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Treatment of Garden Waste by Vermicomposting Process using Additives

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Abstract - *Solid waste management is the major challenge faced by the world in today's date. So a sustainable and potential solution that can manage generated waste eco-friendly and efficiently is a need of time. Vermicomposting is a process that decomposes the organic waste by worms and micro-organisms into value added, nutrient-rich and humus-like material called as vermicompost. Vermicomposting can be proved as cost-effective and can allow sustainable utilization of solid waste generated. The aim of this study was to treat garden waste generated in college campus of Government College of Engineering Amravati. Field scale model of vermicomposting was set up and vermicomposting was done in high density polyethylene (HDPE) bags of size 12ft long, 4ft wide and 2ft deep. Experimental study was carried out to evaluate the effect of various additives on efficiency of vermicomposting process. Vermicomposting was done by using epigeic earthworm Eisenia Fetida and additives such as biochar, sawdust, T- Viride and vermiwash were used to check the efficiency of vermicomposting process. High lignin contents in garden waste makes the growth of earthworms and micro-organisms difficult in vermicomposting. Effective use of additives can encourage the growth of earthworms, accelerating the decomposition process. They act as a catalyst for the process of vermicomposting. The results of the given study indicates that the additive aided vermicomposting process results in higher percentage degradation of organic matter, enrichment of nutrients and better quality of final vermicompost.*

***Key Words*: Vermicomposting, Vermicompost, Earthworm, Additives, Biochar, Vermiwash, Vermiwash, Sawdust, Garden waste, Earthworm, Eisenia Fetida**

1. INTRODUCTION

Industrialization becomes very significant for developing countries like India having large number of population [9]. The rapid of growth of industrialization resulting into huge generation of all type of waste. In all these wastes, municipal solid waste is a major concern. Thus, environmental pollution originated from Municipal Solid Waste (MSW) call for more sustainable waste management systems [6]. Disposal of solid wastes can be done by many methods like landfilling, incineration, recycling, conversion to biogas, disposal into sea and composting. Major sources of municipal wastes are vegetable waste, agro and kitchen waste, garden waste [7]. Organic waste is biodegradable but there is numerous increase in landfills due to disposal of waste which makes an urgent need of eco-friendly way of disposal of waste as everyone wants to live in neat and clean environment. Vermicomposting can be the efficient method of disposal of organic waste as biodegradation is the key thing in characteristics of organic waste.

Garden waste (GW) is comprised of residues such as fallen leaves, grass cuttings, and bush and tree trimmings produced in urban areas [29]. Management of garden waste is not that difficult like managing plastic waste but the problem is there huge amount of generation which impart unnecessary load on municipal solid waste management system. Though not harmful to environment, open disposal of garden waste can create nuisance and an undesirable view. Hence the only option is to recycle the garden waste. Recycling garden waste by composting/vermicomposting technique coverts the waste into manure to increase soil fertility as the cost of fertilizers showing exponential graph that is unbearable for local farmers. Vermicompost has several advantages over chemical fertilizers and is useful to crops. Vermicompost contains nutrients (in plant available form), humic acid, and growth hormones and hence is used extensively as an organic fertilizer at a large scale in organic farming [30].

Vermicomposting has been identified as one of the potential method of treatment of solid waste as it is cost-effective, resource generative and also treats the waste in natural way. During vermicomposting, organic matter is stabilised by the enhanced decomposition (humification) in presence of earthworms [2], but by a non-thermophilic process [3]. Vermicomposting employs earthworms and micro-organisms to convert organic waste (garden waste) into nutrient rich manure called as vermicompost which is an organic fertilizer. Earthworms are important Vermiresources having simple, cylindrical, coelomate and segmented body characterized by presence of setae [31]. Eisenia fetida is considered as the most eurythermal species of epigeic earthworms [4]. In recent years due to high cost of fertilizers and low availability of organic manures, the recycling of Organic wastes for increasing soil fertility has gained importance [8].

There are various additives that can be added to the vermibeds along with the cattle dung. Use of additives actually enhance the process of vermicomposting and promotes fast degradation of garden waste. Biochar, trichoderma viride, sawdust and vermiwash were the additives used during the experimentation work. Trichoderma viride is a potent bio control agent and used extensively for soil borne disease. Studies have also showed that microorganisms like Trichoderma which degrade cellulosic substrates can be used to improve vermicomposting (25,26). Earthworms prefer trichoderma in greater extent. Significant increase in coccons and adult earthworm has been recorded in tricoderma treated media [31]. Biochar is a carbonaceous product resulting from the slow pyrolysis of carbon-rich biomass under low oxygen conditions [28]. Biochar addition increased the growth and reproduction of E. fetida, increased enzymatic activities, accelerated the decomposition of lignin and dissolved organic carbon, enhanced nitrification and humification, reduced the time required for the compost to be toxicity-free for seed germination, and enhanced the vermicomposting process[29]. Vermiwash is a Brown colored liquid fertilizer, which is a byproduct of vermicomposting treatment collected after water passes through vermicomposting unit. It is a storehouse of several nutrients and microorganisms, it can be effectively use in vermicomposting. The sawdust residue can be incorporated in clay as a pore-forming agent which proves beneficial in vermicomposting technique for survival of earthworms. Sawdust is one of the layer of bedding of vermireactor. Sawdust bedding promotes the better cocoons production and number of worm.

The aim of this study is to treat the garden waste efficiently by installing an eco-friendly and resource generative vermicomposting treatment plant and to study the effect of additives on vermicomposting process and its parameters. To find out the most suitable additive that promotes the efficient vermicomposting process depends upon the results obtained.

1.1. Vermicomposting Process

In contrast to traditional disposal methods, vermicomposting has received increasing attention as an environmentally friendly way to dispose of and utilize organic wastes. Vermicomposting involves the bio-oxidation and stabilization of organic material under aerobic and mesophilic conditions through the combined action of earthworms and microorganisms [11]. The whole process of vermicomposting takes place in two phases: the active phase or direct process and the maturation phase or indirect phase. During the active phase, earthworms modify the physical, chemical, and biological characteristics of waste. Earthworms ingest the waste and add various beneficial enzymes and microbes during digestion [13]. As most of the activities take place in the gut of earthworms, the active phase is also known as the gut-associated process. In the maturation phase, earthworms process the waste and alter it biochemically [14]. In this process, microbes act on vermicast and convert it into vermicompost, hence it is also known as the cast-associated process. Gomez Brandon and Dominguez [15] defined vermicomposting as a bio-oxidative process in which earthworms interact with the decomposer community (bacteria, fungi, actinomycetes) to stabilize organic waste by altering its physical and biochemical properties. Most of the organic components are degraded and the residuals are transformed into stabilized vermicompost, which is rich in nutrients, hormones, and humic substances [16].

The quality of composts depends on several factors viz. type of substrate (organic residues), aeration, humidity, pH, temperature, and the earthworm species used during vermicomposting. Therefore, it is necessary to evaluate specific characteristics, such as composition and abundance of microorganisms, organic C, total N, P and K content, humic acids (HAs) and enzymatic activities, in order to know the dynamics of vermicomposting [5]. The percentage of nitrogen, phosphorous and potassium in vermicompost was found to increase while pH and total organic carbon declined as a function of the vermicomposting period [10]. During vermicomposting the pH and EC of waste are either increased or decreased from the initial day. The optimum pH range suitable for biological and earthworms activity is 5.5–8.5. Earthworm activity is more at near neutral pH. The function of earthworm and microorganism depends on sufficient moisture content of the vermicomposting system. It is reported that 50–90% of moisture content is required for earthworm activity. For the survival of the Eisenia fetida species, 50–90% moisture required, but earthworm grows rapidly within the moisture range 60–80% [27]. According to Reinecke and Venter [17], optimum moisture amount for Eisenia fetida and Eisenia andrei was above 70% in cow manure.

Temperature has a significant influence on earthworm activity. At low temperature, food consumption of earthworms reduced significantly. The reproduction rate and metabolic activity of earthworm start to decline. Earthworms hibernate and move to deeper layers of the compost [18]. Higher temperature promotes microbial activity in the composting bed which indirectly reduces oxygen content. Reduction of oxygen has a negative impact on the survival and activity of earthworm. According to various reports, within temperature range of 10–35 °C earthworm activity becomes very high [19,20].Waste degradation depends on C/N ratio and when it is too high or too low degradation of waste is very slow. Higher C/N ratio in substrate always favors earthworm growth and reproduction rate. An optimum C/N ratio is necessary for the effective vermicomposting process because microbes required carbon for body metabolism and nitrogen for the synthesis of protein [21,22]. Vermicompost contains higher phosphorous content than raw materials. When the organic materials pass through earthworms gut, some phosphorus in a bound form converted to available form. It is due to the direct action of earthworm gut enzymes and the stimulation of various phosphorous solubilizing microbes (PSM). Acid and alkaline phosphatase enzyme released in mid-gut of earthworm, which mineralizes the phosphorous content [23,24,25].

2. MATERIALS AND METHODS

2.1. Raw waste and additives

Garden waste generated in college campus of Government College of Engineering Amravati, was collected by garden keeper which includes waste from several types of plant's fallen leaves as well as twig and branches. Chudekar agro. Garden waste shredder machine was used for waste shredding. Shredder has 50 to 75 kg/hour shredding capacity with average 3 unit/hour power consumption. 20 days old well-seasoned cattle dung was procured from nearby dairy farm. Additives used in experimental work includes biochar, sawdust, vermiwash and Trichoderma viride.

2.2. Experimental setup

Arrangement and components of vermibeds plays important role in convenient operation of plant. High density polyethylene (HDPE) bags of size 12ft long, 4ft wide and 2ft deep was selected for the vermicomposting treatment. These bags are specially designed to provide aeration as well as drainage of vermiwash. It is provided with holes at sides and bottom for aeration purpose and drainage purpose respectively. Holes are covered with plastic mesh with opening of 1 mm diameter. 20 days old well-seasoned cattle dung was procured from nearby dairy farm which was air-dried for 10 days to remove heat and unwanted gases from it which may prove harmful to the earthworms. Slurry of cattle dung was poured after each layer of shredded waste hence forming alternate layers of waste and cowdung slurry. Garden waste was pre-composted for 3 days after mixing cow dung to remover heat generated due to curing of cow dung and is kept well watered to make it suitable for acclimatization of earthworms. Experimental work was carried out in three HDPE bags and the reading were taken in triplicate.

2.3. Chemical Analysis

The pH and EC of vermicompost was determined by using Hach Dual pH-conductivity meter, model HQ440D, USA, by mixing 1 gram of powdered sample with 10 ml of distilled water for 15 min. Changes in temperature was recorded using a digital thermometer (4 in 1 soil tester). Changes in moisture content during vermicomposting was recorded using analog moisture meter. Analysis of carbon, nitrogen, phosphorous and potassium was done using 'Mridaparikshak' soil testing equipment developed by Indian Institute of Soil Science. % carbon and nitrogen was determined to calculate C/N ratio. All the analysis were carried out in triplicate and the mean values was calculated using Microsoft excel. Graphical representations of evolution in pH, moisture, Temperature, EC, organic carbon, nitrogen, C/N ratio, phosphorus and potassium were also statistically interfaced with error bars.

3. RESULTS AND DISCUSSION

3.1. Raw waste characterization

The garden waste was shredded using waste shredder into fines and tested for the initial reading of the parameters. Small portion of the garden waste was oven dried and pulverized for chemical testing including pH, EC, organic carbon, nitrogen, C/N ratio, potassium, phosphorus. Moisture content of raw garden waste was found to be 50% and initial C/N ratio was measured as 46.58. pH was found to be 5.89 and the EC was 1.76 ds/m. Organic carbon(%) and nitrogen(%) of raw waste were 32.14 and 0.69 respectively. Values of potassium(%) and phosphorous(%) of raw waste were observed to be 10.12 and 0.65 respectively.

3.2. Analysis of waste mixed with additives

Raw garden waste was mixed with cow dung slurry and additives biochar, T. Viride, vermiwash and sawdust were added to the vermicomposting units in certain proportions. The values of chemical parameters of waste with the additives added is as shown in the table below.

Table -1: characteristics of waste mixed with additives

parameter	Control (no additive)	GW+ Sawdust	GW+ Biochar	GW+ T-viride	GW+ Vermiwash
MC (%)	61.35	59.5	60.26	59.78	59.85
pH	5.84	5.8	5.9	5.86	5.85
Temp(^{0}C)	27.04	27.48	27.42	27.95	27.62
EC(ds/m)	1.85	1.82	1.8	1.79	1.80
OC (%)	35.22	36.35	37.63	34.77	37.11
N (%)	0.81	0.85	0.93	0.88	0.91
C/N Ratio	43.38	42.90	39.10	39.26	39.67
K (%)	11.63	11.67	13.07	12.65	12.35
P (%)	0.78	0.88	1.20	1.09	0.95

Note: The values in above table indicate the mean of three readings

3.3. Effect of additives on change in pH during vermicomposting

Mineralization of N and P and formation of ammonium ions, carboxylic and phenolic groups, and humic acids are the regulatory factors for pH. Change in EC is due to the release of soluble salts and the availability of mineral salts. The increase in pH could have been caused by the decomposition of the organic compounds, which leads to the generation of ammonium [32]. The decrease in pH during the later stage of vermicomposting might be attributed to the synthesis of organic acids and production of phenolic compounds, as well as to the reduction of readily degradable organic nitrogenous compounds [33]. Decomposition of organic matter leads to formation of ammonium (NH_4) ions and humic acids. These two components have exactly opposite effect on the pH. Presence of carboxylic and phenolic groups in humic acids caused lowering of pH while ammonium ions increased the pH of the system. Combined effect of these two oppositely charged ions actually regulates the pH of vermicompost leading to a shift of pH towards neutrality [5]. The pH values in all treatments were within an acceptable range for the growth and development of E. fetida. Highest initial value of pH were recorded in GW+biochar (8.52) as compared to others. Vermicompost obtained from control recorded highest pH (7.75) followed by GW+sawdust (7.53), GW+vermiwash (7.32), GW+T viride (7.00) and GW+ biochar(6.52) (chart-1).

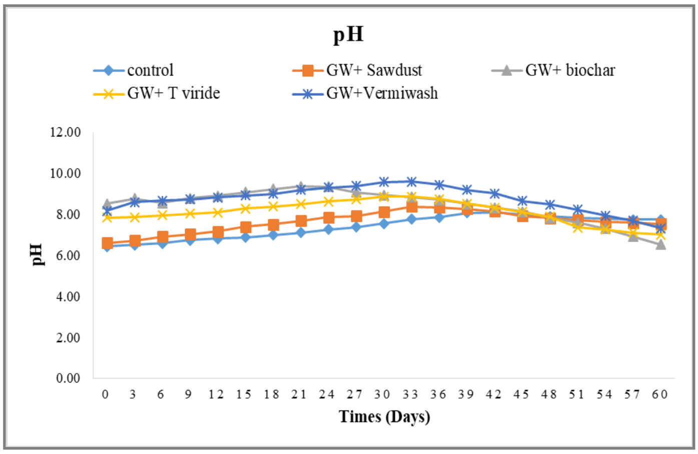

Chart -1: Evolution of pH during vermicomposting treatment

3.4. Effect of additives on change in moisture content during vermicomposting

Maintaining sufficient moisture content is the most important point of concern. The reduction rate of moisture is greater in vermicast than manure. Low moisture content has a detrimental impact on the sexual development of earthworms. When the moisture content is low, earthworms develop clitella in late. Various chemical reactions used water as medium and nutrient also transport through the water during vermicomposting process [27]. It is reported that 50–90% of moisture content is required for earthworm activity. For the survival of the Eisenia fetida species, 50–90% moisture required [27]. Initial moisture content of all the vermicomposting unit was within the range necessary for the survival of the earthworms. Highest moisture content was observed in vermicompost obtained from GW+ biochar (60.57) due to high water holding capacity of biochar. Moisture content in vermicompost obtained from control (51.52) and GW+ sawdust (52.89) were lowest due to the lack of additives that can hold enough water during vermicomposting process (chart-2).

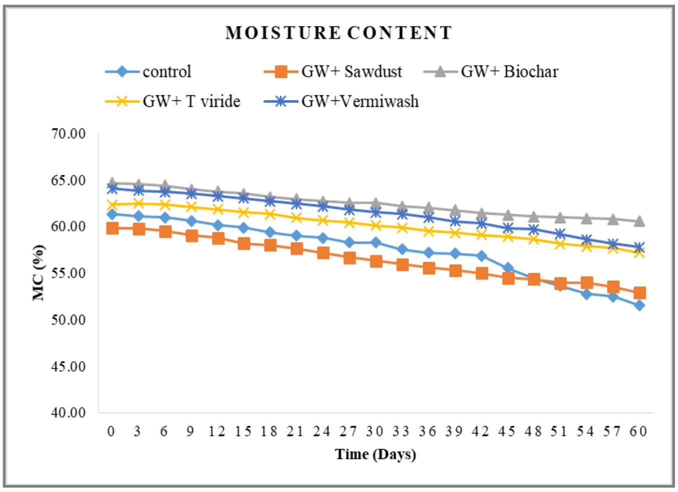

Chart -2: Change in moisture content during vermicomposting treatment

3.5. Effect of additives on change in temperature during vermicomposting

Higher temperatures in vermicomposting systems cause loss of nitrogen as ammonia volatilization and lower temperatures fail to destroy pathogenic organisms. At high temperature metabolic activity of earthworms and micro-organism hinders affecting the decomposition rate. The optimal temperature for nitrification and denitrification activity in soils varies between 20–30 °C. Hence the temperature in all the units were maintained in the range of 20 to 30 °C. Highest initial temperature were observed in GW+ Sawdust (27.62). Temperature was maintained by regular application of water. Gradual increase in temperature were observed due to various chemical reaction taking place during vermicomposting process but the variation was still maintained within the optimal range.

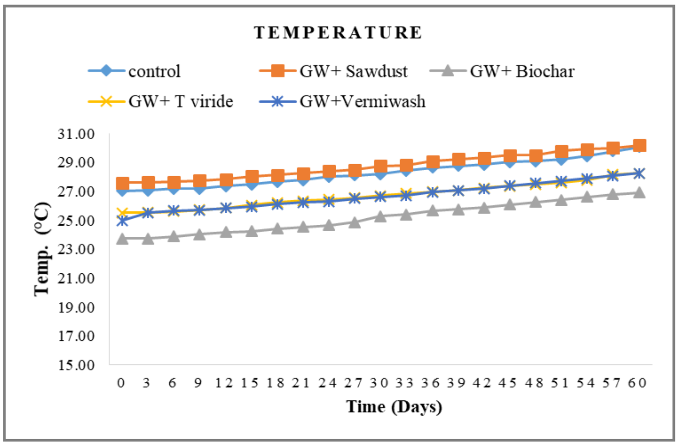

Chart -3: Change in temperature during vermicomposting treatment

3.6. Effect of additives on change in electric conductivity (EC) during vermicomposting

The electrical conductivity (EC) value gradually increased in all three treatments from 0 to 6-7 weeks and then sharply decreased until the completion of cycle. Initial EC values that was recorded are control (1.85), GW+ sawdust (1.80), GW+biochar (2.18), GW+ T Viride (1.88), GW+ Vermiwash(2.19). The increase in EC could be due to the mineralization of organic matter leading to the release of phosphate, ammonium, K+, and other soluble mineral salts in available forms [34]. The subsequent decrease in electrical conductivity values could be as a result of volatilization of ammonia and formation of in soluble compounds which reduced the number and mobility of ions [38]. Lowest EC value is recorded in GW+ Sawdust (2.24) followed by control (2.51), GW+ T Viride (2.84), GW+Biochar (3.61), GW+ Vermiwash (3.85).

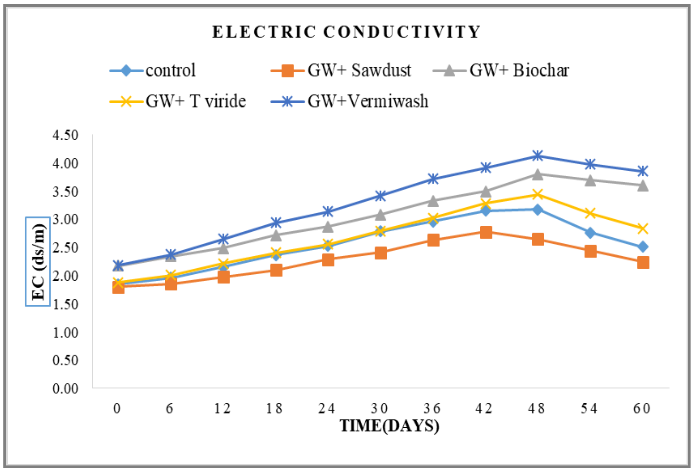

Chart -4: Change in EC during vermicomposting treatment

3.7. Effect of additives on change in organic carbon (OC) and nitrogen (N) during vermicomposting

A steady decrease in total organic carbon content was recorded in all treatments with vermicomposting time. OC loss is likely due to the mineralization of the organic matter through time. High initial value of organic carbon was recorded in GW+ Biochar (37.63%) due to the presence of carbonaceous elements in biochar. Biochar greatly influences nutrient dynamics enhancing the decomposition and mineralization of organic waste. Least value of OC was recorded in GW+biochar (24.93) with respect to the other units (control 28.07%, GW+ Sawdust 27.79%, GW+ T viride 27.58% and GW+ Vermiwash 28.44%) at the end of treatment.

The total nitrogen values exhibited an upward trend throughout the vermicomposting period. The loss of organic carbon during decomposition is responsible for the increase in N content in the final product [39], and the conservation of N and subsequent decrease in C/N in waste decomposition is a commonly seen phenomena. Earthworms can also increase the N content of the composting materials by adding nitrogenous excretory substances, enzymes, body fluids, mucous, and even decaying earthworm tissues [37], while improving microclimatic conditions during composting, which increases the numbers of N-fixing bacteria in the vermicast. Among the five units GW+biochar recorded the maximum increase in nitrogen content (1.59 %) as it favours the reproduction of earthowms which helps in increasing the nitrogen content by adding enzyms, body fluids etc. Vermicompost obtained from control and GW+sawdust recorded same mean value of nitrogen at 60th day.

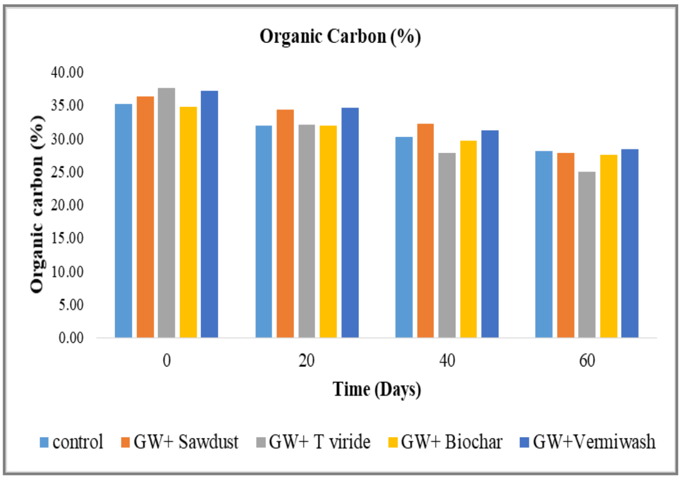

Chart -5: Change in organic carbon during vermicomposting treatment

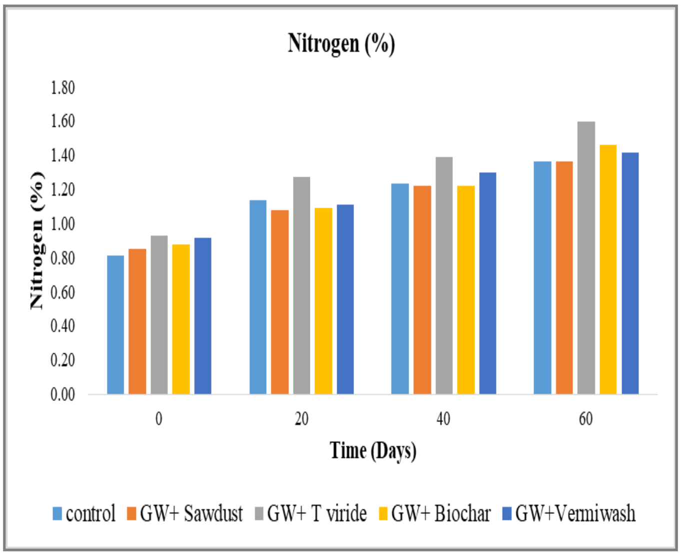

Chart -6: Change in nitrogen during vermicomposting treatment

3.8. Effect of additives on change in C/N ratio during vermicomposting

If the C/N ratio is too high in the substrate and nitrogen content is less, microbial activity decreases. Earthworm addition accelerates the degradation process by digesting the substrate and carbon is lost as CO_2 in the microbial respiration process. Simultaneously, nitrogen is enriched in the feed by the addition of mucus, nitrogenous excretory products resulting in an overall decrease in C/N ratio. At high pH, nitrogen is lost as volatile ammonia, so pH decrease plays an important role in nitrogen retention. Unless the C/N ratio is in the range of 25–20:1, a plant cannot assimilate mineral nitrogen and at this point, it is considered that vermicompost reached maturity level [35]. According to reports when final C:N value decreases below 20, it signifies that the vermicompost attains maturity [35].C/N Ratio were calculated using obtained values of organic carbon and nitrogen. High C/N ratio is recorded initially in control (43.38). Steady decrease in C/N ratio was observed in all the units during vermicomposting time. Lesser the C/N ratio better the quality of vermicompost. GW+Biochar records least C/N ration (15.70) among others (control 21.29, GW+ Sawdust 20.44, GW+ T Viride 18.90 and GW+ Vermiwash 20.10). All the recorded values of C/N ratio were within the acceptable limit i.e. below 20.

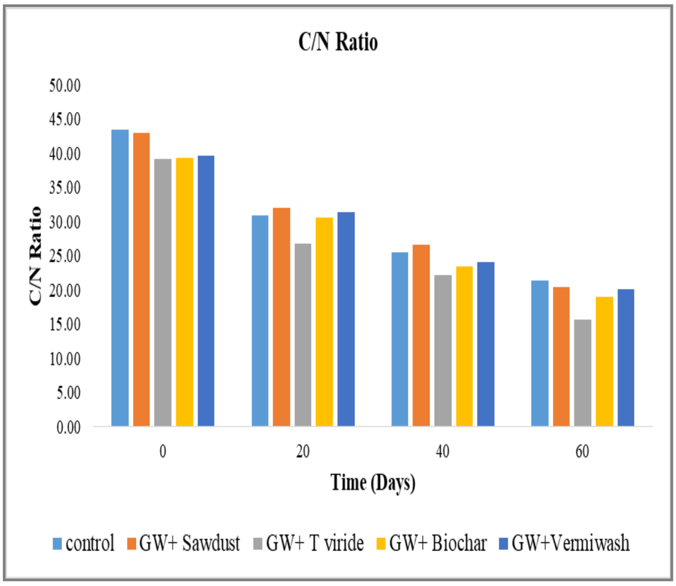

Chart -7: Change in C/N ratio during vermicomposting treatment

3.9. Effect of additives on change in Potassium and phosphorous during vermicomposting

Acid production during organic matter decomposition by the microorganisms is the major mechanism for solubilisation of insoluble P and K [34]. Therefore, the presence of large number of microflora in the gut of earthworm might play an important role in increasing P and K content in the process of vermicomposting. The P content also increase due to a direct action of earthworm gut, enzymes and indirectly by stimulation of the microflora [36]. Bacterial and faecal phosphate activity of earthworms probably lead towards mineralization and mobilization of phosphorus [37].Among the all vermicomposting units GW+ biochar was the most efficient with respect to the increase in potassium content (16.75 %) followed by GW+T viridae (15.60 %), GW+vermiwash (15.18%), GW+T sawdust (15.00 %) and control (14.30 %). the addition of biochar as addititve in vermicomposting treatment increases the degredation rate and the activities of cellulase, urease, and alkaline phosphatase. Vermicompost obtained from GW+ biochar has highest potassium (16.75 %) and phosphorus content (2.60%).

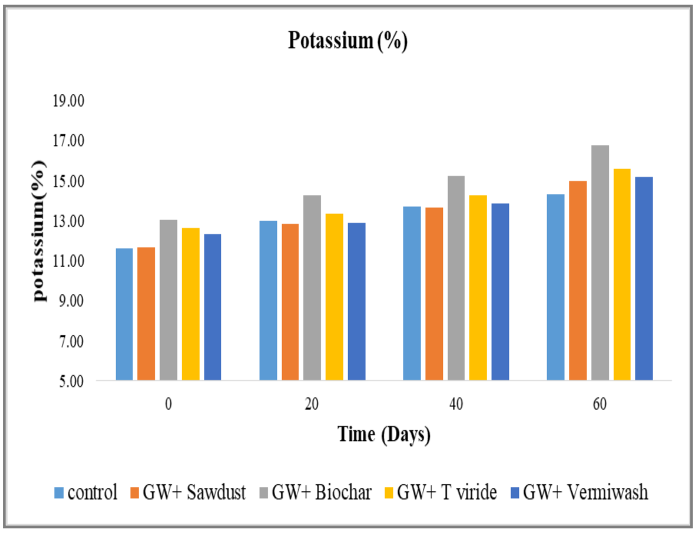

Chart -8: Change in potassium during vermicomposting treatment

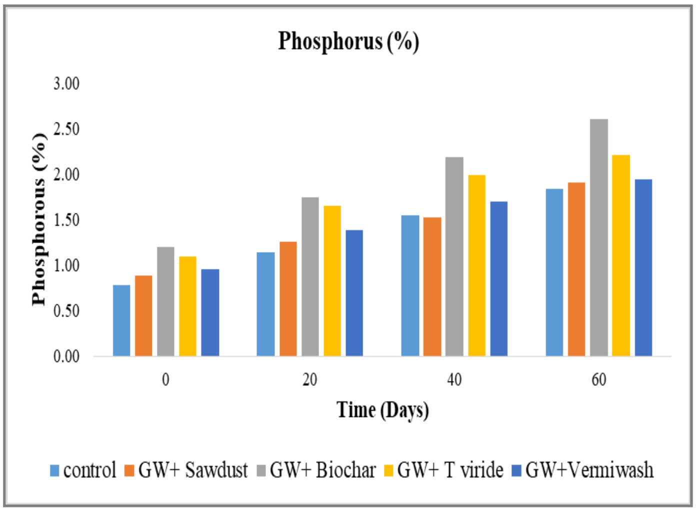

Chart -9: Change in phosphorous during vermicomposting treatment

4. CONCLUSIONS

It can be concluded that vermicomposting is an eco-friendly and feasible technology for the garden waste treatment. Addition of additives enhances the degredation of waste and results into better quality of vermicompost. Additives promotes the better growth of earthworms which results into fast degredation of organic waste. Vermicompost obtained from the additives aided vermicomposting units were richer in nutrients than the vermicompost obtained from control unit. When C/N ratio reach below 20, it signifies that vermicompost attains maturity level hence vermicompost obtained from GW+biochar is said to be well matured with the least value of C/N ratio also it gives higher value of nitrogen content, phosphorous and potassium as compared to other additives. Vermicompost obtained from biochar treated garden waste was found to be more nutrient-rich and having chemical properties suitable for the use as a soil conditioner.

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