Optimization of Straw Size, Dose of Compost Inoculant along with Engineering and Microbiological Parameters for Paddy Straw Degradation in Shortest Possible Time

Mohd. Muzamil[1]*, Indra Mani[1], Adarsh Kumar[1], Livleen Shukla[2] and Satish Lande[1]

[1]Division of Agricultural Engineering, IARI, New Delhi -110012, India.
[2]Division of Microbiology, IARI, New Delhi - 110012 ,India.

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The aim of the study was to analyze the extent of involvement of labour in manual chopping of paddy straw and also to determine its optimum size for the development of paddy straw collector-cum-chopper to degrade the valuable agro residue in shortest possible time for value added product using microbial inoculants for composting. Three sizes were selected; after harvest, single blade chopping (CPS4-5 cm) and two blades chopping (CPS2-3 cm) of manually operated chaff cutter. Three different doses of compost inoculant prepared from *Aspergillus awamori*, *Trichoderma* viride and *Aspergillus nidulans* (T1: untreated; T2: 300 g; T3:500 g; T4: 1000 g) were applied on the paddy straw for conversion to compost. The moisture content was maintained at 60 % of water holding capacity (WHC) by adding water at different intervals. The straw size of CPS4-5 cm with T8 treatment surpasses all other treatments in terms of low cost for chopping and power consumption along with improvement of selected parameters - pH 7.0 with subsequent increase in electrical conductivity 0.5 dS/m, nitrogen content 0.78 %, phosphorus 93.7 ppm, potassium 0.69 % with 56.9 % decrease in carbon content from first turning to fourth turning in 35 days. The C: N ratio decreased from 84.89 to 18.70 (a reduction of 77.97 %) from initial value and is a definite parameter for conversion of substrate to compost. The study showed that though some of the parameters for CPS2-3 cm were better than that of CPS4-5 cm at 1000 g inoculant dose (T_8 and T_{12}), overall the latter was found to be the best size for the development of paddy straw collector-cum-chopper as well as preparation of compost in shortest possible time.

Key words: Straw size, inoculant dose, pH, C: N ratio, Paddy Straw collector-cum-chopper, compost.

Adoption of efficient farm machinery with heavy reliance on the intensification of agriculture, giving higher share to fertilizers has resulted in manifold increase in production of farm communities for feeding the burgeoning population. On one side, the bumper harvest has saved the humanity from certain holocaust, while on the other side the decline in the productive capacity of agricultural lands (Tripathi *et al.*, 2006) and repeated cultivation without any concrete mechanism for straw management had caused reduction in organic matter (Ghosh *et al.*, 2004). Rice (Oryza sativa L.) is a major crop grown worldwide with the annual productivity around 800 million metric tonnes, also responsible for generation of large production of rice (paddy) straw (Soest, 2006). The management of rice residues through direct incorporation of straw in soil is associated with certain problems such as immobilization of plant nutrients particularly nitrogen and reduced germination of subsequent crops. Moreover, rice straw waste contains high C: N ratio of about 80:1, rich in silica (about 11 %) and lignin, which makes it difficult to get degraded (Kumar *et al.*, 2006). Therefore, farmers resort to *in situ* burning of a part of crop residues that remain

* To whom all correspondence should be addressed.
Mobile; +91-8800878018;
E-mail: muzamil4951@gmail.com

scattered in the field and is difficult to collect (Jacobs *et al*., 1997; Reinhardt *et al*., 2001). Biomass burning has drawn global concerns for its effects on visibility, health, global climate change (Lemieux *et al*., 2004) as well as serious traffic accidents in addition to the loss of valuable resource (Chou *et al*., 2009). The appearance of Asian Brown Cloud (ABC) over South-East Asia was a grim reminder about the damage caused by burning in open fields. About 38.5 lakh tonnes of organic carbon, 59000 tonnes of N, 2000 tonnes of P and 34000 tonnes of K are lost by paddy straw buring (Beri & Sidhu, 1999). Pollutants emitted during biomass burning can produce significant changes in blood parameters as indicated by lymphocytosis, eosinophilia and neutrophilia in sheep (Ahmed *et al*., 2003) oxidative stress (Rivero *et al*., 2005) as well as kidney (Uboh *et al*., 2010) and liver dysfunctions in buffaloes (Massaguer *et al*., 2002). Burning releases considerable amounts of toxicants which function as endocrine disruptors and affect the integrity of reproductive function in mammals and ultimately contribute to infertility (Smith *et al*., 2007).

Crop residues are important sources of plant nutrients and shoulder the responsibility for maintaining the stability of agricultural ecosystem. Therefore, sustaining crop productivity depends upon the amendment of organic as well as mineral fertilizers. India produces more than 3000 million tonnes of organic wastes annually which includes crop residues, animal shed wastes, rural and urban wastes, vegetable market wastes, forest and industrial wastes (Gupta *et al*., 1998; Sharholy *et al*., 2008). About 500 Mt are generated from crop residues with highest production in Uttar Pradesh (60 Mt) followed by Punjab (51 Mt) and Maharashtra (46 Mt). Cereals (rice, wheat, maize, millets) generate 70% i.e. 352 Mt residue followed by fibres (66 Mt), oilseed (29 Mt), pulses (13 Mt) and sugarcane (12 Mt). Rice crop has the individual share of 34% followed by wheat 22% and 13% fibre crops.

Composting of rice straw arises as a safe alternative option which results in reusability of the nutrients contained in the residue (Kausar *et al* 2010). Management of paddy straw through composting will avoid air pollution caused by residue burning; prevents loss of plant nutrients and organic matter (Sidhu and Beri, 2005) and leaching of nitrates (Sidhu and Brar, 1997). The primary step in the preparation of compost in shortest time from paddy straw requires the size reduction, which can be accomplished by cutting or grinding (Arif, 1999).

Straw chopping is necessary as a pre-treatment to incorporation into the soil or enhancement of decomposition rate. It reduces the length of straw avoiding long pieces of material fouling on cultivation and swing implement. It also eases the mixing process with soil, enhances active biological breakdown of the straw.

The mechanization has failed to solve the problem of efficient utilisation of paddy straw, as paddy straw gets entangled within the blades of locally available choppers and cause blocking. Moreover, most commonly available land preparatory implements like offset disc harrow and rotavators has very low efficiency in spreaded straw conditions and are unable to do a good job (Anonymous, 2002). Thus, an integrated management technique of collecting, conveying, chopping, composting is the need of the hour. In the backdrop of current scenario, a study was made to determine the energy consumption along with drudgery involved by measuring heart rate in chopping the paddy straw and an effort to determine the optimum size using microbial inoculum suitable for the development of paddy straw collector-cum-chopper.

MATERIALS AND METHODS

Utilisation of manually operated Chaff cutter

India has about 10.4 million manually operated chaff cutters 2.74 million powered and 0.166 million animal-operated chaff cutters (17th Livestock Census, 2003) used for cutting green as well as dry fodder (Table 1).

In order to measure the energy consumption associated with the chopping of paddy straw, a 500 Nm torque sensor was attached with the manually operated chaff cutter. The operation was conducted on three subjects; A (age 27 years, weight 69.2 kg), B (age 35 years, weight 55 kg) and C (age 25 years, weight 67 kg). Two persons were needed, one to feed the paddy straw to feeding roller and other to operate the chaff cutter. The heart rate monitor was attached with the operator to determine the drudgery involved in chopping the paddy straw. Initially, only one blade of the chaff cutter was used, which was gradually increased to two, after measuring the heart rate and human power consumption, Table 2. The two sizes obtained from one blade (4-5 cm) and two blades (2-3 cm) along with the normal harvested size of paddy straw was subjected to composting in order to determine the optimum size of the paddy straw for the development of paddy straw collector-cum-chopper. The doses of the inoculant were varied as untreated, 300g, 500g and 1000 g per tonne of the material handled.

Inoculum

The inoculum containing a fungal consortium of three fungi; *Aspergillus awamori, Trichoderma viride* and *Aspergillus nidulans* were used with varying doses to analyze the decomposition pattern of different sizes of paddy straw. The Fineness Modulus, an indicative of proportion of fine and coarse aggregates in compost inoculum was measured by sieve analysis technique and found to be 6.32.

Fineness Modulus = + Cumulative % Retained / 100

= 631.8 / 100 = 6.32

Compost Preparation

The three sizes of paddy straw were allowed to decompose in 60 litre perforated lid plastic bins after adding 3-4 days old cow dung, soil, and old compost in the ratio of 8:1:0.5:0.5 with varying rates of inoculant. The level of moisture was maintained at 80% by adding water at different intervals of composting wherever required. The materials were turned at an interval of every eight days. A total of 12 treatments with three replications were as follows:

T1: Unchopped Paddy straw (UPS) + cow dung + soil + old compost

T2: Unchopped Paddy straw (UPS) + cow dung + soil + old compost + 300g inoculant per tonne

T3: Unchopped Paddy straw (UPS) + cow dung + soil + old compost + 500 g inoculant per tonne

T4: Unchopped Paddy straw (UPS) + cow dung + soil + old compost + 1000 g inoculant per tonne

T5: Chopped Paddy (4-5 cm) straw (CPS4-5) + cow dung + soil + old compost

T6: Chopped Paddy (4-5 cm) straw (CPS4-5) + cow dung + soil + old compost + 300g inoculant per tonne

T7: Chopped Paddy (4-5 cm) straw (CPS4-5) + cow dung + soil + old compost + 500 g inoculant per tonne

T8: Chopped Paddy (4-5 cm) straw (CPS4-5) + cow dung + soil + old compost+ 1000 g inoculant per tonne

T9: Chopped Paddy (2-3 cm) straw (CPS2-3) + cow dung + soil + old compost

T10: Chopped Paddy (2-3 cm) straw (CPS2-3) + cow dung + soil + old compost + 300g inoculant per tonne

T11: Chopped Paddy (2-3 cm) straw (CPS2-3) + cow dung + soil + old compost + 500 g inoculant per tonne

T12: Chopped Paddy (2-3 cm) straw (CPS2-3) + cow dung + soil + old compost+ 1000 g inoculant per tonne

Chemical Analysis

The samples were collected at different turning intervals, dried and grinded to pass through 2 mm sieve for chemical analysis of pH, EC, ash carbon, nitrogen, phosphorus and potassium. Total Nitrogen was estimated by micro-Kjeldahl method (AOAC, 1965), Phosphorus and Potassium by Spectro photometric and Flame photometric methods (Tandon, 2005). C: N ratio was calculated by dividing the percentage of organic carbon with percentage of total nitrogen (Anonymous,2006).

RESULTS

Changes in pH and EC during degradation in plastic bins

The breakdown of complex molecules into simpler ones by the action of microbes in the inoculant led initially decrease in pH and increase in electrical conductivity in all the treatments (Table 3 & 4). The UPS decomposes slowly owing to larger molecular size as compared to the chopped paddy straw. For UPS laded with 1000 g inoculant dose (T4), pH decreased from 9.25 to 7.51 with 39.3 % increase in electrical conductivity from first to fourth turning. Initially the rate of composting was higher due to increase in microbial load as well as activity. The best treatment was CPS2-3 cm showing pH reduction from 9.6 to 6.64 with an increase in electrical conductivity from 0.43 to 0.67 dS/m (an increase of 53.4 %) after 35 days of composting. The results scrutinised by SPSS statistical software confirms the significance of smaller size for preparing neutral compost with higher electrical conductivity.

Total Nitrogen

Total Nitrogen was measured by Kjeldahl's method. The reduction in the particle size with the growth of microbes resulted in an increase in the nitrogen content of the compost thereby helping in preparation of N enriched compost, Figure 1. The UPS also showed decomposition but at a slower rate and lower increase in nitrogen content. Both CPS4-5 cm and CPS2-3 cm sizes showed higher content along with 1000 g inoculant dose. The former led to an increase of 95 % from initial value i.e. 0.4 to 0.78 % while the latter increased by 86.4 % from initial value i.e.0.44 to 0.82 % during first to fourth turning. This was mainly due to slow and continuous decomposition of CPS4-5 cm as compared to CPS2-3 cm size. The statistical analysis showed that the results were significant at 5 % level of significance, signifying the importance that both the sizes can be swapped for the development of paddy straw collector-cum-chopper.

Table 1. Chaff cutter population in India (millions)

Location	Manually Operated	Animal Operated	Power Operated	Total
Rural	10.10	0.16	2.210	12.47
Urban	0.3	0.006	0.064	0.37
Total	10.40	0.166	2.274	12.84

Ash Carbon and Phosphorus

The process of composting was also associated with the decrease in carbon content (Table 5) and subsequent increase in phosphorus level, Figure 2. Similar results as in total nitrogen

Table 2. Heart Rate and Power Consumption in manually operated Chaff cutter

A					B				C			
Heart Rate, bpm		Power, W			Heart Rate, bpm		Power, W		Heart Rate, bpm		Power, W	
One blade	Two blades	One blade	Two blades	Time, sec	One blade	Two blades	One blades	Two blades	One blade	Two blades	One blade	Two blades
85.6	92.7	61.7	92.3	30	80.2	89.3	80.9	90.4	76.6	81.0	67.31	108.4
93.4	107.8	83.7	105.5	60	87.4	94.6	85.8	80.1	83.4	89.4	50.93	108.7
100.8	119.5	58.6	93.6	90	93.7	99.5	71.8	77.1	91.6	94.3	61.57	80.5
106.6	125.3	70.5	86.5	120	96.2	105.7	85.6	101.7	96.4	98.7	55.37	123.5
113.8	135.5	109.7	118.3	150	100.0	112.0	64.7	113.2	100.0	104.7	84.23	110.9
130.5	166.4	82.93	89.5	180	115.8	126	96.0	91.92	112.3	124.8	79.25	94.8
156.2	181.2	90.22	91.5	210	129.1	143.5	73.6	122.4	114.6	148.1	74.3	88.2
169.9	186.9	95.0	127.8	240	147.8	162.1	115.9	117.4	129.5	153.2	98.3	133.1
174.3	185.8	80.5	99.4	270	159.8	177.8	124.5	136.4	140.9	169.7	74.6	104.9
184.6	198.3	86.4	116.4	300	177.5	193.5	132.7	150.0	155.4	180.5	81.0	120.4

* Values are avg. of three replications

Table 3. Reduction in pH during composting

	UPS					CPS4-5					CPS2-3			
	Sampling Interval in days					Sampling Interval in days					Sampling Interval in days			
Treatment	8	16	24	32	Treatment	8	16	24	32	Treatment	8	16	24	32
T1	9.43	9.05	8.55	8.12	T5	9.42	8.81	8.33	7.99	T9	9.25	8.66	8.11	7.65
T2	9.27	8.93	8.40	7.96	T6	9.42	8.9	8.24	7.71	T10	9.81	9.09	7.98	7.52
T3	9.29	8.72	8.19	7.63	T7	9.35	8.82	7.92	7.24	T11	9.43	8.52	7.59	7.07
T4	9.25	8.66	8.08	7.51	T8	9.39	8.43	7.54	6.97	T12	9.60	8.24	7.42	6.64

* Values are avg. of three replications

content were achieved where the loss of carbon content from 32.5 to 13.89 % was observed along with an increase of 47.1 to 103.8 ppm (increase of 120 per cent) phosphorus content for CPS2-3 cm endowed with 1000 g inoculant dose. It was also observed that for CPS4-5 cm at same inoculant dose, the carbon content decreased by 56.9 per cent and phosphorus increased by 104 per cent. UPS showed lower content of carbon and phosphorus in comparison to CPS4-5 cm and CPS2-3 cm with carbon reduction of 38 % and phosphorus hardly exceeding 80 ppm after fourth level of turning. Thus, it is necessary to chop the paddy straw to ensure its faster decomposition as well as nutrient enrichment to be applied to exhausted soil. Statistical analysis revealed that size of paddy straw, days of composting; inoculant dose had significant effect on reduction in carbon and increase in phosphorus content at 5 % level of significance.

Potassium

Earlier farmers demand was for N & P but nowadays the demand for K is also increasing rapidly and undeniably, Potassium is essential

Table 4. Variation in EC during composting

	UPS					CPS4-5					CPS2-3			
	Sampling Interval in days					Sampling Interval in days					Sampling Interval in days			
Treatment	8	16	24	32	Treatment	8	16	24	32	Treatment	8	16	24	32
T1	0.23	0.3	0.3	0.3 (30.43)	T5	0.3	0.4	0.4	0.4 (33.33)	T9	0.3	0.4	0.4	0.4 (33.33)
T2	0.27	0.29	0.36	0.4 (48.14)	T6	0.33	0.4	0.4	0.5 (51.51)	T10	0.37	0.4	0.5	0.5 (35.13)
T3	0.3	0.33	0.4	0.43 (43.3)	T7	0.33	0.4	0.5	0.5 (56.6)	T11	0.4	0.5	0.5	0.56 (40.0)
T4	0.33	0.4	0.4	0.46 (39.3)	T8	0.4	0.43	0.5	0.5 (25)	T12	0.43	0.46	0.56	0.67 (53.4)

* Values are avg. of three replications
% ↓↑ over initial is given in parentheses

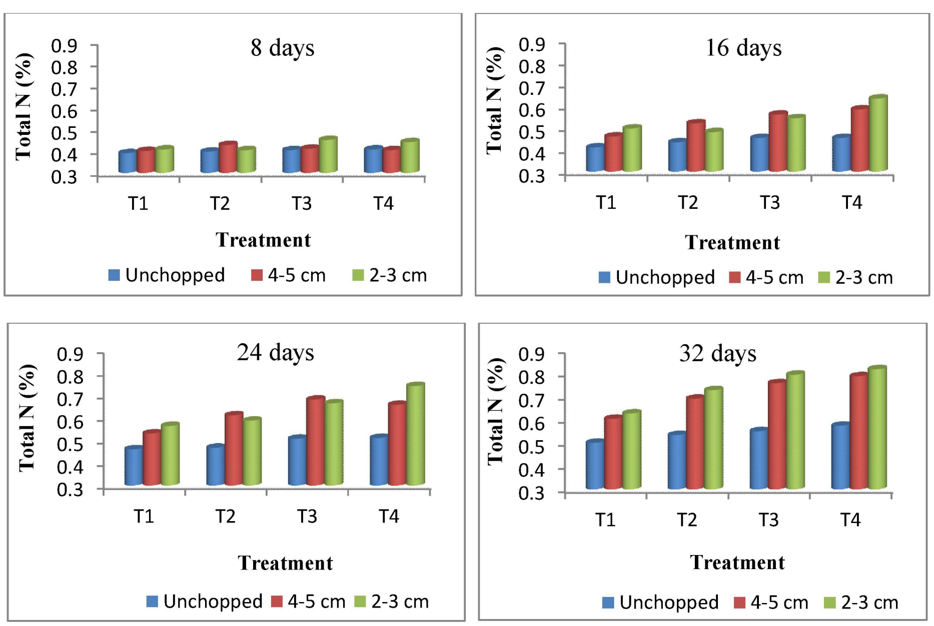

Fig. 1. Total nitrogen content during composting in plastic bins

component in the compost which adds feather to its charisma for being suitable replacement to hazardous agro-chemicals. The composted material of CPS2-3 cm size showed an increase in potassium content from 0.36 to 0.77 % in comparison with CPS4-5 cm, where it increased from 0.32 to 0.69 % at 1000 g inoculant dose after 35 days of composting, Figure 3. Statistical analyses by SPSS software heavily favoured the treatment of CPS2-3 cm.

C: N ratio

C: N ratio is considered as ultimate criteria to determine the feasibility of the material for composting; high initial C:N ratio will cause a slower beginning and the required composting time to be longer than usual (Tuomela *et al.*, 2000) while low initial C:N ratio results in high emission of NH_3 (Tiquia and Tam, 2000). During composting, C: N ratio decreases due to loss of gases at periodic intervals. The UPS showed the slow the slow reduction in C: N ratio, reaching a value of 40.46 from 92.6 with 1000 g inoculant dose, Figure 4. The CPS4-3 cm with 1000 g inoculant dose resulted in C: N ratio reduction of 77.9 % , which was comparable with 77% of C: N ratio reduction by CPS2-3 cm size. The results in conformity with BIS standards for composting.

Table 5. Reduction in Ash Carbon during composting

Treatment	Ash Carbon (%)												Days
	UPS				CPS4-5				CPS2-3				
T1	36.7	34.3	30.5	26.8	36.0	30.2	25.1	22.0	34.5	27.0	22.6	19.5	8
T2	35.7	33.0	29.1	25.5	36.7	29.7	25.0	18.6	35.5	29.3	23.6	16.5	16
T3	35.6	31.9	26.4	23.8	35.3	27.8	22.5	16.5	34.9	27.7	21.5	14.6	24
T4	37.6	32.3	25.8	23.1	34.2	24.6	19.73	14.7	35.5	25.3	19.1	13.8	32

* Values are avg. of three replications

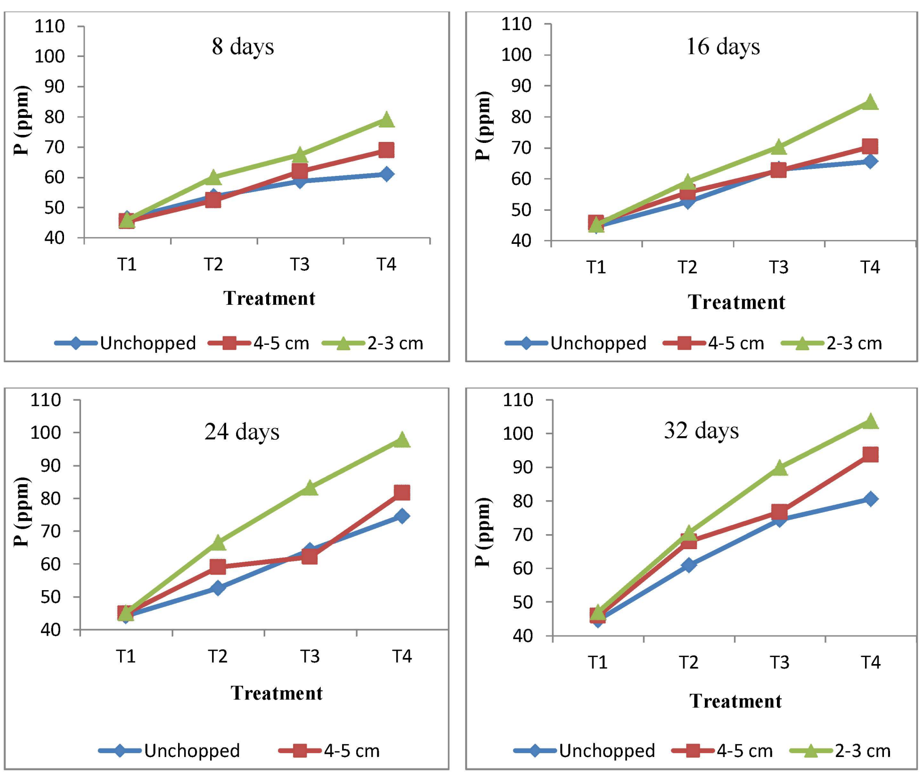

Fig. 2. Changes in Phosphorus content during composting in plastic bins

DISCUSSION

The compost serves as an alternative to hazardous agro-chemicals to enrich the exhausted soil with necessary ingredients. Three different sizes were tested to find the feasibility of the materials for composting in shortest possible time. The slow degradation pattern of UPS due to larger molecular size prevents the growth of micro-organisms and was responsible for keeping the

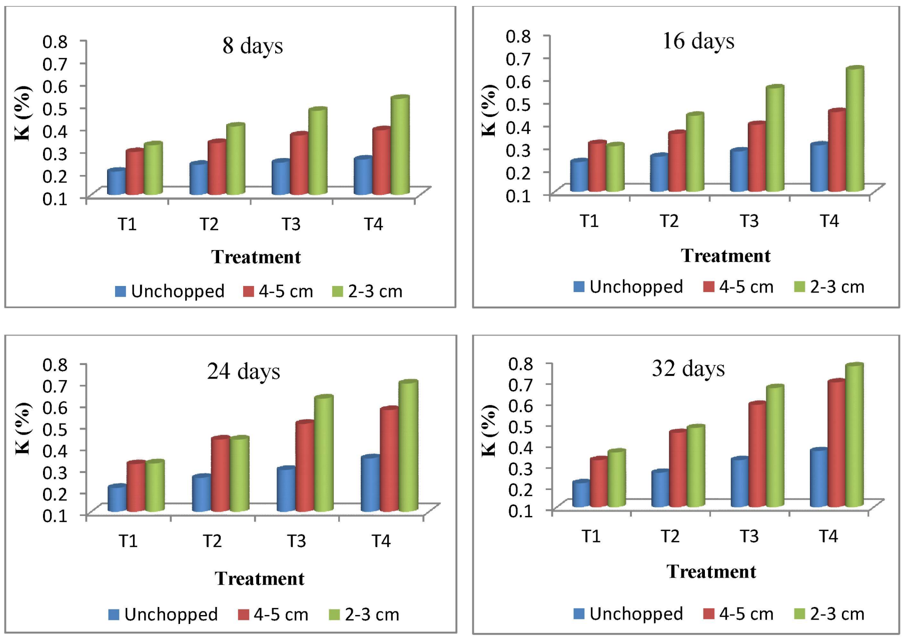

Fig. 3. Alteration in Potassium content during composting

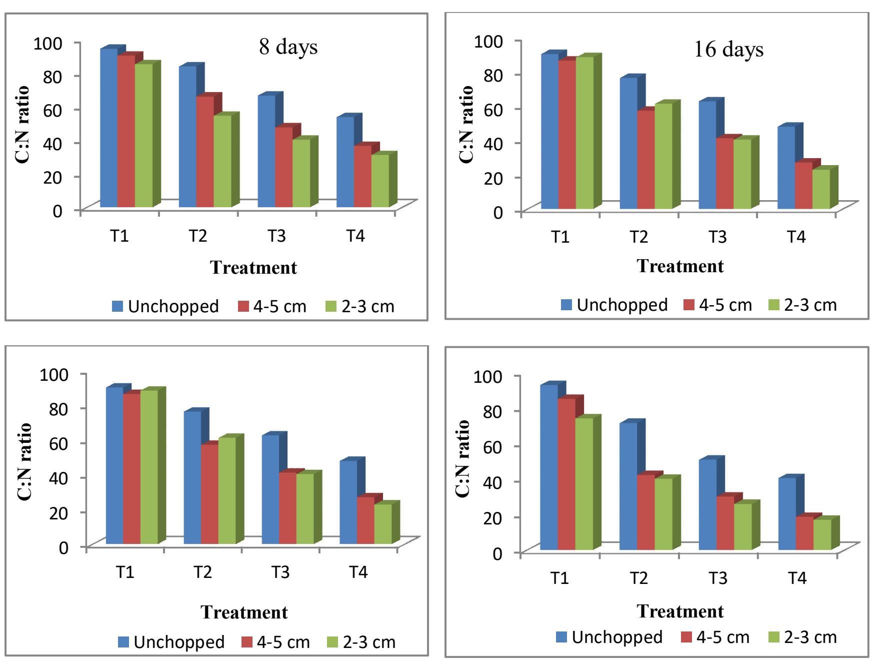

Fig. 4. C: N ratio variation at different intervals during composting

value of nutrients at low level and also needed longer time for degradation. The pH remained alkaline in unchopped paddy straw even after four stages of turning and completion of 35 days with most of the parameters not favourable with BIS standards. It showed marginal increase in electrical conductivity to 0.47 dS/m, nitrogen 0.57 % potassium 0.37 %, phosphorus 80.6 ppm even with highest dose of inoculant i.e. 1000 g per tonne of the material handled (T4). Even C: N ratio was not obtained within the limit set by BIS necessary to be entitled for the completion of degradation and formation of compost. Thus, it becomes clear that chopping of paddy straw is an essential operation to transform the paddy straw biomass into nutrient rich compost in shortest possible time.

The CPS2-3 cm size has shown desirable results in terms of attaining the values recommended by BIS for efficient composting. The pH of the compost which is essential to maintain the neutrality of the soil remained in the safe zone, from 9.6 to 6.64 with increase in electrical conductivity to 0.67 dS/m, nitrogen 0.82%, potassium 0.77 %, phosphorus 103.8 ppm and C: N ratio reaching to 17.01 during whole period of degradation i.e. 35 days. However, the problem with CPS2-3 cm paddy straw was initial decomposition rate was very high which exhausted moisture, which was essential for sustaining microbial growth. This problem was compensated by 4-5 cm paddy straw, where slow and continuous decomposition ensures the enrichment of the compost by proper utilisation of the resources. The compost pH reached to 6.97, electrical conductivity 0.5 dS/m, nitrogen 0.78 %, potassium 0.69%, phosphorus 93.7 ppm with C: N ratio reaching to 18.7.

Considering the cost, power and labour intensive work involved in chopping the paddy straw, it was found that CPS4-5 cm was optimum to convert paddy straw size (4-5 cm) was optimum to convert into compost within 35 days in plastic bins and was selected for the development of paddy straw collector-cum-chopper for rapid composting.

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Notations:

UPS	= unchopped paddy straw
CPS2-3 cm	= chopped paddy straw 2-3 cm
CPS4-5 cm	= chopped paddy straw 4-5 cm

REFERENCES

1. 17th Livestock Census. (2003). All India Summary Report. Krishi Bhavan, New Delhi: Department of Animal Husbandry, Ministry of Agriculture, Govt of India.
2. A.O.A.C. (1965). *Official Methods of Analysis.* 12th Edn. Association of Official Analytical Chemists. Washington D.C., p 219.
3. Ahmed, W.M., A.A. Abou Mossallam, E.M. Hanfiand S.I. Shalaby, Observations on fertility and mutagenicity of Egyptian ewes exposed to products of rice straw combustion with special reference to the effect of flunixine meglumine. *J. Egypt. Vet. Med. Assoc.*, 2003; **63**: 195-212.
4. Anonymous. Annual Report, *Mechanization of rice-wheat cropping system for increasing the productivity* (NATP project), Department of Farm Power and Machinery, Punjab Agricultural University, Ludhiana 2002.
5. Anonymous, (2006). The fertilizer (control) order. New Delhi :Rakmo Press Pvt. Ltd.
6. Arif, E.M. Development and performance of a shredder machine for composting. PhD Thesis Agric. Mech. Dept, Fac. Of Agric., *Ain Shams Univ.* : 1999; 45-79.
7. Beri V and Sidhu B S. *Management of rice residue in agriculture*. Paper presented at the Annual day of Punjab Chapter of ISAE on 'Paddy Straw Management', held at PAU, Ludhiana on February 26, 1999.
8. Chou, C.S., S.H. Lin and W.C. Lu, Preparation and characterization of solid biomass fuel made from rice straw and rice bran. *Fuel Process. Technol.,* 2009; **90**: 980-987.
9. Ghosh, P.K., P. Ramesh, K.K. Bandyopadhyay, A. K. Tripathi, K. M. Hati, A. K. Misra and C. L. Acharya, Comparative effectiveness of cattle manure, poultry manure, phosphocompost and fertilizer- NPK on three cropping systems in vertisols of semi-arid tropics. Crop yield and

system performance. *Bioresour. Technol.,* 2004; **95**: 77-83.

10. Gupta, S., K. Mohan, R. Prasad, S. Gupta and A. Kansal, Solid waste management in India: Option and opportunities. *Resour. Conserv. Recycl.,* 1998; **24**: 137-154.
11. Jacobs, J., R. Kreutzer and D. Smith, Rice burning and asthma hospitalizations in Butte County, California, 1983-1992. *Environ. Health Perspect.*, 1997; **105**: 980-985.
12. Kausar, H., Sariah, M., Mohd Saud, H., Zahangir Alam, M., and Razi Ismail, M. Development of compatible lignocellulolytic fungal consortium for rapid composting of rice straw. *International Biodeterioration and biodegradation.* 2010; **64**. pp. 594–600.
13. Kumar, A., S. Gaind and L. Nain, Evaluation of thermophilic fungal consortium for paddy straw composting. *Biodegradation,* 2006; **19**: 395-402.
14. Lemieux, P.M., C.C. Lutesb and D.A. Santoiannib, Emissions of organic air toxics from open burning: A comprehensive review. *Prog. Energy Combustion. Sci.,* 2004; **30**: 1-32.
15. Massaguer, A., S. Perez-Del-pulgar, P. Engel and J. Serratosa, Concanavalin-A-induced liver injury is severely impaired in mice deficient in Pselectin. *J. Leukoc. Biol.,* 2002; **72**: 262-270.
16. Reinhardt, T. E., R. D. Ottmar and C. Castilla, Smoke impacts from agricultural burning in a rural Brazilian town. *J. Air Waste Manag. Assoc.,* 2001; **51**: 443-450.
17. Rivero, D.H., S.R. Soares, G.L. Filho, J.J. Godleski L. Antonangelo, M. Dolhnikoff and P.H. Saldiva, Acute cardiopulmonary alterations induced by fine particulate matter of São Paulo, *Brazil. Toxicol. Sci.,* 2005; **85**(2): 898-905.
18. Sharholy, M., K. Ahmad, G. Mahmood and R. C. Trivedi, Municipal solid waste management in Indian cities- A review. *Waste Management.,* 2008; **28**:459-467.
19. Sidhu B S and Brar M S. Paddy Straw for maintaining soil health and production. *Prog Fmg,* 1997; 13-14.
20. Sidhu, B. S., & Beri, V. Experience with managing rice residues in intensive rice-wheat cropping system in Punjab. In I. P. Abrol, R. K. Gupta & R. K. Malik (Eds.), *Conservation agriculture: Status and prospects* (pp. 55–63). New Delhi: Centre for Advancement of Sustainable Agriculture, National Agriculture Science Centre 2005.
21. Smith, T.L., S.T. Merry, D.L. Harris, J.J. Ford, J. Ike, A.E. Archibong and A. Ramesh, Speciesspecific testicular and hepatic microsomal metabolism of benzopyrene, an ubiquitous toxicant and endocrine disruptor. Toxicol. *In vitro*, 2007; **21**: 753-758.
22. Soest, P.J.V., Rice straw, the role of silica and treatments to improve quality. *Anim. Feed Sci. Technol.,* 2006; **130**: 137-171.
23. Tandon, H. L. S. Methods of analysis Soils, Plants, Waters, Fertilizers & organic Manures New Delhi: Fertilizers development and Organization 2005.
24. Tiquia, S.M. and N.F.Y. Tam. Fate of nitrogen during composting of chicken litter. *Environmental Pollution,* 2000; **110**: 535-541.
25. Tripathi, R.P., S.Peeyush and S. Surendra, Soil physical response to multi-year rice-wheat production in India, *Int. J. Soil Sci.,* 2006; **1**: 91-107.
26. Tuomela, M., M. Vikman, A. Hatakka and M. Itavaara. Biodegradation of lignin in a compost environment: A review. *Bioresource Technology,* 2000; **72** (2): 169– 183.
27. Uboh, F.E., M.I. Akpanabiatu, M.U. Eteng and E.U. Eyong, Exposure to gasoline and kerosene vapours: A risk factor for nephrotoxicity in rats. *Internet J. Toxicol*., 2010; **7**: 2. (In press).