# Vermicomposting of Vegetable Wastes with Cowdung Using Three Earthworm Species *Eisenia foetida, Eudrilus eugeniae and Perionyx excavatus.*

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**Abstract:** Comparative study was performed to evaluate composting efficiency of three earthworm species viz. *Eisenia foetida, Eudrilus eugeniae and Perionyx excavatus*. The results clearly elucidate that experiment (2) with *Eisenia foetida* gives over all best results followed by experiment (3), experiment (4) and experiment (1). The results show a high increase in nitrogen, potassium and high decrease in organic carbon, C/N and C/P ratios in experiments (2), (3) and (4). There was maximum (117.39%) increased found in nitrogen content of experiment (2), while minimum (9.13%) in experiment (1). The maximum (110%) increased found in potassium content of experiment (2) while minimum (51.61%) increase observed in experiment (1). [Nature and Science. 2010;8(1):33-43]. (ISSN: 1545-0740).

**Key words:** *Eisenia foetida, Eudrilus eugeniae, Perionyx excavatus,* Vegetable waste, Cowdung

## 1. Introduction

Earthworms play an important role in soil. The Greek Philosopher, Aristotle, named them the 'Intestine of Earth'. In India, so far, 509 species, referable to 67 genera and 10 families, have been reported (Kale, 1991). The increase in population has resulted increases demand of wastes. The disposal of wastes now days prime concern. According to an estimate that India produces about 3000 million tones of wastes annually and more than 60% are of decomposable. With the progressive increase in the size of the world population resulted large volumes of organics wastes produced all over the world. The disposal of bio-degradable solid wastes from domestic agriculture and industrial sources has caused increasing environmental and economic problems. The growth of industries and ever increasing human population has led to an increased accumulation of waste materials (Joshi and Chauhan, 2006). Vegetable wastes are one of the major sources of municipal wastes. Recycling of wastes through vermitechnology reduces the problem of non-utilization of wastes. Alternative to chemical fertilizers, locally available organic wastes of anthropogenic and natural products were used as biofertilizers after employing earthworm as decomposers, for degradation and recycling to enhance the production of crops which are free from pollution and health hazard (Bakthvathsalam and Ramakrishnan, 2004). Vermicompost has higher economic value compared with compost derived from traditional methods. Vermicompost are finally divided peat like materials with high porosity, aeration, drainage and water holding capacity. Vermicomposts contain in nutrients in forms that are readily taken up by the plants.

## 2. Material and Methods

Plastic containers (50 cm in diameters depth 16 cm) were used for the culture of earthworms. Vegetable waste was collected from local market and cut into small pieces. It comprising of green peas, brinjals, french beans, cabbages, tomatoes, parts of cauliflower and carrot. All these vegetable waste were partially decomposed in nature. *Eisenia foetida, Eudrilus eugeniae and Perionyx excavatus* picked from a stock culture maintained in a kitchen garden near residential area. One week old cowdung was collected from the cowshed and used in experiment because fresh cowdung can be dangerous for earthworms due to decomposition process. By using vegetable wastes and cow dung, four experiments were set up in plastic containers. In experiment (1), the bedding was prepared by mixing of partially decomposed vegetables wastes with partially decomposed cow dung used in equal amounts (w/w) and without earthworms. The experiment (2), the bedding was same as of experiment (1) but with *Eisenia foetida*. In the experiment (3) the bedding was similar as in experiment (1) but with *Eudrilus* *eugeniae*. While in the experiment (4), the bedding was same as in experiment (1) but with *Perionyx excavatus*. Fifty earthworms were introduced in the experiment (2), (3) and (4). The moisture content was maintained between 50-70% throughout the study period by sprinkling adequate quantities of water. During the experiment the aeration was given to vermibeds twice in a week.

The followings chemical parameters of each bedding materials were analyzed: Organic carbon was determined by Walkley and Black (1934) method. Total Kjeldahl nitrogen (TKN) was determined as per method of (Bremner and Mulvaney, 1982). Available phosphorus was analysed by employing method (Olsen et al. 1954) and Potassium was determined by ammonium acetate extractable method (Simard, 1993). The pH of the composts was determined using glass electrode pH meter (Jackson, 1973). All the above nutrients and C/N, C/P ratios were analyzed after every 30 days. In experiments (2), (3) and (4) the earthworm population and cocoons were estimated by hand sorting and counted at the completion of 150 days through washing over a sieve (Kale and Krishnamoorthy, 1982). Data were analyzed through two-way ANOVA using SPSS software (SPSS Inc., version 10.0) for assessing the significance of quantitative changes in different parameters due to earthworm's activities.

## 3. Result and Discussion

The data on pH, Organic Carbon, Nitrogen, Phosphorus, Potassium, C/N and C/P ratios of all experiments are presented in Fig. 1, 2, 3, 4, 5, 6 and 7, respectively. However the data on number of earthworms and earthworm's cocoons in the experiments are given in Fig. 8 and 9, respectively. However Table 1, 2, 3, 4, 5, 6 and 7 shows changes in values pH, Organic Carbon, Nitrogen, Phosphorus, Potassium, C/N ratio and C/P ratio, respectively. Table 8, 9, 10 and 11 shows the Correlations (Pearson) of experiment 1, 2, 3 and 4 respectively.

### 3.1 pH

From Fig. 1, Experiment (1), pH range was between 8.2 to 7.8. In experiment (2), pH range was between 8.2 to 7.3, whereas in experiment (3) it was between 8.2 to 7.5. While pH range for experiment (4) was between 8.2 to7.6. There was 4.88%, 10.98%, 8.54% and 7.3% reduction in experiment (1), experiment (2), experiment (3) and experiment (4), respectively, in pH from initial day to final day. With the progress of vermicomposting the pH value tended towards neutral (Chudhary, 2000). This decrease may be due to $CO_2$ and organic acids produced during microbial metabolism (Edwards and Boglen, 1996). A decrease in pH of the control and test experiments has been reported (Joshi and Chauhan, 2006). Inter correlation of experiment 1 (Table 8), pH with carbon ($r$=0.989, $p$<0.01), pH with nitrogen ($r$= -0.987, $p$<0.01), pH with phosphorus ($r$= -0.972, $p$<0.01), pH with potassium ($r$= -0.987, $p$<0.01), pH with C/N ratio ($r$=0.988, $p$<0.01) and pH with C/P ratio ($r$=0.984, $p$<0.01). Correlation of experiment 2 (Table 9), pH with carbon ($r$=0.955, $p$<0.01), pH with nitrogen ($r$= -0.970, $p$<0.01), pH with phosphorus ($r$= -0.976, $p$<0.01), pH with potassium ($r$= -0.971, $p$<0.01), pH with C/N ratio ($r$=0.976, $p$<0.01) and pH with C/P ratio ($r$=0.977, $p$<0.01). Correlation of experiment 3 (Table 10), pH with carbon ($r$=0.975, $p$<0.01), pH with nitrogen ($r$= -0.939, $p$<0.01), pH with phosphorus ($r$= -0.980, $p$<0.01), pH with potassium ($r$= -0.952, $p$<0.01), pH with C/N ratio ($r$=0.987, $p$<0.01) and pH with C/P ratio ($r$=0.984, $p$<0.01). While correlation of experiment 4 (Table 11), pH with carbon ($r$=0.947, $p$<0.01), pH with nitrogen ($r$= -0.980, $p$<0.01), pH with phosphorus ($r$= -0.989, $p$<0.01), pH with potassium ($r$= -0.996, $p$<0.01), pH with C/N ratio ($r$=0.939, $p$<0.01) and pH with C/P ratio ($r$=0.963, $p$<0.01).

### 3.2 Organic Carbon (O.C.)

The organic carbon of all experiments declined during study period as shown in Fig. 2. In experiment (1), organic carbon was 3.90 and 3.33 g/kg at initial day (0 day) and 150 days (final day), respectively. For experiment (2), it was 3.90 and 3.12 g/kg at initial day and 150 days, respectively. While in experiment (3) organic carbon was 3.90 and 3.19 g/kg at initial day and 150 days, respectively and in experiment (4) organic carbon was 3.90 and 3.28 g/kg at initial day and 150 days, respectively. Organic carbon decreased by 14.62, 20%, 18.21% and 15.89% in experiments (1), (2), (3) and (4), respectively, from initial day to 150 days. The reduction in organic carbon could be due to the respiration activity of earthworms and microorganisms (Curry et al. 1995; Edwards and Boglen, 1996). After 3-4 months there was increase in organic carbon due to the addition of earthworms cast, which are rich in organic carbon. The organic carbon is lost as $CO_2$ and N increases as a result of carbon loss (Bansal and Kapoor, 2000). Inter correlation of experiment 1 (Table 8), carbon with pH ($r$=0.989, $p$<0.01), carbon with nitrogen ($r$= -0.986, $p$<0.01), carbon with phosphorus ($r$= -0.964, $p$<0.01), carbon with potassium ($r$= -0.977, $p$<0.01), carbon with C/N ratio ($r$=0.996, $p$<0.01) and carbon with C/P ratio ($r$=0.988, $p$<0.01). Correlation of experiment 2 (Table 9), carbon with pH ($r$=0.955, $p$<0.01), carbon with nitrogen ($r$= -0.925, $p$<0.01), carbon with phosphorus ($r$= -0.940, $p$<0.01), carbon with potassium (*r*= -0.930, *p*<0.01), carbon with C/N ratio (*r*=0.988, *p*<0.01) and carbon with C/P ratio (*r*=0.990, *p*<0.01). Correlation of experiment 3 (Table 10), carbon with pH (*r*=0.975, *p*<0.01), carbon with nitrogen (*r*= -0.900, *p*<0.05), carbon with phosphorus (*r*= -0.957, *p*<0.01), carbon with potassium (*r*= -0.930, *p*<0.01), carbon with C/N ratio (*r*=0.989, *p*<0.01) and carbon with C/P ratio (*r*=0.995, *p*<0.01). While correlation of experiment 4 (Table 11), carbon with pH (*r*=0.947, *p*<0.01), carbon with nitrogen (*r*= -0.954, *p*<0.01), carbon with phosphorus (*r*= -0.978, *p*<0.01), carbon with potassium (*r*= -0.967, *p*<0.01), carbon with C/N ratio (*r*=0.961, *p*<0.01) and carbon with C/P ratio (*r*=0.978, *p*<0.01).

### 3.3 Nitrogen (N)

From Fig.1, in experiments (1), (2), (3) and (4) the nitrogen content were 1.15, 1.15, 1.15 and 1.15 g/kg, respectively, at initial day. While it was 1.37, 2.50, 2.43 and 2.14 g/kg in experiment (1), (2), (3) and (4), respectively, at 150 days. Nitrogen content was reduced by 19.13%, 117.39%, 111.30% and 89.96% in experiment (1), (2), (3) and (4), respectively, from initial day to 150 days. Some workers have reported higher content of nitrogen, phosphorus and potassium and micronutrients in vermicompost (Delgado et al. 1995; Jambhekar, 1992). Increase in nitrogen content in *P. excavatus* worked vermicompost of sugarcane trash and cowdung substrate as compared to controls was reported (Ramalingam and Thilagar, 2000). Experiment 1 (Table 8), nitrogen with pH (*r*=0.987, *p*<0.01), nitrogen with carbon (*r*= -0.986, *p*<0.01), nitrogen with phosphorus (*r*= -0.990, *p*<0.01), nitrogen with potassium (*r*= -0.993, *p*<0.01), nitrogen with C/N ratio (*r*=0.995, *p*<0.01) and nitrogen with C/P ratio (*r*=0.996, *p*<0.01). Correlation of experiment 2 (Table 9), nitrogen with pH (*r*= -970, *p*<0.01), nitrogen with carbon (*r*= -0.925, *p*<0.01), nitrogen with phosphorus (*r*= 0.996, *p*<0.01), nitrogen with potassium (*r*= 0.997, *p*<0.01), nitrogen with C/N ratio (*r*= -0.959, *p*<0.01) and nitrogen with C/P ratio (*r*= -0.959, *p*<0.01). Correlation of experiment 3 (Table 10), nitrogen with pH (*r*= -0.939, *p*<0.01), nitrogen with carbon (*r*= -0.900, *p*<0.05), nitrogen with phosphorus (*r*= 0.986, *p*<0.01), nitrogen with potassium (*r*= 0.986, *p*<0.01), nitrogen with C/N ratio (*r*= -0.951, *p*<0.01) and nitrogen with C/P ratio (*r*= -0.936, *p*<0.01). While correlation of experiment 4 (Table 11), nitrogen with pH (*r*= -0.980, *p*<0.01), nitrogen with carbon (*r*= -0.954, *p*<0.01), nitrogen with phosphorus (*r*= -0.991, *p*<0.01), nitrogen with potassium (*r*= 0.989, *p*<0.01), nitrogen with C/N ratio (*r*= -0.984, *p*<0.01) and nitrogen with C/P ratio (*r*= -0.990, *p*<0.01).

### 3.4 Available Phosphorus

The values of available phosphorus of all experiment are given Fig. 4. In experiment (1), available phosphorus was 0.69 and 0.88 g/kg at initial day and 150 days, respectively, with a reduction of 27.54% from initial day to 150 days. In experiment (2), it was 0.70 and 1.12 g/kg at initial day and 150 days, respectively, with a reduction of 60% from initial day to 150 days. In experiment (3), available phosphorus was 0.69 and 1.05 g/kg at initial day and 150 days, respectively, with a reduction of 52.17% from initial day to 150 days, while in experiment (4), it was 0.69 and 0.99 g/kg at initial day and 150 days, with a reduction of 43.48% from initial day to 150 days. It has been established that higher amount of phosphorus is found in test experiment than control experiment using earthworm species (Anonymous, 1992). Increases in the amount of phosphorus in the vermicompost with the progress of time (Tripathi and Bhardwaj, 2004). Experiment 1 (Table 8), available phosphorus with pH (*r*= -0.972, *p*<0.01), available phosphorus with carbon (*r*= -0.964, *p*<0.01), available phosphorus with nitrogen (*r*= 0.990, *p*<0.01), available phosphorus with potassium (*r*= 0.996, *p*<0.01), available phosphorus with C/N ratio (*r*= -0.979, *p*<0.01) and available phosphorus with C/P ratio (*r*= -0.993, *p*<0.01). Correlation of experiment 2 (Table 9), available phosphorus with pH (*r*= -976, *p*<0.01), available phosphorus with carbon (*r*= -0.940, *p*<0.01), available phosphorus with nitrogen (*r*= 0.996, *p*<0.01), available phosphorus with potassium (*r*= 0.999, *p*<0.01), available phosphorus with C/N ratio (*r*= -0.972, *p*<0.01) and available phosphorus with C/P ratio (*r*= -0.974, *p*<0.01). Correlation of experiment 3 (Table 10), available phosphorus with pH (*r*= -0.980, *p*<0.01), available phosphorus with carbon (*r*= -0.957, *p*<0.05), available phosphorus with nitrogen (*r*= 0.986, *p*<0.01), available phosphorus with potassium (*r*= 0.990, *p*<0.01), available phosphorus with C/N ratio (*r*= -0.987, *p*<0.01) and available phosphorus with C/P ratio (*r*= -0.979, *p*<0.01). While correlation of experiment 4 (Table 11), available phosphorus with pH (*r*= -0.989, *p*<0.01), available phosphorus with carbon (*r*= -0.978, *p*<0.01), available phosphorus with nitrogen (*r*= -0.991, *p*<0.01), available phosphorus with potassium (*r*= 0.997, *p*<0.01), available phosphorus with C/N ratio (*r*= -0.972, *p*<0.01) and available phosphorus with C/P ratio (*r*= -0.988, *p*<0.01).

**3.5 Potassium (K)**

The values of potassium in all experiment are presented in Fig. 4. In experiment (1), potassium range was between 0.31 to 0.47g/kg. In experiment (2), potassium range was between 0.30 to 0.63 g/kg. In experiment (3), it was between 0.31 to 0.59 g/kg. While potassium range for experiment (4) was between 0.31 to 0.53 g/kg. The maximum (110%) increased found in experiment (2) while minimum (51.61%) increase observed in experiment (1). It has been reported that higher content of potassium found in a vermicompost. The increase in nitrogen, phosphorus and potassium in the vermicompost confirms the enhanced mineralization of these elements due to enhanced microbial and enzyme activity in the guts of worms (Parthasarathi and Ranganathan, 2000). Experiment 1 (Table 8), potassium with pH ($r$= -0.987, $p$<0.01), potassium with carbon ($r$= -0.977, $p$<0.01), potassium with nitrogen ($r$= 0.993, $p$<0.01), potassium with available phosphorus ($r$= 0.996, $p$<0.01), potassium with C/N ratio ($r$= -0.986, $p$<0.01) and potassium with C/P ratio ($r$= -0.995, $p$<0.01). Correlation of experiment 2 (Table 9), potassium with pH ($r$= -971, $p$<0.01), potassium with carbon ($r$= -0.930, $p$<0.01), potassium with nitrogen ($r$= 0.997, $p$<0.01), potassium with available phosphorus ($r$= 0.999, $p$<0.01), potassium with C/N ratio ($r$= -0.962, $p$<0.01) and potassium with C/P ratio ($r$= -0.965, $p$<0.01). Correlation of experiment 3 (Table 10), potassium with pH ($r$= -0.952, $p$<0.01), potassium with carbon ($r$= -0.930, $p$<0.05), potassium with nitrogen ($r$= 0.986, $p$<0.01), potassium with available phosphorus ($r$= 0.990, $p$<0.01), potassium with C/N ratio ($r$= -0.967, $p$<0.01) and potassium with C/P ratio ($r$= -0.959, $p$<0.01). While correlation of experiment 4 (Table 11), potassium with pH ($r$= -0.966, $p$<0.01), potassium with carbon ($r$= -0.967, $p$<0.01), potassium with nitrogen ($r$= -0.989, $p$<0.01), potassium with available phosphorus ($r$= 0.997, $p$<0.01), potassium with C/N ratio ($r$= -0.963, $p$<0.01) and potassium with C/P ratio ($r$= -0.981, $p$<0.01).

**3.6 C: N Ratio**

For experiment (1), C: N ratio was found to have decreased by 28.32% from initial day to final day (150 days). The C: N ratio for experiments (2), (3) and (4), the reduction was 63.42%, 61.36% and 54.87%, respectively, from initial day to final day (150 days). Vermicompost with *Eisenia foetida* of crop residues and cattle dung resulted in significant reduction in C: N ratio and increase in N (Bansal and Kapoor, 2000; Talashikar et al. 1999). Experiment 1 (Table 8), C: N ratio with pH ($r$= 0.988, $p$<0.01), C: N ratio with carbon ($r$= 0.996, $p$<0.01), C: N ratio with nitrogen ($r$= -0.995, $p$<0.01), C: N ratio with available phosphorus ($r$= 0.979, $p$<0.01) and C: N ratio with potassium ($r$= -0.986, $p$<0.01). Correlation of experiment 2 (Table 9), C: N ratio with pH ($r$= 976, $p$<0.01), C: N ratio with carbon ($r$= 0.988, $p$<0.01), C: N ratio with nitrogen ($r$= -0.959, $p$<0.01), C: N ratio with available phosphorus ($r$= 0.972, $p$<0.01) and C: N ratio with potassium ($r$= -0.962, $p$<0.01). Correlation of experiment 3 (Table 10), C: N ratio with pH ($r$= 0.987, $p$<0.01), C: N ratio with carbon ($r$= 0.989, $p$<0.05), C: N ratio with nitrogen ($r$= -0.951, $p$<0.01), C: N ratio with available phosphorus ($r$= -0.987, $p$<0.01) and C: N ratio with potassium ($r$= -0.967, $p$<0.01). While correlation of experiment 4 (Table 11), C: N ratio with pH ($r$= 0.939, $p$<0.01), C: N ratio with carbon ($r$= 0.961, $p$<0.01), C: N ratio with nitrogen ($r$= -0.984, $p$<0.01), C: N ratio with available phosphorus ($r$= -0.972, $p$<0.01) and C: N ratio with potassium ($r$= -0.963, $p$<0.01).

**3.7 C: P Ratio**

For experiment (1), C: P ratio was 5.65 and 3.78 g/kg at initial day and 150 days. With a reduction of 33.09% from initial day to 150 days. In experiment (2), C: P ratio was 5.57 and 2.78g/kg at 0 day and 150 days, with a reduction of 50.09% from initial day to 150 days. In experiment (3), C: P ratio was 5.65 and 3.04 g/kg at 0 day and 150 days, with a reduction of 49.16% from initial day to 150 days, While for experiment (4), it was 5.65 and 3.31 g/kg, with a reduction of 41.42% from initial day to 150 days. Reduction in C: P ratio in vermicompost reported (Karmegam and Daniel, 2000). Experiment 1 (Table 8), C: P ratio with pH ($r$= 0.984, $p$<0.01), C: P ratio with carbon ($r$= 0.988, $p$<0.01), C: P ratio with nitrogen ($r$= -0.996, $p$<0.01), C: P ratio with available phosphorus ($r$= 0.993, $p$<0.01), C: P ratio with potassium ($r$= -0.995, $p$<0.01) and C: P ratio with C:N ratio ($r$= -0.955, $p$<0.01). Correlation of experiment 2 (Table 9), C: P ratio with pH ($r$= 977, $p$<0.01), C: P ratio with carbon ($r$= 0.990, $p$<0.01), C: P ratio with nitrogen ($r$= -0.959, $p$<0.01), C: P ratio with available phosphorus ($r$= -0.974, $p$<0.01), C: P ratio with potassium ($r$= -0.965, $p$<0.01) and C: P ratio with C:N ratio ($r$= -0.999, $p$<0.01). Correlation of experiment 3 (Table 10), C: P ratio with pH ($r$= 984, $p$<0.01), C: P ratio with carbon ($r$= 0.995, $p$<0.01), C: P ratio with nitrogen ($r$= -0.936, $p$<0.01), C: P ratio with available phosphorus ($r$= -0.979, $p$<0.01), C: P ratio with potassium ($r$= -0.959, $p$<0.01) and C: P ratio with C:N ratio ($r$= 0.998, $p$<0.01). While correlation of experiment 4 (Table 11), C: P ratio with pH ($r$= 963, $p$<0.01), C: P ratio with carbon ($r$= 0.978, $p$<0.01), C: P ratio with nitrogen ($r$= -0.990, $p$<0.01), C: P ratio with available phosphorus ($r$= -0.988, $p$<0.01), C: P ratio with potassium ($r$= -0.981, $p$<0.01) and C: P ratio with C:N ratio ($r$= -0.995, $p$<0.01).

**3.8 Number of Earthworms and Cocoons**

The number of earthworms in experiments (2), (3) and (4) were 50, 50 and 50 at initial day and at final day it was 152, 131 and 113, respectively. Thus there was 204%, 162% and 126% increase in number of earthworms in experiments (2), (3) and (4) from initial day to final day (150 days). The numbers of cocoons in experiments (2), (3) and (4) were 291, 247 and 211, respectively.

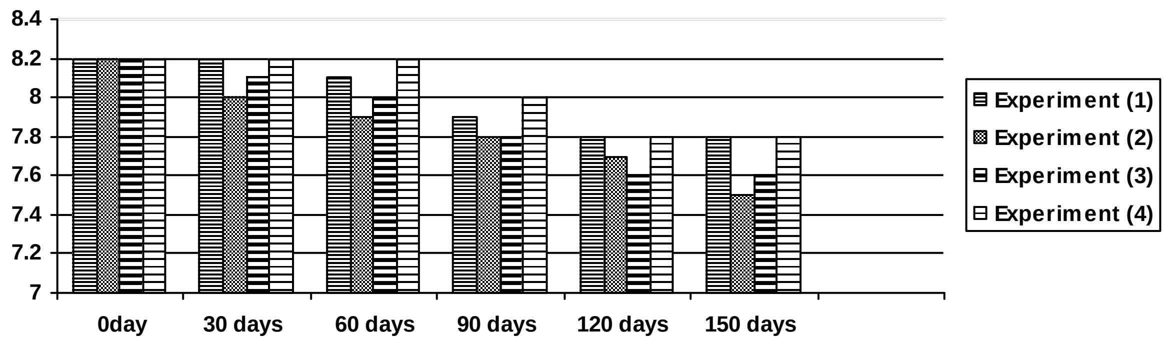


Fig 1-Changes in pH during study period.

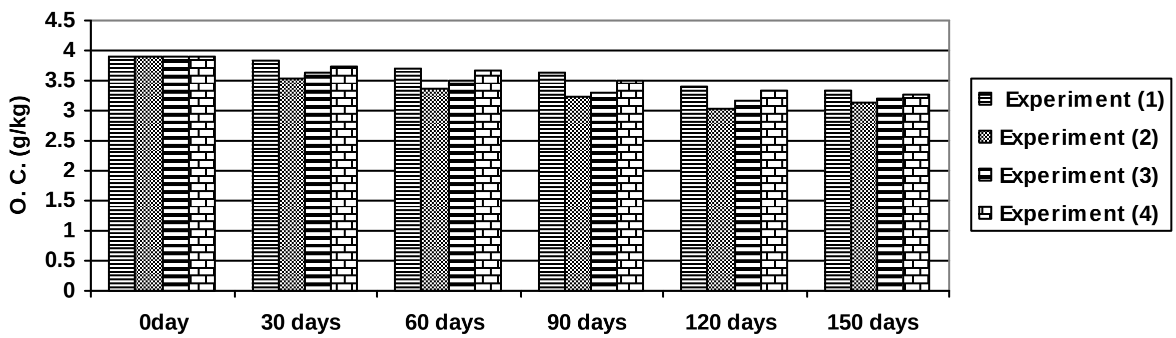


Fig 2-Changes in Organic Carbon (g/kg) during study period.

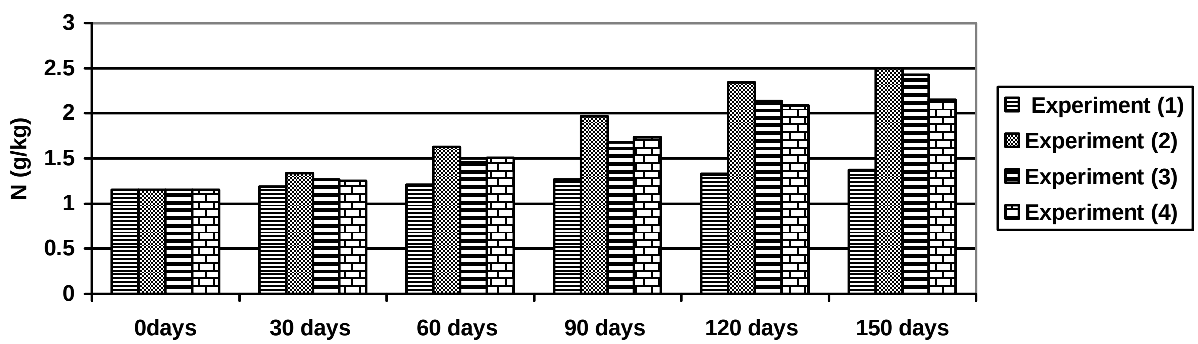


Fig 3-Changes in N (g/kg) during study period.

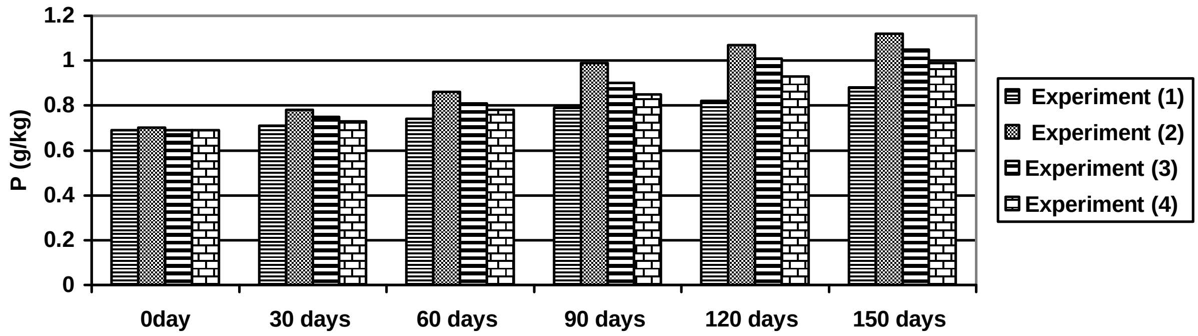


Fig 4-Changes in P (g/kg) during study period.

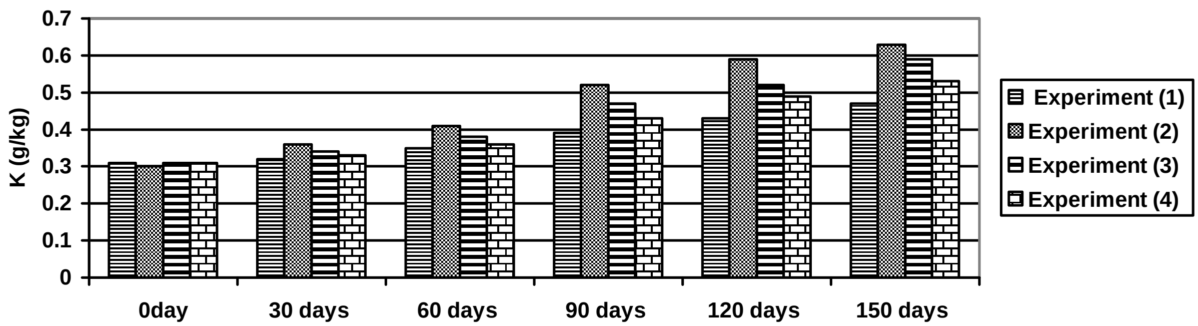


Fig 5-Changes in K (g/kg) during study period.

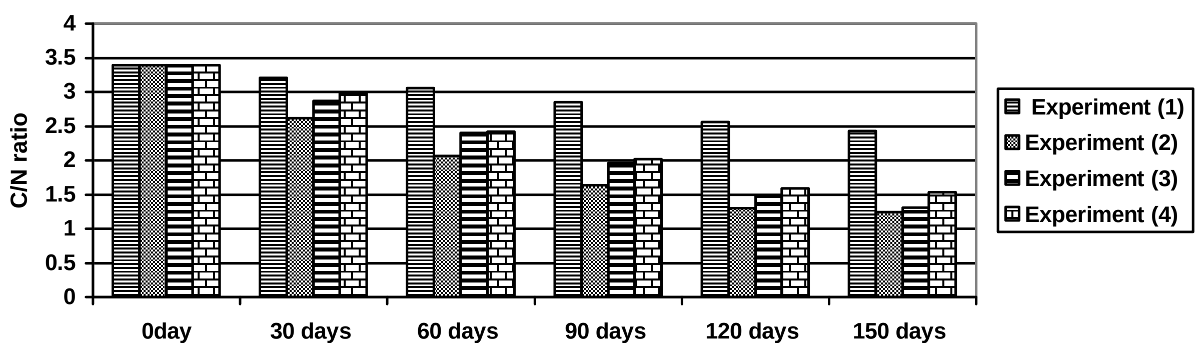


Fig 6- Changes in C/N ratio (g/kg) during study period.

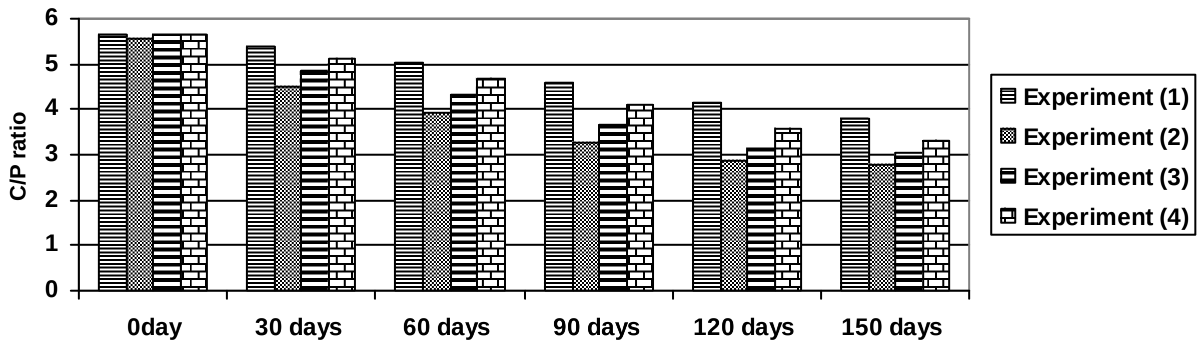


Fig 7- Changes in C/P ratio (g/kg) during study period.

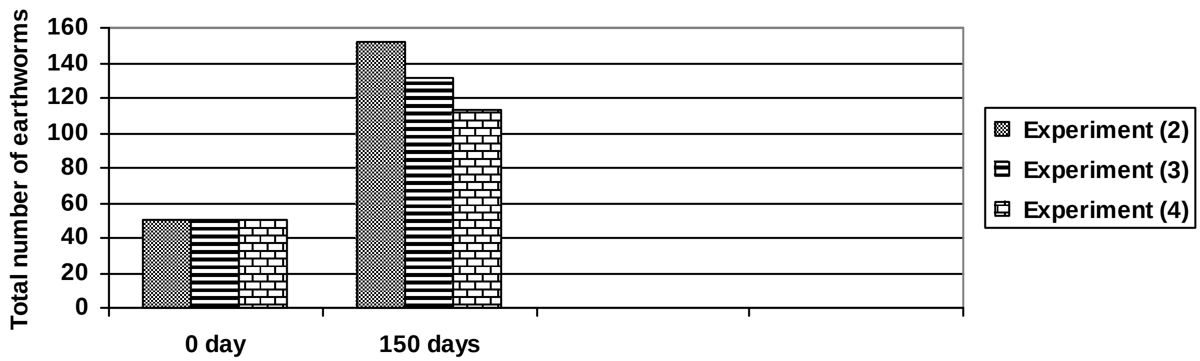


Fig 8 - Number of *Eisenia foetida* in experiments (2), (3) and (4) during study period.

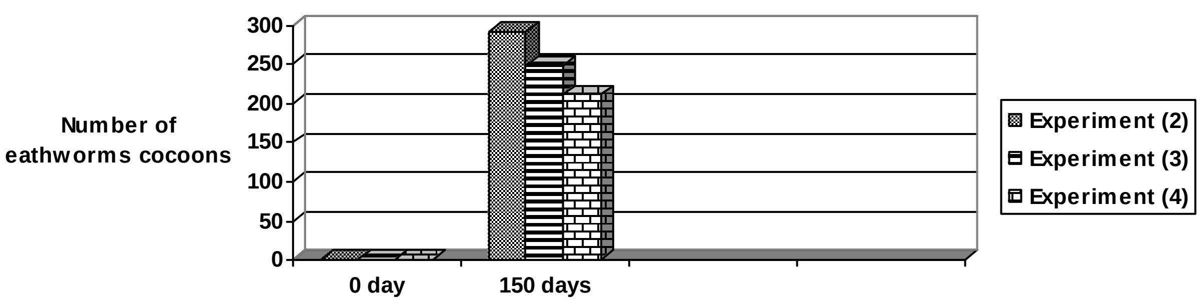


Fig 9 - Number of earthworms cocoons in experiments (2), (3) and (4) during study period.

Table 1-Changes in pH during study period

| | 0 day | 30 day | 60 day | 90 day | 120 day | 150 day |
|---|---|---|---|---|---|---|
| Control (1) | 8.28 | 8.26 | 8.19 | 8.10 | 7.93 | 7.90 |
| Experiment (2) | 8.28*** | 8.03*** | 7.92*** | 7.81*** | 7.70*** | 7.54*** |
| Experiment (3) | 8.28*** | 8.18*** | 8.01*** | 7.83*** | 7.61*** | 7.68*** |
| Experiment (4) | 8.28* | 8.25* | 8.20* | 8.01* | 7.81* | 7.71* |

Significant at: $*p < 0.05$, $***p < 0.001$

Table 2-Changes in Organic Carbon (g/kg) during study period

| | 0 day | 30 day | 60 day | 90 day | 120 day | 150 day |
|---|---|---|---|---|---|---|
| Control (1) | 3.92 | 3.82 | 3.71 | 3.63 | 3.41 | 3.33 |
| Experiment (2) | 3.92*** | 3.52*** | 3.38*** | 3.25*** | 3.05*** | 3.12*** |
| Experiment (3) | 3.92*** | 3.64*** | 3.51*** | 3.30*** | 3.17*** | 3.19*** |
| Experiment (4) | 3.92* | 3.73* | 3.66* | 3.50* | 3.34* | 3.28* |

Significant at: $*p < 0.05$, $***p < 0.001$

Table 3-Changes in N (g/kg) during study period

| | 0 day | 30 day | 60 day | 90 day | 120 day | 150 day |
|---|---|---|---|---|---|---|
| Control (1) | 1.15 | 1.19 | 1.21 | 1.27 | 1.33 | 1.37 |
| Experiment (2) | 1.15*** | 1.34*** | 1.63*** | 1.97*** | 2.34*** | 2.50*** |
| Experiment (3) | 1.15*** | 1.27*** | 1.46*** | 1.68*** | 2.14*** | 2.43*** |
| Experiment (4) | 1.15*** | 1.25*** | 1.51*** | 1.73 | 2.09*** | 2.15*** |

Significant at: $*p < 0.05$, $***p < 0.001$

Table 4-Changes in P (g/kg) during study period

| | 0 day | 30 day | 60 day | 90 day | 120 day | 150 day |
|---|---|---|---|---|---|---|
| Control (1) | 0.69 | 0.71 | 0.74 | 0.79 | 0.82 | 0.88 |
| Experiment (2) | 0.70*** | 0.78*** | 0.86*** | 0.99*** | 1.07*** | 1.12*** |
| Experiment (3) | 0.69*** | 0.75*** | 0.81*** | 0.90*** | 1.01*** | 1.05*** |
| Experiment (4) | 0.69** | 0.73** | 0.78** | 0.85** | 0.93** | 0.99** |

Significant at: $**p < 0.01$, $***p < 0.001$

Table 5-Changes in K (g/kg) during study period

| | 0 day | 30 day | 60 day | 90 day | 120 day | 150 day |
|---|---|---|---|---|---|---|
| Control (1) | 0.31 | 0.32 | 0.35 | 0.39 | 0.43 | 0.47 |
| Experiment (2) | 0.30*** | 0.36*** | 0.41*** | 0.52*** | 0.59*** | 0.63*** |
| Experiment (3) | 0.31** | 0.34** | 0.38** | 0.47** | 0.52** | 0.59** |
| Experiment (4) | 0.31** | 0.33** | 0.36** | 0.43** | 0.49** | 0.53** |

Significant at: $**p < 0.01$, $***p < 0.001$

Table 6- Changes in C/N ratio (g/kg) during study period

| | 0 day | 30 day | 60 day | 90 day | 120 day | 150 day |
|---|---|---|---|---|---|---|
| Control (1) | 3.39 | 3.21 | 3.06 | 2.85 | 2.56 | 2.43 |
| Experiment (2) | 3.39*** | 2.62*** | 2.07*** | 1.64*** | 1.30*** | 1.24*** |
| Experiment (3) | 3.39*** | 2.87*** | 2.40*** | 1.96*** | 1.48*** | 1.31*** |
| Experiment (4) | 3.39*** | 2.98*** | 2.42*** | 2.02*** | 1.59*** | 1.53*** |

Significant at: ****p*<0.001

Table 7- Changes in C/P ratio (g/kg) during study period.

| | 0 day | 30 day | 60 day | 90 day | 120 day | 150 day |
|---|---|---|---|---|---|---|
| Control (1) | 5.65 | 5.38 | 5.01 | 4.59 | 4.15 | 3.78 |
| Experiment (2) | 5.57*** | 4.51*** | 3.93*** | 3.28*** | 2.85*** | 2.78*** |
| Experiment (3) | 5.65*** | 4.85*** | 4.33*** | 3.67*** | 3.14*** | 3.04*** |
| Experiment (4) | 5.65*** | 5.11*** | 4.69*** | 4.12*** | 3.59*** | 3.31*** |

Significant at: ****p*<0.001

Table 8-Correlations (Pearson) of Experiment 1

| | pH | Carbon | Nitrogen | Phosphorus | Potassium | C/N Ratio |
|---|---|---|---|---|---|---|
| Carbon | 0.989** | | | | | |
| Nitrogen | -0.987** | -0.986** | | | | |
| Phosphorus | -0.972** | -0.964** | 0.990** | | | |
| Potassium | -0.987** | -0.977** | 0.993** | 0.996** | | |
| C/N Ratio | 0.988** | 0.996** | -0.995** | -0.979** | -0.986** | |
| C/P Ratio | 0.984** | 0.988** | -0.996** | -0.993** | -0.995** | 0.995** |

** Correlation is significant at the 0.01 level (2-tailed)

Table 9- Correlations (Pearson) of Experiment 2

| | pH | Carbon | Nitrogen | Phosphorus | Potassium | C/N Ratio |
|---|---|---|---|---|---|---|
| Carbon | 0.955** | | | | | |
| Nitrogen | -0.970** | -0.925** | | | | |
| Phosphorus | -0.976** | -0.940** | 0.996** | | | |
| Potassum | -0.971** | -0.930** | 0.997** | 0.999** | | |
| C/N Ratio | 0.976** | 0.988** | -0.959** | -0.972** | -0.962** | |
| C/P Ratio | 0.977** | 0.990** | -0.959** | -0.974** | -0.965** | 0.999** |

** Correlation is significant at the 0.01 level (2-tailed)

Table 10- Correlations (Pearson) of Experiment 3

| | pH | Carbon | Nitrogen | Phosphorus | Potassium | C/N Ratio |
|---|---|---|---|---|---|---|
| Carbon | 0.975** | | | | | |
| Nitrogen | -0.939** | -0.900* | | | | |
| Phosphorus | -0.980** | -0.957** | 0.986** | | | |
| Potassum | -0.952** | -0.930** | 0.986** | 0.990** | | |
| C/N Ratio | 0.987** | 0.989** | -0.951** | -0.987** | -0.967** | |
| C/P Ratio | 0.984** | 0.995** | -0.936** | -0.979** | -0.959** | 0.998** |

** Correlation is significant at the 0.01 level (2-tailed),* Correlation is significant at the 0.05 level (2-tailed)

Table 11- Correlations (Pearson) of Experiment 4

| | pH | Carbon | Nitrogen | Phosphorus | Potassium | C/N Ratio |
|---|---|---|---|---|---|---|
| Carbon | 0.947** | | | | | |
| Nitrogen | -0.980** | -0.954** | | | | |
| Phosphorus | -0.989** | -0.978** | 0.991** | | | |
| Potassium | -0.996** | -0.967** | 0.989** | 0.997** | | |
| C/N Ratio | 0.939** | 0.961** | -0.984** | -0.972** | -0.963** | |
| C/P Ratio | 0.963** | 0.978** | -0.990** | -0.988** | -0.981** | 0.995** |

** Correlation is significant at the 0.01 level (2-tailed)

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