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Rice residue management for rice based cropping system in Cauvery delta zone – A review

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ABSTRACT

Rice straw produced from field is utilized for multiple purposes *viz.*, incorporation in field itself, feeding paddy straw to the animals, burning in the field and thatching the farm houses. The above methods are uneconomical for the farmers and unhealthy for the animals. The new methods *viz.*, composting, mushroom production and new animal feeding is identified as efficient methods for farmers in Cauvery delta zone. Cauvery delta zone includes the entire revenue taluks of Thanjavur, Thriuvarur, Nagappatinam districts numbering 20, five revenue taluks of Trichy districts, two of Cuddalore and one taluk of Puddukkottai districts thus the zone comprises of 28 revenue taluks of the eastern belt of state. All these taluks are benefited by the river Cauvery.

Key words: Animal feed, Burning, Cauvery delta zone, Compost, Efficient, Mushroom, Rice straw.

Cauvery delta zone lies in the eastern part of Tamil Nadu. The most prevalent cropping systems followed in Cauvery delta zone are rice-rice, rice-rice-rice and rice-rice-pulses/cotton/gingelly major crops. Intensive irrigated rice systems, with two and sometimes three rice crops are produced each year in the same field, which are a dominant agricultural land use pattern in the lowland tropics and subtropics of Asia. Cauvery delta zone has a total geographic land area of 14.47 lakh ha which is equivalent to 11.13% of the state area. In the total area, Thanjavur district occupies 57% of Cauvery delta zone followed by Trichy, Ariyalur, Cuddalore and Pudukkottai districts (Paramasivan and Pasupathi, 2016).

Typical amounts of nutrients in rice straw at harvest are 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 of straw on a dry weight basis (Dobermann and Witt, 2000). This paper reviews the existing methods of paddy straw utilization and proposing some efficient methods. In field the nutrient level may increase through composting, modified animal feed method may increase weight of the animal and farmer's economy status improvement through the mushroom production.

Quantity of residue: Ministry of New and Renewable Energy (MNRE 2009), Govt. of India estimated that about 500 Mt of crop residue is generated every year. Among different crops, cereals generate 352 Mt residue followed by fibres (66 Mt), oilseeds (29 Mt), pulses (13 Mt) and sugarcane (12 Mt) (Fig. 1).

The cereal crops (rice, wheat, maize, millets) contribute 70% while rice crop alone contributes 34% of crop residues. Wheat ranks second with 22% of residues whereas fibre crops contribute 13% of residues generated from all crops (Calculated from MNRE report, 2009).

PRESENT METHOD OF UTILIZATION OF RICE RESIDUE

Crop residues are natural resources with exceptional value to farmers. These residues are used as animal feed, composting, thatching for rural homes and fuel for domestic and industrial use.

Burning: A large portion of the residues, about 140 Mt, is burned in field primarily to clear the field from straw and stubble after the harvest of the preceding crop. Half the quantity of agro-residues thus produced finds use as roofing material, animal feed, fuel and packing material, while the other half is disposed of by burning in the field. Burning agro-residues in the field is considered as a cheap and easy means of disposal of excess residues. This practice appends to air pollution and increases soil erosion (Dobermann and Fairhurst, 2000).

Straw incorporation: Dobermann and Fairhurst (2002) found that straw is the only organic material available in significant quantities to most rice farmers. About 40% of the nitrogen (N), 30 to 35% of the phosphorus (P), 80 to 85% of the potassium (K) and 40 to 50% of the sulfur (S) taken up by rice remains in vegetative plant parts at crop maturity.

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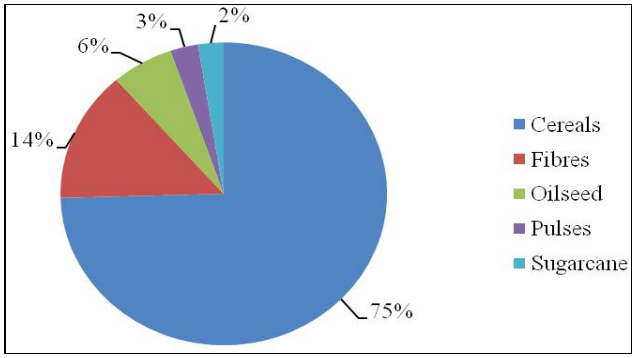


Fig 1: Residue production in India from different crops.



Fig 2: Happy seeder in operation.

Rice stubble is composted *in situ* successfully either through their incorporation into soil or by aerobic decomposition making piles. Rapid *in situ* aerobic method of composting involves periodical spraying of moisture and turning of materials and the processes consume considerable energy. Co-composting of rice straw with poultry manure was reported to save carbon loss (Devi *et al.*, 2012).

Zero-till seed-cum-fertilizer drill such as Happy Seeder (Fig. 2), Turbo Seeder and rotary-disc drill have been developed for direct drilling of seeds in presence of surface residue. These machines are very useful for managing crop residues for conserving moisture and nutrients and controlling weeds as well as moderating soil temperature.

Recommended rate of fertilizer for thaladi is 150:60:60 kg/ha (N:P:K). If the farmer incorporating 6.5 tonnes of paddy straw in the field 52:18:130 kg/ha (N:P:K) is achievable. The remaining can be applied through inorganic fertilizer, since the fertilizer cost will be reduced.

Existing method of animal feed: National Dairy Development Board found that inadequate production of green fodder in the country compelled the farmers to utilize dry roughages as livestock feed particularly for the ruminants. In one estimate, it has been found that in the country, there are about 310 Mt of these dry roughages produced annually. Among these straw, *bhusa, karbi* and hay are noteworthy. In all developed countries, feeding of high quality hay is in practice. Due to unavailability of high quality dry roughages, straw, *bhusa and karbi* form the major bulk of livestock feed in India. Feeding of inferior quality dry roughage is reflected in low productivity of animals.

PROBLEMS IN EXISTING RICE RESIDUE MANAGEMENT

Burning: Burning causes almost complete N loss, P losses of about 25%, K losses of 20%, and S losses of 5 to 60%. The amount of nutrients lost depends on the method used to burn the straw (Dobermann and Fairhurst, 2002). Burning of residues reduced microbial biomass to 57% of that in plots of winter wheat receiving barnyard manure (Collins *et al.*, 1991).

Burning commonly aimed at controlling the soil borne diseases, is a common practice in India particularly when there is a short fallow period or scarcity of water (Bhattacharjee *et al.*, 2013). It is not considered to be a good practice from the point of both energy conservation and environmental pollution (Ocio *et al.*, 1991).

Amamsiri and Wickramasinghe (1978) concluded that conversion of rice straw to ash results in a large loss of nitrogen and a small loss of potassium. From the view point of nitrogen, burning straw is indeed wasteful, but burning and addition of ash seem to be a less troublesome way of putting the straw back to a rice crap under the field conditions.

The quantity of straw 6.5 tonnes produced from one ha land and their nutrient content removed by burning is presented in Table 1.

Challenges in feeding rice straw

Low digestibility: Rice straw has very high silica content (8 to 14%) compared with alfalfa hay (1 to 2%). Silica is indigestible and decreases digestibility of the feed. This is particularly true in the rice leaves, which contain the highest levels of silica.

Low protein: The crude protein of 2 to 7% on a dry matter basis in rice straw requires protein supplementation to meet the nutritional requirements of most cattle.

Problem of incorporation of crop residues in relation to crop growth

i. Conversion of inorganic compounds to organic compounds by micro-organisms or plants. So that the inorganic compounds is prevented from being accessible to plants.

ii. Phytotoxicity is a toxic effect by a compound on plant growth. Such damage may be caused by a wide variety of compounds, including trace metals, salinity, pesticides, phytotoxins or allelochemicals (Wallace and Whitehead, 1980).

iii. Incorporation of straw and stubble into wet soil (during plowing) results in temporary immobilization of N and a significant increase in methane (CH_4) emission from rice paddy, a practice that contributes to greenhouse gases (Rao and Mikkelsen, 1976).

Efficient method for utilization of rice straw

Efficient method for utilization of rice straw in different ways like composting, improved method of animal feed and mushroom cultivation are proposed in this review.

Composting of paddy straw: Composting is the process of decomposition and stabilization of organic matter under controlled condition. Composting is a controlled biological decomposition process that converts organic matter to a stable, humus-like product and the process depend upon microorganisms, which utilize decomposable organic waste both as an energy and food source (Sajnanath and Sushama, 2004).

Amamsiri and Wickramasinghe (1978) suggested that addition of rice straw compost will eliminate most of the problems arising from direct application of straw. Compost can be added without causing problems associated with tillage, with toxic products produced by decomposing straw and with nitrogen immobilization. Further, owing to the high temperatures achieved during composting insects and disease causing organisms present in the straw may have got destroyed.

Table 1: NPK lost by removal of straw from one ha field.

Nutrient	Available per cent of nutrient in paddy straw*	If straw removed totally from field (kg)	Loss of nutrient by burning outside of field *	
			%	kg
N	0.8	52.0	25	13
P	0.27	17.5	25	4.38
K	2	130.0	20	26
S	0.1	6.5	60	3.9
Si	7	455.0	#	#

* Values taken from Dobermann and Fairhurst (2002).
# No data available

Table 2: NPK available in the compost.

Nutrient	Nutrient available in compost (%)	Nutrient available in compost from 1 ha field (6052 kg) (kg)
N	1.8	109
P	1.4	85
K	1.8	109

Table 3: Comparative results of compost and incorporation of paddy straw.

Nutrient	Nutrient available in compost (from 6.5 t rice straw) (kg)	Nutrient available by incorporating in field (6.5 t rice straw) (kg)
N	109	52
P	85	18
K	109	130

Composted rice straw manure contains NPK as 1.8, 1.4 and 1.8% respectively (Refaee, 2012). Considering the moisture content in rice straw as 6.89% (Zhang *et al.* 2012), the compost produced per hectare of land from 6500 kg of rice straw is 6052 kg. Total NPK available in the compost is mentioned in Table 2. Compared with incorporation of rice straw, composting had more nutrient than that. Those comparative results are presented in Table 3.

Saini *et al.*, (2013) studied the effect of herbicides on microbial population of soil as influenced by straw management techniques in wheat. The experiment consisting of five straw management techniques *viz.*, zero till sowing with Happy Seeder (combine harvested), in standing stubbles (loose straw removed), (complete burning of rice straw), bed sowing, (rice straw removed) and conventional tillage (partial burning of rice straw) in main plots i.e. horizontal blocks.The weed control treatments were sulfosulfuron 25 g/ha, mesosulfuron + iodosulfuron 12 g/ha + pinoxaden 50 g/ha and unsprayed (control). They found that the highest microbial population was observed in control plots as compared to those in herbicidal treatments. Residue management significantly influenced the level of both microbial count and microbial mass.

Pathak *et al.*, (2006) found the treatments with the incorporation of rice straw at 5 Mg ha^{-1} with additional amount of inorganic N (60 kg N ha^{-1}) or inoculation of microbial culture had similar grain yields to that of the treatment with no straw incorporation. The lowest yield was recorded in the plots where rice straw was incorporated in soil without additional inorganic N and with manure

Table 4: Recommended ration for selected cattle (Drake *et al.*, 2002).

Cattle	Ration recommendation
Cows, dry	50% rice straw and grass hay or supplement
Cows, average milking, with calves	Maximum of 25% rice straw and high quality hay or supplement. Weight loss and reduced performance may occur.
Cows, superior milking, with calves	Rice straw not recommended. With a maximum of 25% rice straw, expect reduced performance.
Heifers, replacement just before calving	Rations similar to superior milking ability cows; crude protein slightly lower and TDN slightly higher.
Streers, 272 to 318 kg, gaining 0.45 kg/day	Similar to average milking cows; crude protein slightly lower and TDN slightly higher.
Streers, 272 to 318 kg, gaining 0.68 kg/day	Rice straw not recommended. With a maximum of 25% rice straw, expect reduced performance.
Heifers, 272 to 318 kg, gaining 0.23 kg/day	Similar to average milking cows; crude protein slightly lower and TDN slightly higher.
Heifers, 272 to 318 kg, gaining 0.45 kg/day	Rice straw not recommended. With a maximum of 25% rice straw, expect reduced performance.

TDN- Total Digestible Nutrients

application. El-Shahawy *et al.,* (2006) suggested that the ground straw into the soil at different concentrations (125 - 500 g m^{-2}) was consistently more effective in suppressing growth and development of a wide range of broad and narrow-leaved weeds than the intact straw, either applied simultaneously or three months prior to sowing of cucumber seeds. Eight phenolic acids were identified in the rice straw residues on TLC including cinnamic acid, salicylic acid, vanillic acid, p-hydroxy benzoic acid, 2, 5 dihydroxy benzoic acid, ferulic acid, o-coumaric acid and p-coumaric acid. It has been suggested that the phenolic acids might be considered the key factor of rice allelopathy against suppressing a wide range of mono- dicotyledonous weeds in different crops.

Animal feed: Drake *et al.,* (2002) recommended the ration per cattle with the components of paddy straw and fodder are mentioned below.

- Rations with greater amounts of rice straw may result in loss of body weight.
- For cows with calves, rice straw generally should not exceed 25% of the ration and medium to high quality alfalfa.

The recommended ration for selected cattle is mentioned in Table 4, it may increase the productivity.

Mushroom cultivation: Mushroom cultivation from the paddy straw is efficient and useful method for improving the economy of farmer. Fresh, disease free paddy straw is the ideal substrate. 10-15 kg paddy straw is necessary for preparing one bed. In recent years, it is cultivated inside plastic film houses to maintain the temperature of around 25-35°C and relative humidity of 75-80%. The mushrooms start appearing from all sides in 6-10 days as tiny buttons, which can be harvested in another 4-5 days. The harvesting is to be done at the button stage itself, since the opened sporocarp will be more fibrous. Usually, 1-2 kg of mushroom can be harvested from 10 kg substrate (TNAU agritech portal).

Mushroom production level	=5 kg/d
Straw required per day	= 10 kg
No. of days in a year for mushroom production	= 365 days
Paddy straw required for mushroom production throughout the year	= 3650 kg

Effect of paddy straw on soil health, crop yield and quality: Mandal *et al.,* (2004) found that residue management practices affect soil physical properties *viz*., soil moisture, temperature, aggregate formation, bulk density and hydraulic conductivity. Soil temperature is influenced through the change in radiant energy balance and insulation. Rice crop residues are highly siliceous, and have the potential of transforming electrochemical properties of acidic soils that reduces P fixation; improving base retention and increasing the soil pH. Rice straw incorporation coupled with organic manure increases grain yield of wheat and improves soil physical condition. Thus, if residues are managed properly, then it can warrant the improvements in soil properties and the sustainability in crop productivity.

Watanabe *et al.,* (2009) conducted a field experiment to study the effects on yield and soil properties of the continuous application of rice straw compost to an alluvial soil in the Mekong Delta, Vietnam. Fourteen rice crops, two crops per year, were grown by direct seeding of the crop. There were seven treatments: no fertilizer and compost, compost with no fertilizer, 20, 40, 60 and 80% of the fertilizer application rate with compost, respectively, full strength fertilizer application as $N:P_2O_5:K_2O$ at 100:30:30 kg ha^{-1} in the dry season and 80:30:30 kg ha^{-1} in the wet season without compost. Compost prepared from the rice straw was applied at 6 Mg ha^{-1} (fresh weight) at the cultivation of each crop. The rice yield in no fertilizer and compost treatment declined at a rate of 0.163 Mg ha^{-1} yr^{-1} in the wet season, but there was no decline in rice yield in compost with no fertilizer treatment. In treatments with compost, the yield reached its plateau at 40% of the fertilizer application rate with compost, suggesting that compost could replace part of the fertilizer. This long-term field trial showed that the continuous application of rice straw compost has some positive effects on rice yield as well as on soil physical properties.

CONCLUSION

Efficient methods of rice straw utilization for Cauvery delta zone farmer's is identified as composting, new method of animal feed and mushroom production. Composting may be increase the nutrient availability of the field. phenolic acids might be considered the key factor of rice allelopathy against suppressing a wide range of mono-dicotyledonous weeds in different crops. Continuous application of rice straw compost has some positive effects on rice yield as well as on soil physical properties. Compared with existing animal feed the new method may increase the weight and milk production.

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