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Carbon nitrogen and phosphorus dynamics during vermicomposting of paddy straw inoculated with lignocellulolytic fungi*

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Renewable biological resources, like compost, vermicompost are the chief sources to maintain the soil health and crop production.

In India, rice (*Oryza sativa* L.) is the most important cereal crop with an annual production of more than 87 million tonnes (MoA 2005) and 120 million tonnes of paddy straw. Half the quantity of paddy straw produced finds use as roofing material, animal feed, fuel and packing material, the other half disposed off by burning in the field. But paddy straw is not considered to be good animal feed due to its low protein content, poor palatability, high silica (11–15%) and lignin content (12%) and low digestibility. Burning paddy straw in the field is considered a cheap and easy means of disposal of excess straw, however this practice contributes to air pollution and increases soil erosion (Abdeel Azim 2001). Direct incorporation of rice straw in field solves the problem of air pollution but it is not feasible due to the short time gap between harvesting of rice and sowing of wheat. (*Triticum astivum* L.emend. Fiori & Paol.). Besides, it involves additional cost of labour, irrigation and extra tillage. Moreover, observations of long-term experiments indicate that though incorporation of rice straw in soil improves soil health significantly, it may decrease the subsequent crop yields due to production of microbial phytotoxins and immobilization of the available nitrogen. Besides, rice straw incorporation increases the Methane emission from rice field, which in turn adds to the concerns of global warming.

Composting has been used as an excellent means of disposal of organic wastes, like paddy straw, sugarcane trash and other agricultural wastes. Fungi, like *Trichoderma harzianum* (Raabe 2001) are known to play an important role in composting of lignocellulosic materials.

The composting of agricultural residues rich in lignocellulose, like paddy straw generally takes 180 days to obtain good and mature compost (Ishii and Takii 2003). High lignin content restricts the enzymatic and microbial access to the cellulose in paddy straw. Cellulose degrading micro-organisms hasten the biodegradation of crop residues such as straw, leaves, trash etc. and such cultures have been used for composting of plant residues (Ishii and Takii 2003, ElDin and AboSedera 2001) but still time taken for composting is too long. This time constraint can be overcome by using some lignin degrading micro-organisms in combinations with the cellulose-degrading micro-organisms.

In nature, during decomposition of paddy straw many micro-organisms, like fungi, bacteria and actinomycetes of mesophilic, thermophilic and thermotolerant nature play significant roles at various stages. But these bacteria and actinomycetes, some of which are potential lignocellulose degraders (Conghos and Santamaria 2003.), have not been exploited much for composting. In order to hasten the biodegradation of crop residues such cultures can be used in combination with the conventional fungal cultures.

The recycling of crop residues through vermicomposting is a highly desirable option for the farmers. However, the use of paddy straw in vermicomposting along with *A. awamori* which is a lignocellulolytic fungi as well as phosphate solubilizer has shown significant results to improve the quality of vermicomposting. Keeping all the above in view, an investigation was taken up to study the dynamics of biological and chemical parameter during degradation of paddy straw inoculated with lignocellulolytic fungi as well as *Eisenia foetida.*

Paddy straw was collected from the IARI farms, New Delhi, Earthworms, viz. *Eisenia foetida* were obtained from Entomology Division, IARI and the cowdung required for the experiment was collected from Todapur Farm areas of New Delhi. *Aspergillus awamori* a compost inoculum was produced in mass at Microbiology Division using Pearl millet [*Pennisetum glaucum* (L) R. Br. Stuntz] seeds which were not fit for food and feed. The seeds were sterilized and

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inoculated with *A. awamori* and incubated for 15 days and then inoculated in paddy straw for composting. The experiments were conducted in cemented pits at Microbiology Division, IARI and 40 kg chopped paddy straw (4–6 cm) size was filled in each pit (2m×1.5m×1.5 m). The following treatment combinations were conducted in triplicates.

T_1, paddy straw waste (uninoculated); T_2, paddy straw waste + *E. foetida;* T_3, paddy straw waste + *A.awamori;* T_4, paddy straw waste + *E. foetida*+ *A.awamori*

Two kg cowdung slurry was mixed with the compost inoculum @ 300g/tonnes and sprinkled on the composting mass in each pit wherever needed while only the slurry without inoculum was sprinkled and the optimum moisture (60–70%) was maintained throughout the composting or degradation period. Care was taken that all the pits degradation was started on the same day. Decomposition was continuously carried on till the final product was ready with periodical turnings of 15 days interval up to 60 days. The temperature of the paddy straw compost was observed by using dial thermometer up to a depth of 40 cm at 3–4 sites in a pit. After 15 days of initial decomposition, earthworms *Eisenia foetida* were introduced @ 1 000/pit but care was taken to check the temperature of pits before adding the worms so that it should not be higher than 30°C as high temperature kills the introduced worms. The samples of the paddy straw compost were collected and analyzed at 30 days intervals for organic carbon (%), total nitrogen (%) and total phosphorus (%), respectively and for estimating the humus content.

During the degradation of paddy straw, the initial bulk volume was reduced to one-third with the passage of time. Earthworms which were added also consumed the paddy straw and reduced the volume and produced cast in a very rapid way. The worm castings were analyzed for chemical and biological properties. As temperature is one of the deciding factors for the inoculated organism, therefore, it was recorded regularly during the process of composting, especially for monitoring the thermophilic phase. The maximum temperature of 47°C was recorded with *A. awamori* on the day 15, followed by that of uninoculated pits. It was 10°C higher than the atmospheric temperature that might be due to higher ambient temperature in the initial period of composting, further, temperature varied from 38°C to 27°C in the entire period of composting which may be due to regular turning, aeration and mixing of water in all the treatments and it also supported by the multiplication of earthworms in the pits when they get the optimum temperature for the survival.

The loss of organic carbon from the composted material increased gradually with increase of time period. The data on changes in organic carbon and total nitrogen content during decomposition of the paddy straw are presented in Table 1. The carbon content of the compost mass of paddy straw dropped by 20.4% in the control as compared with the initial carbon content of the raw material during the first month. The loss was more with *E. foetida* showing the maximum decomposition of 48.5%, followed by the treatment inoculated with *A. awamori* 36.8%. By the end of 60 days maximum reduction of carbon was observed in all treatments. Maximum reduction of 65.6% of carbon over the initial and 45.2% over the uninoculated control was observed, where the paddy straw was inoculated with a combination of *A. awamori* and *E. foetida* and the next best treatment was inoculation of *E. foetida* showing a significant reduction of 63% as compared to single inoculation of *A.awamori* (55.8%) at the end of 60 days. It is evident from the data that fungi inoculation single or in combination with *E. foetida* resulted in fair amount of reduction in carbon ranging from 55.8 to 65.6% over the initial. The amount of nitrogen increased as the enrichment period progressed, and highest value (1.1%) was obtained in the combined treatment

Table 1 Changes in organic carbon, total N and C : N ratio, total P (%) and available P (ppm) during vermicomposting

Treatment	Sampling interval in days						Sampling interval in days			
	Carbon (%)		Nitrogen (%)		C: N ratio		Total P (%)		Available P (ppm)	
	30	60	30	60	30	60	30	60	30	60
T_1	38.9 (20.4)	26.8 (45.2)	0.47 (23.6)	0.52 (36.8)	82.7	51.5	0.14	0.16	92.8	107.1
T_2	25.2 (48.5)	18.1 (63.0)	0.74 (94.7)	0.85 (123.6)	34.0	21.2	0.16	0.17	109.3	121.6
T_3	30.9 (36.8)	21.6 (55.8)	0.74 (105.3)	0.86 (126.3)	27.6	25.1	0.18	0.20	130.8	162.3
T_4	25.8 (20.4)	16.8 (65.6)	0.79 (23.6)	1.1 (36.8)	32.6	15.2	0.19	0.22	143.7	166.3
Initial	48.9		0.38		128.6		0.13		90.7	

% ↓↑ over initial is given in parentheses

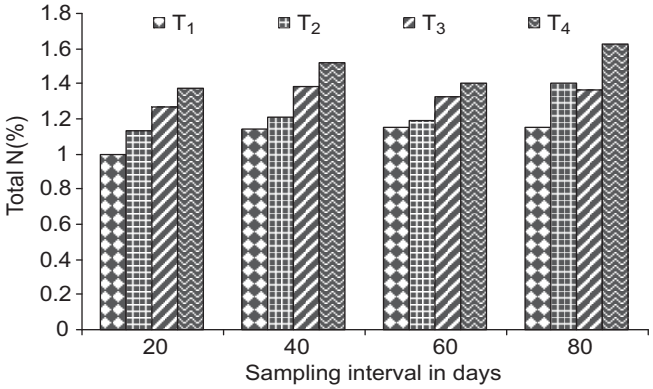

Fig 1 Changes in total N (%) during production of paddy straw vermicompost

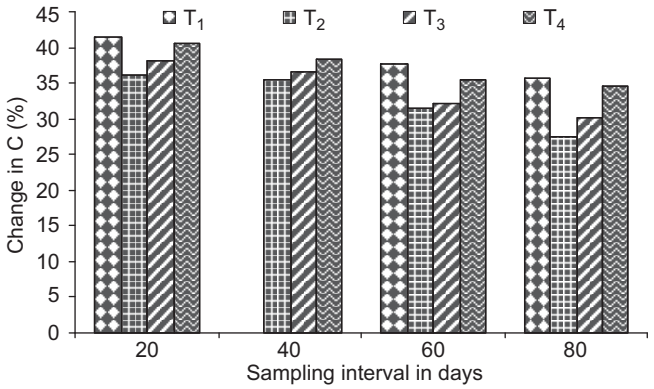

Fig 2 Changes in organic carbon (%) during vermicompost

of *A. awamori* and *E. foetida* revealing 189.6% increase over initial Fig 1. The treatment (0.86%) which followed the best was with inoculation with cellulolytic fungi *A.awamori* showing 126.3% increase over the initial at the end of 60 days. Single inoculation with *E. foetida* (0.85%) also proved effective and gave 123.6% increase over the initial. By and large it can be seen that *E. foetida* addition was also able to consume more nitrogen as compared to the treatments where it was not added. There was not much increase in N content in the treatment where *E. foetida* was inoculated indicated that nitrogen immobilization might be by *E. foetida*. Consequent to loss in carbon and gain in nitrogen the C : N ratio was progressively lowered along the inoculation period Table 1. The lowest C : N ratio (15.2) was encountered in treatment where dual inoculation of *A.awamori* and *E. foetida* were given with paddy straw registering 70.48% drop over un-inoculated control after 60 days. It was followed by 58.3% drop-wise enriched compost was treated with only *E. foetida* showing C : N ratio of 21.2. Other treatments also showed C : N ratio in the range between 15.2 to 51.5. The inoculation of paddy straw with *A. awamori* resulted in significant lowering of C : N ratio in comparison to initial after 60 days. Studies on the change in total phosphorus during decomposition of paddy straw revealed that there was significant increase in total phosphorus content in all treatments over initial as well as over control in all the intervals. (Table 1) Maximum value at 60 days was encountered in the treatment where paddy straw was enriched with a combination of fungi *A. awamori* and earthworm *E. foetida* (0.21%) showing 37.5% increase over un-inoculated control after 60 days. In the treatments with paddy straw, it was observed that 25% after 60 days of inoculation increase over control. (Table 1) It can be seen that the available phosphorus content increased as the incubation period progressed and highest values of available P were observed in all the treatments. The maximum value 166.3 ppm showing 55.27% increase over the uninoculated control was observed after 60 days in the treatment where paddy straw enriched with a combination of *A. awamori* and *E. foetida*. It is evident from the result that *A. awamori* played a significant role regarding availability of available P in comparison of *E. foetida* as it contributed 13.5% increase alone with paddy straw as compared to *A. awamori* which attributed 51.54% increase with paddy straw after 60 days of inoculation over uninoculated control.

Humus synthesis increased with passage of time and maximum humus percentage of 11.5% with paddy straw inoculated with *A.awamori* and *E. foetida*, followed by *A. awamori* with 9.4% compared with initial 2.3% (Fig 2). It showed that inoculated control, and combined inoculation was better than single inoculation. The quality of humus content increased after 60 days; the production of humus was greater after 2 months of decomposition and this might be possible because polymeric reaction leading to humus formation occur when the temperature of the compost reduced down to ambient temperatures.

The un-inoculated paddy straw decomposition could not be completed by 60 days and showed 51.5 C : N ratio and it contained 0.52% N and 107 ppm available P. Enrichment of paddy straw with earthworms *E. foetida* and *A. awamori* not

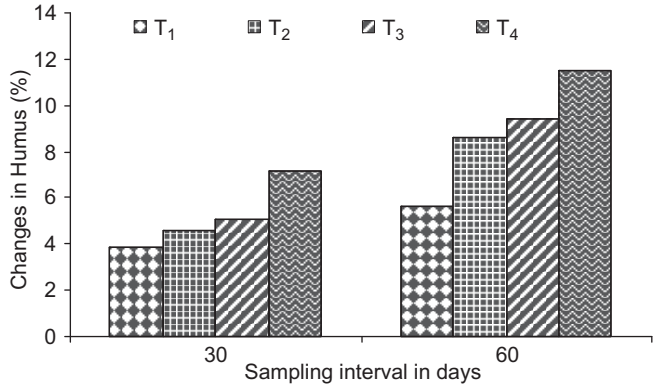

Fig 3 Changes in humus (%) during vermicompost

only hastened the process of degradation of paddy straw but also provided larger amounts of available phosphorus (166ppm) and nitrogen contents (1.1%) in the compost and improved the quality of the compost. The C : N ratio 15.2 was obtained within 60 days and thus benefited by 30 days while there was additional benefit of 59 ppm available P and 0.58% N respectively. The humus content of enriched paddy straw was 12.3% as compared to uninoculated control 5.9% after 60 days of composting which resulted in 6 4% of humus content in treated paddy straw with earthworms *E. foetida* and *A. awamori*.

SUMMARY

Organic agriculture is a unique production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles and soil biological activity, and this is accomplished by using on-farm agronomic, biological and mechanical methods in exclusion of all synthetic off farm inputs. Vermicompost was prepared in cemented pits of size 2m×1.5m×1.5 m method using paddy straw as a substrate with *Eisenia foetida* an efficient earthworm and cellulolytic fungus *Aspergillus awamori,* a lignocellulolytic fungus was inoculated @ 300 g/tonne paddy straw to hasten, the composting process and optimum moisture (60 to 70%) was maintained throughout the composting period. The initial C/N ratio 128.6 in uninoculated paddy straw dropped markedly and ranged 51.5 to 15.2 in different treatment after 60 days of composting. Maximum reduction of 16.8% over the initial 48.9% in uninoculated control was observed after 60 days in the treatment where paddy straw was inoculated with a combination of *E. foetida* and *A. awamori* whereas the reduction in the control was only 26.8% over initial and 0.38% in uninoculated control. The C/N ratio of paddy straw with *E. foetida* and *A. awamori* was observed 15.2 after 60 days which indicated a significant parameter for the maturity of compost. Available P also increased significantly from initial value of 107 ppm in inoculated control to 166.3 ppm in the treatment where paddy straw was inoculated with *A. awamori* and *E. foetida*. Therefore realizing the maximum benefits by using *A. awamori* with *E. foetida* for making vermicompost with paddy straw as a substrate needs to be adopted. This ecofriendly technology is practically feasible, economically attractive and safe for environment.

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