EFFICIENCY OF NUTRIENT BASED COMPOST ACTIVATOR ON COMPOSTING OF GREEN BIOMASS: EFFECT ON PHYSICO-CHEMICAL, BIOLOGICAL PARAMETER AND MATURITY OF COMPOST

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A B S T R A C T

Nutrient based compost activator was prepared and its effects were studied on rice straw (RS), wheat straw (WS), garden waste (GW) and saw dust (SD). Compost activator composed of jaggery (2%), polyethylene glycol (PEG) (0.25%), peptone (0.25%) and spores of *Trichoderma viride, Trichoderma reesei, and Phanerochaete chrysosporium*. The effectiveness of compost activator was investigated through assessing their influence on physico-chemical and biological parameter such as microbial count, enzymatic activities, organic matter degradation, C/N ratio, bulk density, germination test and quality of finished compost. Addition of compost activator decrease the composting period significantly. Also, it improves the compost quality and removes infectious pathogen. It is also helpful in decreasing lignin generated inhibitors. Due to compost activator though final product not completely mature but it reaches near to maturity as compare to control.

Keywords:Compost activator, compost maturity, C/N ratio, NPK, cellulase, Microbial Growth.

1.0 Introduction

Abundant amount of municipal solid waste (MSW), agro-waste, food waste, vegetable waste etc. are being generated due to rapid urbanization, green revolution and industrialization [1]. Composting is one of the best options for management of such huge biomass, as it yields nutritionally rich manure which improves soil health and fertility. Composting is process of biotransformation of complex organic material to simple and stable material which supplies essential soil mineral for plant with implementing soil conditioning properties with reducing toxicity and pathogenic organisms [2]. However, composting is a time consuming process which makes it unfavourable for entrepreneurship prospects. Thus, rapid composting is “need of hour” as it reduces significant duration of composting and providing more stable compost, with the supplementation of nutrient. The rapid composting was done by using various techniques including are addition of nutrients (carbon and nitrogen source) which blooming the microflora of compost, addition of bulking agent which trapped excess moisture and provide sufficient aeration and addition of surfactant which increase production of hydrolytic enzyme [3]. The effects of chemical additives such as jaggery, polyethylene glycol, lime, coal fly ash, wood ash, green liquor dregs, bauxite, natural zeolites, and kaoline on composting of municipal solid waste and agricultural waste [3-11].Himanen and Hanninen [12] studied the effect of commercial additives containing iron, magnesium, manganese, and calcium hydroxide on composting and reported mineral addition improve nutritional value of compost. Similarly, Yu and Huang [13] studied the effect of sodium acetate on composting of food waste and found

an increase in microbial activity. Addition of ash in composting studied by Koivula et al. [5] and reported that, it improves mineralization of compost and formation of humic acids, also reduce the formation of H_2S. Effects of lime amendment on composting of sewage sludge was studied by Fang and Wong [14] and reported less than 1% lime is useful to enhance composting process. The effect of various additives such as fly ash, phosphogypsum, jaggery, lime, and polyethylene glycol (PEG) on green waste composting was investigated by Gabhane et al. [3] and reported reduction in duration of composting with improved quality of compost. Jaggery and PEG show more effects than other additive signifying importance of nutrient requirement and production of lignocellulose degrading enzymes. Jaggery increase microbial growth whereas, PEG boost enzyme production. Compost activators are usually mixtures of different amounts of various microorganisms, nutrients, enzymes and pH-balancing compounds that are meant to enhance microbial activity and compost stability when they are in contact with the waste material [3, 12].

Commercially available activators are nothing but sugar solution congaing fungal spore. Which initially boosts microbes but fail to produces enzymes. Thus, well balanced compost activator is needed which not only boost the microbial population also increase the production of lignocellulose degrading enzymes such as cellulase, hemicellulose, laccase, amylase, dehydrogenase etc. Though the lot of research is running for develop a commercial compost activator, the effective compost activator is not developed yet.

Therefore, in the present study we prepare compost activator and studied its efficiency on rise straw (RS), wheat straw (WS), garden waste (GW) and saw dust (SD). One of the major aims of our study is to study efficacy of compost activator on physic-chemical and biological parameter such as C/N, cellulose degradation, lignin degradation, enzyme activity, microbial count etc. Another objective of present study is to reduce composting duration and produce compost of best quality.

2.0 Experimental

2.1. Collection and processing of composting material

The garden waste (GW) was collected from the garden area of National Environmental Engineering Research Institute (NEERI) which includes grass, leaf, litter and small branches of tree. Wheat straw (WS) and rice straw (RS) was collected from the farmyard near to Nagpur. Similarly, saw dust (SD) procured from saw mill, Nagpur. After initial screening all substrate sun dried initially for 2-3 days followed by oven drying at 70° C for about 92 hours in a hot air oven and cut into the size of 10–25 mm for further experiments. Known quantity of this powdered material was subjected to initial compositional analysis and the remaining for composting experiments.

2.2 Preparation of compost activator

Compost activator was prepared by adding 2g jaggery, 0.25g PEG, 0.25g peptone and 0.025g spore of *Phanerochaete chrysosporium* and *Trichoderma viride* in a 100 ml Sterile distilled water. Whole content was mixed and incubate at 30 ^{0}C using a shaker incubator (INNOVA 43R) for 48 hour.

2.3 Experimental set up

Composting experiments were carried out in thermocol boxes of 2 kg capacity. One kilogram of dried and shredded composting material was taken in a tray, sprinkled with water and added 100 ml of compost activator. The contents are mixed thoroughly and put in the thermocol box. Three replicates were maintained for each substrate and necessary care was taken to minimize any external disturbance affecting to the composting process. The control experiment also prepared where compost activator not added. The experiments were carried out in the laboratory with an average room temperature of 25 ± 3 ^{0}C and relative humidity as 60 ±5%. Moisture content was maintained to 55-60% throughout the composting period. Samples were collected from all experiments once in 3 days up to 21 days and were analyzed for physical, chemical and biological parameters. Changes in temperature during composting were recorded using a mercury thermometer kept permanently in the composters.

2.4 Chemical analysis

All the chemical analysis was performed on dried and powdered samples. The pH of compost was determined in deionized water with 1:10 (W/V) compost: water ratio [15]. The organic carbon content of compost was estimated by combustion method [16]. The total nitrogen (TN) content of the sample was

estimated using LECO Protein-Nitrogen Analyzer (Model FP528). The cellulose concentration of compost was estimated by HNO_3-ethanol method of Liu [17]. Lignin content of sample was estimated by 72% (v/v) H_2SO_4 method according to Liu [17]. The concentration of potassium was estimated using flame photometer (Systronics-Model-128). Phosphate estimation was carried out by stannous chloride method using UV spectrophotometer at 690 nm. Estimation of phenolic compound was carried out by UV-VIS spectrophotometry [18].

2.5 Physical analysis

2.5.1 Particle size determination

Particle size determination was carried out by sieve analysis method where compost samples were sieved through sieves of different mesh sizes (0.5–15 mm) until the amount retained becomes more or less constant. The sieved particles of different fractions were weighed separately and using their weights the cumulative passing percentage (CPP) was calculated as per Gabhane et al. [3].

$$CPP = 100 - \%\,\text{Retention} \quad (1)$$

Where,

$$\%\text{Retention} = \frac{\text{Wt.of sample retained in sieve}}{\text{Total wt.of sample}} \quad (2)$$

2.5.2 Bulk density

Bulk density was determined by using pycnometer method [19] and calculated using the formula:

$$\text{Bulk density (g/cm3)} = \frac{\text{Weight of sample in gram}}{\text{Volume of sample (cm 3)}} \quad (3)$$

2.6. Biological parameter

2.6.1. Enzyme assay

The assay of four enzymes (cellulase, amylase) was carried out by using liquid extract of compost in distilled water in the ratio of 1:10 (W/V). The cellulase activity was determined in fresh samples every after 3 days interval up to 21 days by filter paper assay [20]. The activity is reported in FPU/g/h. The value of 2.0 mg of reducing sugar as glucose from 50 mg of filter paper (4% conversion) in 60 minute has been designated as the intercept for calculating filter paper cellulase units (FPU) as per IUPAC standards. The amylase activity was assayed at pH 5.2 employing sodium acetate–acetic acid buffer with 1% soluble starch as substrate. Estimation of maltose sugar carries out by 3, 5-dinitrosalicyllic acid and expressed as unit of α-amylase as milligram of maltose produced during 5 minute incubation with 1% starch [21].

2.6.2. Microbial population

Total fungal count of compost samples was determined by serial dilution method. One gram of compost sample (dry weight) was taken and serially diluted in sterile distilled water. One millilitre from each dilution was plated onto potato dextrose agar media and incubated at 30° C for 48 h. For bacterial count one millilitre from each dilution plated on nutrient agar media and incubated at 37° C for 24 h. The colony forming units (CFU) were counted and the values were multiplied with dilution factor and expressed in CFU/g of compost.

2.7. Assessment of compost maturity.

2.7.1 Germination index

The seed germination was carried out by germinating seeds of *Vigna aconitifolia* on petri-dish (15-cm-diameter). Petri-dish fills with cotton nearly width of 1cm. The cotton bed were moistened with a compost extract which is prepared by adding 50 ml of water to 5 g of compost in a flask and agitating the mixture at 150 rpm for 1 h. All the germinating dishes were incubated at 25 °C for 7 days. The root length (RL), shoot length and seed germination percentage (SGP) of seedlings were determined. RL and SGP of plants moistened with tap water were also measured and used as the control. The germination index (GI) was determined according to the following formula [22](Zucconi et al., 1981):

$$\text{GI (\%)} = \frac{\text{No. of Germinated seed with compst extract} \times \text{RL} \times 100}{\text{Mean no. of germinated seeds in dishes with water} \times \text{mean RL}}$$

3.0 Result and discussion

3.1. Effect of compost activator on temperature profile

Fig 1 shows the temperature profile of composting of activator added compost and control. Perusal of result shows that addition of activator increase temperature of compost early than control experiments. It extends thermophilic phase (TP) up to 10 days, however in control it will reach up to 6 days. In all experiment temperature rise was observed from second day of composting and it was highest in WA followed by RA, SA, and GA. Lowest TP was observed in SC and SA which is probably due to unsuitable material for growth of bacteria and fungi.

TP was observed in both control and activator added experiment, nearly 3-5ºC temperature increase was observed in activator added experiment which is due to increase in population of microorganism. From 3rd day of composting, boosting of fungal population starts and lost up to 15th day. During this period (3-15) temperature is above the room temperature but lower than initial TP, which is reveal that initial TP is only due to bacterial population which is 5-6 fold more than fungal population. During composting period there is suddenly drop in temperature at 9-12 day which is probably due to decline in bacterial population. At last (16-21day) temperature more or less constant this is called as maturation stage. One most interesting observation was observed during composting experiment i.e. differences of temperature among all experiments goes parallel up to the end of composting period. That means, temperature of activator experiment was high in initial TP, intermediate phase and at maturation stage. This finding clearly shows efficiency of activator during all phases of composting. Effect of jaggery and PEG boost microbial count which extent and heighten TP was documented by Gabhane et al [3]. Similar, observation also noted by Jang et al. [23] and Raut et al. [24].

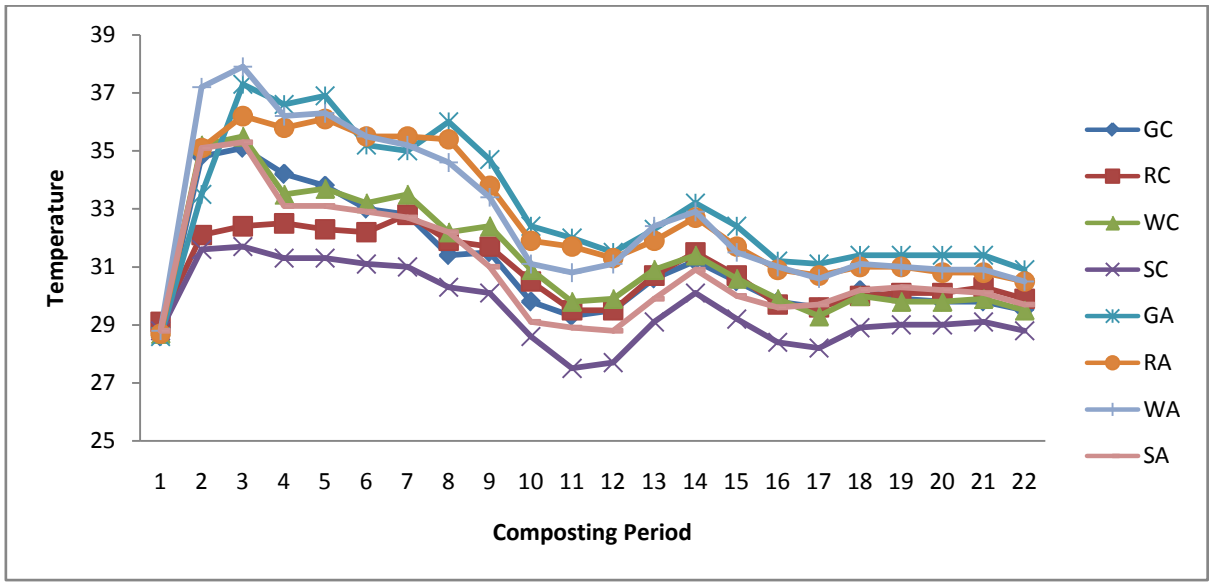

Fig 1 Effect of compost activator on temperature profile (GC = garden waste control, RC = rice straw control, WC = wheat straw control, SC = saw dust control, GA = garden waste activator, RC = rice straw activator, WA=wheat straw activator, SA=saw duct activator)

3.2. Effect of compost activator on pH profile of composting

Effect of compost activator on pH profile was shown in Fig 2. The result shows that continuous increase in pH of all compost experiment. Change in pH is significant up to 9th day, afterword it is marginal. Among the raw substrate saw dust having low pH (4.68) whereas other substrate showing pH near to 7. The low pH of saw dust is probably due to presence of more lignin, tannins, and phenolic compound which is acidic in nature. All activator added experiment shows slightly high pH than respective control which is due to increase in nitrogen content and decrease in

carbon. Several researchers [3, 24, and 25] documented that, degradation of organic biomass result in increase in total nitrogen which ultimately increases pH of compost.

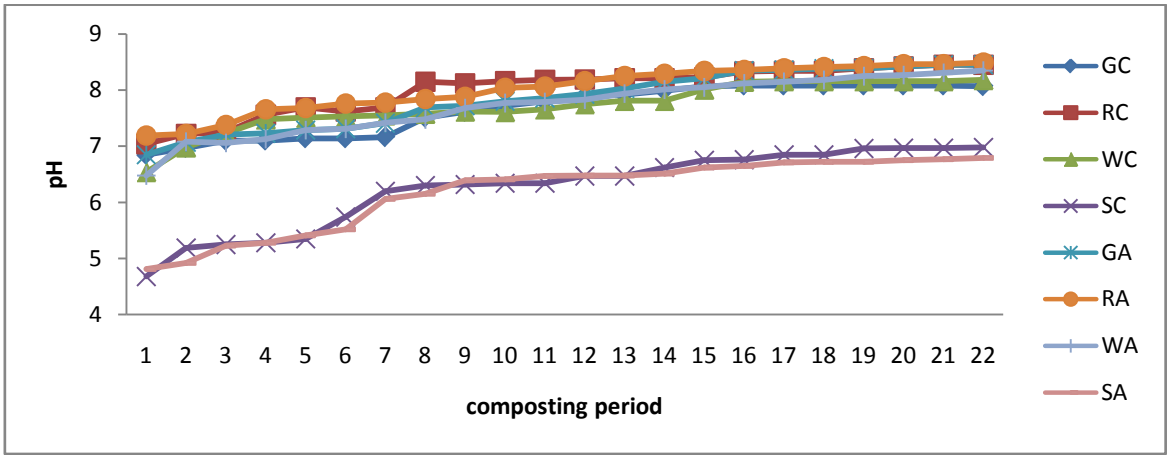

Fig 2 effect of compost activator on pH profile

3.3. Efficiency of compost activator on microbial biomass

Fig 3 and 4 shows the bacterial and fungal population of activator added and control composting experiments. Bacterial count increases up to third day and start decline from 6th day. Effect of activator was observed in first three days after that bacterial population significantly decreases irrespective of activator. Fungal population start rising from 3rd day but significant increase was observed at 6th day and it start decline from 9th day. The rate of declination of fungus was not as sharp as bacterial population. Effect of activator on fungal growth is more pronounce than bacterial growth. Activator enhances fungal growth two fold up to 18th day as compared to control. Therefore, it can say that activator favour fungal growth rather than bacterial growth which is essential for degradation of lignocellulosic substrate.

While comparing fungal and bacterial growth, bacterial count was dominated for initial three day and then fall down. Also, bacterial count is nearly five times more than fungal count. Therefore, it is clear that thermophilic phase is probably due to bacteria rather fungi. After 3rd day bacteria start decline which is probably due to their short life span, accumulation of toxic metabolite and scarcity of food. Mostly bacteria are not degrading lignin and cellulose therefore they face food competition among them. Despite of these entire reason one most important is dominance of fungal growth which may antagonized the bacterial population [24]. Increase in microbial population after addition of nutrient in compost was early documented by Raut et al. [24] and Gabhane et al [3] where glucose and jaggery was used as additives.

Among the different substrates, bacterial and fungal count is highest in GA and WA followed by RA. In SA and SC both the count very less which is probably due to generation of anaerobic condition due to small particle size.

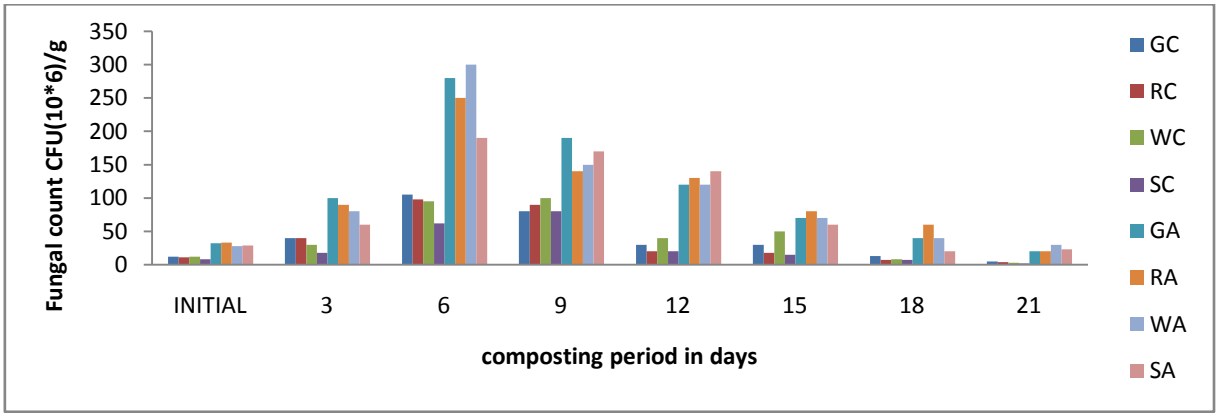

Fig 3 Effect of compost activator on fungal growth

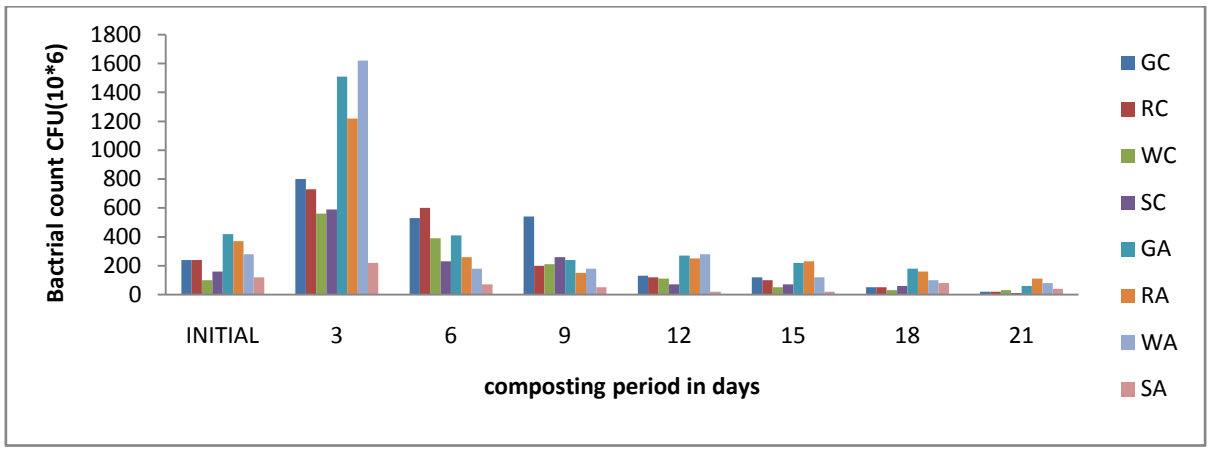

Fig 4 Effect of compost activator on bacterial growth

3.4. Efficiency of compost activator on enzymatic activity.

Fig 5a & b show effects of compost activator on amylase and cellulase activity. Perusal of result shows that amylase activity (Fig 5a) increase from 3rd and is highest at 6th day and then it decline slowly. At the end of composting period (21th day) it will be negligible. Increase activity in early phase is due to rapid increase in microbial count whereas, decrease due to reduction of starch. The result parallel with bacterial growth as bacteria is mostly responsible for synthesis of amylase. Similar observation also documented by Raut et al [24] while studying MSW composting with various additive. Amylase activity in compost activator is slightly higher than control experiments; however significant increase was not observed.

Fig 5b shows effect of compost activator on cellulase activity. The significant activity was observed between 3rd and 9th day. The result of amylase and cellulase clearly indicate degradation of amorphous carbohydrates occurs in first 12 days. Remaining crystalline part of carbohydrates degrades very slowly. Cellulase activity of compost activator is higher than control which is due to increase fungal count after addition of activator. Similar observation also noted by Gabhane et al [3] and stated addition of jiggery and PEG support the fungal growth. As per Rao et al [25] jaggery is a high nutritional substrate for microorganism as it consists of 50–70% sugar, 20–25% invert sugar, 4–6% protein, sufficient amount nutrients and vitamins. PEG shows stimulatory action on cellulase enzyme production [1, 27 28], thus combine action of jaggery and PEG shows significant impact on cellulase activity.

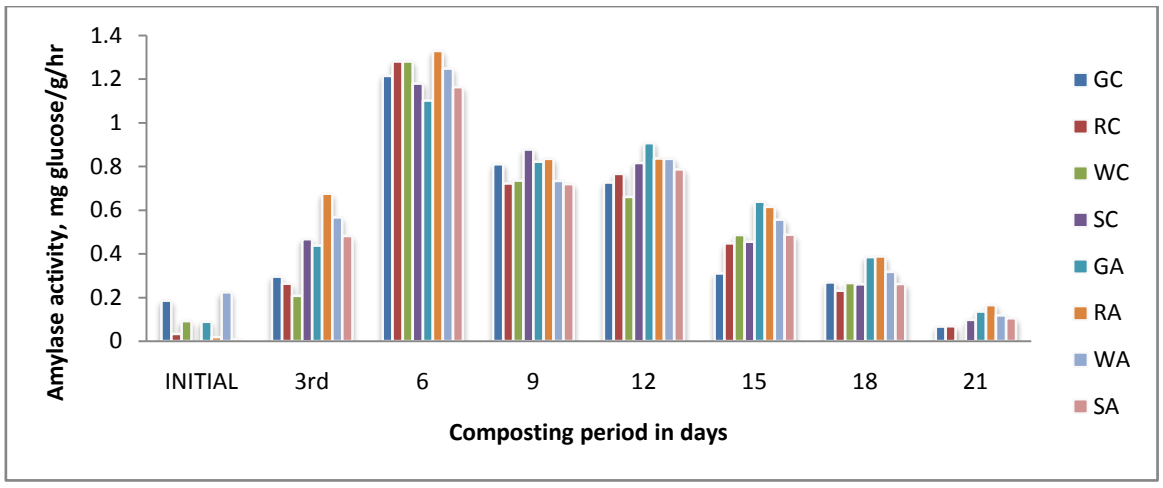

Fig 5a Effect of compost activator on amylase activity

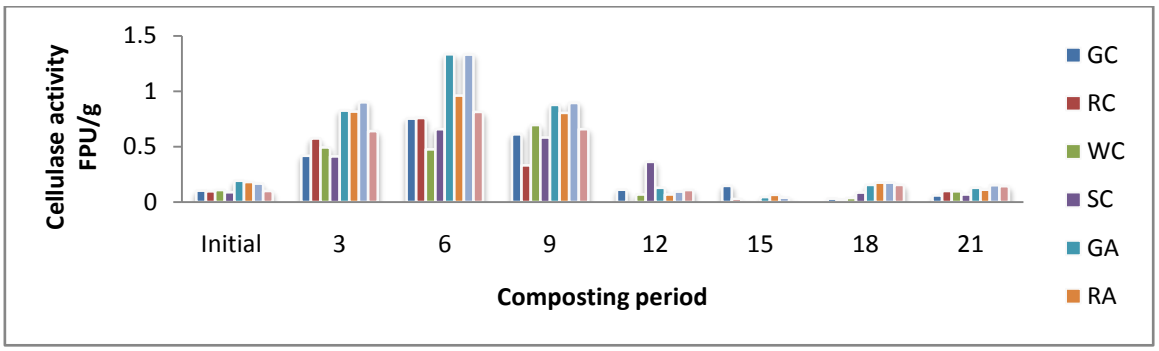

Fig 5b Effect of compost activator on cellulase activity

3.5 Effect compost activator on cellulose and lignin degradation

The reduction in cellulose concentration during composting is mainly due to the cellulolytic action of microbes. In the present investigation cellulose degradation was observed throughout the composting period but degradation is more pronounced after 12th day of composting and is significantly more in activator added experiments (Fig 6a). Overall highest cellulose degradation was observed in WA and RA followed by GA and SA. As compared to respective control the cellulose degradation in all activator experiments is more than 6-7 %. The cellulose degradation rates every after three days is also high in all activator added compost than control and is highest in 12-15 day period followed by 15-18 and 18- 21th. In the initial phase of composting only 5-15 % of cellulose get degraded while in the later phase 20-30 % of degradation was observed. Therefore it can assume that actual cellulose degradation was started from 12th day which is start of mesophilic phase in present investigation.

Lignin is one of the most recalcitrant components in composting which degrade slowly during composting. Fig 6b shows cumulative degradation of lignin with and without activator. Unlike cellulose degradation lignin shows continuous reduction up to end of composting period which is slightly sharper at end. Influence of activator in lignin degradation was also positive as showing higher degradation as compared to control. Among the experiments degradation was highest in RA (13.88%) followed by GA (8.85%), SA (7.275%) and WA (3.3%) over respective control.

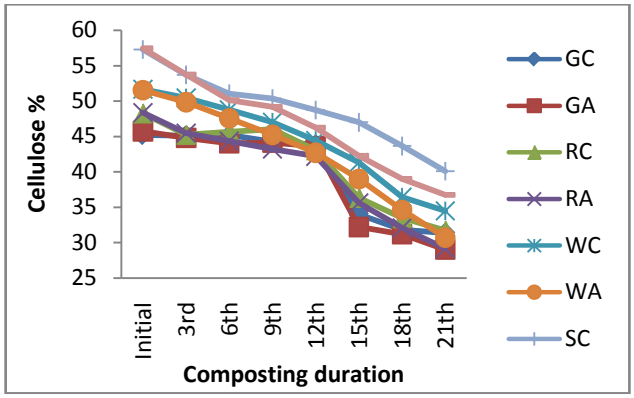

Fig 6a effects of compost activator on cellulose

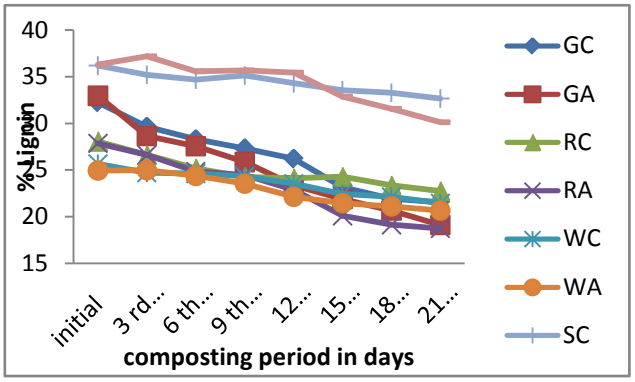

Fig 6b lignin degradation

3.7 Effect compost activator on TOC, TN, and C/N ratio

Fig 7 shows effect of activator on C/N ratio which is most accepted index for compost maturity [30] and is 10-14 for mature compost [29]. Among the treatments, maximum reduction of TOC was observed in GA (11.51%) followed by RA (10.18%). All the activator treatments show higher reduction over respective control. Similarly, an increase in total nitrogen content was observed in all activator treatments, which indicates faster rate of organic matter degradation. As a result, C/N ratio of finished compost in these cases showed significant reduction. Similar observation also noted by Gabhane et al. [3], [24] Anand et al. [25]

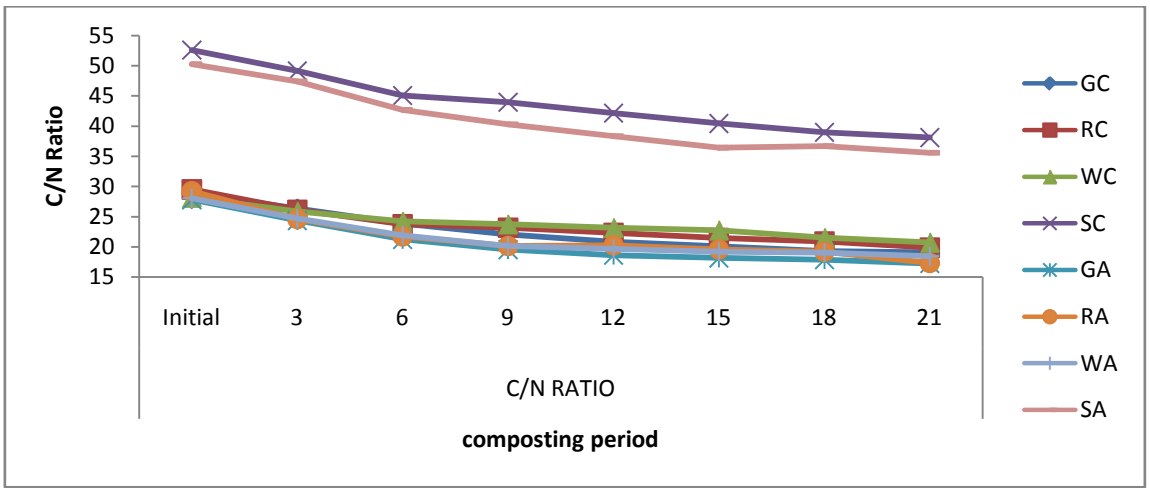

Fig 7 Effects of compost activators on C/N ratio

3.8 Effects of activator on maturity of compost.

The presence of phytotoxic is a common problem associated with immature composts which is arises from incomplete degradation of lignin [30] Estimation (Table 2) of phenolics (gallic acid equivalent) in compost provides clear idea regarding maturity of compost. In the present investigation phenolic compound was observed in all experiment but it is high in saw dust. At the middle of composting phenolics concentration was increase which is probably due to degradation of lignin. At the last phase concentration of phenolic decline indicates maturation start. Addition of activator shows increase phenolics compared to control. It is probably due degradation of lignin continuous till end of composting period. Thus, decreased phenolics in control are not due to maturity of compost but it is due to reduction in lignin degrading fungi. Fungal data (Fig 3) support this finding. Though, in activator added compost maturity come late the final product will better than control. Quality of compost should be tested by estimation of seed germination index. Seed germination index (Fig 8) is another index of compost maturity. In the present investigation the major difference was not observed among the control and activator indicating compost not fully mature within 21 days. However, compost activator shows more germination index at 2% compost extract.

	GC	GA	RC	RA	WC	WA	SC	SA
IN	0.7066	0.5000	0.7200	0.8200	0.7520	0.5733	3.3933	2.1400
3	0.6266	0.5600	0.5200	0.7066	0.6520	0.6800	3.1133	2.2266
6	0.9533	0.5533	0.4866	1.1200	0.8400	0.8133	2.4000	1.6333
9	0.8600	0.6800	0.5733	1.0200	0.6720	0.6866	2.1800	1.5733
12	0.8533	0.6200	0.4533	0.8866	0.6800	0.5333	2.1400	1.1466
15	0.8133	0.5866	0.4400	1.2200	0.7320	0.6933	1.4400	0.9000
18	0.6933	0.8000	0.5200	0.9200	0.6600	0.7600	1.2666	0.8266
21	0.6466	0.6866	0.2666	0.6533	0.5320	0.6466	1.1000	0.8600

Table 2 Total phenolics g/ kg (Gallic acid equivalent)

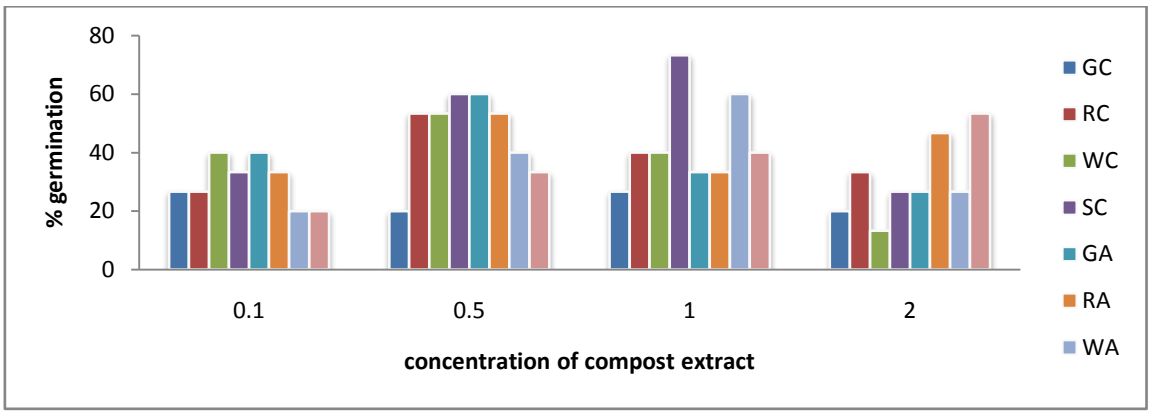

Fig 8 Effect of compost activator on seed germination index

3.9 Effect of compost activator on particle size distribution and bulk density of finished compost

Gradation test is one of the simple measures of organic matter degradation and compost maturity index [31]. As per compost experts like Darlington, [30] normally, the compost which have 90% cumulative passing through 12.6 mm sieve is best compost. In the present study 0.5–15 mm size sieves were used to fractionate the material and to calculate cumulative passing percentage. Accordingly, it was found that all compost activator passed gradation test except saw dust at it is already fine powered and rate of degradation is not correlated with particle fractionation (Table.3).

The initial BD of the substrate used in the present investigation is in the range of 0.72 - 0.73 for GC, RC and WC whereas, SC shows 0.87 (Table 4). Bulk density in all experiment increase and is highest in all compost activator treatment. Maximum increase in bulk density was found in RA (0.98) followed by GA (0.86). In saw dust there is marginal increase in BD which is relates with low degradation. Similar observation also documented by Gabahne et al [3].

	GC	GA	RC	RA	WC	WA	SC	SA
Fraction I (0.5)	12.2260	14.5953	6.5848	14.4087	3.9749	9.4554	26.5719	26.0916
Fraction II(1.68)	45.5603	60.0431	39.1188	44.4577	21.8368	37.3169	92.5176	97.6875
Fraction III(3.55)	86.1639	90.8307	87.6191	88.1329	46.3707	83.5701	100	100
Fraction IV(8)	100	100	100	100	84.5691	100	100	100
Fraction V(15)	100	100	100	100	100	100	100	100

Table 3 Effect of compost activator on the particle size distribution of finished compost (gradation test)

Treatments	**BD after 0 Day**	**BD after 21 day**
GC	0.728	0.786
GA	0.726	0.862
RC	0.726	0.778
RA	0.731	0.987
WC	0.720	0.747
WA	0.723	0.764
SC	0.875	0.884
SA	0.877	0.885

Table 1 Effects of compost activator on bulk density

4.0 Conclusion

The results of present study demonstrate the effect of compost activator on four different substrates. Grass, wheat straw, and rice straw are more flexible to degradation however, saw dust is more recalcitrant. Thus, effect of activator on SD is very low. Nutrient rich compost activator not only boosts bacterial and fungal count but also increase its viability. Increase in microbial count reflex in enzyme activity. Cellulase and amylase activity are increased in all activator added compost. Thermophilic phase is very essential for composting for several reason like it reduce

composting duration, it improve compost quality and remove pathogen. In the present investigation addition of activator risen the TP. Also, activator improves pH of final compost. Degradation of cellulose and lignin also improve in the presence of activator. Compost activator shows good impact on compost maturity indices such as C/N ratio, phenolics, seed germination test and gradation test. After studying the result of maturity indices it clear within 21 days compost could not mature, however activator reduce maturity period significantly. Also, final product of 21 days compost could not show toxic effect on plant.

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