In-Situ Rice residue management practices and its impact on climate, Soil fertility and crop productivity : A review

ABESTRACT

Around two-thirds of all food contributes in India is produced in the Indo-Gangetic Plains (IGP), where rice and wheat are the two main crops. In India, rice is grown on the largest percentage of land (32%) followed by wheat (23%). Reusing rice residues has an impact on the soil's characteristics and crop yield. Rice residues are significant natural resources. With a total yield of 10 to 12 t/ha, a rice-wheat sequence depletes the soil of more than 300 kg N, 30 kg P, and 300 kg K per ha. Residue burning results in nutrient losses of 100% C, 90% N, 60% S, and 25% each of P and K. Air pollution has a negative impact on health, including respiratory conditions, eye and skin irritation, and other conditions. An analysis has been done based on the stated research findings from various researchers. It is necessary to study and update the technology in order to prevent residues from burning in the rice and wheat cropping system. A good alternative for their management is to in-situ incorporate rice wastes with microbial consortia in wheat crops. Increased yield, water productivity, and profitability can be achieved by incorporating microbial consortia, while *Phaleris minor* weed is reduced, further enhancements to soil quality. Because rice residues are a substantial source of plant nutrients, applying them continuously will improve fertiliser management and reduce air pollution.

Key words: Rice residue, Productivity, Microbial consortia

Introduction

A highly productive rice-wheat zone of the Indo-Gangetic Plains of India contributes about two-thirds of the total food production of the nation. The rice-wheat is the most production system in the Indo-Gangetic Plains (IGP) of India, covering nearly 10.5 million hectares, including 4.1 million hectares of the northwestern states comprising Punjab, Haryana, and western Uttar Pradesh. In India, rice has the most area coverage (32% of all cropland), followed by wheat. However a succession of 10–12 t/ha of rice followed by 300 kg N, 30 kg P, and 300 kg K are removed from the soil (Brar et al., 2019).

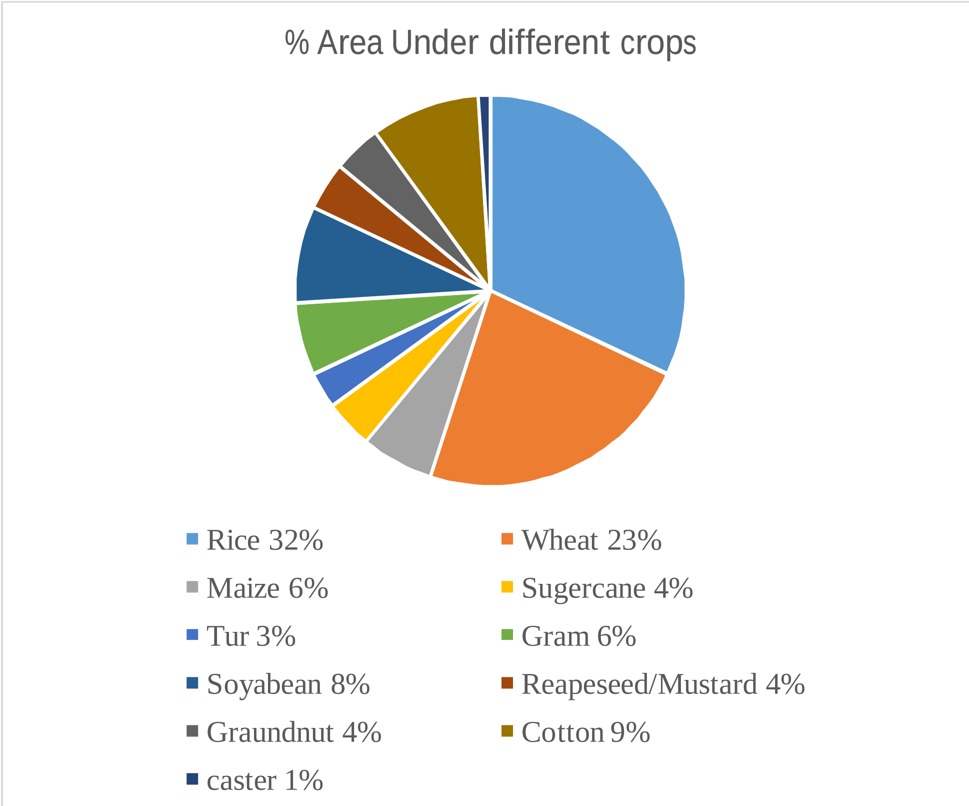

Figure 1: Distribution of total area under selected crops (TIFAC & IARI report 2018)

Generate of Rice residue

The portion of the plant that is still on the field after harvest and consists of stalks, stubbles, and leaves is known as crop residue. The Indian economy depends heavily on agriculture, which produces enormous amounts of crop leftovers. 500 million tonnes of crop residue are produced annually on average (Anonymous, 2016), and this number is projected to rise. The most common cropping system in India is the rice-wheat system, which accounts for around 25% of the production of residue (Sarkar et al., 1999; Bisen and Rahangdale, 2017). The residue to crop ratio and the dry matter percentage of residue in crop biomass can be used to determine how much residue was created. Punjab (51 mt), Maharashtra (60 mt), and Uttar Pradesh were expected to generate the most crop residue (46 mt). On the basis of crop type, crop residue from various crops can be divided into cereals, pulses, oil seeds, sugarcane, and fibre crops. According to Anonymous (2014), cereals account for the majority (59%) of residue production, followed by sugarcane (27%), and fibre crops account for the least (3%). Of the surplus residues from cereal crops, rice accounts for 44 MT, while wheat accounts for 24.5 MT (Jain et al. 2014). In India, rice residue production totals 225.48 MT, with a surplus of 43.85 MT (Anonymous, 2018).

Table 1: Area, residue production and surplus residue of rice in state of India

S/N	**state**	**Area (000 ha)**	**Residue production(000 t)**	**Annual surplus (000 t)**
1	Andhra Pradesh	2570.87	16925.74	1340.52
2	Arunachal Pradesh	126.07	356.78	35.32
3	Assam	2523.32	10484.05	1134.64
4	Bihar	3206.94	15035.21	3043.12
5	Chhattisgarh	4169.95	14759.48	1461.19
6	Goa	44.30	248.33	63.92
57	Gujarat	719.95	3156.28	937.41
8	Haryana	1242.66	7733.03	1827.19
9	Himachal Pradesh	74.84	262.43	155.88
10	Jammu & Kashmir	275.86	711.71	70.46
11	Jharkhand	1501.87	7488.94	1482.81
12	Karnataka	1384.03	8315.67	413.00
13	Kerala	201.91	1090.07	92.67
14	Madhya Pradesh	1799.86	5776.53	571.25
15	Maharashtra	1581.83	6200.23	613.79
16	Manipur	195.46	994.58	636.78
17	Meghalaya	40.47	201.64	59.89
18	Mizoram	57.85	122.03	59.70
19	Nagaland	185.44	857.59	84.90
20	Odisha	4115.25	15502.85	1971.68
21	Punjab	2896.47	23067.68	16787.33
22	Rajasthan	140.89	586.46	0.00
23	Sikkim	11.50	42.38	4.20
24	Tamil Nadu	1757.13	12598.97	1247.30
25	Telangana	1710.15	11429.93	905.25
26	Tripura	309.07	1786.33	141.48
27	Uttar Pradesh	5837.43	27701.21	7437.92
28	Uttarakhand	271.17	1240.69	184.24
29	West Bengal	5372.47	30648.82	1085.21
30	**All India**	**44360**	**225487**	**43857.0**

(Anonymous, 2018)

Plant nutrient in Rice residue

Given that carbon makes up around 40% of all dry biomass, cereal leftovers are an important part of the stability of agricultural ecosystems and an excellent source of plant nutrients and SOM. At maturity, the vegetative components still contain around 40% of the N, 30%–35% of P, 80–85% of K, and 40–50% of S that the rice crop has absorbed. Likewise, 25 to 30 percent of N and P, 35 to 40 percent of S, and 75 to 75 percent of K absorption are preserved in wheat residues. On a dry weight basis, rice straw typically contains 5-8 kg N, 0.7-1.2 kg P, 12-17 kg K, 0.5-1 kg S, 3-4 kg Ca, 1-3 kg Mg, and 40-70 kg Si per tonne (Dobermann and Witt, 2000).

The amount of NPK found in the 197 Mt of rice and wheat residues produced in India is almost 4.1x 106 Mt. Given that Punjab has an excess of 30% of wheat straw and 90% of rice straw, the annual amount of NPK recycled would be roughly 0.54 Mt. In addition to NPK, a tonne of leftover rice and wheat contains 9–11 kg S, 100 g Zn, 777 g Fe, and 745 g Mn. The nutritional potential of the remaining residues is 6.5 Mt of NPK each year, which accounts for 30% of India's total NPK consumption, assuming that 50% of CRs are used as cattle feed and fuel. So, recycling these materials is not only required for environmental reasons but is also required for economic reasons in a country like ours. Under typical fertilization procedures, the continuous removal and burning of crop residue can result in net nitrogen losses, which will ultimately increase fertilizer input costs in the near term and decrease soil quality and productivity in the long run. Wheat and rice both remove a lot of K each year, 210 to 360 kg K_2O $ha^{-1}yr^{-1}$, respectively. Left in the field, rice straw contains K, a readily available nutritional supply that is immediately released for plant usage (Yadvinder-Singh, et al, 2014).

Most farmers choose to burn their fields because it is a quick and simple alternative to cleaning them, and because they are unaware of their value and lack the necessary technologies for in-situ integration of residues. Unfortunately, this technique of burning results in significant losses of priceless organic matter and plant nutrients, as well as environmental pollutants, fire hazards, etc. Moreover, this burning approach decreases the effectiveness of herbicides because the ash produced interferes with the herbicides employed, especially root uptake ones, leading to increased weed infestation and ultimately weed nutrient mining. It is urgently necessary to manage rice residues in-situ and ex-situ by surface mulching, incorporating, composting, and spraying microbial consortia (Pusa decomposer and trash decomposer) in the soil in order to improve soil health and crop productivity. After harvest, one strategy to sustain soil fertility is to leave crop residues in the field, such as rice residues. Because inorganic fertiliser costs have climbed and yields in monoculture cropping systems have decreased, farmers and academics have become more interested in crop rotation and crop residue management as useful management strategies. Studies has demonstrated that returning agricultural wastes to the soil increased crop productivity, soil fertility and tilth, decreased wind and water erosion, and minimized nutrient losses through runoff and leaching (Lal, 1980; Lal et al., 1980; Maurya and Lal, 1981; Bukert et al., 2000; Shah et al., 2003; Shafi et al., 2007).

Practices of rice residue management

Rice residue is a type of agricultural waste that conserves natural resources and enhances the physical, chemical, and biological qualities of soil through recycling. More than N 300, P 30, and K 300 kg ha-1 are removed from the soil by a rice-wheat sequence that yields 7 t ha-1 of rice and 4 t ha-1 of wheat. The residues of rice and wheat can reach 7-10 t ha-1 yr-1. Asian farmers must handle 5-7 t ha-1 of rice leftovers, while wheat straw is typically used as dry animal feed (Pathak et al., 2006). Because paddy straw has a high lignin and silica content and a low protein content, it accumulates in fields and is hazardous to cattle. Rice residue management solutions are numerous. Among these include being taken out of the field, left on the soil's surface, mixed into the ground, burned directly into the soil, composted, or utilised as mulch for subsequent crops. In the tropics, agricultural wastes are rarely recycled in the field; instead, they are either gathered for use as fuel, animal feed, or bedding, or they are burned there. Agricultural residues that have been removed from the field can also be used as animal bedding, a substrate for composting, the production of biogas, or the cultivation of mushrooms. They can also be utilised as a raw material for industry, as well as for cooking and other home uses. The disposal strategy is determined by regional factors (Shahid et al., 2013).

Rice residue burning

The majority of grain residue is produced by the rice crop, then the wheat crop. While other agricultural products have a minimal contribution, sugarcane, rice, wheat, maize, and various oilseeds account for the majority of residue production. According to its utilisation patterns, in-situ burning of this waste varied from state to state. In rice fields, the percentage of crop residue burned varied among states from 8 to 80 percent, with Punjab, Haryana, and Himachal Pradesh burning the most crop residue (80%), followed by Karnataka (50%) and Uttar Pradesh (25%). (Gupta et al., 2003; Jain et al., 2014). Although it has several benefits, the bulk of the agricultural population in west U.P., Punjab, and Haryana is primarily interested in burning stubble for the next sowing due to lack of understanding. The remaining paddy residues in the field provide a significant challenge when the following crop is sown. Farmers gain distinct advantages from burning rice or agricultural residue in the field, such as time- and cost savings (Lal, 2008). Moreover, it is a method for weed, disease, and bug (Gadde et al., 2009; Lal, 2008; NDEP, 2003). Yet, burning rice straw has a significant negative impact on the chemical characteristics of the soil. In situ residue burning is known to reduce the organic nutrient forms in nutrient pools in soil, boost soil supplement turnover rates, and redistribute nutrients throughout the soil profile, according to Fisher and Blinkley (2000).

The only organic resource that most rice farmers have access to in considerable amounts is rice leftovers like straw. Prior to the following crop cycle, burning rice straw to black carbon would result in a large increase in macronutrients (P and K) and a reduction in undesirable arsenic mobilisation in rice yields (Schaller et al., 2018). Burning rice residues as a post-harvest management technique raised the pH of the soil and the K and Zn availability of nutrients. Burned soil exhibits a severe decrease of soil organic matter. 2020 (Hani et al.). Burning rice straw tends to encourage the release of Ca, Mg, and K, but it also significantly reduces the amount of rice straw organic carbon in organic matter (Beerling et al., 2018). According to (Sharma and Mishra, 2001), the volume of residue burned and the fire's intensity have an impact on how much carbon and nutrients are lost during burning. N, P, K, and S losses from completely burning rice straw at 470 °C in a muffle furnace were 100, 20, 20, and 80%, respectively. 2001 (Sharma and Mishra).

` Several studies have revealed that prolonged fire irreversibly reduced the soil's microbial community, significantly reducing the number of bacteria participating in nitrification (Raison, 1979), (1980; Biederbeck et al.)

A subsequent crop's weed flora may change in both quality and quantity as a result of how the preceding crop's residues are managed (Kumar and Goh, 2000). Burning residue reduces the seed supply by removing viable seeds (Singh et al., 2005). Yet, it has also been noted that burning can encourage the growth of weeds like silver grass and wild oats (Chitty and Walsh, 2003). Compared to residue incorporation, residue burning resulted in lower weed density and biomass (Khaliq et al., 2013).

Empact on environment of Burning

Massive N (80%), P (25%), K (21%) and S (4-60%) losses as well as air pollution arise from burning. According to statistics, the peak Air Quality Index (AQI) for the months of November 2019 and December 2019 in New Delhi, Noida, and Ghaziabad was between 480 and 490. Apart from various illnesses, respiratory conditions, skin and eye discomfort are among the health repercussions of air pollution. (Srinivasan and Abirami, 2020). Burning rice residue increases greenhouse gas emissions with negative environmental effects (Gujral *et al*., 2010; Lohan *et al.*, 2013). But, burning residue is not a practical solution because it has a huge carbon footprint and reduces the sustainability of the greatest agricultural system in the world (Singh et al., 2020). In addition to GHG emissions, burning residue results in nutritional losses of 100% C, 90% N, 60% S, and 25% of P and K. the year 2002 (Dobermann and Fairhurst). According to estimates, one tonne of paddy straw burning results in the loss of 5.5 kg of nitrogen, 2.3 kg of phosphorus, 25 kg of potassium, and 1.2 kg of sulphur in addition to organic carbon. Typically, crop waste from various crops (Anonymous, 2019). Field crop residue burning in the open emits gaseous and particle pollutants (Badarinath et al., 2006; Zhang et al., 2008). Such field residue burning has a negative impact on both air pollution and population health, including respiratory illnesses, skin and eye irritation, and other illnesses. (Long et al., 1998; Auffhammer et al., 2006; Srinivasan and Abirami, 2020). Fine particulate matter (PM) less than 2.5 g inhaled causes asthma and may potentially exacerbate bronchial attack symptoms.

Rice residue removal

The removal of rice residue is a common procedure in India, Pakistan, Bangladesh, and Nepal. Agricultural surplus straw can be used for a variety of beneficial purposes, including animal bedding, fuel, building materials, composting for the growth of mushrooms, mulching for orchards and other crops, and bedding for vegetables like cucumbers and melons. It can also be used as a raw material in industrial processes (e.g., papermaking). The rice field may lose part or all of the nutrients in the straw during the process (Dobermann and Fairhurst 2002).

Table 2: 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	0.5-1.0	0.5-1.0	40-70

Source (Dobermann and Fairhurst 2002)

Rice residue incorporation

Straw addition increases the organic matter, N, P and K contents of the soil. Few studies found that subsequent yields were lower during the first to third years after incorporating rice straw 30 days before planting wheat because soil nitrogen became immobilized in the presence of crop residue with a wide range of C:N ratios, but subsequent yields were unaffected in subsequent years (Mandal et al., 2004). The impact of time of integration on rice residue decomposition and N mineralization-immobilization was investigated in 1992-1993, according to Yadvinder-Singh et al., 2004. Prior to wheat planting, the mass loss of residue was 25% for a 10 day decomposition period, 35% for a 20 day period, and 51% for a 40 day decomposition period. Throughout the wheat season, residue released between 6 and 9 kg ha of nitrogen. When residue was let 10 days or more to break down, the immobilizations of urea N reduced. The prolonged application of rice residue boosted the soil's C content.

The immobilization of inorganic N and its negative impact due to N shortage are the main drawbacks of incorporating cereal straw. During harvest, the decomposition of rice straw is slowed and soil nitrate is immobilised, lowering the N uptake and productivity of succeeding wheat crops by around 40%17,18. due to the addition of straws (Mandal et al., 2004).

When compared to straw removal, the inclusion of straw considerably enhanced wheat production by an average of 58%. Straw incorporation increased soil accessible nitrogen, phosphate, and potassium in the 0–20 cm soil layer by more than 15% compared to straw removal. When straw was incorporated as opposed to removed, the soil's cation exchange capacity and organic carbon in the 0–20 cm soil layer both rose by 8% and 22%, respectively. Opposite to straw removal, incorporation of straw dramatically decreased soil bulk density while significantly raising the soil's saturation water content. Straw inclusion significantly boosted the urease, invertase, and catalase activities in the 0-15 cm soil layer as well as the microbial carbon and nitrogen levels in the 0-20 cm soil layer, which increased by 59% and 54%, respectively. >2 mm of soil aggregates. Hence, complete integration of straw may considerably improve soil fertility and maintain crop production (Zhao et al., 2019)

Lowland rice is the main agricultural source of emissions for many developing nations in Asia and a significant source of anthropogenic greenhouse gas emissions

(GHGEs). Moreover, one of the biggest global sinks of soil organic carbon is found in rice soils. derived from anaerobic oxidation (Allen et al., 2020). Yet, using straw considerably boosted methane (CH4) emission from anaerobic degradation during rice cultivation (Song et al., 2019)

In the 0–15 and 15–30 cm soil layers, respectively, the retention and incorporation of residue has been shown to increase the water-stable aggregates by 15.65% and 7.53%. Compared to no mulch, rice straw mulch enhanced wheat grain production, decreased crop water use by 3–11%, and improved WUE by 25%. (Walia and Parameswari, 2019).

2013 according to Dotaniya. Rice (Oryza sativa L.) and wheat (Triticum aestivum L. emend. Fiori and Paol.) system was researched in Pantnagar, Uttarakhand, to determine the effects of three crop residue management strategies (crop residue assimilation, residue burning, and residue removal). The rice crop absorbed more nitrogen (123.6 kg ha-1) and potassium (179.5 kg ha-1) when crop residue was added compared to other treatments. In the case of wheat, N and K uptakes were respectively 11.7% and 7.9% higher when residue was included compared to when it was removed. Yet, the outcome was comparable to the burning of residues in both crops, finding greater production and nutrient uptake by the wheat and rice crops (Prasad et. al., 2010; Kumar *et al.*, 2016).

Table 3: Effect of crop residue management practices, nitrogen and potassium levels on yield and nutrient uptake in rice-wheat cropping system

Treatment	**Grain yield (t ha^{-1})**		**Nutrient uptake (kg ha-1)**					
			Rice			**Wheat**		
	Rice	**Wheat**	**N**	**P**	**K**	**N**	**P**	**K**
Crop residue removed	6.29	4.26	113.1	21.2	164.2	112.4	19.0	91.7
Crop residue burnt	6.41	6.20	117.6	22.4	175.6	122.8	21.1	97.2
Crop residue incorporated	6.56	6.35	123.6	24.5	179.5	127.3	23.0	99.6
SEm±	0.06	0.07	3.1	0.5	4.4	3.4	0.3	1.9
CD (P=0.05)	0.19	0.21	9.6	1.6	13.8	10.8	0.9	5.8

Source Dotaniya, 2013

Rice residue as a surface mulch

For soil conservation and to prevent water losses through evaporation, residue retention on the soil's surface appears to be a superior option. Also, it lessens the germination of weed seeds and aids in the development of soil microbial communities, which increases soil organic carbon, a key marker of soil health. For this, a new, advanced-generation seed drill has been developed. According to Sidhu et al. (2007), the Happy Seeder will increase the use of conservation agriculture. As long as the residues are distributed evenly, the Happy seeder performs well for direct drilling in standing as well as loose residues. In comparison to no mulch, the rice straw mulch enhanced wheat grain production, decreased crop water use by 3–11%, and improved WUE by 25%. In lower levels (>0.15 m), mulch produced 40% higher root length densities than no-mulch, perhaps as a result of improved soil moisture retention in deeper layers, according to Chakraborty et al (2008, 2010). There is no requirement for pre-sowing irrigation when wheat is seeded with HS after rice harvest in the remaining soil moisture (Yadvinder-Singh et al., 2010b). Without pre-sowing irrigation, sowing wheat in the remaining soil moisture will result in a 20% reduction in irrigation water usage, saving 80 kWh of electricity and 160 kg of CO2 emissions. The rice-wheat system in the northwest IGP has embraced zero-till wheat, which has improved wheat output, profitability, and resource use effectiveness (Erenstein and Laxmi 2008, Ladha et al. 2009). The adoption of ZT wheat on a sizable portion of the RW system in the NW-IGP has improved wheat production, profitability, and resource use effectiveness (Erenstein and Laxmi, 2008). Only when zero tillage is constantly used and at least 30% of previous crop residue is left on the soil surface will its potential benefits be completely realised. Using Happy Seeder (HS) will encourage more people to practise conservation agriculture in the area (Sidhu et al., 2007).

Impact of Rice residue on weed

Wheat yield increased as a result of residue integration reducing weed density, particularly of Phalaris minor (Khankhaneet et al., 2009). Salam and others, 2020. The dry weight and minimal weed density were discovered during integration. The RWCS's weed flora is suppressed by residue retention on the soil surface due to mulching effects, mechanical impedance of the weed seedlings, and a lack of exposure to light. The impacts of rice residue's allelopathy may aid in weed management in wheat crops. The retention of crop residue on the soil's surface has a negative impact on how well pre-emergence herbicides work (Kaur et al., 2021).

Impact Rice residue management on Soil Properties

Lower soil BD was found in a conservation agriculture tillage management system Edwards et al., 1992, residue incorporation, effect of residue management on soil bulk density (BD) (Sindu and Sur, 1993). Rice residue alters soil structure, macrospore percentage, and aggregate stability primarily, increasing soil hydraulic conductivity and infiltration rate (Mandu et al., 1993). pH The most crucial elements that govern soil fertility can be affected by rice residue management.

Several reports show that soil pH rose regardless of whether rice waste was burned, incorporated, or mulched (Mandal et al., 2004). Elevation in soil pH following fire was typically attributed to accretion as ash residue are dominated by carbonates of alkali and alkaline earth metal but also vary in content of silica, heavy metals, silicon dioxides, phosphorus, and minor amounts of organic and inorganic N. (Raison et al., 1979).

Burning for an extended period of time reduced the soil's microbial community, significantly reducing the nitrifying bacteria's number (Raisen et al., 1979; Biederbech et al., 1980). To recuperate from that activities can take several months to five years (Tisdall, 1992). The sequestration of carbon in the soil is impacted by declining nutrient levels, which also cause a drop in soil fertility. However, total C and N in the soil's microbial biomass increased right away following the incorporation of rice straw under aerobic conditions; they reached their maximum value after each application after one week (2 g C as rice straw Kg-1 soil after every six weeks), and then they started to decline (Azmal et al., 1997). Application of rice residue with a C: N ratio of 52.1 (Nugroho and Kuwatsuka, 1992) and simultaneous application of rice residue and NH4 -N to the soil under highland soil enhanced the number of denitrifiers, which in turn increased the microbial population. In India, rice residue-treated soil had 5–10 times as many inhabited microorganisms and 1.5–11 times as many fungi as soil containing residues that were either burned or removed (Beri et al., 1992).

Use of microbial consortia

Recently, Bio decomposer microbial consortium (PUSA decomposing capsule) developed by IARI New Delhi gained popularity and is capable of degrading paddy residue biologically through enzymatic activity within 20-25 days and IARI also issued licence to 12 companies to start production on commercial scale Other state governments also opted for this and gained satisfactory results in addition to this, Delhi government also initiated spraying the decomposer across the city to prevent biomass burning In 2020 Punjab Agricultural University, Ludhiana began its trials on 3000 hectares of land in all districts to test its performance But despite of ongoing trials, paddy residue burning issue still holds strong and lesser time window between harvesting and cultivation of two crops is one of the concerns of the farmer Also, for better outcome the decomposing consortium require additional efforts Our aim of this poster presentation is to cover the possibilities and the problems associated with the use of PUSA decomposers from the perspective of Punjab.

PUSA Bio decomposers

• Syntrophic microbial consortia is composed of 6 fungal and 2 bacterial species

• Psychrotrophic and Mesophilic species are employed for the degradation of paddy waste

• Enzymatic activity of consortia leads to degradation of lignocellulose pectin etc

• This leads to conversion of waste to compost which can promote fertility and also decrease air pollution and it occurs in 20 25 days

• Activity leads to decrease in carbon content (As per C/N ratio analysis) and increase in humic and fulvic acid (HA and FA respectively)

• Mesophilic fungi *Aspergillus awamori Aspergillus nidulans Phanerochaete chrysosporium Trichoderma viride Psychrotrophic fungi Eupenicilliium crustaceum Paceliomyces sp* Psychrotrophic bacteria *Bacillus atropheus Bacillus sp.* (Shukla *et al.,* 2016)

A study (Casciatori *et al.,* 2013) reported the conversion of sugarcane bagasse, orange pulp and peel and wheat bran into enzymes. Mixing of wed biomass, crop residue in various ratios (50:50, 50:100) in plots and various sub-plots along with microbes such as *Trichoderma viridi* and *Pleurotus sp* as spawn seeds resulted in increased yield, improvement in soil pH, nitrogen, phosphorus, potassium and soil organic carbon and overall crop productivity and also aiding in environmental sustainability (Choudhary *et al.,* 2020).

Table 4: Effect of residue on yield, nitrogen uptake in no-till wheat

Treatment	**Grain yield (kg ha^{-1})**		**Straw yield (kg ha^{-1})**		**Nitrogen Uptake by wheat (kg ha^{-1})**	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006 -07
R1(Residue removal)	3069	3386	4752	5021	72.49	82.36
R2(Residue retention)	3264	3581	5019	5296	73.59	86.60
R3 Residue retention	3321	3617	5100	5332	73.78	88.34

with Trichoderma)						
Sem±	51.90	55.79	60.30	82.66	0.29	1.33
CD (P=0.05)	163.54	175.78	190.00	260.43	0.90	4.18

Source **Kumar *et al.*, 2017**

As compared to residue retention alone (3264 and 3681 kg ha-1) and residue removal, the rice residue retention with Trichoderma application provided considerably greater crop growth (Table 4), yield characteristics, grain (3321 and 3617 kg ha-1) and straw yield (3069 and 3386 kg ha-1). Wheat absorbed the most nitrogen after Trichoderma spraying in terms of residue retention (Kumar et al., 2017).

Conclusion

Based on the reported research findings from multiple researchers, an analysis has been conducted. To stop residues from burning in the rice and wheat cropping systems, it is essential to research and upgrade technologies. The in-situ incorporation of rice wastes with microbial consortia in wheat crops is a suitable alternative for their management. Microbial consortia can be used to increase yield, water productivity, and profitability while lowering *Phaleris minor* weed. Improvements to the soil's quality. Continuous application of rice wastes, which are an important source of plant nutrients, can help control the usage of fertilisers and lower air pollution.

Reference

Allen, J., Pascual, K. S., Romasanta, R. R., Trinh, M. V., Thach, T. V., Hung, N. V., ... & Chivenge, P., 2020. Rice straw management effects on greenhouse gas emissions and mitigation options. In *Sustainable Rice Straw Management* (pp. 145-159). Springer, Cham.

Anonymous, 2018.Estimation of surplus crop residue in inda for biofuel production. Join Report of TIFAC & IARI.

Anonymous, 2019. Report on Review of The Scheme "Promotion Of Agricultural Mechanisation For In-Situ Management of Crop Residue in States of Punjab, Haryana, Uttar Pradesh And Nct Of Delhi Ministry of Agriculture and Farmers Welfare Krishi Bhawan Deptt. of Agriculture, Cooperation & Farmers Welfare *Government of India*, New Delhi.

Auffhammer, M., Ramanathan, V., Vincent, J., 2006. Integrated model shows that atmospheric brown clouds and greenhouse gases have reduced rice harvests in India. *Proceedings of the National Academy of Sciences* **103**(52): 19668-19672.

Azmal, A. K. M., Murmoto, T., Shindo, H. and Nishiyama, M. 1997. Changed in Microbial biomass after continues application of Azzola and rice stra in soil. *Soil Science Plant Nutrient*, **43**: 811-818.

Badarinath, K.V.S., Chand, T.R.K., Prasad, V.K., 2006. Agricultural crop residue burning in the Indo-Gangetic plains e a study using IRS-P6 AWiFS satellite data. *Current Science* **91**(8): 1085-1089.

Beerling, D. J., Leake, J. R., Long, S. P., Scholes, J. D., Ton, J., Nelson, P. N., & Kelland, M., 2018. Farming with crops and rocks to address global climate, food and soil security. Nature plants, **4**(3), 138-147.

Beri V., Sindhu, B. S.,Bhat, A.K. and Singh, B. 1992. Nutrent and soil properties as affected by management of crop residue. In: Proc. Intl. Symposium on Nutrient on management and sustained productivity Vol 2 Ludhiana, Dept. of Soil, PAU pp. 133-135

Beri, V., Sidhu, B.S., Bahl, G.S. and Bhat, A.K. 1995. Nitrogen and phosphorus transformations as affected by crop residue management practices and their influence on crop yield. *Soil Use Manage*. **11**:51-54.

Biederbeck, V.O., Campbell, C.A. Bowren, K.E., Schnitzer, M. and McIver, R.N. 1980. Effect of burning cereal straw on soil properties and grain yields in Saskatchewan. *Soil Sci. Soc. Am. J,* 44:103-110.

Casciatori F.P., Laurentino C. L., Lopes K. C. M., de Souza A. G. and Thomeo J. C., 2013. “Stagnant effective thermal conductivity of Agro-industrial residues for solid-state fermentation”. *International Journal of Food Properties*, **16**: 1578 – 1593.

Chakraborty, D., Garg, R. N., Tomar, R. K., Singh, R., Sharma, S. K., Singh, R. K., ... & Kamble, K. H., 2010. Synthetic and organic mulching and nitrogen effect on winter wheat (Triticum aestivum L.) in a semi-arid environment. *Agricultural Water Management*, ***97***(5): 738-748.

Chakraborty, D., Nagarajan, S., Aggarwal, P., Gupta, V. K., Tomar, R. K., Garg, R. N., ... & Kalra, N., 2008. Effect of mulching on soil and plant water status, and the growth and yield of wheat (Triticum aestivum L.) in a semi-arid environment. *Agricultural water management*, ***95***(12): 1323-1334.

Chitty, D. and M. Walsh. 2003. The burning issues of annual ryegrass seed control. In '*Crop Updates* 2003 Weeds, Perth

Choudhary V.K., Gurjar D. S. and Meena R. S., 2020. "Crop residue and weed biomass incorporation with microbial inoculation improve the crop and soil productivity in the rice (*Oryza sativa* L.) – toria (*Brassica rapa* L.) cropping system". *Environmental and Sustainability Indicators* (in press).

Dobermann, A. and Fairhurst, T.H. (2002). Rice straw management, *Better Crops International*, **16**, 7-11**.**

Dotaniya, M. L., 2013. Impact of crop residue management practices on yield and nutrient uptake in rice-wheat system. *Current Advances in Agricultural Sciences (An International Journal)*, ***5***(2): 269-271.

Edwards, J. H., Wood, C. W., Thurlow, D. L. and Ruf, M. E., 1992. Tillage and crop rotation effect on fertility status of Hapludand soil. *Soil Sci. Soc. Am. J., 56*, 1577-1585.

Erenstein O and Laxmi V 2008. Zero tillage impacts in India's rice wheat systems: a review. *Soil Till Res* **100:** 1–14.

Erenstein O, Laxmi V., 2008. Zero-tillage impacts in India's rice wheat systems: a review. *Soil and Tillage Research.* 2008; **100**(1-2):1-14.

Fisher, R. F., & Binkley, D., 2000. Soil organic matter. Ecology and management of forest soils, 139-160

Gadde, B., Bonnet, S., Menke, C., Garivait, S., 2009. Air pollutant emissions from rice straw open field burning in India, Thailand and the Philippines. *Environmental Pollution* **157**, 1554-1558.

Gujral, J., Davenport, S. and Jayasuriya, S. (2010). Is there a role for agricultural offsets in sustainable infrastructure development: A preliminary assessment of issues', Chapter 25 in India Infrastructure Report 2010, Oxford University Press.

Hani, N. W., Rashid, N. F. A., & Hashim, M. H., 2021. Effects of burning rice residues on soil chemical properties in sekinchan rice field. Lumpur International Agriculture, Forestry and Plantation Conference (KLIAFP10), 22-23.

Kaur, R., Kaur, M., Deol, J. S., Sharma, R., Kaur, T., Brar, A. S. and Choudhary, O. P. (2021). Soil Properties and Weed Dynamics in Wheat as Affected by Rice Residue Management in the Rice–Wheat Cropping System in South Asia. *Plants MDPI*, **10**: 953

Khaliq, A., Gondal, M. R., Matloob, A., Ullah, E., Hussain, S., & Murtaza, G., 2013. Chemical weed control in wheat under different rice residue management options. *Pakistan Journal of Weed Science Research*, ***19***(1) 1-14.

Khankhane, P. J., Barman, K. K. and Varshney J. G., 2009. Effect of rice residue management practices on weed density, wheat productivity and soil fertility in a swell-shrink soil *Indian Journal of Weed Science*, **41**(1&2): 41-45.

Kumar, K. and K.M. Goh. 2000. Crop residues and management practices: Effects on soil quality, soil nitrogen dynamics, crop yields, and nitrogen recovery. *Advances Agron*. **68**: 197-31.

Kumar, R., Singh, U. P., & Mahajan, G., 2017. Influence of residue and weed management practices on no-till wheat (*Triticum aestvium* L.) under rice-wheat cropping system. *Indian Journal of Soil Conservation*, ***45***(2): 198-202.

Kumar, V., & Dash, B., 2016. Long-term effect of crop residues and zinc fertilizer on crop yields, nutrient uptake and fertility buildup under rice-wheat cropping system in calciorthents. *International journal of bio-resource, environment and agricultural sciences (ijbeas).* ***2(****4): 430-435,*

Ladha, J. K., Kumar, V., Alam, M.M., Sharma, S., Gathala, M., Chandana, P., 2009. Integrating crop and resource management technologies for enhanced productivityin South Asia. In: Integrated Crop and Resource Management in the Rice Wheat System of South Asia (Eds: Ladha J K, Singh Y, Erenstein O and Hardy B) *International Rice Research Institute, Los Banos, Philippines.* 69-108

Lal, R., 1980. Soil erosion as a constraint to crop production. In: Priorities for Alleviating Soil Related Constraints to Food Production in Tropics, *Inst. Rice Res., Los Banos,* pp. 405–423.

Lal, R., De Vleeschauwer, D.,Malfa Nganje, R., 1980. Changes in properties of a newly cleared tropical alfisol as affected by mulching. Soil Sci. Soc. Am. J. 44, 827–833.

Long, W., Tate, R., Neuman, M., Manfreda, J., Becker, A., Anthonisen, N., 1998. Respiratory symptoms in a susceptible population due to burning of agricultural residue. *Chest*, **113**(2): 351.

Mandal, K. G., Misra, A. K., Hati, K. M., Bandyopadhyay, K. K., Ghosh, P. K., & Mohanty, M., 2004. Rice residue-management options and effects on soil properties and crop productivity. *Journal of Food Agriculture and Environment,* ***2***: 224-231.

Mando, A. Strosnijder, L. and Brussard, L. 1996. Effect termites on infiltration into crused soil. *Geoderma*, **74**:13-24

Maurya, P.R., Lal, R., 1981. Effects of different mulch materials on soil properties and on root growth and yield of maize (Zea mays) and cow pea (Vigna uniguiculata). *Field Crop Res.* 33–45.

NDEP, 2003. The Nevada Handbook for Agricultural Open Burning. Nevada Division of Environmental Protection (NDEP), *Las Vegas*, USA.

Nugroho, S. G. and Kuwatsuka, S., 1992. Concurrent obsrervation of several process of nitrozenmetabolism in soil amended with or-genic materia. III. Changed in Microbial Population following application of ammonium nitrogen. *Soil Science Plant Nutrient*, **38**: 799-810.

Pathak, H., Singh, R., Bhatia, A. and Jain, N., 2006. Recycling of rice straw to improve wheat yield and soil fertility and reduce atmospheric pollution. Paddy Water Environ**. 4:** 111-117.

Prasad, R. K., Kumar, V., Prasad, B., & Singh, A. P., 2010. Long-term effect of crop residues and zinc fertilizer on crop yield, nutrient uptake and fertility build-up under rice-wheat cropping system in calciorthents. *Journal of the Indian society of soil Science*, **58**(2): 205-211.

Prihar S. S, Arora V. K .and Jalota S. K. 2010. Enhancing crop water productivity to ameliorate groundwater fall. *Curr Sci* **99:** 588- 93

Raison, R.J. 1979. Modification of the soil environment by vegetation fires, with particular reference to nitrogen transformation: a review. *Plant Soil* **51**:73-108.

Salam, M. A., Ferdus, J., Sultana, A., & Salek, A., 2020. Effect of rice residue on weed suppression and yield performance of boro rice. *Archives of Agriculture and Environmental Science*, ***5***(3): 320-327.

Schaller, Jörg & Wang, Jiajia & Planer-Friedrich, Britta., 2018. Black carbon yields highest nutrient and lowest arsenic release when using rice residuals in paddy soils OPEN. Scientific Reports. 8. 10.1038/s41598-018-35414-3.

Shafi, M., Bakht, J., Jan, M.T., Shah, Z., 2007. Soil C and N dynamics and maize (Zea mays) yield as affected by cropping systems and residuemanagement in Northweste Pakistan. *Soil and Till. Res*. **94**, 520–529.

Shah, Z., Shah, S.H., Peoples, M.B., Schwenke, G.D., Herriedge, D.F., 2003. Crop residue and fertilizer N effects on nitrogen fixation and yields of legume–cereal rotations and soil organic fertility. *Field Crops Res*. **83**, 1–11.

Shahid, M., Tripathi, R., Mohanty, S., Thilagam, K., & Nayak, A. K., 2013. Rice Residue Management for Improving Soil Quality. *Rice Knowledge Management Portal*, http://www.rkmp.co.in

Sharma, P.K., and Mishra, B., 2001. Effect of burning rice and wheat crop residues: Loss of N, P. K and S from soiland changes in nutrient availability. *J. Indian Soc. Soil. Sci*., **49**:425-429.

Shukla *et al.*, 2016 Syntrophic microbial system for ex situ degradation of paddy straw at low temperature under controlled and natural environment Applied Microbiology and Biotechnology **4** 30-37. doi 10 7324 /JABB 2016 40205

Sidhu H. S., Manpreet-Singh, Humphreys E., Yadvinder-Singh, Balwinder-Singh, Dhillon S. S., Blackwell J., Bector V., Malkeet- Singh and Sarbjeet-Singh, 2007. The Happy Seeder enables direct drilling of wheat into rice stubble. *Aus J Exp Agric* **47:** 844-54.

Sidhu, B.S. and Beri, V. (1989). Effect of crop residue management on yields of different crops and soil properties, Bioogical Wastes, **27**, 15-27.

Sidhu, H. S., Humphreys, E., Dhillon, S. S., Blackwell, J., & Bector, V., 2007. The Happy Seeder enables direct drilling of wheat into rice stubble. *Australian Journal of Experimental Agriculture*, ***47***(7): 844-854.

Sindhu, A. S. and Sur, H. S., 1993. Effect of incorporation of legume crop straw on soil properties and crop yield in maize –wheat sequence. Tropical Agriculture, **70**(3).

Singh, P., Singh, G. and Sodhi, G.P.S. (2020). Energy and carbon footprints of wheat establishment following different rice residue management strategies vis-à-vis conventional tillage coupled with rice residue burning in north-western India, *Energy*, 200, 117554.

Singh, Y., Thind, H. S., & Sidhu, H. S., 2014. Management options for rice residues for sustainable productivity of rice-wheat cropping system. *Journal of Research Punjab Agricultural University*, ***51***(3&4): 209-220.

Song, H. J., Lee, J. H., Jeong, H. C., Choi, E. J., Oh, T. K., Hong, C. O., & Kim, P. J., 2019. Effect of straw incorporation on methane emission in rice paddy: conversion factor and smart straw management. *Applied Biological Chemistry*, ***62***(1): 1-13.

Srinivasan, G. and Abirami, A., 2020. Mitigation of crop residue burning induced air pollution in New Delhi – a review. *International Journal of Engineering Applied Sciences and Technology,* **5**(8): 282-291

Tisdell, J. M., 1992. How stubble affects Organic matter, Plants and animals in the soil. *Journal Agriculture, **33**:*18-21

Yadvinder-Singh, Bijay-Singh and J. Timsina. 2005. Crop residue management for nutrient cycling and improving soil productivity in rice-based cropping systems in the tropics. *Advances Agron*. **85**: 269- 407.

Yadvinder-Singh, Singh, B., Ladha, J. K., Khind, C. S., Khera, T. S., & Bueno, C. S., 2004. Effects of residue decomposition on productivity and soil fertility in rice–wheat rotation. *Soil Science Society of America Journal*, ***68***(3): 854-864.

Zhang, H., Ye, X., Cheng, T., Chen, J., Yang, X., Wang, L., Zhang, R., 2008. A laboratory study of agricultural crop residue combustion in China: emission factors and emission inventory. *Atmospheric Environment* **42**, 8432-8441.

Zhao, X., Yuan, G., Wang, H., Lu, D., Chen, X., & Zhou, J., 2019. Effects of full straw incorporation on soil fertility and crop yield in rice-wheat rotation for silty clay loamy cropland. *Agronomy, **9***(3): 133.