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EFFECT OF VERMICOMPOST FROM RICE STRAW AND COW DUNG BY *EISENIA FETIDA* ON GROWTH AND REPRODUCTION OF *E. FETIDA* CULTURED IN DIFFERENT WASTES

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SUMMARY

Earthworms play an important role in the ecosystem which can decompose any kind of biodegradable waste. A large amount of rice straw is generated every year which is usually burnt in the field and causes a lot of air pollution, climate change, loss of soil fertility and many health-related problems. Due to this reason, the present study was carried out to determine the nutrient status of vermicompost produced from rice straw using *Eisenia fetida* and its effect on growth and yield of wheat (*Triticum aestivum*) crop. Rice straw was mixed with cow dung as: 10% rice straw + 90% cow dung, 20% rice straw + 80% cow dung, 30% rice straw + 70% cow dung and only cow dung. The maximum growth and reproduction of *E. fetida* occurred in 10% rice straw with 90% cow dung mixture. Hence, it can be concluded that vermicompost is an appropriate alternative to chemical fertilizers.

Key words: *Eisenia fetida*; rice straw; vermicomposting; Growth; fecundity; reproduction; population

Rice straw is one of the agricultural wastes generated every year in large amount as it is staple food crop in most of the countries. With growing demand of food, more rice is produced every year, hence, more rice straw is generated. Rice straw is the residual product at the time of harvesting of rice crop.

(a) Impact of rice straw

The rice straw generated from crop is burnt or allowed to be decomposed in the soil. The uncut portion of rice straw (stubble) is burnt or decomposed in the soil to prepare the soil for growing next crop. Every year tonnes of rice straw is burnt which causes a lot of air pollution, respiratory and other health related problems. Some state governments, viz. Haryana, Punjab, Delhi etc. have banned burning of stubble, though farmers burn it every year. Farmers burn the stubble as it requires least labour, less time and no money. The burning of stubble releases carbon dioxide, volatile organic compounds (VOC), hydrocarbons, particulate matter and harmful gases like nitrogen dioxide (NO_2), nitrous oxide (N_2O), carbon monoxide (CO) and methane (CH_4) (Liu *et al.*, 2019). The emissions of stubble burning are transported through air across state and national boundaries which affect air quality (Abdurrahman *et al.*, 2020). The air quality in north Indian cities, especially Delhi, becomes more severe during the November month after harvesting (Mishra, 2019). Stubble burning also affects fertility of soil by removing essential nutrients like nitrogen, phosphorus, potassium and other micro nutrients (Singh *et al.*, 2018) and also increases temperature of soil up to 42°C which kills useful microbes residing in the soil layer up to 2.5 cm depth (Jain *et al.*, 2014), affects agricultural productivity by damaging leaves, grains or causing assimilation of heavy metals (Abdurrahman *et al.*, 2020). For example, SO_2 in the atmosphere causes acid rain which damages plants, aquatic animals, soil, and may cause death of plants (Augustaitis *et al.*, 2010). Air pollution causes many health problems such as skin and eye irritation or in some cases; it may cause severe neurological, cardiovascular and respiratory problems (Abdurrahman *et al.*, 2020). Stubble burning also affects climate and weather conditions through the release of greenhouse gases like carbon dioxide and methane which lead to global warming.

(b) Management of rice straw

Vermicomposting and composting are environment friendly, easy to maintain as well as cost effective methods widely used for waste management (Grasserova *et al.*, 2020). In composting; bacteria or fungi are used to decompose organic matter. In vermicomposting; earthworms are employed to convert biodegradable waste into nutrient rich organic manure which is performed by the enzymes and microorganisms present in their gut (Dominguez, 2004; Yadav and Garg, 2019).

(c) Benefits of vermicomposting of rice straw

The vermicompost contains seven times more nutrients than the compost which has been prepared without using earthworms (Yadav and Gupta, 2017). Heat released during composting kills pathogens present in organic waste (Grewal *et al*., 2006). Hence, composting followed by vermicomposting kills harmful microorganisms (Ndegwa and Thompson, 2001). Thermophilic stage of composting is detrimental to earthworms, so earthworms are added to the waste after completion of this phase to continue the process of decomposition (Dominguez, 2004). Tognetti *et al*. (2005) reported that precomposted vermicompost is rich in nutrients and microbial content. Precomposting also saves time and space required for vermicomposting. Earthworms are able to degrade different types of pollutants like polycyclic aromatic hydrocarbons as well as accumulate heavy metals (Sinha *et al*., 2008). Thus, earthworms are potential bioindicators of metal pollution.

(d) Ideal properties of earthworm for vermicomposting

Many species of earthworms are known but certain species are used for vermicomposting. For vermicomposting, they must have a high fecundity rate, high growth rate, high vermiconversion rate, wide range of temperature tolerance and ability to feed on different types of organic wastes (Sharma and Garg, 2019a; Gupta and Garg, 2017).

(e) Earthworms and vermicomposting

The growth rate, fecundity and survivability of earthworms, *Eisenia fetida* has a pivotal role in the process of vermicomposting (Singh *et al*., 2010). The growth and reproduction of it are influenced by the type of substrate used for vermicomposting. This, in turn, affects the quantity and quality of the final products viz. vermicompost and worm biomass. The paper waste and rice straw used as substrates in different proportions for vermicomposting with cow dung as bulking agent (Sharma and Garg, 2018) and maximum growth rate of *E. fetida* was observed in 10% rice straw + 90% cow dung. The ratio of bulking agent affects growth and reproduction of earthworms due to its greater amount and the growth of earthworms increased up to 75 days, thereafter, it decreased. The cattle manure i.e. bulking agent increased survivability, biomass, and number of cocoons and juveniles of *E. fetida* with respect to control i.e. garden waste alone (Gong *et al*., 2019). The various substrates used for vermicomposting with different physicochemical properties affects the process (Mousavi *et al*., 2020). Lignocellulosic waste such as leaf litter is produced in large amount which is usually dumped and burnt in open areas; when mixed with cow dung in bulk which can be recycled successfully to form nutrient-rich vermicompost (Sharma & Garg, 2019). Teak leaf litter (*Tectona grandis*), mixed with cattle manure in different ratios utilised in vermicomposting for 105 days using *E. fetida* and satisfactory gain in biomass (22.38-39.64 g) and reproduction (21.27-31.60 hatchlings/worm) of earthworms was observed.

(f) Vermicomposting of agriculture wastes

Vermicomposting of harvested waste biomass of potato crop (*Solanum tuberosum*) using *E. fetida* also showed a significant increase in number and biomass of earthworms on addition of cow dung (Das & Deka, 2021). An invasive weed *Parthenium hysterophorus* was bio-transformed into an organic fertilizer using polyculture of earthworms *E. fetida* and *E. eugeniae* (Devi & Khwairakpam, 2021) and an increase in biomass i.e. 46.25% in treatment containing 400g *P. hysterophorus* and 600 g cow dung; was observed during the experiment. The various types of organic wastes *viz*. false ashoka (*Polyalthia longifolia*), Parthenium (*P. hysterophorus*), cotton residue (*Gossypium*), lawn grass (*Agrostis*) and cattle manure were employed for vermicomposting to observe the growth and reproduction of *E. fetida* (Nagannawar *et al*., 2021). At the end of experiment, the biomass and growth rate of earthworms were observed maximum in *Parthenium* waste and minimum in false ashoka waste. The earlier attainment of sexual maturity and maximum cocoon production in cattle manure followed by other wastes was observed in cattle manure. This study revealed that *E. fetida* can be used to decompose variety of wastes as it feeds voraciously, breeds throughout the year and tolerates wide range of temperature and moisture. Sharma *et al*. (2022) mixed the dairy sludge, sugarcane press mud with cattle manure in different ratios has a significant growth of earthworms was observed during vermicomposting. Das *et al*. (2022) employed *E. fetida* to convert biomass wastes of medicinal plants *viz*. turmeric (*Curcuma longa*) and ginger (*Zingiber officinale*) into value-added product i.e. vermicompost and observed that both biomass (21.05%) and population (41.96%) of earthworms increased at maturity of vermicompost with respect to their initial level. Yatoo *et al*. (2022) utilized free-floating macrophytes i.e., *Azolla*, *Lemna* and *Salvinia* supplemented with cow manure and kitchen waste for vermicomposting and observed increased nutrient content as well as growth and reproduction rate of earthworms. Shafique *et al.* (2023) observed growth and reproduction of *E. fetida* after 45 days, and after 90 days and recorded maximum adult earthworms at the end of vermicomposting. The biomass of used earthworms was recorded as 15mg initially; but at the end of experiment, it was recorded as 300mg. Juveniles were not seen in the first week of vermicomposting but after 90 days the maximum number of juveniles were also recorded. Cocoon production was increased due to favorable environmental conditions.

MATERIALS AND METHODS

In the present investigation vermicompost was prepared from rice straw using *E. fetida* at screen house number 4 of Zoology Department, College of Basic Sciences & Humanities, CCS Haryana Agricultural University. The materials used and methods adopted for the studies are explained below. The composting worms, *E. fetida* were obtained from Department of Agronomy, CCSHAU, Hisar. Rice straw was collected from Innovation Centre for Agriwaste Management (ICAWM), CCSHAU, Hisar. Cow dung was procured from Janta Biogas Plant of Department of Microbiology, CCSHAU, Hisar.

Preparation of feed material for earthworms

The key component of vermicomposting was rice straw in the present investigation. For the preparation of vermicompost, the addition of cow dung to the rice straw acts as food supplement for earthworms and makes decomposition faster (Sabrina *et al*., 2009). The collected rice straw was soaked in water (Plate 2) for two weeks so that it became softer. Then, it was dried in sunlight (Plate 3) and shredded to about 1cm length (Plate 4) (Wei *et al*., 2012). Shredding of rice straw was carried out at Department of Renewable and Bio Energy Engineering, College of Agriculture Engineering & Technology, CCS HAU, Hisar. Cow dung was pre-composted before mixing (Plate 1). The shredded rice straw was mixed with cow dung as mentioned in table-1 and water was added to the substrates for thorough mixing and to initiate decomposition (Plate 5, 6, 7, 8).

Experimental set up

The experiment was conducted at screen house number 4 under shade to prevent earthworms from direct sunlight and rainfall (Plate 9). The experimental layout was Complete Randomized Design (CRD) with a total number of 12 plastic tubs

i. Each tube of 40 L capacity each were filled with 20 kg mixture in three replicates were used.
ii. The mixtures were precomposted by sprinkling water and turning regularly for 20 days to release heat and harmful gases produced during decomposition.
iii. After precomposting; 50 unclitellated earthworms were weighed and transferred into each tub.
iv. Water was sprinkled as and when required to maintain moisture and temperature.
v. All the tubs were covered with gunny bags to reduce water loss and provide favorable conditions to earthworms.
vi. The composting mixtures were turned regularly for proper aeration and elimination of foul smell generated during decomposition of waste.

The experiment was carried out for 90 days during August-October, 2021. The parameters *viz*. length, weight, total number of adults and cocoons of earthworms were recorded on 45^{th} and 90^{th} day of release of earthworms.

RESULTS

The results of the present investigations are presented in the following subheadings:

Effect of rice straw on growth and reproduction of *E. fetida*

Earthworm, *E. fetida* was employed for vermicomposting of rice straw. The length and weight of *E. fetida* were recorded on 0, 45^{th} and 90^{th} day.

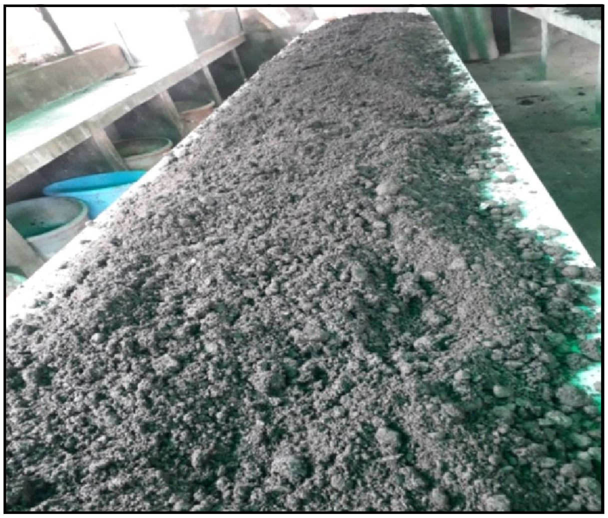

Plate 1: Precomposting of cow dung

Plate 2: Soaking of rice straw in water

Plate 3: Drying of rice straw

Plate 4: Shredding of rice straw

Plate 5: Vermicomposting of cow dung

Plate 6: Vermicomposting of 10% Rice straw

Plate 7: Vermicomposting of 20% Rice straw

Plate 8: Vermicomposting of 30% Rice straw

Plate 9: Setup of 1st experiment

Plate 10: Culture of *Eisenia fetida*

TABLE 1
Composition of materials used in preparation of vermicompost

S. No.	Treatments	Description
1.	Control	100% cow dung
2.	T_1	Cow dung (90%) + Rice straw (10%)
3.	T_2	Cow dung (80%) + Rice straw (20%)
4.	T_3	Cow dung (70%) + Rice straw (30%)

Effect of different compositions of rice straw and cow dung on variation in mean individual biomass of *E. fetida*

The average body weight of earthworms was increased over time and reached its maximum value on 90th day. The initial body weight (g) of *E. fetida* was in the range of 0.240 ± 0.010 to 0.257 ± 0.009. The maximum body weight (g) was recorded in T_1 (1.121 ± 0.014), followed by T_2 (0.913 ± 0.005), T_3 (0.872 ± 0.016) and control (0.740 ± 0.025). Hence, maximum growth was recorded in T_1. The weight of earthworms increased 4.36 times of initial body weight (Table 1).

Effect of different compositions of rice straw and cow dung on variation in average body length of *E. fetida*

During the experiment, the average body length of *E. fetida* during was increased in all the feed stocks and maximum length was achieved on 90th day. The initial body length (cm) of *E. fetida* was in the range of 4.967 ± 0.120 to 5.333 ± 0.167. The maximum length (cm) was recorded in T_1 (8.767 ±

0.145), followed by T_2 (7.867 ± 0.203), T_3 (7.067 ± 0.088) and control (6.433 ± 0.088). The maximum increase in length was recorded in T_1 (Table 2).

Effect of different compositions of rice straw and cow dung on reproductive potential of *E. fetida*

The total number of cocoons produced by *E. fetida* during the process of vermicomposting was increased in all the treatments and maximum number of cocoons were recorded on 90th day in T_1 (652.667 ± 2.726), followed by T_2 (536.000 ± 5.292), T_3 (463.667 ± 5.812) and control (334.667 ± 2.907) (Table 3).

Number of adult, *E. fetida* retrieved from different treatments

The total number of adult, *E. fetida* retrieved from different treatments during the process of vermicomposting was increased in all the treatments over time and the maximum number of adult, *E. fetida* (per container) were recorded in T_1 (214.000 ± 3.055), followed by T_2 (188.333 ± 2.334), T_3 (175.000 ± 1.732) and control (151.333 ± 2.028) on 90th day (Plate 10 & Table 4).

DISCUSSION

The survival, biomass and reproduction of *E. fetida* play an important role in determining the quality of vermicompost (Gong *et al*., 2019). *E. fetida* was employed for vermicomposting of rice straw in the present investigation in which 50 non-clitellated *E. fetida* were transferred into each container. The growth and reproductive potential of *E. fetida* such as mean individual biomass, body length, number of cocoons and adults were recorded on 0, 45th and 90th days. Cocoons and adult *E. fetida* were lacking on the initial day.

TABLE 1

Effect of different compositions of rice straw and cow dung on variation in mean individual biomass of *E. fetida*

S. No.	Treatments	Mean individual biomass of *E. fetida* (g/worm)*		
		0 Day	45 Days	90 Days
1.	Control: 100% cow dung	0.240 ± 0.010	0.411 ± 0.008	0.740 ± 0.025
2.	T_1: Cow dung (90%) + Rice straw (10%)	0.247 ± 0.012	0.785 ± 0.011	1.121 ± 0.014
3.	T_2: Cow dung (80%) + Rice straw (20%)	0.257 ± 0.009	0.543 ± 0.012	0.913 ± 0.005
4.	T_3: Cow dung (70%) + Rice straw (30%)	0.250 ± 0.006	0.483 ± 0.006	0.872 ± 0.016
	C.D.	NS	0.031	0.055
	SE (m)	0.009	0.009	0.017
	SE(d)	0.013	0.013	0.024
	C.V.	6.576	2.952	3.159

*Mean ± S.E, NS= Non Significant.

TABLE 2

Effect of different compositions of rice straw and cow dung on variation in average body length of *E. fetida*

S. No.	Treatments	Average body length of *E. fetida* (cm)*		
		0 Day	45 Days	90 Days
1.	Control: 100% cow dung	5.200 ± 0.153	5.833 ± 0.033	6.433 ± 0.088
2.	T_1: Cow dung (90%) + Rice straw (10%)	5.333 ± 0.167	7.433 ± 0.145	8.767 ± 0.145
3.	T_2: Cow dung (80%) + Rice straw (20%)	4.967 ± 0.120	6.767 ± 0.088	7.867 ± 0.203
4.	T_3: Cow dung (70%) + Rice straw (30%)	5.167 ± 0.088	6.333 ± 0.067	7.067 ± 0.088
	C.D.	NS	0.307	0.462
	SE (m)	0.135	0.093	0.139
	SE(d)	0.191	0.131	0.197
	C.V.	4.539	2.438	3.206

*Mean ± S.E, NS= Non-Significant.

5.1 Average body weight and length of *E. fetida*

The present study revealed an increase in mean individual biomass of *E. fetida* and the maximum value was found on 90th day. The initial body weight (g) was in the range of 0.240 ± 0.010 to 0.257 ± 0.009. The maximum body weight (g) was recorded in T_1 (1.121 ± 0.014), followed by T_2 (0.913 ± 0.005), T_3 (0.872 ± 0.016) and control (0.740 ± 0.025) which indicates the maximum growth occurred in T_1. Similarly, the body length of *E. fetida* showed an increasing trend during vermicomposting and the maximum body length was recorded on 90th day. The initial body length (cm) of *E. fetida* was in the range of 4.967 ± 0.120 to 5.333 ± 0.167. The maximum body length (cm) was recorded in T_1 (8.767 ± 0.145), followed by T_2 (7.867 ± 0.203), T_3 (7.067 ± 0.088) and control (6.433 ± 0.088). Hence, the maximum increase in length was recorded in T_1. The results revealed that mixing rice straw with cow dung enhances the growth of *E. fetida* as compared to control (only cow dung). The difference in growth performance of *E. fetida* in different treatments might be due to the quality of raw material and the percentage of mixing substrate (Vodounnou *et al.*, 2016).

Many researchers have conducted experiments to recycle organic waste into value-added product i.e. vermicompost. It has been suggested that 25 to 30% of organic waste mixed with 70 to 75% of other nutrient-rich substrates such as cattle dung can be efficiently transformed into vermicompost while a higher concentration of organic waste adversely affects earthworms (Singh *et al.*, 2020). Industrial wastes such as sludge from the paper mill industry can be efficiently converted into nutrient-rich manure when mixed with cow dung in suitable proportion (25% paper mill sludge and 75% cow dung) by using *E. fetida* (Mohan, 2017).

Similar results were found by earlier researchers (Khwanchai & Kanokkorn, 2018) during vermicomposting of different agricultural wastes and reported higher N, P and K content (1.10% nitrogen,

TABLE 3
Effect of different compositions of rice straw and cow dung on reproductive potential of *E. fetida*

S. No.	Treatments	Total number of cocoons (per container)	
		45 Days	90 Days
1.	Control: 100% cow dung	156.333 ± 2.963	334.667 ± 2.907
2.	T_1: Cow dung (90%) + Rice straw (10%)	396.333 ± 2.332	652.667 ± 2.726
3.	T_2: Cow dung (80%) + Rice straw (20%)	349.667 ± 3.757	536.000 ± 5.292
4.	T_3: Cow dung (70%) + Rice straw (30%)	207.333 ± 3.712	463.667 ± 5.812
	C.D.	10.746	14.593
	SE (m)	3.245	4.406
	SE(d)	4.589	6.232
	C.V.	2.026	1.536

*Mean ± S.E.

TABLE 4
Number of adult, *E. fetida* retrieved from different treatments

S. No.	Treatments	Total number of adults (per container)	
		45 Days	90 Days
1.	Control: 100% cow dung	51.667 ± 0.333	151.333 ± 2.028
2.	T_1: Cow dung (90%) + Rice straw (10%)	71.333 ± 0.667	214.000 ± 3.055
3.	T_2: Cow dung (80%) + Rice straw (20%)	64.000 ± 1.155	188.333 ± 2.334
4.	T_3: Cow dung (70%) + Rice straw (30%)	56.333 ± 0.882	175.000 ± 1.732
	C.D.	2.704	7.747
	SE (m)	0.816	2.339
	SE(d)	1.155	3.308
	C.V.	2.325	2.224

*Mean ± S.E.

0.66% phosphorus and 1.31% potassium) in vermicompost as compared to raw material and a gain in biomass of earthworms (28.33-104.67%) over initial weight. Singh & Kalamdhad (2016) also reported similar results during vermicomposting of weed *Salvinia natas* using earthworm *E. fetida*. Vermicomposting of weed *Ageratum conyzoids* with cow dung resulted in an increase in the biomass of earthworms (Devi & Khwairakpam, 2020).

5.2 Reproductive potential of *E. fetida* (number of cocoons and adults)

In the present study, the number of cocoons (per container) was found to be maximum in T_1 (652.667 ± 2.726), followed by T_2 (536.000 ± 5.292), T_3 (463.667 ± 5.812) and control (334.667 ± 2.907) on 90th day. During the present study, the number of adult, *E. fetida* increased and the maximum number (per container) was found in T_1 (214.000 ± 3.055), followed by T_2 (188.333 ± 2.334), T_3 (175.000 ± 1.732) and control (151.333 ± 2.028) on 90th day. Thus, it indicates that the addition of rice straw to cow dung favours the reproduction of *E. fetida*. In the present study, the higher proportion of rice straw in treatments T_2 and T_3 decreases the growth and reproduction of *E. fetida* is consistent with the study by Sharma and Garg (2018). The quality of substrate used for vermicomposting influences the decomposition and population of earthworms (Suthar, 2008a). It has been suggested that variation in palatability, nutrient content and presence of some growth retarding substances affect the growth and reproduction of earthworms during vermicomposting of crop residue (Suthar, 2008b). An increase in the number of hatchlings, adults and cocoons during vermicomposting of soybean meal and sugarcane bagasse was reported by Cai *et al.* (2022). Rice straw was reported to be suitable for the growth and reproduction of earthworms with maximum worm biomass, cocoons and hatchlings (Shak *et al.*, 2014).

In a similar study by Shafique *et al.* (2023), maximum adult earthworms were recorded at the end of vermicomposting. Initially, the biomass of used earthworms was recorded as 15 mg but at the end of experimentation the biomass was recorded as 300 mg. Juveniles were not seen in the first week of vermicomposting but after 90 days the maximum number of juveniles were recorded. Cocoon production was increased due to favorable environmental conditions. The current study also reveals that the maximum fecundity was recorded during vermicomposting.

CONCLUSIONS

The maximum body weight (g) of *E. fetida* was recorded in 10% rice straw (1.121 ± 0.014) followed by 20% rice straw (0.913 ± 0.005), 30% rice straw (0.872 ± 0.016) and cow dung (0.740 ± 0.025) on 90th day. The maximum body length (cm) of *E. fetida* was recorded in 10% rice straw (8.767 ± 0.145) followed by 20% rice straw (7.867 ± 0.203), 30% rice straw (7.067 ± 0.088) and cow dung (6.433 ± 0.088) on 90th day. The maximum number of cocoons were recorded in 10% rice straw (652.667 ± 2.726) followed by 20% rice straw (536.000 ± 5.292), 30% rice straw (463.667 ± 5.812) and cow dung (334.667 ± 2.907) on 90th day. The maximum number of adults, *E. fetida* were recorded in 10% rice straw (214.000 ± 3.055) followed by 20% rice straw (188.333 ± 2.334), 30% rice straw (175.000 ± 1.732) and cow dung (151.333 ± 2.028) on 90th day.

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