Project ID : 802

Competitive Research Grant

Sub-Project Completion Report

on

Studies on the performance of vermicompost and organic materials for improving soil fertility and crop productivity

Project Duration

From May 2017 to September 2018

Soil Science Division
Bangladesh Institute of Nuclear Agriculture (BINA)
BAU Campus, Mymensingh

Submitted to
Project Implementation Unit-BARC, NATP 2
Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215

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Acronyms

BINA	Bangladesh Institute of Nuclear Agriculture,
DAS	Days after sowing
DAT	Days after transplanting
GMR	Giant mimosa residue
RS	Rice straw
PM	Poultry manure
DMRT	Duncan's multiple range test
AEZ	Agro ecological zone
ATI	Agriculture Training Institute
CD	Cowdung
OC	Organic carbon

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Executive Summary

Inorganic fertilizers are applied in farms heavily for boost up crop production which is detrimental to the soils and environments. On the other hand organic manures are not harmful for soils and environment. Application of different well decomposed organic manures like crop residues, poultry manures, green manures, cowdung, compost, vermicompost may combat this situation. Direct application of fresh residues is often harmful for crop growth and soil environment. Well composted organic manures are congenial for soil health and crops. Conventional composting takes much time and this compost are not well synchronized for nutrient demand of the crops. There is a great scope to develop a technology for enriching the nutrient values of compost through vermicomposting with earthworms. Vermicomposting is a simple biological process of composting in which certain species of earthworms are used to enhance the process of waste conversion into a better end product. The process is faster than conventional composting; because the material passes through the earthworms gut. The resulting earthworm castings (worm manure) are rich in nutrients and narrow in C:N ratio. Vermicompost provides all nutrients in readily available form which is well synchronized for nutrients demand of the crops than conventional compost. In our country, vermicomposting is mainly based on cowdung and low in plant nutrients. Now a days, cowdung is less available for vermicomposting due to inadequate production and multi-purpose utilization. Alternative organic materials of cowdung or reduce the usage of cowdung in producing of vermicompost may combat this situation. The project formulated with the following objectives: i) isolation and selection of effective earthworms as rapid decomposer for different organic residues, ii) selection of suitable organic residues/combination for producing vermicompost with effective earthworms and iii) investigate the effects of vermicompost on soil fertility and crop productivity.

Earth worms isolated from three agro-ecological zones (AEZ 3, AEZ 9 and AEZ 11) of Bangladesh and soil samples collected from the same corresponding spots. Earthworms were also collected from different vermicompost pits in surveying areas. Maximum earthworms (127 earthworms m^{-2} area) were found in mahogani plantation at BINA substation farm, Jamalpur (AEZ 9) and minimum earthworms were recorded from mixed plantation of RARS farm Ishurdi, Pabna (AEZ 11) and mixed garden of ATI, Ishurdi, Pabna. Positive correlation observed between the abundance of earthworms and soil properties like organic C, N and P whereas negative correlation observed with soil bulk density, soil pH and exchangeable K. Collected redwigglers (*Eisenia foetida*) and local mixed earthworms (*Perionix excavatus, Lumbricus rubellus*, *Eudrilus eugeniae etc.)* have been used on different organic materials like cow dung, poultry manures, rice straw, giant mimosa residues and their different combinations for decomposition and nutrient release. Among the 15 treatments combination, greater CO_2 was evolved with the rice straw aided treatments with redwiggler earthworms during decompostion. Red wigglers can decompose faster of the different organic materials and made the vermicompost greater stable than the mixtures of local earth worms. Maximum total N (1.16%), P (0.61%), K(1.57%) and S(0.4%) contents were observed in the treatment T_4 (Soil+ CD+RS+PM+GMR+Ew_1). Mixtures of soil, cowdung (CD), rice straw (RS), poultry manure (PM), giant mimosa residue (GMR) at the ratio of 2:2:1.33:1.33:1.33 with redwiglers earthworms were more suitable for the production of quality and nutrient rich vermicompost among the different treatment combinations.

Field experiments were conducted in three AEZ (AEZ-3: Farmer's field, Rangpur, AEZ-11: Farmer's field, Ishurdi and AEZ-9: BINA farm, Mymensingh) to investigate the integrated effect of vermicompost and chemical fertilizer (CF) on the Mustard – Boro- T.aman rice cropping pattern. The results indicated that 75% CF with 4 t ha^{-1} vermicompost or 85% CF with 2 t ha^{-1} vermicompost almost equally effective to produce seed yield of mustard (Binasharisha 10) and grain yield of Boro rice (Binadhan- 14) which was also comparable with the full dose (100%) of chemical fertilizer NPKS. In the production of T. aman rice,75% CF with 2 t ha^{-1} vermicompost was equally effective to 100% CF (NPKS). Therefore 15-25% chemical fertilizer (NPKS) could be saved either with the application of 75% CF with 4 t ha^{-1} vermicompost or 85% CF with 2 t ha^{-1} vermicompost for Mustard-Boro rice-T.aman rice cultivation.

CRG Sub-Project Completion Report (PCR)

A. Sub-project Description

1. **Title of the CRG sub-project**: Studies on the performance of vermicompost and organic materials for improving soil fertility and crop productivity
2. **Implementing organization:** Bangladesh Institute of Nuclear Agriculture (BINA)
3. **Name and full address with phone, cell and E-mail of PI/Co-PI (s):**

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4. **Sub-project budget (Tk):**
   - 4.1 **Total**: 21,40,735/
   - 4.2 Revised (if any): 21,40,735/
5. **Duration of the sub-project:**
   - 5.1 **Start date (based on LoA signed):** May 2017
   - 5.2 **End date**: 30 September 2018

6. **Justification of undertaking the sub-project:**

Production of food grain in Bangladesh has been increased substantially in the last decades but risk is prevailing in food security due to ever rising population. This phenomenon always leads to raise more crops from a piece of land in every year which caused the rapid declining of soil fertility and soil health (Ali *et al.*1997). Less addition of organic matter in soil made the situation more vulnerable. A cheaper and more sustainable measure might be taken to improve the productivity through the application of organic sources of plant nutrients. Application of non-stabilized compost to soil may lead to immobilization of plant nutrients and cause phytotoxicity (Camberdella *et al.,* 2003). Conventional composting takes much time to mature the compost and they are not well synchronized for nutrient demand of the crops. There is a great scope to develop a technology for enriching the nutrient values of compost through vermicompsting with epigeic earthworms. Vermicomposting is a simple biological process of composting in which certain species of earthworms are used to enhance the process of waste conversion into a better end product. The process is faster than conventional composting; because the material passes through the earthworms gut. The resulting earthworm castings (worm manure) are rich in nutrients and narrow in C:N ratio (Goyal *et al*., 2005). Vermicompost provides all nutrients in readily available form which is well synchronized for nutrients demand of the crops than conventional compost.

In our country, vermicomposting is mainly based on cowdung and earthworms and low in plant nutrients. Now a day, cowdung is less available for vermicomposting due to inadequate production and multi-purpose utilization. Alternative organic materials of cowdung may combat this situation. But information or studies are very scanty for production of vermicompost with native diversified earthworms and various agricultural wastes (agricultural wastes, city wastes, poultry farm wastes etc) which have great scope for tuning this technology.

7. Sub-project goal: Increased soil fertility to enhance crop productivity

8. Sub-project objective (s):

a) Isolation and selection of effective earthworms as rapid decomposer for different organic residues

b) To select the suitable organic residues/combination for producing vermicompost with effective earthworms.

c) To see the effects of vermicompost on soil fertility and crop productivity.

9. Implementing location (s): Soil Science Division, BINA, Mymensingh, Ishurdi sadar and Rangpur sadar

10. Methodology in brief:

Experiment 1: **Background survey and isolation of earthworms from three agro-ecological zones (AEZs)**

Background survey and isolation of earth worms:

Earthworms were isolated from different places (Table 1) of three AEZ namely AEZ 9 (Old Brahmaputra Flood Plain), AEZ 11 (High Ganges River Flood plan.) and AEZ 3 (Tista meander Flood Plain. Soil was opened by spade about the area of 1 m^2 at the depth of 0-15 cm and visible earthworms were carefully separated from soil by hand and recorded their abundance (no. m^{-2}). Geographical position (GPS) was recorded in each sampling spot. Isolated earthworms were brought at the laboratory into the plastic pot with soil. The collected earthworms were maintained into the mixture of partial decomposed cowdung and loam soil (1:1) providing dark condition with the help of gunny bags. Earthworms also collected from different Vermicompost farms and pits (Table 2).Collected earth worms were multiplied in cowdung for further use.

Collection of soil samples:

Soil samples were collected from same location where earth worms were isolated. About one kg of soil was taken for analysis of different soil properties. Core samples were taken from 0-15 cm depth for determination of soil bulk density for each sample location.

Preparation of soil samples for chemical analysis

The collected soils were air-dried, mixed well and sieved to remove the pieces of plant roots and other debris. All the soils were stored in plastic bottle for analysis of different properties viz. texture, pH, soil organic C, total N, available P, exchangeable K and available S and soils were analzed following the methods as described in the Fertilizer Recommendation Guide 2012 (FRG-2012).

Table 1.Description of sites for survey and isolation of earthworms from different AEZs

SL No.	Code No.	GPS reading	AEZ, area and locations	Land use
			AEZ11: High Ganges River Floodplain **<u>Ishurdi, Pabna:</u>**	
1.	ISD-1	N:24^0 07.386′ E: 89^0 04.867′	BINA, Substation Farm	Fallow
2.	ISD-2	N:24^0 07.129′ E: 89^0 05.460′	Aronkula	Fallow
3.	ISD-3	N:24^0 07.394′ E: 89^0 04.787′	ATI	Mixed garden
4.	ISD-4	N:24^0 07.362′ E: 89^0 04.709′	RARS	Mixed garden
5.	ISD-5	N:24^0 06.651′ E: 89^0 06.077′	Charmirkamari	Mixed garden
			Satkhira sadar:	
6.	SAT-1	N:22^{0}45.071′ E: 89^{0}06.411′	BINA substation Benerpota	Coconut garden

7.	SAT-2	N: 22^0 44.728’ E: 89^0 0.1593’	Nebakhali	Mango orchard
8.	SAT-3	N: 22^0 45.052’ E: 89^0 01.361’	Godaghata Kormkarpara	Fallow (Jute)
9.	SAT-4	N: 22^0 45.750’ E: 89^0 06.900’	Ramitia, Nagarghata	Banana garden
10	SAT-5	N: 22^0 45.794’ E: 89^0 06.877’	Motbari, Nagarghata	Mango orchard

Table 1.Continued

SL No.	Code No.	GPS reading	AEZ, area and location	Land use
			AEZ 9: Old Brahmaputra Floodplain **Mymensingh sadar:**	
11.	My-1	N:24^0 42.715′ E: 90^0 26.847’	Boyra	Vegetable -Fallow
12.	My-2	N:24^0 40.165′ E: 90^0 26.994’	Bhabokhali	Banana garden
13.	My-3	N:24^0 40.321′ E: 90^0 25.149’	Churkhai	Chili field
14.	My-4	N:24^0 46.150′ E: 90^0 26.869’	Shombugonj	Mixed garden
15.	My-5	N:24^0 43.553′ E: 90^0 25.764’	BINA Farm	Giant mimosa field
			Jamalpur:	
16.	JP-1	N:24^0 56.318’ E:$89^0$55.523’	BINA substation farm	Mahogani plantation
17.	JP-2	N:24^0 56.287’ E:$89^0$55.896’	RARS	Brinjal-fallow
18.	JP-3	N:24^0 56.228’ E:$89^0$55.806’	Chandra	Mixed garden
19.	JP-4	N:24^0 57.560’ E:$89^0$54.856’	Goabaria	Mixed garden
20.	JP-5	N:24^0 55.331’ E:$89^0$54.581’	Rashidpur	Dhaincha-fallow

Table 1.Continued

SL No.	Code No.	GPS reading	AEZ, area and location	Land use
			AEZ 3: Tista Meander Floodplain Rangpur	
21.	RP-1	N:25^0 43.402′ E: 89^0 16.720′	BINA sub station farm	Summer mungbean -Fallow
22.	RP-2	N:25^0 42.511′ E: 89^0 14.769′	Ghagot para, Akkelpur	Sugarcane
23.	RP-3	N:25^0 42.281′ E: 89^0 14.146′	Dangarpara, Akkelpur	Mango orchard
24.	RP-4	N:24^0 47.936′ E: 89^0 14.129′	Chabbish Hazari, Burirhar	Ginger field
25.	RP-5	N:25^0 49.201′ E: 89^0 14.471′	Uttar Kubaro	Amaranthus
			Dinajpur	
26.	DP-1	N:25^0 44.983′ E:88^0.40.365′	Gornurpur	Litchi orchard
27.	DP-2	N:25^0 44.509′ E:88^{0}40.430′	Wheat Research Center, Nashipur	Maize field
28.	DP-3	N:25^0 42.932′ E:88^{0}39.710′	Nashipur	Balack gram field
29.	DP-4	N:25^0 36.502′ E:88^{0}40.779′	Chuniapara	Mixed garden
30.	DP-5	N:25^0 35.472′ E:88^{0}42.429′	Jaliapara	Fallow

Table 2. Collection of earthworms from vermicompost pits from different areas

SL No.	GPS reading	Name of source	Used organic materials	Type of earthworms
1.	N= 24^0 06.651' E= 89^0 06.077'	Farmer's vermicompost pit Charmirkamari Ishurdi, Pabna	Cowdung	Red wiggler (*Eisenia foetida*)
2.	N= 24^0 07.444' E= 89^0 03.542'	Upzilla Agricultue office, Ishurdi, Pabna	Cowdung	-do-
3.	N= 22^0 44.719' E= 89^0 0.1578'	Farmer's Vermicompost Farm Nebakhali, Satkhira	Cowdung	-do-
4.	N= 24^0 46.150' E= 90^0 26.869'	Farmer's vermicompost pit Roghurampur Shombugonj, Mymensingh	Cowdung	-do-
5.	N= 24^0 56.287' E= 89^0 55.896'	Vermicompost shed RARS Jamalpur	Cowdung	-do-
6.	N=$25^0$49.211' E=$89^0$14.454	Farmer's vermicompost Farm Uttar Kubaro, Rangpur	Cowdung	-do-
7.	N=$25^0$49.096' E=$89^0$14.516'	Farmer's vermicompost Farm Uttar Kubaro, Rangpur	Cowdung	-do-

Experiment 2: **Evaluation of different earthworms on the basis of decomposition and nutrient release using various organic residues**

The glasshouse experiment conducted for selection of efficient earthworms and suitable organic materials for producing quality vermicompost. Soil was collected from farmer's field, Mymensingh. Rice straw and cowdung were collected from farmer's house, Boyra, Mymensingh. Partial decomposed poultry manure was collected from poultry farm, Kewatkhali, Mymensingh. Earthworms-1 (*Eisenia foetida*) –EW_1 was collected from farmer's vermicompost pit, Nebakhali, Satkhira sadar. Earthworms-2 (EW_2) was mixed culture

(*Perionix excavatus, Lumbricus rubellus*, *Eudrilus eugeniae*,etc) which have been isolated from giant mimosa field, BINA farm, Mymensingh and other soils.

Fifteen treatment combinations were used for the experiment. These were as follow:

T_1: Soil + cowdung (CD)+Rice straw (RS)+ Earthworms -1(Ew_1)
T_2: Soil+ CD+poultry manure (PM)+Ew_1
T_3: Soil+ CD+Giant mimosa residue (GMR)+Ew_1
T_4: Soil+ CD+RS+PM+GMR+Ew_1
T_5: Soil+RS+PM+GMR+Ew_1(Without CD)
T_6: Soil + CD+RS + Mixed earthworms -2(Ew_2)
T_7: Soil+ CD+PM +Ew_2
T_8: Soil+ CD+GMR +Ew_2
T_9: Soil+ CD+RS+PM+GMR+Ew_2
T_{10}: Soil+ RS+PM+GMR+Ew_2 (Without CD)
T_{11}: Soil+ CD +RS
T_{12}: Soil+ CD+PM
T_{13}: Soil+ CD+GMR
T_{14}: Soil+ CD+RS+PM+GMR
T_{15}: Soil+ RS+PM+GMR (Without CD)

The experiment conducted in Completely Randomized Design with four replication at the Glass House, Soil Science Division, BINA, Mymensingh. Treatment wise organic materials have been filled up into the plastic pots (50L size). Initial nutrients status of the different residues has been given in the table 3. About eight kilogram of organic materials was taken in each pot but their ratio were varied from treatment to treatment (Table 4). Filled up organic residues were mixed up properly and sufficient water was added for wetting the residue. All the treatments pre-incubated about 5 weeks for overcoming of thermal phase and softening the organic materials, so that released earthworms can survive and multiply into organic residues. The total incubation period was 15 weeks (pre-incubation for 5 weeks +after inoculation with earthforms for 10weeks). Evolution of carbon dioxide (CO_2) and changes of pH have been recorded in 7 days interval after inoculation of eartmworms as treatment plan up to 10 weeks. Evolution of CO_2 was measured by sodium hydroxide alkali (NaOH) trapping and titrating with hydrochloric acid (Jain et al. 2003). The trap was prepared taking 40 ml of 2 M NaOH in a plastic bottle of 100 ml in size. Such traps were placed on the surface of decomposing organic materials in the pots for each treatment and empty glass jar were inverted on the trap so that trap can stand in central position and inserted the glass jar about 2cm into the decomposing organic materials for air tied the system. Empty pot with alkali alone was used as control. After 7 days, traps were collected at 11.00 a.m. covering with screw cap and replaced with new traps. Timing was maintained in such a way that CO_2 absorption takes place for 7 days. Data were collected at 7 days interval up to 10 weeks. The evolution of CO_2 expressed in mg CO_2 cm^{-2} $week^{-1}$. Organic carbon and total N, P, K and S determined from the final decomposed organic materials or vermicompost.

Table 3. Nutrient contents in different organic materials used in the experiment

Organic materials	Org C(%)	%N	%P	%K	%S
Poultry manure	29.15	1.34	0.45	1.1	0.85
Cowdung	35.3	0.78	0.38	0.46	0.28
Rice straw	37.5	0.67	0.12	1.4	0.09
Giant mimosa residue	31.0	1.76	0.25	0.56	0.34
Soil	0.94	0.13	15 (mg kg^{-1})	0.13 (meq%)	14 (mg kg^{-1})

Table 4. Rates of different organic materials used for each treatment on the basis of oven dry for incubation

Treatment Code	kg pot^{-1}					Earthworms
	Soil	Cowdung (CD)	Rice straw (RS)	Poultry manure (PM)	Giant mimosa residue (GMR)	
T_1	2	2	4	0	0	EW1
T_2	2	2	0	4	0	EW1
T_3	2	2	0	0	4.0	EW1
T_4	2	2	1.33	1.33	1.33	EW1
T_5	2	0	2	2	2	EW1
T_6	2	2	4	0	0	EW2
T_7	2	2	0	4	0	EW2
T_8	2	2	0	0	4.0	EW2
T_9	2	2	1.33	1.33	1.33	EW2
T_{10}	2	0	2	2	2	EW2
T_{11}	2	2	4	0	0	-
T_{12}	2	2	0	4	0	-

T_{13}	2	2	0	0	4	-
T_{14}	2	2	1.33	1.33	1.33	-
T_{15}	2	0	2	2	2	-

Experiment **3**: **Integrated effects of vermicompost with inorganic fertilizer on soil fertility and crop productivity**

Field experiments were conducted to investigate the effect of vermicompost on soil fertility and crop productivity in the Mustard -Boro rice-T.aman rice cropping sequence. The experiments were carried out with eight treatments and three replication in Randomized Complete Block Design (RCBD). The treatments for the crops used in the experiments were as follows:

T_1: Native soil fertility

T_2:100% chemical fertilizer (CF)

T_3: 75% CF

T_4: 75% CF + Vermicompost (VC) @ 4 tha^{-1}

T_5:85%CF

T_6: 85% CF + VC @ 4 tha^{-1}

T_7: 75%CF +VC @ 2 tha^{-1}

T_8: 85%CF+VC @ 2 tha^{-1}

The unit plot size was 3m× 4m in all the location. The experiments conducted at three location viz. i) BINA farm Mymensingh (AEZ-9) ii) Farmer's field Khoddo Tampat, Rangpur sadar (AEZ-3) and iii) Farmer's field, Ista, Ishurdi, Pabna (AEZ-11). Initial soil was collected from all the location to determine the physico-chemcal properties. The properties of initial soil have been given in the Table 5. Fertilizer applied on the basis of soil test (STB) (Table 6). Nutrient content of applied vermicompost was determined and have been given in table 7. Amount of nutrients added from vermicompost (VC) in Mustard, Boro rice and T. aman rice were determined (Table 8). After harvest of Mustard (Binasharisha-10), then Binadhan-14 and Binadhan-17 were transplanted in the Boro and T.aman seasons respectively, following same layout. Mustard was sown on 23, 20 and 27 Nov. at Mymensingh, Rangpur and Ishurdi, respectively and hrvasted on 8, 11 and 21 Feb. 2018 at Mymensingh, Rangpur and Ishurdi, respectively. Boro rice transplanted on 01, 08 and 07 March 2018 at Mymensingh, Rangpur and Ishurdi, respectively and harvested on 21, 29 and 27 May 2018, respectively. T.aman rice transplanted on 01, 08 and 07 August 2018 at Mymensingh, Rangpur and Ishurdi respectively and harvested on 10, 06 and 13 Nov. 2018, respectively. Yield and yield contributing characters of mustard, Boro rice and T. aman rice were recorded during the harvest. Post harvest soil was collected after harvesting of T. aman rice for determination of pH and Org.C and different nutrients (N, P, K and S) following the methods as described in the FRG (2012).

Table 5. Properties of initial soils of different experimental field

Soil properties	BINA farm Mymensingh	Rangpur sadar (Farmer's field)	Ishurdi, Pabna (Farmer's field)
Soil texture	Silt loam	Silt loam	Silty clay loam
pH	6.85	5.9	7.1
Organic carbon(%)	0.93	0.91	0.84
Total N(%)	0.1	0.09	0.1
Available P (mg kg^{-1} soil)	15.0	13.0	14.0
Exchangeable K ($cmolkg^{-1}$)	0.151	0.141	0.171
Available S (mg kg^{-1} soil)	15.0	14.0	13.0

Table 6. Full (100%) fertilizer rates (kg ha^{-1}) on the basis of soil test for mustard, Boro and T. aman rice at different location.

Location	Mustard				Boro rice				T.aman rice			
	N	**P**	**K**	**S**	**N**	**P**	**K**	**S**	**N**	**P**	**K**	**S**
i) BINA farm Mymensingh	87	18	47	10	131	9.8	60.4	10.2	87	8	40	12
ii) Khoddo Tampat, Rangpur sadar (Farmer's field)	120	20	49	11	136	11.9	64	11.2	120	8	42	10

iii) Ista, Ishurdi, Pabna (Farmer's field)	87	19	49	12	131	11	63.6	**11.5**	87	8	35	10

Table 7. Nutrient contents in applied vermicompost

N (%)	P (%)	K (%)	S(%)
1.3	**0.6**	**1.4**	**0.38**

Table 8. Amount of nutrients added from vermicompost (VC) in mustard or boro rice or T. amam rice

Rate of vermicompost ($t\ ha^{-1}$)	Amount of Nutrients ($kgha^{-1}$)			
	N	P	K	S
2	26	12	28	7.6
4	52	24	56	15.2

11.Results and discussion:

Experiment 1: Background survey and isolation of earthworms from three agro-ecological Zones (AEZs)

Various earthworms were isolated from different places from six areas (Ishurdi, Satkhira sadar, Mymensingh sadar, Jamalpur sadar, Rangpur sadar and Dinajpur sadar) of three AEZs (AEZ 9, AEZ 11and AEZ 3) which have been presented in the table 9. Different physico-chemical properties of corresponding soils were related to the abundance of earthworms have been presented in the table 10 and fig. 2a-f. The properties of collected soils varied in their texture, pH, bulk density EC, organic C, total N, available P and exchangeable K (Table 10). The abundance of earthworms also related with the properties of different soils. Gray coloured and large sized earthworms were isolated from maximum sites. Maximum earthworms (127 earthworms m^{-2} area) were found in mahogani plantation at BINA substation farm, Jamalpur (AEZ 9) where the soil was loam and minimum earthworms were recorded from mixed plantation of RARS farm Ishurdi, Pabna (AEZ 11) and mixed garden of ATI, Ishurdi, Pabna (Table 9). As regard to AEZ the highest number of earthworms were observed in the AEZ 9 (Fig.1) followed by the AEZ 3. The results showed the positive correlation of soil properties organic C, N and P with the earthworms abundance and a negative correlation was observed with soil bulk density, soil pH and exchangeable K. Salehi et al. (2013) reported that correlation coefficient showed a positive correlation of organic C and total N and negative correlation of pH and bulk density with earthworms biomass. The present results indicated that abundance of earthworms (no. m^{-2} area) was varied with the changes of land use, land type, soil properties and other anthropogenic practices. Changes in vegetation can affect the distribution and abundance of earthworms through changes in litter quality and indirectly through changes in soil properties (Muys and Granval, 1997; Irannejad and Rahmani, 2009). Hence, loam soil, organic C, N, P and almost neutral soil pH are favourable for higher number of all earthworms types in this study.

Table 9. Abundance of earth worms in soils of different AEZs

SL No.	**GPS reading**	**AEZ, Area and Location**	**Land use**	**Abundance of earth worm m^{-2} (No.)**	**Size and colour of earthworms**	**Code No.**	**Types of earthworms**
		AEZ 11: Isurdi, Pabna:					
1.	N:24^0 07.386′ E: 89^0 04.867′	BINA, Substation Farm	Fallow	15	Black, Large	ISD-1	*Perionix excavatus*
2.	N:24^0 07.129′ E: 89^0 05.460′	Aronkula	fallow	10	Black, Large	ISD-2	do
3.	N:24^0 07.394′ E: 89^0 04.787′	ATI	Mixed garden	8	Grey, Large	ISD-3	do
4.	N:24^0 07.362′ E: 89^0 04.709′	RARS	Mixed garden	8	Red, thin, narrow	ISD-4	*Eisenia. foetida*
5.	N:24^0 06.651′ E: 89^0 06.077′	Charmirkamari	Mixed garden	20	Black, large	ISD-5	do
		Satkhira sadar:					
6.	N:22^{0}45.071′ E: 89^{0}06.411′	BINA substation	Coconut garden	17	Grey, Large	SAT-1	*Lumbricus rubelus*
7.	N: 22^0 44.728′ E: 89^0 0.1593′	Nebakhali	Mango orchard	25	Grey, Large,	SAT-2	do
8.	N: 22^0 45.052′ E: 89^0 01.361′	Godaghata Kormkarpara	Fallow (Jute)	34	Reddish Large	SAT-3	*E.. foetida*
9.	N: 22^0 45.750′ E: 89^0 06.900′	Ramitia, Nagarghata	Banana garden	10	Reddish large	SAT-4	do
10	N: 22^0 45.794′ E: 89^0 06.877′	Motbari, Nagarghata	Mango orchard	15	Black, Large	SAT-5	*P. excavatus*
		AEZ 9: **Mymensingh**					

		sadar:					
11.	N:24^0 42.715′ E: 90^0 26.847′	Boira	Fallow	41	Grey, Large	My-1	*P. excavatus*
12.	N:24^0 40.165′ E: 90^0 26.994′	Bhabokhali	Banana garden	10	Black, Large	My-2	do
13.	N:24^0 40.321′ E: 90^0 25.149′	churkhai	Chili field	34	Black, Large	My-3	*do*
14.	N:24^0 46.150′ E: 90^0 26.869′	Shombugonj	Mixed garden	70	Grey, large	My-4	*L. rubelus*
15.	N:24^0 43.553′ E: 90^0 25.764′	BINA Farm, Mymensingh	Giant mimosa field	95	Black, Large Grey, Large Reddish medium large	My-5	*P. excavatus* *E.. foetida*
		<u>Jamalpur:</u>					
16.	N:24^0 56.318′ E:89^{0}55.523′	BINA substation farm	Mahogani plantation	127	Grey, Large Reddish, large	JP-1	*P. excavatus* *E.. foetida*

Table 9. continued

SL No.	GPS reading	AEZ, Area and Location	Land use	Abundance (no. m^{-2})	Size and colour earthworms	Code No.	
17.	N:24^0 56.287′ E:89^{0}55.896′	RARS	Brinjal-fallow	55	Grey, Large,	JP-2	*P. excavatus*
18.	N:24^0 56.228′ E:89^{0}55.806′	Chandra	Mixed garden	33	Grey, Large	JP-3	do
19.	N:24^0 57.560′ E:89^{0}54.856′	Goabaria	Mixed garden	60	Grey, Large	JP-4	do
20.	N:24^0 55.331′ E:89^{0}54.581′	Rashidpur	Dhaincha-fallow	15	Grey, Large	JP-5	do
		AEZ 3: Tista Meander Floodplain **Rangpur**					
21.	N:25^0 43.402′ E: 89^0 16.720′	BINA sub station farm	Summer mungbean -Fallow	54	Redish, Grey, Large	RP-1	*E. foetida*
22.	N:25^0 42.511′ E: 89^0 14.769′	Ghagot para, Akkelpur	Sugarcane	11	Black, medium	RP-2	*Eudrillus eugeni*

							ae
23.	N:25⁰ 42.281′ E: 89⁰ 14.146′	Dangarpara, Akkelpur	Mango orchard	22	Black Large	RP-3	do
24.	N:24⁰ 47.936′ E: 89⁰ 14.129′	Chabbish Hazari, Burirhat	Ginger field	30	Black Large	RP-4	*do*
25.	N:25⁰ 49.201′ E: 89⁰ 14.471′	Uttar Kubaro	Amaranthus	30	Black, large,	RP-5	*do*
		Dinajpur					
26.	N:25⁰ 44.983′ E:88⁰.40.365′	Gornurpur	Summer mungbean -Fallow	30	Grey, Large	DP-1	*P. excavatus*
27.	N:25⁰ 44.509′ E:88⁰40.430′	Wheat Research Center, Nashipur	Sugarcane	35	Large, Grey	DP-2	do
28.	N:25⁰ 42.932′ E:88⁰39.710′	Nashipur	Mango orchard	21	Grey, Large	DP-3	do
29.	N:25⁰ 36.502′ E:88⁰40.779′	Chuniapara	Ginger field	38	Grey Large	DP-4	do
30.	N:25⁰ 35.472′ E:88⁰42.429′	Jaliapara	Amaranthus	11	Large, Grey	DP-5	do

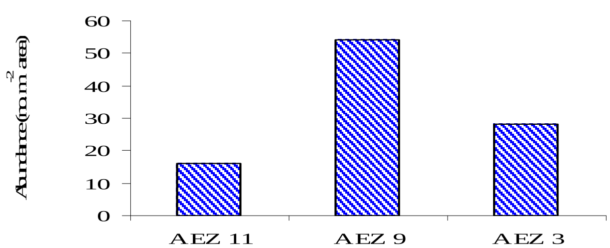
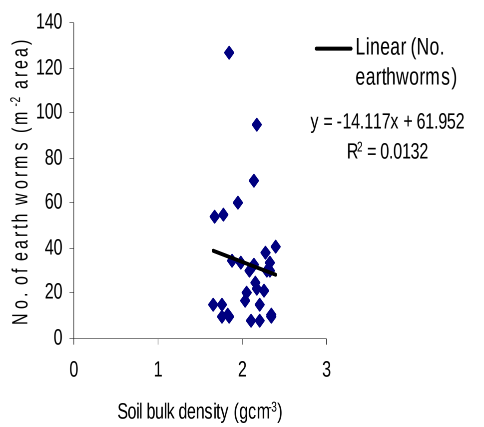


Fig 1. Average abundance of earthworms in the soils of different AEZ

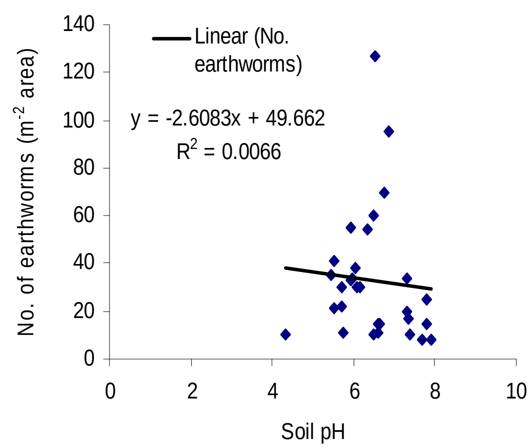
Table 10. Physico-chemical charateristics of corresponding soils where from earthworms isolated

Sample code and AEZ	Soil pH	Texture	Bulk density (g cm^{-3})	Org.C (%)	EC (dsm^{-1})	Total N (%)	Availabe P (mgkg^{-1}	Exchangeable K (meq%)
AEZ- 11:								
ISD-1	7.78	Silt loam	1.4	0.70	0.55	0.14	13.6	0.171
ISD-2	7.4	Silt loam	1.32	0.93	0.32	0.13	16.3	0.192
ISD-3	7.7	Silt Loam	1.37	0.86	0.65	0.15	10.8	0.156
ISD-4	7.92	Silt loam	1.4	0.74	0.32	0.12	9.6	0.143
ISD-5	7.3	Sill loam	1.29	0.78	0.74	0.07	13.7	0.167

SAT-1	7.36	Silt loam	1.25	1.05	1.6	0.10	12.0	0.182
SAT-2	7.79	Silt loam	1.26	1.08	1.2	0.13	11.5	0.211
SAT-3	7.31	Sill loam	1.39	0.74	1.3	0.11	14.8	0.198
SAT-4	6.51	Silt loam	1.28	1.01	1.5	0.14	18.3	0.225
SAT-5	6.59	Silt loam	1.22	1.68	1.8	0.16	16.5	0.234
AEZ-9:								
My-1	5.52	Silt loam	1.3	0.85	0.09	0.10	14.0	0.125
My-2	4.34	Silt loam	1.51	0.59	0.15	0.10	9.2	0.136
My-3	5.96	Sill loam	1.38	0.702	0.25	0.09	12.2	0.127
My-4	6.75	Silt loam	1.18	1.17	0.34	0.11	8.4	0.128
My-5	6.85	Silt loam	1.37	0.702	0.18	0.08	14.9	0.132
JP-1	6.52	Silt loam	1.23	1.092	0.13	0.16	15.8	0.082
JP-2	5.94	Silt loam	1.29	0.98	0.08	0.12	9.3	0.095
JP-3	5.94	Sill loam	1.43	0.74	0.06	0.08	10.6	0.121
JP-4	6.49	Silt loam	1.26	1.05	0.21	0.09	11.2	0.078
JP-5	6.65	Silt loam	1.47	0.62	0.15	0.09	10.9	0.092
AEZ-3:								
RP-1	6.33	Silt loam	1.52	0.66	0.17	0.09	13.4	0.157
RP-2	5.73	Silt loam	1.53	0.62	0.26	0.11	12.0	0.134
RP-3	5.72	Sill loam	1.46	0.86	0.08	0.10	11.9	0.108
RP-4	6.08	Silt loam	1.56	0.51	0.29	0.11	12.8	0.132
RP-5	6.15	Silt loam	1.39	0.85	0.14	0.12	9.7	0.125
DP-1	5.72	Silt loam	1.54	0.55	0.25	0.07	10.7	0.093
DP-2	5.44	Silt loam	1.57	0.59	0.36	0.08	14.8	0.117
DP-3	5.52	Sill loam	1.56	0.51	0.31	0.09	11.0	0.108
DP-4	6.04	Silt loam	1.45	0.74	0.19	0.09	9.5	0.132
DP-5	6.59	Silt loam	1.57	0.54	0.20	0.11	8.2	0.128
Range	4.34-7.92		1.22-1.57	0.51-1.71	0.06-1.8	0.07-0.17	8.2-18.5	0.078-0.234



a.



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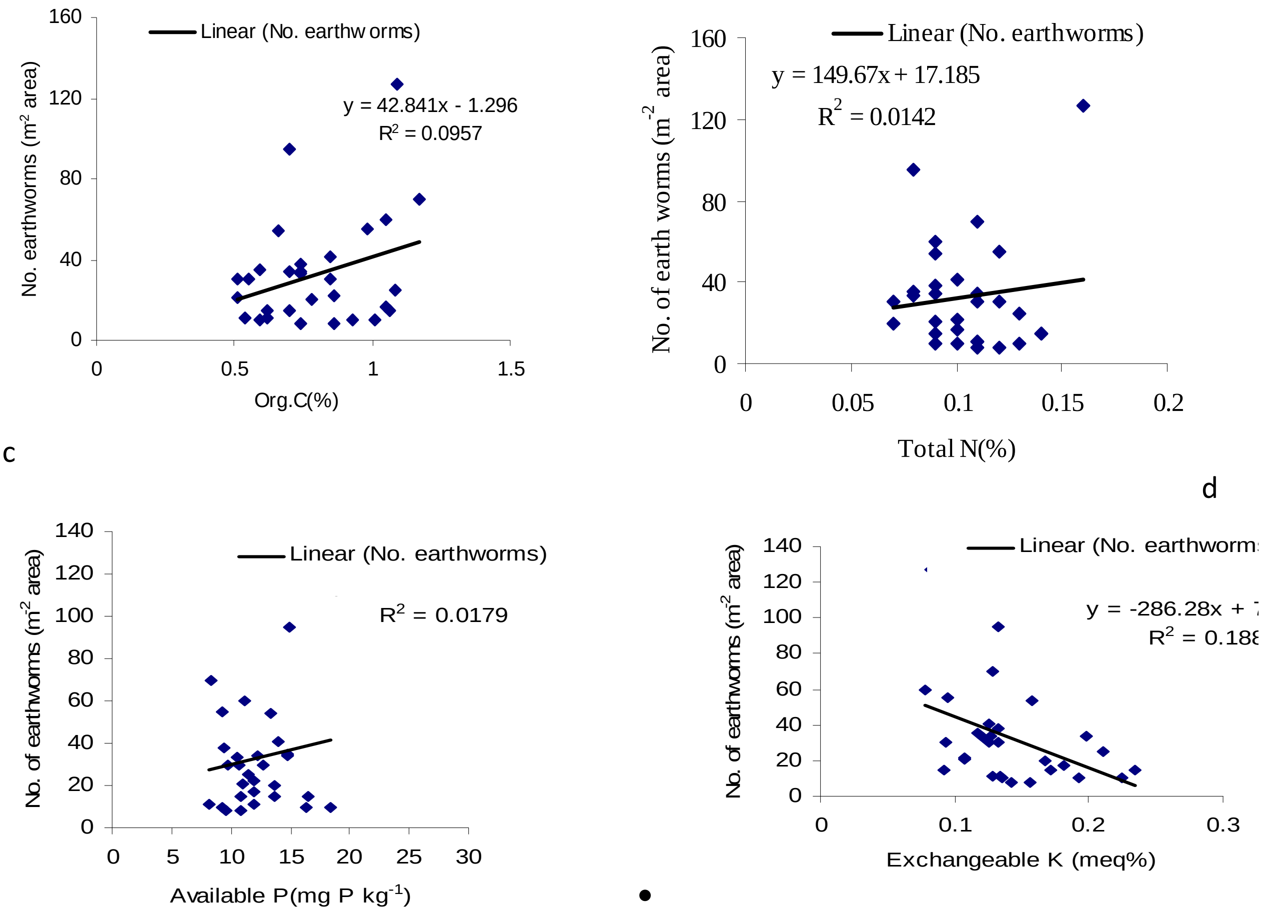


Fig 2(a-f). Correlation (n=30) between different soil parameters and abundance of earthworms

Experiment 2: **Effect of different earthworms on decomposition and nutrient release using various organic residues**

The incubation of different organic materials and their combination inoculated with earthworms or without earthworms were conducted to select the suitable organic materials and effective earthworms on the basis of decomposition and nutrient contents in decomposed organic materials in glass house.

Evolution of CO_2 during decomposition of residues after inoculated with earthworms:

Measurement of CO_2 evolution is an important indices for understanding the compost maturation or stabilization over the decomposition periods. Therefore, after pre-incubation of the treatments, CO_2 was measured for every week up to 10 weeks i.e. until the termination period. The data on evolution of CO_2 have been shown in the figure 3a and 3b. At first week, all the treatments showed highest peaks of CO_2 both in with earthworms (fig.1a) or without earthworms (Fig.1b) aided treatments. After second week, evolution was gradually decreased up to termination time (at 10 th week) but some variation was observed regarding with earthworms types and organic materials. As regard to earthworms, the earthworm-1(EW_1) aided treatments evolved greater CO_2 than the earthworm-2 aided treatments with all the organic materials at early incubation period. Without earthworms treated organic materials evolved lesser amount of CO_2 than with earthworms treated organic materials at early incubation periods and peaks were also higher in later incubation period than the with earthworm treatments. The result indicated that earthworm-1 faster decomposed the organic materials or stabilized the compost than the earthworm-2 (Ew_2). As regard to organic materials treatment T_1 gave maximum peaks of CO_2 all most throughout the incubation periods might be due to high carbon content in rice straw than other combination of organic materials. The treatment T_3 and T_8 evolved less carbon dioxide in throughout the incubation period might be due to low C:N ratio in the giant mimosa residue and this organic materials goes faster stabilization than all other treatments. The result indicated that the characteristic of organic materials were also vital factor during the vermicomposting for faster decomposition or stabilization of the vermicompost. The treatments T_3 and T_4 converted more stable vermicompost than other treatments might be both the treatment received giant mimosa residue owing low C:N ratio.

Changes of pH in different incubation period

pH was higher (7.74-9.26) during early active decompostion stages then decreased the pH in later stage. End of the incubation period pH almost neutral except poultry manure added treatments (Table 11). The changes of pH were congenial for multiply of earthworms during decompostion in all the organic materials.

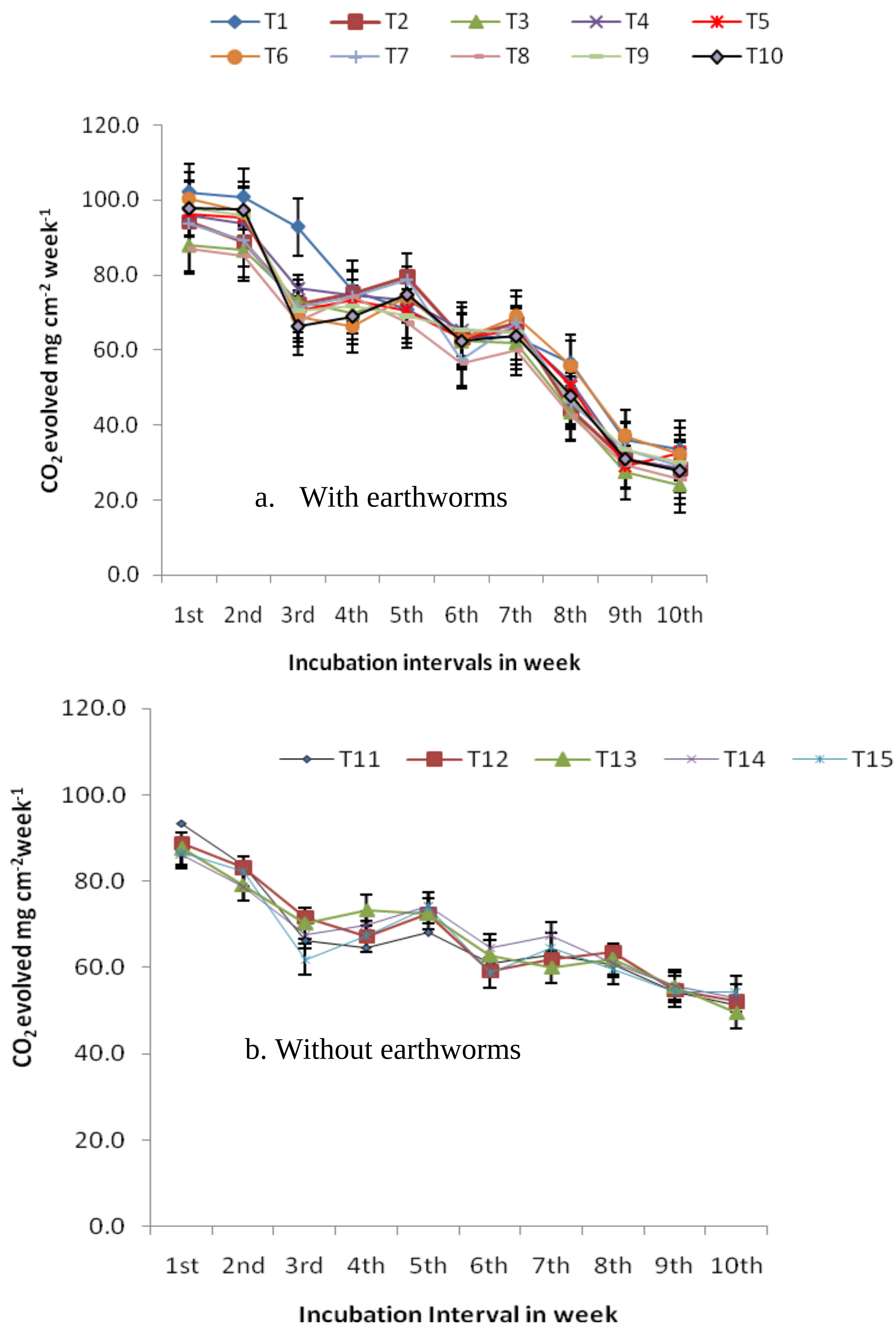


Fig.3. (a-b). Effects of earthworms on evolution of carbon dioxide during the decomposition of organic materials with or without earthworms in different incubation intervals

Table 11. Changes of pH due to various treatments in the different incubation periods

Treatments	Days after incubation				
	0	7	28	49	70
T_1	8.9	8.87	8.45	7.8	7.2
T_2	9.3	9.26	9.2	9.1	9.1
T_3	8	7.98	8.1	7.7	7.3
T_4	8.88	8.85	8.66	7.8	7.4
T_5	8.91	8.89	8.65	7.9	7.5
T_6	9	8.97	8.6	8	7.8
T_7	8.44	8.4	9.24	9.2	9.2
T_8	8.33	8.31	8.3	7.9	7.4
T_9	8.7	8.66	8.63	7.85	7.5
T_{10}	8.6	8.51	8.6	8.1	7.6
T_{11}	9	8.95	8.52	8.4	7.6
T_{12}	8.65	8.61	9.15	9.12	9.15
T_{13}	7.76	7.74	8.15	8	7.4
T_{14}	8.45	8.43	8.67	8.55	7.5
T_{15}	8.55	8.5	8.78	8.54	7.6

Number of earthworms at the end of incubation:

Earthworms were counted at the end of the incubation and number of earthworms have been shown in the fig 4. The highest number of redwigglers (*Eisenia foetida*) earthworms were recorded in the treatment T_3 (Soil+ CD+GMR+Ew_1) followed by the treatment T_4 (Soil+ CD+RS+PM+GMR+Ew_1) at the end of the incubation. These two treatment combination might be produced more stable vermicompost among the treatments.

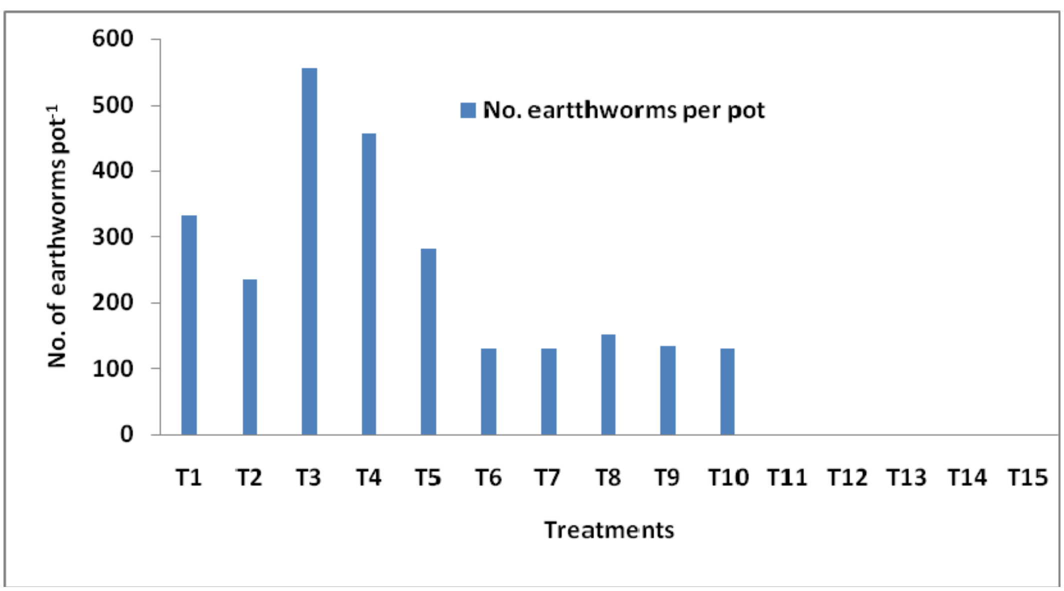


Fig. 4. Number of earthworms as affected by different treatments at the end of

the incubation

Nutrient contents in decomposed organic materials/vermicompost

Organic carbon, total N, P, K and S contents and C:N, C:P and C:S ratio were affected with earthworms or without earthworms treated organic materials during the end of the incubation and the results have been presented in the table 12. The lowest organic carbon and C:N ratio were recorded in the treatment T_2 followed by the treatment T_3 and the highest organic carbon and C:N ratio was observed in the treatment T_{15}. The lowest C:P and C:S ratio were recorded with the treatment T_2 followed by the treatment T_4 which indicated that more decomposition occurred in these in treatments than other treatments. The results indicated that the Earthworm-1 (*Eisenia. foetida*) treated organic materials (Treatments T_1, T_2 T_3 and T_4) which made more stable vermicompost than other treatment combinations. The third lowest organic carbon content and C:N ratio were observed in the treatment T_4 which received poultry manure+ giant mimosa residue+rice straw + cowdung+ earthworm-1 which is comparable with the treatment T_3. Maximum total N (1.16%) P (0.61%), K(1.57%) and S(0.4%) contents were observed with the treatment T_4 (Soil+ CD+RS+PM+GMR+Ew_1) followed by the treatment T_2 (Soil+ CD+poultry manure +Ew_1) and the lowest was recorded in the treatment T_{11}(Soil+ CD +RS).. The results showed that the mixture of low (like giant mimosa) and high (like rice straw) C:N ratio containing different organic materials treated with earthworms could be an effective approach for producing vermicompost. The results revealed that the mixtures of soil, cowdung (CD), rice straw (RS), poultry manure (PM) and giant mimosa residue (GMR) at the ratio of 2:2:1.33:1.33:1.33 with redwiglers *(Eisenia foetida)* earthworms were more suitable for the production of quality and nutrient rich vermicompost among the different treatment combinations.

Table 12. Effects of earthworms and organic materials on organic carbon and total N, P, K and S contents in decomposed organic materials/vermicompost at the end of the incubation

Treatments	O.C (%)	Total N(%)	C:N ratio	%P	C:P ratio	% K	%S	C:S ratio
T_1: Soil + cowdung (CD)+Rice straw (RS)+ Earthworms -1(Ew_1)	14.3	0.78	18.3	0.26	55.0	1.91	0.25	57.2
T_2: Soil+ CD+poultry manure (PM)+Ew_1	9.5	1.09	8.7	0.52	18.3	1.43	0.36	26.4
T_3: Soil+ CD+Giant mimosa residue (GMR)+Ew_1	10.9	1.05	10.4	0.32	34.1	1.42	0.30	36.3
T_4: Soil+ CD+RS+PM+GMR+Ew_1	13.3	1.16	11.5	0.61	21.8	1.57	0.40	33.3
T_5: Soil+RS+PM+GMR+Ew_1(Without CD)	16.9	0.87	19.4	0.32	52.8	1.53	0.32	52.8
T_6: Soil + CD+RS + Mixed earthworms -2(Ew_2)	15.1	0.74	20.5	0.21	71.9	1.64	0.22	68.6
T_7: Soil+ CD+PM +Ew_2	12.1	0.94	13.0	0.52	23.3	1.38	0.35	34.6
T_8: Soil+ CD+GMR +Ew_2	12.9	0.96	13.5	0.24	53.8	1.32	0.28	46.1
T_9: Soil+ CD+RS+PM+GMR+Ew_2	13.3	0.96	13.9	0.49	27.1	1.47	0.37	35.9
T_{10}: Soil+ RS+PM+GMR+Ew_2 (Without CD)	17.9	0.82	21.9	0.30	59.7	1.39	0.29	61.7
T_{11}: Soil+ CD +RS	17.3	0.65	26.6	0.18	96.1	1.56	0.17	101.8
T_{12}: Soil+ CD+PM	13.6	0.88	15.5	0.46	29.6	1.35	0.34	40.0
T_{13}: Soil+ CD+GMR	14.5	0.87	16.7	0.22	65.9	1.25	0.29	50.0
T_{14}: Soil+ CD+RS+PM+GMR	15.8	0.90	17.5	0.33	47.9	1.45	0.31	51.0
T_{15}: Soil+ RS+PM+GMR (Without CD)	18.0	0.75	24.1	0.29	62.1	1.37	0.26	69.2

Experiment **3**: **Integrated effects of vermicompost with inorganic fertilizer on soil fertility and crop productivity**

Field experiments conducted to investigate the effect of vermicompost on soil fertility and crop productivity in the Mustard -Boro rice-T. aman cropping sequence at Farmer's field, Rangpur, Farmer's field Ishurdi and BINA farm, Mymensingh. The results have been given below.

Yields of Mustard

Seed yield of mustard (Binasharisha 10) was significantly influenced with the different treatments at Rangpur, Ishurdi and Mymensingh (Table 13). Maximum seed yield was observed with the treatment T_6 (1.82, 1.26 and 1.49 t ha^{-1} at Rangpur, Ishurdi and Mymensingh, respectively) in all the location followed by the treatment T_8 (1.80, 1.23 and 1.46 t ha^{-1} at Rangpur, Ishurdi and Mymensingh, respectively but they were identical with the treatments T_4 and T_2 for producing of seed yield of mustard. The treatment T_6 gave identical seed yield with treatment T_2, T_4 and T_8 at Rangpur and Mymensingh while at

Ishurdi, the treatment T_6 gave statistically similar seed yield with all the treatments except the treatments T_1 and T_2. The treatments T_4, T_6 and T_8 did not differ significantly in case of seed yield of mustard which were also comparable to the treatment T_2 (100% chemical fertilizer). The lowest seed yield of mustard was observed with the treatment T_1 at all the location. Similar trends were also observed in case of straw yield of mustard at all the location. The results indicated that 75% chemical fertilizer (CF) with 4 t ha^{-1} vermicompost or 85% CF with 2 t ha^{-1} vermicompost almost equally effective to produce seed yield of mustard (Binasharisha 10) which was also comparable with the full dose from only chemical fertilizer (100% CF). Therefore 15-25% chemical fertilizer (NPKS) could be saved either with the application of 75% CF with 4 t ha^{-1} vermicompost or 85% CF with 2 t ha^{-1} vermicompost for mustard cultivation in Bangladesh.

Some yield contributing characters viz. plant height, siliqua $plant^{-1}$, seed $siliqua^{-1}$ and plant population m^{-2} of mustard also recorded and presented in the table 14. The treatments T_4, T_6 and T_8 showed also better performance in the growth and development of yield contributing characters which was very comparable with the treatment T_2 (100% CF).

Nutrients uptake by mustard

Total N, P and K uptakes were significantly affected with the different treatments at Rangpur, Ishurdi and Mymensingh (15). Maximum N uptake was observed in the treatment T_8 (85%CF+VC @ 2 tha-1) at Rangpur and Ishurdi whereas the treatment T_6 (85% CF + VC @ 4 tha^{-1}) showed maximum N uptake at Mymensingh. N uptake by mustard observed identical in the treatment T_8, T_6, and T_4 in all the location. The lowest N uptake was observed with the control treatment T_1 (Native soil fertility) in all the location. The highest P uptake observed in the treatment T_6 (85% CF + VC @ 4 tha^{-1}) in all the location followed by the treatment T_8. The highest K uptake obtained with the treatment T_6 at Ishurdi and Mymensingh whereas the treatment T_8 showed maximum K uptake at Rangpur. The result indicated that application of vermicompost with chemical fertilizer (CF) increased the nutrients uptake by mustard than only sole application of CF.

Yields of Boro rice

Grain yield of Boro rice (Binadhan-14) was significantly influenced with the different treatments at Rangpur, Ishurdi and Mymensingh (Table 16). Maximum grain yield was observed with the treatment T_6 (6.64 t ha^{-1}), T_4 (4.81 t ha^{-1}) and T_8 (5.44 t ha^{-1}) at Rangpur, Ishurdi and Mymensingh, respectively. But the treatments T_2, T_4 and T_6 and T_8 gave statistically identical grain yield of boro rice in the all the locations. The treatments T_4, T_6 and T_8 did not differ significantly in case of grain yield of boro rice in every location which were also comparable to the treatment T_2 (100% chemical fertilizer). The lowest grain yield of boro rice was observed with the treatment T_1 at all the location. In case of straw yield, the highest yield was found in the treatment T_6 at Rangpur and Ishurdi and Treatment T_5 at Mymensingh. The lowest straw yield was observed with the treatment T_1 at all the locations. Some yield contributing characters vizs. plant height, panicle length, effective tiller hill^{-1} and filled grains panicle^{-1} were also influenced with the different treatments (Table 17). The treatments T_4, $T_{6,}$ T_7 and T_8 showed similar performance in the growth and development of yield contributing characters which was very comparable with the treatment T_2 (100% CF).The results indicated that 75% chemical fertilizer (CF) with 4 t ha^{-1} vermicompost or 85% CF with 2 t ha^{-1} vermicompost almost equally effective to produce grain yield of boro rice which was also comparable with the full dose from only chemical fertilizer (100% CF). Therefore 15-25% chemical fertilizer (NPKS) could be saved either with the application of 75% CF with 4 t ha^{-1} vermicompost or 85% CF with 2 t ha^{-1} vermicompost for the cultivation of Boro rice.

Nutrient uptakes by boro rice

Total N, P and K uptakes of Boro rice were significantly affected with the different treatments in every location (Table 18). Maximum N uptake was observed in the treatment T_6 (85%CF+VC @ 4 tha^{-1}) at Rangpur and Mymensingh whereas the treatment T_4 (75% CF + VC @ 4 tha^{-1}) showed maximum N uptake at Ishurdi. Almost N uptake by Boro rice observed statistically identical in the treatment T_8, T_6, T_4 and T_2 in all the location. The lowest N uptake was observed with the control treatment T_1 (Native soil fertility) in all the location. The highest P uptake observed in the treatment T_6 (85% CF + VC @ 4 tha^{-1}) in all the location followed by the treatment T_8 (85% CF + VC @ 2 tha^{-1}). The highest K uptake by boro rice obtained with the treatmentT_6 at Rangpur and Mymensingh whereas the treatment T_2 showed maximum K uptake at Ishurdi but the treatment T_2, T_4, T_6 and T_8 were statistically similar in respect of K uptake. The result revealed that the application of vermicompost with reduced rates of chemical fertilizer (CF) influenced the nutrients uptake of boro rice which was comparable to the sole application of 100%CF.

Yields of T. aman rice

Grain yield and straw yields of Boro rice (Binadhan-17) were significantly influenced with the different treatments at Rangpur, Ishurdi and Mymensingh (Table 19). Maximum grain yield was observed with the treatment T_7 at all the location (6.26, 6.07 and 6.02 t ha^{-1}, at Rangpur, Ishurdi and Mymensingh, respectively) followed by the treatments T_2 (5.17 and 5.96 t ha^{-1}) at Rangpur and Ishurdi and T_8 (5.81 tha^{-1}) at Mymensingh. But the treatments T_2, $T_{4,}$ T_7 and T_8 gave statistically identical grain yield of T.aman rice in all the locations. The treatments T_4, $T_{6,}$ T_7 and T_8 were comparable to the treatment T_2 (100% chemical fertilizer) for producing of grain yield of T. aman rice. The lowest grain yield of T. aman was observed with the treatment T_1 (Native soil fertility) at all the location. The highest straw yield was found with the treatment T_7 at Rangpur and Mymensingh whereas the treatment T_5 gave highest straw yield at Ishurdi. The lowest straw yield was observed with the treatment T_1 at all the locations. Some yield contributing characters vizs. plant height, panicle length and effective tiller hill^{-1} were also influenced with the different treatments (Table 20). The treatments T_4, T_6 and T_8 showed better performance in the growth and development of yield contributing characters which was very comparable with the treatment T_2 (100% CF). The results indicated that 75% chemical fertilizer (CF) with 2 t ha^{-1} vermicompost almost equally effective to 100% CF to produce grain yield of T.aman. Therefore 15-25% chemical fertilizer (NPKS) could be saved with the application of 75% CF with 2 t ha^{-1} vermicompost for cultivation of T. aman rice.

Nutrients uptake by T.aman rice

Total N, P and K uptakes of T. aman rice were significantly influenced with the different treatments in all the locations (Table 21). Maximum N, P and K uptakes by T. aman were observed in the treatment T_7 (85%CF+VC @ 2 tha^{-1}) at all the locations except K uptake at Ishurdi. The treatment T_8 showed maximum K uptake at Ishurdi followed by the treatment T_7. The treatments $T_{7,}$ and T_8, were showed statistically similar NPK uptakes to the treatment T_2 in all the location. The lowest NPK uptake was observed with the control treatment T_1 (Native soil fertility) in all the location. The results revealed that the application of vermicompost with reduced rates of chemical fertilizer (CF) influenced the nutrients uptake of T.aman rice which was comparable to the sole application of 100%CF.

Changes of nutrients status in post harvest soil

Post harvest soils were analyzed for pH, organic carbon, total N, available P, exchangeable K and available S to see the changes of nutrients status after cultivating of Mustard- Boro rice-T.aman in all the locations (Tables 22-24). The changes in soil pH, organic carbon and different nutrient status were observed due to the integrated use of fertilizers and vermicompost. Soil pH increased in Rangpur and Mymensingh locations due to the application of vermicompost with chemical fertilizer where initial soil reaction was slightly acidic to neutral. At Ishurdi, soil pH decreased where initial soil reaction was slightly alkaline. Organic amendments might be enhanced the increasing of pH in acidic soil and decreasing in alkaline soil. Organic carbon and N, P, K and S contents in post harvest soils were increased in the vermicompost treated plots than sole application of chemical fertilizers might be due to organic matter added through vermicompost at all the locations (Table 24-26). Soil fertility did not varied prominently with the application of variable amount of vermicompost might be due to short term application of vermicompost (only one cropping cycle) but some positive changes of soil fertility was observed in the various doses of vermicompost. Hence, the result revealed that soil amended with vermicompost @ 2-4 tha^{-1} with reduced rates (15-25%) of chemical fertilizers (NPKS) is a good option to sustain the soil fertility in the Mustard- Boro rice-T.aman cropping sequence.

Table 13. Effect of vermicompost with inorganic fertilizer on seed and straw yield (t ha^{-1}) of mustard (Binasharisha- 10) at different location during 2017-18

Treatments	Rangpur		Ishurdi		Mymensingh	
	Seed yield	Straw yield	Seed yield	Straw yield	Seed yield	Straw yield
T_1	0.58c	2.22b	0.29c	0.83b	0.26d	1.41b
T_2	1.72a	4.47a	1.22a	3.78a	1.43ab	3.23a
T_3	1.42b	4.36a	0.81b	3.27a	0.88c	3.03a
T_4	1.76a	4.51a	1.20a	3.73a	1.44ab	3.37a
T_5	1.53b	4.44a	1.07a	3.43a	1.03c	3.10a
T_6	1.82a	4.55a	1.26a	3.91a	1.49a	3.40a
T_7	1.54b	4.45a	1.13a	3.63a	1.34b	3.33a
T8	1.80a	4.71a	1.23a	3.85a	1.46ab	3.32a
CV(%)	6.25	5.50	12.26	10.50	7.09	8.00

Note:T_1: Native soil fertility, T_2:100% chemical fertilizer (CF), T_3: 75% CF, T_4: 75% CF + Vermicompost (VC) @ 4 tha^{-1}, T_5:85%CF, T_6: 85% CF + VC @ 4 tha^{-1}, T_7: 75%CF +VC @ 2 tha^{-1}, T_8: 85%CF+VC @ 2 tha^{-1}

Table 14. Effect of vermicompost with inorganic fertilizer on yield contributing characters of mustard at different location during 2017-18

Treatment	Rangpur				Ishurdi				Mymensingh			
	Plant height (cm)	Siliqua $plant^{-1}$ (no.)	Seeds $siliqua^{-1}$ (no.)	Plants m^{-2} (no.)	Plant height (cm)	Siliqua $plant^{-1}$ (no.)	Seeds $siliqua^{-1}$ (no.)	Plants m^{-2} (no.)	Plant height (cm)	Siliqua $plant^{-1}$ (no.)	Seeds $siliqua^{-1}$ (no.)	Plants m^{-2} (no.)
T_1	65.5b	31.9d	11.97c	135.8b	52.6b	18.3b	11.2b	83.0b	29.8b	11.5c	9.3c	125.0b
T_2	97.4a	102.4ab	15.6a	170.7a	83.8a	62.4a	15.4a	181.3a	91.2a	76.7ab	15.9a	173.0a
T_3	93.0a	72.7bc	13.0bc	160.5a	81.2a	56.3a	14.5a	162.7a	80.1a	66.8b	12.1b	155.0ab
T_4	98.5a	101.3ab	15.3a	166.9a	83.5a	63.0a	15.4a	179.0a	80.7a	80.2ab	15.8a	168.7a
T_5	93.6a	82.2abc	14.5ab	164.2a	83.3a	59.0a	15.0a	173.3a	80.0a	74.8ab	14.8a	166.3a
T_6	98.7a	106.3a	16.1a	168.3a	86.1a	64.0a	15.8a	183.3a	86.3a	86.7a	16.0a	172.0a
T_7	98.3a	88.2c	14.5ab	171.0a	83.1a	60.0a	15.2a	180.0a	80.3a	75.0ab	15.5a	167.0a
T_8	99.3a	105.2a	15.8a	164.0a	83.1a	64.6a	15.6a	187.7a	81.6a	83.0a	15.9a	170.0a
CV(%)	4.68	19.92	5.86	8.89	6.00	9.67	9.05	11.17	8.62	12.28	7.71	9.25

Table 15. Total N, P, and K uptakes (kg ha^{-1}) by mustard as affected by different treatments

Treatment	Rangpur			Ishurdi			Mymensingh		
	N	P	K	N	P	K	N	P	K
T_1	28.8e	7.3e	34.8e	11.5d	3.0f	13.7f	14.8e	4.0f	22.0e
T_2	91.6b	25.2b	81.9b	65.1ab	18.5b	66.4b	72.6b	20.8c	63.0b
T_3	72.9d	19.1d	75.0d	44.4c	11.4e	53.4e	46.4d	13.0e	50.8d
T_4	93.8ab	25.6b	82.5b	52.8bc	18.1b	65.1b	73.9ab	21.5b	64.7a
T_5	82.2c	22.9c	77.2cd	57.5abc	16.1d	59.2d	55.1c	15.7d	55.7c
T_6	96.9a	27.3a	84.3ab	68.4a	19.6a	69.1a	76.4a	22.5a	66.4a

T_7	85.9c	24.0c	79.3c	63.2ab	17.6c	62.3c	70.9b	20.0c	62.5b
T_8	97.3a	26.5ab	85.1a	68.3a	18.6b	67.0ab	74.7ab	21.5b	63.9b
SE	**1.33**	**0.50**	**0.74**	**4.36**	**0.32**	**0.65**	**1.19**	**0.28**	**0.83**
CV(%)	**7.54**	**6.78**	**7.96**	**14.02**	**5.94**	**9.45**	**8.23**	**7.52**	**6.87**

Table 16. Effect of vermicompost with inorganic fertilizer on grain and straw yield (t ha^{-1}) of Boro rice (Binadhan- 14) at different location during 2017-18

Treatments	Rangpur		Ishurdi		Mymensingh	
	Grain yield	Straw yield	Grain yield	Straw yield	Grain yield	Straw yield
T_1	2.30e	2.52c	2.73c	3.04b	2.68e	2.42d
T_2	6.60a	6.13ab	4.72a	4.46a	5.26ab	4.95ab
T_3	5.28d	6.13ab	3.96b	4.23a	4.38d	4.84ab
T_4	6.50ab	6.07b	4.81a	4.36a	5.17abc	4.93ab
T_5	6.15bc	6.23ab	4.18ab	4.33a	4.70cd	5.04ab
T_6	6.64a	6.70a	4.80a	4.35a	5.38a	5.25a
T_7	6.00c	6.35ab	4.54ab	4.13a	4.80bcd	4.39c
T_8	6.53a	6.23ab	4.61ab	4.44a	5.44a	4.73bc
CV(%)	**8.82**	**5.66**	**9.54**	**7.05**	**5.67**	**5.21**
lsd	**0.385**	**0.574**	**0.717**	**9.65**	**0.47**	**0.416**

Table 17. Effect of vermicompost with inorganic fertilizer on yield contributing characters of Boro rice (Binadhan 14) at different location during 2017-18

Treatment	Rangpur				Ishurdi				Mymensingh			
	Plant height (cm)	Panicle length(cm)	Effective tiller (no.)	Filled grain panicle^{-1} (no.)	Plant height (cm)	Panicle length(cm)	Effective tiller (no.)	Filled grain panicle^{-1} (no.)	Plant height (cm)	Panicle length(cm)	Effective tiller (no.)	Filled grain panicle^{-1} (no.)
T1	73.27c	16.47c	5.9b	63.0e	67.0b	16.7b	6.3b	78.8c	71.3c	17.5b	6.4d	80.0d
T2	93.73a	20.80ab	9.1a	120.0ab	91.3a	18.9ab	9.0a	112.0a	84.9ab	22.5a	10.0a	112.3a
T3	90.20b	19.47b	8.5a	92.20d	83.0a	17.9ab	8.3a	91.5b	81.3b	21.5a	8.8c	96.7c
T4	93.20a	21.13a	9.3a	119.0ab	90.00a	19.8a	9.7a	109.0a	84.7ab	22.0a	9.6abc	111.0ab
T5	93.07ab	21.07a	8.6a	101.8cd	86.00a	18.9ab	8.7a	96.3b	84.3ab	21.8a	8.9bc	98.0bc
T6	93.40a	21.20a	9.3a	120.3a	90.67a	19.8a	9.7a	110.9a	85.5ab	22.5a	9.8abc	116.0a
T7	93.63a	21.13a	8.9a	108.9bc	87.0a	19.2	8.7a	102.0ab	84.7ab	22.1a	9.1abc	105.0abc
T8	93.00ab	21.20a	9.2a	118.7ab	91.0a	19.8a	9.6a	111.3a	87.7a	22.5a	10.1a	113.3a
CV(%)	**3.84**	**4.00**	**9.62**	**6.11**	**8.54**	**6.92**	**10.6**	**7.03**	**3.1**	**3.79**	**6.61**	**7.77**
lsd	**2.92**	**1.424**	**1.44**	**11.29**	**12.68**	**2.28**	**1.62**	**12.5**	**4.444**	**1.05**	**1.05**	**14.15**

Table 18. Total N, P, and K uptakes (kg ha^{-1}) by Boro rice as affected by different treatments

Treatment	Rangpur			Ishurdi			Mymensingh		
	N	P	K	N	P	K	N	P	K
T_1	34.9d	7.1d	42.2d	42.2c	7.9c	48.7b	38.8d	8.8e	39.6d
T_2	105.3a	25.8ab	115.1ab	76.6a	18.1a	82.1a	84.3a	21.1ab	90.1ab
T_3	85.5c	18.8c	104.6c	63.4b	13.3b	71.6a	68.9c	15.4d	82.4c
T_4	104.0ab	25.5b	113.2b	77.7a	17.7a	80.4a	83.1a	19.8b	90.1ab
T_5	98.7b	23.5c	111.9bc	68.4ab	15.2b	76.6a	76.9b	18.3c	88.6b
T_6	108.5a	27.3a	122.4a	77.5a	18.1a	80.2a	86.2a	21.9a	95.0a

T_7	98.3b	25.1b	115.0ab	72.5ab	17.2ab	75.7a	75.4b	18.7c	79.5c
T_8	105.1a	26.4a	116.4ab	75.7a	17.8a	81.9a	85.8a	21.3ab	87.6b
SE	**1.96**	**0.47**	**2.98**	**3.01**	**0.71**	**3.55**	**1.8**	**0.42**	**1.93**
CV(%)	**7.21**	**6.84**	**5.86**	**7.54**	**7.83**	**8.23**	**7.87**	**6.85**	**8.93**

Table 19. Effect of vermicompost with inorganic fertilizer on grain and straw yield (t ha^{-1}) of T.aman rice (Binadhan -17) at different location during 2018

Treatments	Rangpur		Ishurdi		Mymensingh	
	Grain yield	Straw yield	Grain yield	Straw yield	Grain yield	Straw yield
T_1	3.26d	4.03c	3.00d	4.05b	3.11c	3.92b
T_2	5.17a	5.72a	5.96a	6.18a	5.76a	5.54a
T_3	3.97c	4.76b	3.70c	5.67a	3.81c	5.66a
T_4	5.18a	5.80a	5.64a	6.02a	5.43a	5.87a
T_5	4.88b	5.44a	4.69b	6.05a	4.69b	5.37a
T_6	5.05a	5.53a	5.74a	6.35a	5.32ab	5.77a
T_7	5.26a	6.08a	6.07a	6.28a	6.02a	5.87a
T_8	5.13a	5.75a	5.94a	6.33a	5.81a	5.78a
SE	**0.114**	**0.203**	**0.265**	**0.321**	**0.279**	**0.306**
CV(%)	**7.92**	**6.53**	**9.0**	**9.45**	**9.69**	**9.69**

Note:T_1: Native soil fertility, T_2:100% chemical fertilizer (CF), T_3: 75% CF, T_4: 75% CF + Vermicompost (VC) @ 4 tha^{-1}, T_5:85%CF, T_6: 85% CF + VC @ 4 tha^{-1}, T_7: 75%CF +VC @ 2 tha^{-1}, T_8: 85%CF+VC @ 2 tha^{-1} .

Table 20. Effect of vermicompost with inorganic fertilizer on yield contributing characters of T. aman rice (Binadhan- 17) at different location during 2018

Treatment	Rangpur			Ishurdi			Mymensingh		
	Plant height (cm)	Panicle length(cm)	Effective tiller (no.)	Plant height (cm)	Panicle length(cm)	Effective tiller (no.)	Plant height (cm)	Panicle length(cm)	Effective tiller (no.)
T_1	85.5c	20.5b	8.9c	86.5b	20.8c	8.8d	85.9c	20.47b	8.9c
T_2	95.4a	26.5a	11.1a	98.5a	24.1a	13.1a	98.0a	23.53a	12.7a
T_3	91.1b	25.1a	9.9b	95.1a	23.5b	10.4b	94.6b	24.13a	10.1b
T_4	94.1a	26.5a	10.8ab	98.7a	25.3a	12.3ab	99.8a	25.53a	11.9ab
T_5	91.7b	26.1a	10.6ab	95.9a	24.3a	11.3b	95.1b	24.87a	10.7b
T_6	94.8a	25.2a	11.0a	99.6a	24.9a	13.4a	99.6a	24.13a	12.0a
T_7	94.3ab	27.3a	11.3a	96.8a	25.1a	13.0a	97.0a	25.23a	12.6a
T_8	95.7a	25.7a	11.3a	97.6a	24.9a	13.0a	96.9a	24.67a	11.6b
SE	**1.02**	**0.96**	**0.43**	**1.12**	**0.74**	**0.35**	**1.30**	**0.96**	**0.31**
CV(%)	**5.8**	**6.56**	**6.93**	**6.9**	**7.8**	**8.4**	**6.3**	**6.6**	**7.5**

Table 21. Total N, P and K uptakes (kg ha^{-1}) by T.aman as affected by different treatments

Treatment	Rangpur			Ishurdi			Mymensingh		
	N	P	K	N	P	K	N	P	K
T_1	52.5e	11.5d	64.8c	50.1d	11.4d	65.3c	50.9d	10.8d	63.2b
T_2	85.7a	23.0a	101.5a	97.0a	26.5a	111.8a	91.8a	23.9a	100.5a
T_3	65.1d	15.9c	80.3c	65.1c	16.4c	93.3b	67.7c	15.7c	93.1a

T_4	83.8b	22.6a	101.7a	91.9a	24.8a	107.0a	89.3a	23.4a	103.5a
T_5	79.4c	20.7b	94.4b	79.5b	21.0b	102.5a	78.1b	19.6b	92.9a
T_6	83.4b	21.8ab	97.3b	94.0a	25.5a	112.2a	87.1a	22.4a	101.7a
T_7	88.3a	23.8a	107.1a	99.3a	27.0a	113.6a	97.5a	25.7a	107.4a
T_8	85.3a	22.9a	101.8a	97.4a	26.7a	113.8a	92.8a	23.8a	104.7a
SE	**1.46**	**0.37**	**2.86**	**3.59**	**0.94**	**4.85**	**4.34**	**1.9**	**5.58**
CV(%)	**7.84**	**6.9**	**5.29**	**7.38**	**7.28**	**8.21**	**9.19**	**9.11**	**10.1**

Table 22. Changes in nutrient status of post harvest soil at Rangpur

Treatments	**pH**	**O.C(%)**	**N(%)**	**P(%)**	**K(cmolkg^{-1})**	**S (mgkg^{-1})**
T_1	5.9	0.90	0.09	13.0	0.139	12.95
T_2	5.8	0.94	0.09	14.2	0.143	13.0
T_3	5.9	0.93	0.09	13.8	0.142	13.0
T_4	6.0	0.95	0.10	14.7	0.144	13.6
T_5	5.8	0.93	0.09	14.2	0.43	13.0
T_6	6.0	0.95	0.10	14.7	0.144	13.5
T_7	6.0	0.95	0.10	14.8	0.145	13.6
T_8	6.0	0.95	0.10	14.6	0.144	13.6
Initial	**5.9**	**0.91**	**0.09**	**13**	**0.141**	**13**

Table 23. Changes in nutrient status of post harvest soil at Ishurdi

Treatments	**pH**	**O.C(%)**	**N(%)**	**P(%)**	**K(cmolkg^{-1})**	**S (mgkg^{-1})**
T_1	7.1	0.83	0.09	13.8	0.170	12.9
T_2	7.1	0.88	0.10	14.1	0.172	13.30
T_3	7.1	0.85	0.10	14.3	0.171	13.0
T_4	7.0	0.91	0.11	14.7	0.173	13.8
T_5	7.1	0.87	0.10	14.4	0.171	13.2
T_6	7.0	0.91	0.11	14.7	0.173	13.7
T_7	7.0	0.91	0.11	14.7	0.173	13.7
T_8	7.0	0.91	0.11	14.7	0.173	13.8
Initial	**7.1**	**0.84**	**0.10**	**14**	**0.171**	**13.0**

Table 24. Changes in soil nutrient status nutrient status of post harvest soil at Mymensingh

Treatments	**pH**	**O.C(%)**	**N(%)**	**P(%)**	**K(cmolkg^{-1})**	**S (mgkg^{-1})**
T_1	6.85	0.91	0.09	14.9	0.150	14.8
T_2	6.9	0.94	0.10	15.3	0.152	15.4
T_3	6.9	0.93	0.10	15.1	0.151	15.1
T_4	6.9	0.96	0.11	15.7	0.154	15.8
T_5	6.9	0.93	0.10	15.2	0.151	15.2
T_6	6.9	0.95	0.11	15.6	0.153	15.7
T_7	6.9	0.95	0.11	15.6	0.153	15.6
.6T_8	6.9	0.96	0.11	15.7	0.154	15.8
Initial	**6.85**	**0.93**	**0.10**	**15**	**0.151**	**15.0**

12. Research highlight/findings :

- Redwigglers earthworms isolated from vermicompost pits and other earthworms were isolated from different areas.
- Maximum earthworms were found in loam soil at BINA substation farm, Jamalpur (AEZ-9).
- Positive correlation observed between the abundance of earthworms and soil properties organic C, N and P whereas negative correlation observed with the soil bulk density, soil pH and exchangeable K.
- Greater amount of CO_2 was evolved with rice straw aided treatments with redwiggler earthworms.
- Red wigglers can decompose faster of the different organic materials and made the vermicompost greater stable than the mixtures of local earth worms.
- Maximum total N (1.16%), P (0.61%) and S (0.4%) contents were observed with the treatment T_4 (Soil+ CD+RS+PM+GMR+Ew_1) where used mixtures of soil, cowdung (CD), rice straw (RS), poultry manure (PM), giant mimosa residue (GMR) at the ratio of 2: 2:1.33:1.33:1.33 with red wiglers earthworms (*Eisenia foetida).*
- Mixtures of soil, cowdung (CD), rice straw (RS), poultry manure (PM), giant mimosa residue (GMR) at the ratio of 2:2:1.33:1.33:1.33 with red wiglers earthworms (*Eisenia foetida)* were more suitable for the production of quality and nutrient rich vermicompost among the treatment combination.
- Based on results, 75% chemical fertilizer (CF) with 4 t ha^{-1} vermicompost or 85% CF with 2 t ha^{-1} vermicompost almost equally effective to the full dose (100%) of CF to produce seed yield of mustard (Binasharisha 10) and grain yield of Boro rice. In T. aman rice, 75% chemical fertilizer (CF) with 2 t ha^{-1} vermicompost equally effective to full dose (100%) of CF.
- Therefore 15-25% chemical fertilizer (NPKS) could be saved either with the application of 75% CF with 4 t ha^{-1} vermicompost or 85% CF with 2 t ha^{-1} vermicompost for Mustard-Boro rice-T. aman cropping sequence.
- Soil fertility (organic carbon, total N, available P, exchangeable K and available S) was slightly increased with the application of vermicompost in the Mustard-Boro rice-T. aman cropping pattern.

Reference

Ali, M. M., Saheed, S. M. and Kubota, D. 1997. Soil degradation during the period 1967-1995 in Bangladesh. II. Selected chemical characters. Soil Sci. Pl. Nutri., 43 (4): 870-890.

FRG 2012, Fertilizer Recommendation Guide2012, BARC, Farmgate, Dhaka

Goyal, S., Dhull, S. and Kapoor, K.K. 2005. Chemical and biochemicl changes and compost maturity indices during vermicomposting of different organic wastes. In: Management of Organic wastes for Crop Production (eds: Kapoor, K.K., Sharma, P.K., Dudeja, S.S. and Kundu, B.S. 2005). CCS Haryana Agril Univ. Hisar. pp 111-116.

Cambardella, C. A., Richard, T. L. and Russell, A., 2003. Compost mineralization in soil as a function of composting process conditions. Eur. J. Soil Biol. 39:117-127.

Jain, M.C, Pathak, H. and Bhatia, A. 2003. Measurement of greenhouse emission from soil and developing emission inventories. In: Pathak H, Kumer S (eds) Soil and greenhouse effect monitoring and evaluation. CBS Publishers and Distributors, New Delhi, pp 65–78.

Salehi, A., Ghorbanzadeh, N. and Kahneh, E. 2013. Earthworms biomass and abundance, soil chemical and physical properties under different poplar plantations in the north of Iran. J.For. Sci. 59(6):223-229.

Muys, B. and Grannval, P 1997. Earthworms as bio-indicators of forest site quality. J. Biol. Biochem,29:323-328.

Irannezad, E. and Rahmani, R. 2009. Evaluation of earthworm abundance and vertical distribution pattern in some forest types of Shast-Kolateh. J. Forest Wood Pro.,62:145-157.

B. Implementation Position

1. Procurement:

Description of equipment and capital items	**PP Target**		**Achievement**		**Remarks**
	Phy (#)	**Fin (Tk)**	**Phy (#)**	**Fin (Tk)**	
(a) Office equipment					All achieved 100%
1. Labtop computer	01no.	59975.0	01no.	59975.0	
2. Desktop computer	01no.	59950.0	01no.	59950.0	
3. Leser Printer	01no.	19960.0	01no.	19960.0	All the equipments installed in the Soil Science Division and are being used for official works and research purposes.
4. UPS	01no.	6985.0	01no.	6985.0	
5. Digital Camera	01no.	24990.0	01no.	24990.0	
6. Scanner	01no.	9945.0	01no.	9945.0	
(b) Lab &field equipment					Achieved 100%
1. Refrigerator	01no.	54975.0	01no.	54975.0	All the equipments are being used for official works and research purposes.
2. EC meter	01no.	159740.0	01no.	159740.0	
3. GPS	01no.	39825.0	01no.	39825.0	
4.Bench top pH meter	01no.	99985.0	01no.	99985.0	
(c) Other capital items					

2. Establishment/renovation facilities:

Description of facilities	Newly established		Upgraded/refurbished		Remarks
	PP Target	Achievement	PP Target	Achievement	
1. Repairing steel holder for glass wares in lab 2. Repairing and screen setting in lab window 3. Repairing bricks made box for the production of vermicompost in BINA cowdung shed. 4. Repair and renovation of electrical switch and socket for different lab equipments and exhaust fan for fume hood.			lum-sum repair, renovation and maintenance	Achieved as described	All items are using for research purposes.
5.Repairing of sitting chair, computer table, tool for refrigerator, door locks and repairing of desk top computer.			lum-sum repair and renovation of office equipments	Achieved as described	All items are being used for official and research purposes.

3. Training/study tour/ seminar/workshop/conference organized:

Description	Number of participant			Duration (Days/weeks/ months)	Remarks
	Male	Female	Total		
(a) Training					
(b) Workshop					

C. Financial and physical progress

<u>**Fig in Tk**</u>

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
A. Contractual staff salary	217694	217694	217694	nil	100%	
B. Field research/lab expenses and supplies	907306	888510	888510	nil	1000%	
C. Operating expenses	224368	197787	197787	nil	100%	
D. Vehicle hire and fuel, oil & maintenance	83675	80525	80525	nil	100%	
E. Training/workshop/seminar etc.	00	00	00	00		
F. Publications and printing	105000	60973	00	60973		refund Tk. 60973/-
G. Miscellaneous	66362	57998	57998	nil	100%	
H. Capital expenses	536330	514044	514044	nil	100%	

D. Achievement of Sub-project by objectives: (Tangible form)

Specific objectives of the sub-project	**Major technical activities performed in**	**Output(i.e. product obtained, visible, measurable)**	**Outcome(short term effect of the**

	respect of the set objectives		research)
a) Isolation and selection of effective earthworms as rapid decomposer for different organic residues	i) Background survey and isolation of earthworms	i) Effective earthworms (Redwigglers and local earthworms) isolated for decomposing of organic residues	Soil fertility increased which enhance crop productivity and also will be increased the income generation of farmers.
b) To select the suitable organic residues/combination for producing vermicompost with effective earthworms.	ii) Evaluation of earthworms for decomposition and nutrient release	ii) Redwigglers earthworms found more effective than locally isolated earthworms. ii)Giant mimosa residues were more suitable among the used residues for producing vermicompost ii)Resource availabilty concern, mixture of cow dung, rice straw, giant mimosa and poultry manure is also a suitable option for producing vermicompost.	
c) To see the effects of vermicompost on soil fertility and crop productivity	iii) Effects of vermicompost on soil fertility and crop productivity.	i) 15-25% chemical fertilizer (NPKS) could be saved either with the application of 75% CF +VC@ 4 t ha^{-1} or 85% CF +VC@ 2 t ha^{-1} for mustard and boro rice cultivation. In T. aman rice cultivation, 25% chemical fertilizer (NPKS) could be saved with the application of 75% CF +VC@ 2 t ha^{-1} .	

E. Materials Development/Publication made under the Sub-project:

Publication	Number of publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.			
Journal publication			
Information development			
Other publications, if any			

F. Technology/Knowledge generation/Policy Support (as applied):

i. Generation of technology (Commodity & Non-commodity)

Nutrient rich vermicompost and reduce the usage of chemical fertilizer in the crop production.

ii. **Generation of new knowledge that help in developing more technology in future**

a. Long-term research should be needed to isolate the diversified effective earthworms from different ecological condition which can be used in produicng of nutrient rich vermicompost with the mixtures of different agro-wastes. Usage of nutrients rich vermicompost in different cropping system will reduce the chemical fertilizer which will leads to more sustaining soil fertility and crop productivity.

iii. Technology transferred that help increased agricultural productivity and farmers' income

iv. Policy Support

Reduce the usage of chemical fertilizer (CF) in the crop production using vermicompost so that CF could be saved.

G. Information regarding Desk and Field Monitoring

i) Desk Monitoring[description & output of consultation meeting, monitoring workshops/seminars etc.):

a) NRM Division, BARC monitored the project activities through desk monitoring report.
b) A research progress workshop of CRG sub-project, NATP Phase II under Soils program, NRM Division held on 01April, 2018 at BARC, Dhaka.
c) A monitoring workshop was held at BARC auditorium 15-16 May 2018 and presented all sub-project activities by the Expert member PIU-BARC (NATP2).
d) Annual Review Workshop on CRG Sub-projects organized by NRM Division, BARC and PIU-BARCt (NATP-2) on 24-25 Sept.2018 at BARC, Dhaka.

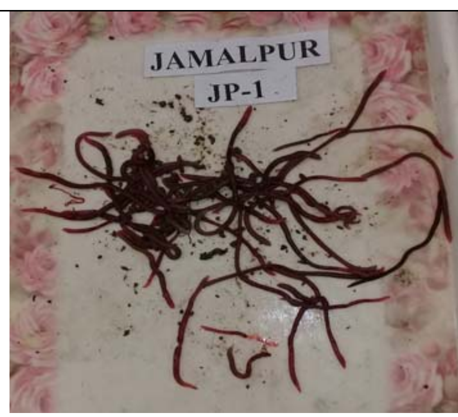
ii) Field Monitoring (time& No. of visit, Team visit and output):

a) Monitored of the field and glashouse activities by the Director, PIU-BARC-NATP-2 along with Expert member of PIU-BARC-NATP-2) and Director (Research), BINA Mymensingh on 06 March 2018. They monitored through field visit, Lab visit and power point presentation of the project activities at BINA, Mymensingh. They remarked satisfactory on research activities as per plan.
b) The Director (Research), BINA, visited mustard experimental field during January and February 2018 and boro rice experimental field during March and April 2018. He also visited T. aman rice experimental plots at Farmer's field Rangpur sadar and Ishurdi sadar and also BINA farm, Mymensingh along with the monitoring team during 26-27 October 2018. They remarked 'good' on experiments and other related research activities.

I. Lesson Learned/Challenges (if any)

i) Diversified earthworms in the soils of different agro-ecological condition are one of great resource in Bangladesh. Need to pay more attention to conduct systematic research on this areas so that more nutrient rich vermicompost could be developed.

J. Challenges (if any)



Photograph group:1: Isolation activities of earthworms from different location

A. B. C

D. E. F.

Photograph group-2: A-C incubation experiment with CO2 collection, D-E: Earthworms counting at the end of incubation, F: Redwiggler earthworms multiplied during the decomposition

Photograph group -3a: Mustard crop (Binasharisha 10) at fermer's field, Tampat, Rangpur sadar.

Photograph group -2b: Mustard crop (Binasharisha 10) at fermer's field,Ista, Ishurdi sadar.

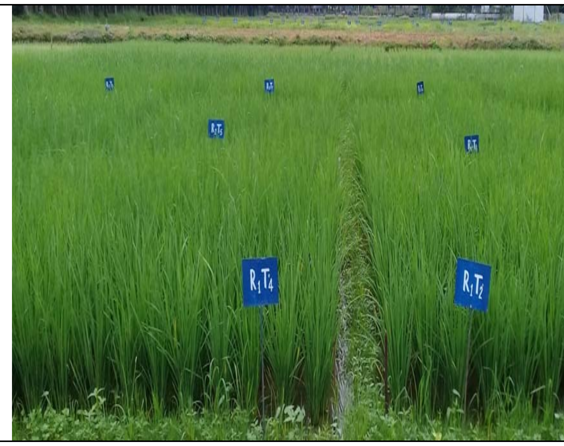
Photograph group -3c: Mustard crop (Binasharisha 10) at BINA farm, Mymensingh.

Photograph group -4a: Boro rice (Binadhan 14) at fermer's field, Tampat, Rangpur sadar


Photograph group -4b: Boro rice (Binadhan -14) at fermer's field,Ista, Ishurdi sadar visited by Director (Training &Planning) along with BINA scientists


Photograph group -4c: Boro rice (Binadhan 14) at BINA farm, Mymensingh visited by

Director (Res.), BINA.



Photograph group -5a.T. aman rice (Binadhan-17) field at BINA farm, Mymensingh

Photograph group -5b.T. aman rice (Binadhan-17) at Farmer's field, Ista, Ishurdi, Pabna,

Photograph group -5c.T. aman rice (Binadhan-17) at Farmer's field, Tampat, Rangpur sadar,

Photograph grouph-6. Experimental sites visited at BINA glass house and BINA farm Mymensingh by the Director, PIU-BARC-NATP-2 along with expert member and Director (Research), BINA Mymensingh.

Signature of the Principal Investigator
Date ..31.01.2019......

Seal

Counter signature of the Head of the organization/authorized representative
Date 31.01.2019
Seal

Dr. Md. Mohsin Ali
Chief Scientific Officer & Head
Soil Science Division
BINA, Mymensingh

Signature of the Principal Investigator
Date ……………………….
Seal

Counter signature of the Head of the organization/authorized representative
Date …………………………..
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