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In-situ crop residue composting: A potential alternative to residue burning

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Abstract

In India, the potential of crop residues is a serious concern and more efforts need to be made to estimate food grain production and availability of crop residues. This review reveals that crop residues of cultivated crops are an important resource and not only as a source of of nutrients for crop production hence also improving the various soil physical, chemical, and biological properties and functions, soil and water quality. Large quantities of crop residues produced in the rice-wheat cropping system in India are a potential source for improving soil carbon sequestration, nutrient cycling. Burning of crop residues is a threat to sustainability concerns. Disposal of rice straw is usually done by burning in open field but this practices resulted in large amount of air pollutants (i.e. CO_2 and NO_2.) and including loss of nutrient. In-situ incorporation of crop residues into the soil for composting is the most common and important technology for the management of agricultural residues. It reduces the volume and weight of agro-residues about 50% consequently produce a stable product (humus) which enhance the physico-chemical and biological properties of the soil. Recycling of rice residues constitutes more potential problems than recycling of wheat straw. Incorporation of wheat residues, increased the yield of rice and also had a positive residual effect on the yield of subsequent wheat crop. It is suggested that in each cropping system, the constraints to production and sustainability should be conceptualized and identified to guide toward the best option. A multidisciplinary and integrated efforts by all agriculturalist are needed to design a system approach for best choice of crop residue management system which enhance both agricultural productivity and sustainability

Keywords: In-situ crop residue composting, a potential alternative, residue burning

Introduction

Soil is one of the most precious natural resources of the earth and to maintain its health it is the moral responsibility of mankind. However, the much quantity of production of food, fuel and feed is causing an irreplaceable damage to its environment. In addition of excessive chemical fertilizers and pesticides and modern cultivation practices deteriorate the soil fertility and productivity. Use of organic wastes as soil amendment may hold a good promise for improving the soil health, crop productivity and reduce the waste disposal problem. Paddy straw is one of the waste organic product whose huge quantity needs some valuable disposal solution (Gaind and Nain, 2007) [29]. Rice, the main cereal crop in the world, is cultivated to more than 148 million hectares under a wide range of ecosystems. In 1960, total rice production was 150 million tons which increased to 645 million tons in 2007. At least 114 countries grow rice and more than 50 countries have an annual production of 100,000 tons or more (USDA 2008) [2]. For every ton of harvested grain produce about 1.35 tons of rice straw in the field which is very huge amount. (Kadam *et al.* 2000) [3]. The disposal of rice straw is a serious concern due to its huge bulk material and slow degradation rate. Moreover, it cannot be used as animal feed because of its low digestibility, low protein, high content of lignin and silica. Due to many problems the straw is disposed through open-burning, which causes serious environmental problems as well as a threat to public health. Rice straw comprises mainly cellulose (36-37%) and hemicellulose (23-24%) encrusted by lignin (15-16%) (Viji and Neelanarayanan, 2015) [41], and a small amount of protein, which makes it high in C: N ratio. Therefore, it is resistant to microbial decomposition as compared to wheat and barley straw (Parr *et al.* 1992) [5]. To make the rice straw composting process economically viable, lignocellulolytic microbes based biodegradation may be an effective alternative to *in-situ* burning (Kumar *et al.* 2008) [6]. If it is incorporated into the soil combined with a low C: N ratio material such as cattle manure (FYM) or municipal sludge combined with lignocellulolytic microorganisms that produces a higher nutrient content organic matter.

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(Ball *et al.* 1990) [7]. Rice straw compost is most commonly applied to paddy field in Japan to improve soil fertility and crop yield (Hatamoto *et al.* 2008) [8]

Crop residues and their availability

The material of the crop plant left in the field after the crop has been harvested and threshed. These residues include stalks, stubble (stems), leaves etc. it is regarded as waste materials that require disposal, but it is recently realized that these waste materials are a tremendous natural sources of nutrient. According to Kim and Dale, 2004 [10] agricultural activities generate huge amount of organic residues including straw, culled fruit and vegetables and residues from forestry. Among the crop residues, rice straw, wheat straw, corn straw and sugarcane bagasse are the major agricultural wastes in terms of quantity of biomass availability. Rice straw is one of the most abundant lignocellulosic wastes available in India and world because rice is the primary staple food for more than half of the world's population among which Asia represents as the largest producing and consuming region. In India, 106.5 MT of rice, 96 MT of wheat and 24 MT of maize production have been reported (DAC 2016) [11] (Table 2). Annually 686 MT of crop residues are generated in India from 28 crops. Out of this, cereals contribute highest amount of residue (89 MT) followed by from sugarcane (56 MT) and others (47MT). But due to poor management the rice residues are mostly burnt in the field which create pollution in the environment. (Hiloidhari *et al.* 2014) [12].

Table 1: Percent composition of lignocelluloses components in major crop residues.

Agricultural residues	Cellulose (%)	Hemicellulose (%)	Lignin (%)	Ash (%)	References
Rice straw	38	25	25	12	Taniguchi *et al.*2010
Wheat straw	33.7	29.9	23.4	4.2	Garcia-Torreiro *et al.* 2016
Sugarcane bagasse	36-39	28.5-31	12.5-3.9	0.8-1.1	Cassia *et al.* 2015
Corn stover	58.29*	-	18.69	-	Kim and Dale 2004
Corn cob	39.71	32.85	12.31	-	Sharma *et al.* 2017
Sorghum straw	61*	-	15	-	Kim and Dale 2004
Barley straw	70	-	9	-	Kim and Dale 2004

* indicates composition comprising cellulose and hemicellulose percentages.

Table 2: Production of crop and their respective residues in world and India.

S. N.	Crops	Annual production (MT)	
		India	World
1	Rice straw	106.5	738
2	Wheat straw	96	711
3	Maize Stover	24	1017
4	Sugarcane bagasses	341	1898
5	Millets (stalk)	11	24.5
6	Cotton (stalk)	18	70
7	Pigeon pea (stalk)	3	4.5

Source: Biomass feedstock composition and property database and adapted from Kim and Dale 2004. [10]

In-situ burning of crop residues and its effects on environment

Burning of rice straw causes nutrients loss in soil and affects human health by polluting air. The burning results in huge losses of carbon (almost 100%) N (up to 80%), P (25%), K (21%) and S (50-60%), thereby depriving the soils of its organic matter (Mandal *et al.* 2004). Burning of residues resulted in loss of soil organic matter, which is a visible threat in sustainability of rice-wheat cropping system. The burning of agricultural residues leads to significant emission of chemically and radiatively important gases and also particulate matter. It also contributes to emission of harmful air pollutants, including polycyclic aromatic hydrocarbons (PAHs) (Korenaga *et al.* 2001) [35], poly-chlorinated dibenzodioxins (PCDDs) and poly-chlorinated dibenzofurans (PCDFs) referred to as dioxins (Gullett and Touati, 2003 [36]; Lin *et al.*, 2007) [37] which have significant toxicological properties and notably potential carcinogens that can cause severe impact on human health. According to Gadi, 2003 one ton of rice straw on burning releases about 3 kg particulate matter, 60 kg CO, 1460 kg CO_2, 199 kg ash and 2 kg SO_2. Similarly, studies have also shown that the amount of organic matter and nutrient content remain in one ton of wheat straw before burning is 413 kg of carbon, 11 kg of nitrogen, 1.4 kg of phosphorus 14.5 kg of potash and 1.1 kg of sulphur (Heard *et al.* 2006) [13]. While the product of burning of the stubble are gases and ash and after burning of the straw and stubbles, most of the nitrogen, carbon and sulphur and lesser amounts of phosphorus and potash stored in this stubbles and fodder are consumed in the fire.

Soil properties as influenced by in-situ incorporation of crop residues

In India, the estimated total amount of crop residues is 91-141 Mt (IARI, 2012) [14]. Residues are good sources of plant nutrients, as well as the primary source of organic matter added to the soil as carbon constitutes about 40% of the total dry biomass. The main components of organic matter are carbohydrate (*e.g.* cellulose), proteins, lipids and lignin. Their capacity to assimilate organic matter is dependent upon their ability to produce the enzymes needed for degradation of the substrate (Tuomela *et al.* 2000) [38]. Some amount of uptake of nitrogen and phosphorus and maximum amount of potassium and sulphur are remain in vegetative parts of rice and wheat. While Van reported that the mean N, P and K amounts in rice straw as 6.2 kg, 1.1kg and 18.9 kg per ton of straw found respectively. Crop residues are the primary source of organic material and a given climatic condition and soil type, the rate of addition of carbon inputs is an important factor for determining the amount of organic matter that can be maintained in the soil. (Kumar and Goh, 2000) [15]. Traditionally, wheat and rice straws have been removed from the fields for various uses like cattle feed, livestock bedding, thatching and fuel. Recently, because of the advent of mechanized harvesting, farmers prefer to burn in-situ these large quantities of crop residue left in the field. Nutrient cycling in the soil-plant ecosystem is an essential component of sustainable agriculture. The use of microbial sprays that can speed decomposition of residue is also an option. According to Singh, 2003 [16], incorporation of cereal crop residues immediately before sowing or transplanting into wheat or rice significantly lowers the crop yield because of immobilization of inorganic N and cause N deficiency. However, in few studies, wheat yields were lower during the first one to three years of rice straw incorporation 30 days prior to wheat planting, but in later years, straw incorporation did not affect wheat yields adversely. According to Kumar and Goh (2000) [15] the incorporation of crop residues alters the soil environment, which in turn influences the microbial population and activity in the soil and subsequent nutrient transformations. This is like a chain of event and for complete achievement of this chain, the management of crop residues with fertilizer, water and other reserves are used in a cropping system. The major problem found in the profitable use of cereals crop residues is the microbial immobilization of soil and fertilizer N. (Mary *et al*. 1996) [17].

Anderson, 1995 observed that the incorporation of crop residues increased organic carbon by 14 to 29% over residue removal treatments in 3 to 10 year of experiments. Particulate organic carbon has been found to be the fraction preferentially lost when the soils are cultivated (Cambardella and Elliott, 1992) [19]. Chan *et al*. 2002 [20] showed that particulate organic carbon more sensitive indicator of changes in organic carbon in soils. Residue burning significantly reduced incorporated organic carbon (<53 µm) consequently lowered the water stability of aggregates<50 µm. Soil organic carbon (SOC) is an important soil property considered as one of soil quality indicators and the other biological soil quality indicators include microbial biomass carbon (MBC) and soil respiration (Suman *et al.,* 2006; Marriot and Wander, 2006) [30, 40], soil microbial population and soil enzyme.

Table 3: The effect of different crop residue management practices on the soil

	Residues		
	Incorporated	**Removed**	**Burnt**
pH	7.7	7.6	7.6
EC (dSm^{-1})	0.18	0.13	0.13
Organic C (%)	0.75	0.59	0.69
Avail. N (kg ha^{-1})	154	139	143
Avail. P (kg ha^{-1})	45	38	32
Avail. K (kg ha^{-1})	85	56	77
Total N (kg ha^{-1})	2002	2002	1725
Total P (kg ha^{-1})	1346	924	858
Total K (kg ha^{-1})	40480	34540	38280

Source: Mandal *et al.* (2004)

Table 4: Effect of crop residue management on organic carbon of soil under rice-wheat cropping system.

References	Type of crop residues	Duration	Residue management	Organic carbon (%)
Kesharwani *et al.* (2017)	Rice straw, nitrogen 150 kg ha^{-1} and sesbania	4	residue removal	0.75
			residue incorporation	0.79
			residue burning	0.7
			residue surface retention + sesbania	0.87
Yadvinder Singh *et al.* (2000)	Wheat straw, green manure (GM) and wheat straw + GM in rice	6	removed	0.38
			incorporated	0.49
			GM	0.41
			straw +GM	0.47
Singh *et al.* (2004)	Wheat straw green manure, and wheat straw + green manure (GM) in rice	6	removed	0.38
			incorporated	0.49
			GM	0.41
			straw	0.47

Bioconversion of crop residues by beneficial microorganism

Composting is one of the most common and beneficial technology for the management of agricultural residues. These residues are of potent source several benefits such as improved soil health and fertility which leads to increased agricultural productivity and soil biodiversity (Singh and Nain, 2014) [21]. For Composting by microbes, this is essential the raw material has C: N ratio between 30 and 35 and the moisture content of the residues is in the range of 55 to 65% to ensure the appropriate conditions for the microorganisms to decompose and transform the crop residues into organic matter (Shilev and Naydenov 2007) [23]. Many microorganisms have been reported with cellulosic activities including many bacterial and fungal strains both aerobic and anaerobic. *Chaetomium*, *fusarium*, *Myrothecium, Trichoderma, Penicillium*, *Aspergillus* and *Trichonympha, Clostridium, Actinomycetes*, *Bacteroides succinogenes*, *Butyrivibrio fibrisolvens* are some fungal and bacterial species responsible for degradation (Schwarz,2001; Milala *et al.* 2005). According to Gaind *et al*. (2009) [24, 25, 26] a microbial consortium comprising *Aspergillus nidulans*, *Trichoderma viride*, *A. awamori* and *Phanerochaete chrysosporium* was used in composting of various crop residues with poultry droppings and rock phosphate (%) which produces N-enriched phosphocompost within two months. The mesophilic phase of composting is governed by the mesophilic microorganisms like bacteria Pseudomonadaceae, Enterobacteriaceae, Streptomycetaceae and *Erythrobacteraceae* families which grow in the temperature range of 15 to 35 ºC and utilize the soluble compounds such as sugar, amino acids and lipids (Bernal *et al*. 2009) [27] After metabolic activities these generate exothermic reactions and increase the composting temperature up to 65 – 85 ºC these phase is called thermophilic phase. (Insam and de Bertoldi 2007) Thermo monosporaceae and Pseudo nocardiaceae possess hydrolytic enzyme degrading lignin, cellulose, hemicelluloses and proteins (Insam and de Bertoldi 2007) [29]. A thermophilic fungal consortia of *A. nidulans, Scytalidium thermophilum* and *Humcola sp*. Was found very effective in decomposition of soybean trash and rice straw (Pandey *et al*. 2009) [29]. Composting at low temperature was accelerated by some psychrotrophic microbial consortium comprising *Eupenicillium crustaceum*, *Paceliomyces sp*. *Bacillus atropheus* and Bacillus sp., was employed for biodegradation of rice straw (Shukla *et al*. 2016) [30].

Future Research Needs

The practice of residue burning or removal doesn't found suitable for environment as well as soil fertility and productivity thus, there is a need to fine tune nutrient management for rice and wheat grown on soils, where crop residues are continuously incorporated. Limited information is available on the interactions between crop residue management and tillage practiced under rice-wheat cropping system. Adoption of in-situ incorporation of crop residue management by farmers of the region will prove immensely useful because of reduced air pollution and recycling of nutrient.

References

1. Gaind Sunita, Nain Lata. Chemical and biological properties of wheat soil in response to paddy straw incorporation and its biodegradation by fungal inoculants. Biodegradation. 2007; 18:495-503.
2. USDA. World rice production, consumption, and stocks from United States Dept. of Agric. USA, 2008, 67-72.
3. Kadam KL, LH Forrest, WA Jacobson. Rice Straw as a Lignocellulosic Resource: Collection, Processing, Transportation, and Environmental Aspects. Biomass Bioenerg. 2000; 18:369-389.
4. Kausher H, Sariah M, Mohd Saud H, Zahahgir Alam M, Razi Ismail M. Isolation and screening of potential Actinobacteria for rapid composting of rice straw. Biodegradation. 2011; 22:367-375.
5. Parr JF, RI Papendick, SB Hornick, RE Meyer. Soil Quality: attributes and relationship to alternative and sustainable agriculture. Ameriacan J Altern. Agric. 1992; 7:5-11.
6. Kumar A, Gaind S, Nain L. Evaluation of thermophilic fungal consortium for paddy straw composting. Biodegradation. 2008; 19:395-402.
7. Ball AS, B Godden, P Helvenstein, MJ Penninckx, AJ Mc Carthy. *Lignocarbohydrate solubilization* from straw by actinomucetes. Appl. Environ. Microbiol. 1990; 56:3017-22.
8. Hatamoto M, Tanahashi T, Murase J, Matsuya K, Hayashi M, Kimura M *et al*. Eukaryotic communities associated with the decomposition of rice straw compost in Japanese rice paddy field estimated by DGGE analysis. Biol. Fertil. Soils. 2008; 44:527-532.
9. Kim S, Dale BE. Global potential bioethanol production from wasted crops and crop residues. Biomass and Bioenergy. 2000; 26:361-375.
10. Kim S, Dale BE. Global potential bioethanol production from wasted crops and crop residues. Biomass and Bioenergy. 2004; 26:361-375.
11. DAC. 2016 Fourth Advance Production Estimates of Majors Crops During, 2015-16.
12. Hiloidhari M, Das D, Baruah DC. Bioenergy potential from crop residue biomass in India. Renew. Sustain. Energy Rev. 2014; 32:504-512.
13. Heard j, Cavers C, Adrian G. Up in smoke-nutrient loss with straw burning. Better crops. 2006; 90(3):10-11.
14. IARI. Crop residues management with conservation agriculture: potential, constraints and policy needs. Indian Agricultural Research Institute, New Delhi, 2012, 32
15. Kumar K, KM Goh. Crop residue management: Effects on soil quality, soil nitrogen dynamics, crop yield, and nitrogen recovery. Adv. Agron. 2000; 68:197-319.
16. Singh Y. Crop residue management in rice-wheat system, Addressing Resource Conservation Issues in Rice-Wheat Systems of South Asia, A resource Book, Rice Wheat Consortium for Indo-Gangetic Plains (CIMMYT), March, 2003.
17. Mary B, S Recous D, Darwis, D Robin. Interactions between decomposition of plant residues and nitrogen cycling in soil. Plant Soil. 1996; 181:71-82.
18. Anderson DW. Decomposition of organic matter and carbon emissions from soils. In R. Lal *et al*. (ed.) Advances in soil science: Soils and global change. CRC Press, Boca Raton, FL, 1995, 165-175.
19. Cambardella CA, ET Elliott. Particulate soil organic matter changes across a grassland cultivation sequence. Soil Sci. Soc. Am. J 1992; 56:777-783.
20. Chan KY, DP Heenan, A Oates. Soil carbon fractions and relationship to soil quality under different tillage and stubble management. Soil Tillage Res. 2002; 63:133-139.
21. Singh S, Nain L. Microorganisms in sustainable agriculture. Proc Indian Natl Sci Acad 80: 357. doi: 10.16943/ptinsa/2014/v80i2/7. 2014
22. Singh Y, Singh B, Ladha JK, Khind CS, Khera TS, Bueno CS. Management effects on residue decomposition, crop production and soil fertility in a rice-wheat rotation in India. Soil Science Society of America Journal. 2004; 68:320-326.
23. Shilev S, Naydenov M. Composting of food and Agricultural Wastes. Util By-Products Treat Waste Food Ind. 2007, 283-301.
24. Schwarz WH. The cellulosome and cellulose degradation by anaerobic bacteria. Applied Microbiology and Biotechnology. 2001; 56(5-6):634-649.
25. Milala MA, Shugaba A, Gidado A, Ene AC, Wafar JA. Studies on the use of agricultural wastes for cellulase enzyme production by *A. niger*. Journal of Agriculture and Biological Science. 2005; 1:325-328.
26. Gaind S, Nain L, Patel VB. Quality evaluation of co-composted wheat straw, poultry droppings and oil seed cakes. Biodegradation. 2009; 20:307-317.
27. Bernal MP, Alburquerque JA, Moral R. Composting of animal manures and chemical criteria for compost maturity assessment. A review. Bioresourc Technol. 2009; 100:5444-5453.
28. Insam H, de Bertoldi M. Microbiology of the composting process. Compost Sci Technol Waste Manag Ser 8:25-48.
29. Pandey AK, Gaind S, Ali A, Nain L. 2009 Effect of bio augmentation and nitrogen supplementation on composting of paddy straw. Biodegradation. 2007; 20:293-306.
30. Shukla L, Suman A, Verma P. Syntrophic microbial system for ex-situ degradation of paddy straw at low temperature under controlled and natural environment. J Appl. Bio Biotechnol. 2016; 4:30-37.
31. Cassia Pereira J, Paganini Marques N, Rodrigues A, Thermophilic fungi as new sources for production of celluloses and xylanases with potential use in sugarcane bagasse saccharification. J Appl. Microbiol. 2015; 118:928-939.
32. Garcia-Torreiro M, Lopez-Abelairas M, Lu-Chau TA, Lema JM. Fungal pretreatment of agricultural residues for bioethanol production. Ind Crops Prod. 2016; 89:486-492.
33. Taniguchi M, Takahashi D, Watanabe D. Effect of steam explosion pretreatment on treatment with Pleurotus ostreatus for the enzymatic hydrolysis of rice straw. J Biosci Bioeng. 2010; 110:449-452.
34. Mandal Krishna G, Misra Arun K, Hati Kuntal M, Bandyopadhyay Kali K, Ghosh, Prabir K, Mohanty, Manoranjan. Rice residue- management options and effects on soil properties and crop productivity. Food, Agriculture & Environment. 2004; 2(1):224-231.
35. Korenaga T, Liu X, Huang Z. The influence of moisture content on polycyclic aromatic hydrocarbons emission during rice straw burning. Chem. Global Change Sci. 2001; 3:117-122.

36. Gullett B, Touati A. PCDD/F emissions from burning wheat and rice field residue. Atmos. Environ. 2003; 37: 4893-4899.
37. Lin LF, Lee WJ, Li HW, Wang MS, Chang-Chien GP. Characterization and inventory of PCDD/F emissions from coal-fired power plants and other sources in Taiwan. Chemosphere, 2007; 68:1642-1649.
38. Tuomela M, Vikman M, Hatakka A, Itavaara M. Biodegradation of lignin in a compost environment: A review. Bioreso. Technol. 2000; 72:169-83.
39. Suman AM, Singh A, Gaur A. Microbial biomass turnover in India subtropical soil under different sugarcane intercropping systems. Agron. J 2006; 98:698-704.
40. Marriot E, Wander M. Total and labile soil organic matter in organic and conventional farming systems. Soil Sci. Soc. Am. 2006; 70:950-959.
41. Viji, Neelanarayanan. Efficacy of Lignocellulolytic Fungi on the Biodegradation of Paddy Straw. Int. J Environ. Res. 2015; 9(1):225-232.
42. Kesharwani, A, Shukla R, Singh V, Pandey DS, Pramanick B, Yadav S *et al*. In-situ rice residue management under rice-wheat cropping system and their influence on wheat productivity. J of Pharma. And Phytoc. 2017; 6(5):1422-1425.
43. Yadvinder-Singh, Bijay-Singh, OP Meelu, CS Khind. Long-term effects of organic manuring and crop residues on the productivity and sustainability of rice-wheat cropping system in Northwest India. In I.P. A bro I *et al*. (ed.) Long-tenn soil fertility experiments in rice-wheat cropping systems. Rice-Wheat Consortium for the Indo-Gangetic Plains, New Delhi, India. 2000, 149-162.