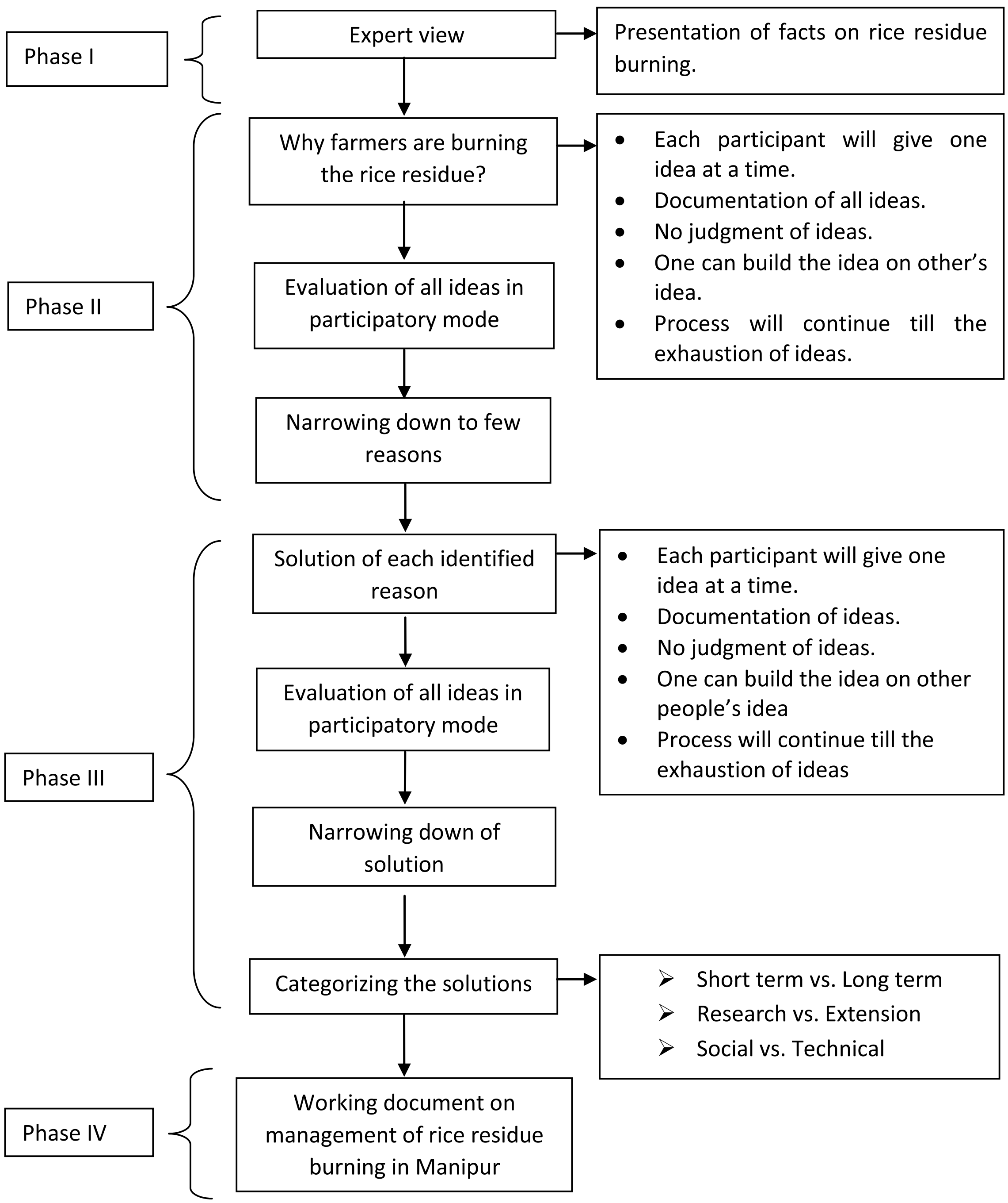

Fig 1. Graphical representation of the procedure for brainstorming workshop

Phase III

In this phase, based on the identified reasons the solution will also be asked from the participants. Again the procedure adopted in the Phase II will continue such as; one idea at a time, documentation of ideas, no judgment of ideas, evaluation of ideas etc. In this phase the orientation of the session become more focused and converged towards the few solutions of identified reasons. Now, the solutions will be categorized under different heads viz., Short term vs. Long term, Research vs. Extension, Social vs. Technical and so on depending upon the available solutions.

Phase IV

This will be the last phase of the brainstorming session. In this phase, few experts will critically examine the identified reasonss and their solutions and accordingly will give their inputs. It will ultimately help in preparing the working document/policy paper on management of rice residue burning in Manipur which can be given to different stakeholders such as Department of Agriculture, Government of Manipur; Directorate of Environment, Government of Manipur; ICAR Research Complex for NEH Region, Meghalaya; Central Agricultural University, Imphal, different NGOs etc. for taking necessary action on the issue.

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