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# Utilization of fly ash as an amendment for sodic soil: An alternate source for gypsum

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**Abstract**
Fly ash (FA) is the byproduct produced from combustion of coal in thermal power plant in large quantity become a solid waste all over the world. The disposal of fly ash by dumping in arable lands leads to degradation of cultivable lands. Though it contains lot of nutrients gaining its importance in agriculture. This study evaluated the potential of fly ash based vermicomposting in recovering the nutrients from fly ash for utilization of fly ash as a sodic soil amendment. Seven combination of partially decomposed cow dung (PCD) and fly ash (FA) at 1:1, 1:2, 1:2.5, 1:3, 2:1, 2.5:1, 3:1 ratios were imposed to find out the best combinations of fly ash based vermicompost (FAV). Earthworm (*Eisenia fetida*) was added to each treatment containing PCD and FA mixed in different ratios. The vermicomposting process was continued up to 42 days (6 weeks) and nutrients such as Total carbon, Total Nitrogen, Total Phosphorus, Total Potassium and Total Calcium content were analyzed. The results showed that among the different combinations, cow dung: fly ash in the ratio of 3:1 reached maturity in rapid matter with low pH, EC and C:N ratio whereas rich in other nutrients like Total Nitrogen (TN), Total Phosphorus (TP), Total Potassium (TK) and Total Calcium (TCa) during the process of vermicomposting. Since the fly ash based vermicompost contains 14.4% calcium content, it can be used as an amendment for sodic soil reclamation.

**Keywords:** Vermicompost, Fly ash, *Eisenia fetida*, Nutrient transformation, amendment, gypsum

## Introduction
In India, sodicity becoming more and more serious problem in irrigated agriculture of around 3.77 million hectare of area because of faulty methods of irrigation, intensive cultivation of high water requirement crops, use of poor quality water, lack of adequate knowledge about soils and poor management practices. Sodic soils are mostly low in organic matter, nitrogen, zinc and soluble calcium resulted in poor crop production (Qadir and schubert, 2002) [12]. High exchangeable sodium interferes with plant nutrition and strongly modifies the physical conditions of soil due to its dispersive effect. High pH affects the transformation of several essential nutrient elements and renders some of the nutrient availability to the plants. These factors are chiefly responsible for reduced crop yields in alkali soil (Rengasamy, 2002) [14]. Eventhough gypsum is the most common amendment used to reclaim sodic soil which led to mining of non-renewable mineral resources of our country and also it increases the cost of production, so an alternative source for gypsum is need nowadays with cost effective and easily available.

Nowadays the demand for power generation is increasing, so there was an increase in thermal power plants which led to the production large quantity of fly ash becomes a solid waste all over the world. The disposal of fly ash also become difficult because of its particle size and large quantity which leads to different health ailments like silicosis, fibrosis of lungs, bronchitis and pneumonitis and also degrade the cultivable arable lands because of the disposal of fly ash by dumping in cultivable lands. Though it rich in lot of nutrients like Ca, K, N, P and micronutrients based on the source of coal used (bituminous and sub bituminous coal), it gaining importance in agriculture. Since, fly ash rich in calcium content the present study was envisaged to prepare fly ash based vermicompost as an alternate source for gypsum in reclamation of sodic soil.

## Materials and Methods

### Study area

The study was conducted in Radioisotope Laboratory, Tamil Nadu Agricultural University, Coimbatore to assess the potential of earthworm (*Eisenia fetida*) in bioconversion of nutrients from fly ash to be effectively used as an amendment. The fly ash (FA) material utilized for the investigation was obtained from a thermal power station, Mettur. Cow dung was obtained from the nearby village which fed the natural vegetation. Foreign particles present in cow dung was removed and then the large clumps were crushed into fine particles. Earthworm (*Eisenia fetida*) used for this study was picked from the nearby commercially produced vermicompost unit. The cow dung which was used in the study was partially decomposed by incubating for 30 days to reduce the production of heat during the thermophilic phase. Then it was mixed with fly ash at different combinations for vermicomposting.

### Experimental Design

In this present study, seven different combinations of fly ash and partially decomposed cow dung was prepared to fed *Eisenia fetida* on dry weight basis *viz.*, cow dung: Fly ash (1:1), cow dung: Fly ash (1:2), cow dung: Fly ash (1:2.5), cow dung: Fly ash (1:3), cow dung: Fly ash (2:1), cow dung: Fly ash (2.5:1) and cow dung: Fly ash (3:1). The general view of fly ash based vermicomposting was showed in the figure 1. Rectangular trays of about 10 kg capacity was taken for the study and were filled with mixtures around 5.0 kg for each treatments and 30 earthworms were released to each treatment for vermicomposting (6 per kg of material). Moisture maintained at 60% with distilled water throughout the study gravimetrically (on weight basis) and the trays were kept in a shaded area in Radioisotope Laboratory, TNAU, Coimbatore. To maintain the required moisture content, water was sprinkled periodically based on the temperature. Changes in temperature has been monitored throughout the study using temperature monitoring sensor. Mortality of earthworm was recorded throughout the study. The initial physico- chemical properties of the partially decomposed cow dung and fly ash used for the experiment were presented in the Table 1.


**Fig 1:** General view of incubation experiment with different combinations of cow dung and fly ash used for vermicompost

**Table 1:** Initial Physico – chemical characteristics of Partially decomposed cow dung (PCD) and Fly ash

| Parameters | PCD | Fly ash |
|---|---|---|
| pH | 8.50 | 10.94 |
| EC (dS $m^{-1}$) | 4.20 | 2.39 |
| Total Nitrogen (%) | 0.84 | 0.22 |
| Total Phosphorus (%) | 0.14 | 0.04 |
| Total Potassium (%) | 0.43 | 2.49 |
| Total Calcium (%) | 3.04 | 18.40 |

### Sampling and sample preparation

During vermicomposting process samples were collected once in a week until maturity. On every sampling, nine samples were taken, three from the top, three in the middle and three at the bottom of each vermicomposting pile. These samples were mixed into a composite sample by uniform mixing and sieved, air dried and ground for further physico – chemical analysis.

### Analytical methodology

Physico – chemical properties were analyzed to determine the availability of total nutrient content in the feedstock mixtures at different time intervals. The samples were analyzed for the following parameters: pH and electrical conductivity (EC) were determined in the suspension ratio of 1:2.5 (w/v) using double distilled water (Jackson, 1973) [7]. Total organic carbon (TOC) was measured after igniting 10 g of sample in muffle furnace at 550 °C for 2 hours (Nelson and Sommers, 1996) [10].

Organic carbon was determined by Chromic acid wet digestion method (Walkley and Black, 1934). Total nitrogen content estimated by Kjedahl distillation method (Jackson, 1973) [7], Total phosphorus by vanadomolybdate method (Jackson, 1973) [7], Total potassium by Flame photometry (Jackson, 1973) [7] and Total calcium by Versanate method using tri acid extract (Jackson, 1973) [7]. The C:N ratio was then calculated from the total carbon and total nitrogen measured (Lukashe *et al.*, 2019) [9]. The change in functional group during the vermicomposting was studied using FTIR spectrum.

### Statistical analysis

AGRES statistical software was used to carry out statistical analysis of all data. Two way analysis of variance (ANOVA), was applied to test the variation in the different chemical properties of vermicompost samples from different treatments at different time intervals. LSD (Least Significant Difference) was applied in order to determine the level of significance among the various physico – chemical properties. Microsoft excel was used to generate graphs.

## Result and Discussion

### Effect of fly ash based vermicompost (FAV) on pH during vermicomposting

The effect of vermicomposting on pH at different stages were showed in the Table 2. There was no significant difference between the treatments and days of vermicomposting but there was a significant decrease observed among the treatments with increasing cow dung proportion. The treatment having the ratio of 3:1 as cow dung and fly ash recorded the lowest pH of 8.12 and the treatment having the ratio of 1:3 as cow dung and fly ash recorded the highest pH of 9.04.

A decreasing trend of pH was observed with the increase in farm yard manure as well as increase in days of vermicomposting. This might be due to the accumulation of organic acids during the bioconversion of organic matter as an intermediate species in the process of decomposition (Atiyeh *et al.*, 2000) [2]. We also observed that there is a decrease in pH upto 28 days of vermicomposting thereafter pH values was almost constant as the vermicomposting tends to be stabilized. The similar results were observed by Alidadi *et al.* (2016) [1] and Bhat *et al.* (2015) [4] in their experiment.

### Effect of fly ash based vermicompost (FAV) on Electrical Conductivity during vermicomposting

The effect of vermicomposting on electrical conductivity of the vermicompost samples were tabulated in Table 3. The lowest value was recorded in the treatment of cow dung and fly ash in the ratio of 3:1 whereas the highest value was recorded in the treatment having cow dung and fly ash in the ratio of 1:3.

There was an increasing trend of electrical conductivity during the initial stages of vermicomposting was observed due to the mineralization of organic materials which increase the mineral salts such as phosphate and ammonia (Lim *et al.*, 2012) [8] whereas decline in EC was recorded in later stages of vermicomposting due to the volatilization of soluble metabolites (ammonium) and the precipitation of dissolved salts such as phosphate (Singh *et al.*, 2016) [5, 16]. The per cent decrease in EC was in the order of cow dung: Fly ash (3:1), cow dung: Fly ash (2.5:1), cow dung: Fly ash (2:1), cow dung: Fly ash (1:1), cow dung: Fly ash (1:2), cow dung: Fly ash (1:2.5) and cow dung: Fly ash (1:3).

### Effect of fly ash based vermicompost (FAV) on Organic Carbon during vermicomposting

Changes in organic carbon content during the process of vermicomposting was showed in the Table 4. The highest organic carbon content was recorded in the treatment of cow dung: Fly ash (3:1) followed by cow dung: Fly ash (2.5:1), cow dung: Fly ash (2:1), cow dung: Fly ash (1:1), cow dung: Fly ash (1:2), cow dung: Fly ash (1:2.5) and cow dung: Fly ash (1:3) which were significantly differ among themselves.

The decreasing trend in organic carbon content occurred with the period of vermicomposting might be due to the decomposition and mineralization of organic matter by earthworm to the substrate material and loss of 'C' compounds as carbon dioxide ($Co_2$). The similar results were reported by Suthar and Sharma (2013) [18].

### Effect of fly ash based vermicompost (FAV) on Total Organic Carbon during vermicomposting

The total organic carbon content in the initial and final stages of vermicomposting was presented in Table 10. A decreasing trend of total organic carbon content was noticed in all fly ash based vermicomposting samples. The maximum and the minimum content of TOC was recorded in the treatments of cow dung: Fly ash in the ratio 3:1 and cow dung: Fly ash in the ratio 1:3 respectively from the initial stage of vermicomposting. Reduction in the dry matter content by mineralization of organic matter and the gut associated microbes in earthworms hastens the activity of carbon mineralization leads to TOC reduction (Suthar and Sharma, 2013) [18].

### Effect of fly ash based vermicompost (FAV) on Total Nitrogen during vermicomposting

The effect of fly ash based vermicomposting on total nitrogen content at different intervals was depicted in the Table 5. The highest nitrogen content was observed in the combination of 3:1 as cow dung and fly ash whereas the lowest nitrogen content was recorded in 1:3 combination of cow dung and fly ash. Since it contains more quantity of fly ash with low nitrogen content, the final product of vermicompost from fly ash rich combinations contain less amount of total nitrogen with respect to other treatments.

With the increasing days of vermicomposting, there was an increasing trend of total nitrogen content was observed. This might be the cause of enhancement of nitrogen content by adding earthworms nitrogenous excretory products, mucus, body fluid, enzymes and even through the decaying of dead worm tissues in the process of vermicomposting (Suthar, 2007).

### Effect of fly ash based vermicomposting on C:N ratio

C:N ratio is an important indicator for determining the maturity of compost, if the value is less than 20 indicate the maturity of the compost for agricultural use (Singh *et al.*, 2016) [5, 16]. C:N ratio of fly ash based vermicompost declined significantly with days of vermicomposting in the presence of earthworm was tabulated in the Table 10. Declining per cent was maximum in 3:1 ratio of cow dung and fly ash followed by cow dung: Fly ash (2.5:1), cow dung: Fly ash (2:1), cow dung: Fly ash (1:1), cow dung: Fly ash (1:2), cow dung: Fly ash (1:2.5) and cow dung: Fly ash (1:3) which recorded the lowest C:N ratio. Decrease in C: N ratio in the range of 55.4 per cent to 65 per cent. The reason for the decline in C:N ratio due to the loss of carbon as carbon dioxide and the enhancement of nitrogen through earthworm excreta. Similar results were observed by Bhat *et al.*, 2013 [3] and Yadav *et al.*, 2013 [22].

### Effect of fly ash based vermicompost (FAV) on Total Phosphorus during vermicomposting

Table 6 showed the changes occurred in total phosphorus content during vermicomposting of fly ash. There was an increasing trend observed in all the treatments. The highest mean value (0.21%) was recorded in the treatment of cow dung and fly ash in the ratio of 3:1 whereas the lowest mean value (0.08%) was recorded in the treatments of cow dung and fly ash in the ratio of 1:2.5 and 1:3. Increase in total phosphorus observed over the period of vermicomposting due to the multiplication of phosphate solubilizing bacteria in the earthworm casts. The increasing trend of total phosphorus was in line with the finding of Suthar and Singh (2008) [19].

**Effect of fly ash based vermicompost (FAV) on Total potassium during vermicomposting**

The effect of vermicomposting on total potassium content was tabulated and presented in the Table 7. The highest potassium content (2.98%) was recorded in 3:1 ratio of cow dung and fly ash and the lowest potassium content (2.24%) was recorded in 1:3 ratio of cow dung and fly ash. An increasing trend of potassium content in fly ash based vermicomposting was observed throughout the period might be the reason of physical decomposition of organic matter due to biological grinding while passing through the gut, coupled with enzymatic activity in worm's gut, which may have caused its increase (Pattnaik and Reddy, 2010) [11].

**Effect of fly ash based vermicompost (FAV) on Total Calcium during vermicomposting**

The effect of vermicomposting on total calcium content was presented in Table 8. An increase in calcium content was observed during the initial stages of vermicomposting in all treatments. The calcium content was increased with increase in cow dung proportion.

This might be due to catalytic activity of carbonic anhydrase present in the secretion from calciferous glands in earthworm since the gut process primarily associated with calcium metabolism (generating $CaCO_3$ by fixing the $CO_2$) during vermicomposting (Ramnarin *et al.*, 2019) [13]. After a week interval there was a decrease in calcium content was observed with increase in fly ash proportion which might be due to the bioaccumulation of calcium in the gut of earthworms. The highest and lowest calcium content after vermicomposting was registered in 3:1 ratio of cow dung and fly ash (14.40%) and 1:2 ratio of cow dung and fly ash (10.60%) respectively.

**Earthworm count and weight of earthworm**

Variation in the ratio of fly ash and cow dung had a greater impact in total weight of earthworm and number of Earthworm were shown in the Table 9. The highest number was recorded in the treatment of cow dung and fly ash in the ratio of 3:1 this might be due to presence of adequate food or substrate for the worms for reproduction and decomposition of raw materials into vermicompost. The highest percentage of increase recorded in 3:1 ratio of CD and FA (130.00%.) whereas the lowest percentage of increase in earthworm was recorded in 1:3 ratio of CD and FA (43.33%) due to the inadequate supply of substrate for decomposition and reproduction.

The percentage increase in earthworm ranges from 43.33% to 130.00%. Similarly the maximum weight recorded in 3:1 ratio of CD and FA treatment (45.98 g) and the minimum weight recorded in 1:3 ratio of CD and FA treatment (26.12 g). The percent increase in weight ranges from 46.91% to 155.73%. The trend of increasing in weight and number of earthworm in the order of 3:1 > 2.5:1 > 2:1 > 1:1 > 1:2 > 1:2.5 > 1:3 as cow dung and fly ash mixtures.

**Table 2:** Change in pH at different stages of FAV

| Treatments | 0 day | 7th day | 14th day | 21st day | 28th day | 35th day | 42nd day | Mean |
|---|---|---|---|---|---|---|---|---|
| PCD: FA (1:1) | 8.74 | 8.63 | 8.59 | 8.52 | 8.44 | 8.44 | 8.44 | 8.54 |
| PCD: FA (1:2) | 9.16 | 9.12 | 9.05 | 8.84 | 8.66 | 8.57 | 8.57 | 8.85 |
| PCD: FA (1:2.5) | 9.28 | 9.21 | 9.17 | 9.02 | 8.98 | 8.95 | 8.95 | 9.08 |
| PCD: FA (1:3) | 9.41 | 9.27 | 9.21 | 9.19 | 9.10 | 9.08 | 9.04 | 9.19 |
| PCD: FA (2:1) | 8.68 | 8.45 | 8.38 | 8.37 | 8.29 | 8.29 | 8.29 | 8.39 |
| PCD: FA (2.5:1) | 8.62 | 8.42 | 8.37 | 8.31 | 8.18 | 8.18 | 8.18 | 8.32 |
| PCD: FA (3:1) | 8.58 | 8.31 | 8.29 | 8.27 | 8.12 | 8.12 | 8.12 | 8.26 |
| Mean | 8.92 | 8.76 | 8.73 | 8.63 | 8.55 | 8.53 | 8.51 | 8.66 |

| Source | SED | CD (0.05) | CD (0.01) |
|---|---|---|---|
| Treatments (T) | 0.08 | 0.16 | 0.21 |
| Days (D) | 0.08 | 0.16 | 0.21 |
| Interaction (T * D) | 0.21 | 0.42 | 0.56 |

**Table 3:** Change in EC ($dSm^{-1}$) at different stages of FAV

| Treatments | 0 day | 7th day | 14th day | 21st day | 28th day | 35th day | 42nd day | Mean |
|---|---|---|---|---|---|---|---|---|
| PCD: FA (1:1) | 3.48 | 3.51 | 3.55 | 3.45 | 3.44 | 3.44 | 3.44 | 3.47 |
| PCD: FA (1:2) | 3.61 | 3.63 | 3.67 | 3.59 | 3.58 | 3.56 | 3.56 | 3.60 |
| PCD: FA (1:2.5) | 4.39 | 4.41 | 4.43 | 4.35 | 4.33 | 4.31 | 4.31 | 4.36 |
| PCD: FA (1:3) | 4.85 | 4.89 | 4.92 | 4.81 | 4.80 | 4.79 | 4.78 | 4.83 |
| PCD: FA (2:1) | 3.36 | 3.34 | 3.40 | 3.31 | 3.27 | 3.27 | 3.27 | 3.32 |
| PCD: FA (2.5:1) | 3.10 | 3.07 | 3.12 | 3.05 | 3.01 | 3.01 | 3.01 | 3.05 |
| PCD: FA (3:1) | 2.91 | 2.89 | 2.96 | 2.87 | 2.83 | 2.83 | 2.83 | 2.88 |
| Mean | 3.68 | 3.67 | 3.72 | 3.64 | 3.61 | 3.60 | 3.60 | 3.65 |

| Source | SED | CD (0.05) | CD (0.01) |
|---|---|---|---|
| Treatments (T) | 0.03 | 0.05 | 0.07 |
| Days (D) | 0.03 | 0.05 | 0.07 |
| Interaction (T * D) | 0.07 | 0.14 | 0.19 |

**Table 4:** Change in Organic carbon ($g\ kg^{-1}$) at different stages of FAV

| Treatments | 0 day | 7th day | 14th day | 21st day | 28th day | 35th day | 42nd day | Mean |
|---|---|---|---|---|---|---|---|---|
| PCD: FA (1:1) | 5.79 | 5.42 | 4.30 | 3.80 | 3.61 | 3.61 | 3.61 | 4.31 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PCD: FA (1:2) | 5.15 | 4.95 | 4.61 | 4.13 | 3.98 | 3.85 | 3.35 | 4.29 |
| PCD: FA (1:2.5) | 5.04 | 4.98 | 4.54 | 4.36 | 3.88 | 3.21 | 3.17 | 4.17 |
| PCD: FA (1:3) | 4.51 | 4.47 | 4.38 | 3.65 | 3.23 | 2.97 | 2.32 | 3.65 |
| PCD: FA (2:1) | 6.31 | 5.15 | 4.97 | 4.43 | 3.86 | 3.86 | 3.86 | 4.63 |
| PCD: FA (2.5:1) | 7.79 | 6.13 | 5.54 | 4.68 | 3.94 | 3.94 | 3.94 | 5.14 |
| PCD: FA (3:1) | 9.01 | 6.08 | 5.23 | 4.98 | 4.12 | 4.12 | 4.12 | 5.47 |
| Mean | 6.23 | 5.31 | 4.84 | 4.30 | 3.85 | 3.64 | 3.48 | 4.52 |

| **Source** | **SED** | **CD (0.05)** | **CD (0.01)** |
|---|---|---|---|
| Treatments (T) | 0.04 | 0.09 | 0.12 |
| Days (D) | 0.04 | 0.09 | 0.12 |
| Interaction (T * D) | 0.12 | 0.23 | 0.31 |

**Table 5:** Total N (%) in FAV at different stages

| **Treatments** | **0 day** | **7th day** | **14th day** | **21st day** | **28th day** | **35th day** | **42nd day** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| PCD: FA (1:1) | 0.448 | 0.672 | 0.784 | 0.840 | 0.952 | 0.952 | 0.952 | 0.80 |
| PCD: FA (1:2) | 0.336 | 0.504 | 0.560 | 0.616 | 0.678 | 0.751 | 0.784 | 0.60 |
| PCD: FA (1:2.5) | 0.300 | 0.392 | 0.448 | 0.560 | 0.572 | 0.623 | 0.672 | 0.51 |
| PCD: FA (1:3) | 0.260 | 0.280 | 0.280 | 0.448 | 0.490 | 0.530 | 0.560 | 0.41 |
| PCD: FA (2:1) | 0.616 | 1.008 | 1.064 | 1.176 | 1.232 | 1.232 | 1.232 | 1.08 |
| PCD: FA (2.5:1) | 0.728 | 1.288 | 1.400 | 1.568 | 1.680 | 1.680 | 1.680 | 1.43 |
| PCD: FA (3:1) | 0.784 | 1.456 | 1.624 | 1.736 | 1.960 | 1.960 | 1.960 | 1.62 |
| Mean | 0.50 | 0.80 | 0.87 | 0.99 | 1.07 | 1.10 | 1.12 | 0.92 |

| **Source** | **SED** | **CD (0.05)** | **CD (0.01)** |
|---|---|---|---|
| Treatments (T) | 0.012 | 0.023 | 0.031 |
| Days (D) | 0.012 | 0.023 | 0.031 |
| Interaction (T * D) | 0.031 | 0.061 | 0.081 |

**Table 6:** Total P (%) in FAV at different stages

| **Treatments** | **0 day** | **7th day** | **14th day** | **21st day** | **28th day** | **35th day** | **42nd day** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| PCD: FA (1:1) | 0.090 | 0.090 | 0.100 | 0.140 | 0.170 | 0.170 | 0.170 | 0.13 |
| PCD: FA (1:2) | 0.070 | 0.080 | 0.080 | 0.090 | 0.100 | 0.110 | 0.120 | 0.09 |
| PCD: FA (1:2.5) | 0.050 | 0.070 | 0.071 | 0.072 | 0.080 | 0.096 | 0.110 | 0.08 |
| PCD: FA (1:3) | 0.040 | 0.050 | 0.070 | 0.090 | 0.096 | 0.098 | 0.100 | 0.08 |
| PCD: FA (2:1) | 0.100 | 0.110 | 0.110 | 0.140 | 0.150 | 0.150 | 0.150 | 0.13 |
| PCD: FA (2.5:1) | 0.130 | 0.150 | 0.150 | 0.170 | 0.250 | 0.250 | 0.250 | 0.19 |
| PCD: FA (3:1) | 0.150 | 0.160 | 0.170 | 0.210 | 0.270 | 0.270 | 0.270 | 0.21 |
| Mean | 0.09 | 0.10 | 0.11 | 0.13 | 0.16 | 0.16 | 0.170 | 0.13 |

| **Source** | **SED** | **CD (0.05)** | **CD (0.01)** |
|---|---|---|---|
| Treatments (T) | 0.002 | 0.004 | 0.006 |
| Days (D) | 0.002 | 0.004 | 0.006 |
| Interaction (T * D) | 0.006 | 0.011 | 0.015 |

**Table 7:** Total K (%) in FAV at different stages

| **Treatments** | **0 day** | **7th day** | **14th day** | **21st day** | **28th day** | **35th day** | **42nd day** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| PCD: FA (1:1) | 2.53 | 2.59 | 2.63 | 2.68 | 2.72 | 2.72 | 2.72 | 2.66 |
| PCD: FA (1:2) | 2.21 | 2.23 | 2.29 | 2.38 | 2.41 | 2.41 | 2.42 | 2.34 |
| PCD: FA (1:2.5) | 2.14 | 2.15 | 2.19 | 2.23 | 2.25 | 2.27 | 2.27 | 2.22 |
| PCD: FA (1:3) | 2.13 | 2.13 | 2.15 | 2.19 | 2.21 | 2.24 | 2.24 | 2.18 |
| PCD: FA (2:1) | 2.61 | 2.67 | 2.73 | 2.78 | 2.81 | 2.81 | 2.81 | 2.75 |
| PCD: FA (2.5:1) | 2.67 | 2.71 | 2.76 | 2.82 | 2.84 | 2.84 | 2.84 | 2.78 |
| PCD: FA (3:1) | 2.74 | 2.85 | 2.89 | 2.95 | 2.98 | 2.98 | 2.98 | 2.91 |
| Mean | 2.43 | 2.48 | 2.51 | 2.58 | 2.60 | 2.61 | 2.61 | 2.55 |

| **Source** | **SED** | **CD (0.05)** | **CD (0.01)** |
|---|---|---|---|
| Treatments (T) | 0.02 | 0.04 | 0.05 |
| Days (D) | 0.02 | 0.04 | 0.05 |
| Interaction (T * D) | 0.05 | 0.10 | 0.13 |

**Table 8:** Total Ca (%) in FAV at different stages

| **Treatments** | **0 day** | **7th day** | **14th day** | **21st day** | **28th day** | **35th day** | **42nd day** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| PCD: FA (1:1) | 12.20 | 12.40 | 12.60 | 12.80 | 12.80 | 12.80 | 12.80 | 12.63 |
| PCD: FA (1:2) | 13.00 | 13.20 | 12.80 | 11.20 | 10.80 | 10.60 | 10.60 | 11.74 |
| PCD: FA (1:2.5) | 13.40 | 13.60 | 13.00 | 12.40 | 11.60 | 11.20 | 11.20 | 12.34 |
| PCD: FA (1:3) | 13.80 | 14.00 | 13.20 | 12.60 | 12.00 | 11.60 | 11.60 | 12.69 |
| PCD: FA (2:1) | 12.00 | 12.40 | 12.60 | 12.80 | 13.00 | 13.20 | 13.20 | 12.74 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PCD: FA (2.5:1) | 11.80 | 12.00 | 12.40 | 12.80 | 13.20 | 13.60 | 13.60 | 12.77 |
| PCD: FA (3:1) | 11.40 | 12.20 | 12.80 | 13.40 | 14.00 | 14.40 | 14.40 | 13.23 |
| Mean | 12.51 | 12.83 | 12.77 | 12.57 | 12.49 | 12.49 | 12.49 | 12.59 |

| Source | SED | CD (0.05) | CD (0.01) |
|---|---|---|---|
| Treatments (T) | 0.102 | 0.202 | 0.267 |
| Days (D) | 0.102 | 0.202 | 0.267 |
| Interaction (T * D) | 0.269 | 0.533 | 0.706 |

**Table 9:** Number of earthworms present and its weight before and after vermicomposting

| Treatments | Number of earthworms present (Nos.) | | | Weight of earthworm (g) | | |
|---|---|---|---|---|---|---|
| | Initial | Final | % of increase | Initial | Final | % of increase |
| PCD: FA (1:1) | 30.0 | 50.0 | 66.67 | 17.67 | 31.00 | 75.44 |
| PCD: FA (1:2) | 30.0 | 48.0 | 60.00 | 17.71 | 27.48 | 55.17 |
| PCD: FA (1:2.5) | 30.0 | 45.0 | 50.00 | 17.63 | 26.23 | 48.78 |
| PCD: FA (1:3) | 30.0 | 43.0 | 43.33 | 17.78 | 26.12 | 46.91 |
| PCD: FA (2:1) | 30.0 | 59.0 | 96.67 | 17.64 | 34.22 | 93.99 |
| PCD: FA (2.5:1) | 30.0 | 62.0 | 106.67 | 17.73 | 37.82 | 113.31 |
| PCD: FA (3:1) | 30.0 | 69.0 | 130.00 | 17.98 | 45.98 | 155.73 |

**Table 10:** C:N ratio

| Treatments | Initial | | | Final | | | Per cent decrease in C/N ratio |
|---|---|---|---|---|---|---|---|
| | TC (%) | TN (%) | C:N ratio | TC (%) | TN (%) | C:N ratio | |
| PCD: FA (1:1) | 14.83 | 0.45 | 33.11 | 12.00 | 0.95 | 12.60 | 61.95 |
| PCD: FA (1:2) | 13.30 | 0.34 | 39.57 | 13.20 | 0.78 | 16.84 | 57.44 |
| PCD: FA (1:2.5) | 13.10 | 0.30 | 43.67 | 12.86 | 0.67 | 19.13 | 56.19 |
| PCD: FA (1:3) | 12.41 | 0.26 | 47.74 | 11.92 | 0.56 | 21.29 | 55.40 |
| PCD: FA (2:1) | 17.21 | 0.62 | 27.94 | 14.24 | 1.23 | 11.56 | 58.63 |
| PCD: FA (2.5:1) | 22.56 | 0.73 | 30.99 | 18.98 | 1.68 | 11.30 | 63.54 |
| PCD: FA (3:1) | 24.80 | 0.78 | 31.63 | 21.70 | 1.96 | 11.07 | 65.00 |

## Conclusion

On optimizing the various combinations of fly ash based vermicomposting, the treatment cow dung with fly ash in the ratio of 3:1 showed a maximum nutrient recovery with low pH and EC. It also rich in organic carbon and other nutrients with respect to other combinations. Though it contains more amount of calcium of 14.40 per cent after vermicomposting, we can use as an alternate source for gypsum in reclaiming sodic soil.


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